DEPARTMENT OF
ECOLOGY
State of Washington

Sediment Management Standards Rule Revisions

Chapter 173-204 WAC

Environmental Impact Statement

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Sediment Management Standards Rule Revisions

Chapter 173-204 WAC

Environmental Impact Statement

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Chapter 1 - Introduction and Purpose

Sediment in areas of Puget Sound and in freshwater bodies throughout Washington State are known to be contaminated with toxic substances such as petroleum-derived compounds, chlorinated organic compounds, and metals. Many contaminants are present at higher concentrations in sediment than in the associated water column because the contaminants do not dissolve easily and tend to adhere to sediment particles.

Sediment Cleanup Sites

Legislation was passed in Washington in 2006 that provided substantial funding for the restoration and recovery of Puget Sound by the year 2020. The legislation led to the formation of the Puget Sound Initiative (PSI), with the goal of making Puget Sound swimmable, fishable, and diggable by 2020. Under the PSI, Ecology's Toxics Cleanup Program (TCP) has increased its emphasis on cleanups in the Puget Sound area. TCP has prioritized cleanup in seven priority bays within Puget Sound and has sped up efforts to clean and restore these contaminated sites. TCP is using a bay-wide approach rather than a site-specific approach to cleaning up sites within a geographic area, resulting in more rapid and streamlined cleanups.

By January 2008, Ecology site managers had identified 150 sediment cleanup sites or areas of concern with enough information to perform some degree of environmental analysis. Most sites are in marine sediment in Puget Sound (115 sites), while a small number are in freshwater sediment (35 sites). Of these 150 sites, 56 percent of them (84 sites) have been cleaned up or are in the process of being cleaned up. However, additional sites have also been added to the list, keeping the total number of sites requiring action at around 170 sites. Cleanup includes initial investigation, remedial investigation, feasibility study, design phase, and cleanup and monitoring actions.

The Environmental Dilemma – The Need for the Sediment Management Standards (SMS) Rule

Most of the impacted sediment is located in productive nearshore and estuarine areas where they pose risks to human health and the environment. Consequently, actions to clean up and prevent sediment contamination have multiple benefits including:

- *Decreasing human exposure and health risks.* People can be exposed to sediment contamination through physical contact (e.g., playing on beaches) or by eating fish and shellfish. Cleanup actions reduce human exposure and health risks by removing or capping contaminated sediment. For example, monitoring data have shown that mercury concentrations in crab in Bellingham Bay have significantly decreased following cleanup.

- *Reclaiming and restoring critical habitat in the productive nearshore environment.* Many cleanup projects are located in areas with significantly degraded habitat. Cleanup projects are often designed to include habitat restoration actions. For example, a cleanup in Fidalgo Bay included actions to improve habitat that have shown measurable results with new growth of eelgrass and kelp.

- *Decreasing contaminant exposure to aquatic life in the productive nearshore environment.* Most cleanup actions are located in relatively shallow marine and freshwater environments where aquatic species are exposed to contaminated sediment. Cleanup actions allow for the recovery of these areas by removing or capping contaminated sediment. For example, follow-up studies at the Eagle Harbor Superfund site have shown that liver lesions in English sole have significantly decreased after the interim action sediment cleanup was completed (Meyers et al., 2008).

The Regulatory Dilemma – The Need for Revisions to the SMS Rule

The original SMS rule provided a solid foundation for making decisions to clean up and manage sediment in Puget Sound. Ecology recognized the SMS decision framework worked well when making decisions based on acute and chronic ecological risks to the benthic community (sediment toxicity) in Puget Sound. However, the original SMS rule did not work as well when making decisions at sites outside of Puget Sound and/or where bioaccumulatives are chemicals of concern. There are four main reasons for these difficulties:

- *The original SMS rule did not provide a clear path for making cleanup decisions based on human health protection.* Cleanup levels based on human health protection are often much lower than the SMS biological and chemical criteria. This situation is complicated by the fact that the original SMS rule did not provide clear methods and policies for selecting cleanup levels based on human health protection.

- *The original SMS rule did not provide a clear path for making cleanup decisions based on toxicity to freshwater benthic organisms.* The original rule had a narrative statement for protection of the freshwater benthic community but lacked numeric criteria.

- *The original SMS rule did not provide a clear path for reaching cleanup decisions or liability resolution that take into account background concentrations and ongoing discharges.* Lower cleanup levels translate into larger sites. The SMS rule did not provide clear methods or policies on how to define cleanup sites in situations where risk-based sediment concentrations fall below *ambient* or *background* levels. As sites grow larger, the decision-making process becomes more challenging because of the increased number of sources and Potentially Liable Parties (PLPs).

- *The original SMS rule did not provide a clear framework for synchronizing cleanup actions and source control requirements at sites where cleanup requirements are based on human health protection.* Larger sites require multiple solutions and longer time frames.

Experience to date indicates that we will not be able to achieve these cleanup levels solely by dredging and/or capping contaminated sediment. Rather, solutions will require decades to implement and will require a combination of measures that include prevention, source control, active sediment cleanup, and institutional controls. The original SMS rule did not provide clear methods and policies for making decisions in these types of situations.

Multiple Strategies Over Long Time Frames Will Be Needed to Remediate Sediment Contamination

Ecology recognizes that combinations of strategies are needed to remediate sediment contamination. These include:

- Active cleanup measures (e.g., dredging, capping) can reduce risks by eliminating exposure to contaminated sediment in the near term. However, we will rarely be able to dredge our way to complete success. This is especially pertinent to risks from bioaccumulative chemicals because they are ubiquitous in the aquatic environment and toxic at very low concentrations.
- Actions to prevent the initial production and release of hazardous substances.
- Actions to prevent or minimize the discharge of hazardous substances into adjacent water bodies. Source control measures are expensive and will require several decades to fully implement, particularly with respect to ubiquitous contaminants in stormwater runoff.
- Institutional controls will help bridge the time frames between active cleanup measures and long-term goals However, institutional controls have limited effectiveness for aquatic sites.

Efforts to address contaminated sediment were plagued by uncertainties about the appropriate level of human health protection, timing, and feasibility of source control to prevent recontamination, how to deal with background levels of contamination, and the ability of PLPs to resolve their liability for historical releases. Site-specific efforts to resolve these issues caused lengthy cleanup delays resulting in inefficient use of available cleanup funds and continued exposure to unhealthy levels of hazardous substances. The regulatory dilemma is reflected in the following question:

What is a workable decision-making framework for selecting sediment cleanup measures (e.g., dredging, capping, natural recovery) at cleanup sites or cleanup units given:

- *The current scientific information on the health and environmental risks posed by contaminated sediment, and the uncertainties and variability in those risks.*
- *The detected background concentrations of hazardous substances in site and reference sediments, which are often higher than human health risk-based sediment concentrations, calculated using current risk assessment methods.*
- *The extended time needed to reduce ongoing discharges to levels that are needed to prevent recontamination of remediated areas.*
- *The high costs of active cleanup and source control measures and the uncertainties in those costs.*

This overarching question and the associated issues noted above informed and shaped the objectives developed by Ecology for this SMS rulemaking revision process.

Ecology's Rulemaking Objectives

Ecology has revised the cleanup provisions in the SMS rule and has identified four overarching objectives for this rule revision process:

- Establish clear methods and policies for selecting sediment cleanup standards based on human health risks.

- Establish clear requirements for sediment cleanup standards at freshwater sediment sites by adopting biological and chemical criteria for the protection of freshwater benthic communities.

- Establish a clear path for reaching cleanup decisions and liability resolution that takes into account background concentrations and ongoing discharges.

- Update the procedures for synchronizing cleanup actions and source control requirements at sites where cleanup requirements are based on human health protection.

To meet these broad objectives, Ecology had to consider and balance a number of issues and interests and ensure that specific needs were addressed in the alternatives developed for consideration during this rulemaking process:

- *Protection of human health and the environment.* Ecology's overall goal is to establish a decision-making framework that reduces exposure from sediments that pose risks to human health and the environment. Toward that end, Ecology designed a process that accelerates implementation of cleanup measures and integrates them with broader measures to prevent and/or control the production and discharge of hazardous substances.

- *Scientifically and legally defensible standards.* An important goal was to develop standards that are scientifically and legally defensible. Toward that end, Ecology has reviewed the scientific literature and consulted with scientists experienced in sediment contamination issues. Where conflicting opinions or recommendations exist, Ecology has attempted to reconcile the various positions to arrive at a scientifically defensible and workable approach.

- *Integrate and ensure compliance with state and federal laws and regulations.* There are a wide range of local, state, and federal requirements applicable to sediment management activities. Ecology has worked to ensure compliance with existing requirements and to avoid creating conflicting, unduly burdensome, or duplicative requirements.

- *Provide a predictable approach for sediment investigations and cleanup.* Implementation of the original narrative standards produced considerable variability in both the quality and methodologies used to develop sediment cleanup standards and make cleanup decisions. The rule revisions are designed to provide a more predictable and efficient decision-making process.

- *Provide efficient cleanup of contaminated sediment sites.* An important objective of the rule revisions is to increase the efficiency of site cleanup. By establishing a clear decision-making process, Ecology hopes to establish a system that focuses available funds on site cleanup actions in ways that minimize project delays and transaction costs.

- *Allow flexibility to address site-specific circumstances.* When developing the rule revisions, Ecology has tried to balance the goals of regulatory consistency, predictability, and efficiency with the need to provide some flexibility to address individual site situations.

The ability of each of the alternatives selected for evaluation to meet these issues and interests is addressed through application of the evaluation criteria, which is discussed in Chapter 5.

Statutory Authority

Ecology addresses sediment contamination primarily through the Model Toxics Control Act (MTCA; chapter 70.105D RCW), which is the primary legal authority for the SMS rule revisions (Part V) and authorizes Ecology to require or perform environmental cleanups.

MTCA establishes requirements for Ecology to identify cleanup procedures and standards that are protective of human health and the environment. This law provides the primary authority for the SMS rule (Part V) revisions to sediment cleanup provisions.

As a general declaration of policy, MTCA states that:

> *"Each person has a fundamental and inalienable right to a healthful environment, and each person has a responsibility to preserve and enhance that right. The beneficial stewardship of the land, air, and waters of the state is a solemn obligation of the present generation for the benefit of future generations."*[1]

The statute further states that:

> *"A healthful environment is now threatened by the irresponsible use and disposal of hazardous substances. There are hundreds of hazardous waste sites in this state, and more will be created if current waste practices continue. Hazardous waste sites threaten the state's water resources, including those used for public drinking water. Many of our municipal landfills are current or potential hazardous waste sites and present serious threats to human health and the environment."*[2]

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[1] RCW 70.105D.010(1).

[2] RCW 70.105D.010(2).

The purpose of MTCA is to prevent or remedy these threats to human health and the environment. MTCA's general declaration of policy states:

> *"[t]he main purpose of this act is … to clean up all hazardous waste sites and to prevent the creation of future hazards due to improper disposal of toxic wastes into the state's land and waters."*[3]

To accomplish these statutory goals, MTCA requires Ecology to accomplish several objectives. The statute specifies those objectives in RCW 70.105D.030(2). In particular, MTCA requires Ecology "*to immediately implement all provisions of this chapter to the maximum extent practicable, including investigative and remedial actions where appropriate."* Furthermore, MTCA requires Ecology to adopt, and thereafter enforce, rules under chapter 34.05 RCW. This includes:

> *Publish and periodically update minimum cleanup standards for remedial actions at least as stringent as the cleanup standards under Section 121 of the federal cleanup law, 42 U.S.C. Sec. 9621, and at least as stringent as all applicable state and federal laws, including health-based standards under state and federal law[.]*[4]

Ecology's Rulemaking Approach

The need for SMS rule revisions and potential rule changes have been the topic of extensive discussions and scientific investigations carried out by Ecology and other state and federal agencies since the original SMS rule was adopted in 1991. Ecology announced its plans to revise the SMS and MTCA Cleanup Regulation in February 2009. In November 2010, the Governor signed Executive Order 10-06 which established a one-year rule moratorium for non-essential rulemaking. Ecology decided to stop work on the MTCA rule revisions, but elected to continue work on the SMS rule revisions. The agency published a revised rule announcement (CR-101) in mid-2011.

During the rule development process, Ecology conducted numerous stakeholder meetings between February 2009 and December 2011 and continues public involvement in the form of presentations and discussion at conferences and the Sediment Management Annual Review Meetings. These activities were conducted to gain a better understanding of the technical and policy issues and to address concerns and opinions from a wide range of interest groups on these issues. These activities include:

- Ecology published a series of scoping papers on key rulemaking topics in June 2009. Public comments helped Ecology identify key technical and policy issues.

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[3] Id.

[4] The federal cleanup law referenced in MTCA is the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986

- Ecology formed two rule advisory committees in November 2009: the MTCA/SMS Advisory Group and the Sediment Workgroup. Ecology held 15 meetings with one or both of these groups between November 2009 and December 2010. Over that period, Ecology worked with those groups to develop draft changes to the sediment cleanup provisions (Part V of the SMS rule) and the MTCA rule, and to help formulate the alternatives addressed in this document.

- Ecology formed a new advisory group in September 2011 to review and discuss preliminary draft rule language. This group (Sediment Cleanup Advisory Committee) included people who had participated on the earlier groups and additional interested parties. Ecology held three meetings with this group between October 2011 and December 2011.

- Ecology made several presentations at the Sediment Management Annual Review Meetings held each May, Water Quality Partnership meetings, and regional sediment conferences.

Ecology incorporated changes to the rule in response to comments from advisory group members and the general public. The proposed rule was submitted and ready for public comment on August 15, 2012.

Ecology has worked with other public and private organizations to complete several technical reviews and studies to support the development of the SMS rule revisions. Key efforts have included the following:

- Ecology participated in the Regional Sediment Evaluation Team (RSET) efforts to develop freshwater sediment quality values for both cleanup and dredge material management.

- Ecology consulted with the MTCA/SMS Science Panel on key rulemaking issues. These include freshwater sediment standards and fish consumption rates.

- Ecology conducted a scientific peer review process where international sediment experts were asked to review the draft freshwater sediment criteria report, the process used to develop chemical and biological criteria, and the robustness of the datasets.

- Ecology submitted the technical report on fish consumption rates for formal public comment.

In addition to technical studies, Ecology obtained an informal opinion from the Office of the Attorney General concerning authority, rule structure, and key legal issues.

Purpose of the Environmental Impact Statement

The State Environmental Policy Act (SEPA, chapter 43.21C RCW) and SEPA rules (chapter 197-11 WAC) requires that an Environmental Impact Statement (EIS) be prepared for proposed rulemaking with probable significant adverse effects on the quality of the environment. Ecology decided to produce an EIS regardless of any potential adverse impacts on the quality of environment the rule revisions may have.

The purpose of this document is to evaluate the potential adverse environmental impacts associated with implementing sediment cleanup actions under several alternate approaches. The choice of approach will influence the nature, magnitude, and probability for adverse impacts by specifying requirements for sediment cleanup standards. Adverse impacts fall into two broad categories:

- *Impacts from Residual Concentrations.* Environmental impacts may be caused by residual sediment concentrations that remain following the completion of cleanup actions. The long-term impacts are associated with residual contamination levels are directly related to the relative stringency of the cleanup standards for a particular site.

- *Impacts from Cleanup Actions.* Environmental impacts may also be caused by the cleanup technologies used to complete cleanup actions. Short-term impacts associated with completing a cleanup action are generally inversely related to the relative stringency of the cleanup standards for a particular site.

These two broad categories also address other objectives of the SMS rule revisions including cleanup decisions and liability resolution that takes into account background concentrations and ongoing discharges, and synchronizing cleanup actions and source control requirements. The programmatic evaluation in this document, by the development of case studies, is intended to encourage and facilitate public involvement in decisions regarding the environmental tradeoffs associated with the selection of sediment cleanup standards. Individual site-specific environmental impacts are not evaluated in this document. The environmental impacts associated with individual contaminated sediment sites will be evaluated prior to the initiation of cleanup activities on a case-by-case basis.

Public Comments on the Environmental Impact Statement Scoping Notice

Suggestions were made to ensure that evaluation of EIS alternatives included an analysis of the following:

- How conservative cleanup standards based on protection of human health will affect adverse impacts in terms of:
  - Protection of human health and the environment; and
  - Delayed or fewer cleanup actions.
- How cleanup decisions and resolution of liability are affected.
- How source control and synchronizing cleanup actions and source control requirements would work.
- How a default fish consumption rate in the SMS rule, approved as a water quality standard, will affect cleanup and future Water Pollution Control Act (WPCA) revisions.

Organization of the Environmental Impact Statement

Following this introductory chapter, the remainder of this EIS document is organized into four additional chapters and several appendices:

Chapter 2 – Original Sediment Management Standards. This chapter describes the major provisions of the MTCA, WPCA, and SMS rules with particular emphasis on the sediment cleanup provisions. Additionally, when agencies consider adoption of significant legislative rules, they must be coordinated with federal, state, and local laws, regulations, and ordinances. To meet this need, a summary of the relationships between the SMS and other applicable federal, state, and local requirements is provided in Appendix A.

Chapter 3 – Description of the Rulemaking Alternatives. Ecology evaluated several approaches for revising the sediment cleanup provisions to address human health protection and freshwater sediment. The chapter also describes the rulemaking alternatives considered in this document and the rationale for selecting those alternatives. Specific issues that were evaluated during the alternative development process are provided in Appendix B.

Chapter 4 – Case Studies. Ecology prepared several case studies to illustrate the impacts of the rulemaking alternatives. These case studies illustrate how the range of alternatives considered in this EIS could affect differences in sediment cleanup. Chapter 4 provides an introduction to the Case Studies, with additional information on risk calculations provided in Appendix C, the background technical document on freshwater sediments provided in Appendix D, and presentation of cleanup levels identified for case studies presented in Appendix E.

Chapter 5 – Evaluation of Impacts and Alternatives. This chapter provides an overview of the process that is used to evaluate the environmental impacts of each of the rulemaking alternatives, and an analysis of the impacts of the proposed alternatives. Information on the Affected Environment that is subject to these impacts is provided in Appendix F. Chapter 5 also includes the evaluation of the alternatives based on the identified impacts, the results of the case studies, and other factors discussed in previous chapters.

Chapter 6 – References. This chapter contains a list of references cited in this document.

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Chapter 2: Original Sediment Management Standards

Introduction

Washington's hazardous waste cleanup law, the Model Toxics Control Act (MTCA; chapter 70.105D RCW), mandates that site cleanups protect the state's citizens and environment. To implement this statutory mandate, Ecology established cleanup standards and requirements for the cleanup of hazardous waste sites (cleanup actions). The rule establishing these standards and requirements was developed by Ecology in consultation with the Science Advisory Board (established under the Act) and with representatives from local government, citizen, environmental, and business groups. The rule was first published in February 1991, with amendments in January 1996, February 2001, and October 2007.

The cleanup standards and requirements in the MTCA rule that directly address sediment cleanup actions defer compliance to the Sediment Management Standards (SMS) rule (chapter 173-204 WAC):

> **Sediment Management Standards – WAC 173-340-710(d)**
>
> *"Sediment cleanup actions conducted under this chapter shall comply with the sediment cleanup standards in chapter 173-204 WAC. In addition, a remedial investigation/feasibility study conducted under WAC 173-340-350 shall also comply with the cleanup study plan requirements under chapter 173-204 WAC. The process for selecting sediment cleanup actions under this chapter shall comply with the requirements in WAC 173-340-350 through 173-340-390."*
>
> **Sediment Cleanup Standards - WAC 173-340-760**
>
> *"In addition to complying with the requirements in this chapter, sediment cleanup actions conducted under this chapter must comply with the requirements of chapter 173-204 WAC."*

Additionally, the state Water Pollution Control Act (WPCA; chapter 90.48 RCW) provides Ecology with authority to issue wastewater discharge permits; the limits set on these permits and associated monitoring requirements must consider the potential impacts to receiving water on sediment quality. The relationship between MTCA and the Water Pollution Control Act to the SMS is illustrated on Figure 2.1. The SMS rule was first promulgated in March 1991, with revisions to the rule adopted in December 1995.

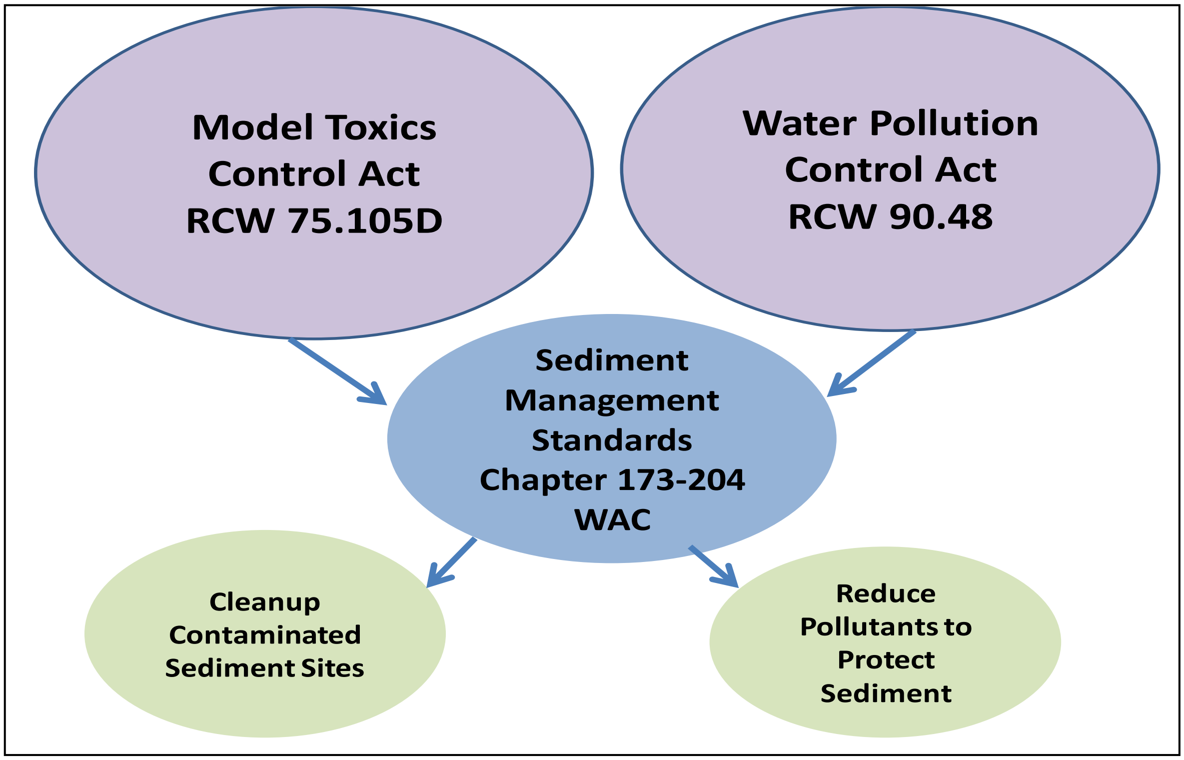

Figure 2.1: Relationship of the Sediment Management Standards to Other State Regulations

In adopting the SMS rule (chapter 173-204 WAC) in 1991, Ecology established a comprehensive decision framework that serves as the primary regulation for managing contaminated sediment, as illustrated on Figure 2.2.

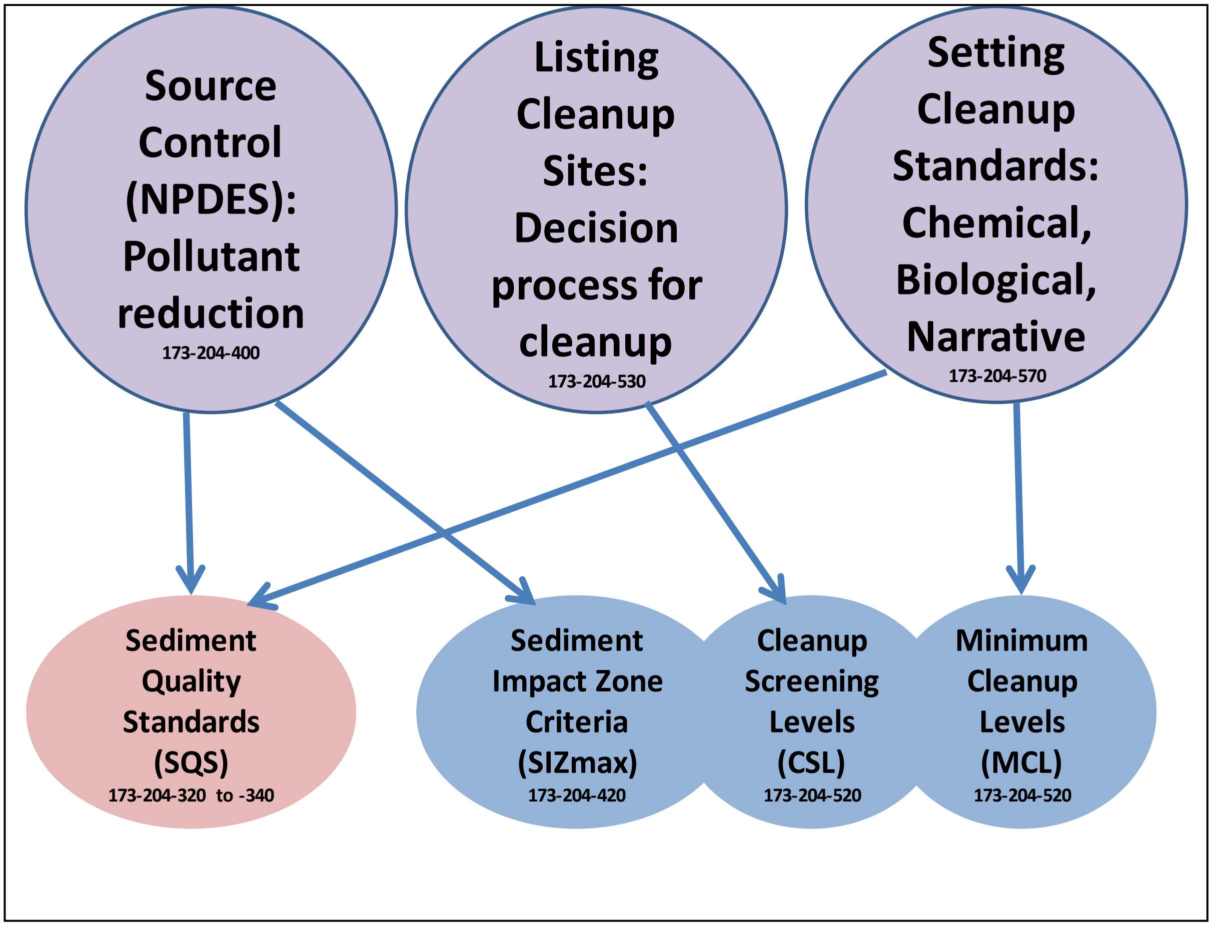

Figure 2.2: Functions of the original Sediment Management Standards

The original SMS rule included three major components:

- Part III (WAC 173-204-300 to -350, Sediment Quality Standards) establish sediment quality standards (SQS) that provide a "regulatory and management goal for the quality of sediments throughout the state."
- Part IV (WAC 173-204-400 to -420, Sediment Source Control) establish a decision-making process to evaluate and establish source control requirements to protect sediment quality.
- Part V (WAC 173-204-500 to -590, Sediment Cleanup Standards) establish a decision-making process to identify, screen, rank, prioritize, and cleanup contaminated sediment sites. Part V is being revised.

The original SMS contained numeric criteria that apply to Puget Sound marine sediments:

1. The "No Adverse Effects Level," called **the Sediment Quality Standard (SQS)**, as shown on Figure 2.2, defined in WAC 172-204-320, and used as the sediment quality goal for Washington State sediment.
2. The "minor adverse effects level," called the **Sediment Impact Zone Maximum Level (SIZmax)**, defined in WAC 173-204-420. The sediment **Cleanup Screening Level (CSL)/Minimum Cleanup Level (MCUL)**, defined in WAC 173-204-520. These are shown on Figure 2.2 and are used as an upper regulatory level for source control and cleanup decision making, respectively.

The original SMS rule outlined specific standards and decision-making processes to protect biological resources and cleanup contaminated sediment. The original SMS rule included specific chemical and biological standards (numerical criteria) for marine sediment. However, the original SMS rule only included narrative standards for the protection of human health and protection of the benthic community in freshwater sediment.

There are many contaminated sediment sites that pose risks to human health or are located in freshwater systems in the state of Washington under the MTCA or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) oversight. Because of the lack of adopted human health or freshwater standards, the narrative standard required a site-specific evaluation to determine cleanup standards. This site-specific process created inconsistency on how to address cleanup for protection of human health or how freshwater sediment sites are cleaned up to protect the benthic community.

SMS Rule Part III: Sediment Quality Standards

Part III of the SMS rule establishes the SQS that provide a "regulatory and management goal for the quality of sediments throughout the state" (WAC 173-204-100(3)).

The Sediment Quality Standards (SQS) provide *"…chemical concentration criteria, biological effects criteria, human health criteria, and other toxic, radioactive, biological, or deleterious substances criteria which identify surface sediments that have no adverse effects, including no acute or chronic adverse effects on biological resources and no significant health risk to humans…"*(WAC 173-204-100(3) and WAC 173-204-300).

The SQS values are defined using a combination of chemical and biological criteria and narrative standards that are summarized in Table 2-1 (presented at end of chapter). The established SQS numeric criteria and confirmatory biological tests are limited to protection of the marine benthic community. Narrative standards are used for the protection of human health and designation of freshwater sediment quality. The SQS designation for marine sediment is based on the results of the chemical analysis and confirmatory biological testing as follows:

- Sediment with chemical concentrations equal or less than the applicable chemical and human health criteria is designated as having no adverse effects on biological resources, and not posing a significant threat to humans, and pass the applicable SQS of WAC 173-204-320 through 173-204-340.
- Sediment with chemical concentrations that exceed the applicable chemical or human health criterion is designated as having adverse effects on biological resources or posing significant human health threats and fails the applicable SQS of WAC 173-204-320 through 173-204-340.
- Sediment samples that pass the confirmatory biological tests are designated as passing the applicable SQS of WAC 173-204-320 through 173-204-340 for protection of the benthic community. Any sediment sample that fails any one of the required confirmatory biological tests shall be designated as failing the applicable SQS of WAC 173-204-320 through 173-204-340.

The confirmatory biological benthic community toxicity tests for designating marine sediment include acute and chronic effects tests. The acute effects tests include the amphipod mortality and larval development bioassays. The chronic effects tests include benthic infaunal abundance, juvenile polychaete growth bioassay, and Microtox saline extract test for decreased luminescence.

The rule revisions focus on Part V of the SMS rule. Part III of the original and revised SMS rule does not include any confirmatory biological tests for the protection of human health or for freshwater sediment sites.

Table 2-1: Original SMS Narrative Standards for Freshwater Sediments

<table>
<tr><th>Sediment Type</th><th>Part III Sediment Quality Standards (WAC 173-204-300 to -350)</th><th>Sediment Type</th><th>Sediment Impact Zone Maximum (SIZmax) Criteria (WAC 173-204-420)</th><th>Cleanup Screening Level (CSL) and Minimum Cleanup Levels (MCULs) (WAC 173-204-520)</th></tr>
<tr><td rowspan="3">Puget Sound Marine Sediments</td><td>Ecological Protection. Includes chemical and biological criteria that define the SQS for Puget Sound marine sediment based on preventing adverse effects to benthic organisms (i.e., no acute or chronic effects) as determined when chemical concentrations exceed applicable chemical criteria and any one of the confirmatory marine sediment biological tests demonstrate adverse effects as defined by SMS biological effects criteria (WAC 173-204-320(3)).</td><td rowspan="3">Puget Sound Marine Sediments</td><td>Ecological Protection. Includes chemical and biological criteria for Puget Sound marine sediment. These criteria are based on preventing minor adverse effects to benthic organisms (WAC 173-204-420((3)).</td><td>Ecological Protection. Chemical and biological criteria that are used to define the CSLs and MCULs for Puget Sound marine sediment. These criteria are based on preventing minor adverse effects in benthic organisms (WAC 173-204-520(2), -(3)).</td></tr>
<tr><td>Human Health Protection. Department may determine SQS based on human health protection on a case-by-case basis and the criteria, methods, and procedures necessary to meet the intent of the chapter (i.e., no significant health risk to humans) (WAC 173-204-320(5)).</td><td>Human Health Protection. The department may determine the SIZmax based on human health protection on a case-by-case basis that represents no significant health risk to humans (WAC 173-204-420((4))</td><td>Human Health Protection. The department may determine the CSL and MCUL based on human health protection on a case-by-case basis that represents no significant health risk to humans (WAC 173-204-520(4)).</td></tr>
<tr><td>General. Other toxic, radioactive, biological, or deleterious substances in or on sediment shall be at or below concentrations that cause no adverse effects in marine biological resources and below concentrations that correspond to a significant health risk to humans, as determined by Ecology. Ecology shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of this chapter (WAC 173-204-320(5)).
Non-anthropogenic background concentrations shall be used as the SQS when such background concentrations are higher than otherwise applicable SQS based on ecological or human health protection (WAC 173-204-320(6)).</td><td>General. Other toxic, radioactive, biological, or deleterious substances to protect biological resources and human health (WAC 173-204-420((5)).
Non-anthropogenic background concentrations apply as criteria when concentrations are higher than benthic or human health criteria (WAC 173-204-420(6)).</td><td>General. Other toxic, radioactive, biological, or deleterious substances shall be protective of human health and the environment (WAC 173-204-520(5)).

Non-anthropogenic background concentrations apply as criteria when background concentrations are higher than benthic or human health criteria. (WAC 173-204-520(6)).</td></tr>
<tr><td rowspan="2">Other Marine Sediments</td><td>Ecological Protection. The department may determine SQS for protection of ecological species for non-Puget Sound marine sediment on a case-by-case basis using criteria, methods, and procedures necessary to meet the intent of the chapter (WAC 173-204-320(1)(c)).</td><td rowspan="5">Other Marine, Low Salinity, and Freshwater Sediments</td><td rowspan="2">Ecological Protection. The department may determine SIZmax for non-Puget Sound marine sediment on a case-by-case basis using criteria, methods, and procedures necessary to meet the intent of the chapter (WAC 173-204-420(1)(b), (c), (d).</td><td rowspan="2">Ecological Protection. The department may determine CSLs or MCULs for non-Puget Sound marine sediment on a case-by-case basis using criteria, methods, and procedures necessary to meet the intent of the chapter (WAC 173-204-520(1)(b)), (c)), (d).</td></tr>
<tr><td>Human Health Protection. Case-by-case determinations to meet the intent of the chapter (i.e., no significant risk to humans).</td></tr>
<tr><td>Low Salinity Sediments</td><td>Ecological Protection. The department may determine SQS for low salinity sediments on a case-by-case basis using criteria, methods, and procedures necessary to meet the intent of the chapter (WAC 173-204-330).
Human Health Protection. Case-by-case determinations to meet the intent of the chapter (i.e., no significant risk to humans).</td><td rowspan="3">Human Health Protection. Case-by-case determinations to meet the intent of the chapter (i.e., no significant risk to humans).</td><td rowspan="3">Human Health Protection. Case-by-case determinations to meet the intent of the chapter (i.e., no significant risk to humans).</td></tr>
<tr><td rowspan="2">Freshwater Sediments</td><td>Ecological Protection. The department may determine SQS for freshwater sediment on a case-by-case basis using criteria, methods, and procedures necessary to meet the intent of the chapter (WAC 173-204-340).</td></tr>
<tr><td>Human Health Protection. Case-by-case determinations to meet the intent of the chapter (i.e., no significant risk to humans).</td></tr>
</table>

SMS Rule Part IV: Sediment Source Control

Part IV of the SMS rule establishes a decision-making process to evaluate and establish source control requirements to protect sediment quality. The SMS rule states that the sediment source control standards shall be used for controlling the effects of point and non-point discharges to the sediment through the National Pollutant Discharge Elimination System (NPDES) permit program, state water quality permits, administrative orders, and other means determined appropriate by Ecology.[5]

Part IV contains the following key provisions:

Source Control Goal. The SMS rule states that the goal for managing source control activities is to reduce and ultimately eliminate adverse effects on biological resources and significant health threats to humans from sediment contamination[6]. The SQS in Part III establish the goal for source control activities.

Sediment Impact Zones. The SMS rule allows Ecology to set forth the standards for the establishment, maintenance, and closure of sediment impact zones (SIZ)[7, 8] that allow sediment contamination above the SQS. Specific requirements of this allowance include:

- If a discharge is predicted to exceed the SQS, and the discharger is applying all known and reasonable technologies (AKART) or best management practices (BMPs; as applicable)[9] to the discharge, a sediment impact zone may be approved as one provision of a discharge permit. The degree of contamination allowed will be as low as possible based on modeling predictions, and will be used to estimate the impact of a discharge on the receiving waters and surface sediment quality for a period of ten years.

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[5] WAC 173-204-100(5).

[6] WAC 173-204-410(1)(a)

[7] WAC 173-204-200(23) states that "…'Sediment impact zone' means an area where the applicable sediment quality standards of WAC 173-204-320 through 173-204-340 are exceeded due to ongoing permitted or otherwise authorized wastewater, storm water, or nonpoint source discharges and authorized by the department within a federal or state wastewater or stormwater discharge permit, or other formal department authorization…"

[8] WAC173-204-415(1)

[9] WAC 173-204-415 (1 (d) states that " …(the discharger) has adequately addressed alternative waste reduction, recycling, and disposal options through application of all known, available, and reasonable methods of prevention, control, and treatment to minimize as best practicable the volume and concentration of waste contaminants in the discharge.

- The location of an authorized sediment impact zone shall avoid whenever possible and minimize adverse impacts to areas of special importance, such as critical habitat or water supply intake areas.[10]
- The size of the allowable sediment impact zone must be as small as practicable. Monitoring, to assure compliance with the impact zone area and degree of effect, will also be required as a condition of the sediment impact zone authorization. To ensure recovery of impacted sediments to concentrations allowed under the rule, closure requirements may include continued monitoring and active cleanup.
- Re-evaluation during the NPDES permit renewal process.
- The closure of an authorized sediment impact zone may be required when the discharger has violated the SIZ maintenance standards[11]or is no longer needed or eligible under the standards[12].

Sediment Impact Zone Maximum (SIZmax) Criteria. Section 420 defines the allowable concentrations of sediment contaminants that can be authorized through the SIZ process. They are established at concentrations that represent "minor adverse effects"[13] to human health and the environment. As with the SQS in Part III, the SIZmax values are defined using a combination of chemical and biological criteria and narrative standards that are summarized in Table 2-1.

Preventing New Cleanup Sites. Section 410(1)(c) requires source control to prevent the creation of new cleanup sites.

The rule revisions do not include significant changes to Part IV.

SMS Rule Part V: Sediment Cleanup Standards

Part V of the original SMS rule established a decision-making process for managing contaminated sediment. These procedures included identifying and investigating sites, establishing cleanup standards, selecting a cleanup remedy, and establishment of sediment recovery zones, if applicable. Key provisions include:

Screening Sediment Stations Clusters of Potential Concern (WAC 173-204-510). The first step is to identify sampled locations where sediment chemical concentrations exceed the SQS.

[10] WAC 173-204-415 (3)

[11] WAC 173-204-415 (5)

[12] WAC 173-204-410 through 173-204-415

[13] WAC 173-204-200(15) provides a definition for "minor adverse effects" that includes chemical and biological criteria based on allowing significant effects in one of the biological tests used to establish the sediment quality standards.

- Each location where a sediment sample is collected is referred to as a station. Ecology maintains an inventory of sediment samples in the Environment Information Management database.
- Using sampling information, groups of stations that exceed the cleanup screening level (CSL) chemical or biological criteria may be defined as station clusters of potential concern. Stations that pass the criteria are identified as station clusters of low concern.

Identifying stations of potential concern is intended to efficiently determine whether a cluster of stations is of sufficient concern to merit further evaluation in a hazard assessment step.

Cleanup Screening Levels Criteria (WAC 173-204-520). This section defines the criteria for establishing cleanup standards. The cleanup screening level (CSL):

- Includes numeric chemical and biological criteria for marine sediment (WAC 173-204-520(2) and – (520)(3).
- Establishes minor adverse effects as the level above which station clusters of potential concern are defined, and at or below which station clusters of low concern are defined (WAC 173-204-510(2)).
- Establishes the levels above which station clusters of potential concern are defined as cleanup sites (WAC 173-204-530).

Original requirements are summarized in Table 2.1. CSLs or MCULs established for the protection of human health or for contaminated freshwater sediment sites are on a site-specific basis.

Hazard Assessment and Site Identification (WAC 173-204-530). This section defines requirements for performing hazard assessments and identifying sediment cleanup sites. Under the SMS rule, sediment cleanup sites include areas where three or more sediment stations have chemical concentrations or biological effects that exceed the CSLs specified in WAC 173-204-520, human health criteria, or other toxic, radioactive, biological, or deleterious substance criteria shall be defined as cleanup sites.[14]

Ranking and List of Sites (WAC 173-204-540). This section defines the process for ranking identified sediment cleanup sites. The objective of ranking is to assess the relative hazard posed by different contaminated sediment sites to both human health and the environment to efficiently allocate resources to remediate contaminated sediments that pose the greatest environmental and public health threat.

Types of Cleanup and Authority (WAC 173-204-550). This section acknowledges that cleanup of contaminated sites can occur under the authorities of chapters 90.48 (WPCA) and 70.105D RCW (MTCA); and may also be initiated by the federal government pursuant to CERCLA. Ecology plans to promulgate the revisions to Part V under the authority of MTCA.

[14] WAC 173-204-530 (4) (g)

Cleanup Study (WAC 173-204-560). This section defined requirements for investigating cleanup sites and evaluating cleanup alternatives. Revisions to this section include synchronizing the terminology and requirements with similar MTCA requirements for remedial investigations and feasibility studies (RI/FS).[15]

Sediment Cleanup Standard (WAC 173-204-570). This section established a process for developing site-specific sediment cleanup standards. In the SMS rule, cleanup standards define the concentrations that must be met for cleanup. Key provisions include:

- *Sediment Cleanup Objective.* The SQS specified in WAC 173-204-320 through -340 define the sediment cleanup objective for all cleanup actions. The sediment cleanup objective identifies sediments that have no acute or chronic adverse effects on biological resources, and which correspond to no significant health risk to humans.
- *Site-Specific Determinations.* Site-specific sediment cleanup standards are established as close as practicable to the SQS taking into account net environmental protection (including the potential for natural recovery of the sediments over time), cost, and technical feasibility. The cleanup standard is determined to be between the lower bound SQS and the upper bound CSL/MCUL.

Maximum Allowable Concentrations. The MCUL defined in the original SMS was the maximum allowable chemical concentration and biological effects level permissible at the cleanup site to be achieved by ten years after the completion of active site cleanup.

- *Applicable Requirements.* All cleanup standards must ensure protection of human health and the environment, and must meet all legally applicable federal, state, and local requirements.[16] The MTCA Cleanup Regulation is an applicable requirement. Under MTCA, sediment cleanup standards must be based on a reasonable maximum exposure and target risk levels of one-in-one million (cancer risk) and a hazard quotient of one (non-cancer risks).

Revisions to this section include clarifying establishing cleanup standards based on protection of human health, incorporating background concentrations to establish cleanup standards, and adopting freshwater sediment standards to protect the benthic community.

Cleanup Action Decision (WAC 173-204-580). A final step in the cleanup process is to select the appropriate cleanup alternative(s). This section defines criteria for selecting sediment cleanup actions.

Revisions to this section include synchronizing the terminology and requirements with similar MTCA remedy selection requirements[17].

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[15] WAC 173-340-350, Remedial Investigation and Feasibility Study

[16] WAC 173-204-570 (5)

[17] WAC 173-340-360, Selection of Cleanup Action

Sediment Recovery Zones (WAC 173-204-590). This section defined the requirements for establishing and monitoring sediment recovery zones. For cleanups that do not meet the sediment cleanup objective, a sediment recovery zone is issues to allow time for monitored natural recovery to take effect.

SMS Requirements Applicable to DMMP Dredged Material Disposal Sites

Part IV of the SMS rule establishes requirements that are applicable to the open water dredged material disposal sites managed by the Dredged Material Management Program (DMMP). The SMS rule incorporates the DMMP (formerly Puget Sound Dredged Disposal Analysis;) sediment characterization requirements by reference. Important features include:

Limitations on Open-Water Disposal. Dredged material cannot be taken to open-water disposal sites if the material will cause site conditions that exceed the SIZmax/CSL (see Figure 2.3). While the SMS rule authorizes Ecology to designate open-water disposal sites as Sediment Impact Zones if disposal activities result in sediment concentrations above the SQS, the results of monitoring over the last 20 years demonstrate that on-site chemistry and bioassay results are largely below SQS for benthic effects.

Chemical and Biological Criteria Based on Sediment Toxicity. The original and revised SMS rule includes chemical and biological toxicity tests that are used to identify sediment that poses "no adverse effects" and "minor adverse effects" to the benthic community. The chemical and biological toxicity tests focus on acute and sub-chronic effects to the benthic community. Consequently, the benthic criteria and benthic toxicity tests do not directly address risks to fish, wildlife, and humans posed by the bioaccumulation in the food web.

Human Health Narrative Standard. The SMS rule states that the SQS and SIZmax/CSL must both be established at levels that are "…below levels which correspond to no significant health risk to humans" (WAC 173-204-320(1)(a) and 173-204-420(1)(a), respectively). Determinations on what concentrations satisfy this narrative standard are made on a case-by-case basis when making suitability determinations for individual projects.

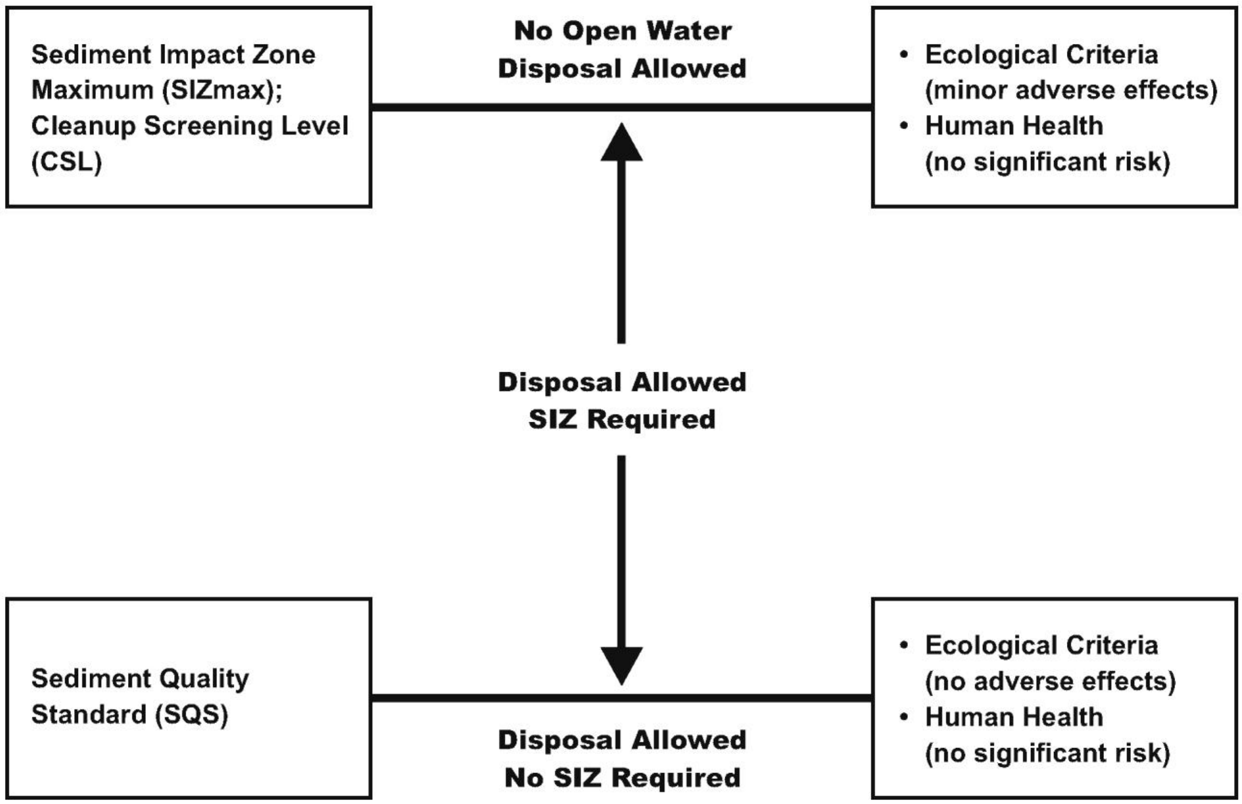

Figure 2.3: Open Water Disposal Sites Two-Tier Decision-Making Framework

Requirements for Open Water Disposal Sites. The SMS rule states that Ecology will establish requirements for dredging activities and disposal sites that include the testing and disposal requirements developed by the DMMP program and cited in various DMMP and PSDDA documents[18]. The SMS rule also states that (when necessary) Ecology may authorize sediment impact zones of DMMP sites through administrative orders issued under chapter 90.48 RCW.

Relationships Between Source Control, Cleanup and Dredging Requirements

Ecology evaluated the interrelationships between dredging and sediment cleanup when developing the original SMS rule and attempted to align the requirements for dredging, cleanup, and source control (Figure 2.4). Ecology's overall goal was to create a regulatory framework that allows different programs to be implemented without conflict The Final Environmental

[18] WAC 173-204-410(7)(a) states that the SMS guidelines shall include testing and disposal guidelines cited in several DMMP documents including (1) Management Plan Report – Unconfined Open Water Disposal of Dredged Material, Phase I, (Central Puget Sound), June 1988, or as amended; (2) Management Plan Report – Unconfined Open Water Disposal of Dredged Material, Phase II, (North and South Puget Sound), September 1989, or as amended; and (3) Users Manual for Dredged Material Management in Puget Sound, November 1990, or as amended.

Impact Statement for the SMS rule (Ecology 1990) discussed key relationships between the regulatory limits applicable to dredging and sediment cleanup. These include:

- The quality of dredged material that meets current disposal guidelines for unconfined, open-water disposal, and any permitted sediment impact zones, should not trigger a cleanup. Therefore, the current DMMP disposal guidelines should be at or below the CSL.
- Permitted sediment impact zones should not result in sediment contamination levels that will adversely impact navigation dredging by increasing the cost of dredged material disposal. Therefore, the current DMMP disposal guidelines used for open-water disposal sites should be at or below the CSL.
- Current DMMP disposal guidelines should be at or below the CSL.
- The degree of contamination used for screening of potential cleanup areas is an appropriate level to use when defining a minimum degree of cleanup to be achieved for all sites. Therefore, the CSL and MCUL should be established at the same level.
- Because there is an underlying need to ensure basic and comparable protection in all sediment management activities, decisions for source control, cleanup, and dredging should be based on comparable statutory mandates for environmental protection and human health.

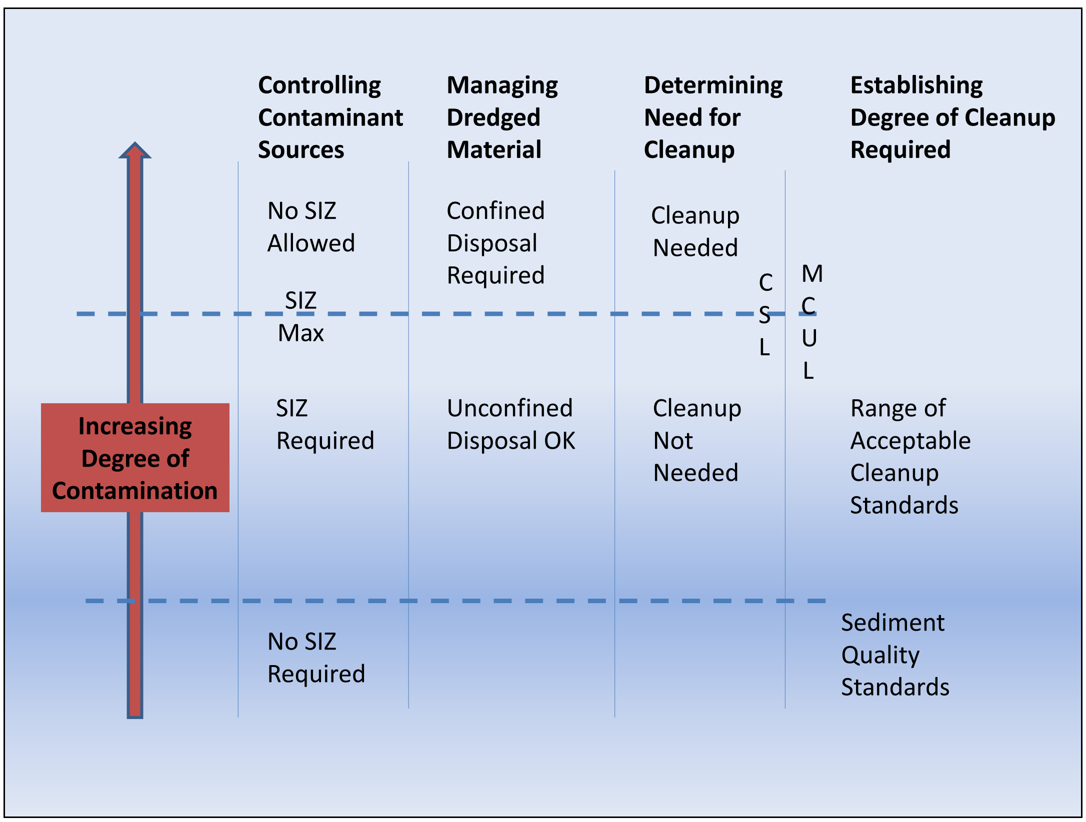

Figure 2.4: Relationship between SIZmax, CSL, and MCUL

Relationship of Existing Laws and Regulations to the Sediment Management Standards

When adopting significant legislative rules, agencies must "…coordinate the rule, to the maximum extent practicable, with other federal, state, and local laws applicable to the same activity or subject matter…".[19] Implementation of the SMS rule must be coordinated with many federal, state, and local laws, regulations, and ordinances. A discussion of the relationship between the SMS rule revisions and other applicable federal, state, and local requirements is provided in Appendix A.

[19] Chapter 34.05.328 (1) (i) RCW

Chapter 3 – Rulemaking Alternatives

Participants in the rulemaking process identified several alternative approaches for achieving the rulemaking objectives discussed in Chapter 1. This chapter describes these alternatives in sufficient detail to allow a programmatic evaluation and a comparison of environmental impacts.

The chapter is divided into three main sections. The first section briefly describes existing considerations evaluated by Ecology in developing the rulemaking alternatives. The second section describes the five alternatives for achieving human health protection. The third section describes the five alternatives for the freshwater sediment criteria.

Alternatives Development Process

The alternative approaches to establishing sediment cleanup standards evaluated in this EIS were developed after review and evaluation of a number of considerations. These include:

- The basic approaches used to establish sediment cleanup standards (or levels). This includes approaches used by Ecology and other federal and state programs.
- The law that provides the authority for revising the SMS - the Model Toxics Control Act. Ecology identified certain legal requirements that alternatives must satisfy, such as protection of human health and the environment and compliance with all relevant and applicable requirements (ARARs).
- The policies and principles in the original SMS rule (for example, the decision to allow biological testing results to override the results of sediment chemistry).
- The range of technical, policy, and implementation issues surrounding the rule revisions. These issues are discussed in detail in Appendix B, and referenced as appropriate throughout this document.
- Advisory group and public comments to ensure that alternatives selected for evaluation reflect the range of ideas and opinions on all potential approaches for achieving the rulemaking objectives.

Description of Alternatives – Human Health

This section describes the five potential alternatives for achieving human health protection. Each subsection summarizes an alternative, describes the process to be used to establish cleanup standards under the alternative, and summarizes how the standards would be implemented.

Alternative 1: Original Rule (the No Action Alternative)

Under Alternative 1, Ecology would not adopt new requirements for sediment cleanup standards. Ecology would continue to establish sediment cleanup standards based on the following requirements:

- *Benthic Toxicity.* The original SMS rule including marine chemical and biological criteria that are used to establish sediment cleanup standards based on preventing adverse effects on benthic communities.
- *SMS Human Health Narrative.* The original SMS rule including a narrative standard of "no significant human health risk." Because the original SMS rule lacked specifics of how to interpret this narrative, Ecology has interpreted this narrative as the MTCA iprovisions. Specifically, the risk levels and the reasonable maximum exposure scenario that includes subsistence or tribal use scenarios.
- *Legally Applicable Requirements.* The original SMS rule specifying "…[a]ll cleanups standards must …meet all legally applicable federal, state, and local requirements…" Legally applicable requirements include the MTCA Cleanup Regulation and the Water Quality Standards for Surface Waters.

Ecology generally used a multi-step process to establish sediment cleanup criteria under the original SMS rule.

Process to Establish Sediment Cleanup Standards Under Human Health Alternative 1

• *Develop Conceptual Site Model.* Site information is evaluated to identify potential receptors and exposure pathways. People can be exposed to sediment contamination through physical contact when playing on beaches, digging for shellfish, or by eating fish and shellfish.
• *Identify Contaminants of Concern/Risk Drivers.* Site information is evaluated to identify sediment contaminants that significantly contribute to overall site risk. These substances represent the risk drivers for the site.
• *Calculate Risk-Based Concentrations.* Standard risk assessment equations are used to develop risk-based concentrations for the contaminants of concern that take into account relevant exposure pathways identified in the conceptual site model.
• *Identify Background/Reference Concentrations.* Available information is used to identify background or reference area concentrations.
• *Establish Sediment Cleanup Objective.* The original SMS rule establishes a long-term sediment cleanup objective that is conceptually similar to the MTCA cleanup levels (no modification based on technical possibility and net environmental benefit). The sediment cleanup objective is establish at the highest of the following three levels:
    • Risk-based concentration for the most sensitive receptor. These concentrations are calculated using the general methods and policies in the MTCA rule (See **Key MTCA Policies** below);
    • Natural background. Area not influenced by "localized human activities." as defined in MTCA (WAC 173-340-200); or
    • The practical quantitation limit (PQL).
• *Establish Sediment Cleanup Standards.* Under the original SMS rule, contamination levels above the sediment cleanup objective are addressed using a combination of active cleanup

measures, source control, natural recovery, and institutional controls. The upper tier, the CSL, is used to define areas that require active cleanup measures.[20]. In this regard, the SMS sediment cleanup standards are conceptually similar to MTCA remediation levels. Under the original SMS rule, sediment cleanup standards are established as close as practicable to the sediment cleanup objective taking into account cost, technical possibility, and net environmental benefits. Areas with concentrations between the sediment cleanup standard and the cleanup objective (the sediment quality standards [SQS]) are addressed through a sediment recovery zone (e.g., source control, natural recovery, institutional controls) that is part of the cleanup action alternative selected for a particular site. See Chapter 2 of this document for additional information.

Key MTCA Policies and Methods Applicable to Sediment Cleanup Levels

- Cleanup levels are based on estimates of the "reasonable maximum exposure" (RME). The MTCA rule defines the RME as "the highest exposure that is reasonably expected to occur at a site under current and potential future site use."[21] The RME is designed to represent a high end (but not worst case) estimate of individual exposures. The RME is defined as reasonable because it is a product of several factors that are an appropriate mix of average and upper-bound estimates. RME estimates typically fall between the 90 and 99.9 percentile of the exposure distribution. The RME takes into account both current and reasonably foreseeable future conditions. MTCA has a default fish consumption rate of 54 grams per day (g/day) for recreational use scenario. However, under the RME, the fish consumption rate may be adjusted upward to protect high exposure populations such as tribes (additional information and discussion about the basis of exposure assumptions is provided in Appendix B).
- Cleanup levels will be determined to be the highest of risk-based level, natural background, or PQL.

Additional information on the relationship between the SMS rule and MTCA cleanup regulations is provided in Appendix A.

- Cleanup levels are calculated using toxicity values (e.g., cancer slope factors, reference dose values) developed by the Environmental Protection Agency (EPA) or other environmental agencies.
- Cleanup levels are based on *acceptable* or *target* risk levels described in the MTCA cleanup rule. Key provisions include:

[20] WAC 173-204-570(3) specifies that "…the minimum cleanup level is the maximum allowed chemical concentration and level of biological effects permissible at the cleanup site to be achieved by year ten after completion of the active cleanup action."

[21] See WAC 173-340-708 (3) (b). CERCLA provides a similar definition "…the highest exposure that is reasonably expected to occur at a Superfund site…"

- One in one million (1E-06) for any one carcinogenic chemical and exposure pathway.[22]
- One in one hundred thousand (1E-05) for all of the carcinogenic chemicals combined and multiple exposure pathways.
- A hazard index of 1.0 for multiple non-carcinogenic chemicals and/or multiple exposure pathways.
  (additional information and discussion on the issue of appropriate level of protection is presented in Appendix B)

- The MTCA rule does not provide equations for calculating sediment cleanup levels, but Ecology generally uses the exposure equations and parameters in MTCA and adjusts for sediment-specific media and scenarios, such as tribal fish consumption.
- The MTCA rule allows for site-specific adjustments to risk-based cleanup levels based on natural background concentrations and analytical limits. In MTCA, natural background concentrations can include both naturally occurring and anthropogenic chemicals, such as PCBs and mercury.

Implementing Human Health Alternative 1

Under this alternative, the Cleanup Screening Level (CSL, see Chapter 2) would be used to identify sediment that requires cleanup and sediment cleanup standards would be the concentration (sediment cleanup level) that must be met at the site or site unit at the point of compliance within a specified time frame, or used to identify where active cleanup should occur.

"**Site Units**" means discrete subdivisions of an individual contaminated sediment site that are being evaluated for the purpose of establishing cleanup levels. Site units are based on consideration of unique location, environmental, spatial, or other conditions determined appropriate by Ecology, e.g., cleanup under piers, cleanup in eelgrass beds, cleanup in navigation lanes.

This framework would include the following elements:

- *Identification of Cleanup Sites.* A site is initially identified as an area of potential concern that requires additional investigation through an initial hazard assessment, which is based primarily on the likelihood of sediment concentrations exceeding ecological criteria. The only potential human risk evaluated as part of the initial hazard assessment of a site is the threat that contaminant concentrations may pose to humans through ingestion of contaminated fish and shellfish. Although the original SMS rule authorizes Ecology to identify a cleanup site based on a determination that the site presents a significant risk to human health, Ecology has not exercised that authority to date. Once the hazard assessment indicates the potential for the site to present a threat, the procedures subsequently used for site identification generally involve assessment of biological effects.

[22] A 1E-06 risk level means an estimated risk of one additional cancer above the background cancer rate, per 1,000,000 individuals.

- *Performing the Remedial Investigation and Setting Site Boundaries.* Site information/data are collected, developed, and evaluated during the Remedial Investigation (RI) so that site boundaries (and site units) can be delineated, cleanup levels established, and cleanup actions identified. Part of the RI involves conducting a human health risk assessment. The results of this risk assessment may redefine site boundaries that had been preliminarily defined through comparison of sediment concentrations to ecological criteria, and serve to inform cleanup standards set for the site.
- *Active Cleanup Measures.* The original rule uses a combination of technologies including active cleanup measures (such as dredging and capping) for sediments including a reasonable restoration time frame (10 years).
- *Source Control Measures.* Source control requirements are based on the likelihood of exceeding ecological criteria (WAC 173-204-320), which include numerical concentration criteria and biological effects criteria. Source control requirements are not based on protection of human health, which are addressed on a case-by-case basis.
- *Identification of Cleanup Sites.* Sites requiring cleanup would be identified based on whether sediments at the site exceed the cleanup standard. The boundary of a cleanup site would be defined based on the cleanup standard/level for the site. A sediment recovery zone would not be part of a cleanup action alternative selected for a particular site, because there would not be a defined sediment cleanup objective that is different from the cleanup level.

Figure 3.1 illustrates how cleanup actions under Alternative 1 might look over time. With cleanup levels set at a risk-based standard, natural background, or the PQL, and with source control based on ecological criteria and water quality standards (with limited to no application of the human health narrative), the ongoing discharges and difficulty of meeting the cleanup standard would impact the feasibility of being able to achieve cleanup. Additionally, with no liability settlements for sites available, and high transaction costs resulting from multiple PLPs, and a case-by-case approach, longer time frames for active cleanup would be expected. This would extend the time period for exposure to higher concentrations of contaminants.

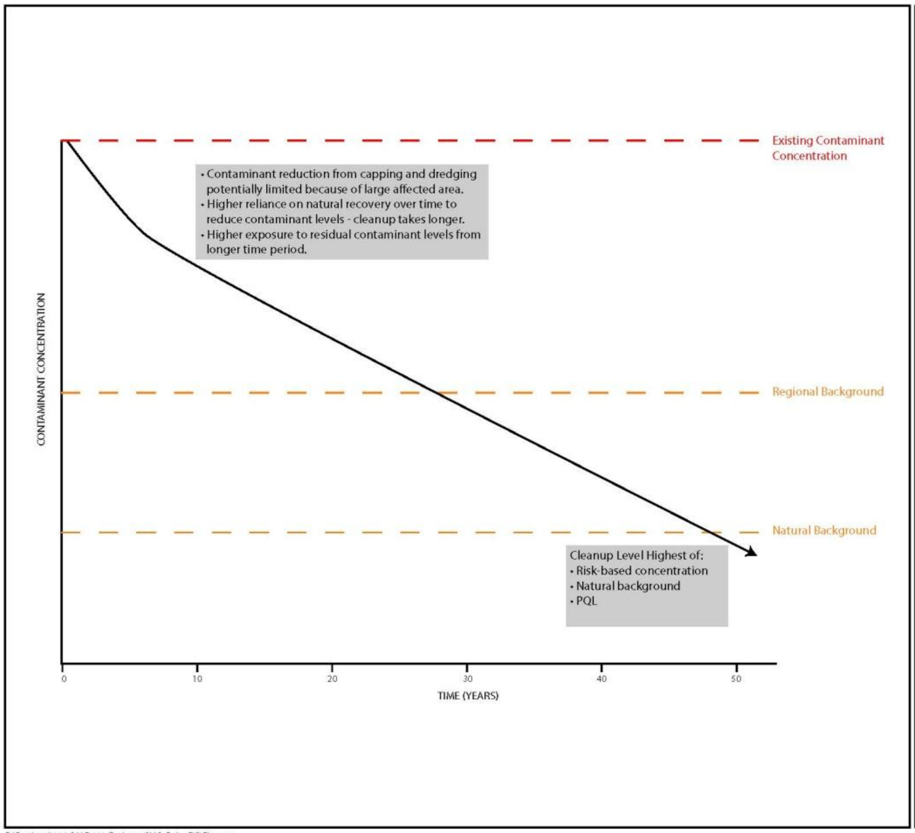

FIGURE 3.1
Human Health Alternative 1 - Cleanup Progression Over Time

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The human health case studies presented in Appendix E also illustrate how cleanup levels might be set for various environments for Human Health Alternative 1 (see Appendix E, Tables E.2, E.5, E.8, and E.11):

Human Health Case Study 1 (Non-Urban Shoreline, Table E.2). The cleanup level for dioxin/furan congeners was set at the PQL, and cleanup levels for cadmium and carcinogenic PAHs was set at MTCA natural background.

Human Health Case Study 2 (Urban Shoreline, Table E.5). The cleanup levels for arsenic and carcinogenic PAHs were set at MTCA natural background.

Human Health Case Study 3 (Urban Embayment, Table E.8). The cleanup level for mercury was set at MTCA natural background, and the cleanup level for dioxin/furan congeners was set at the PQL.

Human Health Case Study 4 (Freshwater River, Table E.11). The cleanup level for PCBs was set at the PQL.

Alternative 2: Risk-Based Concentrations Based on Reasonable Maximum Exposure (RME)

Under Alternative 2, Ecology would establish sediment cleanup levels for human health protection using risk levels and methods similar to those in the MTCA Cleanup Regulation.

The process for establishing sediment cleanup levels under Alternative 2 is similar to the approach used under the original SMS rule (as described previously for Alternative 1). The two main differences are:

- Risk-based concentrations would not be adjusted to reflect non-anthropogenic background concentrations, MTCA natural background, or a PQL.
- Risk-based concentrations would not be adjusted to reflect technical possibility or net environmental benefit.

Process to Establish Sediment Cleanup Levels Using Human Health Alternative 2
• *Develop a Conceptual Site Model.* Site information is evaluated to identify potential exposure pathways. • *Identify Contaminants of Concern/Risk Drivers.* Site information is evaluated to identify sediment contaminants that significantly contribute to overall site risk. • *Calculate Risk-Based Concentrations.* Standard risk assessment equations are used to develop risk-based concentrations for the contaminants of concern that take into account relevant exposure pathways identified in the conceptual site model. • *Establish Sediment Cleanup Standard.* Under this approach, the sediment cleanup level would be established at the risk-based concentration.

Implementing Human Health Alternative 2

Under this alternative, sediment cleanup levels would still be used to identify sediments that require active cleanup (e.g., dredging, capping). This framework would include the following elements:

- *Sediment Cleanup Levels.* Sediment cleanup levels based on human health protection would be established using the MTCA methods and policies. Key features of MTCA were summarized for Alternative 1. A “Reasonable Maximum Exposure” (RME) is one in which exposure parameters selected for use in calculating a risk-based cleanup levels would be at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but still within a realistic range of exposure (EPA, 1989). For Alternative 2, the MTCA allowance for site-specific cleanup level adjustment based on background or PQL would not apply. Cleanup levels would be based on the acceptable (target) risk levels described in the MTCA cleanup rule (a one-in-one million risk level for any one carcinogenic chemical and single exposure pathway, one-in-one hundred thousand risk level for all combined carcinogenic chemicals and exposure pathways, a hazard quotient of 1.0 for single non-carcinogenic chemicals and single exposure pathway, and hazard index of 1.0 for multiple non-carcinogenic chemicals/exposure pathways).

- *Active Cleanup Measures.* The original rule uses a combination of technologies including active cleanup measures (such as dredging and capping) for sediments including a reasonable restoration time frame (10 years).
- *Identification of Cleanup Sites.* Sites requiring cleanup would be identified based on whether sediments at the site exceed the risk-based cleanup level. The boundary of a cleanup site would be defined based on the risk-based cleanup level for the site. A sediment recovery zone would not be part of a cleanup action alternative selected for a particular site, because there would not be a defined sediment cleanup objective that is different from the cleanup level.
- *Source Control Measures*.

Figure 3.2 illustrates how cleanup actions under Alternative 2 might look over time.

- With cleanup levels set at a 1E-06 risk level, no allowance for adjustment for either background or the PQL, and source control based on ecological criteria and water quality standards (with limited to no application of the human health narrative), the ongoing discharges and difficulty of achieving the risk-based level would impact the feasibility of being able to achieve cleanup at sites.
- Lack of liability settlements for sites, high transaction costs because of multiple PLPs, higher cleanup costs because of the need to address large areas through dredging or capping, and a higher likelihood of having to address recontamination, would lead to the need for longer time frames for active cleanup. This would extend the time period for exposure to higher concentrations of contaminants.

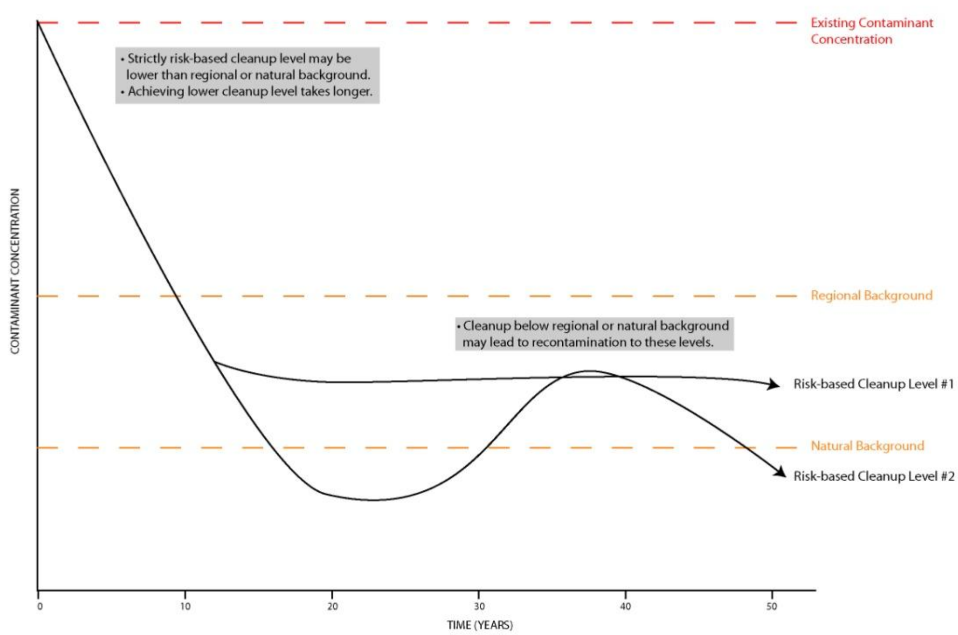

FIGURE 3.2
Human Health Alternative 2 - Cleanup Progression Over Time

The human health case studies presented in Appendix E also illustrate how cleanup levels might be set for various environments for Human Health Alternative 2 (see Appendix E, Tables E.2, E.5, E.8, and E.11):

Human Health Case Study 1 (Non-Urban Shoreline, Table E.2). The cleanup level for dioxin/furan congeners and carcinogenic PAHs was set at a concentration equal to a carcinogenic risk of 1E-05, and the cadmium cleanup level was set at a concentration equal to a hazard quotient of 1.0.

Human Health Case Study 2 (Urban Shoreline, Table E.5). The cleanup levels for arsenic and carcinogenic PAHs was set at a concentration equal to a carcinogenic risk of 1E-05.

Human Health Case Study 3 (Urban Embayment, Table E.8). The cleanup level for mercury was set at a concentration equal to a hazard quotient of 1.0, and the cleanup level for dioxin/furan congeners was set at a concentration equal to a carcinogenic risk of 1E-06.

Human Health Case Study 4 (Freshwater River, Table E.11). The cleanup level for PCBs was set at a concentration equal to a carcinogenic risk of 1E-06.

Alternative 3: Risk-Based Concentrations Based on Federal CERCLA Requirements

Under Alternative 3, Ecology would establish sediment cleanup standards using the policies and methods specified in the National Contingency Plan (NCP) and relevant EPA risk assessment guidance. [23] This is similar to the MTCA risk-based alternative and reflects the minimum requirement under the MTCA law.[24]

The approach for establishing cleanup levels is similar to the Alternatives 1 and 2 (e.g., use of RME and EPA toxicity values). However, several important differences influence the stringency of this alternative relative to those alternatives. These include:

- Risk-based cleanup levels for chemicals classified as known and potential carcinogens would be based on a total site risk of one in ten thousand (1E-04). Total site risk takes into account all of the carcinogenic chemicals identified as contaminants of concern and multiple exposure pathways.[25]
- Initial cleanup levels for non-carcinogenic chemicals would be identical to those presented in Alternatives 1 and 2 (i.e., based on a hazard quotient of 1.0 for single non-carcinogenic chemicals, and a hazard index of 1.0 for multiple non-carcinogenic chemicals and/or multiple exposure pathways).
- Under federal CERCLA, background includes both naturally occurring background (substances in the environment that have not been influenced by human activity) and anthropogenic background (natural and human-made substances present in the environment because of human activities and not specifically related to the site in question). Cleanup levels could be set based on background by either definition, if determined to be higher than human health-based standards. This background concept is similar to Ecology's "regional background" concept for the revised rule.
- Exposure factors used under federal CERCLA are of less a "default" nature and more detailed than those used in MTCA. Although they will not result in substantively different cleanup levels, they are more cumbersome to employ and more time and resources would be needed to identify appropriate exposure scenarios and associated exposure factors on every site.

The process for establishing sediment cleanup levels under Alternative 3 is similar to the approach used under Alternative 1, with the exception of different risk levels and type of background.

[23] Risk Assessment Guidance for Superfund, Parts A through F (1989 to 2009), US EPA, Office of Emergency and Remedial Response, Washington, DC.

[24] The MTCA statute requires that cleanup standards must be at least as stringent as standards established under applicable state and federal laws, including Section 121 of the federal Superfund law.

[25] Id.

Process to Establish Sediment Cleanup Levels Using Human Health Alternative 3

• *Develop a Conceptual Site Model.* Site information is evaluated to identify potential exposure pathways.
• *Identify Contaminants of Concern/Risk Drivers.* Site information is evaluated to identify sediment contaminants that significantly contribute to overall site risk.
• *Calculate Risk-Based Concentrations.* Standard risk assessment equations are used to develop risk-based concentrations for the contaminants of concern that take into account relevant exposure pathways identified in the conceptual site model.
• *Identify Background/Reference Concentrations.* Available information is used to identify background or reference area concentrations.
• *Establish Sediment Cleanup Level.* Under this approach, the sediment cleanup level would be established at the highest of the following two levels:
    • Risk-based concentration for the most sensitive receptor; or
    • Anthropogenic background.

Implementing Human Health Alternative 3

Under this alternative, sediment cleanup levels would still be used to identify sediment that requires active cleanup (e.g., dredging, capping). This framework would include the following elements:

- *Sediment Cleanup Levels.* Sediment cleanup levels based on human health protection would be established using the EPA methods and policies.
- *Active Cleanup Measures.* Unlike the original rule, active cleanup measures would be required for all sediment that is predicted to exceed the risk-based cleanup levels following a reasonable restoration time frame (10 years).
- *Identification of Cleanup Sites.* Sites requiring cleanup would be identified based on whether sediment at the site exceeds the cleanup level. The boundary of a cleanup site would be defined based on the cleanup standard for the site. A sediment recovery zone would not be part of a cleanup action alternative selected for a particular site, because there would not be a defined sediment cleanup objective that is different from the cleanup level.

Figure 3.3 illustrates how cleanup actions under Alternative 3 might look over time. Cleanup levels for any of the alternatives would be set either at a higher risk standard or at an established area/regional background level. This, along with the opportunity to achieve liability settlements for sites (which is somewhat more feasible given the higher cleanup levels), smaller areas requiring cleanup, and resulting lower cleanup costs may result in faster initiation of cleanup. However, source control will be based on ecological criteria and water quality standards (limited to no application of the human health narrative). Ongoing discharges will affect the feasibility of being able to achieve cleanup a sites and increase the likelihood of having to deal with recontamination in the future.

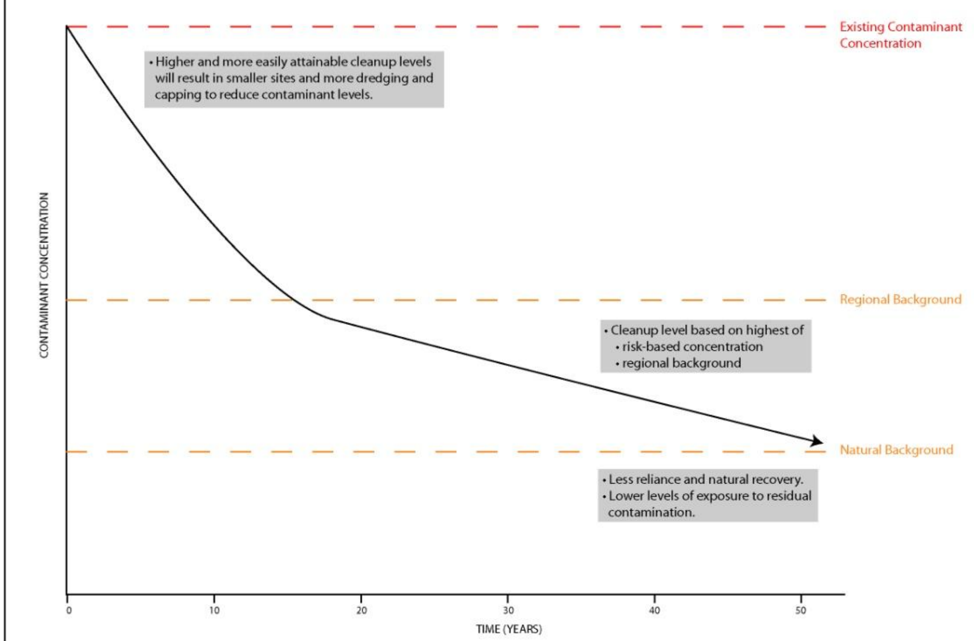

FIGURE 3.3
Human Health Alternative 3 - Cleanup Progression Over Time

The human health case studies presented in Appendix E also illustrate how cleanup levels might be set for various environments for Human Health Alternative 3 (see Appendix E, Tables E.2, E.5, E.8, and E.11):

Human Health Case Study 1 (Non-Urban Shoreline, Table E.2) – the cleanup level for dioxin/furan congeners, carcinogenic PAHs, and cadmium would all be set at regional background.

Human Health Case Study 2 (Urban Shoreline, Table E.5) – the cleanup levels for arsenic and carcinogenic PAHs would be set at regional background.

Human Health Case Study 3 (Urban Embayment, Table E.8) – the cleanup levels for dioxin/furan congeners and mercury would be set at regional background.

Human Health Case Study 4 (Freshwater River, Table E.11) – the cleanup level for PCBs was set at a concentration equal to a carcinogenic risk of 1E-05.

Alternative 4: Regional Background and Practical Quantitation Limit (PQL)

Under Alternative 4, sediment cleanup levels would be established at concentrations equal to the highest of regional background or the PQL.

The original SMS rule provides a definition of "nonanthropogenic background," and in rare cases where there are elevated concentrations from nonanthropogenic sources, this background may be used.[26] The original SMS does not provide a definition of area background and natural background (which are defined by MTCA), and it does not specify how background is defined when setting cleanup levels for human health protection. These differences in SMS and MTCA rules create confusion when making decisions at sediment cleanup sites.

The MTCA rule approach for background, which was developed for soil, sets cleanup levels at *natural background* if natural background is higher than the concentration associated with the MTCA rule acceptable human health risk level. *Natural background* is defined in the MTCA rule as "the concentration of hazardous substance consistently present in the environment that has not been influenced by localized human activities."[27] There has been difficulty in determining what natural background concentrations are for sediment because of the ambiguity in what is meant by "localized human activities," the dynamic nature of sediment, and the numerous sources of contamination to the sediment environment.

Sediment contamination differs from upland soil contamination in several ways:

- In many cases, sources of contamination to sediment, such as stormwater runoff and industrial discharge subject to a permit, is ongoing and will continue to provide a source of contamination to sediment in the future until source control measures are fully implemented.
- Water overlying sediment moves contaminants over wide areas of impact relative to most releases of contamination on surface soil.

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[26] WAC 173-204-320 (6) Puget Sound marine nonanthropogenically affected sediment quality criteria. Whenever nonanthropogenically affected sediment quality is of a lower quality….than the applicable cleanup screening levels or minimum cleanup levels criteria established under this section, the existing sediment chemical and biological quality shall be identified on an area-wide basis as determined by the department and used in place of the standards of WAC 173-204-520.

[27] WAC 173-340-200. "Natural background" means the concentration of hazardous substance consistently present in the environment that has not been influenced by localized human activities. For example, several metals and radionuclides naturally occur in the bedrock, sediments, and soils of Washington State due solely to the geologic processes that formed these materials and the concentration of these hazardous substances would be considered natural background. Also, low concentrations of particularly persistent organic compounds, such as polychlorinated biphenyls (PCBs), can be present in surficial soils and sediment concentrations throughout much of the state as a result of global distribution of these hazardous substances. The low concentrations would be considered natural background. Similarly, concentrations of various radionuclides that are present at low concentrations throughout the state as a result of global distribution of bomb testing and nuclear accidents would be considered natural background."

These factors present problems relative to definition and use of "natural background" as a sole cleanup level for sediment. To address this issue, different definitions of background have been developed to allow background to be used in setting sediment cleanup levels. In addition to the existing definition of "natural background," the concept of "***regional background***" has been introduced, and is the basis of cleanup levels under Alternative 4.

Ecology's "regional background" definition for the revised rule for application to sediments is as follows:

"Regional background" means the concentration of a contaminant within a department-defined geographic area that is primarily attributable to diffuse sources, such as atmospheric deposition or storm water, not attributable to a specific source or release. The department will determine the geographic area for establishing regional background for a contaminant.

This definition of regional background includes low level, ubiquitous concentrations; it is generally expected to be greater than or equal to natural background, and less than *area background*, as defined in MTCA (WAC 173-340-200[28]). The relationship of regional background and natural background to each other is shown for a hypothetical site on Figure 3-4. Additional discussion on how Ecology defines background is provided in Appendix B.

[28] Area background is defined by WAC 173-340-200 as ".the concentrations of hazardous substances that are consistently present in the environment in the vicinity of a site which are the result of human activities unrelated to releases from that site."

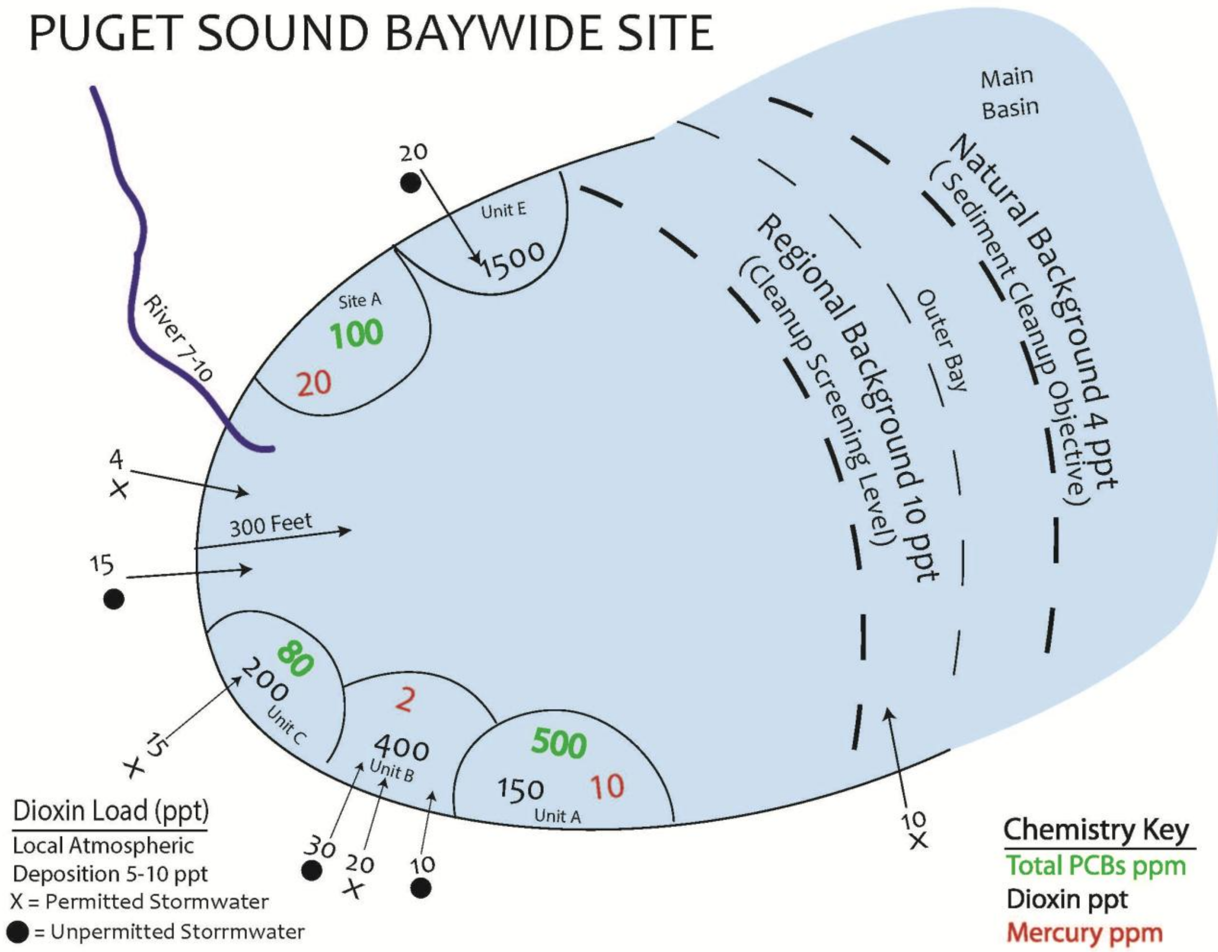

Figure 3.4: Puget Sound Baywide Site

Proposed Alternative 4 would set cleanup levels for sediment based on this definition of regional background. In the event that a strictly human health-based concentration is lower than that prescribed by regional background, no further adjustment downward would be made to the cleanup level. These regional background-based concentrations would also not be adjusted to reflect technical possibility or net environmental benefit. However, if a regional background-based cleanup level is lower than analytical limits, the cleanup level would be based on the PQL.

Methods that will be used to calculate regional background levels are described in the Sediment Cleanup Users Manual guidance. Regional background concentrations must exclude areas under the direct influence of known or suspected contaminated sources including, but not limited to, areas within a cleanup site. If a water body is not beyond the direct influence of a significant source of contamination, an alternative geographic approach to determine regional background may be used with approval by Ecology.

Implementing Human Health Alternative 4

Under Alternative 4, sediment cleanup levels would still be used to identify sediments that require active cleanup (e.g., dredging, capping). This framework would include the following elements:

- *Sediment Cleanup Levels.* Sediment cleanup levels would be the highest of regional background or practical quantitation limits.
- *Active Cleanup Measures.* Unlike the original rule, active cleanup measures would be required for all sediments that are predicted to exceed the cleanup levels following a reasonable restoration time frame (10 years).
- *Identification of Cleanup Sites.* Sites requiring cleanup would be identified based on whether sediment at the site exceed the cleanup level. The boundary of a cleanup site would be defined based on the cleanup standard for the site. A sediment recovery zone would not be part of a cleanup action alternative selected for a particular site, because there would not be a defined sediment cleanup objective that is different from the cleanup level.

Figure 3.5 illustrates how cleanup actions under Alternative 4 would look over time. Cleanup levels would be based on some type of regional/area background, with a default to the PQL if it is higher. This, along with the opportunity to achieve liability settlements for sites (which is somewhat more feasible given the higher cleanup levels), smaller areas requiring cleanup, and resulting lower cleanup costs may result in faster initiation of cleanup. However, source control will be based on ecological criteria and water quality standards (limited to no application of the human health narrative). Ongoing discharges will impact the feasibility of being able to achieve cleanup a sites, and increase the likelihood of having to deal with recontamination in the future.

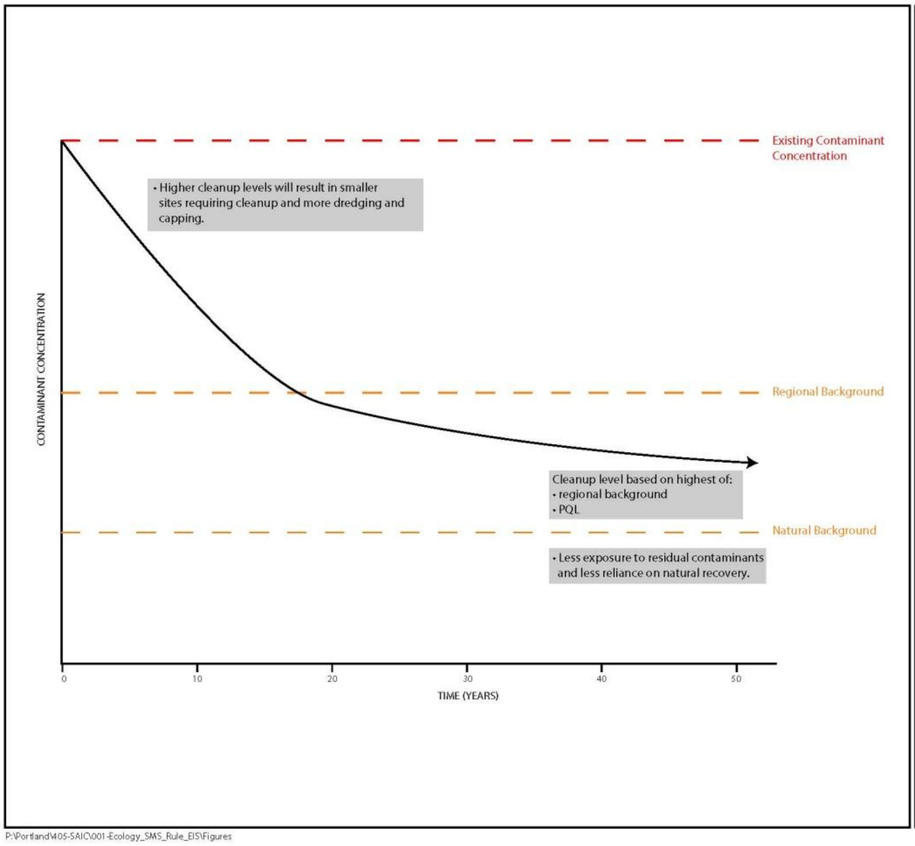

FIGURE 3.5
Human Health Alternative 4 - Cleanup Progression Over Time

The human health case studies presented in Appendix E also illustrate how cleanup levels might be set for various environments for Human Health Alternative 4 (see Appendix E, Tables E.2, E.5, E.8, and E.11):

Human Health Case Study 1 (Non-Urban Shoreline, Table E.2). The cleanup level for dioxin/furan congeners would be set at the PQL, and cleanup levels for carcinogenic PAHs and cadmium would be set at regional background.

Human Health Case Study 2 (Urban Shoreline, Table E.5). The cleanup levels for arsenic and carcinogenic PAHs would be set at regional background.

Human Health Case Study 3 (Urban Embayment, Table E.8). The cleanup levels for dioxin/furan congeners and mercury were set at regional background.

Human Health Case Study 4 (Freshwater River, Table E.11). The cleanup level for PCBs was set at the PQL.

Alternative 5 – Combination

Alternative 5 was suggested by the language in both the SMS and MTCA rules that requires both compliance with ARARs and protection of human health and the environment and retains the original two-tier framework for establishing cleanup levels. It allows for consideration of both natural and regional background concentrations of hazardous substances in the environment. This alternative could be established within the original two-tier SMS framework that allows sediment cleanup levels to be set within a range between an upper and lower bound. The upper value would be referred to as the Cleanup Screening Level (CSL), which is defined to be the upper bound allowed as a cleanup level, and the concentration that would trigger the potential need for cleanup. This upper bound would be established as the **highest** of three concentrations determined for the site:

- Risk-based concentration;
- Regional background; and
- The PQL.

The lower bound would be referred to as the Sediment Cleanup Objective (SCO). This lower bound concentration would be set as the **highest** of three concentrations determined for the site:

- Risk-based concentration;
- Natural background; and
- The PQL.

Alternative 5 will use the MTCA RME framework for calculation of risk-based cleanup levels (using site-specific fish consumption rates) and the SMS for benthic criteria. See Chapter 4 and Appendix C for additional information on exposure parameters used in each alternative analysis.

The site-specific cleanup level established for the site, based on protection of human health, would be somewhere in the range between the CSL (upper bound) and SCO (lower bound), and would be established on the basis of technical possibility and net adverse environmental impact. Because of the tendency of sources of sediment contamination to influence wide areas unless source control is implemented, this alternative would allow PLPs to reach a settle their obligations for individual site units if the cleanup standard for that unit is met and their source(s) controlled. At the same time, Alternative 5 will allow for site or bay-wide contaminant concentrations to be further reduced over time (toward the SCO concentration) through cleanup of multiple site units and source control implementation on a regional scale. The two-tier framework proposed by Alternative 5 is illustrated on Figure 3.6. Additional information on use of uniform versus site-specific cleanup levels, restoration time frames and sediment recovery zones, the relationship between SMS rule cleanup and source control provisions, and on use of site units as a means of defining site remediation requirements is provided in Appendix A.

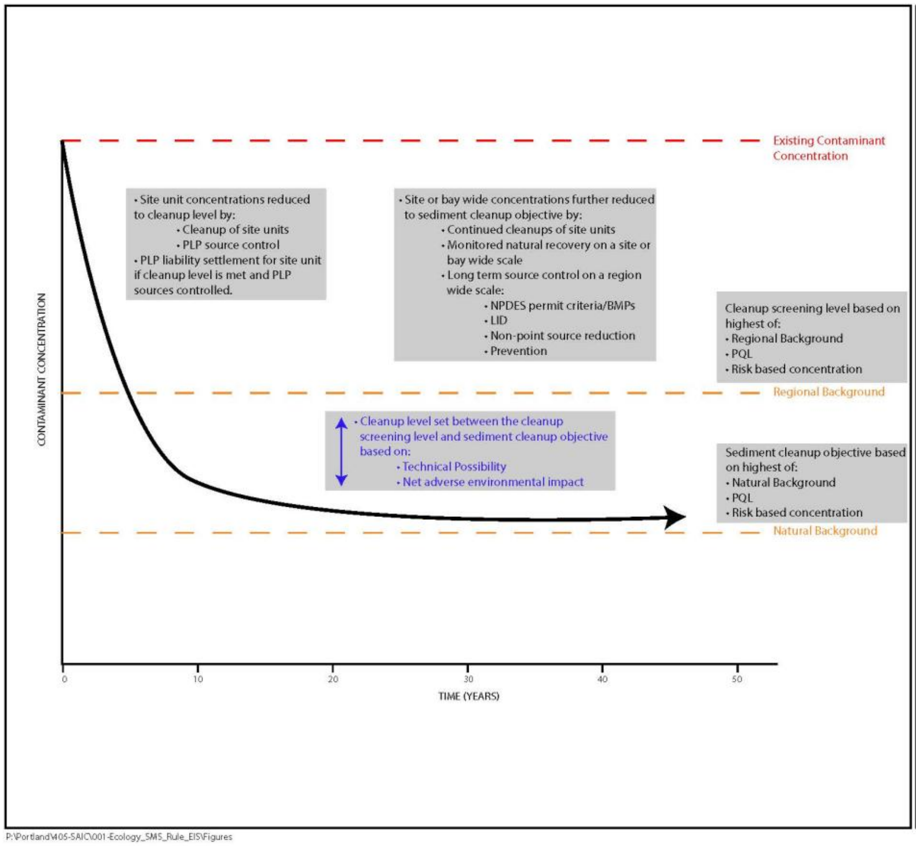

FIGURE 3.6
Human Health Alternative 5
- Cleanup Progression Over Time

The two-tier framework provides incentives for early cleanup actions in allowing the cleanup level to be established between two tiers, and potentially on a regional background value. The lower sediment cleanup goal is achieved over a longer period of time through a combination of active cleanup, source control, and natural recovery. Additionally PLPs will be more likely to initiate cleanup because settlements of their cleanup obligations will be available for achieving cleanup at site units. Early PLP source control measures implemented to meet requirements will reduce the potential for recontamination. Overall, these factors will lead to more certainty, faster cleanup of more contaminated areas, lower transaction costs, and lower cleanup costs.

The human health case studies presented in Appendix E also illustrate how cleanup levels might be set for various environments for Human Health Alternative 5 (see Appendix E, Tables E.2, E.5, E.8, and E.11):

Human Health Case Study 1 (Non-Urban Shoreline, Table E.2). The cleanup level for dioxin/furan congeners would be set at the PQL (which in this case represents both the CSL and the SCO) and the cleanup levels for both cadmium and carcinogenic PAHs would be set at a concentration equal to both MTCA natural background and regional background (the SCO and CSL, respectively, and both set at the same concentration).

Human Health Case Study 2 (Urban Shoreline, Table E.5). The cleanup level for arsenic would be set at a concentration equal to both MTCA natural background and regional background (the SCO and CSL, respectively, and both set at the same value) and carcinogenic PAHs would be set between a concentration based on a carcinogenic risk of 1E-05 (the SCO) and regional background (the CSL).

Human Health Case Study 3 (Urban Embayment, Table E.8). The cleanup level for dioxin/furan congeners would be set somewhere between regional background (the CSL) and the PQL (the SCO). The cleanup level for mercury would be set at regional background/MTCA natural background (the SCO and CSL, respectively, and both the same value).

Human Health Case Study 4 (Freshwater River, Table E.11). The cleanup level for PCBs would be set somewhere in the range between a concentration equal to a carcinogenic risk of 1E-05 (the CSL) and the PQL (the SCO).

Description of Alternatives – Freshwater Sediment Standards

The originals rule includes a two-tiered decision-making framework to protect the function and integrity of the benthic community. The SMS rule outlines specific standards and decision-making processes to protect biological resources and cleanup contaminated sediment, and includes adopted numeric chemical and biological criteria for marine sediments. However, the original SMS rule only included narrative criteria for freshwater sediment for protection of the benthic community that correspond to the Sediment Quality Standards (SQS), Sediment Impact Zone Maximum Criteria (SIZmax), Cleanup Screening Level (CSL) and Minimum Cleanup Level (MCUL). Further information on these criteria is provided in Chapter 2 of this document.

There are many contaminated freshwater sediment sites in Washington State under MTCA or CERCLA oversight. Because of the lack of adopted freshwater sediment criteria, the narrative standard requires a site-specific evaluation to determine cleanup standards. This site-specific process can create inconsistency on how freshwater sediment sites are cleaned up.

The following section describes the five alternatives for establishing criteria for freshwater sediment for protection of the benthic community, provides examples of cleanup criteria under each alternative, and discusses how the criteria would be implemented. The sediment criteria discussed and evaluated in this section are for protection of the benthic community only and do not apply to human health or bioaccumulative impacts to higher trophic level species.

Alternative 1: Original rule (the No Action Alternative)

Under Alternative 1, Ecology would not adopt new criteria for the protection of the freshwater benthic community. Under Alternative 1, sediment cleanup criteria for freshwater sediment would continue to be established on a site-specific basis using the original SMS narrative standard for SCO (no adverse effects) and CSL (minor adverse effects). Evaluation of freshwater sediment would rely on biological testing for confirmation of sediment quality. Site use history and existing data is examined, looking at known or suspected concentrations of potential contaminants of concern to determine if there is *reason to believe* there may be toxicity caused by contaminants. As a basis for evaluating potential toxicity, site data may be compared to existing sediment quality values (SQVs).

The chemical guidance values used currently include Ecology's 2003 Sediment Quality Values (Interim SQVs; Ecology, 2003) and the Threshold Effects Concentrations (TECs) and Probable Effects Concentrations (PECs) established by MacDonald et al. (2000). The interim SQVs are generally applied to sites in Western and Eastern Washington, whereas the TECs and PECs are applied site specifically in Eastern Washington. The basis for each of these chemical guidance values are as follows:

- *2003 SQVs.* The 2003 Sediment Quality Values are derived using the floating percentile method and are explained in the Ecology report titled, "Development of Freshwater Sediment Quality Values for Use in Washington State" (Ecology, 2003). The method that was used to derive the guidance values is summarized here. These values were based on synoptic chemistry and bioassay data (sediment samples were collected for chemistry and bioassay testing were collected simultaneously and from the same location) from the Pacific Northwest region.

  The floating percentile method is designed to select an optimal percentile of chemical concentrations that provides a low rate of false negative predictions of toxicity (hits incorrectly predicted as non-hits). Individual chemical concentrations are then adjusted upward until the rate of false positive predictions of toxicity (non-hits incorrectly predicted as hits) are decreased to their lowest possible level while retaining the same low false negative rate. This method allows the actual percentile of chemical concentrations to be varied independently for different contaminants, increasing the overall ability of the chemical criteria to correctly predict the toxicity of a sample (increased reliability). At very low false negative rates, the rate of false positive predictions generally increases, resulting in overly conservative SQVs. Conversely, low false positive rates can result in high false negative rates and underestimates of toxicity. The 2003 SQV were based on a limited dataset with a limited group of organic analytes.

- *Threshold Effects Concentrations and Probable Effects Concentrations.* Threshold Effects Concentrations (TEC) and Probable Effects Concentrations (PEC) are "consensus-based values," derived from a suite of other nationally and internationally derived benchmarks. The TEC and PEC values combine benchmarks derived from both toxicity and benthic community endpoints for both freshwater and marine sediments, and uses synoptic data from various states.

  The TEC values are intended to identify chemical concentrations below which harmful effects on benthic organisms are *not expected to occur*; whereas the PECs identify chemical concentrations above which effects on benthic organisms are *expected to occur frequently*. The TECs are based on

  - Threshold Effect Levels (TELs) developed with data from the Great Lakes region (Smith et al., 1996);

- Effects-Range Low values (ERL) based on marine toxicity and benthic community date from the United States (Long and Morgan, 1995); and
- Apparent Effects Threshold (AET) values based on freshwater amphipod toxicity tests (MacDonald et al., 2000).

PEC values are based on

- Probable Effect Levels (PEL; Smith et al., 1996);
- Effects-Range Median values (ERM; Long and Morgan, 1995);
- Severe-Effects Levels (Persaud et al., 1993); and
- Toxic Effect Thresholds (MacDonald et al., 2000).

Additional information on the appropriate level of protection for ecological receptors under the SMS is presented in Appendix A.

Where there is reason to believe toxicity may occur based on a comparison to the 2003 Interim SQVs or TECs/PECs above, sediment quality is assessed using a suite of biological toxicity tests and may include *H. azteca*, *C. dilutus*, or Microtox, as indicated in the Sampling and Analysis Plan Appendix (SAPA; Ecology 2008).

Because the evaluation of chemical concentrations and use of biological testing is determined on a case-by-case basis, there may be a lack of consistency in application of the assessment methods between sites. Regional differences in the use of interim SQVs or TECs/PECs may lead to differences in determining when toxicity is suspected and the designations of sediment cleanup sites or the scope of the biological testing required. The suite of biological toxicity tests and whether the treatments are compared to references or controls may also vary on a site-by-site basis.

Examples of Cleanup Criteria (Alternative 1)

Currently, two sets of freshwater SQVs are used to evaluate the potential for benthic effects at freshwater sites in Washington State. These include the Interim SQVs developed by Ecology in western Washington or TECs and PECs in eastern Washington. The SQVs for metals and organic contaminants included in Alternative 1 are presented in Tables 3.1 and 3.2, respectively.

Consistent with the SMS and the marine sediment criteria, two levels of biological responses are currently used for each of the freshwater test endpoints. The performance biological testing criteria for the control, reference and test treatments are presented in Table 3.3. These tables are presented at the end of this chapter.

Alternative 2: Minimize False Negatives (10 Percent False Negative Rate)

Under Alternative 2, both chemical and biological criteria would be established for freshwater sediments. Chemical criteria would be based on the floating percentile method described for Alternative 1 using a false negative rate of 10 percent.

Chemical criteria under this alternative would be based on an expanded dataset of over 1800 toxicity data points associated with 582 sediment samples from a broader geographic area, representing Washington, Oregon, and Idaho. The data are summarized in the report "Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho" (Ecology, 2011).

Alternative 2 would also establish biological criteria for an expanded suite of freshwater sediment bioassays to provide consistent confirmatory toxicity testing for any sediment sample that had exceeded the chemical criteria as defined in the original SMS. Ecology has developed biological criteria, defining a suite of bioassays and endpoints that may be conducted as a confirmatory or override step, or simultaneously with chemical analysis. The following test endpoints were selected by Ecology for inclusion in the freshwater criteria:

- *Hyalella azteca* – 10-day mortality (acute)
- *Hyalella azteca* – 28-day mortality (chronic)
- *Hyalella azteca* – 28-day growth (chronic)
- *Chironomus dilutus* (formerly *C. tentans*) – 10-day mortality (acute)
- *Chironomus dilutus* (formerly *C. tentans*) – 10-day growth (acute)
- *Chironomus dilutus* (formerly *C. tentans*) – 20-day mortality (chronic)
- *Chironomus dilutus* (formerly *C. tentans*) – 20-day growth (chronic)

The proposed biological criteria include a selection from this list with the following requirements:

- At least 2 species;
- At least 3 endpoints;
- At least 1 chronic test; and
- At least 1 non-lethal endpoint.

Unlike marine biological criteria, the freshwater biological criteria developed by Ecology are based on a comparison to control treatments. This is because of the lack of established reference sites in Washington and the highly variable responses observed in reference sediments. Comparison to reference sediments may be allowed on a case-by-case basis. Control and reference performance criteria were defined for each test based on national method guidance, the results of round-robin tests, and levels of control and reference performance observed by regional laboratories.

Examples of Cleanup Criteria (Alternative 2)

Chemical criteria would be based on the floating percentile method using a false negative rate of 10 percent. This option would provide SQS and CSL values that minimize the number of false negative predictions of toxicity (hits incorrectly predicted as non-hits). However, by minimizing the false negative rate (10 percent), the number of false positives would increase from 33 to 50 percent. The overall reliability (predictive ability) of this alternative would be 62 to 71 percent, depending on the biological testing endpoint. The SQS and CSL values for Alternative 2 are presented in Tables 3.1 and 3.2.

Consistent with the SMS and the marine sediment criteria, two levels of biological responses were developed for each of the freshwater test endpoints. The SQS levels were set for each test based on the minimum detectable difference (MDD) from the results of the ASTM round-robin tests. The CSL was defined as a response 10 to 15 percent greater than the MDD. The performance biological testing criteria for the control, reference, and test treatments are presented in Table 3.3.

Alternative 3: Minimize False Positives (30 Percent False Negative Rate)

Under Alternative 3, both chemical and biological criteria would be established for freshwater sediments. Chemical criteria would be based on the floating percentile method using a false negative rate of 30 percent. Chemical criteria under Alternative 3 would be based on an expanded dataset of over 1800 toxicity data points from a broader geographic area, representing Washington, Oregon, and Idaho (Ecology, 2011). Biological criteria would be established using the expanded suite of biological toxicity tests presented in Alternative 2.

Examples of Cleanup Criteria (Alternative 3)

Under Alternative 3, chemical criteria would be based on the floating percentile method using a false negative rate of 30 percent. This option would provide SQS and CSL values that minimize the number of false positive predictions of toxicity (non-hits incorrectly predicted as hits). However, by minimizing the false positive rate (12 to 21 percent), the number of false negatives would increase to approximately 30 percent. The overall reliability (predictive ability) of this alternative would be 72 to 88 percent, depending on the biological testing endpoint. The SCO and CSL values for Alternative 3 are presented in Tables 3.1 and 3.2.

Alternative 3 would also provide for confirmatory toxicity testing for any sediment sample that had exceeded the chemical criteria as defined in the SMS. The performance biological testing criteria for the control, reference, and test treatments are presented in Table 3.3.

Alternative 4: Balance False Negative and False Positive Rates (20 Percent False Negative Rate)

Under Alternative 4, both chemical and biological criteria would be established for freshwater sediment. Chemical criteria would be based on the floating percentile method using a false negative rate of 20 percent. Chemical criteria under Alternative 4 would be based on an expanded dataset of over 1800 toxicity data points from a broader geographic area, representing Washington, Oregon, and Idaho (Ecology, 2011). Biological criteria would be established using the expanded suite of biological toxicity tests presented in Alternative 2.

Examples of Cleanup Criteria (Alternative 4)

Under Alternative 4, chemical criteria would be based on the floating percentile method using a false negative rate of 20 percent. The resulting false positive rate would be 12 to 32 percent. This alternative was generally a reliable predictor of toxicity (71 to 88 percent), and met reliability and efficiency goals agreed to by Ecology and the RSET technical workgroup. Alternative 4 balances sensitivity with project scope and cost. The SCO and CSL values for Alternative 4 are presented in Tables 3.1 and 3.2.

Alternative 4 would also provide for confirmatory toxicity testing for any sediment sample that had exceeded the chemical criteria as defined in the SMS. The performance biological testing criteria for the control, reference, and test treatments are presented in Table 3.3.

Alternative 5: Establish Only Biological Criteria

Under Alternative 5, chemical cleanup criteria for freshwater sediments would continue to be established on a site-specific basis using the original SMS narrative standard for SCO (no adverse impacts) and CSL (minor adverse impacts). However, biological criteria for a standard suite of biological toxicity tests would be established and provide consistency across the state for the types of tests required and interpretive criteria that are applied. Biological criteria would be established using the expanded suite of biological toxicity tests presented in Alternatives 2 through 4.

Examples of Cleanup Criteria (Alternative 5)

The chemical guidance values under Alternative 5 would be similar to those of Alternative 1, including the 2003 Interim SQVs and the TECs/PECs

Alternative 5 would provide criteria for biological testing supporting confirmatory toxicity testing that could be applied initially to designate sediment quality, or where the site-specific choice is made to screen sediments using the one of the SQVs identified in Alternative 1. The performance biological testing criteria for the control, reference, and test treatments are presented in Table 3.3.

Implementation

Each of the freshwater alternatives would be implemented in a similar manner. Under Part V of the SMS rule, chemical and/or biological criteria will be used to screen, identify, and rank cleanup sites; define cleanup standards; and delineate a sediment impact zones and recovery zones. Both the screening studies and remedial investigation/feasibility studies will use a two-tiered system, the SCO and CSL, to determine sediment quality.

The sediment cleanup objectives (SCO) are chemical, biological, and human health criteria that represent concentrations predicted to have no adverse effects on biological resources and human health and represent the long-term goal for sediment quality in Washington State. The higher cleanup screening levels (CSL) are criteria that predict “minor adverse effects” defined as the maximum concentration of sediment contamination allowed at a cleanup site. Sediments of potential concern are identified either by chemical screening using the proposed SQVs followed by confirmatory biological testing or by concurrent chemical analysis and biological testing. Those stations exceeding the chemical and/or biological CSL criteria are then identified as exceeding the maximum allowable concentration. Cleanup criteria are then established for a site, targeting a level between the SCO and CSL, but as near the SCO as possible, balancing technical possibility and net adverse environmental impact.

Under each of the freshwater alternatives, both chemical and biological criteria will be used to designate sediment quality for the benthic community in a manner consistent with Part V of the rule. Under Alternative 1 (No Action Alternative), sediment quality in freshwater sediments would continue to follow narrative guidance, with chemical screening Interim values and biological toxicity tests and thresholds determined by Ecology on a case-by-case basis. Under Alternatives 2 through 4, numeric criteria would be established for both chemical and biological determinations. Under Alternative 5, the chemical SQVs would be determined on a case-by-case basis, with the biological testing thresholds being established in the rule. For Alternatives 2 through 5, chemical or biological criteria would be added to Part V of the rule.

Table 3.1 - Sediment Quality Values for Metals

Analyte (mg/kg)	2003 SQVs (Alternative 1)		Other SQGs (Alternative 1)		10 % FN rate (Alternative 2)		20% FN Rate (Alternative 4)		30% FN rate Alternative 3	
	SCO	**CSL**	**TEC**	**PEC**	**SCO**	**CSL**	**SCO**	**CSL**	**SCO**	**CSL**
Arsenic	20	51	9.79	33	5.9	7.1	14	120	14	34
Cadmium	1.1	1.5	0.99	4.98	0.83	2.1	2.1	5.4	3.7	6.3
Chromium	95	100	43.4	111	72	220	72	88	72	220
Copper	80	830	31.6	149	320	1200	400	1200	970	1200
Lead	340	430	35.8	128	>1300	--	360	> 1300	360	>1400
Mercury	0.28	0.75	0.18	1.06	0.41	0.66	0.66	0.8	0.66	0.80
Nickel	60	70	22.7	48.6	22	29	26	110	26	110
Selenium	--	--	--	--	0.29	7.7	11	> 20	11	>20
Silver	2.0	2.5	--	--	0.57	1.7	0.57	1.7	0.73	1.7
Zinc	130	400	121	459	3200	>4200	3200	> 4200	2400	3200

SCO = Sediment Cleanup Objective, CSL = Cleanup Screening Level
TEC: Threshold Effects Concentration; PEC: Probable Effects Concentration (MacDonald et al., 2000)
Values in blue are below the PQL
-- = no value available
> “greater than” value indicates that the toxic level is unknown, but above the concentration shown. The SCO and CSL are established at the “>” value.

Table 3.2 - Sediment Quality Values for Organics

Analyte	2003 SQVs (Alternative 1)		TEC/PEC (Alternative 1)		10 % FN rate (Alternative 2)		20% FN Rate (Alternative 4)		30% FN rate (Alternative 3)	
	SCO	**CSL**	**TEC**	**PEC**	**SCO**	**CSL**	**SCO**	**CSL**	**SCO**	**CSL**
Conventional Pollutants (mg/kg)										
Ammonia	--	--	--	--	130	230	230	300	250	>780
Sulfides	--	--	--	--	19	250	39	61	250	340
Organic Chemicals (µg/kg)										
4-Methylphenol	670	670	--	--	180	260	260	2000	260	510
Benzoic acid	650	650	--	--	2900	3800	2900	3800	2900	3800
beta-HCH	--	--	--	--	7.2	11	7.2	11	11	--
bis(2-Ethylhexyl)phthalate	230	32	--	--	460	22000	500	22000	1100	31000
Carbazole	--	--	--	--	1100	1400	900	1100	1100	1400
Dibenzofuran	400	440	--	--	38	680	200	680	680	3800
Dieldrin	1.9	3.5	1.9	61.8	4.9	22	4.9	9.3	4.9	9.3
Di-n-butyl phthalate	1400	1400	--	--	380	450	380	1000	380	450
Di-n-octyl phthalate	26	45	--	--	39	>1100	39	> 1100	39	>1100
Endrin ketone	--	--	--	--	2.7	8.5	8.5	--	8.5	--
Pentachlorophenol	400	690	--	--	1200	>1200	1200	> 1200	1200	>1200
Phenol	420	1200	--	--	120	210	120	210	120	210
Monobutyltin	--	--	--	--	540	>4800	540	> 4800	52	540
Dibutyltin	--	--	--	--	910	130000	910	130000	910	130000
Tributyltin	--	--	--	--	47	200	47	320	110	320
Tetrabutyltin	--	--	--	--	97	>97	97	> 97	97	>97
Total Aroclors	60	120	59.8	676	110	250	110	2500	120	1700
Total DDDs	--	--	4.88	28	310	2500	310	860	110	310
Total DDEs	--	--	3.16	31.3	21	910	21	33	21	910
Total DDTs	--	--	4.16	62.9	15	8100	100	8100	100	8100
Total PAHs	--	--	1610	22800	4500	10000	17000	30000	26000	35000
Bulk Petroleum Hydrocarbons (mg/kg)										
TPH-Diesel	--	--	--	--	340	1700	340	510	390	1700
TPH-Residual	--	--	--	--	810	4400	3600	4400	3600	4000

SCO = Sediment Cleanup Objective, CSL = Cleanup Screening Level
TEC: Threshold Effects Concentration; PEC: Probable Effects Concentration (MacDonald et al., 2000)
Values in blue are below the PQL
Values in red are derived from marine criteria
> "greater than" value indicates that the toxic level is unknown, but above the concentration shown
-- = no value available

Table 3.3 - Bioassay Interpretation Criteria

Test	QA Control[a]	QA Reference[b]	SCO	CSL
Hyalella Azteca 10-day mortality	**C ≤ 20%**	**R ≤ 25%**	**T - C >15%**	**T -C > 25%**
Hyalella Azteca 18-day mortality	**C ≤ 20%**	**R ≤ 30%**	**T – C > 10%**	**T – C > 25%**
Hyalella Azteca 28-day growth	**C ≥ 0,15 mg/ind**	**R ≥ 0.15 mg/ind**	**T/C < 0.75**	**T/C < 0.6**
Chironomus dilutes 10-day mortality	**C ≤ 30%**	**R ≤ 30%**	**T – C > 20%**	**T – C > 30%**
Chironomus dilutes 10-day growth	**C ≥ 0.48 mg/ind**	**R/C ≥ 0.8**	**T/C < 0.8**	**T/C < 0.7**
Chironomus dilutes 20-day mortality	**C ≤ 20%**	**R ≤ 35%**	**T – C > 15%**	**T – C > 25%**
Chironomus dilutes 20-day growth	**C ≥ 0.48 mg/ind**	**R/C ≥ 0.8**	**T/C < 0.75**	**T/C < 0.6**

a: Control is the recommended point of comparison for test treatments.
b: Ecology-approved reference only.
C: Control
R: Reference
T: Treatment

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Chapter 4: Case Studies

This chapter describes case studies conducted to evaluate the SMS rule revision alternatives that were considered by Ecology for both the protection of human health and for determining freshwater sediment cleanup criteria. The purpose of these case studies is for illustration purposes only to compare and contrast the effect each potential alternative would have on cleanup decisions. The information presented in the case studies, such as calculations of background values or cleanup levels, is not intended to reflect any decisions that Ecology has made on a site-specific basis. The case studies presented in this chapter and in Appendix E use actual sediment chemistry data results collected from Washington State sediment sites. However, because of the need to compare the case studies among the identified alternatives, the cleanup levels established in the case studies do not reflect the actual site-specific cleanup levels. This is because cleanup standards and cleanup decisions are made using site-specific information collected over a number of years. For example, Ecology used consistent procedures (such as risk assessment equations) for all case studies, which is not necessarily reflective of the equations and site-specific information used for the actual cleanup sites. In selecting the sites for the case studies it was not Ecology's intent to accurately reflect any prior or ongoing cleanup decisions. Therefore, the data are discussed in abstract or have been transposed to hypothetical locations for the purpose of visual displays in the individual case studies.

The five case studies for the rule revisions for protection of human health include four actual sediment cleanup sites and a comparison to the Puget Sound-wide sediment chemistry data available in Ecology's Environmental Information Management (EIM) database. The case studies selected for this evaluation are comprised of both urban and non-urban embayments impacted by different chemical or chemical groups that pose potential risk to human health. Each case study discussion presents how the five alternatives described in Chapter 3 would affect decision-making relative to setting cleanup levels for the protection of human health. The various cleanup levels are then compared to the site data to evaluate the relative locations and spatial area of impacted sediments that may require a cleanup action. Case study evaluations for the protection of human health rule revisions were based on readily available data and do not reflect site-specific cleanup decisions.

The cleanup levels developed as part of alternatives analysis for the four site-specific datasets are then compared to the sediment chemistry data available in EIM to determine the percentage of Puget Sound-wide sediment sampling locations that would exceed a given cleanup level.

A description of each case study and the cleanup level analysis based on protection of human health is provided in Appendix E. The exposure assumptions used in making human health risk-based cleanup level calculations are provided in the next section of this chapter.

Three case studies are presented for evaluating the alternatives considered for the development of freshwater sediment criteria for protection of the benthic community. The first is a state-wide evaluation of the predictive ability for chemical screening values associated with each of the alternatives. Stations in the EIM database that had paired bioassay and chemical datasets were included in this analysis. The second case study is an assessment of the ability of each of the alternatives to predict the outcome of the proposed toxicity tests. This case study used an extensive compilation of synoptic chemical and biological data from freshwater sediment studies in Washington and Oregon. The third case study was designed to better understand how the different alternatives would affect a specific cleanup site. In this case study, datasets in Lake Union were evaluated relative to each of the alternatives. As noted above, evaluations were based on readily available data and do not reflect site-specific cleanup decisions. A description of each of the three case studies used for analysis of the freshwater sediment alternatives, and the results of this evaluation, are presented in Appendix E.

Human Health Case Studies Assumptions

To provide consistency in the application and evaluation of the alternatives, standard assumptions were adopted for the presentation of each case study. The site-specific cleanup levels for the alternative evaluations were developed using human health risk guidance variables from actual cleanup sites. The cleanup levels were determined from the primary exposure pathway at each site using the RME scenario for carcinogenic and non-carcinogenic risks for the various chemicals of concern at each site. Seafood ingestion was determined to be the primary human health exposure pathway. Alternatives 1 through 5 were evaluated using seafood ingestion rate parameters currently used or proposed at cleanup sites. All cleanup levels were calculated based on adult exposure.

Carcinogenic and non-carcinogenic cleanup levels were evaluated separately because of differences in assumptions about the mechanism of these toxic effects. Carcinogenic chemicals were assumed to have no threshold for carcinogenicity and were presented as an excess cancer risk of contracting cancer over a 70-year lifetime from the site-related exposure. The excess cancer risk was one-in-one-million probability (MTCA acceptable risk level of 1E-06) for single carcinogens and one-in-one-hundred-thousand probability (risk level of 1E-05) for multiple carcinogens.

Human health tissue cleanup levels for carcinogenic compounds were calculated using Equation 1 for non-polar hazardous substances (dioxin/furan congeners, cPAH, and PCB aroclors) and Equation 2 for the remaining hazardous substances. The risk assessment variables and their associated definitions are presented in Table 4.1. Case study-specific parameters are listed in Table 4.2, chemical-specific slope factors and reference doses are listed in Table 4.3, and biota-sediment accumulation factor/biota accumulation factor (BSAF/BAF) values for each case study are listed in Table 4.4.

Chemicals with non-carcinogenic health effects are generally not toxic below a certain threshold; a critical chemical dose must be exceeded before adverse health effects are observed. The potential for non-carcinogenic health effects is expressed as a hazard quotient (HQ). Exposures resulting in an HQ less than or equal to 1 are unlikely to result in non-cancer adverse health effects. Tissue concentrations for non-carcinogenic hazardous compounds were calculated using Equation 3 and the associated risk assessment variables in Tables 4.1 through 4.4.

The BSAF and BAF values in Equations 1 through 3 were necessary for converting tissue concentrations to sediment cleanup levels. The BSAF was the lipid-normalized tissue concentration divided by the total organic carbon (TOC)-normalized sediment concentration. The BAF was not normalized for lipid content or organic carbon and was simply the tissue concentration divided by the sediment concentration. BSAF values were calculated for non-polar organic compounds, and BAF values were calculated for the metals.

Because BSAF/BAF values are species-specific, the shellfish/fish consumption rates (FCR) for each case study were assumed to consist of consumption from a single species or related group of organisms (Tables 4.2 and 4.4, respectively). The BSAF/BAF values were adapted from previous studies within Puget Sound. The clam BSAF/BAF values were average values from multiple co-located pairings of clams and surface sediment. These values were representative of whole body (muscle plus viscera) clam tissue concentrations. The benthic fish BSAF/BAF values were represented by lingcod fillets including skin. Lingcod were assumed to have a relatively small home range. Surface sediment samples within one-half of a kilometer of the capture location were considered representative of the lingcod home range. Benthic fish were represented by rock sole. Both rock sole and Dungeness crab have a home range of several kilometers. BSAF/BAF values for these species were calculated using averaged surface sediment concentrations from the entire bay from which the tissue samples were collected. Dungeness crab tissue was represented by multiple whole body replicates (muscle and hepatopancreas), while rock sole was represented by the fillets with skin on.

Equation 1 $$Cleanup\ Level_{\text{sediment}} = \frac{CR \times BW \times AT \times UCF \times S_{foc}}{SF_O \times FCR \times FDF \times EF \times ED \times SL \times BSAF}$$

Equation 2 $$Cleanup\ Level_{\text{sediment}} = \frac{CR \times BW \times AT \times UCF}{SF_O \times FCR \times FDF \times EF \times ED \times BAF}$$

Equation 3 $$Cleanup\ Level_{\text{sediment}} = \frac{HQ \times BW \times AT \times UCF \times RfD_O}{FCR \times FDF \times EF \times ED \times BAF}$$

Table 4.1 - Definitions for Risk Equation Variables

Abbreviation	Definition	Value	Units
Cleanup $Level_{sediment}$	Sediment Cleanup Level	Calculated Value	mg/kg
CR	Cancer Risk	1E-06	unitless
HQ	Hazard Quotient	1	unitless
BW	Body Weight	see Table 4.2	kg
AT	Averaging Time	25,550	days
UCF	Unit Conversion Factor	1,000	ug/kg
SF_o	Oral Slope Factor	see Table 4.3	kg-day/mg
RfD_o	Oral Reference Dose	see Table 4.3	mg/kg-day
FCR	Fish/Shellfish Consumption Rate	see Table 4.2	grams/day
FDF	Fish/Shellfish Diet Fraction	see Table 4.2	proportion
EF	Exposure Frequency	365	days/year
ED	Exposure Duration	70	years
BSAF	Biota Sediment Accumulation Factor	see Table 4.4	unitless
BAF	Biota Accumulation Factor	see Table 4.4	unitless
SL	Fish/Shellfish Lipid Fraction	1.3	percent
S_{foc}	Fraction of Organic Carbon in Sediment	3.0	percent

Table 4.2 - Case Study-Specific Parameters for Calculation of Sediment Cleanup Level (CUL)

	Case Study			
	1	**2**	**3**	**4**
Exposure Factor	cadmium, cPAHs, dioxin/furan congeners	arsenic, PCB Aroclors, cPAHs	mercury, dioxin/furan congeners	PCB Aroclors
FCR = consumption rate (g/day)	Clams	Benthic Fish	Dungeness Crab	Freshwater Clams
Alternatives 1-5	499	97.5	173	81
BW = Body weight (kg)	79	81.8	81.8	70
FDF = diet fraction	1.0	1.0	1.0	0.25

Table 4.3 - Carcinogenic Slope Factors (SF) and Non-Carcinogenic Reference Dose Values (RfDo) for Chemicals of Concern (COC)

	Chemicals of Concern					
Toxicity Factor	**Arsenic**	**Cadmium**	**Mercury**	**cPAHs**	**PCB Aroclors**	**Dioxin/Furan Congeners**
SFo = Oral slope factor	1.5	--	--	7.3	2	150000
RfDo = Oral reference dose	--	0.001	0.0003	--	--	--

-- - not applicable

Table 4.4 - Weighted Average BSAF/BAF Values Used in Equations 3 and 4

	Case Study			
	1	**2**	**3**	**4**
Chemicals of Concern	Target Species			
	Clams	**Benthic Fish**	**Dungeness Crab**	**Freshwater Clams**
BAF				
Arsenic	--	0.53	--	--
Cadmium	0.34	--	--	--
Mercury	--	--	9.03	--
BSAF				
Dioxin/Furan TEQ	0.13	--	0.79	--
Total PCB Aroclors	--	0.37	--	3.32
cPAH TEQ	0.11	0.07	--	--

The calculations that were conducted to determine risk-based cleanup levels for human health case studies 1 through 5 are presented in Appendix C.

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Chapter 5: Evaluation of Impacts and Alternatives

This chapter briefly summarizes the potential impacts of the proposed alternatives (both human health and freshwater sediment criteria alternatives) on the environment. The State Environmental Policy Act (SEPA) defines elements of the environment to be considered in an EIS. The elements of the environment that are expected to be affected by implementation of the SMS rule include features of the physical environment (sediment, water, and air quality), the biological environment (plants and animals), and the human environment (both human health and the aspects of the environment that are human-generated, such as economics, cultural resources, noise and aesthetics, transportation, and land and water use).

A full description of these environmental elements is provided in Appendix E. The last section of this chapter is devoted to an evaluation of the alternatives, which uses information developed in the case studies presented in Chapter 4 and Appendix E, as well as the analysis of impacts presented in this chapter.

Elements of the Environment and Effects of the Alternatives

In general, the cleanup stringency requirements differ within both human health alternatives and freshwater sediment alternatives. Cleanup stringency is defined by:

- The allowable chemical concentrations;
- The time frame allowed for cleanup, and
- Areas requiring cleanup.

These three factors vary by alternative; therefore, the impacts on the affected environment may also vary. The environmental impacts may be the result of the amount of contamination that remains over time before cleanup occurs or the contamination that remains after cleanup has been completed (both are referred to as residual contamination in this document), or by the cleanup activity itself. While some impacts apply to both residual contamination and cleanup actions, the nature of those impacts may differ. For example, impacts on human health in relation to residual contamination come primarily from consumption of contaminated seafood, while impacts associated with site cleanup result primarily from activities associated with handling and disposal of contaminated sediment, as well as redistribution of contamination that can occur with dredging.

Environmental impacts from residual contamination will be greater the longer the time period before cleanup has been completed, and the higher the level of residual contamination allowed to be left in place post-cleanup. As allowable residual contamination levels decrease under an alternative with more stringent cleanup levels, the long-term impacts associated with this alternative would also be assumed to decrease, in general.

With respect to the environmental impacts from the cleanup activity itself, the nature of these impacts would be the same for each of the alternatives; the extent of the impacts will vary in relation to the amount of sediment cleaned up and the disposal method used. As the volume of sediment requiring active cleanup decreases under an alternative with higher (less stringent) cleanup levels, the short-term impacts associated with the implementation of cleanup action activities would also decrease. If active measures are postponed because of the actual or perceived difficulty of achieving cleanup levels or negotiating a successful cleanup agreement, the impacts associated with allowing contaminated sediment to remain in place potentially increases. Cleanup-related impacts also vary depending on the type of action taken. In general, the cleanup action alternatives applicable to contaminated sediment are limited to in-place capping, removal, in situ treatment, and natural recovery (including enhanced and monitored). Sediment removed from the site can be taken to another aquatic location for capping, disposed of in confined nearshore or upland locations, or disposed of on land. In the case of upland disposal, there may be impacts on terrestrial and freshwater species and on human health through direct exposure or drinking water exposure. Conversely, when contaminated sediments are disposed of in-water, there may be impacts on aquatic species and on human health through consumption of chemically contaminated seafood. Use of natural recovery as a remedy may also present impacts to aquatic species and human health because contaminants may be accessible for longer time periods than from an active cleanup.

The evaluation of the environmental impacts presented in the following sections is qualitative since actual site impacts will vary with site-specific conditions. The relative impacts of each alternative were estimated and determinations made as to whether the alternative will increase or decrease the potential for adverse impacts relative to the impacts associated with existing laws and regulations. Although much of the focus on the environmental effects of the rule concerns Puget Sound sediments (because Puget Sound is where the majority of contaminated sediment sites and available data are located), discussion of potential effects on areas where contaminated freshwater sediments may be present is also presented.

Potential Impacts to the Physical Environment

Potential impacts to the physical environment from the proposed alternatives under consideration include effects on sediment, water, and air quality. Each of these elements of the physical environment is described in Appendix F. This section summarizes the potential impacts of the proposed alternatives on the physical environment.

Sediment Quality

Residual contamination impacts on sediment quality are the result of contamination left in place for the duration of and following cleanup implementation, including the residual contamination left after dredging (dredge residuals). Cleanup actions for sediments may be active measures (capping or dredging) or more passive methods (natural attenuation). Cleanup actions may include requirements to control ongoing sources of contamination that could cause sediments to become recontaminated. There may be associated impacts to sediment quality from both residual contamination and from implementation of cleanup actions.

In general, impacts on sediment quality from residual contamination can be summarized as follows:

- Higher (less stringent) cleanup levels leave more contaminated material in place, resulting in higher potential for impact on sediment quality (assuming that any contaminant left in place presents some risk). Lower (more stringent) cleanup levels lessen this potential impact; however, more stringent cleanup requirements may lead to delays in cleanup, extending the period of in-place contamination and potential impact.
- Longer cleanup time frames (for example, allowance for natural attenuation as a remedy) would allow in-place contamination to remain exposed for longer time periods, increasing the potential for sediment impacts. Shorter cleanup time frames may reduce that particular impact, but introduce other potential impacts through use of more aggressive remedial actions.
- Site-specific conditions, such as presence of water currents or predominance of fine-grained sediments, may exacerbate issues described above.

In general, impacts on sediment quality from cleanup actions can be summarized as follows:

- Higher (less stringent) cleanup levels would result in a smaller area requiring cleanup. If dredging or capping, the footprint of these actions may be smaller. However, more contamination would be left in place. Lower (more stringent) cleanup levels may result in larger remedial action footprint, and may leave less contamination for future impacts; however, as the remedial action footprint becomes larger, impacts from the cleanup action may become a concern.
- More aggressive cleanup actions such as dredging or capping may result in more re-suspension and redistribution of contaminated sediment (amount will vary with the size and complexity of the site and techniques used); however, this potential is considered when planning a dredging or capping action, controlled to be minimal, and factored into establishing cleanup boundaries.
- Site-specific currents could act to erode capping material once placed, allowing exposure and potential movement of contaminated sediments; however, this potential is considered when planning a capping action.
- If cleanup actions are implemented without concurrent successful source control, recontamination of sediments may result after cleanup is completed.

The proposed alternatives for the SMS rule revision differ in stringency of cleanup and allowed time frame for cleanup implementation; in this regard, they differ in their potential impacts on sediment quality. Impacts on sediment quality associated with each of the alternatives under consideration (human health and freshwater sediments) are presented in Table 5.1.

Water Quality

Similar to its impact on sediment, residual contamination impacts on water quality are the result of contamination left in place for the duration of and following cleanup implementation. However, impacts on water quality will occur only if the contaminated sediment becomes re-suspended in the water column, or if significant pre-water fluxes (movement of water through contaminated sediment) are present. Re-suspension of contaminated sediment in the water column could occur through strong currents (natural, or those caused by ship passage). If the local environment is highly dispersive, transport may occur quickly and water quality problems would not occur. The potential for water quality impacts from residual contamination is higher in relatively quiescent environments where contaminants are continually released from sediment into the water column because of propeller wash or other mechanical disturbances or where there is a significant flux of contaminants through the sediment (e.g., groundwater seeps).

Impacts of cleanup actions on water quality can be either short or long term. In cases where dredging occurs, some short-term water quality impacts at cleanup sites and at aquatic disposal sites are anticipated from the dredging activity at the contaminated sites and the placement of sediment at the disposal sites. At some contaminated sites, the increase in water column particulate levels resulting from cleanup activities may in turn lead to the release of sediment-bound ammonia and local reductions in dissolved oxygen (from increased oxygen demand of anoxic sediment disturbed during cleanup activities). While these impacts are expected to be temporary under each alternative, they would be of longer duration with alternatives that would lead to more stringent cleanup levels, which would require dredging of a larger volume of material. However, existing controls (e.g., providing mixing zones, restricting dredging to times when adverse effects would be reduced) would minimize any significant impacts that might occur at the site.

Long-term impacts of cleanup actions on water quality are correlated with the cleanup level and remedy selected, and its implementation time frame. Lower (more stringent) cleanup levels reduce the potential for release of the contaminants to the water column. Less aggressive remedies, with longer time frames for implementation (such as natural attenuation), allow the potential for release to remain in place for a longer time period.

The proposed alternatives for SMS rule revision differ in stringency of cleanup and allowed time frame for cleanup implementation; in this regard, they differ in their potential impacts on water quality. Impacts on water quality associated with each of the alternatives under consideration (human health and freshwater sediments) are presented in Table 5.1.

Table 5.1 - Impacts of Alternatives on Sediment Quality and Water Quality

Alternative	Sediment Quality Impacts	Water Quality Impacts
Human Health Alternatives		
Alternative 1 – Original Rule (No Action)	• Use of narrative standard could result in inconsistent decision making and reduce predictability of cleanup goals. • Lower cleanup levels may be unachievable or delay cleanups; residual contaminant levels post-cleanup would be lower; larger potential dredge footprint could lead to greater short-term re-suspension/redistribution of sediment.	• Use of narrative standard could result in inconsistent decision making and reduce predictability of cleanup goals. • Lower cleanup levels may be unachievable or delay cleanups; residual contaminant levels post-cleanup would be lower; larger potential dredge footprint could lead to greater short-term re-suspension/redistribution of sediment into water column.
Alternative 2 – Risk-Based Concentration Based on RME	• Lower cleanup levels may be unachievable or delay cleanups; residual contaminant levels post-cleanup would be lower; larger potential dredge footprint could lead to greater short-term re-suspension/redistribution of sediment.	• Lower cleanup levels would result in lower potential impact on water quality; however, they may also result in delayed cleanup actions, which may adversely impact water quality.
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	• Higher cleanup levels would result in higher levels of residual contamination (may be brought down by natural attenuation); cleanup actions may be initiated sooner.	• Higher cleanup levels may result in greater impact on water quality; however, cleanup actions may be initiated sooner.
Alternative 4 – Regional Background or PQL	• Higher cleanup levels would result in higher levels of residual contamination (may be brought down by natural attenuation); cleanup actions may be initiated sooner.	• Higher cleanup levels would result in greater impact on water quality; use of regional background as the standard will only reduce water quality impacts to that point.
Alternative 5 - Combined	• Greater flexibility would allow cleanup levels to be achieved and maintained with concurrent source control. • Residual contamination levels may be elevated for a time period, but more reliably addressed because of higher likelihood of cleanup and source control.	• Potential short-term impact on water quality if time is needed to implement source control; longer term impacts are reduced because of increased likelihood of cleanup and source control success.

Table 5.1 - Impacts of Alternatives on Sediment Quality and Water Quality

Alternative	Sediment Quality Impacts	Water Quality Impacts
Freshwater Sediment Criteria Alternatives		
Alternative 1 – Original Rule (No Action)	• High false positive rate would result in lower criteria and less allowance for residual contamination. • Lower criteria may be unachievable, result in inconsistent application, delayed cleanups, and reliance on passive actions (e.g., natural attenuation) that could result in longer term exposure to contamination.	• Lower criteria could result in lower impacts on water quality. • Lower criteria may result in delayed cleanups, potentially impacting water quality for longer time period; more reliance on passive actions (e.g., natural attenuation) that could result in longer term water quality impacts.
Alternative 2 – Minimize False Negatives	• Maximizing false positives may increase cleanup area boundary; this may result in lower residual contamination. • Larger cleanup areas may cause cleanup delays, or reliance on passive actions (e.g., natural attenuation) that could result in longer term exposure to contamination.	• Lower criteria and potentially larger cleanup areas will reduce impact on water quality. • Lower cleanup standards may delay cleanup actions or rely more heavily on passive actions (e.g., natural attenuation) that could result in longer water quality impacts.
Alternative 3 – Minimize False Positives	• Higher likelihood of clean areas designated as contaminated. • Higher criteria may result in more rapid cleanups, less reduction on passive measures, and reduction on contaminant levels more quickly.	• Higher criteria may lead to higher impacts on water quality. • Higher criteria may result in more rapid cleanups, less reduction on passive measures, and less water quality impact.
Alternative 4 – Balance False Negatives and False Positives	• High likelihood of correct definition of contaminated area, with lower impact from residual contamination. • More predictable cleanup process will promote cleanups.	• High likelihood of correct definition of contaminated area, with lower water quality impacts. • More predictable cleanup process will promote cleanups.
Alternative 5 – Establish Only Biological Criteria	• Expense of biological testing and developing site-specific criteria may result in limited use and increased cleanup uncertainty. • Uncertainty may delay cleanup actions, increasing impact from residual contamination.	• Expense of biological testing and developing site-specific criteria may result in limited use and increased cleanup uncertainty. • Uncertainty may delay cleanup actions, increasing water quality impacts.

Air Quality

The proposed revisions to the SMS rule are not expected to have significant impacts on air quality. No air quality impacts are anticipated as a result of residual contamination, and any impacts from cleanup actions are expected to be limited and short term in nature. Some hydrocarbon releases, including hydrocarbon byproducts and particulate material from diesel fumes, would be released from machinery and boats and from trucks involved in the cleanup activities. In addition, dredging and removal of sediment may release volatile contaminants into air and water. While the impacts associated with such releases would be greater for alternatives with more stringent cleanup levels (requiring a larger amount of material to be subject to remedy), they are expected to be insignificant under each of the alternatives.

Potential Impacts to the Biological Environment

Potential impacts to the biological environment from the proposed alternatives under consideration include effects on small and large aquatic organisms (including fish, birds, and mammals) and plants as well as nearshore terrestrial organisms and plants. Each of these elements of the biological environment is described in Appendix D. This section summarizes the potential impacts of the proposed alternatives on the biological environment.

Both residual contamination and cleanup actions can potentially impact the biological environment. As with the physical environment, the degree of impact will depend on cleanup stringency and time frame allowed to achieve cleanup. The extent to which biological resources will be impacted under each of the alternatives cannot be precisely determined. However, the degree of impact will vary in relation to the quantity and the extent of sediment contamination remaining in place after cleanup activities have been undertaken.

Chronic exposure of marine and freshwater benthic invertebrates and demersal (bottom dwelling) fish to residual contamination may lead to permanent modifications of the biological communities. For particularly sensitive species, the residual levels of some contaminants may even cause acute effects. The possible effects of residual contamination on individuals include mortality, reduced growth, reduced reproductive success (e.g., no reproduction, reduced fecundity, reduced larvae survival), lesions or tumors, behavioral changes (e.g., avoidance), or genetic mutations and chromosomal abnormalities. Biological impacts on demersal fish in Puget Sound have been identified at existing levels of contamination. For example, Malins et al., (1984) identified elevated prevalence of liver lesions (including tumors) in English sole captured in several contaminated areas of Puget Sound. Juvenile salmonids may also be impacted by consuming prey living in contaminated sediment. Adult anadromous and freshwater fish, shore birds, and marine and freshwater mammals (including endangered species) may be impacted through contamination of the food chain.

Impacts on individuals from the presence of residual contamination may be manifested at the population level as reduced abundance or local species extinction, reduced tolerance to other stresses, loss of effectiveness in particular ecological roles (e.g., reduced ability of a predator to capture prey), or genetic alterations. Alterations in the population of one species may in turn affect the distribution and abundance of other species, even if these other species are not directly affected by the residual contamination. The exposure of aquatic and riparian plants to residual contaminants can result in reduced growth, failure to reproduce, or death.

Cleanup actions also have associated impacts on biological resources. Sediment excavation or capping may result in habitat destruction and removal or burial of aquatic organisms, especially benthic species. In general, the types of impacts on plants and animals resulting from cleanup activities will be the same under each of the alternatives. However, it is expected that activities required to achieve more stringent cleanup levels would result in greater short-term impacts on plants and animals because of potentially larger cleanup areas.

Potential impacts of cleanup actions on specific species could include the following:

Plankton. Dredging/capping could cause increased suspension/re-suspension of sediment, which could promote (by raising nutrient levels) or inhibit (by shielding light and blocking photosynthesis, adhering to their surface and interfering with gas/nutrient transport or feeding activities) plankton growth and reproduction. Impacts would be expected to be localized and short term.

Aquatic Plants. As with plankton, decreased ability to photosynthesize with reduced light conditions from increased sediment in the water column, but effects would be expected to be localized and short term. Eelgrass and kelp beds could be destroyed during dredging activities, and recovery would take long periods of time. Because of its critical function as habitat, potential impacts would require planning to minimize and mitigated.

Benthic Macroinvertebrates and Megainvertebrates. These biological resources could be removed or killed during dredging activities, or buried during capping activities. Suspended particles can interfere with gill function. Impacts would be expected to be higher with more stringent cleanup levels, but overall are expected to be minimal and short term, and recovery would occur relatively quickly.

Fish. Increased suspended solids during dredging/capping activities may decrease available oxygen and clog gill surfaces. Food sources may be covered by capping. However, these effects are expected to be limited because fish will move, and benthic organisms that serve as food will quickly recover. Impacts on anadromous fish would be mitigated by limiting activities to periods when fish are not feeding or migrating.

Aquatic Mammals and Water Birds. Elevated turbidity may temporarily impact water birds by limiting visibility and impacting feeding. However, birds are highly mobile and expected to move during activities. Aquatic mammals generally avoid human activities and are unlikely to be impacted.

Terrestrial Species. Upland impacts will only occur if upland disposal is needed. In this event, existing habitat would be destroyed and vegetation removed. The impact would depend on availability of similar habitat in proximity to the impacted area.

Impacts to biological resources will vary by site. The extent of impacts on plants and animals expected to result from cleanup activities will be assessed on a site-by-site basis by performing an ecological inventory of the area to be disturbed, which will identify species (particularly threatened or endangered species) that may suffer adverse impacts from implementation of cleanup activities.

The proposed alternatives for SMS rule revision differ in stringency of cleanup and allowed time frame for cleanup implementation; in this regard, they differ in their potential impacts on biological resources. Impacts on biological resources associated with each of the alternatives under consideration (human health and freshwater sediments) are presented in Table 5.2.

Table 5.2 - Impacts of Alternatives on Biological Environment

Alternative	
Human Health Alternatives	
Alternative 1 – Original Rule (No Action)	• Lower cleanup levels would decrease impacts on biological communities from residual contamination; however, greater uncertainty in defining cleanup goals and greater inconsistency in rule application could lead to greater impacts.
Alternative 2 – Risk-Based Concentration Based on RME	• Lower cleanup levels would decrease impacts on biological communities from residual contamination; however, potential delays in cleanup initiation or failure to complete cleanup may increase impacts.
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	• Higher cleanup levels and associated residual contamination could result in greater impacts on biological resources. However, higher cleanup levels may lead to more rapid cleanup actions, reducing impacts.
Alternative 4 – Regional Background or PQL	• Higher cleanup levels and associated residual contamination could result in greater impacts on biological resources. However, higher cleanup levels may lead to more rapid cleanup actions, reducing impacts.
Alternative 5 - Combined	• Prioritized cleanup of highly contaminated sediment will reduce impacts quickly. Extension of time on cleanup of less contaminated areas may prolong lower level impacts. However, the likelihood of cleanup actions starting and being completed successfully is higher, reducing impacts.
Freshwater Sediment Criteria Alternatives	
Alternative 1 – Original Rule (No Action)	• Lower criteria will result in lower levels of residual contamination and fewer impacts. However, cleanups may be delayed, increasing potential for impacts. Greater uncertainty in defining cleanup goals and greater inconsistency in rule application could result in higher impacts. • More reliance on passive actions (e.g., natural attenuation) that could result in more long-term impacts.
Alternative 2 – Minimize False Negatives	• Lower criteria will result in lower levels of residual contamination and fewer impacts. However, delays in cleanup action and greater reliance on passive actions (e.g., natural attenuation) could result in more long-term impacts.
Alternative 3 – Minimize False Positives	• Higher criteria and associated levels of residual contamination could result in more impacts. • Cleanup actions would be more likely to happen, decreasing long-term impact potential.
Alternative 4 – Balance False Negatives and False Positives	• Higher likelihood of correctly identifying site boundaries and the flexibility to address more highly contaminated areas first will likely lead to less impact because cleanups are conducted quickly and effectively.
Alternative 5 – Establish Only Biological Criteria	• Cleanups may be delayed because of cost and timing issues related to reliance on biological testing for site characterization. This could result in greater impacts. • Reliance on biological tests may result in application of more protective criteria, resulting in lower impacts.

Potential Impacts to the Human Environment

Potential impacts to the human environment from the proposed alternatives under consideration include effects on human health, economics, fishing, cultural resources, noise and aesthetics, water use, and land use. Each of these elements of the human environment is described in Appendix F. This section summarizes the potential impacts of the proposed alternatives on the human environment.

Human Health

Both residual contamination and cleanup actions can potentially impact human health. Similar to the discussion of other environmental elements, the degree of impact of changes to the SMS will depend on cleanup stringency and the time frame allowed to achieve cleanup. The extent to which human health will be impacted under each of the alternatives cannot be precisely determined. However, the degree of impact will vary in relation to the quantity and the extent of sediment contamination remaining in place after cleanup activities have been undertaken.

The primary risk to human health resulting from residual concentrations of contaminants remaining in the sediment as a result of cleanup action is the risk associated with consuming contaminated fish or shellfish. Some impact to human health may be sustained by dermal exposure to water or sediment, incidental ingestion of contaminated water or sediment during recreational activities, and inhalation of vapors released by contaminated sediment. Each of these potential impacts is discussed in greater detail below.

Potential impacts to human health are **carcinogenic** or **non-carcinogenic** health effects:
Carcinogenic health effects = no safe exposure threshold (even a low dose has some risk).
Non-carcinogenic health effects = a threshold exists below which risks to human health are negligible.

A direct quantitative comparison of the human health risks associated with the alternatives is not possible because they are based on biological measures of risk that are not directly predictive of human health impacts. There may be significant differences in the relative degree of toxicity of a given compound in mammalian vs. aquatic species. For example, metals such as copper and zinc are toxic to humans only in high concentrations but are toxic to fish at low concentrations. Similarly, polychlorinated biphenyls (PCBs), dioxins, and other organic contaminants that are highly toxic or carcinogenic to humans bioconcentrate in fish tissue with little biological effect.

A risk assessment approach to estimating human health risks from contaminated sediment would be based primarily on consumption of contaminated fish and shellfish. The original SMS at 173-204-570 WAC identified the sediment cleanup objective as “no significant threat to humans”. Under MTCA, surface water cleanup standards are established based on a default fish consumption rate of 54 grams/day[29]. This default parameter used in establishing surface water cleanup standards is based on a recreational angler exposure scenario developed by Ecology in the 1980s. In 2008, Ecology asked the MTCA Science Advisory Board for advice on a site-specific fish consumption rate applicable to a cleanup action being conducted in the Port Angeles Harbor. The harbor is located within the usual and accustomed fishing area for the Lower Elwha Klallam Tribe[30]. The Board agreed with Ecology's conclusion that the recreational default fish consumption rate currently used in MTCA rule does not represent a RME for populations who typically eat higher amounts of fish and shellfish.

No details are provided in the original SMS to determine sediment cleanup standards that are protective of human health. However, because both MTCA and SMS rules apply, sediment cleanup standards protective of human health are based on the MTCA acceptable risk levels and RME and are the highest concentrations of the following:

- Risk-based cleanup concentration for the most sensitive receptor;
- Natural background concentration; and
- Practical quantitation limit (PQL).

Sediment cleanup standards that are protective of human health need to account for both bioaccumulation and fish consumption. Responding to both the need to review the fish consumption rate used in setting MTCA surface water quality standards, and to provide a basis for developing sediment cleanup levels protective of human health from consumption of fish and shellfish, Ecology is developing a report to help inform site-specific decisions on fish consumption rates (Ecology, 2012). This study is discussed in Appendix B. Site-specific fish consumption rates were used in calculating cleanup values for human health alternatives in the human health case studies evaluated in Chapter 4 and Appendix E.

The human health and freshwater sediment criteria alternatives considered in this EIS represent different concentrations for cleanup levels and areal extent of contaminants that define the site footprint. In general, increasing concentrations of contaminants in sediment, water, fish, and shellfish increase the likelihood of adverse human health effects and the likely severity of effects associated with exposure to contaminants. Thus, to the extent that they vary in their requirements for degree of cleanup, alternatives that leave greater levels of contaminants post-cleanup may also be associated with less reduction of human health risks.

However, the qualitative nature of this comparison of the alternatives in terms of the potential for adverse effects on human health should be stressed. In addition, the uncertainties inherent in human health risk assessments are significant. In addition to uncertainty associated with

[29] The fish diet fraction is defined under MTCA as the fraction of the fish consumed estimated to come from the site.

[30] MTCA Science Advisory Board (SAB) Meeting Notes for SAB Meetings held December 14, 2007, March 11 and June 2, 2008. Web location for SAB meeting notes: http://www.ecy.wa.gov/programs/tcp/SAB/SAB_mtg_info/mtg_info.htm

estimates of chemical toxicity, health risk also varies with the degree of exposure to toxic contaminants, which depends on several factors including:

- *Exposure Pattern.* Whether the person consumes any contaminated fish or shellfish or comes into contact with contaminated sediment.
- *Exposure Rate.* Amount of fish or shellfish consumed, or frequency of contact with sediment.
- *Dose.* Levels of contaminant concentrations in edible tissues of fish and shellfish and in sediment.
- *Bioaccumulation Factor.* The amount of contamination in sediment that bioaccumulates in fish and shellfish.
- *Fish Home Range.* The exposure of fish to bioaccumulative contaminants that are, in turn, eaten by humans.

These exposure factors are related to the contaminant concentrations in sediment and to the areal extent of elevated contaminant concentrations. As the area of sediment contamination increases, the higher potential that more of the fish or shellfish's foraging territory will be within the contaminated area, thus potentially increasing the contaminant concentration in fish and shellfish tissue and the human health risks associated with ingestion of fish and shellfish. Shellfish and fish that have small feeding ranges relative to those of other fish will be most highly influenced by increases in contaminants in localized areas.

Persons involved in recreational activities (e.g., fishing, wading, and clam digging) in marine intertidal zones and the shoreline of freshwater bodies such as rivers and lakes may be exposed via dermal contact and incidental ingestion of contaminants in sediment or released as water-soluble components. As contaminant concentrations increase, exposures may be more severe. In addition, as the area of contamination increases, the likelihood of potential exposure increases.

The quantity of contaminated fish and shellfish consumed depends on the degree of contact with contaminated sediment areas. Many of the contaminated sediment sites are located in shoreline and nearshore areas where people could come into physical contact with contaminated sediment. The potential risks to human health from dermal exposure may be limited because many contaminated areas tend to be situated near industrial or business districts where people do not tend to swim or recreate. However, given that access is not directly restricted and that some contaminated areas lie near public parks and fishing areas, persons could enter contaminated areas (particularly in intertidal zones and the shoreline of rivers and lakes) and be exposed to contaminants in sediment, water, and tissues of fish and shellfish.

Potential impacts to human health from cleanup actions will likely be focused on workers who are participating in cleanup activities. On-site workers may be adversely affected during cleanup operations by exposure to contaminants, heat or cold stress, physical hazards, and fatigue. Sediment cleanup actions pose additional hazards related to working on boats such as injury from sampling gear, slipping, and risk of drowning. There may be some limited risk to the general population from cleanup actions through exposure to contaminants released during cleanup activities.

The impacts to on-site workers can be substantially mitigated through the implementation of site-specific health and safety plans. If significant impacts to the general population from contaminant release during cleanup operations are anticipated, they may be mitigated by implementing control technologies to limit the release of contaminated materials.

The nature of these human health impacts would be the same under each of the alternatives. However, there would be a greater potential for impacts to occur under the more stringent alternatives because cleanup of a larger quantity of contaminated sediments would be required and cleanup activities would take place over a longer period of time.

In addition to these potential impacts on cleanup workers and the general population, transportation-related injuries or fatalities may be a factor for sites where cleanup actions require long-distance hauling of contaminated sediment to an upland disposal location. In an analysis set forth in the MTCA Cleanup Standards EIS (Ecology, 1990b), it is estimated that over 4 million tons of contaminated soil would be transported to Arlington, Oregon, before one traffic-related fatality would be expected. The data and assumptions relied on to conduct this analysis are equally applicable to the consideration of impacts associated with the transport of contaminated sediment in this study. However, since the cost of aquatic disposal is significantly less than the cost of upland disposal (and have fewer environmental impacts), aquatic disposal will be used when deemed appropriate on a case-by-case basis. Additionally, dredged material disposal sites are not likely to be available for all contaminated sediments, and sediment that will recover naturally to the cleanup level concentration within a specified time frame will remain in place. Thus, in many cases minimally contaminated sediment may not require any cleanup action.

Impacts resulting from traffic-related accidents will not be known in advance and, therefore, cannot be as easily planned for or mitigated as other impacts associated with cleanup activities. However, routing trucks through low traffic volume areas, scheduling trips for off-peak hours, and designating emergency response plans can help reduce the risk of significant impacts.

Impacts on human health associated with each of the alternatives under consideration (human health and freshwater sediments) are presented in Table 5.3.

Table 5.3 - Impacts of Alternatives on Human Health

Alternative	
Human Health Alternatives	
Alternative 1 – Original Rule (No Action)	• Lower cleanup levels would decrease impacts on human health from residual contamination. However, greater uncertainty in defining cleanup goals and greater inconsistency in rule application could lead to greater impacts.
Alternative 2 – Risk-Based Concentration Based on RME	• Lower cleanup levels would decrease impacts on human health from residual contamination. However, potential delays in cleanup initiation or failure to complete cleanup may increase impacts.
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	• Higher cleanup levels and associated residual contamination could result in greater impacts on human health. However, higher cleanup levels may lead to more rapid cleanup actions, reducing impacts.
Alternative 4 – Regional Background or PQL	• Higher cleanup levels and associated residual contamination could result in greater impacts on human health. However, higher cleanup levels may lead to more rapid cleanup actions, reducing impacts.
Alternative 5 - Combined	• Prioritized cleanup of highly contaminated sediment will reduce impacts on human health quickly. Extension of time on cleanup of less contaminated areas may prolong lower level impacts. However, the likelihood of cleanup actions starting and being completed successfully is higher, reducing impacts.
Freshwater Sediment Criteria Alternatives	
Alternative 1 – Original Rule (No Action)	• Lower criteria will result in lower levels of residual contamination and fewer impacts to human health. However, cleanups may be delayed, increasing potential for impacts. Greater uncertainty in defining cleanup goals and greater inconsistency in rule application could result in higher impacts. • More reliance on passive actions (e.g., natural attenuation) could result in long-term impacts.
Alternative 2 – Minimize False Negatives	• Lower criteria will result in lower levels of residual contamination and fewer impacts to human health. However, delays in cleanup action and greater reliance on passive actions (e.g., natural attenuation) could result in long-term impacts.
Alternative 3 – Minimize False Positives	• Higher criteria and associated levels of residual contamination could result in more impacts to human health. • Cleanup actions would be more likely to happen, decreasing long term impact potential.
Alternative 4 – Balance False Negatives and False Positives	• Higher likelihood of correctly identifying site boundaries and the flexibility to address more highly contaminated areas first will likely lead to less impact because cleanups are conducted quickly and effectively.
Alternative 5 – Establish Only Biological Criteria	Not Applicable

Economics

The expected economic costs in relation to the proposed alternatives will be evaluated in an economic impact assessment issued in conjunction with this EIS when it is issued a final document. At this time in the evaluation process, the analysis of economic impacts is limited to a qualitative assessment of the alternatives relative to the level of effort required to characterize a site, the amount of cleanup that would potentially be required, and the amount and type of monitoring that would be required to complete and maintain a cleanup action.

The economic impacts resulting from implementation of the cleanup standards increase as the cleanup levels become more stringent, because a larger quantity of sediment will require characterization and cleanup. The major factors that affect cost of cleanup are the type of cleanup action (e.g., capping vs. dredging vs. natural recovery), the total amount of contaminated sediment at any one site, and the disposal option for dredged sediment.

Table 5.4 summarizes the economic impacts associated with the alternatives for rule revision for protection of human health and freshwater sediment.

Fishing

Residual contamination can cause impacts to the fish themselves through consumption of their food. Young fish and forage fish will consume benthic invertebrates, crustaceans, and copepods that have accumulated contaminants, passing contamination up through the food chain to larger fish that consume them. Adult fish may also take in sediment contamination via material that has re-suspended in the water column, either from normal physical processes in the water, or from dredging or capping activities. Commercially and recreationally important demersal (bottom dwelling) fishes (e.g., English sole, rock sole, starry flounder, and several species of rockfish) and shellfish would be directly exposed to residual sediment contamination. Consumption of these resources could also pose a health risk to humans (see Human Health Impacts above).

Some fish and shellfish that are harvested recreationally from Commencement Bay, Elliott Bay, and Eagle Harbor are documented to have been affected by toxic contamination. In each of these areas, warnings against consumption of fish and shellfish have been posted, and health advisories have been issued. In addition, elevated levels of fish lesions associated with sediment contamination have been identified in many urban areas of Puget Sound, including Everett Harbor, Elliott Bay, and Commencement Bay. The extent to which these problems may be present as a result of residual contamination is dependent on the cleanup levels required, and the time period in which cleanup is required to occur. Increased impacts from cleanup actions that result from suspended sediment would be expected to be short term.

Impacts on fishing associated with existing contamination levels in Puget Sound will be addressed to a degree under each of the alternatives. The degree of protection provided by the alternatives increases with increasingly stringent cleanup levels.

Table 5.4 summarizes the impacts on fishing associated with the alternatives for rule revision for protection of human health and freshwater sediment.

Cultural Resources

Puget Sound and freshwater lakes and rivers are cultural resources to all residents of the state to the extent that its amenities are an important component of their lifestyles. For many tribes, high cultural values are associated with Puget Sound and its living resources, which play a key role in spiritual and religious ceremonies. Other ethnic groups such as southeast Asians may also have strong cultural ties and traditional food sources in Puget Sound. While these and other groups may suffer some cultural impacts from implementation of the proposed rule, the cultural impacts for most state residents are likely to be negligible, because sediment quality conditions are expected to improve under each of the alternatives.

Cultural resources may be adversely impacted if aquatic resources are diminished or if people avoid harvesting seafood or engaging in other recreational fishing because of real or perceived health risks associated with contamination. The inability to harvest seafood affects traditional lifestyles and religious and spiritual traditions surrounding aquatic resources. Economic shifts resulting from reduced quantity or quality of harvestable seafood may also affect cultural integrity and practices.

People could be exposed to elevated levels of contaminants in seafood by harvesting fish and shellfish from areas with residual contamination. In general, exposure would be highest when harvesting resident organisms (e.g., bottomfish, crabs, clams) from contaminated areas, and lowest when harvesting migratory or transient organisms such as salmon. Therefore, cultural resources are most likely to be affected in areas where crab and bottomfish are harvested. The potential impacts on these cultural resources will vary in relation to the health risks associated with the human health and freshwater sediment criteria alternatives. Impacts on cultural resources are analogous to impacts on biological resources, human health, and fishing, which have been discussed previously in this chapter.

Site cleanup activities may result in impacts on cultural resources to the extent that these activities (e.g., dredging and capping) lower the quality of experience derived from activities such as tribal and recreational fishing and shellfish harvesting. However, the impacts resulting from these activities will probably be minimal or completely absent under each of the alternatives because of existing regulatory requirements that govern dredge and fill operations. For example, the WA Department of Fish and Wildlife hydraulic project approval (chapter 220-110 WAC) and the federal Clean Water Act Section 404 (40 CFR 125) permit process should effectively prevent cleanup activities from interfering with tribal or commercial fishing and minimize impacts on the resource by imposing restrictions on the timing of dredging and dredged material disposal.

Table 5.4 - Impacts of Alternatives on Economics

Alternative	Economic Impacts	Fishing Impacts
Human Health Alternatives		
Alternative 1 – Original Rule (No Action)	• Use of narrative standard could result in inconsistent decision making and reduce predictability of cleanup goals, resulting in higher costs to implement cleanup, and to monitor post-remedy. • Lower cleanup levels would result in higher costs in site characterization and cleanup actions.	• Lower cleanup levels would be more protective of fishing. However, more uncertainty in defining cleanup goals and higher inconsistency in rule application may result in greater overall impacts on fishing.
Alternative 2 – Risk-Based Concentration Based on RME	• Lower cleanup levels would result in higher costs in site characterization and cleanup actions. • Difficulty in achieving cleanup goals could result in higher implementation and post-remedy monitoring costs.	• Lower cleanup levels would result in lower fishing impacts. However, potential delays in cleanup and higher likelihood that cleanups would not be completed would increase impacts on fishing.
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	• Higher cleanup levels would result in lower site characterization and cleanup costs, and potentially lower costs in monitoring during remedial actions and post-remedy.	• Higher cleanup levels may increase impacts to fishing. However, cleanup actions may be implemented and completed more quickly, reducing impacts.
Alternative 4 – Regional Background or PQL	• Higher cleanup levels would result in lower site characterization and cleanup costs, and potentially lower costs in monitoring during remedial actions and post-remedy.	• Higher cleanup levels may increase impacts to fishing. However, cleanup actions may be implemented and completed more quickly, reducing impacts.
Alternative 5 - Combined	• Cleanup costs may be equivalent to other alternatives, but the likelihood of success in implementing cleanup and meeting cleanup standards is higher, thereby decreasing overall costs.	• Completion of cleanup may extend over a longer time period, but higher likelihood of success would lead to overall reduced impacts on fishing.

Table 5.4 - Impacts of Alternatives on Economics

Alternative	Economic Impacts	Fishing Impacts
Freshwater Sediment Criteria Alternatives		
Alternative 1 – Original Rule (No Action)	• Lower cleanup levels, the need to address sites on a case-by-case basis, and potential inconsistent application of levels of protectiveness and site characterization methods may increase cost of site characterization, remedy implementation, and post-remedy monitoring.	• Lower cleanup levels would be more protective of fishing. However, more uncertainty in defining cleanup goals and higher inconsistency in rule application may result in greater overall impacts on fishing.
Alternative 2 – Minimize False Negatives	• Lower cleanup levels (developed by minimizing false negatives) and larger designated site areas may result in increased cost of site characterization, remedy implementation, and post-remedy monitoring.	• Lower cleanup levels over wider areas would lessen impacts on fishing. However, delays in cleanup or more reliance on passive actions could increase impacts on fishing.
Alternative 3 – Minimize False Positives	• Higher cleanup levels (developed by minimizing false positives) and smaller designated site areas may result in decreased cost of site characterization, remedy implementation, and post-remedy monitoring.	• Higher cleanup levels could result in more impacts on fishing, although these would be expected to be relatively minor. More rapid cleanups may occur, decreasing impacts on fishing.
Alternative 4 – Balance False Negatives and False Positives	• Costs are better controlled through more accurate site delineation, appropriate scale of remedy, and lower costs of monitoring during post-remedy.	• Higher likelihood of correctly identifying contaminated site boundaries and flexibility in the process to addressing higher impact areas early in cleanup could result in lower overall impacts on fishing.
Alternative 5 – Establish Only Biological Criteria	• Relying on biological tests and delays in cleanup actions because of uncertainty in testing results (and potentially more required testing) may increase costs.	• Delays in cleanup actions from uncertainty in testing results may increase impacts on fishing.

Cultural resources such as historic or archeological sites could be affected by land-based disposal of sediment. However, state guidelines preclude siting new hazardous waste disposal facilities in archeological sites or historic areas designated by the state or federal government. The state also has a responsibility to preserve historic sunken vessels or aircraft that could be affected by dredging, capping, or aquatic disposal of sediment. Therefore, impacts on these cultural resources are expected to be minimal from each of the alternatives. Potential impacts on these cultural resources and means of mitigating and preserving historic properties affected by site cleanup would be addressed in site-specific documents.

Transportation

Transportation impacts are at issue only in relation to cleanup actions. Cleanup activities could disrupt the normal uses of the waters in the location of cleanup sites for the duration of cleanup activities. Such disruptions are not expected to be significant in most locations. For example, aquatic vessels could go around the cleanup equipment in larger water bodies, such as Puget Sound. However, cleanup activities in spatially constricted locations could severely or totally limit the ability of vessels to avoid a cleanup site. While these impacts would be of a shorter duration when less sediment is removed, they would be of the same nature under each of the alternatives. The only means of mitigating these impacts is to conduct cleanup operations from shore when possible, thereby keeping the transportation routes as clear as possible. However, shore-based cleanup may not be possible when a site is located some distance from shore, and the decision to work from the shore would in turn increase land use impacts.

If sediments are excavated for upland disposal, terrestrial areas where transportation may be affected are defined by the relationship between the physical distribution of contaminated sediment sites undergoing cleanup actions and the locations of available upland disposal facilities. Transportation corridors between contaminated sediment sites undergoing cleanup actions and disposal facility locations would bear the greatest impacts of cleanup operations. Local transportation impacts are generally associated with vehicles coming and going from the cleanup site. These impacts will vary depending on site-specific factors such as road conditions, local population sizes, traffic patterns, degree of congestion, and cleanup technologies used at the site. Though contaminated sediment sites are located throughout Washington, many are in industrialized areas, where water and land transportation activities are greatest.

The use of mixed waste landfills historically has been the preferred method of choice for upland disposal of sediments too contaminated for aquatic disposal or nearshore disposal. Sensitive routes include the vicinity of the land-based cleanup operation, specific highways, and transportation corridors where increases in traffic congestion or accidents are likely to occur. Congestion may result from population densities, natural features, or construction activities. Certain routes are particularly sensitive to high levels of traffic, because they already experience restricted traffic flow at all hours and peak congestion during rush hour travel periods.

To improve federal and state management of open-water disposal sites, DMMP was developed to provide long-range regional planning for a lasting, effective solution for dredged material disposal. Dredging activity has occurred throughout Puget Sound for several decades.

Historically, dredged material has been disposed of in a variety of environments. In recent years, the availability of upland and nearshore disposal sites has become increasingly scarce, resulting in greater reliance on unconfined, open-water sites for disposal of dredged material.

Impacts are expected to be relatively short term, lasting only for the duration of the cleanup activities. The potential for these impacts to occur is the same for each of the alternatives, although the extent of impact could increase as a higher volume of sediment is disposed of in upland locations. Local transportation-related impacts can be mitigated in several ways, including building improved roads if needed, directing traffic away from the site, scheduling cleanup-related vehicles to arrive and depart during non-peak traffic hours, and adding noise barriers and wetting road surfaces to decrease noise and dust associated with vehicles coming and going from the site. Impacts that might be associated with long-distance trucking on a specific project can be estimated by comparing normal traffic volume statistics with the number of truckloads needed to haul the waste from a contaminated site.

Noise and Aesthetics

Noise and aesthetic impacts would be limited to those occurring during the implementation of cleanup activities and, therefore, are expected to be temporary in nature. Shoreline areas could be affected by site remedial activities because most areas of sediment contamination tend to be relatively close to the shoreline and near urban areas. Although dredging equipment and marine vessels including tugs and tug-barge combinations may increase noise levels in the vicinity of a contaminated sediment site, these impacts will be controlled in compliance with state and federal noise standards. When noise levels are significant, they can be adequately reduced by using sound barriers. The magnitude of noise impacts and the need for mitigative measures will be considered in site-specific documents.

As previously noted, the areas of sediment contamination tend to be relatively close to the shoreline and near urban areas. Therefore, persons located along various shorelines or bluff areas and in many office buildings will be able to view cleanup activities. Aesthetic impacts will be the same under each of the alternatives and cannot be easily mitigated.

Water Use

As previously noted, surface water use impacts from residual contamination are not expected to be significant. The disposal of contaminated sediment on land could adversely impact groundwater and possibly drinking water supplies. These impacts would be minimized through appropriate siting and design of disposal sites as well as groundwater monitoring around the sites. Disposal facility siting and design will be in conformance with applicable state and federal laws.

Land Use

Cleanup actions at an aquatic site can restore or enhance opportunities for land use of the shoreline environment. If residual contamination is left to naturally recover after active cleanup, some types of land use may be precluded during the recovery period (e.g., fishing piers). Higher degrees of contamination could discourage recreational or bottom harvesting activities for longer periods of time because of increased environmental and human health risks. Current and potential land uses will be one factor in determining the standards during application of the updated SMS.

As contaminated sediment sites are subjected to remedial action, some amount of land will be affected, either by the storage of vehicles and equipment or with the construction of staging areas necessary for sites cleaned up directly from land. Depending on the chosen alternative, remedial actions requiring lengthy operation or maintenance could result in the restriction of use of the land on which the operation is situated. While the duration of these impacts would be greater under the more stringent alternatives, impacts are expected to be temporary and insignificant under each of the alternatives.

The more potentially significant impacts on land use are limited to those related to nearshore and upland disposal of contaminated material. Nearshore disposal of contaminated sediment is of concern to Ecology and the public because of the higher potential for contact by humans and other species. Thus, it is likely that a substantial amount of sediment deemed unacceptable for aquatic disposal would require upland disposal. As a result, the pressure on existing disposal facilities will result in the need to develop new facilities. Land used to store sediment removed during a cleanup action may not be suitable for other economic uses.

Capping contaminated sediment in place may result in restrictions on land use such as no anchoring zones to protect the integrity of the cap. This is because of the need to protect the integrity of the cap. If a sediment cap is placed on state-owned aquatic lands, this may require approval from WA Department of Natural Resources because of the potential land use restrictions.

Programmatic Impacts

Programmatic impacts from the proposed alternatives would be impacts on other state programs and state resource use. These impacts will vary with the stringency of the various alternatives, which in turn influences the extent and type of cleanup to be undertaken.

The most significant programmatic impact that might be expected from adoption of proposed alternatives would be on state resources needed to implement cleanup. Alternatives with associated lower cleanup levels, or alternatives that make it more likely that cleanups would proceed more rapidly, could put greater demands on state resources. Alternatives with more stringent cleanup levels would put a greater demand on limited state personnel and monetary resources because a greater number of sites would be defined as contaminated and these additional sites would require investigation and cleanup. Ecology could choose to limit active intervention or response to those sites posing the greatest risks to human and environmental health. However, all sites considered contaminated under the selected alternative would require some initial resources to determine their priority ranking relative to human and environmental health risks. The stringency of the selected alternative may also affect the willingness of the liable parties to accept the need to participate in site cleanup. Negotiations, enforcement orders, and litigation could become necessary in a greater number of cases, thereby placing an even greater demand on limited agency resources. Such actions would result in delays getting cleanup done effectively and efficiently.

Summary of Unavoidable Adverse Impacts

A limited array of unavoidable adverse impacts have been identified through the process of assessing environmental impacts:

- Some impacts on commercial, recreational, and tribal fisheries and cultural resources are expected, and directly tied to potential biological and human health impacts. Contaminant levels with some alternatives are higher than others, and there may be impacts to fisheries and cultural resources under alternatives that have associated higher cleanup levels. Although these impacts would be localized to the vicinity of contaminated sediment sites, considered cumulatively the impacts could be significant.
- During cleanup of contaminated sediment sites there is a potential for short-term impacts on water quality, aquatic life, noise, aesthetics, land use, water use, transportation, and human health. These impacts will likely be greater if more stringent alternative cleanup levels are selected. Because of the potentially higher level of impacts resulting from increased traffic, resource use, and need for landfill capacity associated with cleanups under alternatives that have associated lower cleanup levels (requiring more sediment to be remediated), short-term remedial impacts under these alternative could be more significant than those with higher associated cleanup levels.

Under each of the alternatives, the cost of cleaning up contaminated sediment sites is considered significant. However, the costs associated with more stringent alternatives are greater, both at individual sites and from a program-wide perspective.

Evaluation of the Alternatives

Introduction

The purpose of this section is to describe the process used by Ecology to evaluate the rulemaking alternatives described in Chapter 3, conduct the overall evaluation, and present the preferred alternatives. This section is divided into three subsections. In the first subsection, the overall evaluation process is described. In the second subsection, the proposed human health and freshwater sediment criteria are assessed relative to the evaluation criteria. In the last subsection, a summary of the scoring results for each of the alternatives is presented, and the preferred alternative is identified.

Evaluation Process

Three categories of criteria are used in the evaluation process. The first category is the *threshold criteria*, which include:

- Impacts to human health and the environment from residual contamination,
- Impacts to human health and the environment from cleanup measures, and
- Compliance with ARARs.

Threshold criteria receive the most weight in the evaluation because they reflect requirements or goals of MTCA and the SMS.

The second category of criteria is the *balancing criteria*. These criteria include:

- Technical feasibility,
- Ability to measure compliance, and
- Cost effectiveness.

These criteria represent practical considerations that affect cleanup implementation. Although recognized as important, these criteria receive less weight in the evaluation than the threshold criteria.

The third set of criteria (*modifying criteria*) contains only one criterion, which is regulatory precedence. This criterion relates to the defensibility of the rule and its consistency with other regulations, and is given the least weight in the evaluation. However, it may affect the outcome if the alternatives are ranked similarly under the preceding sets of criteria.

Each alternative is scored high, medium, or low relative to each criterion within each of the three criteria groups. The scoring scheme for each of the groups of criteria is as follows:

	Assigned Score Value		
	High	**Medium**	**Low**
Threshold Criteria	12	8	4
Balancing Criteria	6	4	2
Modifying Criteria	3	2	1

The evaluation process was run separately for each of the two sets of alternatives (Human Health and Freshwater Sediment Criteria). The identified preferred alternative from each group was then combined to derive the final preferred alternative.

Evaluation of the Alternatives

Threshold Criteria

In this section, the five alternatives for rule revision for protection of human health and the five alternatives for freshwater sediment criteria are evaluated with respect to requirements or goals of MTCA, the SMS and the WPCA, expressed by three threshold criteria for impacts on human health and the environment (residual contamination), impacts on human health and the environment (cleanup measures), and compliance with ARARs.

Threshold Criterion 1 — Protection of Human Health and the Environment (Residual Contamination)

This criterion ranks the alternatives in each group using the following scores:

> *Low.* The residual concentrations allowed under this alternative will result in high residual risk relative to other alternatives. Policies and procedures associated with this alternative are based on less-health conservative assumptions and result in cleanup levels greater than under other alternatives for many contaminants.
> *Medium.* The residual concentrations allowed under this alternative will result in moderate residual risk relative to other alternatives. However, residual risk will be less than other alternatives when taking into account both residual concentrations and the time needed to achieve those reductions.
> *High.* The residual concentrations allowed under this alternative will result in low residual risk relative to other alternatives. Cleanup levels associated with this alternative are based on health-conservative assumptions and result in cleanup levels lower than under other alternatives for many contaminants.

Because the degree to which any of the alternatives is protective is not known, the alternatives are ranked under this criterion in terms of the relative chemical concentration and area of contamination left in place under each alternative.

The results of scoring the human health alternatives for Threshold Criterion 1 are presented in Table 5.5. In general, cleanup levels that are set through use of Alternatives 3, 4, and 5 will be more protective of human health and, therefore, score higher with respect to this threshold criterion than Alternatives 1 and 2.

The results of scoring the freshwater sediment criteria alternatives for Threshold Criterion 1 are presented in Table 5.6. In general, cleanup levels that are set through use of Alternatives 1, 2, and 4 will be more protective of the environment and, therefore, score higher with respect to this threshold criterion than Alternatives 3 and 5.

Threshold Criterion 2 — Protection of Human Health and the Environment (Cleanup Measures)

This criterion considers the human health and environmental risks and impacts associated with cleanup activities. The alternatives are ranked using the following scores:

> *Low.* The removal or capping of sediment requiring cleanup under the alternative are likely to produce significant short-term risks to human health and the environment relative to other alternatives.
> *Medium.* The removal or capping of sediment requiring cleanup under the alternative are likely to cause some short-term impacts on human health and the environment relative to other alternatives.
> *High.* The removal or capping of sediment requiring cleanup under the alternative are likely to cause limited short-term impacts on human health and the environment relative to other alternatives.

The results of scoring the human health alternatives for Threshold Criterion 2 are presented in Table 5.5. In general, cleanup levels that are set through use of Alternatives 4 and 5 (and to a lesser extent Alternatives 1 and 3) will be more protective of human health and, therefore, score higher with respect to this threshold criterion than Alternative 2.

The results of scoring the freshwater sediment criteria alternatives for Threshold Criterion 2 are presented in Table 5.6. In general, cleanup levels that are set through use of Alternatives 3 and 4 (and to a lesser extent Alternatives 2 and 5) will be more protective of the environment and, therefore, score higher with respect to this threshold criterion than Alternative 1.

Threshold Criterion 3 — Compliance with ARARs

This criterion is used to evaluate whether the alternatives would allow chemical concentrations that are at least as stringent as levels associated with available ARARs addressing contaminated sediment cleanup levels. This evaluation will determine the degree to which the alternative complies with legally applicable requirements for cleanup. The alternatives are ranked using the following scores:

> *Low.* The alternative is unlikely to comply with all legally applicable requirements for all contaminants and situations.
> *Medium.* The alternative will comply with all legally applicable requirements, but is unlikely to comply with relevant and appropriate requirements for all contaminants and situations.
> *High.* The alternative will comply with all legally applicable or relevant and appropriate requirements.

The results of scoring the human health alternatives for Threshold Criterion 3 are presented in Table 5.5. In general, cleanup levels that are set through use of Alternatives 4 and 5 (and to a lesser extent Alternative 3) will be more protective of human health and, therefore, score higher with respect to this threshold criterion than Alternatives 1 and 2.

The results of scoring the freshwater sediment criteria alternatives for Threshold Criterion 3 are presented in Table 5.6. In general, cleanup levels that are set through use of Alternatives 4 and 5 will be more protective of the environment and, therefore, score higher with respect to this threshold criterion than Alternatives 1, 2, and 3.

Table 5.5 - Evaluation of Human Health Alternatives Relative to Threshold Criteria

Alternative	Threshold Criterion 1 Protection of Human Health and the Environment (Residual Contamination)	Score[1]	Threshold Criterion 2 Protection of Human Health and the Environment (Cleanup Measures)	Score	Threshold Criterion 3 Compliance with ARARs	Score
Alternative 1 – Original Rule (No Action)	Lower, more difficult to achieve cleanup levels. Less capping and dredging because of cost, and more reliance on natural recovery. Higher residual contamination for longer time period.	L (4)	Removal or capping sediment requiring cleanup will cause some short-term impacts. Low cleanup levels will result in larger sites and dredge/cap footprints.	M (8)	Will comply with all legally applicable or relevant and appropriate requirements.	H (12)
Alternative 2 – Risk-Based Concentration Based on RME	Lower, more difficult to achieve cleanup levels. Less capping and dredging because of cost, and more reliance on natural recovery. Higher residual contamination for longer time period.	L (4)	Removal or capping sediment requiring cleanup will cause some short-term impacts. Low cleanup levels will result in larger sites and dredge/cap footprints (likely largest footprint of each alternative)	L (4)	Will comply with all legally applicable or relevant and appropriate requirements.	H (12)
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	Higher, more easily attainable cleanup levels. Smaller sites requiring cleanup, more dredging and capping, less reliance on natural recovery. Less residual contamination.	M (8)	Removal or capping sediment requiring cleanup will cause some short-term impacts. Low cleanup levels will result in larger sites and dredge/cap footprints.	M (8)	Will comply with all legally applicable requirements, but is unlikely to comply with relevant and appropriate requirements for all contaminants and situations.	M (8)
Alternative 4 – Regional Background or PQL	Higher, more easily attainable cleanup levels. Smaller sites requiring cleanup, more dredging and capping, less reliance on natural recovery. Less residual contamination.	M (8)	Removal or capping sediment requiring cleanup will cause some short-term impacts. Higher cleanup levels will result in smaller sites and dredge/cap footprints.	H (12)	Will not likely comply with all legally applicable requirements for all contaminants and situations.	L (4)
Alternative 5 - Combined	Lower cleanup levels than Alternatives 3 and 4; however, has mechanism to immediately reduce high risk areas, while allowing longer period to achieve risk-based cleanup. Overall lower residual contamination.	H (12)	Removal or capping sediment requiring cleanup will cause some short-term impacts. This alternative allows efficient cleanup of high concentration units within a larger site and more attainable cleanup levels (and immediate risk reduction).	H (12)	Will comply with all legally applicable or relevant and appropriate requirements.	H (12)

[1] L = Low, M = Medium, H = High (Assigned Score Value)

Table 5.6 - Evaluation of Freshwater Sediment Criteria Alternatives Relative to Threshold Criteria

Alternative	Criterion 1 Protection of Human Health and the Environment (Residual Contamination)	Score[1]	Criterion 2 Protection of Human Health and the Environment (Cleanup Measures)	Score	Criterion 3 Compliance with ARARs	Score
Alternative 1 – Original Rule (No Action)	Reliance on narrative standard would cause inconsistent decision making and cleanup levels. Could result in very low cleanup levels (below natural background and PQL in some cases), with decreased confidence in relationship between concentrations and toxicity. Low cleanup levels would reduce benthic community health risk. Increased reliance on natural recovery, and resulting longer term exposure.	M (8)	High false positive rate results in large area identified for cleanup, including sediment that may not be toxic. Biological testing would be done on site-by-site basis, increasing uncertainty. High number of stations will require testing, and high cost will result in more composite sampling, with resulting uncertainty and expanded cleanup site, which may lead to higher short term impacts.	L (4)	Unlikely to comply with all legally applicable requirements for all contaminants and situations. Original SMS has a narrative standard that doesn't provide freshwater criteria but does provide a cleanup framework. Use of non-promulgated standards outside of Ecology guidance is not consistent with SMS or MTCA requirements. Lack of organic criteria with other SQGs may not be in compliance with ESA requirements.	L (4)
Alternative 2 – Minimize False Negatives	Reliance on narrative standard would cause inconsistent decision making and cleanup levels. Could result in very low cleanup levels (below natural background and PQL in some cases), with decreased confidence in relationship between concentrations and toxicity. Low cleanup levels would reduce benthic community health risk. Increased reliance on natural recovery, and resulting longer term exposure.	M (8)	High false positive rate results in large area identified for cleanup. However, inclusion of biological criteria would allow for confirmation of contamination, and potentially reduce cleanup area. High number of stations will require testing, and high cost will result in more composite sampling, with resulting uncertainty and expanded cleanup site, but biological criteria could reduce size of cleanup.	M (8)	Unlikely to comply with all legally applicable requirements for all contaminants and situations. Not consistent with the SMS or MTCA risk management approach that allows for some adverse impacts to benthic community and has a risk assessment process and risk management approach to developing cleanup criteria.	L (4)
Alternative 3 – Minimize False Positives	High false negative rate could result in lack of cleanup in areas that represent a threat. Higher cleanup levels may result in more rapid cleanup actions.	L (4)	Low false positive results, and maximize likelihood of accurate delineation of cleanup site. This would result in low implementation risk.	H (12)	Unlikely to comply with all legally applicable requirements for all contaminants and situations. May not comply with ARARs because of the less conservative nature of the criteria and higher likelihood of designating sites as nontoxic that are actually toxic.	L (4)

Table 5.6 - Evaluation of Freshwater Sediment Criteria Alternatives Relative to Threshold Criteria

Alternative	Criterion 1 Protection of Human Health and the Environment (Residual Contamination)	Score[1]	Criterion 2 Protection of Human Health and the Environment (Cleanup Measures)	Score	Criterion 3 Compliance with ARARs	Score
Alternative 4 – Balance False Negatives and False Positives	Balance results in more accurate prediction of toxicity and high confidence in correlation between concentration and toxicity. Cleanup levels won't be as low as other alternatives, but are less likely to be below natural background and PQL, resulting in more rapid cleanups.	M (8)	Balance would result in cleanup area larger than that defined by Alternative 3, but lower than that defined by Alternatives 1 and 2. A moderately well defined cleanup area would result in more moderate risk during cleanup implementation.	H (12)	Will comply with all legally applicable or relevant and appropriate requirements. Approach behind criteria development is in compliance with SMS and MTCA framework. Two-tier criteria allow for risk management and risk assessment cleanup decisions, some adverse impacts on the benthic community, and protection of endangered species.	H (12)
Alternative 5 – Establish Only Biological Criteria	More expensive site characterizations because of biological testing; may result in less consistency and predictability of outcome, based on need to develop chemical criteria on site-by-site basis.	L (4)	Inclusion of biological testing criteria reduces likelihood of high levels of contamination remaining post-remedy. High number of stations will require testing, and high cost will result in more composite sampling. Resulting moderately well defined cleanup area would result in more moderate risk during cleanup implementation.	M (8)	Will comply with all legally applicable or relevant and appropriate requirements.	H (12)

[1] L = Low, M = Medium, H = High (Assigned Score Value)

Balancing Criteria

In this section, the five alternatives for rule revision for protection of human health and the five alternatives for freshwater sediment criteria are evaluated with respect to practical considerations associated with rule implementation. These considerations are defined as balancing criteria.

Balancing Criterion 1 — Technical Feasibility

Several factors will influence the ability to implement the revised SMS. For example, the lower the cleanup criteria, the larger the areas requiring cleanup will likely be. This will lead to difficulty in achieving cleanup standards through aggressive measures such as dredging and capping on this scale, demonstrating that cleanup has been achieved because of the higher likelihood of rapid recontamination by adjacent material and upland sources, and maintaining sites at prescribed cleanup levels over a long time. The criterion of technical feasibility is used to evaluate the alternatives with respect to the goal of achieving cleanup criteria within an acceptable period of time, and maintaining these criteria.

The technical feasibility of achieving the long-term sediment quality goal within a reasonable period of time and be able to maintain that goal over time is assessed by considering both the cleanup standard concentration represented by each of the alternatives, as well as the means by which the standard will be achieved. The original SMS allows the incorporation of natural recovery into a site cleanup plan, as deemed appropriate by Ecology. This allowance for natural recovery could result in sediment contaminated above the sediment cleanup objective remaining in place for a reasonable time period. This assessment of alternatives recognizes that natural recovery is a function of many site-specific conditions (e.g., source loading, sediment accumulation rate, susceptibility of site contaminants to degradation or transformation). In addition, it is recognized that initial conditions, represented by the elevation of one or more particular chemical concentrations above the sediment cleanup criteria, play a major role in determining recovery rate.

For the Technical Feasibility criterion, the alternatives are ranked using the following scores:

> *Low.* The technical feasibility of meeting the specified cleanup standard at some point in the future, and maintaining compliance with that standard over time, is unlikely.
> *Medium.* The technical feasibility of meeting the specified cleanup standard at some point in the future, and maintaining compliance with that standard over time, is at most 50 percent likely.
> *High.* The technical feasibility of meeting the specified cleanup standard at some point in the future, and maintaining compliance with that standard over time, is highly likely.

The results of scoring the human health alternatives for Balancing Criterion 1 are presented in Table 5.7. In general, cleanup levels that are set through use of Alternatives 4 and 5 are more technically feasible and, therefore, score higher with respect to this balancing criterion than Alternatives 1, 2, and 3.

The results of scoring the freshwater sediment criteria alternatives for Balancing Criterion 1 are presented in Table 5.8. In general, cleanup levels that are set through use of Alternatives 3 and 4 are more technically feasible and, therefore, score higher with respect to this balancing criterion than Alternatives 1, 2, and 5.

Balancing Criterion 2 — Ability to Measure Compliance

The five human health and five freshwater sediment criteria alternatives differ with regard to the ability to accurately measure compliance with the cleanup standard established by the alternative. Thus, compliance achievement is evaluated in terms of whether chemical concentrations identified in the alternatives can be accurately measured at those levels to determine whether cleanup has been achieved (i.e., are the quantification limits equal to or lower than the cleanup standard specified by the alternative). Quantification limits refer to the ability to measure sediment chemical concentrations with a high degree of analytical confidence. Chemicals can be detected below quantification limits, but the reported quantities are often considered estimates, which may not always be acceptable for assessing regulatory compliance. The alternatives are ranked using the following scores:

> *Low.* The alternative does not provide a clear and predictable decision framework for establishing cleanup standards and selecting cleanup actions. The ability to measure compliance is limited because cleanup criteria for many contaminants are likely to fall below PQLs.
> *Medium.* The alternative does not provide a more clear and predictable decision framework for establishing cleanup standards and selecting cleanup actions. The ability to measure compliance is less limited because cleanup criteria for some contaminants are likely to fall below PQLs.
> *High.* The alternative provides a clear and predictable method for establishing cleanup standards and selecting cleanup actions. The ability to measure compliance is high because the alternative provides a mechanism for dealing with situations where cleanup criteria fall below PQLs.

The results of scoring the human health alternatives for Balancing Criterion 2 are presented in Table 5.7. In general, cleanup levels that are set through use of Alternatives 4 and 5 are more able to accurately measure compliance with the cleanup standard and, therefore, score higher with respect to this balancing criterion than Alternatives 1, 2, and 3.

The results of scoring the freshwater sediment criteria alternatives for Balancing Criterion 2 are presented in Table 5.8. In general, cleanup levels that are set through use of Alternatives 3 and 4 are more able to accurately measure compliance with the cleanup standard and, therefore, score higher with respect to this balancing criterion than Alternatives 1, 2, and 5.

Balancing Criterion 3 — Cost Effectiveness

Cost effectiveness is evaluated by comparing the cost or economic consequences associated with implementation of the cleanup criteria alternatives. The economic impacts associated with implementation of the revised SMS is evaluated in a cost benefit analysis in conjunction with the draft EIS and draft rule language. The cost associated with sediment cleanup will always be significant, no matter which alternative is ultimately selected. However, if the alternatives are evaluated relative to each other with respect to the area that may be defined for cleanup, the time frame over which cleanup is required, the methods that will be required to complete cleanup within that time frame, and the likelihood of recontamination, some differences in cost effectiveness of the alternatives becomes evident.

The alternatives are ranked using the following scores:

Low. The alternative is likely to result in significant economic costs that are not commensurate with the benefits of complying with this alternative.
Medium. The alternative is likely to result in less significant economic costs that are more commensurate with the benefits of complying with this alternative.
High. The alternative is likely to result in economic costs that are commensurate with the benefits of complying with this alternative.

The results of scoring the human health alternatives for Balancing Criterion 3 are presented in Table 5.7. In general, cleanup levels that are set through use of Alternatives 4 and 5 are more cost effective and, therefore, score higher with respect to this balancing criterion than Alternatives 1, 2, and 3.

The results of scoring the freshwater sediment criteria alternatives for Balancing Criterion 3 are presented in Table 5.8. In general, cleanup levels that are set through use of Alternative 4, and to a lesser extent through use of Alternatives 2, 3, and 5 are more cost effective and, therefore, score higher with respect to this balancing criterion than Alternative 1.

Modifying Criteria

In this section, the human health and freshwater sediment criteria alternatives are evaluated with respect to public concerns and perceptions, which are addressed through the single modifying criterion of regulatory precedence. This criterion is used to evaluate whether each alternative has been used in other environmental legislation or regulations with goals similar to those of the SMS. A detailed discussion of federal, state, and local laws and regulations related to the proposed rule is provided in Appendix A.

Table 5.7 - Evaluation of Human Health Alternatives Relative to Balancing Criteria

Alternative	Criterion 1 Technical Feasibility	Score[1]	Criterion 2 Ability to Measure Compliance	Score	Criterion 3 Cost Effectiveness	Score
Alternative 1 – Original Rule (No Action)	Unlikely that very low cleanup levels can be achieved and maintained; large site footprint requiring capping or dredging will have high risk of recontamination from difficulty of controlling sources to low standard and from sediment redistribution.	L (4)	Does not provide a clear and predictable decision framework for setting cleanup levels and selecting cleanup actions. It does provide a means of dealing with situations where the cleanup level falls below PQL.	M (8)	Likely to result in increased economic costs that are not commensurate with the benefits of compliance based on the large site footprint, resulting in significant environmental actions that may not result in significant environmental benefits.	L (4)
Alternative 2 – Risk-Based Concentration Based on RME	Unlikely that very low cleanup levels can be achieved and maintained; large site footprint requiring capping or dredging will have high risk of recontamination from difficulty of controlling sources to low standard and from sediment redistribution.	L (4)	Does not provide a clear and predictable decision framework for setting cleanup levels and selecting cleanup actions. The ability to measure compliance is limited because cleanup criteria for many contaminants are likely to fall below PQL.	L (4)	Likely to result in significant economic costs that are not commensurate with the benefits of compliance based on the large site footprint, resulting in significant environmental actions that may not result in significant environmental benefits.	L (4)
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	Feasibility of achieving and maintaining cleanup levels is at most 50 percent likely, because of potentially higher cleanup levels if risk-based concentrations are at or above background.	M (8)	Does not provide a clear and predictable decision framework for setting cleanup levels and selecting cleanup actions. The ability to measure compliance is limited because cleanup criteria for many contaminants are likely to fall below PQL.	L (4)	Likely to result in economic costs that are commensurate with the benefits of compliance.	M (8)
Alternative 4 – Regional Background or PQL	Feasibility of achieving and maintaining cleanup levels is highly likely. If cleanup level is within the range of upland sources, the likelihood of recontamination is lower. Higher feasibility of upland source control by improved BMPs and treatment.	H (12)	The alternative provides a clear and predictable method for establishing cleanup levels and selecting cleanup actions. The ability to measure compliance is high because regional background can generally be reliably measured with current analytical methods.	H (12)	Likely to result in economic costs that are commensurate with the benefits of compliance. Site dredging/capping footprints will be smaller, cleanup levels will be more attainable, and this will result in more cost effective cleanup with significant risk reduction.	H (12)
Alternative 5 - Combined	Feasibility of achieving and maintaining cleanup levels is highly likely. If cleanup level is within the range of upland sources, the likelihood of recontamination is lower. Higher feasibility of upland source control by improved BMPs and treatment.	H (12)	The alternative provides a clear and predictable method for establishing cleanup levels and selecting cleanup actions. The ability to measure compliance is high because it provides a mechanism for dealing with situations where the risk-based cleanup level falls below PQL.	H (12)	Likely to result in economic costs that are commensurate with the benefits of compliance. Site dredging/capping footprints will be smaller, cleanup levels will be more attainable, and the ability to cleanup site units within larger site will lead to more cost effective cleanups with significant and rapid risk reduction.	H (12)

[1] L = Low, M = Medium, H = High (Assigned Score Value)

Table 5.8 - Evaluation of Freshwater Sediment Criteria Alternatives Relative to Balancing Criteria

Alternative	Criterion 1 Technical Feasibility	Score[1]	Criterion 2 Ability to Measure Compliance	Score	Criterion 3 Cost Effectiveness	Score
Alternative 1 – Original Rule (No Action)	Cleanup levels will be below natural background and PQL for some contaminants. Need for biological testing will be determined on site-by-site basis, with some sites compared to reference sediment, which can be highly variable, resulting in test failures or potential false positive results.	M (8)	Sites are addressed on a case-by-case basis without assurance of consistency in cleanup level application or level of protectiveness. Screening levels for some contaminants would be set below natural background or PQL.	L (4)	Relies on various SQGs for predicting sediment toxicity, which allows lower predictability than considered adequate by Ecology. Results in very high false positive rate (70 to 90 percent) with need for extensive testing programs and high likelihood of designating clean sediment as needing cleanup.	L (4)
Alternative 2 – Minimize False Negatives	Maximizing false positives will result in more cleanup levels set at values below natural background and PQL.	L (4)	Both chemical and biological criteria would be established, with two-tiered framework and option to use biological testing to verify. However, low false negative rate will result in some screening level values set below background or PQL.	M (8)	Higher false positive rate will result in screening values set below natural background and PQL, and need for extensive testing programs. However, the likelihood of need for additional actions is minimized.	M (8)
Alternative 3 – Minimize False Positives	Maximizing false negatives will result in fewer cleanup levels set at values below natural background and PQL.	H (12)	Both chemical and biological criteria would be established, with two-tiered framework and option to use biological testing to verify. High false negative rate will result in fewer screening level values set below background or PQL.	H (12)	Chemical screening levels would be higher, with a lower rate of false positives, which would reduce scope of testing programs and cleanup efforts. However, higher allowed rate of false negatives presents higher environmental risk.	M (8)
Alternative 4 – Balance False Negatives and False Positives	Will minimize the number of chemical screening level values below natural background and PQL through the balanced approach.	H (12)	Both chemical and biological criteria would be established, with two-tiered framework and option to use biological testing to verify. Balanced false negative/false positive will result in some screening level values set below background or PQL.	H (12)	Balance will result in best designation of site extent, balancing cost of additional site characterization and cost of cleanup with long-term potential impact on environment. Highest consistency and predictability.	H (12)
Alternative 5 – Establish Only Biological Criteria	Substantially more site characterization and development of site-specific chemical values will be needed. As a result, there will likely be fewer concentrations below natural background or PQL.	M (8)	Establishes only biological criteria. Chemical criteria would be established on case-by-case basis, leading to low consistency/predictability. Low false negative rate will result in some screening level values set below background or PQL.	L (4)	Would require substantially more site characterization, development of site-specific chemical criteria, and more costly monitoring.	M (8)

[1] L = Low, M = Medium, H = High (Assigned Score Value)

Modifying Criterion—Regulatory Precedence

The alternatives are ranked using the following scores:

> *Low.* The policies and procedures used to implement this alternative are significantly different than original SMS and MTCA cleanup requirements. Similar policies and procedures are not used by other Ecology programs, regional sediment programs or cleanup programs in other states.
> *Medium.* The policies and procedures used to implement this alternative are consistent with original SMS and MTCA cleanup requirements. Similar policies and procedures are used by some (but not all) Ecology programs, regional sediment programs or cleanup programs in other states.
> *High.* The policies and procedures used to implement this alternative are similar to original SMS and MTCA cleanup requirements. Similar policies and procedures are commonly used by other Ecology programs, regional sediment programs or cleanup programs in other states.

The results of scoring the human health alternatives for the single modifying criterion are presented in Table 5.9. In general, cleanup levels that are set through use of Alternative 1, and to a lesser extent Alternatives 3 and 5, are more consistent with original cleanup requirements and, therefore, score higher with respect to the modifying criterion than Alternatives 2 and 4.

The results of scoring the freshwater sediment criteria alternatives for the single modifying criterion are presented in Table 5.9. In general, cleanup levels that are set through use of Alternative 4 are more consistent with original cleanup requirements and, therefore, score higher with respect to the modifying criterion than Alternatives 1, 2, 3, and 5.

Identification of the Preferred Alternative

The summary of scoring of the five human health alternatives is presented in Table 5.10, and the summary of scoring of the five freshwater sediment criteria alternatives is presented in Table 5.11.

The Threshold, Balancing, and Modifying Criteria were used to evaluate each alternative relative to prescribed factors; however, the preferred alternative must also be identified based on the requirements of the Washington State Administrative Procedures Act (chapter 34.05.325(e)), which states:

> *"…after considering alternatives, the agency must adopt the least burdensome alternative that will achieve the goals and objectives identified…."*

The requirements of the Act are consistent with those called for in a report issued recently by Thrive Washington (a joint research consortium headed by the Washington Roundtable and the Washington Research Council) titled, *Confronting Washington State's Overlapping Regulatory Structures* (Thrive Washington, 2011). This report calls for elimination of redundant, inconsistent, and unnecessary regulation without sacrificing safety and quality of life.

Table 5.9 - Evaluation of Alternatives Relative to Modifying Criterion – Regulatory Precedence

Alternative		Score[1]
Human Health Alternatives		
Alternative 1 – Original Rule (No Action)	Policies and procedures are similar to original SMS and MTCA cleanup requirements. Similar policies and procedures are commonly used by other Ecology programs, regional sediment programs or cleanup programs in other states.	H (12)
Alternative 2 – Risk-Based Concentration Based on RME	Policies and procedures are significantly different than original SMS and MTCA cleanup requirements. Similar policies and procedures are not used by other Ecology programs, regional sediment programs or cleanup programs in other states.	L (4)
Alternative 3 – Risk-Based Concentration Based on Federal Guidance or Regional Background	Policies and procedures are similar to original SMS and MTCA cleanup requirements. Similar policies and procedures are not used by other Ecology programs, but are used by some regional sediment programs or cleanup programs in other states.	M (8)
Alternative 4 – Regional Background or PQL	Policies and procedures are significantly different than original SMS and MTCA cleanup requirements. Similar policies and procedures are not used by other Ecology programs, regional sediment programs or cleanup programs in other states.	L (4)
Alternative 5 - Combined	Policies and procedures are similar to original SMS and MTCA cleanup requirements. Similar policies and procedures are not used by some (but not all) Ecology programs, regional sediment programs or cleanup programs in other states.	M (8)
Freshwater Sediment Criteria Alternatives		
Alternative 1 – Original Rule (No Action)	Lacks promulgated chemical and biological criteria for freshwater sediment and does not follow the original SMS regulatory framework for addressing contaminated sediment. Sites are addressed on a case-by-case basis without assurance that there will be consistency in required cleanup levels, level of protectiveness, or methods for characterizing a site.	L (4)
Alternative 2 – Minimize False Negatives	Will result in lower screening values (because of minimizing false negatives) and lower cleanup levels. Limited in its accuracy in predicting sediment that is actually contaminated; will include sediment that is not toxic. Not consistent with the original SMS framework that relies on a risk management approach and allows some adverse effects to the benthic community.	L (4)
Alternative 3 – Minimize False Positives	Will result in higher screening values (because of minimizing false positives) and higher cleanup levels. Limited in its accuracy in predicting sediment that is actually contaminated; will exclude sediment that is toxic.	M (8)
Alternative 4 – Balance False Negatives and False Positives	Consistent with the original SMS regulatory framework for addressing contaminated sediment. Chemical and biological criteria development is similar to existing SMS framework, allows some adverse effects within a risk management framework, and relies on regional data to develop the criteria.	H (12)
Alternative 5 – Establish Only Biological Criteria	Consistent with the original SMS framework for biological criteria but inconsistent with the chemical criteria. Does not allow for chemical criteria to be used as a screening tool. Biological criteria used for validation of toxicity in developing site-specific cleanup levels.	M (8)

[1] L = Low, M = Medium, H = High (Assigned Score Value)

The results of scoring of the human health alternatives indicate that the overall highest scoring alternative (with a total score of 56) was Alternative 5 (Combination). The human health alternative that scored next highest, with a total score of 43, was Alternative 4 (Regional Background and PQL). Alternative 5 received a "high" score for the three Threshold Criteria and the three Balancing Criteria, and a score of "medium" for the single Modifying Criterion.

The freshwater sediment criteria alternative which scored the highest overall (with a total score of 49) was Alternative 4 (Balance False Negatives and False Positives). The freshwater sediment criteria alternative that scored next highest, with a total score of 38, was Alternative 3 (Minimize False Positives). Alternative 4 received a "high" score for the Threshold Criteria except the first criterion (where it scored medium), the three Balancing Criteria, and the single Modifying Criterion.

Based on scoring relative to the criteria alone, the Preferred Alternative would be a combination of human health Alternative 5 (Combination) and freshwater sediment criteria Alternative 4 (Balance False Negatives and False Positives). The full descriptions of these alternatives (as presented in Chapter 3) are summarized below.

In addition to scoring highest, the identified preferred alternatives meet the requirements of the Administrative Procedures Act, and address concerns stated in the Thrive Report. The Thrive Report discusses the concept of "the last 10 percent", which is an issue coined by economist to differentiate between regulations that are able to address 90 percent of an issue, and those additional regulations or regulatory requirements that are needed to address "the last 10 percent". According to economists, and as discussed in the Thrive Report, while the regulatory requirements needed to address the 90 percent bulk of the issue oftentimes represent reasonable requirements, those needed to address the last 10 percent of the issue are often disproportionately costly and difficult to achieve compliance. The identified preferred alternatives are consistent with meeting the goal of addressing the first 90 percent of the issue:

- Preferred Human Health Alternative 5 (Combined) is focused on addressing areas of high contaminant concentration (partly addressed through allowance to define cleanup units), providing incentive to PLPs to initiate and complete cleanup in highest risk areas. This significantly reduces risk in both the short and long term. Source control is the means by which the last 10 percent of the cleanup requirements are met, rather than setting an unattainable cleanup standard to address the last 10 percent of cleanup needs.
- Preferred Freshwater sediment criteria Alternative 4 (Balance False Negative and False Positive) sets a 20 percent false negative rate, minimizing the likelihood of proclaiming a contaminated site as clean (and addressing the initial 90 percent of cleanup) while not setting cleanup criteria so low that clean sites may be proclaimed to be dirty (the last 10 percent).

Although the Thrive Report may be interpreted as calling for no additional changes to the existing SMS, the need for additional clarity in the sediment regulations is clearly needed, based on the analysis presented in this document. The Preferred Alternative (combination of human health Alternative 5 and freshwater sediment criteria Alternative 4) provides the balance of improved clarity in the existing regulations and efficiency in their application, while not representing additional requirements for cleanup that are costly and burdensome.

Human Health Alternative 5 – Combination

Alternative 5 requires both compliance with ARARs and protection of human health and the environment, and allows for consideration of both natural and regional background concentrations of hazardous substances in the environment. This alternative could be established within the original two-tier SMS framework that allows sediment cleanup levels to be set within a range between an upper and lower bound. The upper value would be referred to as the Cleanup Screening Level (CSL), which is defined to be the upper bound allowed as a cleanup level, and the concentration that would trigger the potential need for cleanup. This upper bound would be established as the *highest* of three concentrations determined for the site:

- Risk-based concentrations;
- Regional background; and
- Practical quantitation limit (PQL).

The lower bound would be referred to as the Sediment Cleanup Objective (SCO). This lower bound concentration would be set as the *highest* of three concentrations determined for the site:

- Risk-based concentration;
- Natural background; and
- Practical quantitation limit (PQL).

The site-specific cleanup level established for the site, based on protection of human health, would be somewhere in the range between the CSL (upper bound) and SCO (lower bound), and would be established on the basis of technical possibility and net adverse environmental impact. Because of the tendency of sources of sediment contamination to influence wide areas unless source control is implemented, this alternative would allow PLPs to meet their obligations for their site (referred to as a site unit) if the cleanup standard for their site is met and their source(s) controlled. At the same time, Alternative 5 will allow for site or bay-wide contaminant concentrations to be further reduced over time (toward the SCO concentration) through cleanup of multiple site units and source control implementation on a regional scale. The two-tier framework proposed by Alternative 5 is illustrated on Figure 3.6.

Freshwater Sediment Criteria Alternative 4 - Balance False Negative and False Positive Rates (20 Percent False Negative Rate)

Under Alternative 4, both chemical and biological criteria would be established for freshwater sediments. Chemical criteria under this alternative would be based on the Floating Percentile Method (FPM) and an expanded data set of over 1800 toxicity data points from a broader geographic area, representing Washington, Oregon, and Idaho (Michelsen, 2011). Biological criteria would be established using the expanded suite of biological tests presented in Alternative 2.

Under Alternative 4, chemical criteria would be based on the FPM using a false negative rate of 20 percent. The resulting false positive rate would be 12 to 32 percent. This alternative was generally a reliable predictor of toxicity (71 to 88 percent), and met reliability and efficiency goals agreed to by Ecology and the RSET scientific advisory board. This alternative is consistent with the no adverse and minor adverse effects process used to develop the SMS marine criteria and the SMS risk management framework. This alternative balances sensitivity with project scope and cost.

This alternative would also provide for confirmatory toxicity testing for any sediment sample that had exceeded the chemical criteria as defined in the SMS.

Table 5.10 - Evaluation Scoring Summary – Human Health Protection Alternatives

Alternative	Threshold Criteria			Balancing Criteria			Modifying Criteria	Final Score
	Protection of Human Health and the Environment (Residual Contamination)	Protection of Human Health and the Environment (Cleanup Measures)	Compliance with ARARs	Technical Feasibility	Ability to Measure Compliance	Cost-Effectiveness	Regulatory Precedence	
Alternative 1: Original Rule (No Action)	Low (4)	Medium (8)	High (12)	Low (2)	Medium (4)	Low (2)	High (3)	**35**
Alternative 2: Risk-Based Concentration Based on RME	Low (4)	Low (4)	High (12)	Low (2)	Low (2)	Low (2)	Low (1)	**27**
Alternative 3: Risk-based Concentration Based on Federal Guidance or Regional Background	Medium (8)	Medium (8)	Medium (8)	Medium (4)	Low (2)	Medium (4)	Medium (2)	**36**
Alternative 4: Regional Background and PQL	Medium (8)	High (12)	Low (4)	High (6)	High (6)	High (6)	Low (1)	**43**
Alternative 5: Combination	High (12)	High (12)	High (12)	High (6)	High (6)	High (6)	Medium (2)	**56**

Table 5.11 - Evaluation Scoring Summary – Freshwater Sediment Criteria Alternatives

Alternative	Threshold Criteria			Balancing Criteria			Modifying Criteria	Final Score
	Protection of Human Health and the Environment (Residual Contamination)	Protection of Human Health and the Environment (Cleanup Measures)	Compliance with ARARs	Technical Feasibility	Ability to Measure Compliance	Cost-Effectiveness	Regulatory Precedence	
Alternative 1: Original Rule (No Action)	Medium (8)	Low (4)	Low (4)	Medium (4)	Low (2)	Low (2)	Low (1)	25
Alternative 2: Minimize False Negatives	Medium (8)	Medium (8)	Low (4)	Low (2)	Medium (4)	Medium (4)	Low (1)	31
Alternative 3: Minimize False Positives	Low (4)	High (12)	Low (4)	High (6)	High (6)	Medium (4)	Medium (2)	38
Alternative 4: Balance False Negatives and False Positives	Medium (8)	High (12)	High (8)	High (6)	High (6)	High (6)	High (3)	49
Alternative 5 – Establish Only Biological Criteria	Low (4)	Medium (8)	High (8)	Medium (4)	Low (2)	Medium (4)	Medium (2)	32

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Chapter 6 - References

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Appendix A: Relationship of Existing Laws and Regulations to the Sediment Management Standards

Introduction

When adopting significant legislative rules, agencies must "…coordinate the rule, to the maximum extent practicable, with other federal, state, and local laws applicable to the same activity or subject matter…"[31]. Implementation of the SMS rule must be coordinated with many federal, state, and local laws, regulations, and ordinances. This section describes the relationship between the SMS rule revisions and other applicable federal, state, and local requirements. The discussion is presented in presented in six parts:

- Federal Laws and Approval Requirements;
- Tribal Regulations;
- Regional Programs;
- State Rules and Regulations;
- Local Ordinances and Permit Requirements; and
- Conflicting Requirements.

Federal Laws and Approval Requirements

Federal laws that significantly apply to activities and subject matter addressed by the SMS include:

- The Clean Water Act (33 USC 1251 et seq.);
- The Comprehensive Environmental Response Compensation and Liability Act (CERCLA, 42 USC 9601 et seq.), as amended by the Superfund Amendments and Reauthorization Act (SARA);
- The Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.), as amended by the Hazardous and Solid Waste Amendments of 1984 (40 CFR 280);
- The Coastal Zone Management Act of 1972, as amended (16 USC 1451 et seq.); and
- The River and Harbors Act of 1899 (33 USC 401 et seq.).

This section presents a summary of these federal laws and their application to the SMS, and identifies other federal laws and regulations that are more tangentially related to the SMS.

[31] Chapter 34.05.328 (1) (i) RCW

The Clean Water Act (CWA)

Purpose. Restore and maintain the chemical, physical, and biological integrity of the nation's waters.

Applicability to the SMS. Several requirements of the CWA and its implementing regulations apply to the implementation of SMS cleanup standards and source control standards under the proposed rule. These are summarized in Table A-1.

Table A-1 - Applicability of the Federal Clean Water Act to the SMS

CWA Section	General Requirements	Specific Provisions and Applicability to the SMS
40 CFR 131.21	Any modifications to water quality standards must be approved by EPA.	• State submits officially adopted version of rules to EPA • EPA administrator must notify sate within 60 days if approved or 90 days if not approved
CWA Section 401	Establishes requirements for point-source discharge permits (NPDES permits) for pollutant discharge into navigable waters.	• 40 CFR 122 implements issuance of NPDES permits (administered by state for non-federal facilities); dischargers are required to get permit. • 40 CFR 129 sets effluent limitations and standards for toxic pollutants. • Discharges requiring sediment impact zone will have requirements specified in a permit .
CWA Section 404	Establishes guidelines and requirements for discharge or disposal of dredged material into specified in-water disposal sites.	• 404(b) sets guidelines for permits to be issued for discharge • Permit required for sediment capping, except for CERCLA actions, or when contaminated sediments are disposed of in an aquatic or nearshore environment • US Army Corps of Engineers has responsibility for processing dredge permits required under Section 10, River and Harbors Act of 1899.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

Purpose. Investigation and response to the release or threatened release of hazardous substances from inactive hazardous waste sites, on both land and water. Strives to ensure that sites are cleaned up by responsible parties whenever possible; when a responsible party cannot be located or can not complete cleanup, CERCLA provides for cleanup actions by the federal government under a government trust fund. Pursues enforcement and cost recovery to allow public trustees to recover cleanup costs from responsible parties. Section 121 defines basic cleanup requirements (protection of human health and the environment, cost effectiveness, compliance with the National Contingency Plan). Preferred cleanup response is treatment to reduce volume, toxicity and mobility of contamination.

Applicability to the SMS. Under MTCA, state cleanup standards must be at least as stringent as applicable state and federal laws (including CERCLA Section 121)[32]. A Superfund site with contaminated sediments that is receiving federal funding and cleanup assistance (such as Commencement Bay, Harbor Island, and Eagle Harbor) must meet all CERCLA requirements. Additionally the SMS will be an Applicable, Reasonable and Appropriate Requirement (ARAR) for federal Superfund sites, and, therefore, will apply to all federal sites in the state.

Resource Conservation and Recovery Act (RCRA)

Purpose. Federal program to manage solid and hazardous waste; identifies materials to be considered hazardous wastes and regulates the generation, treatment, storage, and disposal of solid and hazardous wastes.

Applicability to the SMS. RCRA is an ARAR for evaluating the appropriateness of cleanup actions at contaminated sites. Washington State Department of Ecology has responsibility for implementing most aspects of the federal RCRA program; responsibility for implementing most of the solid waste aspects has been delegated to local governments. Treatment/disposal of contaminated sediments at upland locations must comply with RCRA and state solid waste management requirements (state requirements in most cases are more stringent; in these cases only state requirements apply). See additional discussion of state solid and hazardous waste management programs in later section on State Programs.

Coastal Zone Management Act

Purpose. Establishes policy to preserve, protect, develop, and wherever possible, restore or enhance the resources of the nation's coastal zone. Establishes a framework for states to develop and implement state shoreline management programs, as done in Washington[33]. The state may then delegate responsibility to local governments (e.g., the Tacoma Shoreline Master Program).

[32] 70.105D.030(2)(d) RCW

[33] Shoreline Management Act, Chapter 90.58 RCW

Applicability to the SMS. State Shoreline Management Act supersedes the requirements of the Coastal Zone Management Act; see discussion in later section on State Programs.

River and Harbors Act

Purpose. Prohibits the unauthorized obstruction or alteration of any navigable waters of the United States (Section 10), and requires a federal recommendation (e.g., permit for dredging in navigable waters, regardless of location for dredged material disposal, in contrast to CWA Section 404 permits) for any work affecting the course, location, condition, or physical capacity of a waterway.

Applicability to the SMS. Contaminated sediment site cleanup actions that require dredging in or alteration of navigable waters will require a Section 10 permit (administered by the USACOE).

Other Federal Laws

The following federal laws and regulations are more tangentially related to implementation of the SMS. Source control and cleanup actions under the SMS will likely meet their requirements; however, some provisions of these laws and regulations may be relevant to the cleanup of particular sites and will need to be considered on a case-by-case basis.

- Toxic Substances Control Act (TSCA) (15 USC 2601 et seq.)
- Safe Drinking Water Act (SDWA), as amended (42 USC 300 et seq.)
- Clean Air Act, as amended (42 USC7401 et seq.)
- Federal rules for the transportation of hazardous materials
- Occupational Safety and Health Act (OSHA) (29 CFR 651 et seq.)
- Historic Sites, Building and Antiquities Act (16 USC 461 et seq.)
- Archeological and Historic Preservation Act of 1974 (16 USC 469 et seq.)
- Abandoned Shipwreck Guidelines (54 Federal Register 1362-658, April 4, 1989)
- Endangered Species Act of 1973 (16 USC 1531 et seq.)[1]
- Fish and Wildlife Coordination Act (16 UDC 661 et seq.)
- Fish and Wildlife Improvement Act of 1978, and Fish and Wildlife Act of 1956 (16 USC 742 et seq.)
- Fish and Wildlife Conservation Act of 1980 (16 USC 2901 et seq.)
- Wetlands Protection (33 CFR 320.4(b) and Executive Order 11990, May 24, 1977)
- Protection and Enforcement of the Cultural Environment (Executive Order 11593, May 15, 1971)
- Flood Plain Management (Executive Order 11988)

[1]Although a chemical background concentrations (as defined by MTCA and regional background) may be identified as an appropriate cleanup level under the SMS, presence of a federally designated endangered species may require establishment of a risk-based cleanup level, which may be below the identified background concentration.

Tribal regulations

Several tribes in the Puget Sound region have significant jurisdiction over usual and accustomed fishing grounds that may be included in portions of identified contaminated sediment sites. These and other environmental concerns of affected tribes will be addressed on a case-by-case basis.

Regional Programs

Regional programs are those administered by both state and federal entities, or by multiple states. Two regional programs, the Dredged Material Management Program and the Regional Sediment Evaluation Team, are related to implementation of the SMS.

Dredged Material Management Program

Purpose. Federal navigation channels, port terminal ship berths, and small boat harbors in Puget Sound must be dredged periodically to maintain the commercial and recreational services provided by these facilities. Material removed from cleanup sites is managed under the Dredged

Material Management Program (DMMP), which oversees disposal at sites within Puget Sound[34], the Strait of Juan de Fuca, and the coastal embayments of the Grays Harbor and Willapa Bay sites. It provides guidelines for the sampling, testing, and evaluation of dredged material to ensure that such material is acceptable for unconfined, open-water disposal[35]. These evaluation procedures are used to assess projects conducted under Sections 401 and 404 of the CWA, and establish disposal site management plans to address navigation and discharge conditions of disposal permits. It also addresses site selection and monitoring for Puget Sound disposal sites. DMMP is jointly administered by the U.S. Army Corps of Engineers, U.S. EPA, Ecology, and the Washington Department of Natural Resources.

Applicability to the SMS. The DMMP disposal sites are intended for disposal of routine dredge materials; as such, sediment excavated as part of a cleanup would be disposed of at a DMMP sites only at acceptably low and protective concentrations.

Regional Sediment Evaluation Team

Purpose. The Regional Sediment Evaluation Team (RSET) is composed of representatives from Washington, Oregon, Idaho, and federal agencies. It is designed to provide the highest caliber scientific advice combined with practicable knowledge about the administrative use of that information to ensure science-based regulation. RSET has produced a Sediment Evaluation Framework (SEF) manual, which presents a sediment characterization framework to provide clarity and consistency in sediment evaluation of dredging projects in the states of Washington, Oregon, and Idaho. The various agencies signed an agreement to implement the evaluation procedures and process and to provide continued participation in the process of updating the manual.

Applicability to the SMS. The SEF manual provides a regional framework for the assessment, characterization, and management of freshwater sediments in the Pacific Northwest for open water disposal. It was intended that the SEF, which consolidates the existing regional sediment testing guidance manuals, be technically applicable throughout the Pacific Northwest for sediment assessment, and provide for continuous improvement of methods for sediment sampling, testing, and analysis to support regulatory management decisions for dredge material disposal at a region-wide level, and maintenance of the sediment quality database. This is consistent with the CWA, which called for development of regional guidelines, particularly for water bodies related to more than a single state.

[34] Concerns about the appropriateness of disposing of this dredged material in Puget Sound, the selection of appropriate aquatic disposal sites, and the lack of consistent dredged material evaluation, led in part to the Puget Sound Dredged Disposal Analysis (PSDDA) study (1990).

[35] The original evaluation procedures and the rationale for the procedures (*Evaluation Procedures Technical Appendix – Phase I (Central Puget Sound))* were published in June 1988 (PSDDA, 1988); these guidelines have been updated several times over the last 20 years based on new scientific information. Current procedures are described in the *Dredged Material Evaluation and Disposal Procedures (User's Manual)* published in July 2008 (DMMP, 2008).

A very important aspect of the SEF is its ability to continuously evolve. Using newly available information, the RSET agencies will revise and refine all aspects of the program within a publicly accessible forum. The mechanism for ensuring this is regular meetings similar to or concurrent with Sediment Management Annual Review Meetings (SMARMs).

State Rules and Regulations

Several state laws and regulations are directly applicable to the SMS, addressing cleanup requirements, permitting, cleanup activities, disposition of dredged sediment, and other aspects of related activities.

Model Toxics Control Act

Purpose. The MTCA (chapter 70.105D RCW), the state statute paralleling CERCLA, is designed primarily for the cleanup of sites contaminated by hazardous substances. Under MTCA, cleanup standards must be at least as stringent as all applicable state and federal laws and the cleanup standards of CERCLA Section 121 (see discussion of CERCLA above).

Applicability to the SMS. MTCA provides authority for adoption of the SMS rule as it applies to site cleanups, and this rule will be incorporated by reference into the cleanup standards rule being developed pursuant to MTCA. Thus, the requirements of the SMS will apply to the cleanup of those contaminated sediment sites that are subject to MTCA, the state cleanup statute.

Water Pollution Control Act

Purpose. The Water Pollution Control Act (chapter 90.48 RCW) is the state's antidegradation policy for surface water quality. Under the its authority, as well as the CWA, the Ecology water quality program evaluates water bodies to identify water quality issues and determines municipal and industrial wastewater discharge compliance with the state water quality standards (chapter 173- 201 WAC) and CWA goals. There is also an antidegradation policy for groundwater quality, which is at least as stringent as the federal Safe Drinking Water Act.

Applicability to the SMS. As previously noted, CWA Section 401 requires state approval of activities that may result in a discharge into state waters. Such approval may be conditioned to assure compliance with state water quality standards. This approval may be required when contaminated sediment cleanup activities result in discharges into state waters. chapter 90.48 RCW also provides Ecology with the authority to issue state waste discharge permits (implemented through chapter 173-216 WAC). While NPDES permits (also issued by Ecology; see discussion of CWA Section 404 above) apply to pollutant discharges from point sources into navigable waters, state waste discharge permits are required for indirect discharges of wastes into sewage systems or underground water.

The applicable requirements of the SMS will be used by Ecology in establishing the necessary levels of environmental protection when issuing wastewater discharge permits, particularly the potential impacts to receiving-water sediment quality will be considered in establishing permit treatment requirements and permit effluent limitations (all effluent discharges must be conditioned with AKART to reduce the quantity of contaminants in the effluent as much as possible). In addition, the rule will be used to establish monitoring requirements for discharges that may affect sediments.

With respect to SMS applicability to groundwater, the state law requires that all beneficial uses of groundwater are to be maintained and protected, and existing water quality is to be protected against degradation. Groundwater quality standards are currently being developed. Once completed, they will be applicable requirements for sediment cleanup actions using upland disposal facilities (i.e., contaminated sediments must be disposed of in a manner that will not degrade existing groundwater quality).

Aquatic Lands Act

Purpose. The Aquatic Lands Act (chapter 79.105 RCW) gives the Department of Natural Resources (DNR) the authority to allow aquatic lands to be used for the disposal of dredged material. The department has developed open-water regulations (chapter 332-30 WAC) and has established several open-water sites for the disposal of dredged material. DNR also manages a lease program for state-owned aquatic lands.

The DNR will approve use of an open-water disposal site if the following conditions are met:

- There is no practical upland disposal alternative, or aquatic disposal would be beneficial (e.g., beach enhancement);
- All necessary federal, state, and local permits have been acquired; and
- The material is acceptable for in-water disposal.

Applicability to the SMS. Through this program, activities have been initiated to ensure cleanup of contaminated sediments resulting from the activities of lessees. The department will be using the proposed rule to assist in conducting cleanup studies and requiring cleanup actions.

Construction Projects in State Waters (formerly Hydraulics Act)

Purpose. This law (chapter 77.55 RCW) requires that any person proposing to use, divert, obstruct, or change the natural flow or bed of state waters obtain a hydraulic project approval from the Washington Department of Fish and Wildlife. A hydraulic project approval is required for aquatic and nearshore dredging and disposal of dredged material, but not for upland disposal. Projects directly or indirectly harmful to fish life are not approved unless mitigation can be assured by conditioning or modifying the approval. Mitigation is almost always required for aquatic or nearshore confined disposal because of potential impacts on fish habitat.

Applicability to the SMS. If contaminated sediment cleanup activities would result in such impacts, a hydraulic project approval would be required. Mitigation is not required for state or federal cleanup projects if dredging or capping will result in a cleaner aquatic environment or better habitat function and values. However, if the project is a site cleanup administered under

MTCA, state approval or permits are not required as long as all substantive requirements are met.

Shoreline Management Act and Local Shoreline Master Programs

Purpose. The Shoreline Management Act (chapter 90.58 RCW) requires a permit for any "substantial development" (i.e., generally for any development that exceeds $2,500 in value or materially interferes with normal public uses of the water or shoreline) within the shorelines of the state. Shorelines are defined to include designated water bodies and their submerged beds within state territorial limits, all land areas 200 feet landward of ordinary high water, and adjacent wetlands. Development is defined to include dredging, dumping, and filling activities. The primary responsibility to initiate and administer the permit program is assigned to local governments with jurisdiction. The affected local government may issue a substantial development permit if the activity is consistent with both the local Shoreline Master Program and the policies of the Shoreline Management Act.

Applicability to the SMS. The substantive requirements of both the act and the Shoreline Master Program must be considered for cleanup activities in the shoreline area, including sediment cleanup (e.g., aquatic, nearshore, and upland disposal of dredged material; and placement or treatment of contaminated materials).

Solid and Hazardous Waste Management Laws

Purpose. Governs management of solid and hazardous waste. Waste sediment may fall into either category, depending on contaminant concentrations. Chapter 173-303 WAC establishes procedures for defining dangerous and extremely hazardous wastes, which are subject to the dangerous waste regulations and must be treated or disposed of at a permitted or approved hazardous waste facility. These requirements are more stringent than the federal law that defines hazardous waste. If the waste does not qualify as dangerous or extremely hazardous, it is regulated under the solid waste program.

The state Solid Waste Management Laws (chapter 70.95 RCW) are intended to prevent the indiscriminate disposal of solid wastes by specifying treatment, recycling, and disposal standards and implementing a permit system. The act also provides for adequate planning for the management and disposal of solid wastes (Preston, Thorgrimson, 1989). The act assigns primary responsibility for handling solid wastes to the local government. Permitting and enforcement programs for specific waste management facilities are delegated to the county or city board of health.

Applicability to the SMS. These two laws govern how contaminated sediment is managed and its ultimate disposal. In addition to the general provisions noted above, the 1985 revisions to chapter 173-304 WAC create a category of "problem wastes" that include dredged material that is a) not suitable for open-water disposal, b) not dangerous waste, and c) not being disposed of under a CWA Section 404 permit. A permit from the appropriate health department is required for upland disposal of dredged material that is a) too contaminated for confined, open-water disposal, b) not subject to a Section 404 permit, and, c) not dangerous waste (Preston, Thorgrimson, 1989). The treatment or disposal of excavated contaminated sediment also requires a health department permit.

If excavated sediment is classified as a dangerous waste under state regulations, the generator would be required to comply with labeling, manifesting, tracking, reporting, and recordkeeping requirements, as per the requirements of the Hazardous Waste Management Act (chapter 70.105 RCW) and implementing regulations.

Archeological Sites and Resources Act

Purpose. The purpose of the Washington State Archeological Sites and Resources Act (chapter 27.53 RCW) is to ensure protection and preservation of archeological resources within the state.

Applicability to the SMS. Some provisions of the law may be relevant to site cleanups when sunken historic properties might be impacted. Therefore, this statute will need to be considered as appropriate on a case-by-case basis.

Administrative Procedures Act

Purpose. The Administrative Procedures Act (chapter 34.05 RCW) grants state agencies authority to adopt administrative rules that implement policies established by the legislature. This act establishes the procedures for public review and comment on proposed rules with the intention that interested parties work together to negotiate development of rules that are acceptable to all parties while adhering to stated responsibilities of "the protection of public health and safety, including health and safety in the workplace, and the preservation of the extraordinary natural environment with which Washington is endowed."

Applicability to the SMS. Proposed changes to the SMS will be subject to the requirements of this Act with respect to public review and comment.

Local Ordinances and Permit Requirements

As previously noted in discussion of the *Shoreline Management Act*, a substantial development permit is issued at the local level. In addition to this permit, there may be several other local permits or ordinances (e.g., land use approval, building codes, and local health department regulations) that will be applicable to implementation of the SMS. The type and number of these permits and ordinances will vary from jurisdiction to jurisdiction, requiring evaluation on a case-by-case basis.

Conflicting Requirements

The Washington Association of Prosecuting Attorneys (WAPA) directs agencies to ensure that a proposed rule "…does not require those to whom it applies to take an action that violates requirements of another federal or state law." Additionally, Washington State law states that when adopting significant legislative rules, agencies must "…coordinate the rule, to the maximum extent practicable, with other federal, state, and local laws applicable to the same activity or subject matter…"[36] This requirement necessitates the review of existing laws to avoid conflicts with proposed laws.

Ecology has concluded that compliance with the SMS rule revisions will not require cleanup proponents to violate other state or federal laws based on the following rationale:

- State laws, under the CWA, CERCLA, and RCRA, must be at least as stringent as the federal laws. For example, under MTCA, state cleanup standards must be at least as stringent as all applicable state and federal laws. The treatment or disposal of contaminated sediments at upland locations must comply with the pertinent requirements of both the RCRA and state solid waste management programs.
- The approval of the Shoreline Management Act for Washington by the federal government means that the state program requirements supersede the requirements of the Coastal Zone Management Act.
- The site by site basis of evaluation takes into account federal, tribal, state, and local regulations; therefore, any conflicting requirements should be taken into account prior to determination of cleanup actions.
- Participation by federal, state, and local governments in the DMMP and RSET programs provides a process for interagency agreement on regulations for water bodies under multiple jurisdictions.

[36] Chapter 34.05.328 (1) (i) RCW

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Appendix B – Rulemaking Issues

Introduction

Ecology made a number of choices and assumptions when developing and evaluating the alternatives and selecting the preferred alternative. These choices generally reflect a combination of scientific and policy determinations. Ecology recognizes that there is not always a clear separation between scientific and regulatory policy determinations and that multiple interpretations are inevitable given the wide range of situations and fact patterns that arise at individual cleanup sites. Consequently, Ecology has tried to provide a clear rationale for the key scientific and policy choices that helped to shape the proposed rule. This chapter summarizes the rationale for some of the more important choices, and is divided into three sections: issues related to human health, issues related to freshwater sediments, and integrated issues that involved aspects of multiple categories.

Rulemaking Issues Related to Human Health

Appropriate Level of Protection for Human Health

This issue pertains to how to establish the appropriate target or reference cancer risk level and non-carcinogenic hazard index level and how to incorporate background concentrations when establishing sediment cleanup objectives and cleanup levels. Different levels of protection are associated with the five human health alternatives presented in Chapter 3. As noted in Chapter 3, the original SMS (reflected in human health Alternative 1) has a narrative standard for protection of human health limited "no significant health risk to humans" and does not address either area or natural background as defined in MTCA. The target or reference cancer risk level previously used to establish the sediment cleanup objective and cleanup level is the MTCA approach, which includes an increased cancer risk of one-in-one million (1E-06) for any single chemical or exposure pathway, one-in-one hundred thousand (1E-05) for multiple carcinogenic chemicals/exposure pathways, and a hazard index or quotient of 1. In addition, MTCA has a default fish consumption rate of 54 g/day based a recreational use scenario. However, the MTCA RME scenario allows upward adjustments of the fish consumption rate to protect higher exposed populations such as tribes. The rationale for this choice in application of the original SMS has included:

- This approach is consistent with the MTCA rule.
- The use of a 1E-06 cancer risk level is consistent with the cancer risk level used to establish Washington water quality standards (chapter 173-201 WAC) and the National Toxics Rule (EPA 1992).
- The use of a 1E-06 cancer risk level is consistent with approaches used by other state agencies and is the most commonly used risk metric (ATSWMO, 2006).

Human health Alternative 2 would allow a similar risk range, Alternative 3 would allow total cancer risk for the site to be increased to one-in-ten-thousand (1E-04), and Alternative 4 would require that the site be cleaned to a level equivalent to regional background or the practical quantitation limit (PQL), whichever is higher.

The two-tiered framework proposed by Ecology in SMS rule revision (human health Alternative 5) would allow for:

- A sediment cleanup objective based on a cancer risk level of 1E-06 for a single carcinogen/exposure pathway, 1E-05 for multiple carcinogenic chemicals/exposure pathways, and a hazard index or quotient of 1; and
- A cleanup screening level of 1E-05 total site risk (for a single carcinogen/exposure pathway or for multiple carcinogenic chemicals/exposure pathways), and a hazard index or quotient of 1.

The cleanup levels would be determined within this two-tier range.

This two-tiered approach allows for a significant reduction in risk in the near term by allowing the cleanup level to be established between the two levels, while recognizing the need in the longer term for further reducing sediment concentrations to the sediment cleanup objective. It allows for flexibility in addressing larger sites that require multiple solutions (not simply dredging and/or capping) and longer time frames to implement effective solutions and control contaminant sources. The two-tier approach is depicted on Figure 3.6 (Chapter 3). SMS rule revision would not change the risk level set as cleanup objective (the lower risk level of 1E-06) or maximum allowable level for non-carcinogens. The acceptable non-cancer risk limit would remain at 1.0 (hazard quotient or hazard index value).

Basis of Exposure Assumptions

Exposure to hazardous substances is influenced by a wide range of factors, and there are often wide ranges in exposures within a given population as well as numerous inherent uncertainties of actual exposure and impact to human health. Regulators may have some information on the range of values for a particular parameter (e.g., seafood consumption rates, dermal contact with contaminated sediment). However, regulators must also decide which value within the range to use to characterize the range of values (e.g., average or upper end of exposure range). Choosing a summary measure to characterize population exposure reflects an explicit (or implicit) policy choice on the appropriate balance between over- or underestimating exposure levels for particular individuals within the population group.

When setting cleanup levels, the MTCA rule says that exposure scenarios should be based on the reasonable maximum exposure (RME) for a human under current and potential future site use. As noted in Chapter 3, an RME is one in which exposure parameters selected for use in calculating a risk-based cleanup level would be at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but still within a realistic range of exposure (EPA, 1989). A site-specific risk assessment, conducted for CERCLA cleanup site, usually includes two human exposure scenarios: RME and a central tendency exposure (CTE). A CTE scenario is intended to assess exposures that represent average or typical intake of environmental media. However, MTCA does not include the use of a CTE scenario.

The original SMS narrative standard for protection of human health (Alternative 1) does not specify whether exposure to sediment contamination should be evaluated using RME or CTE assumptions. However, it requires that the cleanup objective correspond to no significant human health risk[37], and that applicable requirements in the MTCA rule be met[38]. This has been interpreted by Ecology to require that sediment cleanup objectives be in compliance with MTCA (which is based on the RME) and estimated using a combination of parameters that produce a value in the upper end of the exposure spectrum (although not worst case). The rationale for this choice includes:

- This approach is consistent with the MTCA policies and procedures applicable to sediment cleanup activities.
- This approach is consistent with the policies and procedures for establishing water quality standards.

Alternative 2 exposure assumptions are also based on the RME. Alternative 3 exposure assumptions are consistent with EPA risk assessment guidance. Alternative 4 establishes cleanup levels based on the higher of regional background and the PQL, and no risk-based calculations are made.

The two-tiered framework proposed by Ecology in SMS rule revision (human health Alternative 5) would be calculated using the RME scenario, because the rationale for its selection over the CTE scenario, as stated above, remains the same. Use of the RME scenario becomes especially important for assessment of the fish consumption exposure pathway, which is discussed below.

Fish Consumption Rate

Bottom-dwelling fish and shellfish can accumulate contaminants present in sediment. One of the major concerns associated with contaminated fish and shellfish in Puget Sound is the threat that they pose to humans who consume them. Public health officials are concerned about the risk to humans from eating contaminated seafood. Natural resource managers are concerned because many marine and terrestrial animals (including birds, other fish, and marine mammals) eat fish. These animals can accumulate toxic contaminants present in fish tissues and pass them up the food chain, which can pose an additional health risk to humans (PSWQA, 1990).

Humans may be at risk for illness and serious disease if they consume enough contaminated fish. However, it is difficult to determine where a given level of risk lies. In general, health risks associated with a given chemical are proportional to intake of that chemical. Thus, fish with high concentrations of a given chemical in their tissues pose greater human health risks when eaten than do those with low concentrations. Subpopulations that eat large amounts of locally caught fish and shellfish may face greater risks, such as some recreational fishermen, some tribal

[37] WAC 173-204-570(2)

[38] WAC 173-340-700 through -760

members, and some Asian groups. Studies have shown that some population groups (e.g., Asian-Pacific Islanders) residing near MTCA sites often consume fish and shellfish at much higher rates than recreational anglers. Consequently, exposure estimates based on a recreational angler exposure scenario will generally underestimate exposure to sediment contaminants through fish and shellfish consumption for these population groups.

MTCA includes a default fish consumption rate of 54 g/day based on a recreational use scenario and methods for establishing surface water cleanup levels that are based on preventing health risks associated with the consumption of contaminated fish and shellfish[39]. However, MTCA allows higher fish consumption rates for high exposure groups when developing site-specific cleanup levels. In general, fish consumption rates used at these sites ranged from ~80 to ~500 g/day.

Ecology conducted a significant amount of research and data review during 2010 and 2011, which is summarized in Table 20 of the Ecology DRAFT Report "Fish Consumption Rates Technical Support Document" (Ecology, 2012). Ecology will continue this work to help inform site-specific decisions regarding cleanup. The rationale for including high-exposure population groups in establishing fish consumption rates includes the following:

- *The vast majority of Washington cleanup sites are located in the Usual and Accustomed (U&A) fishing areas for one or more tribes.* The DMMP agencies described the site locations relative to U&A areas in the Phase I and Phase II Surveys (PSDDA, 1988 and 1989; PSDDA 1990). The information in the DMMP documents is consistent with more recent information compiled by the Washington State Department of Transportation (WSDOT, 2008).
- *Available information on fish consumption rates indicates that many tribal members consume much larger amounts of local fish and shellfish than recreational fishers or the general public.* Several researchers have completed surveys of tribal fish consumption habits and patterns.
- *Use of a tribal exposure scenario is consistent with federal guidance for water quality standards.* EPA has approved the SMS rule as part of Washington's water quality standards. Consequently, EPA guidance (EPA, 2000) for developing water quality standards is applicable to the interpretation of the SMS narrative standard. EPA recommends that states consider high exposure population groups when establishing state water quality standards.
- *Use of a tribal exposure scenario is consistent with MTCA policies that are applicable to sediment cleanup actions.* Under the MTCA Cleanup Regulation, cleanup levels are based on estimates of the RME scenario (see previous section).
- *Use of a tribal exposure scenario is consistent with EPA Region 10 guidance for Superfund cleanup actions.* EPA Region 10 has published a decision-making framework for selecting and using tribal consumption data to establish cleanup requirements at federal Superfund sites (EPA, 2007). The framework identifies a four-tiered hierarchy of preferred data sources. Under the EPA Framework, exposure estimates for particular tribes can be based on

[39] WAC 173-340-730.

fish consumption surveys from other tribes (Suquamish or Tulalip Tribes) with similar dietary habits.
- *Use of a tribal exposure scenario is consistent with Title VI of the Civil Rights Act of 1964, federal trust responsibilities, and tribal treaty rights.* Title VI of the Civil Rights Act of 1964 and EPA's implementing regulations (40 CFR 7.25) state that federal grant recipients should not use criteria or methods that have the effect of inequitably treating members of a protected group. Under the federal rules, protected groups include "American Indians" and "Asian and Pacific Islanders."

Collectively, these factors represent strong rationale to use a tribal RME and site-specific fish consumption rates for assessing this exposure pathway from contaminated sediments. Site-specific fish consumption rates have been used in calculating cleanup level calculation for Human Health Alternatives in the Human Health case studies presented in Chapter 4 and Appendix E.

Uniform versus Site-Specific Cleanup Levels

The MTCA cleanup rules provide three options for establishing cleanup levels (Methods A, B, and C). It requires cleanup levels to be based on risk assessments that use the RME scenario. Methods B and C provide specific formulas and standard assumptions for calculating cleanup levels for several media and exposure pathways. In Method B, the acceptable level of risk for individual carcinogens is one-in-one million (1 x 10-6) and for non-carcinogens the hazard quotient is 1. If there is more than one hazardous substance or exposure pathway at a site, the total site risk cannot exceed one in one hundred thousand (1 x 10-5) for carcinogens and a hazard index of 1 for non-carcinogens. Method C is limited in use for soil at industrial properties. Method C differs from Method B in that the acceptable level of risk for individual carcinogens is set at one in one hundred thousand (1 x 10-5) for both individual carcinogens and total site risk.

There is flexibility in the current MTCA rule to allow for use of site-specific risk assessment for setting cleanup levels and selecting remedies, but the cleanup levels must be based on an RME scenario. The framework for site-specific risk assessment is described in Section 708 of MTCA, and the requirements for use of new science to change the standard approaches to risk assessment are described in Section 702 of MTCA.

Ecology considered the question of whether to develop and provide in the revised SMS rule-specific formulas and standard assumptions for calculating sediment cleanup levels. In doing so, Ecology reviewed the basis of sediment cleanups that have been conducted under the original SMS rule, and the factors that have typically been primary in setting site-specific sediment cleanup levels. Based on this review and evaluation, Ecology decided that site-specific risk assessment would continue to be used as the basis of evaluating risk to human health from contaminated sediments. This would apply to the five proposed human health alternatives. This decision was based on several factors:

- The high degree of variability in type and duration of exposure, depending on how a site is used at present and will be in the future;
- The high degree of variability in the nature and extent of sediment contamination; and

- The likelihood that cleanup levels based on either ecological risk or fish/shellfish consumption by humans will be lower than cleanup levels based on direct contact with contaminated sediments.

Ecology is developing guidance for use in evaluating site-specific human health risk from contaminated sediment. Ecology also decided to retain the option to develop site-specific fish consumption rates.

Rulemaking Issues Related to Freshwater Sediments

Basis of Freshwater Sediment Criteria

Appropriate Level of Protection for Ecological Protection

The proposed freshwater biological and chemical criteria associated with the proposed freshwater sediment alternatives are consistent with the level of ecological protection defined in the original SMS rule. The original SMS rule includes a two-tiered decision-making framework to protect the function and integrity of the benthic community. The original SMS identifies a long-term goal of no adverse effects (the sediment quality standards/sediment cleanup objective [SQS/SCO], representing the lower limit of the allowed range) and a "minor adverse effects" level (the cleanup screening level [CSL], representing the upper limit of the allowed range) defined as the maximum level of sediment contamination allowed at a cleanup site. For the freshwater biological criteria, the SCO was set as the minimum detectable difference (MDD) and the CSL was set at 10 to 15 percent greater (than the SCO) effects level. The chemical criteria were then set based on the ability of the concentration to correctly predict the observed biological toxicity in a sample. The proposed chemical sediment quality values (SQVs) reliably predicted biological toxicity and allowed for a range of minor effects between SCO and CSL. Cleanup levels are established for a site between these two values, but as near the SCO as possible, balancing technical possibility and net adverse environmental impact. This approach was as similar as possible to the marine criteria and is consistent with the original SMS rule in terms of overall structure, level of protectiveness, and biological effects.

As with the marine criteria, the freshwater criteria were selected to provide an appropriate balance of sensitivity and efficiency (i.e., balancing false negatives and false positives) on a per-sample basis, while retaining a low enough false negative rate to ensure that contaminated sites would be identified given the amount of data typically available for site identification purposes. To ensure that the criteria are adequately protective, they will be applied within a regulatory framework that includes the option for conducting bioassays as a confirmatory or override step, or simultaneously with chemical analysis. Both the chemical and biological criteria are based on toxicity test species and endpoints that are nationally recognized as animal models that are indicative of benthic community responses to sediment-related contaminants and they are regionally appropriate for Washington State.

The proposed biological and chemical criteria were developed to protect only against toxicity to the benthic community, and did not consider bioaccumulative effects to humans, wildlife, or fish. The proposed criteria were developed to protect populations of benthic communities in sediments, rather than individual species, given the wide natural variation in species abundance and richness seasonally and from year to year. NOAA and USFW evaluated whether the SQS levels were protective of ESA-listed benthic species and determined that were no listed benthic species in Washington that were likely to be affected by cleanup actions.

Choice of Biological Tests and Interpretation Criteria

The proposed freshwater biological tests and criteria used as the basis of cleanup level decision-making for freshwater alternatives include a suite of bioassay organisms, test protocols, and a decision framework for applying those tests. The array of tests was chosen to best represent the range of species that comprise a freshwater benthic community, including sensitive species, life stages, and test endpoints. These were selected from a suite ASTM-approved bioassays for freshwater sediments that have been used to evaluate sediments in Washington State, as well as variety of freshwater habitats nationally and internationally. The amphipod, *Hyalella azteca*, and the midge, *Chironomus dilutus*, were selected because they are widely distributed throughout Washington and found in a broad range of environments, including river, stream, and lake habitats. Both of these species are well established toxicity testing species and have both acute and chronic endpoints. The proposed rule includes mortality and growth endpoints for acute (10-day) and chronic (20- or 28-day) exposures.

The marine toxicity testing standards require a comparison of treatment responses to responses in a reference treatment. In assessing the feasibility of using an analogous comparison for freshwater sediments, Ecology's evaluation of existing freshwater data sets in Washington State indicated that there was no reliability advantage to using comparison to reference rather than a comparison to control. Despite several attempts to develop freshwater reference sites, the variability of responses in the reference stations was quite high, overwhelming any theoretical advantage they may have. In addition, many of the existing data sets that were used to develop the SQVs did not have valid reference sites, limiting the amount of data available to develop freshwater criteria. A comparison to control provided a much larger and more consistent data set for establishing criteria. In addition, other national freshwater sediment values compare the test treatments to controls.

Since treatment effects are defined by a comparison to the responses in the control, program-specific control performance standards were developed for each test used for freshwater sediments. Control performance standards were based on national guidance for the test method, the results of ASTM round robin testing, and an evaluation of the resulting SCO/CSL response levels, compared to their marine counterparts. The SCO response levels for each biological test were set based on the minimum detectable difference derived from the ASTM round robin tests. The CSL/MCUL was then defined as a response that was 10 to 15 percent greater than the SCO response level.

Ecology considered alternative species for inclusion in the freshwater sediment criteria, including established methods with the mayfly, snails, and freshwater clams and mussels. Such species were not included in the SMS program because of the lack of data in Washington State, considerations of the feasibility to conduct such tests in regional laboratories, or lack of ASTM methods. Alternative test species may be appropriate for certain sites, and the proposed rule revision allows for site-specific substitutions on a case-by-case basis.

Choice of Methodology for Establishing Chemical Criteria

Since 2002, Ecology has been developing freshwater SQVs for use in Washington State sediment management programs for cleanup and dredge material management. Consistent with SMS, two levels of criteria were developed corresponding to the SCO and CSL/MCUL. At the beginning of this process it was determined that freshwater Apparent Effects Thresholds (AETs) were not as reliable as the marine AETs. Marine systems are chemically buffered and thus more uniform than freshwater, which have a wide range of chemical, geological, and habitat types. This similarity between marine areas lends itself well to the mathematical methods used to calculate the AETs. However because of the variation among freshwater areas, selection of the highest no-hit values as the AET would allow an unacceptable degree of toxicity. Therefore, a different mathematical approach was used, the FPM, to calculate chemical criteria that would ensure appropriately low levels of toxicity.

Existing freshwater chemical criteria from a variety of data sets were evaluated for use in Washington State. Synoptic sets of chemical and biological data (data for chemical and biological analysis were collected at the same time and location) from sites throughout the Washington, Oregon, and Idaho were compiled and evaluated using a number of freshwater screening values including: the Effects-Range Low and Median (Long et al., 1995); the Threshold and Probable Effects Concentrations (McDonald et al., 2000); and the Threshold and Probable Effects Levels (Smith et al., 1996). Each of the existing criteria was evaluated based on whether it met reliability goals and its relative efficiency in predicting toxic effects. Rates of false negatives (a hit predicted to be a non-hit) and false positives (a non-hit predicted to be a hit) were also evaluated and compared between the screening values for each test species and endpoint. Overall reliability of these screening values was quite low, ranging from 15 to 45 percent and had a combination of sensitivity, efficiency, and overall reliability that did not meet the reliability goals.

To improve the predictability of chemical criteria, Ecology developed the Floating Percentile Method (FPM) which allows for the calculation of alternative freshwater SQVs based on an iterative error rate minimization technique. This method allows for the selection of chemical concentrations that maximize the reliability of the SQVs by minimizing both the false negative and false positive rates. The SQV that is selected for each chemical is a percentile of the data that can be adjusted independently so that the optimal percentile is selected for each chemical. Use of the FPM with over 1,800 acute and chronic bioassay data points resulted in SQVs that were able to accurately identify 75 to 80 percent of the toxic samples, 65 to 95 percent of the non-toxic samples, and overall correctly predicted bioassay results 70 to 85 percent of the time. This was far greater than any of the existing screening values and met the acceptability criteria developed by the Regional Sediment Evaluation Team. Based on these findings, both SCO and CSL/MCUL values were selected using the FPM.

Relationship Between Biological and Chemical Criteria

The proposed freshwater sediment alternatives, biological and chemical criteria are closely associated both in the development of the criteria as well as in the application of the criteria. The freshwater biological and chemical criteria were developed based on a robust dataset that included synoptic biological and chemical data. The biological effects levels were developed first and were defined as the minimum detectable difference (biological SCO) and a response that was 10 to 15 percent greater than the MDD (biological CSL). This allowed for a range of minor adverse effects between SCO and CSL where a site-specific cleanup level is established for a site as near the SCO as possible based on technical possibility and net adverse environmental impact. The chemical SQVs were then developed for each test species and endpoint, identifying a chemical concentration that most reliably predicted the biological SCO and CSL levels toxicity for over 1800 bioassay endpoints. Chemical SQVs were adjusted independently for each contaminant to minimize both the number of false negative and false positives.

Site evaluation under SMS is conducted following a tiered evaluation process that includes both chemical and biological data. Chemical concentrations observed at the site are compared to the effects-based SCO and CSL criteria. The SMS regulatory framework then includes the option for conducting bioassays as a confirmatory or override step, or simultaneously with chemical analysis.

Rulemaking Issues Related to Multiple Factors

Relationship between Human Health and Ecological Criteria

The response of organisms to chemical exposure varies greatly within a given species, and even more widely between species. Chemical concentrations that may be easily tolerated by one species may cause an array of health effects in others. This wide range of responses is because of both differences in sensitivity and extent of exposure. Because of these differences, cleanup levels that may be protective of human health may not be protective of other biota, and levels are sufficient for ecological receptors may not be protective of human health, including sensitive subpopulations. It is because of these differences in sensitivity and response that evaluation of risk to both human and ecological receptors is needed.

For sites where an ecological evaluation is required, cleanup levels would be calculated for both protection of human health and the environment (Revised SMS WAC 173-204-564). In these cases, the lower protective of both human health and the environment is used in the proposed SMS framework. It should be noted that there are cases where cleanup levels determined to be protective of both human health and ecological receptors are below background concentrations, or below the concentration prescribed by analytical PQL. In these cases, background or the PQL would become the cleanup level.

In developing the potential array of alternatives to consider in amending the SMS, Ecology strived to maintain the ability to identify cleanup standards that were protective of both human health and the environment. Ecology also wanted to allow PLPs some flexibility in reaching a liability settlement for their site if the established cleanup standard was met and their sources controlled, and at the same time allow for site or bay-wide contaminant concentrations to be further reduced over time through cleanup of multiple site units and source control implementation on a regional scale. As a result of these multiple needs, a two-tier SMS framework was identified that allows sediment cleanup levels to be set within a range between an upper and lower bound, be protective of both human health and biota, and account for background and analytical limits. This two-tier framework is discussed in greater detail in the section on human health Alternative 5, Chapter 3.

Consideration of Background Concentrations

The MTCA rule requires cleanup s be the highest of a risk-based level, natural background concentration, or practical quantitation limit (PQL). Sediment cleanup goals based on risk may be below background chemical concentrations. This may be especially true for contaminants that bioaccumulate in aquatic organisms and biomagnify in the food chain. As a result, determining background concentrations is critical for establishing site-specific sediment cleanup standards that are both practicable and as protective as possible.

MTCA and the original SMS rule define background differently. MTCA defines natural background as "the concentration of hazardous substance consistently present in the environment that has not been influenced by localized human activities.[40]" The MTCA natural background definition includes both naturally occurring chemicals and sources such as mercury as well as anthropogenic chemicals and sources such as polychlorinated biphenyls. However, Ecology has concluded that the MTCA rule, which was developed for upland sites, is a difficult fit for sediment sites because of the significant differences between upland and aquatic environments. This is especially true with respect to natural background. Typical MTCA sites are upland and associated with identifiable sources that can be traced back to current or historical site operations. Sediment sites typically involve co-mingled contaminant plumes influenced by multiple in-water, upland, upstream, and numerous stormwater and atmospheric depositional sources.

The original SMS rule only addressed non-anthropogenic background and does not clearly specify how background is defined when setting sediment cleanup standards for human health protection. In amending the SMS rule, Ecology needs a workable and practical mechanism for sediment cleanup that takes into account the reality of widespread, ubiquitous, anthropogenic, and naturally occurring chemical concentrations. Under the proposed two-tiered framework, the SMS rule would be modified to include new levels protective of human health: a Cleanup Screening Level (CSL)and a Sediment Cleanup Objective (SCO).

The CSL would represent the upper bound of contamination that can remain at a site. It would be set so that it cannot exceed regional background levels. Regional background would take into account ubiquitous, anthropogenic contamination and be defined as follows:

[40] WAC 173-340-200

"Within an Ecology-defined geographic area, means the concentration of a contaminant within a department-defined geographic area that is primarily attributable to diffuse sources, such as atmospheric deposition or storm water, not attributable to a specific source or release.

The SCO would represent the sediment quality goal and would be established using the current MTCA rule that requires cleanup levels be the highest of a risk-based value, MTCA natural background, or PQLs.

Decisions on Site Units

SMS and MTCA currently provide authority to define and remediate site units or portions of contaminated sites. However, there is not a mechanism to cleanup a site unit with a full liability settlement. Clarifying site unit based decision-making provides a method for accomplishing cleanup actions when there are bay-wide contamination issues from multiple Potentially Liable Persons (PLPs) and numerous sources. Site units often have significantly higher chemical concentrations than an embayment as a whole and are often located in critical habitat nearshore areas. Cleanup of individual site units, while resolving liability, is a pragmatic approach that provides for more efficient and expeditious cleanups. Bay-wide cleanup goals can be reached over time by reducing the redistribution of contaminants from site units as well as overall risk reduction to human health and the environment relative to the site-related contaminants. In addition, by allowing for incremental cleanup actions the capacity for habitat restoration is increased and for natural resource damage is reduced.

Under the proposed human health Alternative 5, PLPs have multiple options regarding settling liability (contribution protection, covenant not to sue) for discrete site units within a larger, bay-wide contaminated site. Settling liability would require that: 1) the scope of the covenant not to sue must be commensurate with PLPs remedial actions; 2) active cleanup measures will be required for areas within the site unit with concentrations above regional background (with adjustments for natural recovery over 10, possibly more, years); and 3) all PLP sources must be controlled to prevent recontamination above the cleanup standard. Ecology has several options for releasing PLP liability for recontamination of a site unit. PLPs are not liable for recontamination that is not their responsibility (any ongoing or future release is not from the PLP or under its authority). The SMS rule revisions would clarify details for accomplishing site unit cleanups and resolution of PLP liability.

Restoration Time Frames and Sediment Recovery Zones

The proposed two-tiered framework provided in human health Alternative 5 maintains the ability to identify cleanup levels that are protective of both human health and the environment. The process for selecting sediment cleanup levels is designed to identify concentrations that must be achieved within a preferred time frame of 10 years after completing active cleanup measures (e.g., dredging, capping) (Section 173-204-560 of the original SMS rule). At some sites, Ecology recognizes that cleanup levels that require protection of human health may lead to larger site or site unit boundaries (and consequent sediment recovery zones), and require longer restoration time frames. A combination of remedial technologies (active cleanup measures, source control, natural recovery, institutional controls and/or future active cleanup of residual concentrations) will be needed to achieve long-term environmental goals.

The requirements for the establishment and monitoring of sediment recovery zones is outlined in the revised SMS rule in WAC 173-204-590 and meets the intent of sediment quality dilution zones authorized where selected cleanup actions leave in place marine, low salinity, or freshwater sediments that exceed applicable sediment quality standards. The revised SMS rule has been clarified regarding what cleanup goals must be met within a specified time frame, and outlining the conditions that allow an extended time frame beyond 10 years[41].

Relationship between SMS Rule Cleanup and Source Control Provisions

Long-term solutions to achieve and maintain risk-based levels will require actions to prevent and control ongoing releases of hazardous substances. Such measures will be implemented over several decades. Given those time frames, ongoing discharges may place practical limits on the degree of sediment cleanup that can be achieved in the near term with active cleanup measures (dredging and capping). The SMS rule includes administrative mechanisms (e.g., sediment recovery zones as described in the previous section) for coordinating active cleanup measures and source control actions.

Ecology also recognizes the potential for recontamination as a serious problem at some sediment cleanup sites. For example, NPDES permitted and unpermitted stormwater and wastewater facilities may discharge at concentrations above human health risk-based sediment cleanup goals and natural background concentrations. To move forward with sediment cleanup in the near term, Ecology needed a mechanism that provides incentive for the PLPs when sediment recontamination is likely from off-site sources (i.e., recontamination is not the fault of the PLP).

Relationship between SMS Rule and MTCA Cleanup Regulation

Management decisions for sediment cleanup sites must comply with both the SMS and MTCA rules. However, differences in the two rules cause confusion about how to comply with both. To align the rules, changes in the SMS are needed to clarify items and resolve differences between the MTCA and original SMS including:

- The terminology used for cleanup standards, required documents, and definitions;
- The process for selecting cleanup standards by clarifying how levels for protection of human health and ecological receptors from bioaccumulative compounds are integrated into SMS criteria and how cost and feasibility are to be considered;
- Aligning SMS remedy selection and requirements at sediment sites to reflect those identified in MTCA, especially the preference for solutions that are permanent to the maximum extent practicable; and
- Clarify the cleanup time frame objective of meeting the SCO at the completion of remedial construction and revise conflicting or ambiguous references.

The SMS rule revisions to WAC 173-204-200 would update and add new definitions required to clarify the rule. Revisions to WAC 173-204-500 to -590 would include levels of protection and procedures to designate sediments with bioaccumulative compounds, renaming the reports to

[41] WAC 173-204-580

match those required under MTCA. This section also would be revised to reflect the MTCA selection criteria for remedial alternatives and to clarify the objectives for setting a cleanup time frame.

Identifying and Managing Variability of Scientific Uncertainty

Variability and uncertainty associated with calculating a risk-based sediment cleanup level that is protective of human health may have ramifications on cleanup decisions and resulting cleanup standards. For sediment sites, variability and uncertainty results from the spatial and temporal heterogeneous nature of the sediment environment and the inherent qualitative and quantitative uncertainty in risk assessments, which impacts risk management decisions. The process for deriving a risk-based concentration relies on RME exposure scenarios. The impact of compounding RME scenarios on risk-based concentrations can result in extremely conservative or health protective risk-based concentrations. In addition, there are significant uncertainties associated with the RME-based approach for assessing fish/shellfish consumption. Identifying and using appropriate fish species for exposure modeling, including home range assumptions for fish species, proportion of fish consumed at the site, proportion of fish species consumed by different populations, and the impact of cooking on fish tissue concentrations add significantly to these uncertainties. In addition, quantification of tissue-sediment relationships for bioaccumulative compounds (the biota-to-sediment accumulation factor [BSAFs]) is one of the more challenging aspects of the risk assessment process. Mechanisms to incorporate uncertainty to allow for meaningful risk management decisions are needed or unnecessary resources will be expended cleaning up to inappropriate cleanup standards.

Site-specific risk-based criteria (RBC) are often a preferred option for cleanup goals because they take into account local sediment properties, ecological conditions, and exposure scenarios. The driver for the RBCs is almost always going to be the ingestion of fish and shellfish from the potential cleanup area, rather than sediment ingestion or dermal exposure.

The sediment properties and ecological conditions are important for determining the BSAF. A substantial number of co-located sediment and tissue samples must be collected or a BSAF cannot be adequately calculated. Less mobile species such as clams are more representative of the area in which they are collected; however, even with these less mobile species the BSAF remains uncertain and highly variable. Tissue types such as crab or pelagic fish are wide ranging and may not spend a significant amount of time feeding in the potential cleanup area. There is an even larger amount of uncertainty in defining sediment RBCs from the ingestion of these highly mobile species.

However, the input parameters of the exposure scenarios are the source of the greatest uncertainty. For example, individuals in a population will have differing levels of exposure because of variability in physiology, life span, fish consumption patterns, and the heterogeneity of sediment (temporal and spatial variability in pollutant concentrations). Failure to account for this variability provides results that do not address the wide range of exposure values possible, and may lead to an overstatement or understatement of risk. When RBCs are evaluated for subsistence fishers and other high fish consumers, it is conservatively assumed that upwards of one pound of fish and shellfish are consumed daily for each person over a lifespan of 70 years. In addition, it is conservatively assumed that all of the consumed food comes from the potential cleanup area. Each of these conservative parameters has a compounding effect, resulting in lower RBCs.

Determining background concentrations first entails defining the background dataset. Background data may constitute either anthropogenic or natural conditions depending on the sample locations included. Datasets selected for inclusion in the background calculation should be representative of the local study area. Making this match is often difficult. If the background data were from an area of coarse sand, while the potential cleanup area consists of fine sand and silt, the calculated background values will be biased low. Failure to account for variability and uncertainty of both the site and background data may lead to assumptions of precision that do not convey the true state of knowledge. Variability and uncertainty of the data can be quantified using frequency distributions and probability distributions, respectively.

PQLs can vary greatly between methods and analytical laboratories. Currently, the PQLs that are evaluated as cleanup levels are average values obtained from a survey of analytical laboratories. Some laboratories will have higher PQLs, and some will be lower. A possible result of having varying PQLs is that the detection limit for a given chemical in one study is above the cleanup level determined for the cleanup site.

Procedures for Updating Sediment Standards

Ecology has several options for updating sediment standards that include case-by-case adaptive management, informally through the Sediment Management Annual Review Meeting (SMARM) process or more formally through direct SMS rule revision as per WAC 173-204-100 (6)[42].

Adaptive management allows for a systematic process for continually improving management policies (i.e., best management practices [BMP]) and decision-making practices (best professional judgment [BPJ]) by learning from the outcomes of previously employed policies and practices. In case-by-case situations, decisions or outcomes from other sites or investigations are taken into consideration for determining how best to proceed. Adaptive management may also incorporate the ‘state of the science’ to determine whether new information or ideas are applicable to site-specific issues or environmental conditions. Successful application of new information or ideas at a site can lead to informal or formal adoption of new procedures or policies.

Informal updates to sediment management policies and guidance include the outcome from general consensus or focused workgroup presentations and discussions that occur through the SMARM. The SMARM is a joint meeting of the DMMP and SMS programs held each year. Each year at the SMARM a series of presentations and papers are presented including: 1) Issue papers, 2) Clarification Papers, and 3) Status Papers. **Issue Papers** are proposals to directly impact policy or technical guidelines. Issue papers need agency head approval to be implemented. **Clarification Papers** are minor updates to current guidelines that can be implemented by the program after public review, without agency head approval. Status Papers

[42] It should be noted that the adaptive management and informal methods for updating sediment standards also comply with WAC 173-204-130, without the formal promulgation of changes to the rule language.

are updates on ongoing work. These papers are for information only. General topic areas addressed through the SMARM process include program development, sampling and testing requirements, sampling and analysis plans, chemical testing, bioassays, and bioaccumulation. SMARM updates are generally incorporated into how sites are investigated and data is interpreted.

Formal updates to the SMS rule include rule revisions promulgated as per WAC 173-204-130 (6) which states that '…revision to this chapter shall be made pursuant to the procedures established within chapter 34.05 RCW, the Administrative Procedure Act.'[43] In addition, SEPA environmental review is required for any non-project action by a state agency that includes the adoption or amendment of 'rules, ordnances, or regulations that will regulate future projects…' Therefore this document is an example of the EIS required by SEPA for formal SMS rule revision.

[43] Chapter 34.05 RCW Part Rule-Making Procedures provides the specific regulatory guidance for rule making as appropriate for the SMS Rule revisions discussed in this document.

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Appendix C – Human Health Risk-Based Cleanup Level Calculation

Table C.1 - Definitions for Risk Equation Variables

Abbreviation	Definition	Value	Units
Cleanup $Level_{sediment}$	Sediment Cleanup Level	Calculated Value	mg/kg
CR	Cancer Risk	$1x10^{-6}$	unitless
HQ	Hazard Quotient	1	unitless
BW	Body Weight	see Table C.2	kg
AT	Averaging Time	25,550	days
UCF	Unit Conversion Factor	1,000	ug/kg
SFo	Oral Slope Factor	see Table C.3	kg-day/mg
RfDo	Reference Dose	see Table C.3	mg/kg-day
FCR	Fish/Shellfish Consumption Rate	see Table C.2	grams/day
FDF	Fish/Shellfish Diet Fraction	see Table C.2	proportion
EF	Exposure Frequency	365	days/year
ED	Exposure Duration	70	years
BSAF	Biota Sediment Accumulation Factor	see Table C.4	unitless
BAF	Biota Accumulation Factor	see Table C.4	unitless
SL	Fish/Shellfish Lipid Fraction	1.3	percent
S_{foc}	Fraction of Organic Carbon in Sediment	3.0	percent

Table C.2 - Case Study-Specific Parameters

	Case Study			
	1	2	3	4
COCs = Chemicals of Concern[1]	cadmium, cPAHs, dioxin/furan congeners	arsenic, PCB Aroclors, cPAHs	mercury, dioxin/furan congeners	PCB Aroclors
FCR = consumption rate (g/day)	Clams	Benthic Fish	Dungeness Crab	Freshwater Clams
Alternatives 1-5	499	97.5	173	81
BW = Body weight (kg)	79	81.8	81.8	70
SDF = diet fraction	1.0	1.0	1.0	0.25

Table C.3 - Carcinogenic Slope Factors (SFo) and Non-Carcinogenic Reference Dose Values (RfDo)

	Arsenic	Cadmium	Mercury	cPAHs	PCB Aroclors	Dioxin/Furan Congeners
SFo = Slope Factor	1.5	--	--	7.3	2	150000
RfDo = Reference dose	--	0.001	0.0003	--	--	--

-- = not applicable

Table C.4 - Weighted Average BSAF/BAF Values

	Case Study			
	1	**2**	**3**	**4**
Target Species	**Clams**	**Benthic Fish**	**Dungeness Crab**	**Freshwater Clams**
BAF				
Arsenic	--	0.53	--	--
Cadmium	0.34	--	--	--
Mercury	--	--	9.03	--
BSAF				
Dioxin/Furan TEQ	0.13	--	0.79	--
Total PCB Aroclors	--	0.37	--	3.32
cPAH TEQ	0.11	0.07	--	--

-- = NA

Human Health Case Study 1 – Non-Urban Shoreline

Risk Equations

Equation 1

$$\mathbf{Cleanup\ Standard}_{sediment} = \frac{CR \times BW \times AT \times UCF \times S_{foc}}{SF_o \times FCR \times FDF \times EF \times ED \times SL \times BSAF}$$

Equation 3

$$\mathbf{Cleanup\ Standard}_{sediment} = \frac{HQ \times BW \times AT \times UCF \times RfDo}{FCR \times FDF \times EF \times ED \times BAF}$$

			Cleanup Level (mg/kg) for Alternative:				
COCs	Calculated Using	CR or HQ	1	2	3	4	5
cPAH TEQ	Equation 1	1.00E-06	0.000455	0.000455	0.000455	0.000455	0.000455
dioxin/furan TEQ	Equation 1	1.00E-06	1.87E-08	1.87E-08	1.87E-08	1.87E-08	1.87E-08
cadmium	Equation 3	1	0.466	0.466	0.466	0.466	0.466

Human Health Case Study 2 – Urban Shoreline

Risk Equations

Equation 1

$$Cleanup\ Standard_{sediment} = \frac{CR \times BW \times AT \times UCF \times S_{foc}}{SF_o \times FCR \times FDF \times EF \times ED \times SL \times BSAF}$$

Equation 2

$$Cleanup\ Standard_{sediment} = \frac{CR \times BW \times AT \times UCF}{SF_o \times FCR \times FDF \times EF \times ED \times BAF}$$

			Cleanup Level (mg/kg) for Alternative:				
COCs	Calculated Using	CR or HQ	1	2	3	4	5
cPAH TEQ	Equation 1	1.00E-06	0.003789	0.003789	0.003789	0.003789	0.003789
PCB Aroclors	Equation 1	1.00E-06	0.002616	0.002616	0.002616	0.002616	0.002616
arsenic	Equation 2	1.00E-06	0.002435	0.002435	0.002435	0.002435	0.002435

Human Health Case Study 3 – Urban Embayment

Risk Equations

Equation 1

$$\boldsymbol{Cleanup\ Standard_{sediment}} = \frac{\boldsymbol{CR \times BW \times AT \times UCF \times S_{foc}}}{\boldsymbol{SF_o \times FCR \times FDF \times EF \times ED \times SL \times BSAF}}$$

Equation 3

$$\boldsymbol{Cleanup\ Standard_{sediment}} = \frac{\boldsymbol{HQ \times BW \times AT \times UCF \times RfDo}}{\boldsymbol{FCR \times FDF \times EF \times ED \times BAF}}$$

			Cleanup Level (mg/kg) for Alternative:				
COCs	Calculated Using	CR or HQ	1	2	3	4	5
dioxin/furan TEQ	Equation 1	1.00E-06	9.21E-09	9.21E-09	9.21E-09	9.21E-09	9.1E-09
mercury	Equation 3	1	0.016	0.016	0.016	0.016	0.016

Human Health Case Study 4 – Freshwater River

Risk Equations

Equation 1

$$Cleanup\ Standard_{sediment} = \frac{CR \times BW \times AT \times UCF \times S_{foc}}{SF_o \times FCR \times FDF \times EF \times ED \times SL \times BSAF}$$

			Cleanup Level (mg/kg) for Alternative:				
COCs	Calculated Using	CR or HQ	1	2	3	4	5
PCB Aroclors	Equation 1	1.00E-06	0.001201	0.001201	0.001201	0.001201	0.001201

Appendix D – Development of Benthic SQVs for Freshwater Sediment in Washington, Oregon, and Idaho

DEPARTMENT OF
ECOLOGY
State of Washington

Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho

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Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho

November, 2011

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Table of Contents

Tables

List of Acronyms

AETs – Apparent Effects Thresholds
ANOVA – Analysis of variance
ASTM – American Society for Testing and Materials
CSL – Cleanup Screening Level
DDD/DDE/DDT – dichlorodiphenyldichloroethane/dichlorodiphenyldichloroethylene/ dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
DMEF – Dredged Material Evaluation Framework
DMMP – Dredged Material Management Program
Ecology – Washington Department of Ecology
EIM – Environmental Information Management System
EPA – United States Environmental Protection Agency
ERL – Effects Range – Low
ERM – Effects Range - Median
ESA – Endangered Species Act
FPM – Floating Percentile Model
ID – State of Idaho
LEL – Low Effects Level
MTCA – Model Toxics Control Act
NOAA – National Oceanic and Atmospheric Administration
OR – State of Oregon
PAHs – Polynuclear aromatic hydrocarbons
PCBs – Polychlorinated biphenyls
PEC – Probable Effects Concentration
PEL – Probable Effects Level
PSEP – Puget Sound Estuary Program
QA/QC – Quality assurance/quality control
QA2 – Quality assurance level 2 (litigation/regulation quality)
RSET – Regional Sediment Evaluation Team
SEDQUAL – Sediment Quality database
SEF – Sediment Evaluation Framework
SEL – Severe Effects Level
SETAC – Society for Toxicology and Chemistry
SL1/SL2 – Screening Level 1 or 2
SMARM – Sediment Management Annual Review Meeting
SMS – Sediment Management Standards
SQVs – Sediment quality guidelines
SQS – Sediment Quality Standard
TEC – Threshold Effects Concentration
TEL – Threshold Effects Level
TEQ – Toxicity equivalency quotient
TPH – Total petroleum hydrocarbons
USF&W – United States Fish and Wildlife Service
WA – Washington State

Executive Summary

In early 2002, the Washington State Department of Ecology (Ecology) embarked on a project to identify, update, and ultimately select freshwater sediment quality values (SQVs) for use in Ecology's sediment management programs. This effort was completed in July 2003 (SAIC and Avocet 2003), and included compilation of freshwater sediment data in western Washington and Oregon, identification of existing freshwater SQVs in North America, an assessment of their reliability in predicting effects in Washington State, and calculation of SQVs with greater reliability than existing SQV sets using the Floating Percentile Model (FPM).

As part of this initial effort, it was determined that freshwater apparent effects thresholds (AETs) were not as reliable as the marine AETs; specifically, they were less conservative. Marine systems are chemically buffered and are far more similar to one another than freshwater areas of the state, which have a wide range of chemical, geological, and habitat types. This similarity between marine areas lends itself well to the mathematical methods used to calculate the AETs. However, because of the variation among freshwater areas, selection of the highest no-hit value as the AET allowed an unacceptable degree of toxicity. Therefore, a different mathematical approach was used for calculating the SQVs that would ensure appropriately low levels of toxicity.

As a result, there are some notable differences between the marine and freshwater SQVs:

- Because the mathematical models used to calculate the SQVs are different, the values cannot be directly compared. For example, the AETs are calculated on a single-chemical basis, while the FPM values are calculated on a multivariate basis, looking at all chemicals together.

- In the 20 years since the marine AETs were first calculated, it has been determined that organic-carbon normalization does not improve the reliability of the SQVs. This was confirmed again in 2003 during the development of proposed SQVs for Ecology (SAIC and Avocet 2003). Therefore, the proposed freshwater SQVs are calculated on a dry weight basis.

- Due to differences in the larger geographic range encompassed by the freshwater SQVs, differences in sources (industries and chemicals) in marine vs. freshwater areas of the state, and differences in bioavailability and toxicity of certain chemicals (especially metals) in freshwater vs. marine systems, there are different chemicals included on each list and different levels for the same chemicals. These differences are based on actual field conditions and are to be expected.

The 2003 Ecology database allowed calculation of four acute and sub chronic SQVs (*Hyalella* 10-day mortality, *Chironomus* 10-day mortality, *Chironomus* 10-day growth, and Microtox) using the FPM. There were not enough data for benthic community indices or chronic freshwater tests to enable calculation of chronic SQVs at that time. There was also a lack of data for areas east of the Cascades, and for a variety of pesticides, herbicides and biocides, among other chemicals.

In 2007, the Regional Sediment Evaluation Team (RSET) decided to update Ecology's freshwater SQVs for inclusion in the Sediment Evaluation Framework (SEF) for Oregon, Washington, and Idaho. The SEF is used to evaluate dredging projects in marine waters and freshwater areas of these three states, and RSET includes a wide variety of federal and state agencies responsible for these regulatory functions. In addition, in 2009, Ecology supported completion of this report as part of the update of the Sediment Management Standards (SMS) and Model Toxics Control Act (MTCA) governing cleanup of sediment sites in Washington State.

The primary goals of the update described in this report were to:

- Include data from a broader geographic area, including areas east of the Cascades and all three states
- Include a broader range of chemicals
- Include at least two chronic tests
- Include several large data sets from recent state and federal cleanup projects, as well as many smaller recent data sets from dredging and cleanup projects
- Obtain consensus among the RSET agencies on how the SQV calculations and reliability analysis should be conducted, along with the final values
- Automate the FPM process so that any of the agencies or stakeholders could make use of it and update the SQVs in the future

Nearly all of these goals were achieved during the update process. The freshwater data set is considerably larger and more diverse in terms of both chemistry and bioassays than it was in 2003, and has been improved from a quality assurance standpoint. The current database allows calculation of FPM values for three acute and two chronic endpoints. All data included in the data set were collected using ASTM- and Ecology-approved bioassay methods and chemistry analytical techniques. The data have been validated to a level suitable for regulation and litigation, known as QA2.

The data were collected from western Washington and Oregon and from eastern Washington. No data were identified in eastern Oregon or Idaho that included both bioassay and chemistry data. The data set encompasses a wide variety of different types of environments, including large and small lakes on both sides of the Cascades, large rivers on both sides of the Cascades such as the Duwamish, Willamette, Columbia, and Spokane Rivers, and small streams. Each data set represents field-collected samples with both chemistry and bioassay data collected at the same time and place. While the data are representative of the majority of freshwater sediment sites encountered in the northwest, it is recognized that benthic toxicity at sites with unique geochemical characteristics will differ and the SQVs are not representative of those sites (e.g., bogs, alpine wetlands, sites with mining, milling or smelting activities, substantial waste deposits, or with unique pH, alkalinity, or other geochemical characteristics). Freshwater bioassays should be used to assess toxicity under these conditions.

The following conclusions can be drawn based on the work presented in this report:

- **Accuracy.** Use of the floating percentile method resulted in SQVs that were able to accurately identify 75-80% of the toxic samples, 65-95% of the non-toxic samples, and correctly predicted overall bioassay results 70-85% of the time (depending on the specific test and endpoint).

- **Comparison to Existing SQVs.** The FPM values represent a substantial improvement in accuracy in identifying non-toxic samples compared to other available SQV sets, greatly improving the implementability and cost-effectiveness of the SQVs. In addition, at the higher effects levels, the FPM values are also able to detect more of the toxic samples than other existing SQV sets.

Based on the conclusions above and an approach developed by the interagency workgroup for combining the individual endpoint values, SQVs for both the SQS/SL1 and the CSL/SL2 levels are recommended for public review, incorporation into the SEF, and MTCA/SMS rule revision (Table ES-1). The method used to develop these values is based on specific assumptions about the levels of risk and error that are considered acceptable at each effects level, and provides the opportunity for revision of the SQVs if alternative policy choices are made during the public review process.

These values were developed to protect only against toxicity to the benthic community in freshwater environments. They are not protective of bioaccumulative effects to humans, wildlife, or fish.

Table ES-1. Proposed Sediment Quality Values

Analyte	SQS/SL1[a]	CSL/SL2[b]
Conventional Pollutants (mg/kg)		
Ammonia	230	300
Total sulfides	39	61
Metals (mg/kg)		
Arsenic	14	120
Cadmium	2.1	5.4
Chromium	72	88
Copper	400	1200
Lead	360	> 1300
Mercury	0.66	0.8
Nickel	26	110
Selenium	11	> 20
Silver	0.57	1.7
Zinc	3200	> 4200
Organic Chemicals (µg/kg)		
4-Methylphenol	260	2000
Benzoic acid	2900	3800
beta-Hexachlorocyclohexane	7.2	11
bis(2-Ethylhexyl)phthalate	500	22000
Carbazole	900	1100
Dibenzofuran	200	680
Dibutyltin	910	130000
Dieldrin	4.9	9.3
Di-n-butyl phthalate	380	1000
Di-n-octyl phthalate	39	> 1100
Endrin ketone	8.5	**
Monobutyltin	540	> 4800
Pentachlorophenol	1200	> 1200
Phenol	120	210
Tetrabutyltin	97	> 97
Total DDDs	310	860
Total DDEs	21	33
Total DDTs	100	8100
Total PAHs	17000	30000
Total PCB Aroclors	110	2500
Tributyltin	47	320
Bulk Petroleum Hydrocarbons (mg/kg)		
TPH-Diesel	340	510
TPH-Residual	3600	4400

[a] Sediment Quality Standard/Screening Level 1
[b] Cleanup Screening Level/Screening Level 2
> "Greater than" value indicates that the toxic level is unknown, but above the concentration shown. If concentrations above this level are encountered, bioassays should be run to evaluate the potential for toxicity.
** No SQV could be set due to limited data above the SQS/SL1 concentration.

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1. Introduction

This report presents the results of the 2010 recalculation of freshwater sediment quality guidelines (SQVs) for Washington, Oregon, and Idaho. The SQVs update was begun by a Regional Sediment Evaluation Team (RSET) workgroup for inclusion in the Sediment Evaluation Framework (SEF) for Oregon, Washington, and Idaho. The SEF is used to evaluate dredging projects in both marine waters and freshwater areas of these three states, and RSET includes a wide variety of federal and state agencies responsible for these regulatory functions. In addition, the Washington Department of Ecology supported development and completion of these SQVs for use in cleaning up contaminated sediment sites under the Sediment Management Standards (SMS) and Model Toxics Control Act (MTCA).

1.1 Freshwater SQV Early Development (2002–2003)

In early 2002, Ecology embarked on a project to identify, update, and recalculate freshwater SQVs for use in Washington State sediment management programs. Two levels of SQVs were developed, corresponding to the SMS narrative Sediment Quality Standard (SQS) and Cleanup Screening Level/Minimum Cleanup Level (CSL/MCUL). In the RSET dredging programs, these levels are referred to as Screening Levels 1 and 2 (SL1 and SL2), respectively. Both designations will be used in this report.

Phase I of the project was completed in December 2002 (SAIC and Avocet 2002), and included:

- An update of the regional freshwater sediment database, including gathering additional synoptic data sets, and conducting quality assurance reviews of all data sets.
- Adding new freshwater bioassay evaluation tools to Ecology's SEDQUAL sediment database and analytical tool, allowing the development of custom bioassay hit/no-hit definitions and comparison of bioassay data to those definitions to identify stations with toxicity.
- A reliability analysis of eight existing North American SQV sets against the newly updated freshwater data set, to evaluate their ability to correctly predict biological hits and no-hits.
- An evaluation of the use of marine Apparent Effects Thresholds (AETs) as freshwater dredged material disposal guidelines and recommended updates to the Columbia River Dredged Material Evaluation Framework (DMEF 1998).

The results of these 2002 analyses indicated that neither existing freshwater SQV sets nor the marine AETs were able to correctly predict both toxic and non-toxic samples with an acceptable degree of reliability in freshwater environments, and further work was therefore needed in Phase II to calculate new freshwater SQVs. Phase II, completed in June 2003, included the following activities (SAIC and Avocet 2003):

- Calculation of freshwater SQVs based on a newly developed iterative error rate minimization technique known as the Floating Percentile Model (FPM).
- A reliability analysis of the FPM SQVs based on the updated regional freshwater data set.
- Recommendations for how these values could be used in Ecology's programs.

This effort produced interim values of good reliability that were applicable to western Washington and Oregon. The interim freshwater SQVs were published and used as guidance by Ecology on a site-specific basis, but have not been promulgated. While the overall reliability was high (approximately 80%) and error rates were low (<20% false negatives and false positives), the data set did not have a geographic scope that encompassed the entire state and did not include chronic tests, due to lack of sufficient chronic data at the time.

1.2 Update of the Freshwater SQVs (2007–2011)

In 2007, RSET undertook an update of Ecology's freshwater SQVs for inclusion in the SEF, beginning a four-year process that concluded in this report. The primary goals of the update described in this report were to:

- Include data from a broader geographic area, including areas east of the Cascades and all three states (WA, OR, ID).
- Include a broader range of chemicals.
- Include at least two chronic tests.
- Include several large data sets from recent state and federal cleanup projects, as well as many smaller recent data sets from dredging and cleanup projects.
- Obtain consensus among the RSET agencies on how the SQV calculations and reliability analysis should be conducted, along with the final values.
- Automate the FPM process so that any of the agencies or stakeholders could make use of it and update the SQVs in the future.

To complete these tasks, an SQV Workgroup was formed and met throughout 2007–2008 to guide the development effort. Members of the workgroup are listed in the acknowledgments, and included federal and state agency representatives and contractors. The final values associated with the workgroup process were calculated in 2008. However, the calculations indicated that the results for two of the most widely used acute mortality bioassays did not meet the workgroup's reliability goals, and consensus was not reached on how to proceed with final development of SQVs.

In 2009, Ecology began an update of the Sediment Management Standards (SMS) and the Model Toxics Control Act (MTCA) regulations. As part of this process, Ecology and the Oregon Department of Environmental Quality (DEQ) agreed to recalculate the results for these two bioassays using alternative effects thresholds recommended by agency technical staff, the SMS Workgroup (an external advisory group for the SMS rule revisions), regional laboratories, and national SQV experts. This approach produced SQVs with improved reliability and a complete set of acute and chronic endpoints with reliable SQVs. Ecology conducted further review by the MTCA/SMS Science Panel and a national scientific peer review in 2009–2010, and EPA Region 10 also provided statistical input. The results of all of these efforts are reflected in this report.

1.3 Public Outreach and Peer Review

The modeling approach used in the FPM and its results have been presented at numerous conferences, workshops, and public meetings to date, including:

- 1999 SETAC North America Conference, Philadelphia, PA
- 2001 Peer review and public demonstrations of the model in Portland and Seattle as part of the Oregon DEQ Portland Harbor site investigation
- 2003 Sediment Management Annual Review Meeting (SMARM), Seattle, WA
- 2004 SETAC North America Conference, Portland, OR
- 2008 Advanced Sediment Cleanup Conference, Seattle, WA
- 2008, 2009, and 2010 RSET/SMARM public meetings in Seattle, Boise, Portland, and Vancouver
- 2009 Battelle International Conference on Remediation of Contaminated Sediments, Jacksonville, FL
- 2009 PNW-SETAC Conference, Port Townsend, WA
- 2011 Advanced Sediment Cleanup Conference, Seattle, WA

In addition, Ecology's rule advisory groups (Sediment Workgroup and MTCA/SMS Advisory Group) for the MTCA/SMS rule revisions reviewed the method in a series of meetings in 2010, the MTCA/SMS Science Panel reviewed the approach in 2010 and 2011, and Ecology requested a review of the method and draft report from four national-level scientific peer reviewers. Additional formal public review and comment will occur during the public review period associated with the SMS rule revision.

1.4 Supplemental Electronic Files

A variety of additional electronic files are available on Ecology's website providing the underlying data set, modeling spreadsheets, and statistical evaluations summarized in Sections 2–4 of this report:

- **Station Locations** – A complete list of the stations included in the data set (Figure 2-1) and their latitudes/longitudes can be found in the spreadsheet "LatLongs.xls".

- **Final Chemistry Data Sets –** The complete chemistry data set summarized in Table 2-4 can be found in the spreadsheet "Final Chemistry.xls". Individual data sets for each bioassay endpoint can be found in spreadsheets of the same name appended with the bioassay abbreviations, e.g., "Final Chemistry-CH10G.xls".

- **Toxicity Test Results –** Results of the toxicity tests in the form of hit (1) or no-hit (0) designations for each sample summarized in Table 2-3 can be found in the spreadsheet "BioHitNoHit.xls". Hit/no-hit files for each of the individual bioassay endpoints can be found in spreadsheets of the same name appended with the bioassay abbreviations, e.g., "BioHitNoHit-CH10G.xls".

- **FPM Step 1. Initial Data Processing** – The results of the first FPM model spreadsheet, which screens, sums, summarizes, and formats the chemistry data for modeling, can be found in the spreadsheet "FPMData.xls". Results of this step for each of the individual bioassay endpoints can be found in spreadsheets of the same name appended with the bioassay abbreviations, e.g., "FPMData-CH10G.xls". One additional spreadsheet, "FPMDataGroups.xls", is also included showing how chemical classes were summed for modeling. The output table of the FPMCalc spreadsheet is imported into the second modeling spreadsheet described below.

- **FPM Step 2. ANOVA Screening –** The results of the second FPM model spreadsheet, which evaluates the association of each chemical with toxicity in the data set, can be found in the spreadsheets named "FPMAnova*.xls". There is one of these spreadsheets for each bioassay endpoint and each effects endpoint, e.g., "FPMAnova-CH10G-SL1.xls". This spreadsheet includes a summary table showing the strength of each chemical's association with toxicity in the data set, the ability to select or deselect chemicals for continued modeling based on these results, and a set of worksheet tabs showing the hit and no-hit distributions for each chemical on which the analysis is based. The output table of the FPMAnova spreadsheet is imported into the third modeling spreadsheet described below.

- **FPM Step 3. Model Calculations** – The results of the third FPM model spreadsheet, which calculates the SQVs (summarized in Section 3.3) and evaluates their predictive reliability (summarized in Section 4.1), can be found in the spreadsheets named "FPMCalc*.xls". There is one of these spreadsheets for each bioassay endpoint and each effects endpoint, e.g., "FPMCalc-CH10G-SL1.xls". As explained in Section 3.1, the model can be run in two different ways, and the results of both are provided on the "Data Storage" tab. The row ultimately selected as the basis of the SQVs presented in this report is highlighted on that tab.

- **Supplemental Statistics** – Spreadsheets for calculating the supplemental statistical evaluations discussed in Section 4.3 can be found in the spreadsheets named "SuppStatistics*.xls". There is one of these spreadsheets for each bioassay endpoint and each effects endpoint, e.g., "SuppStatistics-CH10G-SL1.xls", as well as one for the complete draft SQS/SL1 and one for the CSL/SL2 SQV sets. The template spreadsheet was provided by EPA Region 10, and includes a wide variety of additional statistical measures not used in this report. However, they may be of interest to readers.

2. Database Development

The following sections describe the collection, screening, processing, and assembly of the data set used in the FPM model runs. The resulting data set is also summarized. Additional electronic files containing station locations and the underlying bioassay and chemistry data sets are also available, described in Section 1.4.

2.1 Data Collection

The data set for this effort includes most of the data originally collected by Ecology in 2002-2003 (see SAIC and Avocet 2002, 2003 for details), although some of those original data were excluded during this effort because they did not use modern protocols or had fewer replicates than are currently required (see Appendix B). Additional data collection was conducted in 2007 to obtain data sets from a broader geographic region (all areas of OR, WA, and ID), data sets with chronic bioassays, and more recent data. Data collection efforts continued for approximately one year, and were largely successful in meeting the project goals, as follows:

- The size of the overall data set was approximately tripled from the 2003 data set.
- Data sets were included from east of the Cascades in Washington State.
- The data set includes many analytes not well represented in the 2003 data set.
- Several recent, large studies of special interest to the agencies were included, including Willamette River, Portland Harbor, Upper Columbia River, and Spokane River studies.
- Substantial chronic data was obtained for the *Hyalella azteca* 28-day growth and mortality endpoints.

Several goals of the data collection effort could not be met. No studies with complete analyte lists and synoptic bioassay data were located from Idaho or eastern Oregon. In addition, the only chronic test with sufficient data for inclusion was the *Hyalella azteca* 28-day test (growth and mortality endpoints). While some surveys have been run in recent years using the *Chironomus dilutus* 20-day bioassay, there were less than 30 data points in total and only a few bioassay hits among those samples, which was not sufficient for development of SQVs. It appears that most project proponents are choosing to run the acute *Chironomus* test along with the chronic *Hyalella* test, thus limiting the availability of data for the chronic *Chironomus* test.

A complete list of surveys used for SQV development is provided in Appendix A.

2.2 Initial Data Screening

In assembling the data set, surveys, analytes, and individual data points were screened out if they did not meet certain initial data screening criteria, described below. Appendix B lists all the surveys, stations, and data that were screened out during assembly of the data set.

Synoptic Samples **–** Data were only used if chemistry analyses and bioassays were run on splits from the same homogenized sample. Surveys were not included if chemistry and bioassay samples were collected at different times, from different locations, or from different grab samples.

***Completeness* -** Surveys and stations were screened out if they had an insufficient analyte list. Although it would be ideal for all stations to have the same analyte list when developing SQVs, this is not possible when using historical data sets. At least semivolatiles (e.g., Method 8270) and a complete set of metals was selected as a minimum guideline for including a survey or station, consistent with other national criteria development efforts. Metals and semivolatiles both are significantly associated with toxicity in most contaminated sediment data sets, and if these minimum analytes were not available, toxicity would frequently occur in samples without adequate chemistry to explain it. For some surveys, different stations had varying analyte lists. In these surveys, only those stations with adequate analyte lists were retained. Eleven surveys and an additional 9 stations from one survey were screened out due to insufficient analyte lists. Unfortunately, many eastern Washington surveys fell into this category, having only conventionals and/or a few metals (see Appendix B) co-located with bioassay data.

Surveys were also screened out if insufficient information could be found to conduct chemistry and/or bioassay quality assurance evaluations. Both bioassay and chemistry data were subjected to quality assurance review at a level sufficient to support regulatory development and litigation, known as "QA2" (PTI 1989). Substantial efforts were made to obtain this information, including contacting the original clients, contractors, and laboratories. However, in some cases the data were too old, never had the required information, or could not be provided for a reasonable cost or within a reasonable timeframe. We were unable to obtain data for 5 small surveys (<10 samples each).

***Minimum amount of data* -** For development of SQVs, a minimum number of data points is required. A minimum of 30 detected values was chosen as the lower limit for inclusion on the analyte list at the initiation of the project. Depending on the chemical distributions and range of bioassay responses in the data set, a larger number (up to 100) may be required for some projects; however, this value was chosen to be as inclusive as possible. Several of these chemicals were later removed from the dataset when it was determined that there were only a few toxic stations among the 30+ detected values for that chemical, not enough to develop a reliable criterion.

Chemicals with <30 detected data are listed in Appendix B. These 61 chemicals included primarily volatile or unusual compounds not generally expected to be found for most projects, as well as some herbicides/pesticides not widely used in the Pacific Northwest. However, should they be important for a specific site, bioassay testing is recommended for evaluation of their potential toxicity.

***Nontoxicity* -** Analytes were also screened out for other reasons. Some analytes, such as iron, aluminum, and magnesium, were screened out because they are crustal elements and are naturally present in high concentrations. While some of these compounds can affect the toxicity of other chemicals at certain sites and can be useful in risk assessments, they are not themselves toxic and thus do not require the development of SQVs. Certain conventional analytes, such as grain size parameters and acid-volatile sulfides, were screened out because they are physical parameters or derived quantities. Other derived quantities frequently present in data sets, such as dioxin toxicity equivalency quotients (TEQs) for human health, were also not included, because they are not related to benthic toxicity. These analytes are listed in Appendix B.

Chemistry quality assurance – All chemistry data were qualified to "QA2" level, as defined in Ecology (1989), a high level of quality assurance designed to support rule-making or litigation purposes. Quality assurance was conducted consistent with the SEF (2009) and in accordance with PSEP QA2 (PTI 1989), DMMP (2009), and US EPA (1986, 1987a,b,c, 1999, 2004, 2007) manuals. Individual chemical data were screened out based on qualifiers assigned during the quality assurance process. Data qualified as H, Q, X, or R (defined in Table 2-1 below) were not included in the analysis. Undetected data were also not included, as these data do not provide useful information for the purposes of developing SQVs. Data with these qualifiers were also excluded in Ecology's previous round of FPM calculations.

Table 2-1 Qualifier Definitions for Screened-Out Data

Qualifier	Definition
H	Holding time exceeded (conventionals)
Q	Questionable value
X	Less than 10% recovery
R	Rejected – failure to meet QA guidelines

Bioassay quality assurance – All bioassay data were subjected to a QA2 level of review using an in-house checklist and verification of all original laboratory data and calculations. The review included:

- General project and test endpoint information
- Chain of custody, holding times, and holding conditions
- Sources of organisms and species
- Number of replicates
- Whether all aspects of the protocols were followed/non-standard protocol elements
- Whether all required water quality parameters were measured and within control limits
- Positive control toxicant, control charts, and whether the LC50 was within control limits
- Source of the negative control and whether it was within control limits
- Whether reference samples were within control limits
- Hand-check of all calculations

Six surveys, comprising 46 stations, did not meet one or more minimum QA requirements. Many of these surveys also had an insufficient analyte list as described above (see Appendix B).

2.3 Normalization and Summing

Organic carbon normalization - To date, evaluations of the reliability of dry weight-normalized SQVs vs. organic carbon-normalized SQVs has shown that the dry weight values have equal or better reliability than the organic carbon-normalized values (PSEP 1988, Ecology 1997, SAIC and Avocet 2003). In addition, the use of organic carbon-normalized SQVs leads to implementation difficulties, because it is inappropriate in some situations with large quantities of anthropogenically derived organic carbon or under natural conditions with very low amounts of organic carbon. Consistent with regional dredging guidelines and all other national SQVs, the current SQVs are calculated on a dry weight normalized basis.

Petroleum hydrocarbons **-** In the past, SQVs have been calculated both for individual polynuclear aromatic hydrocarbons (PAHs) and for summed dry weight values such as low molecular weight PAHs and high molecular weight PAHs. In recent years, there has been a trend toward using summed values of PAHs in the development of SQVs, as this may better reflect their mode of action and additive toxicity (Swartz et al., 1995; EPA 2000). A PAH workshop was held in June 2007 among the RSET agencies to discuss how best to handle petroleum toxicity in developing SQVs and bioaccumulative guidelines. The participants at this workshop selected the following approach for dealing with historical data sets.

Historical data should be evaluated on the basis of total PAHs and total petroleum hydrocarbon (TPH) gasoline-, diesel-, and organic-range hydrocarbons. This could be accomplished by assembling one data set with total PAH values, and another data set with the TPH values. Normally, these two types of values should be considered as alternatives rather than being included in the same model run, as PAHs are a subset of TPH. Inclusion of both values in the same model run could theoretically produce unreliable results for one or both values, as they are not independent of one another. However, after multiple model runs it became apparent that TPH was far more strongly associated with petroleum toxicity than PAHs, although there were no TPH data for many stations (see Appendix D for details of the model runs). Therefore, both were retained in the model runs and the two together provided better reliability than either one alone.

Chemical Classes **-** Other sums used in the model runs included total dioxins/furans, total polychlorinated biphenyls (PCBs; sum of Aroclors), total chlordanes (sum of cis- and trans-chlordane, chlordane, alpha-chlordane, gamma-chlordane, cis- and trans-nonachlor, oxychlordane, heptachlor, and heptachlor epoxide), total endosulfans (alpha-endosulfan, beta-endosulfan, and endosulfan sulfate), total DDDs, total DDEs, and total DDTs (o,p' and p,p' isomers). Appendix B lists all of the constituents included in all of the sums, which were not included as individual chemicals in the model runs to reduce covariance among variables.

The following summation rules were used for chemical classes:

- If all constituents were non-detects, the sum for that chemical class was treated in the same manner as non-detected individual chemicals, and excluded from model calculations.

- If some constituents were detected and others were non-detects, the non-detects were assigned a value of one-half the method detection limit and summed with the other constituents.

- Unusually high detection limits (e.g., due to interference noted in QA/QC reports) were not used; instead a value of one-half the standard detection limit for that analysis was used.

- Total PCBs calculated as a sum of Aroclors is an exception to the above summing rules. Aroclors that were undetected were assigned a value of zero. Because Aroclors are already a mixture of PCBs, and individual Aroclor products are frequently used in industrial processes in the absence of other Aroclor products, it cannot be assumed that non-detected Aroclor products are present.

Various methods of dealing with non-detected data as part of summed classes were evaluated by the workgroup, including eliminating undetected constituents (i.e., setting their value to 0), using half the detection limit, or using statistical methods to estimate the true value. Using half the detection limit was selected for the following reasons:

- This approach is generally consistent with the approach outlined in Ecology's SMS regulations and with DEQ's standard practice. Because regulated parties will be required to calculate their sums in this manner, the SQVs should be calculated the same way so that comparisons are valid.

- It should reduce the variability and the error that would be associated with using zero for non-detected constituents of sums where most of the other constituents are detected.

- It is a simpler calculation procedure than other available statistical methods, which each have other limitations and would potentially need to be applied differently depending on the distribution of and/or number of nondetects in each individual chemical sum.

2.4 Comparison to Control vs. Reference

In the marine sediment cleanup and dredging programs, bioassay controls are used to evaluate the performance of the test, and bioassay test samples are compared to reference sediment samples from clean areas of Puget Sound. The reference samples are intended to "correct" for effects that physical parameters of the sediment may have on the test animal. However, reference areas have not been identified in freshwater areas of the state despite significant efforts by the agencies, in part due to much greater variability of freshwater environments and in part due to the lack of uncontaminated upstream areas.

Based on the results of SAIC and Avocet (2002) as well as updated evaluations conducted with the current data set (see Section 3.2 and Appendix D), there appears to be no reliability advantage to using a comparison to reference rather than a comparison to control for this freshwater data set. Freshwater reference areas have not yet been standardized, and the variability of reference stations in the historical data set appears to overwhelm any theoretical advantage they may provide. In addition, depending on the endpoint, approximately two-thirds of the test stations do not have valid reference stations and would have to be excluded from the analysis if comparison to reference were used. Consequently, a comparison to control provides a much larger and more consistent data set to work with in calculating SQVs. Finally, all of the other national SQV sets that have been developed for freshwater have used a comparison to control. Therefore, it was decided to use comparison to control for derivation of SQVs. Appendix D, section D3 covers this issue in more detail.

This decision does not limit how individual regulatory programs may choose to interpret and use their bioassay data. It is anticipated that freshwater reference areas may be identified in the future (Stirling and RSET 2008), and once this process is completed it may be possible to use a comparison to reference for future updates of the SQVs. However, it is likely that the process may be more difficult than in the marine environment because of the more heterogeneous nature of freshwater environments, and there may not be valid reference areas for all freshwater sites.

2.5 Bioassay Tests and Endpoints

Five acute and chronic test endpoints had sufficient data to calculate SQVs:

- Chronic endpoints: *Hyalella azteca* 28-day growth and mortality,
- Acute endpoints: *Hyalella azteca* 10-day mortality and *Chironomus dilutus* 10-day growth and mortality.

While there were some *Chironomus dilutus* 20-day mortality and growth data collected, there were less than 30 data points total and only a few toxic stations, which is not sufficient for calculation of SQVs. Microtox was excluded after a lengthy evaluation process. Microtox protocols have changed sufficiently over the years that the data sets before and after the changes were not comparable, to the extent that attempts to combine these data sets resulted in poor reliability. There were insufficient data using the newer protocols to calculate SQVs. Therefore, it may be possible to calculate Microtox and *Chironomus dilutus* 20-day mortality and growth values in the future.

The first step in performing SQV calculations, once the data have been collected and screened, is the determination of whether adverse biological effects are observed in each sample (called a “hit” if observed and a “no-hit” if not observed). These biological effects levels may also be used to interpret the results of bioassay tests conducted to confirm or over-ride the chemical SQVs on an individual project.

In Washington State sediment programs, identification of adverse biological effects involves a statistical difference from the control or reference plus some threshold of effects, shown in Table 2-2 below. Quality assurance guidelines for control and reference samples are also shown. Development of the thresholds for each bioassay endpoint is presented in Appendix C. Data transformations, selection of null hypotheses, and appropriate statistical tests (depending on the data distribution) are identical to those currently in use by RSET for marine sediment data (Michelsen and Shaw 1996, Fox et al. 1998). In all cases, “statistically significant” means a statistical difference from a control sample at an alpha level of 0.05.

Table 2-2. Quality Assurance and Adverse Effects Levels for Biological Tests

Test	QA Control	QA Reference	SQS/SL1	CSL/SL2
Hyalella azteca 10-day mortality	C ≤ 20%[a]	R ≤ 25%	T – C > 15%	T – C > 25%
Hyalella azteca 28-day mortality	C ≤ 20%[a]	R ≤ 30%	T – C > 10%	T – C > 25%
Hyalella azteca 28-day growth	CF ≥ 0.15 mg/ind	RF ≥ 0.15 mg/ind	T / C < 0.75	T / C < 0.6
Chironomus dilutus 10-day mortality	C ≤ 30%[a]	R ≤ 30%	T – C > 20%	T – C > 30%
Chironomus dilutus 10-day growth	CF ≥ 0.48 mg/ind	RF/CF ≥ 0.8	T / C < 0.8	T / C < 0.7

QA = Quality Assurance
SQS/SL1 = Sediment Quality Standard/Screening Level 1, CSL/SL2 = Cleanup Screening Level/Screening Level 2
C = Control, CF = Control Final, R = Reference, RF = Reference Final, T = Test Sample
[a] These control mortality limits are currently in the process of being reviewed by ASTM and may be lowered in the next few years (Ingersoll et al. 2008)

2.6 ANOVA Analyte Screening

Once the individual biological tests and endpoints had been selected, a second screening of the data set was conducted to remove chemicals that are not apparently associated with toxicity in this data set. This was accomplished by comparing the hit and no-hit distributions to determine if they were statistically different using an ANOVA comparison, with various p values ≤ 0.1, 0.05, 0.005, and 0.0005 to show increasing degrees of association with toxicity. Experience with application of the FPM has shown that chemicals with hit and no-hit distributions that are not statistically different using ANOVA do not affect the reliability of the SQVs developed using that data set. This was verified in some early runs on the Portland Harbor project, as well as recent projects conducted for Ecology (Avocet 2003), ODEQ (1999), San Francisco Bay, and Los Angeles Harbor. These chemicals could be retained in the model, but it would run more slowly and give the same results.

Detailed results of the ANOVA screening evaluations, which were conducted separately for each chemical, effects level, and endpoint combination, are provided in Appendix B. Because the same chemicals did not always contribute to toxicity in all tests and endpoints, the list of chemicals included in the modeling for each endpoint is different. These differences could be due to a variety of factors, including differences in the response of test organisms or endpoints to the chemicals, and differences in the underlying data sets for each test endpoint.

Certain chemicals had no apparent relationship to benthic toxicity for any of the hit/no-hit definitions or endpoints. These included Aldrin, dioxins/furans, gamma-hexachlorocyclohexane, hexachlorobenzene, hexachloroethane, methoxychlor, retene, and total endosulfans. These chemicals were not included in the subsequent model runs and should not be considered chemicals of concern for benthic toxicity at the range of concentrations observed in this database. However, many of these chemicals may still exhibit toxicity to wildlife or human health through bioaccumulative exposure routes and should be evaluated accordingly. Other chemicals were screened out for some endpoints, but nevertheless have final SQVs because they were associated with toxicity for other endpoints.

Chemicals screened out as a result of the ANOVA screening are listed in Appendix B, along with the underlying ANOVA matrices.

2.7 Final Data Set

Figure 2-1 shows the station locations included in the final data set, identifying hit and no-hit stations. The data set comprises 648 stations having various combinations of bioassays at each station, of which 583 are from west of the Cascades (WA and OR) and 65 are from east of the Cascades (WA). Most of the stations are located in three general areas: freshwater locations near Seattle, WA and Portland OR, and the upper Columbia and Spokane Rivers. There are also a number of stations downstream of the Willamette River in the Columbia River. With the exception of the lower Columbia River, which is mainly no-hit stations, hit stations are fairly evenly distributed throughout the data set in these regions. Appendix A provides a list of surveys included in the final data set, including the state and region, number of stations for each bioassay, analyte classes included in the survey, and references.

The numbers of stations for each bioassay endpoint are shown in Table 2-3 (samples that failed quality assurance evaluation are not included). Table 2-3 also shows the number and percentage of stations associated with biological hits for each bioassay and effects level. Overall, toxicity was observed at 12–33% of the stations at the lower SQS/SL1 level and at 7–15% of the stations at the higher CSL/SL2 level.

Table 2-3. Bioassays and Endpoints in Final Data Set

Test	No. of Samples	SQS/SL1[a]	CSL/SL2[a]
Hyalella azteca 10-day mortality	366	89 (24%)	52 (14%)
Hyalella azteca 28-day mortality	312	47 (15%)	27 (7%)
Hyalella azteca 28-day growth	79	26 (33%)	12 (15%)
Chironomus dilutus 10-day mortality	568	85 (15%)	41 (7%)
Chironomus dilutus 10-day growth	525	65 (12%)	49 (9%)

[a] See Table 2-2 for SQS/SL1 and CSL/SL2 definitions

Table 2-4 provides a summary of the concentration distributions for each of the chemicals detected more than 30 times in the data set, including chemicals screened out as described above. For chemicals detected less than 30 times, see Appendix B. In each case, the median was less than the mean, usually by a substantial amount. This pattern indicates a right-skewed data set as would be expected for an environmental data set containing highly contaminated areas. For most chemicals (particularly those remaining after the screening described above), the concentration ranges were quite large, indicating inclusion of both clean and contaminated areas.

Figure 2-1. Station Locations

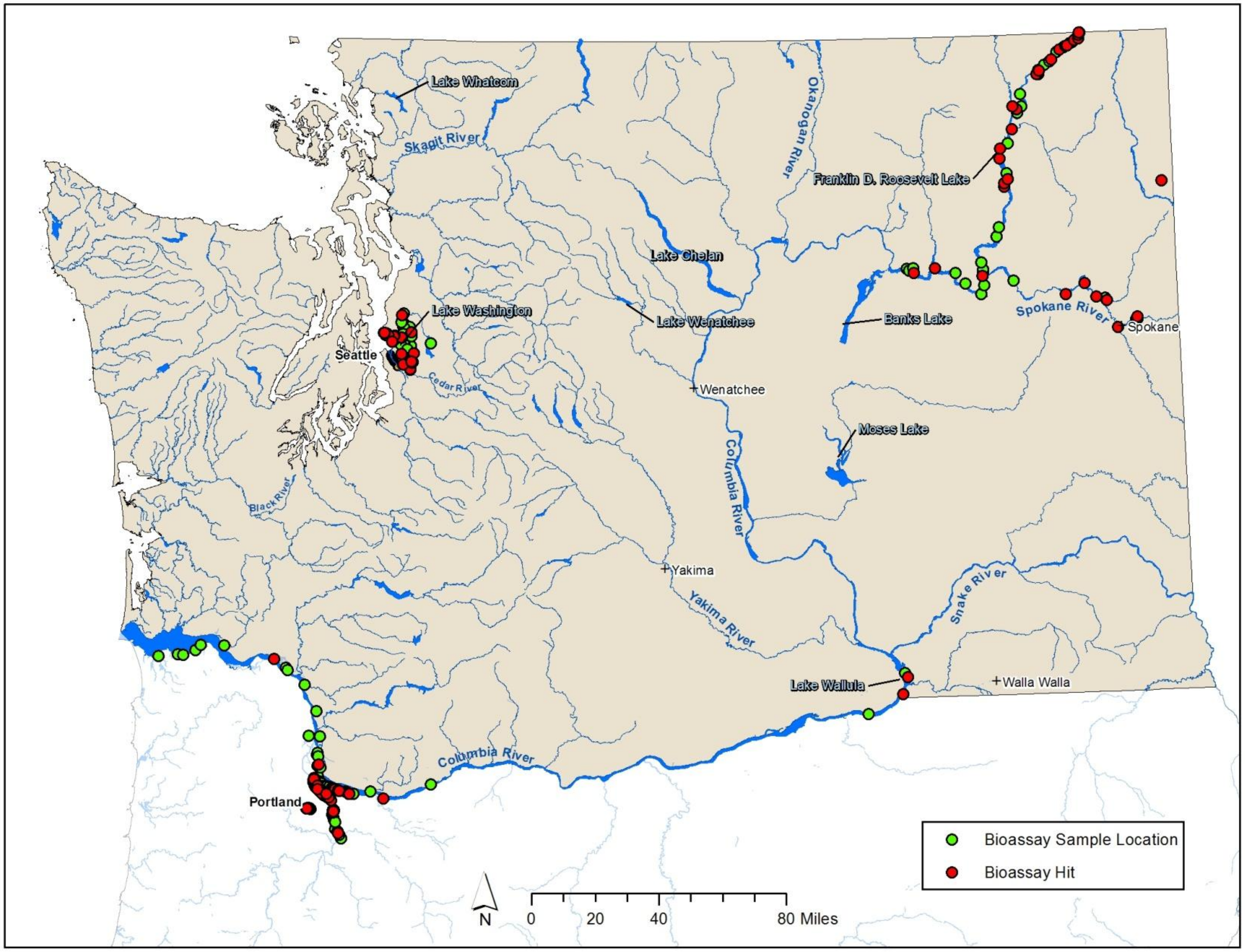

Table 2-4. Chemical Distributions[a]

Analyte	N	Minimum	Median	Mean	Maximum
Conventional Pollutants (mg/kg)					
Ammonia	424	0.050	69	87	780
Total sulfides	329	0.20	7.1	67	7700
Metals (mg/kg)					
Antimony	342	0.050	0.20	3.1	310
Arsenic	613	0.48	4.4	11	1200
Cadmium	528	0.040	0.34	0.97	40
Chromium	533	3.8	30	35	350
Copper	559	3.3	39	120	11000
Lead	519	0.62	26	86	1400
Mercury	535	0.006	0.085	0.29	43
Nickel	544	5.0	23	27	590
Selenium	233	0.040	0.14	0.91	20
Silver	409	0.024	0.21	0.39	4.5
Zinc	568	15	120	390	14000
Organic Chemicals (µg/kg)					
4-Methylphenol	151	4.0	28	200	6300
Aldrin	77	0.052	0.86	14	690
alpha-Hexachlorocyclohexane	66	0.047	0.26	0.83	10
Benzoic acid	64	20	300	810	4200
beta-Hexachlorocyclohexane	131	0.16	1.6	3.0	26
bis(2-Ethylhexyl)phthalate	303	4.2	260	2800	440000
Butylbenzyl phthalate	172	2.7	44	140	2800
Carbazole	218	2.1	25	5000	480000
delta-Hexachlorocyclohexane	48	0.092	0.36	1.1	21
Dibenzofuran	356	0.20	11	8300	2200000
Dibutyltin	124	0.017	20	2600	160000
Dieldrin	61	0.079	0.42	7.9	360
Dimethyl phthalate	47	4.5	49	98	580
Di-n-butyl phthalate	203	4.0	15	92	1800
Di-n-octyl phthalate	62	3.1	40	250	4300
Dioxins/furans (ng/kg)	73	2.4	130	860	28000
Endrin	38	0.043	2.5	7.0	39
Endrin ketone	60	0.078	0.85	2.9	90
gamma-Hexachlorocyclohexane	48	0.20	1.9	2.8	11
Hexachlorobenzene	127	0.26	1.4	4.3	260
Hexachloroethane	44	0.38	1.8	38	1500
Methoxychlor	48	0.048	2.3	4.9	34
Monobutyltin	141	0.16	11	100	4800
Pentachlorophenol	81	0.81	15	290	16000
Phenol	120	3.5	16	47	770
Retene	38	11	1200	39000	810000
Tetrabutyltin	54	0.33	3.0	40	770
Total Chlordanes	218	0.042	1.3	15	670
Total DDDs	318	0.046	4.7	68	3000
Total DDEs	321	0.087	3.0	25	2500

Analyte	N	Minimum	Median	Mean	Maximum
Total DDTs	263	0.077	3.1	130	13000
Total Endosulfans	41	0.048	0.54	8.8	240
Total PAHs	609	0.20	970	120000	36000000
Total PCB Aroclors	320	0.85	72	330	27000
Tributyltin	190	0.029	24	3600	300000
Bulk Petroleum Hydrocarbons (mg/kg)					
TPH-Diesel	184	14	150	870	39000
TPH-Residual	206	16	490	1200	18000

[a] Detected values only, prior to chemical screening described above.

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3. SQV Calculations

The basic concept behind the FPM is to select an optimal percentile of the data set that provides a specified false negative rate and then adjust individual chemical concentrations upward until false positive rates are decreased to their lowest possible level while retaining the same false negative rate (the false negative rate is not allowed to increase).

Once each chemical has been individually adjusted upward to the point where it begins to show an association with toxicity, the false positives will have been significantly reduced while retaining the same false negative rate. In this manner, SQVs can be developed for a number of different target false negative rates (e.g., 0–30%), allowing the trade-offs between false negatives and false positives to be evaluated and a final set of SQVs to be selected. The model spreadsheets for each bioassay endpoint and effects level are available as supplemental electronic files, as described in Section 1.4. Each spreadsheet contains instructions for running the model and the original data set used, to allow duplication of the results.

3.1 Modeling Approach

In summary, the steps required to calculate SQVs using this approach include:

- Compile and screen synoptic chemistry/bioassay data.
- Select toxicity tests and endpoints.
- Assign hit/no-hit status for each station/endpoint combination.
- Develop chemical distributions.
- Select a range of target false negative rates and identify associated optimal percentile values.
- Adjust percentiles for individual chemicals upward to reduce false positives.

The first three bullets above are conducted in preparation for running the model, and are described in Section 2. The model carries out the final three bullets within the spreadsheets.

Excel Spreadsheets. Calculation of SQVs occurs through an iterative automated process using Excel Visual Basic macros, as follows:

1. An appropriate incremental increase for testing is selected for each analyte based on the complete concentration range of that analyte (e.g., 1/10 of the difference between the highest and lowest concentration).

2. The number of false positives contributed by each individual analyte is calculated, and the chemical contributing the most false positives is selected to begin the process.

3. The concentration for that analyte is increased by the chosen increment.

4. After each incremental increase, false negative and false positive rates are recalculated for the entire SQV set.

5. If the false negative rate increases, the chemical concentration is adjusted back down to its previous level and that chemical is "locked in" at that level.

6. If the false positive rate is reduced to zero, the chemical concentration is also locked in at that level.

7. If either of the above two conditions is met, or if the number of false positives for that chemical has been reduced below that of another chemical, the macro moves on to the chemical with the current highest number of false positives. If none of these criteria are met, the macro raises the concentration by another increment and repeats steps 4–7.

8. Incremental increases and recalculations continue until every chemical has reached a point above which false negatives increase or a level at which it has no more false positives.

The model can be run in two manners: 1) for a single selected false negative rate (e.g., 20%), or 2) for a range of false negative rates with a given interval (e.g., 0–30% with steps of 5%). If a range is chosen, the model repeats all of the steps above and creates a new row for each false negative rate in the range (e.g., 0, 5, 10, 15, 20, 25, and 30%). When the model is run for a range of false negative rates, it goes through an additional process after calculating all the rows, as follows:

9. Find the lowest value for each chemical among all the rows and restart the calculations using this set of lowest values. Follow steps 1–8 until the lowest false negative rate target is reached.

10. Start the next row using the results of the first row. Follow steps 1–8 until that row's false negative target has been reached. Repeat for all of the false negative targets in the range until a new set of rows is generated.

This second pass through the data set helps deal with the effects of covariance. Although the initial model assumes that all variables are independent of one another, in reality, some chemicals will co-vary or be co-located and affect each others' results. This can cause a "seesaw" effect, where one chemical concentration is low in some rows while the associated chemical's concentration is high, and vice versa in other rows. Steps 9 and 10 help equalize these effects by finding the lowest concentrations for all chemicals, which may reflect the values they would have in the absence of other co-varying or co-located chemicals, and working evenly back and forth between the chemicals.

Through this process, it is possible to identify those analytes having the greatest association with toxicity in the data set (those whose concentrations cannot be increased without increasing false negatives), and those chemicals having little or no association with toxicity in the data set (those that can be increased to their highest concentrations with no effect on error rates).

The spreadsheets used to develop the SQVs also provide a test area where candidate SQV sets may be adjusted and finalized, and the results of each change tested with respect to all of the reliability parameters (this area also allows the operator to enter any criteria set of their choice and test its reliability against the regional data set).

Hit/No-Hit Definitions. The model was run separately for each individual bioassay endpoint at both the SQS/SL1 and CSL/SL2 effects levels shown in Table 2-2. This allows greater evaluation of the individual bioassay endpoints – for example, which ones behave similarly, which chemical groups each responds to, and which endpoints are most sensitive and reliable.

Pooled endpoints could also be used, which requires assigning one overall hit/no-hit value to a station based on the performance of all the bioassays at that station. For example, a station could be identified as a hit if any one bioassay showed a hit, and there are a number of other decision rules that could also be chosen. However, for development of the SQVs, this approach was not used because of the historical nature of the data set. Stations had varying numbers of bioassays, ranging from 1–5, and many of the stations did not meet current decision rules required by the SMS (at least three bioassays, both acute and chronic). For site-specific evaluations where all stations have the same set of bioassays, a pooled endpoint could effectively be used.

3.2 Exploratory Model Runs

Exploratory model runs were conducted for a variety of scenarios to explore data relationships and provide information on the best possible ways to work with the data set. The following separate model runs were conducted, and results of each are included in Appendix D:

- **Petroleum Hydrocarbons.** The model was run using 1) total PAHs, 2) TPH-diesel and TPH-residual, and 3) both combined for two different data sets. The large data set included all data in the database, for which all stations had PAH data but only about 1/3 had TPH data. The small data set included only those stations that had both PAH and TPH data.

- **Regional Differences.** The model was run for the entire data set, as well as separately for data east of the Cascades and west of the Cascades. This approach reflects the widely differing geochemistry, industries, and analytes associated with these two areas and was intended to evaluate whether different SQVs would be appropriate for these geo-regions.

- **Comparison to Control vs. Reference.** The subset of the data set that includes reference data was used to evaluate the reliability of comparison to control vs. comparison to reference, to test the previous finding (SAIC and Avocet, 2003) that comparison to control provides similar or better reliability than comparison to reference, given the current nature of the data set.

- **Blank-Correction.** It was determined during the quality assurance review that the data sets had not all been blank-corrected in the same manner, and that some common laboratory contaminants rarely found in the environment were inappropriately appearing in the SQV tables. This issue was addressed by re-qualifying all of the historic data sets in a consistent manner, using EPA Contract Laboratory Protocols, and then rerunning the model to assess the effects.

Based on the exploratory model runs, the following decisions were made and are reflected in the final model runs:

- **Petroleum Hydrocarbons.** Total PAHs, as well as TPH-diesel and TPH-residual, were included in the final model runs. The reliability was best when both were included. The TPH measures were more reliable; however, TPH data were missing for many data sets, leading to improved reliability when both were included.

- **Regional Differences.** East- and west-side data were combined into a single data set. The reliability of the different regions varied by endpoint and was highly dependent on the amount of data available on the east side. It may be possible in the future to calculate SQVs for different geographic regions once more data are available.

- **Comparison to Control vs. Reference.** Current results for comparison to reference vs. comparison to control were consistent with SAIC and Avocet (2003), indicating that comparison to control was at least as reliable as comparison to reference and allowed use of a much larger data set. Therefore, the model was run based on comparison to control.

- **Blank-Correction.** For stations with detected concentrations in the blanks, revising the qualifiers consistent with the approach specified by the EPA Contract Laboratory Protocols eliminated analytes from the SQV list known to be common laboratory contaminants (e.g., acetone, methylene chloride) that had previously been associated with a significant number of false positives.

3.3 Final Model Results

Tables 3-1 and 3-2 show the resulting FPM values for each endpoint based on the modeling approach described above and the reliability assessment described in Section 4. These values best meet the reliability goals of Ecology and the RSET SQV development workgroup. “Greater than” signs (>) indicate that the toxicity value for that chemical and endpoint is greater than any of the concentrations in the database, and the maximum concentration is shown in the table.

Table 3-1. Floating Percentile Model Values at the SQS/SL1 Level

Analyte	CH10G	CH10M	HY10M	HY28G	HY28M
Conventional Pollutants (mg/kg)					
Ammonia	> 780	--	> 780	--	230
Total sulfides	39	540	920	--	61
Metals (mg/kg)					
Antimony	42	--	0.3	42	12
Arsenic	120	120	200	14	16
Cadmium	6.3	2.1	13	>23	5.4
Chromium	88	220	--	72	82
Copper	1600	1900	--	400	> 1900
Lead	360	> 1400	> 1300	> 1400	> 1400
Mercury	3	0.8	--	0.66	0.87
Nickel	110	> 590	360	26	> 100
Selenium	> 20	--	--	11	> 20
Silver	0.57	0.64	--	--	1.7
Zinc	> 14000	--	> 4200	3200	3200
Organic Chemicals (µg/kg)					
4-Methylphenol	> 6300	2000	2400	--	260
Benzoic acid	--	2900	3800	--	--
beta-Hexachlorocyclohexane	7.2	11	--	--	11
bis(2-Ethylhexyl)phthalate	> 440000	--	500	--	> 440000
Butylbenzyl phthalate	> 2800	> 2800	--	--	> 2800
Carbazole	1400	1100	2900	--	30000
Dibenzofuran	> 7200	680	3800	--	680
Dibutyltin	910	910	--	--	> 910
Dieldrin	4.9	4.9	--	--	22
Dimethyl phthalate	> 580	> 580	--	--	--
Di-n-butyl phthalate	380	450	--	--	1000
Di-n-octyl phthalate	> 1100	--	39	--	--
Endrin ketone	8.5	8.5	--	--	8.5
Monobutyltin	540	540	--	--	> 540
Pentachlorophenol	> 1200	> 1200	1200	--	> 320
Phenol	> 770	210	250	--	210
Tetrabutyltin	97	97	--	--	> 97
Total Chlordanes	> 670	> 670	--	--	> 670
Total DDDs	860	2500	310	--	2500
Total DDEs	910	910	21	> 5.7	910
Total DDTs	> 13000	100	--	--	8100
Total PAHs	30000	45000	17000	--	330000
Total PCB Aroclors	3100	3400	110	--	3400
Tributyltin	9300	320	--	--	> 9300
Bulk Petroleum Hydrocarbons (mg/kg)					
TPH-Diesel	540	340	1700	--	1700
TPH-Residual	4400	3600	> 8400	--	10000

SQS/SL1 = Sediment Quality Standard/Screening Level 1
CH10G = *Chironomus* 10-day growth, CH10M = *Chironomus* 10-day mortality,
HY10M = *Hyalella* 10-day mortality, HY28G = *Hyalella* 28-day growth, HY28M = *Hyalella* 28-day mortality
> "greater than" value indicates that the toxic level is unknown, but above the concentration shown.

Table 3-2. Floating Percentile Model Values at the CSL/SL2 Level

Analyte	CH10G	CH10M	HY10M	HY28G	HY28M
Conventional Pollutants (mg/kg)					
Ammonia	> 780	--	> 780	--	300
Total sulfides	340	360	920	--	340
Metals (mg/kg)					
Antimony	42	--	0.3	42	> 63
Arsenic	120	120	200	14	16
Cadmium	6.3	13	13	> 23	> 23
Chromium	220	220	> 350	72	> 220
Copper	1600	1900	> 11000	1200	> 1900
Lead	360	> 1400	> 1300	> 1400	> 1400
Mercury	0.66	0.8	0.8	> 0.87	0.87
Nickel	110	> 590	360	> 27	> 100
Selenium	> 20	--	--	11	> 20
Silver	4.1	0.64	4.1	--	1.7
Zinc	> 14000	--	> 4200	3200	> 14000
Organic Chemicals (µg/kg)					
4-Methylphenol	> 6300	2000	2400	--	260
Benzoic acid	--	2900	3800	--	--
beta-Hexachlorocyclohexane	11	11	--	--	11
bis(2-Ethylhexyl)phthalate	> 440000	--	22000	--	> 440000
Butylbenzyl phthalate	> 2800	> 2800	> 1500	--	> 2800
Carbazole	1400	900	2900	--	30000
Dibenzofuran	200	7200	3800	--	7200
Dibutyltin	910	910	130000	--	> 910
Dieldrin	4.9	9.3	--	--	22
Dimethyl phthalate	> 580	> 580	> 580	--	--
Di-n-butyl phthalate	> 1800	>1800	> 1700	--	1000
Di-n-octyl phthalate	> 1100	--	39	--	--
Endrin ketone	8.5	8.5	--	--	8.5
Monobutyltin	540	540	> 4800	--	> 540
Pentachlorophenol	> 1200	> 1200	1200	--	> 320
Phenol	> 770	210	250	--	120
Tetrabutyltin	97	97	--	--	> 97
Total Chlordanes	24	> 670	> 180	--	> 670
Total DDDs	> 3000	2500	310	--	2500
Total DDEs	900	33	> 44	> 5.7	900
Total DDTs	> 13000	8100	> 140	--	8100
Total PAHs	17000	77000	33000	--	1700000
Total PCB Aroclors	3400	3400	2500	--	3400
Tributyltin	9300	320	47	--	> 9300
Bulk Petroleum Hydrocarbons (mg/kg)					
TPH-Diesel	510	510	2100	--	1300
TPH-Residual	4400	8400	> 8400	--	10000

CSL/SL2 = Cleanup Screening Level/Screening Level 2
CH10G = *Chironomus* 10-day growth, CH10M = *Chironomus* 10-day mortality,
HY10M = *Hyalella* 10-day mortality, HY28G = *Hyalella* 28-day growth, HY28M = *Hyalella* 28-day mortality
> "greater than" value indicates that the toxic level is unknown, but above the concentration shown

4. Reliability Assessment

A reliability assessment was conducted following derivation of the SQVs. The assessment was conducted in two parts – first, candidate SQVs were evaluated using standard measures of reliability such as false positives, false negatives, and overall reliability, and these results were used to select the values that appear in Tables 3-1 and 3-2. In addition, these reliability measures were used to compare the FPM SQVs with other freshwater SQV sets available in North America.

Subsequently, EPA and others recommended additional statistical evaluations to further assess the appropriateness of the resulting proposed SQVs. These additional statistical measures are believed to be less affected by the proportion of toxic and nontoxic samples in the data set. Further details of both reliability assessments can be found in the supplemental electronic files, as described in Section 1.4.

4.1 Standard Reliability Measures

The measures of reliability that were used to evaluate and select the final SQVs are defined and illustrated graphically in Figure 4-1:

- **False Negatives:** hits incorrectly predicted as no-hits/total number of hits
- **False Positives:** no-hits incorrectly predicted as hits/total number of no-hits
- **Sensitivity:** hits correctly predicted/total number of hits (100% - % false negatives)
- **Efficiency:** no-hits correctly predicted/total number of no-hits (100% - % false positives)
- **Predicted Hit Reliability:** correctly predicted hits/total predicted hits
- **Predicted No-Hit Reliability:** correctly predicted no-hits/total predicted no-hits
- **Overall Reliability:** correct predictions/total stations

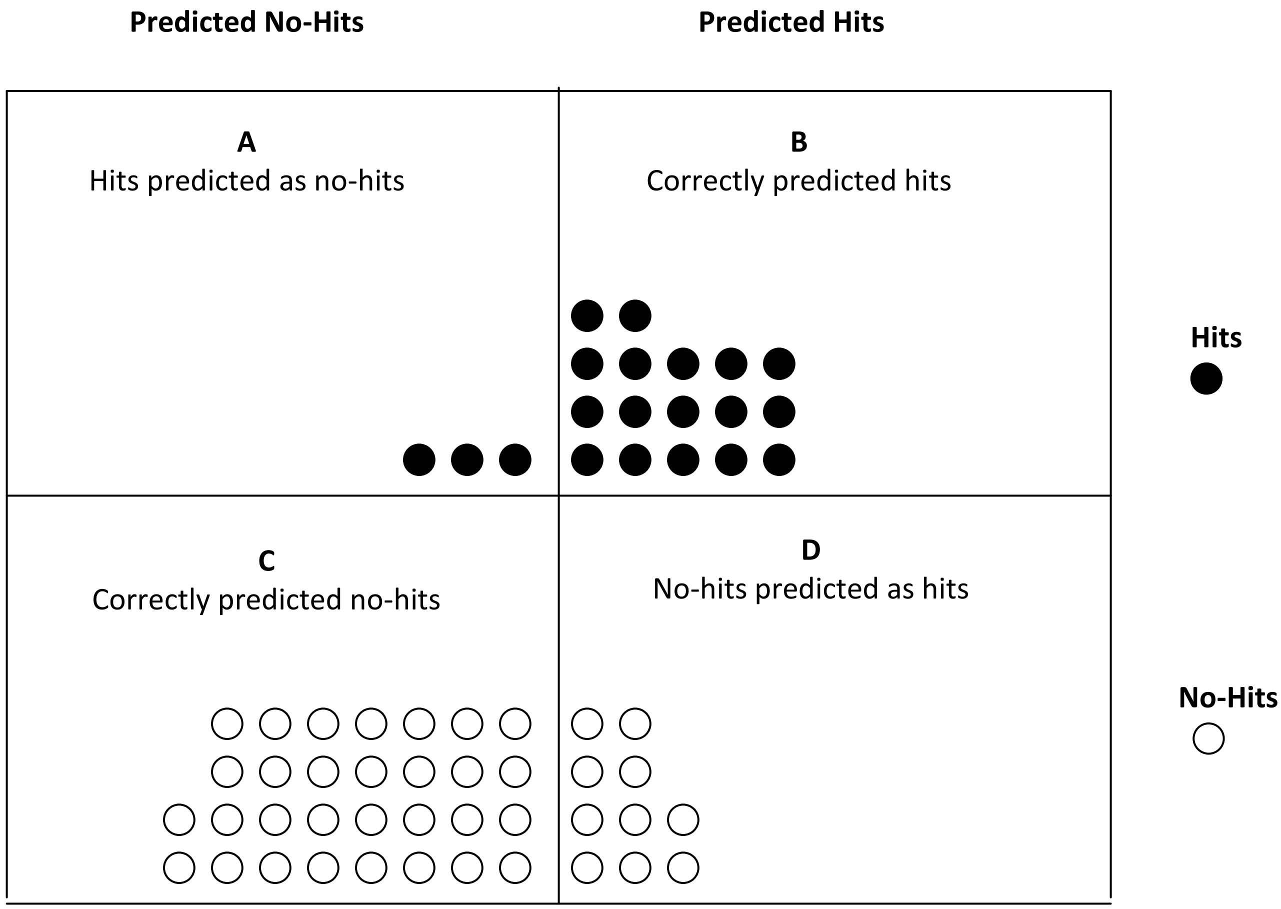
False positives and false negatives are the primary measures of predictive errors used in the reliability assessment. Each of the other reliability values is related to them in some way.

While the performance of any given data set cannot be determined in advance, the workgroup agreed on a set of reliability goals that would guide the selection of the final SQVs, shown in Table 4-1. The goals were based on two factors: 1) the levels of error the agencies believed were appropriate for making regulatory decisions, and 2) the levels of reliability that were considered reasonably achievable based on previous results of the FPM model. The goals for the SQS/SL1 level were designed to be more protective by focusing on greater sensitivity (ability to correctly identify toxic sediments), while at the CSL/SL1 level, efficiency (ability to correctly identify clean sediments) to avoid unnecessary bioassay testing was considered equally important. Of the four measures, high predicted hit reliability (certainty that a predicted hit is actually a hit) is the hardest to achieve in a data set with mainly clean sediments, especially at the SQS/SL1 level. Therefore, that goal was also slightly lower than the others for the SQS/SL1 level.

Table 4-1. Reliability Goals for Proposed Freshwater SQVs

Reliability Measure	Goal (SQS/SL1)	Goal (CSL/SL2)
Sensitivity	80–90	75–85
Efficiency	70–80	75–85
Predicted hit reliability	70–80	75–85
Predicted no-hit reliability	80–90	75–85

Figure 4-1. Reliability Measures – Theoretical Example



Sensitivity = B / (A + B)
False Negatives = A / (A + B)

Efficiency = C / (C + D)
False Positives = D / (C + D)

Predicted-Hit Reliability = B / (B + D)
Predicted-No-Hit Reliability = C / (A + C)

Overall Reliability = (B + C) / (A + B + C + D)

Tables 4-2 and 4-3 show the reliability results for six different choices of false negative rates (0–30% at intervals of 5%) at the SQS/SL1 and the CSL/SL2 levels. Dark blue rows meet the reliability goals selected by the workgroup. Light blue rows are within 5% and are considered borderline. Yellow rows do not meet the reliability goals. As can be seen in the tables below, each bioassay endpoint at each effects level had at least one row that met the reliability goals. However, reliability was considerably better at the CSL/SL2 level.

The cross-hatched box in each of the tables below indicates the row that was selected by the workgroup for derivation of the SQVs. The chemical concentrations corresponding with these rows appear in Tables 3-1 and 3-2. In each case, the selected rows met the reliability goals established by the workgroup. Therefore, the FPM values developed are considered appropriately sensitive, efficient, and reliable. Diagrams similar to Figure 4-1 showing correctly and incorrectly predicted hits and no-hits are provided for each individual endpoint, as well as for the full set of proposed SQS/SL1 and CSL/SL2 values, in Figure 4-2 following the reliability tables. For the full SQG sets, only those stations that had at least three bioassay endpoints (two acute and one chronic or more) as described in the SMS were included, to avoid incorrectly identifying stations as nontoxic due to inclusion of historic data sets with less than a full suite of bioassays.

For consistency, and as a matter of policy, false negative rates for the individual bioassay endpoints were set at 20% for all endpoints except one. This row provides reasonable conservatism, given that all of these values are later combined and the lowest ones selected as the SQVs. In addition, the 20% row consistently met all of the workgroup's reliability goals, providing a good balance between false negatives and false positives and achieving high overall reliability for these bioassays. For one bioassay endpoint, *Hyalella* 10-day mortality at the SL2/CSL level, only the 25% false negative row met the workgroup's reliability goals for these three measures. In addition, it provided the best balance of false negatives and false positives, which is appropriate at the SL2/CSL level. Therefore, this row was selected for this bioassay endpoint.

It is important to note that a 20% false negative rate for a single endpoint at a station is not equivalent to an overall 20% false negative rate for that station. For each chemical, the SQVs for all of the bioassay endpoints were combined and the lowest values chosen as the SQS/SL1 and CSL/SL2 levels (see Section 5.2). Therefore, the regulatory levels for each chemical based on all of the available endpoints together will result in lower false negative rates than for any one bioassay endpoint alone. For further statistical evaluation of the level of bias and conservatism in the proposed SQVs, see Section 4.3.

In addition, multiple stations are used to make decisions about listing and cleaning up contaminated sites. With each additional station of data, the chances of missing a contaminated site decrease. For example, if the false negative rate is 20% for one station, or 0.2, then the false negative rate for three stations is 0.2 x 0.2 x 0.2, or 0.008, approximately 1%. In Ecology's Toxics Cleanup Program, three stations is currently the minimum number of data points required for making initial listing decisions, and many more stations are used for complete site evaluations.

While dredging decisions are often made on the basis of a single station representing a DMMU, bioassay testing is required for open-water disposal if sediment concentrations exceed the lower SQS/SL1 level, which is the lowest of all the endpoint concentrations for each chemical. The bioassay override procedures of the dredging program provide sufficient safety to ensure that unsuitable material is not disposed of in open water.

4.2 Comparison to Existing SQV Sets

Reliability tests were also run for other existing freshwater SQV sets to compare their predictive reliability for this updated data set, including:

- For comparison with SQS/SL1 levels: Effects Range Low (ERL), Threshold Effects Levels (TELs), Threshold Effects Concentrations (TECs), and Lower Effects Levels (LELs).
- For comparison with CSL/SL2 levels: Effects Range Median (ERM), Probable Effects Levels (PELs), Probable Effects Concentrations (PECs), and Severe Effects Levels (SELs).

For a detailed discussion of the narrative intent of these existing SQV sets, how each of them were calculated, the underlying data set used, the specific values used, and the original literature, please see SAIC and Avocet (2002). It should be noted that these SQV sets were calculated using different data sets from that used to calculated the FPM SQVs, as well as from each other. In addition, they include a variety of different bioassay endpoints, which are generally a subset of those used for the FPM, but may include some species that are regionally different from those used for the FPM. Finally, they are generally calculated on a combined-endpoint basis, while the FPM values are calculated (like the AET values) for individual endpoints. Nevertheless, these existing SQV sets are the only other alternatives available for regulatory use, so it is important to provide a comparison of reliability, subject to these caveats.

The reliability of the existing SQV sets for this data set was determined by entering the numerical values for each SQV set into the test row of the model calculation spreadsheets, and calculating the number of correct predictions of toxicity and non-toxicity, as well as false positives and false negatives.

The results are shown underneath each part of Tables 4-2 and 4-3 below for ease of comparison. The following observations can be made:

- At the SQS/SL1 level, the false positives for the existing SQV sets are typically in the 75-95% range, 2-3 times higher than those of the FPM values at an equivalent false negative level. Overall reliability of the existing SQV sets is low, in the 15-45% range, compared to 70-95% for the proposed FPM values. None of the existing SQV sets had a combination of sensitivity, efficiency, and overall reliability that fell within the workgroup's reliability goals for any test, in contrast to the FPM values.

- At the CSL/SL2 level, the existing SQV sets had at least twice the false positive rate of the FPM values, but often had twice the false negative rate as well. Overall reliability was typically 10-30% lower than the FPM values. In only two cases did an existing SQV set come within 5% of the reliability goals set by the workgroup.

Therefore, the FPM values represent a significant improvement in reliability over the available SQVs at both the upper and lower effects levels.

Table 4-2. Reliability of the FPM Results and Existing SQV Sets at the SQS/SL1 Level

Legend for all tables:

(yellow)	Does not meet reliability goals
(light green)	Borderline reliability (within 5% of goals)
(blue)	Meets reliability goals
(hatched blue)	Meets reliability goals; selected for development of SQVs

FPM FN Percentiles – False negative target for the modeling run

SQVs – Existing Sediment Quality Guidelines:

ERL - Effects Range Low, TEL - Threshold Effects Levels, TEC - Threshold Effects Concentrations, LEL - Lower Effects Levels, ERM - Effects Range Median, PEL - Probable Effects Levels, PEC - Probable Effects Concentrations, and SEL - Severe Effects Levels

a. *Chironomus* 10-day growth

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.6	44.8	95.4	55.2	23.1	98.8	60.2
10	9.2	35.9	90.8	64.1	26.3	98.0	67.4
15	13.8	31.7	86.2	68.3	27.7	97.2	70.5
20	20.0	17.0	80.0	83.0	40.0	96.7	82.7
25	24.6	19.6	75.4	80.4	35.3	95.9	79.8
30	29.2	13.5	70.8	86.5	42.6	95.4	84.6

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERL	6.2	85.9	93.8	14.1	13.4	94.2	24.0
TEL	4.6	91.3	95.4	8.7	12.9	93.0	19.4
TEC	7.7	79.6	92.3	20.4	14.1	94.9	29.3
LEL	9.2	88.3	90.8	11.7	12.7	90.0	21.5

b. *Chironomus* 10-day mortality

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.7	40.8	95.3	59.2	29.1	98.6	64.6
10	9.4	33.1	90.6	66.9	32.5	97.6	70.4
15	14.1	26.5	85.9	73.5	36.3	96.7	75.4
20	20.0	21.3	80.0	78.7	39.8	95.7	78.9
25	24.7	19.7	75.3	80.3	40.3	94.9	79.6
30	29.4	16.6	70.6	83.4	42.9	94.2	81.5

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERL	9.2	86.7	90.8	13.3	27.9	79.7	34.2
TEL	5.9	91.3	94.1	8.7	27.5	80.0	31.7
TEC	11.1	79.5	88.9	20.5	29.2	83.3	38.9
LEL	6.5	87.5	93.5	12.5	28.3	83.9	34.3

c. *Hyalella* 10-day mortality

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.5	59.2	95.5	40.8	34.1	96.6	54.1
10	9.0	48.0	91.0	52.0	37.9	94.7	61.5
15	14.6	35.7	85.4	64.3	43.4	93.2	69.4
20	19.1	32.5	80.9	67.5	44.4	91.7	70.8
25	24.7	28.9	75.3	71.1	45.6	90.0	72.1
30	29.2	27.1	70.8	72.9	45.7	88.6	72.4

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERL	2.8	87.5	97.2	12.5	32.0	91.4	37.7
TEL	2.8	88.3	97.2	11.7	31.8	90.9	37.2
TEC	8.3	74.7	91.7	25.3	34.2	87.8	45.1
LEL	4.6	80.9	95.4	19.1	33.3	90.7	41.8

d. *Hyalella* 28-day growth

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	3.8	52.8	96.2	47.2	47.2	96.2	63.3
10	7.7	49.1	92.3	50.9	48.0	93.1	64.6
15	11.5	41.5	88.5	58.5	51.1	91.2	68.4
20	19.2	18.9	80.8	81.1	67.7	89.6	81.0
25	23.1	17.0	76.9	83.0	69.0	88.0	81.0
30	26.9	11.3	73.1	88.7	76.0	87.0	83.5

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERL	13.8	83.3	86.2	16.7	29.0	75.5	36.4
TEL	3.4	93.7	96.6	6.3	28.9	82.4	31.8
TEC	13.8	84.6	86.2	15.4	28.6	73.9	35.4
LEL	3.4	94.1	96.6	5.9	28.8	81.3	31.5

e. *Hyalella* 28-day mortality

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.3	48.3	95.7	51.7	26.0	98.6	58.3
10	8.5	35.8	91.5	64.2	31.2	97.7	68.3
15	14.9	23.8	85.1	76.2	38.8	96.7	77.6
20	19.1	12.5	80.9	87.5	53.5	96.3	86.5
25	23.4	11.3	76.6	88.7	54.5	95.5	86.9
30	29.8	9.1	70.2	90.9	57.9	94.5	87.8

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERL	10.6	83.4	89.4	16.6	16.0	89.8	27.6
TEL	4.3	94.3	95.7	5.7	15.3	88.2	19.2
TEC	10.6	84.5	89.4	15.5	15.8	89.1	26.6
LEL	6.4	95.1	93.6	4.9	14.9	81.3	18.3

Table 4-3. Reliability of the FPM Results and Existing SQV Sets at the CSL/SL2 Level

a. *Chironomus* 10-day growth

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.1	40.8	95.9	59.2	19.5	99.3	62.7
10	8.2	34.7	91.8	65.3	21.4	98.7	67.8
15	14.3	22.3	85.7	77.7	28.4	98.1	78.5
20	18.4	12.4	81.6	87.6	40.4	97.9	87.0
25	24.5	13.7	75.5	86.3	36.3	97.2	85.3
30	28.6	12.8	71.4	87.2	36.5	96.7	85.7

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERM	14.3	41.4	85.7	58.6	17.6	97.6	61.1
PEL	18.4	42.0	81.6	58.0	16.7	96.8	60.2
PEC	30.6	29.8	69.4	70.2	19.3	95.7	70.1
SEL	40.8	23.1	59.2	76.9	20.9	94.8	75.2

b. *Chironomus* 10-day mortality

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	4.5	40.1	95.5	59.9	24.2	99.0	64.1
10	9.0	36.9	91.0	63.1	24.8	98.1	66.4
15	14.9	25.7	85.1	74.3	30.6	97.4	75.5
20	20.9	20.0	79.1	80.0	34.6	96.6	79.9
25	23.9	18.0	76.1	82.0	36.2	96.3	81.3
30	29.9	12.4	70.1	87.6	43.1	95.6	85.6

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERM	28.4	43.5	71.6	56.5	18.0	93.7	58.3
PEL	28.4	44.5	71.6	55.5	17.7	93.6	57.4
PEC	40.3	31.7	59.7	68.3	20.1	92.7	67.3
SEL	50.7	24.6	49.3	75.4	21.2	91.7	72.4

c. *Hyalella* 10-day mortality

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	3.8	60.5	96.2	39.5	20.8	98.4	47.5
10	9.6	56.4	90.4	43.6	21.0	96.5	50.3
15	13.5	45.2	86.5	54.8	24.1	96.1	59.3
20	19.2	28.0	80.8	72.0	32.3	95.8	73.2
25	25.0	24.8	75.0	75.2	33.3	94.8	75.1
30	28.8	20.7	71.2	79.3	36.3	94.3	78.1

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERM	30.8	43.6	69.2	56.4	20.8	91.7	58.2
PEL	30.8	40.4	69.2	59.6	22.1	92.1	60.9
PEC	46.2	28.7	53.8	71.3	23.7	90.3	68.9
SEL	51.9	19.4	48.1	80.6	29.1	90.4	76.0

Note: For this bioassay endpoint, the 25% false negative line was selected because it was the only line that met the reliability goals. In addition, this is a SL2/CSL endpoint; thus it is appropriate to maintain a balance between false negatives and false positives, with both being relatively low.

d. *Hyalella* 28-day growth

FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	0.0	29.9	100.0	70.1	37.5	100.0	74.7
10	8.3	16.4	91.7	83.6	50.0	98.2	84.8
15	8.3	16.4	91.7	83.6	50.0	98.2	84.8
20	16.7	13.4	83.3	86.6	52.6	96.7	86.1
25	25.0	11.9	75.0	88.1	52.9	95.2	86.1
30	25.0	11.9	75.0	88.1	52.9	95.2	86.1

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERM	50.0	45.9	50.0	54.1	6.3	94.6	53.9
PEL	50.0	49.3	50.0	50.7	5.9	94.2	50.6
PEC	61.1	35.9	38.9	64.1	6.3	94.4	62.7
SEL	55.6	30.0	44.4	70.0	8.4	95.3	68.5

e. *Hyalella* 28-day mortality

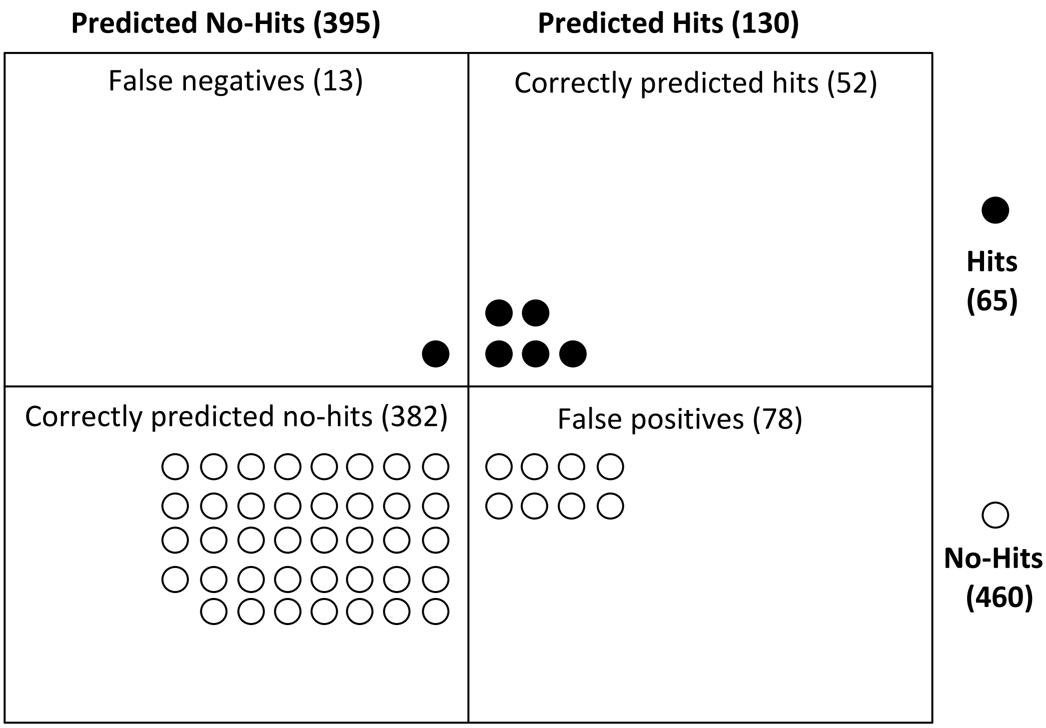
FPM FN Percentiles	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
5	3.7	11.6	96.3	88.4	44.1	99.6	89.1
10	7.4	7.7	92.6	92.3	53.2	99.2	92.3
15	14.8	4.6	85.2	95.4	63.9	98.6	94.6
20	18.5	4.2	81.5	95.8	64.7	98.2	94.6
25	22.2	3.5	77.8	96.5	67.7	97.9	94.9
30	29.6	1.8	70.4	98.2	79.2	97.2	95.8

SQVs	% False Negatives	% False Positives	% Hit Reliability	% NoHit Reliability	% PredHit Reliability	%PredNoHit Reliability	% Overall Reliability
ERM	37.0	45.3	63.0	54.7	11.6	94.0	55.4
PEL	25.9	47.7	74.1	52.3	12.8	95.5	54.2
PEC	33.3	34.0	66.7	66.0	15.7	95.4	66.0
SEL	29.6	28.1	70.4	71.9	19.2	96.2	71.8

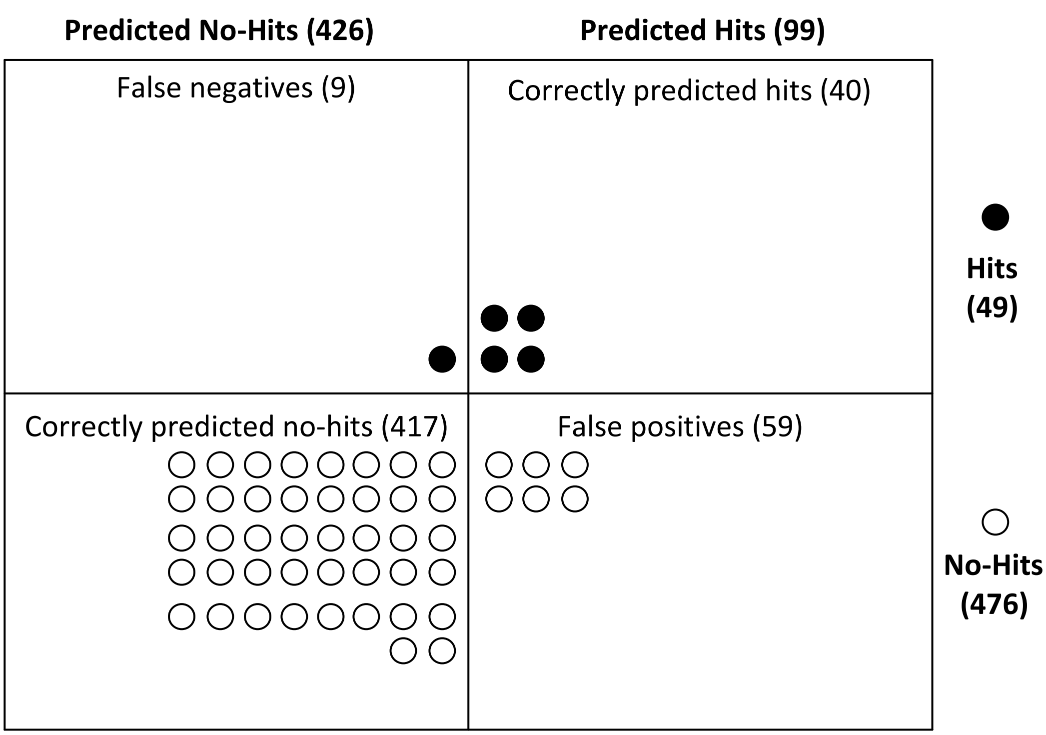
Figure 4-2. Predicted Hits and No-Hits vs. Actual Hits and No-Hits

Note: in all panels, each circle indicates approximately 10 stations

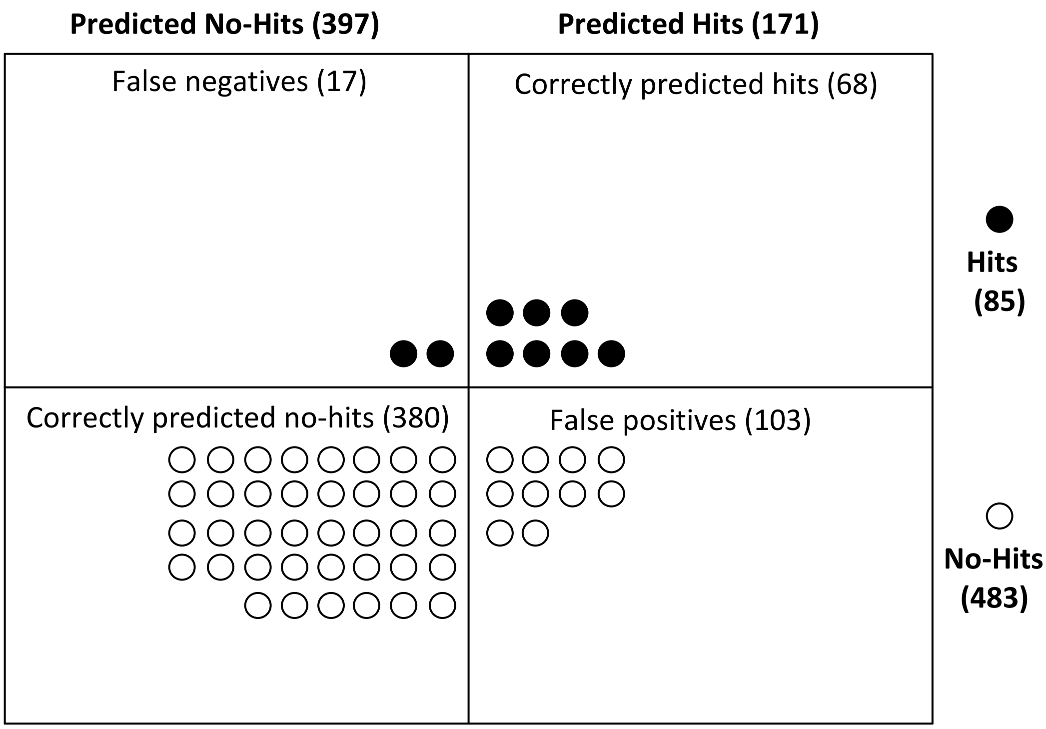
a) *Chironomus* 10-day growth SQS/SL1



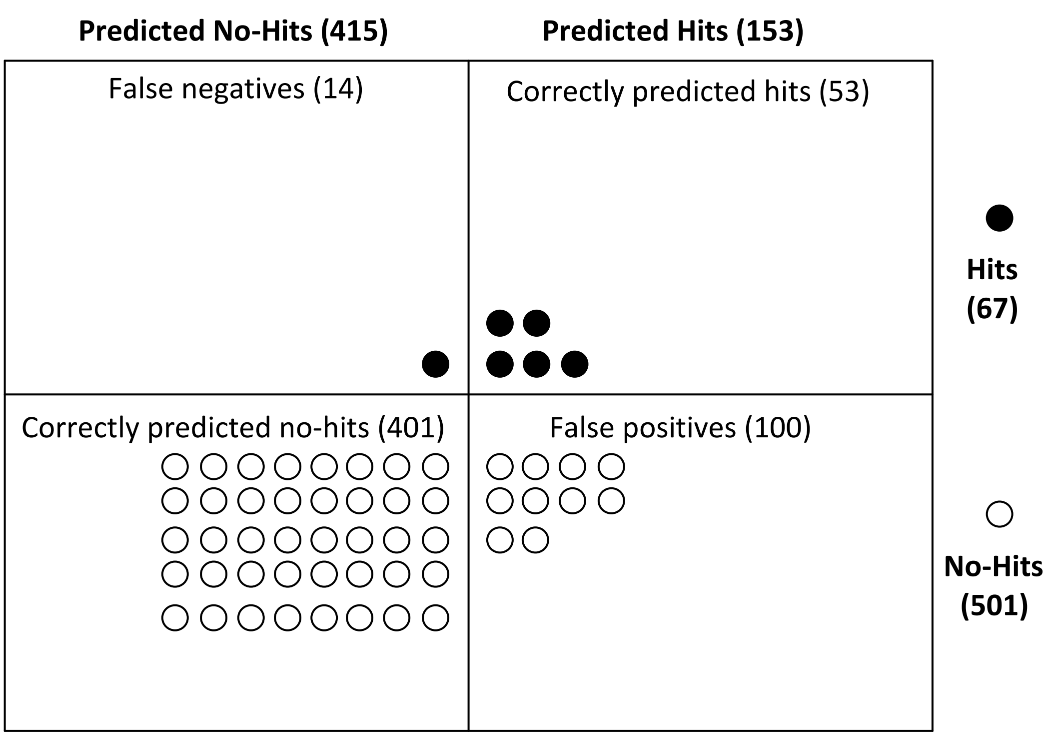
b) *Chironomus* 10-day growth CSL/SL2



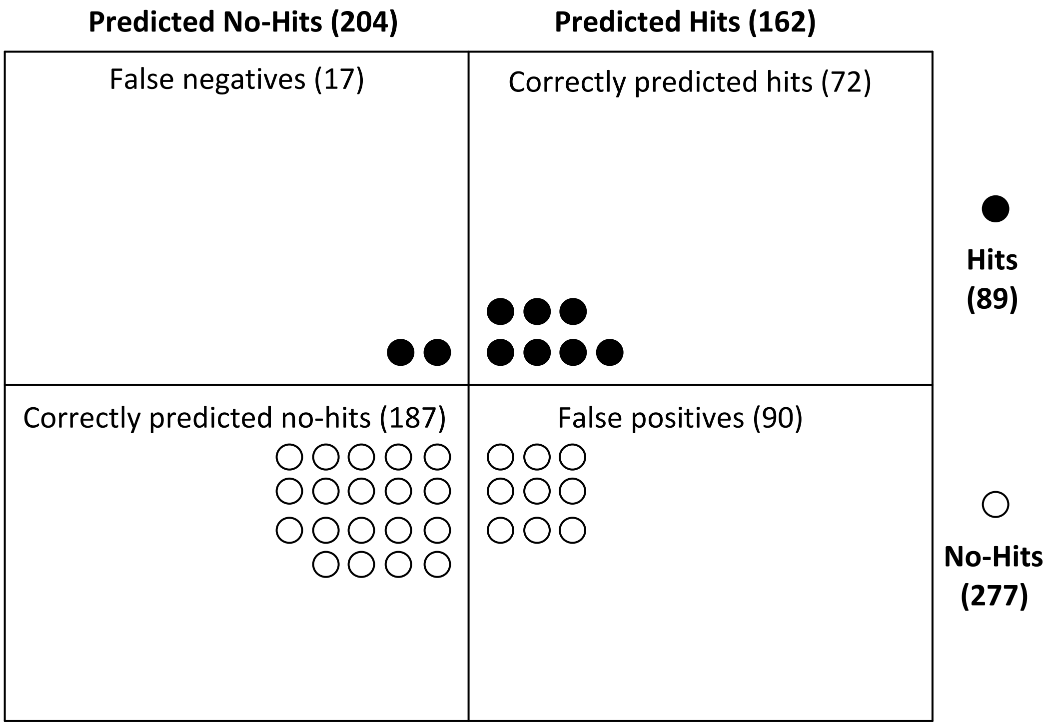
c) *Chironomus* 10-day mortality SQS/SL1



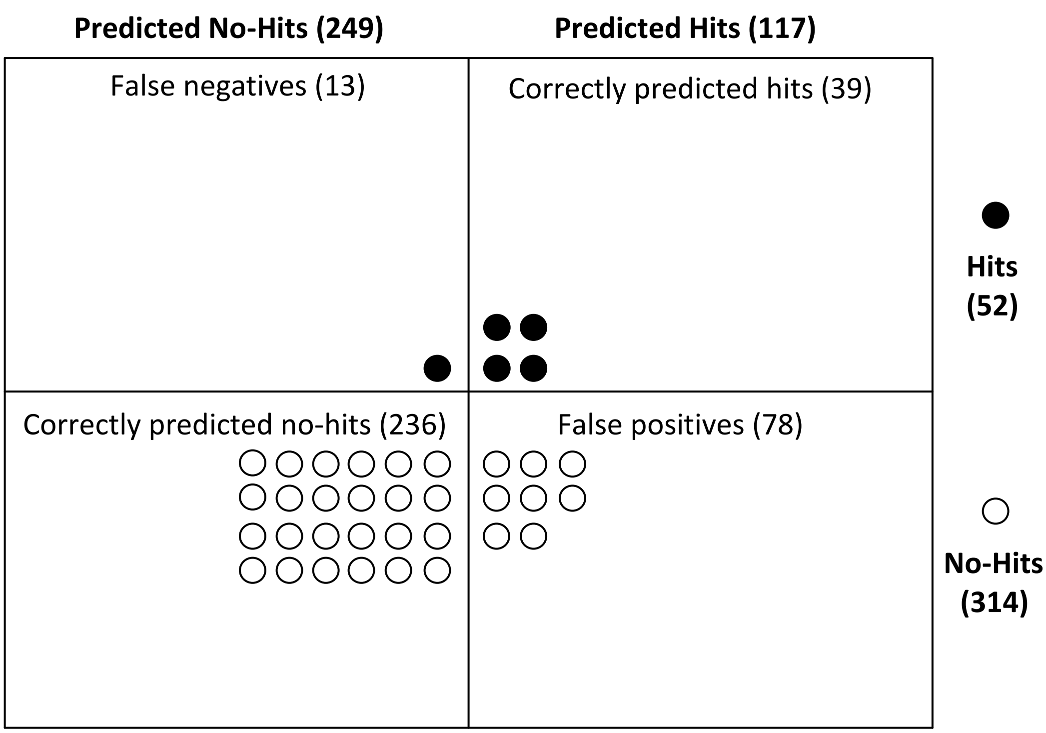
d) *Chironomus* 10-day mortality CSL/SL2



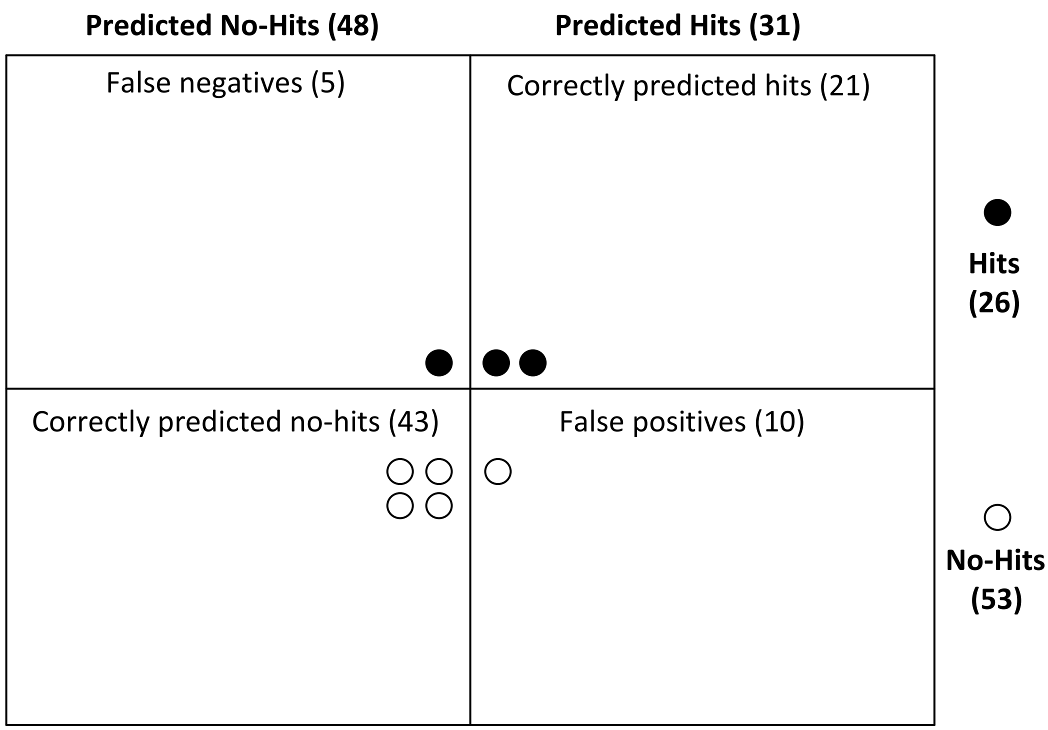
e) ***Hyalella*** **10-day mortality SQS/SL1**



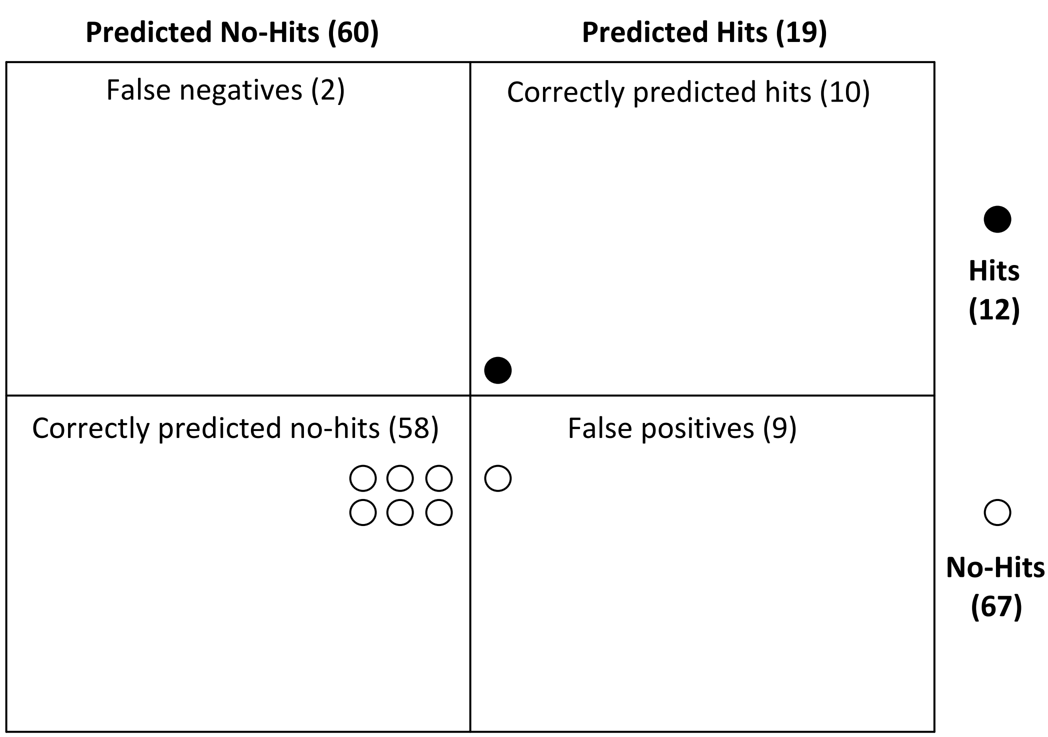
f) ***Hyalella*** **10-day mortality CSL/SL2**



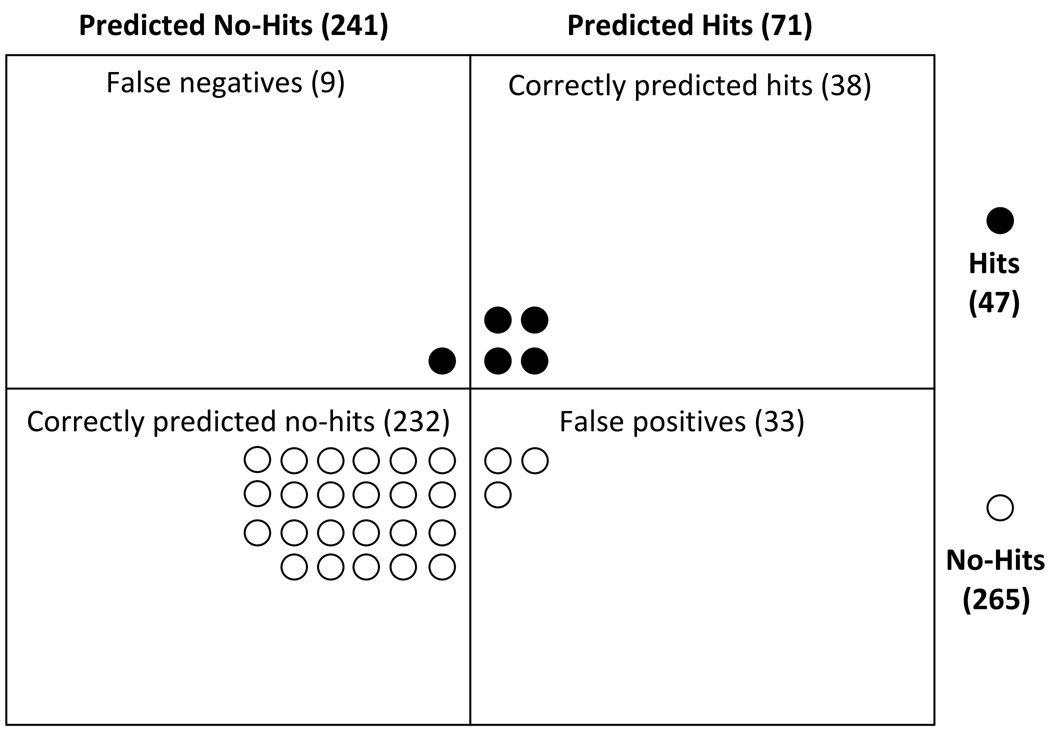
g) *Hyalella* 28-day growth SQS/SL1



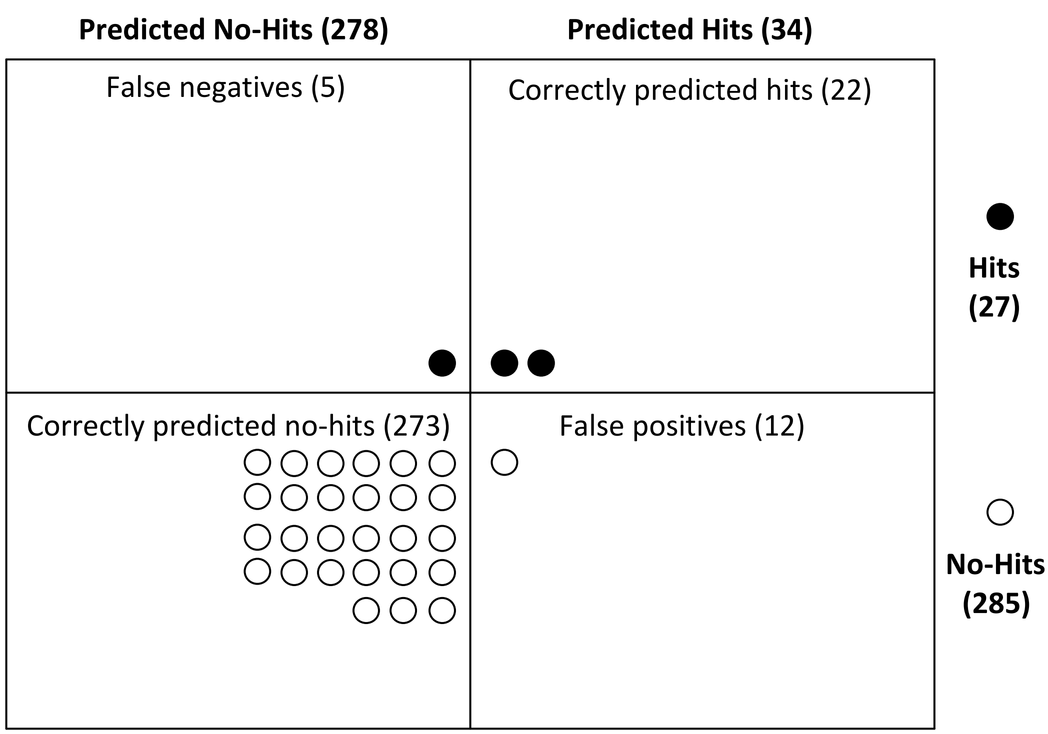
h) *Hyalella* 28-day growth CSL/SL2



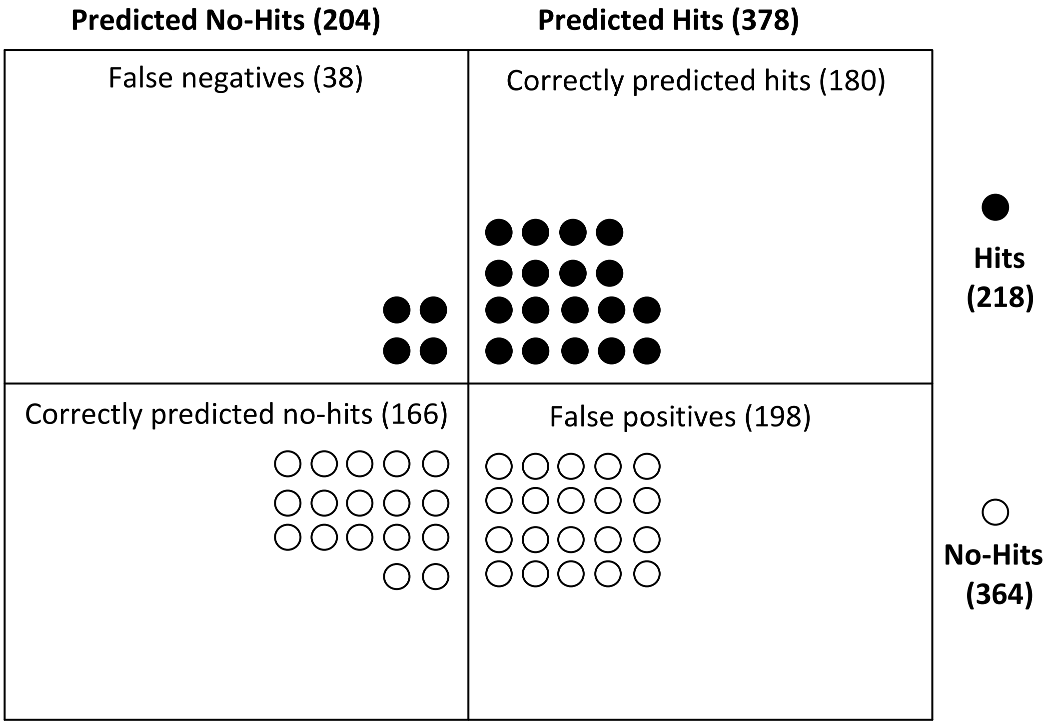
i) ***Hyalella*** **28-day mortality SQS/SL1**



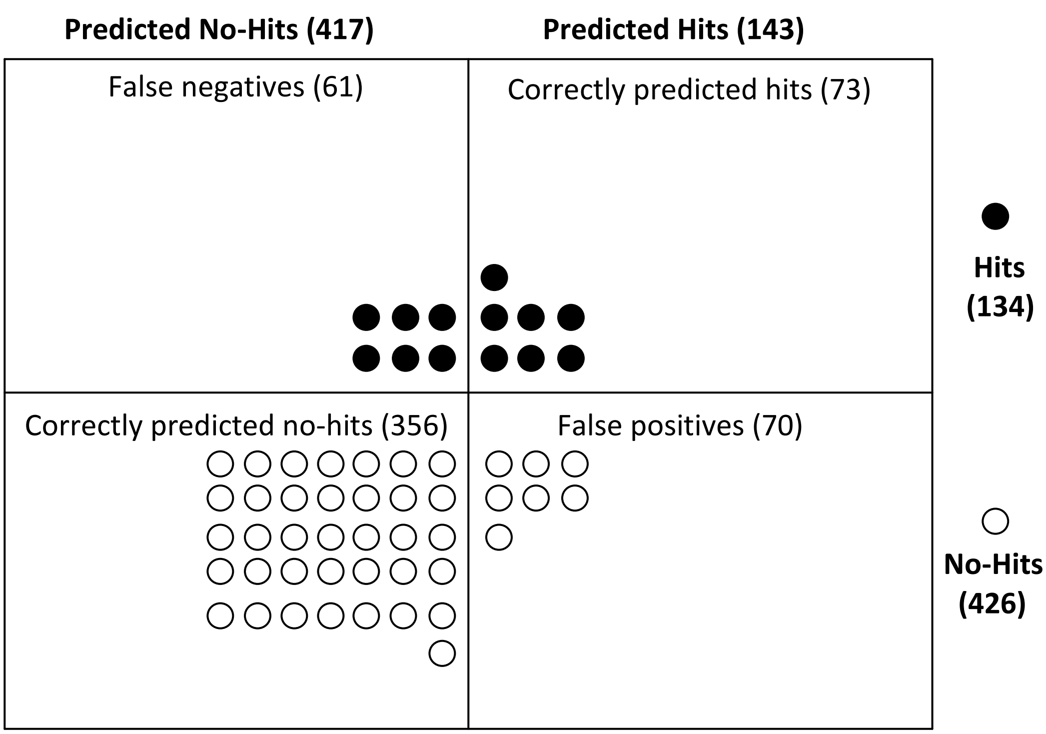
j) ***Hyalella*** **28-day mortality CSL/SL2**



k) SQS/SL1 Proposed SQVs



l) CSL/SL2 Proposed SQVs



4.3 Supplemental Statistical Analyses

In addition to the standard reliability measures described above, EPA suggested that a variety of statistical measures be used that would be less affected or not affected by the prevalence of hits and no-hits in the data set. The following additional statistical measures were agreed upon between EPA and Ecology, all of which can also be calculated using the information in Figure 4-1, including:

- Bias
- Odds ratio
- Hanssen-Kuipers Discriminant

Spreadsheets showing the calculation of these values are available as supplement electronic files, as described in Section 1.4. For each statistical measure, results are shown for both individual bioassay endpoints and the proposed SQS/SL1 and CSL/SL2 SQV sets. For statistical evaluation of the full SQG sets, only those stations that had at least three bioassay endpoints (two acute and one chronic or more) as described in the SMS were included, to avoid incorrectly identifying stations as nontoxic due to inclusion of historic data sets with less than a full suite of bioassays.

4.3.1 Bias

Bias is defined as the number of samples predicted to be toxic divided by the number of samples that are actually toxic. Thus, bias provides a simple measure of how protective a set of standards is:

- Bias > 1 indicates that the SQVs are protective and over-predict toxicity
- Bias = 1 indicates that the SQVs are appropriately predictive
- Bias < 1 indicates that the SQVs are under-protective and under-predict toxicity

Bias is calculated using the following formula, based on Figure 4-1: (B + D)/(A + B).

Bias ranged from 1.2–2.3 for all individual endpoints, and from 1.1–1.7 for the draft SQVs (Tables 4-4 and 4-5). All chronic endpoints and the proposed SQVs had lower bias than all acute endpoints. The reason for this is not known, although it may be that the chronic tests have a larger number of true hits, which may lower the bias. The proposed SQVs had an even larger percentage of true hits than the overall data set due to exclusion of no-hit stations with only one or two bioassays, which also likely lowered the bias.

Ranges of bias were comparable for the SQS/SL1 and CSL/SL2 levels among individual endpoints. However, for the proposed SQVs, the bias was on the protective side (1.7) at the SQS/SL1 level and approximately 1 at the CSL/SL2 level. This suggests that the endpoints were combined appropriately in selecting the final criteria (see Section 3.3), erring on the protective side for the SQS/SL1 and achieving a good balance at the CSL/SL2 level.

Table 4-4. Bias at the SQS/SL1 Level

Endpoint	Correctly Predicted Hits	Correctly Predicted No-Hits	False Predicted Hits	False Predicted No-Hits	Bias
CH10G	52	382	78	13	2.0
CH10M	68	380	103	17	2.0
HY10M	72	187	90	17	1.8
HY28G	21	43	10	5	1.2
HY28M	38	232	33	9	1.5
Proposed SQVs	179	173	191	39	1.7

Table 4-5. Bias at the CSL/SL2 Level

Endpoint	Correctly Predicted Hits	Correctly Predicted No-Hits	False Predicted Hits	False Predicted No-Hits	Bias
CH10G	40	417	59	9	2.0
CH10M	54	375	126	13	2.3
HY10M	39	236	78	13	2.3
HY28G	10	58	9	2	1.6
HY28M	22	273	12	5	1.3
Proposed SQVs	47	352	74	60	1.1

4.3.2 Odds ratio

The odds ratio indicates the strength of a prediction, either for a given chemical or for a group of SQVs. The odds ratio is calculated as the likelihood that a prediction that a sample is toxic or nontoxic is correct over the likelihood that the prediction is incorrect. The odds ratio is calculated using the following equation based on Figure 4-1: (B + C)/(A + D). Thus, an odds ratio of 5 indicates that if there is a prediction of toxicity, the sample is 5 times more likely to actually be toxic than not. A higher odds ratio indicates stronger predictive capability.

The odds ratios range from 9–15 for acute mortality endpoints, and from 18–100 for chronic and growth endpoints (Table 4-6), suggesting that exceedance of SQVs for acute mortality endpoints is less likely to be predictive of true toxicity than exceedance of SQVs based on chronic or growth endpoints. Nevertheless, these odds ratios are relatively high for all individual endpoints, resulting in about a 1–10% chance of not seeing an effect when one is predicted.

The proposed SQVs have somewhat lower odds ratios, indicating that they are somewhat more protective than the values for the individual bioassays. The SQVs for both SQS/SL1 and CSL/SL2 levels have odds ratios of roughly 4:1–6:1, suggesting an 80–85% likelihood of exceeding the biological standards given a chemical SQV exceedance. These odds are in line with the policy goals used to calculate the guideline (80% overall accuracy, maximum of 20% false negatives and 20% false positives).

Table 4-6. Odds Ratios[a]

Endpoint	SQS/SL1	CSL/SL2
CH10G	20	31
CH10M	15	15
HY10M	8.8	9.1
HY28G	18	32
HY28M	30	100
Proposed SQVs	4.0	6.1

[a] The number of correct and false hits and no-hits are the same as shown in Tables 4-4 and 4-5.

4.3.3 Hanssen-Kuipers Discriminant

The Hanssen-Kuipers Discriminant is used to evaluate the fit of a model, and is frequently used to evaluate logistic regression models (but can be used for any model). The Hanssen-Kuipers Discriminant is a less general version of the Kappa statistic, and is used in cases where the prevalence of hits and no-hits in the data set is skewed. The Hanssen-Kuipers Discriminant is calculated using the following equation based on Figure 4-1: $((B \times C) – (A \times D))/((A + B) \times (C + D))$.

This statistic is believed to be unaffected by prevalence and ranges from 0–1. Like r^2, a Hanssen-Kuipers Discriminant value closer to 1 represents a better fit to the data. The following framework has been proposed in the epidemiological literature for interpreting model fit; however, this classification scheme is somewhat arbitrary and may or may not translate well to environmental data:

> κ between .01–.20 = slight
> κ between .21–.40 = fair
> κ between .41–.60 = moderate
> κ between .61–.80 = substantial
> κ between .81–1 = nearly perfect

The results for the Hanssen-Kuipers Discriminant suggest models with “moderate” or “substantial” fits for each individual endpoint (Table 4-7). The best fits are again for the growth and chronic endpoints, with slightly lower values for the acute toxicity endpoints. The proposed SQVs have results suggestive of “fair” fits, with a somewhat better fit at the CSL/SL2 level. However, these represent combined SQVs that were not calculated using the FPM model, but were instead developed by the agencies through selecting the lowest or second-lowest of the individual endpoint values. Having not been developed using a modeling process, it may not be reasonable to expect the higher degrees of fitness to the data that the individual endpoints show. In addition, stations included in the proposed SQV assessments varied in the number and type of bioassays endpoints at each station, which may have reduced the fit.

Table 4-7. Hanssen-Kuipers Discriminants[a]

Endpoint	SQS/SL1	CSL/SL2
CH10G	0.63	0.69
CH10M	0.59	0.59
HY10M	0.48	0.50

HY28G	0.62	0.70
HY28M	0.68	0.77
Proposed SQVs	0.28	0.38

[a] The number of correct and false hits and no-hits are the same as shown in Tables 4-4 and 4-5.

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5. Selection of THE SQVs

5.1 Regulatory Considerations

Two effects levels were developed for each bioassay endpoint, one corresponding to the SQS/SL1 and one corresponding to the CSL/SL2. According to the statutory definition, SQS/SL1 represents a no acute or chronic adverse effects level and this is established as the minimum detectable difference from control, and CSL/SL2 represents a minor adverse effects level.

In the Washington State Sediment Management Standards, the SQS serves as the long-term goal for sediments of the state, and the lower end of the range within which cleanup standards for a site can be selected. The CSL serves as the level above which cleanup sites are designated, and also serves as the upper end of the range within which cleanup standards for a site may be selected, based on balancing environmental protectiveness, cost, and technical feasibility. Thus, a cleanup standard for any given site may be set within a range of allowable adverse effects from the SQS to the CSL, depending on site-specific considerations. This regulatory framework is the same for both freshwater and marine standards, and thus the approach used to develop the freshwater SQVs was as similar as possible to the marine standards in terms of overall structure, level of protectiveness, and biological effects interpretive guidelines.

For all dredging projects in the RSET program, the SL1 serves as the threshold above which biological testing is required to allow open water disposal, and below which open water disposal is permitted without biological confirmation.

As with the marine SQVs, the proposed freshwater SQVs were specifically developed to provide an appropriate balance of sensitivity and efficiency (i.e., balancing false negatives and false positives) on a per-sample basis, while retaining a low enough false negative rate to ensure that contaminated sites would be identified given the amount of data typically available for site identification purposes. To ensure that the SQVs are adequately protective, they will be applied within a regulatory framework that includes the option of conducting bioassays as a confirmatory or override step, or simultaneously with chemical analyses. The suite of bioassays and interpretive endpoints used to develop the SQVs will also be used to interpret the bioassay results to ensure consistency and maximize the reliability of the SQV predictions, although as additional freshwater bioassays are developed over time, the agencies may choose to apply them as appropriate.

The freshwater SQVs were developed to protect populations of benthic communities in sediments, given the wide natural variation in species abundance and richness seasonally and from year to year that exists, especially in freshwater systems. NOAA and USF&W were members of the RSET workgroup and accepted the task of determining whether the SQS/SL1 approach was protective of individual ESA-listed benthic species. NOAA and USF&W representatives reported to the workgroup that there were no listed benthic species in WA, OR, or ID that were present in areas where dredging or cleanup was likely to be conducted (personal communication to Keith Johnson, OR DEQ by Jeremy Buck, US F&W by e-mail, June 12, 2007). Therefore, lower values to protect individual ESA-listed benthic species were not developed.

5.2 Technical Approach

As noted above, the model was run for each individual bioassay endpoint separately, at two effects levels corresponding to SQS/SL1 and CSL/SL2. This approach is desirable because it preserves information about bioassay endpoint sensitivity and reliability, the relationships between bioassay endpoints, and associations between chemicals and toxicity for different endpoints. In addition, it reduces potential problems with combining historic toxicity data with variations among data sets in the bioassay endpoints and chemical analytes at each station, number and variability of replicates, etc.

However, differences in the SQVs between bioassays proved to be much larger than differences between the SQS/SL1 and CSL/SL2 levels for any one bioassay endpoint. Therefore, all of the values in Tables 3-1 and 3-2 were combined into a single distribution for each chemical from which the final SQVs would be selected. This distribution reflects the range of SQVs from the lowest no-effects level to the highest minor effects level. Each chemical had between 4 and 10 values, depending on the number of bioassay endpoints for which an FPM value could be developed for that chemical.

The following method was chosen by Ecology for setting the proposed SQVs:

- **SQS/SL1 –** Select the lowest value for each chemical.
- **CSL/SL2** – Select the next highest significantly different value (>20% higher than the SQS/SL1).

This approach provides conservative values by remaining at the low end of the no-adverse-effects to minor-adverse-effects distribution, while still providing a degree of distance between the two levels for regulatory flexibility in decision-making. A 20% difference between the upper and lower values was chosen to reflect a typical analytical relative percent difference (RPD), and ensures that these values can be distinguished given the typical precision of available analytical methods. The degree of conservatism of these final values was evaluated in Section 4.3.1 and found to appropriately reflect Ecology's policy goals.

5.3 Proposed SQVs

The proposed SQVs based on the approach described above are shown in Table 5-1. For some chemicals, only an SQS/SL1 could be established; the remaining concentrations were all "greater than" values. This suggests that, for these chemicals, only low levels of effects are observed within the concentration range included in this data set. Higher levels of effects may be observed above the "greater than" value. Therefore, that value has been included for site managers' information. At levels above those observed in this data set, bioassays should be run to identify the presence or absence of higher levels of adverse effects.

The values in Table 5-1 are proposed SQVs, based on the many selections and method assumptions outlined in this report. Alternative choices could be made based on public and agency review that may change the SQVs. In addition, implementing agencies and programs may choose to adopt all or only some of the SQVs shown in the table, depending on their program priorities. The final decisions on how to proceed will be made by Ecology, RSET, and the other agencies and programs that may choose to use these values, following appropriate public review and comment.

Table 5-1. Proposed Sediment Quality Values

Analyte	SQS/SL1	Source[a]	CSL/SL2	Source[a]
Conventional Pollutants (mg/kg)				
Ammonia	230	HY28M	300	HY28M
Total sulfides	39	CH10G	61	HY28M
Metals (mg/kg)				
Antimony[b]	0.3	HY10M	12	HY28M
Arsenic	14	HY28G	120	CH10G/CH10M
Cadmium	2.1	CH10M	5.4	HY28M
Chromium	72	HY28G	88	CH10G
Copper	400	HY28G	1200	HY28G
Lead	360	CH10G	> 1300	HY10M
Mercury	0.66	HY28G	0.8	CH10M/HY10M
Nickel	26	HY28G	110	CH10G
Selenium	11	HY28G	> 20	CH10G/HY28M
Silver	0.57	CH10G	1.7	HY28M
Zinc	3200	HY28G/HY28M	> 4200	HY10M
Organic Chemicals (µg/kg)				
4-Methylphenol	260	HY28M	2000	CH10M
Benzoic acid	2900	CH10M	3800	HY10M
beta-Hexachlorocyclohexane	7.2	CH10G	11	CH10M/HY28M
bis(2-Ethylhexyl)phthalate	500	HY10M	22000	HY10M
Carbazole	900	CH10M	1100	CH10M
Dibenzofuran	200	CH10G	680	CH10M/HY28M
Dibutyltin	910	CH10G/CH10M	130000	HY10M
Dieldrin	4.9	CH10G/CH10M	9.3	CH10M
Di-n-butyl phthalate	380	CH10G	1000	HY28M
Di-n-octyl phthalate	39	HY10M	> 1100	CH10G
Endrin ketone	8.5	CH10G/CH10M/HY28M	**	
Monobutyltin	540	CH10G/CH10M	> 4800	HY10M
Pentachlorophenol	1200	HY10M	> 1200	CH10G/CH10M
Phenol	120	HY28M	210	CH10M/HY28M
Tetrabutyltin	97	CH10G/CH10M	> 97	HY28M
Total DDDs	310	HY10M	860	CH10G
Total DDEs	21	HY10M	33	CH10M
Total DDTs	100	CH10M	8100	CH10M/HY28M
Total PAHs	17000	CH10G/HY10M	30000	CH10G
Total PCB Aroclors	110	HY10M	2500	HY10M
Tributyltin	47	HY10M	320	CH10M
Bulk Petroleum Hydrocarbons (mg/kg)				
TPH-Diesel	340	CH10M	510	CH10G/CH10M
TPH-Residual	3600	CH10M	4400	CH10G

SQS/SL1 = Sediment Quality Standard/Screening Level 1, CSL/SL2 = Cleanup Screening Level/Screening Level 2.
> “Greater than” value indicates that the toxic level is unknown, but above the concentration shown.
** No SQV could be set due to limited data above the SQS/SL1 concentration.
[a] CH10G = *Chironomus* 10-day growth, CH10M = *Chironomus* 10-day mortality, HY10M = *Hyalella* 10-day mortality, HY28G = *Hyalella* 28-day growth, HY28M = *Hyalella* 28-day mortality.
[b] Not recommended for promulgation at this time; see Section 5.4.

5.4 Implementing the SQVs

The following information is provided to assist site managers and the regulated community in interpreting the values in Table 5-1, as well as to describe how to address chemicals not included in the table if found in sediments at a site or dredging project.

- **Chemicals not Included in Standard Analyte Lists.** For scientific or programmatic reasons, agencies may decide not to include all of the chemicals in Table 5-1 in their regulations, guidance, or standard analyte list. However, in that case, the values in this table provide useful guidance should one of these chemicals prove to be of concern for a specific site or project. At this time, Ecology is proposing not to include ***antimony*** in the SMS list, due to known issues with the analytical methods, a high level of false positives, and the SQS/SL1 value being below background. Removal of antimony affects correct identification of toxicity for only one station at the CSL level in the data set; thus, its removal is not expected to have a significant impact on identification of sites or dredged sediments with toxicity.

- **Background Concentrations.** The values in Table 5-1 can be considered risk-based values for the benthic community. However, the SMS and dredging guidance provide that if natural background concentrations are higher than the risk-based values, the background values may be used instead. Currently, Ecology is aware of one chemical on the list, ***antimony***, whose SQS/SL1 value may be below state-wide and/or local background concentrations. The Portland District Corps of Engineers has also reported that the SQS/SL1 value for ***nickel*** may be below background in some areas of Oregon. In specific areas such as those influenced by mining, regional geochemical concentrations for other metals may be higher than the SQS/SL1 values shown; this would need to be determined on a site-specific basis. Due to the modeling methodology used, none of the CSL/SL2 values are expected to be below background.

- **Practical Quantitation Limits (PQLs).** All detected concentrations above the method detection limit (MDL) were used for modeling. However, the SMS provides that the PQL will be used if it is higher than the risk-based value. At this time, Ecology is aware that the PQL may be higher than the SQS/SL1 for ***di-n-octyl phthalate*** and ***phenol***. As these SQS/SL1 values are higher than the MDL but lower than the PQL, the PQL may decline over time through analytical advances to below the risk-based value. Until then, the PQL should be used for regulatory decision-making at the SQS/SL1 level. None of the CSL/SL2 values are below the PQL.

- **Greater Than (>) Values.** As noted above, some chemicals have an SQS/SL1 value but only a "greater than" value at the CSL/SL2 level. These chemicals include ***lead, selenium, zinc, di-n-octyl phthalate, Endrin ketone, monobutyltin, pentachlorophenol,*** and ***tetrabutyltin***. Higher levels of effects may be observed above the "greater than" value than were present in this data set. Therefore, the "greater than" value has been included for site managers' information. At levels above those seen in this data set, bioassays should be run to identify the presence or absence of higher levels of adverse effects.

- **Chemicals of Low Concern for Benthic Toxicity.** The model also identified a number of analytes that were not associated with toxicity in the data set for any endpoint, or that had "greater than" values for all bioassay endpoints and effects levels. These chemicals are not considered of significant concern to benthic organisms within the concentration range found in the data set, and include: ***Aldrin, butyl benzyl phthalate, dimethyl phthalate, dioxins/furans, gamma-hexachlorocyclohexane, hexachlorobenzene, hexachloroethane, methoxychlor, retene, total chlordanes,*** and ***total Endosulfans***. The maximum concentrations of these chemicals observed in the data set are listed in Appendix B, Table B-3. Above the levels presented in Table B-3, the toxicity of these analytes is unknown, and bioassay tests should be run.

- **Nontoxic Analytes and Derived Quantities.** Several frequently reported analytes and derived quantities were not included in the modeling because they are not considered toxic chemicals under circumstances commonly encountered in sediments. However, there may be rare situations where these metals are toxic or contribute to toxicity (e.g., mining sites). These include ***grain size parameters, total solids, acid volatile sulfides, aluminum, beryllium, calcium, iron, magnesium, manganese, potassium, sodium,*** and ***vanadium***. ***TEQs*** of any kind are also derived quantities, usually associated with toxic mechanisms in vertebrates and calculated for higher trophic level risk assessments that do not apply to benthic organisms. These analytes and derived quantities generally do not present risks to the benthic community (exceptions are possible for highly concentrated waste materials).

- **Total Organic Carbon.** Although ***TOC*** is not itself an analyte of concern and was not included in the model, excessive TOC may cause high levels of ammonia and sulfides in sediments, which are analytes of concern, and/or may create an inappropriate substrate for benthic life if the TOC is anthropogenic in origin (Kendall and Michelsen 1997). In that case, the source of the high TOC would be treated as a deleterious substance or waste material.

- **Other Chemicals.** A variety of other chemicals have been analyzed in sediments but were not found at sufficient stations to warrant development of SQVs. If a chemical is not in Table 5-1 or on any of the lists above, it likely falls in this category. A complete list of chemicals with <30 detections is listed in Appendix B, Table B-1. If a chemical is not found on any of the lists above or in Table B-1, it was either never analyzed for or never detected in the data set. If a site or dredging project includes frequent detections or high levels of any such chemicals, bioassay tests should be run to evaluate their toxicity.

- **Applicability to Unique Sites.** There are sites where unique geochemical conditions warrant initial testing using bioassays. While the SQVs are developed from data representative of the majority of freshwater sediment sites encountered in the northwest, it is recognized that benthic toxicity at sites with unique geochemical characteristics will differ and the SQVs are not representative of those sites (e.g., bogs, alpine wetlands, sites with mining, milling or smelting activities, substantial waste deposits, or sites with unique pH, alkalinity, or other geochemical characteristics). Freshwater bioassays should be used to assess toxicity under these conditions.

6. Conclusions

In summary, the following observations and conclusions can be drawn:

- **Synoptic Bioassay/Chemistry Data Set.** The freshwater data set is considerably larger and more diverse in terms of both chemistry and bioassays than it was in 2003, and has been improved from a quality assurance standpoint. The current database allows calculation of FPM values for three acute and two chronic endpoints.

- **Geographic Representativeness.** Data sets were collected from western Washington and Oregon and from eastern Washington. No data were identified in eastern Oregon or Idaho that included synoptic bioassay and chemistry data. The data set encompasses a wide variety of different types of environments, including large and small lakes on both sides of the Cascades, large rivers on both sides of the Cascades such as the Duwamish, Willamette, Columbia, and Spokane Rivers, and small streams.

- **Sensitivity, Efficiency, and Reliability.** Use of the floating percentile method results in endpoint-specific SQVs with a sensitivity of 75-80%, efficiency of 65-95%, and overall reliability of 70-85%, depending on the specific endpoint and effects level. Additional statistical analyses confirmed that the SQS/SL1s were appropriately, but not unreasonably, biased on the protective side, and that the CSL/SL2s were evenly balanced between false positives and false negatives. The models for the individual endpoints were found to have a good fit to the data.

- **Comparison to Existing SQVs.** Compared to other SQV sets available for use, the FPM values represent a substantial improvement in efficiency and overall reliability for comparable false negative rates. In addition, at the higher effects levels, the FPM values are also more sensitive than the existing SQV sets.

- **Recommended SQVs.** Based on the conclusions above and the results of the reliability and statistical analyses, SQVs for both the SQS/SL1 and the CSL/SL2 levels are proposed for public review and adoption. The method provides the opportunity for revision of these values if alternative policy choices regarding sensitivity and efficiency are made during the agency and public review process. The method also allows site-specific values to be calculated for unusual or large sites.

- **Benthic Toxicity Only.** These values were developed to protect against toxicity to the benthic community only. They are not protective of bioaccumulative effects to humans, wildlife, or fish.

- **Additional Information for Site Managers.** Additional information on how to implement these values and considerations for sites with unique geochemistry is included in Section 5.4 and Appendix B, including lists of chemicals that were screened out and the reasons for doing so, and how to evaluate chemicals that do not have recommended SQVs.

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APPENDIX A. LIST OF SURVEYS

		Bioassay Endpoints[b]					Analyte Classes[c]								
State (E/W)[a]	Survey	CH10G	CH10M	HY10M	HY28G	HY28M	CON	MET	SV	VOL	CL	PP	DF	TPH	Reference
OR (W)	CBSLOUGH	0	0	20	0	0	X	X	X			X			Columbia Slough Sediment Analyses and Remediation Project, Phase 1 Report, Dames & Moore for City of Portland, 1991
OR (W)	FWDMMP05	26	26	26	0	0	X	X	X		X	X			Sediment Characterization Report, Lower Willamette River Federal Navigational Channel, Corps of Engineers, 2005
OR (W)	FWJSLK04	8	8	8	0	0	X	X	X			X		X	Johnson Lake Site Investigation Report, Arcadis for Owens-Brockway Glass Container, Inc., 2004
OR (W)	FWPHBR04	227	233	0	0	233	X	X	X	X	X	X	X	X	Portland Harbor Remedial Investigation Round 2 Data, Lower Willamette Group, 2004
OR (W)	FWTEKX07	13	13	13	0	0	X	X	X						Tektronix Site Remedial Investigation, Phase III, Windward Environmental, 2007
OR (W)	FWWRSD04	21	21	21	21	21	X	X	X			X			Willamette River Federal Navigation Channel O&M Sediment Characterization Report, Corps of Engineers, 2004
OR/WA (W)	LCBWRS93	0	0	15	0	0	X	X	X			X			Lower Columbia River Backwater Reconnaissance Survey, TetraTech for Lower Columbia River Bi-State Program, 1994
OR (W)	MBCREOS3	43	43	43	0	0	X	X	X						McCormick & Baxter RD Phase I Sediment Survey, Oregon DEQ, 2002
OR (W)	MBCREOS4	17	18	18	0	0	X	X	X						McCormick & Baxter RD Phase II Sediment Survey, Oregon DEQ, 2002
OR (W)	PPTLDT24	4	4	4	0	0	X	X	X			X			Sediment Characterization Study, Marine Terminal 2 Berths 203-206 and Marine Terminal 4 Berth 416, Hart Crowser for Port of Portland, 1999
OR (W)	PSYD&M97	0	0	3	0	0	X	X	X			X			Portland Shipyard Environmental Audit, Dames & Moore for Cascade General, 1998
OR (W)	PSYSEA98	55	55	55	0	0	X	X	X			X			Portland Shipyard Sediment Investigation Data Report, Striplin Env. Assts. for Port of Portland, 1998
OR (W)	ROSSIS99	11	11	11	0	0	X	X	X	X	X	X		X	Ross Island Facility Site Investigation, Hart Crowser for Port of Portland, 2000
OR (W)	TOSCO99	2	2	2	0	0	X	X	X			X			TOSCO Portland Terminal, 1999 Sediment Sampling Results, Portland District Corps of Engineers, 1999
OR (W)	WILREF02	3	3	3	0	0	X	X	X	X		X		X	Willamette Reference Survey, Hart Crowser for the Portland District Corps of Engineers, 2002
OR (W)	WLRPT498	18	18	18	0	0	X	X	X			X			Terminal 4 Slip 3 Sediment Investigation, Hart Crowser for Port of Portland, 1998
OR (W)	WRD&M98	0	0	2	0	0	X	X	X						Portland Shipyard Environmental Audit, Dames & Moore for Cascade General, 1998
WA (E)	BOISECAS	0	0	4	0	0	X	X	X						Class II Inspection of the Boise Cascade Pulp and Paper Mill Wallula Washington, WA Dept. of Ecology EILS, 1993
WA (E)	FWSPOR00	0	0	0	8	8	X	X	X			X			Chemical Analysis and Toxicity Testing of Spokane River Sediments Collected in October 2000, WA Dept. of Ecology EAP, 2001
WA (E)	FWUPCR05	50	50	0	50	50	X	X	X			X	X		Upper Columbia River Site CERCLA RI/FS, CH2M Hill for US EPA Region 10, 2005
WA (E)	SPOKNR94	0	0	3	0	0	X	X	X						Spokane River PCB Study, WA Dept of Ecology EILS, 1994
WA (W)	CARGIL01	0	3	3	0	0	X	X	X			X			Cargill Irving Elevator Terminal, Cargill Irving, 2001
WA (W)	CEDARIV	0	0	5	0	0	X	X	X						Sediment Sampling and Analysis Report Cedar River Delta Sediments, Golder Assts. for City of Renton, 1992
WA (W)	FWLKUN01	5	4	4	0	0	X	X	X		X	X		X	Lake Union Sediment Study, King County DNR, 2001
WA (W)	LKUNDRDK	0	0	4	0	0	X	X	X			X			Sediment Monitoring Program Results Lake Union Drydock Company, Hart Crowser, 1992
WA (W)	LKUNION	0	0	9	0	0	X	X	X			X			Survey of Contaminants in Lake Union and Adjoining Waters, WA Dept. of Ecology EILS, 1989
WA (W)	LKWA00	0	28	28	0	0	X	X	X			X			Lake Washington Baseline Sediment Study, King County, 2000
WA (W)	LUUCSO00	0	6	6	0	0	X	X	X			X			Lake Union University Regulator CSO Post Separation Study, King County, 2000
WA (W)	QUEBAX1	0	0	4	0	0	X	X	X						Distribution and Significance of PAHs in Lake Washington Sediments Adjacent to Quendall Terminals, WA Dept. of Ecology EILS, 1991
WA (W)	QUEBAX3	0	0	3	0	0	X	X	X						Results of Sediment Sampling in the JH Baxter Cove Lake Washington, WA Dept. of Ecology EILS, 1992
WA (W)	SALIII97	22	22	22	0	0	X	X	X			X			Salmon Bay Results of Phase III Sampling, WA Dept of Ecology EAP, 2000
WA (W)	SEACOM94	0	0	3	0	0	X	X	X			X			Sediment Sampling Report Seattle Commons Parcel C Seattle, Washington, 1994
WA (W)	TRI-STAR	0	0	3	0	0	X	X	X			X			Tri-Star Marine NPDES Sediment Monitoring, Beak Consultants, 1997
WA (W)	WEYLONG	0	0	3	0	0	X	X	X						Class II Inspection of Weyerhaeuser Longview Pulp and Paper Mill, WA Dept. of Ecology EILS, 1991
		525	**568**	**366**	**79**	**312**									

[a] OR = Oregon, WA = Washington, E = east of the Cascade Mountains, W = west of the Cascade Mountains.
[b] CH10G = Chironomus 10-day growth, CH10M = Chironomus 10-day mortality, HY10M = Hyalella 10-day mortality, HY28G = Hyalella 28-day growth, HY28M = Hyalella 28-day mortality.
[c] CON = conventionals, MET = metals, SV = semivolatiles, CL = chlorinated hydrocarbons, TPH = total petroleum hydrocarbons, VOL = volatiles, PP = pesticides/herbicides, polychlorinated biphenyls (Aroclors), DF = dioxins/furans

APPENDIX B

DATA SCREENING

Section 2.2 describes the data screening that was conducted during assembly of the data set and prior to conducting the initial model runs. This appendix provides details of the surveys, stations, and chemical and biological data that were screened out of the data set.

Surveys and Stations

The following surveys and stations were identified but were screened out for the reasons given (survey codes are SEDQUAL codes and indicate surveys already entered into SEDQUAL/EIM).

Two early data sets from the McCormick & Baxter Creosoting Company RI/FS (**MBCREOS1** and **MBCREOS2**) were removed from the data set when it was determined that the logistic regression models using the *Hyalella azteca* results for these data sets were significantly different from the rest of the *H. azteca* data sets. These studies were conducted in the 1990–1991 timeframe, and unlike more recent studies, the *H. azteca* organisms were collected locally and may have had different sensitivity to contaminants. Although for some time there had been a general sense that the early McCormick & Baxter results were unusual, this was confirmed in a more rigorous manner by both NOAA (Field et al. 2003) and the Oregon Department of Environmental Quality (Brunelle et al. 2003).

Similarly, the 28-day *Hyalella azteca* growth data from the Portland Harbor RI were ultimately screened out, after much discussion among the agencies. These bioassay data did not show a correlation to any toxic chemicals in the study area and had poor reliability in the modeling results. Removal of these data substantially increased the usability and reliability of the overall *Hyalella azteca* 28-day growth data set. The EPA site managers, the SQV workgroup, and the Lower Willamette Group concurred with this decision (Burt Shepard, US EPA Region 10, personal communication to T. Michelsen, Avocet Consulting on 15 April 2011). However, all other Portland Harbor bioassay data, including the *Hyalella azteca* 28-day mortality data, were retained.

In addition, some surveys and individual stations were screened out because of a low number of replicates in bioassays, below what is considered a minimum standard in modern freshwater protocols (ASTM 2005). Surveys or stations with less than five replicates were screened out. The freshwater ASTM protocols (ASTM 2005) recommend 8 replicates and require a minimum of 4 replicates in order to provide appropriate power under most circumstances. The minimum of 4 is mainly considered appropriate for less rigorous applications, such as trend analysis between years, and is fewer than the PSDDA marine bioassay standard of 5 replicates. Surveys or stations with less than five replicates were screened out, including:

- **LAKROO92 (all 18 stations) –** 7-day Hyalella, 3 replicates.
- **LSAMM99 (all 16 stations)** – Microtox®, 2 replicates

- **MARCO90 (1 station) –** 10-day Hyalella, 3 replicates.
- **QUEBAX2 (all 4 stations) –** 14-day Hyalella, 4 replicates.
- **SIMILK00 (all 4 stations) –** 10-day Hyalella, 4 replicates.
- **TRISTAR (all 3 stations)** – Microtox®, 3 replicates.
- **UNIMAR2 (all 9 stations)** – 14-day Hyalella, 3 replicates.

Surveys and stations were also screened out if they had an insufficient analyte list. A minimum of semivolatiles and metals was selected as a general guideline for including a survey or station, consistent with other national criteria development efforts. For some surveys, different stations had varying analyte lists. In these surveys, only those stations with adequate analyte lists were retained. The surveys and stations screened out included:

- **COLALU94 (all 6 stations) –** Only conventionals.
- **LKROOS92 (2, 8, 10, 11, 15, 17, 19, 61, 71)** – 6 metals and TOC.
- **LKROOS01 (all 10 stations) –** 6 metals plus conventionals.
- **SIMILK00 (all 4 stations) –** metals and conventionals, no organics.
- **STEILLK2 (all 4 stations) –** metals and conventionals, no organics.
- **QUEBAX2 (all 4 stations) –** PAHs and conventionals, no metals.
- **Pope & Talbot Wood Treating Facility, St. Helens, OR** – insufficient chemistry
- **Zidell 2007** – Study still underway, data incomplete
- **Fifteen Mile Creek, OR** – no chemistry other than oxyfluorfen
- **Spokane River 2003, WA** – conventionals and a few metals
- **Mill Creek, WA** – conventionals and a few metals
- **Upper Columbia River 2001, WA** – conventionals and a few metals

Additional data sets were eliminated because insufficient information could be found to conduct QA2 review for either chemistry data or bioassay data or both; or other key information such as lat/longs or the SAP was missing:

- **Modoc Lumber, OR** – missing QA/QC information, SAP, and station locations
- **Weyerhaeuser Klamath Falls** – missing QA/QC information, station locations, and bioassay SAP
- **Pacific Carbide** – missing QA/QC for chemistry, bioassay failed QA/QC review
- **Tri-Met Merlo Garage, OR** – missing SAP, station locations, QA/QC
- **Nichols Boat Works, OR** – missing chemistry QA/QC

Thirteen samples were also deleted from a 2001 Lake Union survey because the percent solids in these samples ranged between 6–26%. This is very low for sediment samples and suggests that these samples were actually floc-like watery material that would not be representative of typical sediments. Five remaining samples with percent solids >45% were retained in the data set.

Analytes

Analytes were also screened out for a variety of reasons. The following analytes are not toxic chemicals, and were screened from the initial data set:

- Grain size parameters
- Total organic carbon
- Total solids
- Acid volatile sulfides
- Derived parameters: Dioxin/furan TEQs (individual and summed dioxin and furan concentrations were retained)

Crustal elements were also removed from the dataset; these parameters are analyzed as part of standard metals suites, but are not known to be toxic at concentrations typically encountered in sediments:

- Aluminum
- Calcium
- Iron
- Magnesium
- Manganese
- Potassium
- Sodium

Certain chemicals were detected less than 30 times in the data set; these chemicals were also screened out as being unlikely to significantly influence toxicity in such a large data set. These chemicals will rarely be encountered, but if they should be encountered at high concentrations at a specific site or hot spot area, bioassay analyses should be conducted to evaluate their toxicity.

Table B-1. Rarely Detected Analytes

Chemical Analytes	Detections
1,2,3,4-Tetrahydronaphthalene	1
1,2,3-Trichloropropane	1
1,2,4-Trichlorobenzene	6
1,2-Dichlorobenzene	12
1,2-Dichloroethane	1
1,4-Dichlorobenzene	26
2,3,4,5-Tetrachlorophenol	5
2,3,4,6-Tetrachlorophenol	1
2,4,5-Trichlorophenol	25
2,4-D	6
2,4-DB	1
2,4-Dichlorophenol	2
2,4-Dimethylphenol	4
2,4-Dinitrotoluene	1
2-Chloronaphthalene	1

2-Chlorophenol	1
2-Methylphenol	8
4-Chloro-3-methylphenol	5
4-Nitroaniline	1
4-Stigmasten-3-one	1
7,10,13-Hexadecatrienoicacid	1
9-Hexadecenoicacid	2
Abietic acid	4
Acetone	30*
Aniline	12
Benzene	19
Benzyl alcohol	28
Bis(2-chloroethyl) ether	2
Caprolactam	1
Carbon disulfide	15
Chlorobenzene	17
Chloroform	21
Chloromethane	1
cis-1,2-Dichloroethene	2
Dehydroabietic acid	3
Dichloromethane	8
Diethyl phthalate	17
Endrin aldehyde	12
Ethylbenzene	16
gamma-Sitosterol	3
Hexachlorobutadiene	32*
Isophorone	3
Isopimaric acid	4
m,p-Xylene	20
MCPA	2
MCPP	2
Methyl iodide	1
Methyl tert-butyl ether	7
Methylene chloride	1
Methylethyl ketone	27
Mirex	7
N-Nitrosodiphenylamine	4
o-Xylene	29
Perylene	8
Phytol	3
Pimaric acid	4
Pristane	7
Sandaracopimaric Acid	1
Styrene	22
Thallium	13
Toluene	16
Trichloroethene	6
Xylenes	2

*This analyte had >30 detections in the entire data set, but <30 detections for any one bioassay endpoint.

Several analytes had enough detected values to be included, but not enough "hit" values for calculation of SQVs (<10). These chemicals included alpha-, delta-, and gamma-hexachlorocyclohexane, Endrin, beryllium, and vanadium. These analytes were excluded from the modeling runs.

A number of chemicals were summed into groups and the individual analytes removed from the data set. The toxicity of these chemicals is additive or synergistic within their groups and is best represented by the group as a whole. Individual SQVs do not need to be established for these constituents, as their toxicity is represented by their group. The groups and their constituents are listed below:

- **DDD isomers:** o,p'-DDD, p,p'-DDD
- **DDE isomers:** o,p'-DDE, p,p'-DDE
- **DDT isomers:** o,p'-DDT, p,p'-DDT
- **Dioxins/Furans:** Total heptachlorodibenzofurans, total heptachlorodibenzo-p-dioxins, total hexachlorodibenzofurans, total hexachlorodibenzo-p-dioxins, octachlorodibenzofuran, octachlorodibenzo-p-dioxin, total pentachlorodibenzofurans, total pentachlorodibenzo-p-dioxins, total tetrachlorodibenzofurans, total tetrachlorodibenzo-p-dioxins
- **Total Chlordanes:** alpha-chlordane, chlordane, cis-chlordane, cis-nonachlor, gamma-chlordane, heptachlor, heptachlor epoxide, oxychlordane, trans-chlordane, trans-nonachlor
- **Total Endosulfans:** alpha-endosulfan, beta-endosulfan, endosulfan sulfate
- **Total PAHs:** 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenz(ah)anthracene, fluoranthene, fluorene, indeno(123-cd)pyrene, naphthalene, phenanthrene, pyrene, total benzofluoranthenes (b+k+j)
- **Total PCB Aroclors:** 1016, 1221, 1242, 1248, 1254, 1260, 1268 (no congener data were available)

ANOVA Screening

The second step of the model runs is to evaluate which chemicals are associated with toxicity in the data set for each chemical and each endpoint (Table B-2). This evaluation is described in Section 2.6, and electronic spreadsheets showing the basis and detailed results of this screening are available as described in Section 1.4.

As a result of this evaluation, it was determined that the following chemicals had no association with toxicity for any of the endpoints, and these chemicals were not retained for further modeling:

- Aldrin

- dioxins/furans
- gamma-hexachlorocyclohexane
- hexachlorobenzene
- hexachloroethane
- methoxychlor
- retene
- total endosulfans

These chemicals are not associated with toxicity to the benthic community at sediment concentrations historically observed in the environment, and thus, SQVs do not need to be set for them.

In addition to these chemicals, some chemicals were not associated with toxicity for some tests and endpoints. These were screened out of modeling runs for these endpoints, but overall SQVs may be set for them because they were associated with toxicity for at least some endpoints. Chemicals screened out for individual endpoints include:

- ***Hyalella azteca* 10-day mortality –** beryllium, butyl benzyl phthalate, chromium, copper, dibutyltin, dimethyl phthalate, di-n-butyl phthalate, mercury, monobutyltin, total chlordanes, total DDTs, tributyltin

- ***Chironomus dilutus* 10-day mortality –** ammonia, antimony, beryllium, bis(2-ethylhexyl) phthalate, dimethyl phthalate, nickel, pentachlorophenol, selenium, vanadium, zinc

- ***Chironomus dilutus* 10-day growth** – ammonia, antimony, beryllium, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, cadmium, di-n-octyl phthalate, selenium, silver, zinc

- ***Hyalella azteca* 28-day mortality** – 4-methylphenol, antimony, arsenic, beryllium, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, chromium, copper, dibutyltin, Endrin, lead, monobutyltin, nickel, pentachlorophenol, selenium, tetrabutyltin, tributyltin, vanadium, zinc

- ***Hyalella azteca* 28-day growth** – antimony, arsenic, cadmium, lead, mercury, nickel, selenium, total PAHs

Modeling Results

Finally, the modeling results identified several analytes whose SQV values were greater than the highest concentrations measured for all tests and endpoints. These analytes include butyl benzyl phthalate, dimethyl phthalate, and total chlordanes. No SQVs will be set for these analytes, but site managers can assume that concentrations within the range in this data set are not of concern for benthic organisms.

Table B-3 summarizes all of the analytes that were screened out, the reason for doing so, and the maximum concentration below which site managers can assume that these analytes are not of concern to benthic organisms (where known and applicable).

Table B-2. ANOVA Screening[a]

Analyte	CH10M SQS/SL1	CH10M CSL/SL2	CH10G SQS/SL1	CH10G CSL/SL2	HY10M SQS/SL1	HY10M CSL/SL2	HY28M SQS/SL1	HYA28M CSL/SL2	HY28G SQS/SL1	HY28G CSL/SL2
4-Methylphenol	1**	1**	1**	1**	1**	1**	0	0*		
Aldrin	0	0	0	0			0	0		
alpha-Hexachlorocyclohexane	1	1	0*	1			1	1*		
Ammonia	0*	0*	0	0*	1*	0*	1**	1*		
Antimony	0	0	0	0	1	1*	0	0	0	0*
Arsenic	1**	1**	1**	1**	1*	1**	0	0	0	0
Benzoic acid	1*	1**	1*	1*	1	1				
Beryllium	0	0	0	0	0	0	0	0	1	1
beta-Hexachlorocyclohexane	1**	1**	1	1**			1**	1**		
Bis(2-ethylhexyl) phthalate	0	0	0	0	1	1*	0	0		
Butyl benzyl phthalate	1	1	0	0	0	0	0	0		
Cadmium	1*	0*	0	0	0	1	1	1	0	0*
Carbazole	1**	1**	1**	1**	1	1*	1**	1**		
Chromium	1	1	1	1	0	0*	0*	0*	1**	1**
Copper	1	1**	1	1*	0	0	0	0	0	1*
delta-Hexachlorocyclohexane	1	1*	0*	1			1*	1**		
Dibenzofuran	1**	1**	1*	1**	1	1	1**	1**		
Dibutyltin	1	1*	0*	1	0	0	0	0		
Dieldrin	1	1**	0*	1**			1	1*		
Dimethyl phthalate	0	0*	1	0*	0	0				
Di-n-butyl phthalate	1**	1**	1**	1**	0	0	1	1**		
Di-n-octyl phthalate	1	0	0	0	0	1				
Dioxins/Furans	0	0	0	0			0	0		
Endrin	1	0	1	1*			0	0		
Endrin ketone	1*	1**	0*	1*			1*	1**		
gamma-Hexachlorocyclohexane	0	0	0	0			0	0		
Hexachlorobenzene	0	0	0	0			0	0		
Hexachloroethane	0	0	0	0			0	0		
Lead	1**	1*	1	1*	1	1	0	0	0	0
Mercury	1*	1**	1	1*	0	0	0*	1	0	0

Analyte	CH10M SQS/SL1	CH10M CSL/SL2	CH10G SQS/SL1	CH10G CSL/SL2	HY10M SQS/SL1	HY10M CSL/SL2	HY28M SQS/SL1	HYA28M CSL/SL2	HY28G SQS/SL1	HY28G CSL/SL2
Methoxychlor	0	0	0	0			0	0		
Monobutyltin	1*	1**	1	1**	0	0	0	0		
Nickel	0	0	1*	0*	1	1*	0	0	0	0
Pentachlorophenol	0	0	1**	0	0*	1	0	0		
Phenol	1**	1**	1**	1**	1	1	1**	1**		
Retene					0	0				
Selenium	0	0	0	0			0	0	0	0
Silver	1	1	0	0*	1	0*	1**	1**		
Sulfide	1**	1	1*	1*	1	1*	1	1**		
Tetrabutyltin	1**	1**	1	1**			0	0		
Total Aroclors	1*	1**	1	1*	1	1	1	1**		
Total Chlordanes	1	1**	1	1*	0	0	1*	1**		
Total DDDs	1**	1**	1**	1**	1*	1**	1**	1**		
Total DDEs	1**	1**	1*	1**	1**	0	1**	1**	0*	1
Total DDTs	1	1*	0	1	0	0	1	1*		
Total Endosulfans	0	0	0	0			0	0		
Total PAHs	1**	1**	1**	1**	1	1*	1**	1**	0	0
TPH-Diesel	1**	1**	1**	1**	1**	0	1**	1**		
TPH-Residual	1**	1**	1**	1**	1	0	1**	1**		
Tributyltin	1*	1**	1	1**	0	0	0	0		
Vanadium	0*	0*	1	1			0	0	1	0
Zinc	0	0	0	0	1	1	0	0	0	1*

SQS/SL1 = Sediment Quality Standard/Screening Level 1, CSL/SL2 = Cleanup Screening Level/Screening Level 2
CH10G = *Chironomus* 10-day growth, CH10M = *Chironomus* 10-day mortality,
HY10M = *Hyalella* 10-day mortality, HY28G = *Hyalella* 28-day growth, HY28M = *Hyalella* 28-day mortality
[a] ANOVA results for the relationship between chemical concentration and toxicity for the indicated test and effects level:
0 = not significant, 0* = significant at $p < 0.1$, 1 = significant at $p < 0.05$, 1* = significant at $p < 0.005$, 1** = significant at $p < 0.0005$
A significance level of $p < 0.05$ was used for screening for SQV development.

Table B-3. Summary of Screened Analytes

Chemical Analyte	Reason for Screening	Maximum concentration for benthic organisms[a]
1-Methylnaphthalene	Included in Total PAHs	N/A
1,2,3,4-Tetrahydronaphthalene	Infrequently detected	Unknown
1,2,3-Trichloropropane	Infrequently detected	Unknown
1,2,4-Trichlorobenzene	Infrequently detected	Unknown
1,2-Dichlorobenzene	Infrequently detected	Unknown
1,2-Dichloroethane	Infrequently detected	Unknown
1,4-Dichlorobenzene	Infrequently detected	Unknown
2-Methylnaphthalene	Included in Total PAHs	N/A
2,3,4,5-Tetrachlorophenol	Infrequently detected	Unknown
2,3,4,6-Tetrachlorophenol	Infrequently detected	Unknown
2,4,5-Trichlorophenol	Infrequently detected	Unknown
2,4-D	Infrequently detected	Unknown
2,4-DB	Infrequently detected	Unknown
2,4-Dichlorophenol	Infrequently detected	Unknown
2,4-Dimethylphenol	Infrequently detected	Unknown
2,4-Dinitrotoluene	Infrequently detected	Unknown
2-Chloronaphthalene	Infrequently detected	Unknown
2-Chlorophenol	Infrequently detected	Unknown
2-Methylphenol	Infrequently detected	Unknown
4-Chloro-3-methylphenol	Infrequently detected	Unknown
4-Nitroaniline	Infrequently detected	Unknown
4-Stigmasten-3-one	Infrequently detected	Unknown
7,10,13-Hexadecatrienoicacid	Infrequently detected	Unknown
9-Hexadecenoicacid	Infrequently detected	Unknown
Abietic acid	Infrequently detected	Unknown
Acenaphthene	Included in Total PAHs	N/A
Acenaphthylene	Included in Total PAHs	N/A
Acid volatile sulfides	Derived parameter	N/A
Aldrin	No relationship to toxicity	Up to a maximum concentration of 690 µg/kg
alpha-Chlordane	Included in Total chlordanes	N/A
alpha-Endosulfan	Included in Total endosulfans	N/A
alpha-Hexachlorocyclohexane	Not enough hits	Minimal data suggests possible toxicity over 5 µg/kg

Chemical Analyte	Reason for Screening	Maximum concentration for benthic organisms[a]
Aluminum	Crustal element	N/A
Aniline	Infrequently detected	Unknown
Anthracene	Included in Total PAHs	N/A
Aroclors (all)	Included in Total PCBs	N/A
Benz(a)anthracene	Included in Total PAHs	N/A
Benzene	Infrequently detected	Unknown
Benzo(a)pyrene	Included in Total PAHs	N/A
Benzo(b)fluoranthene	Included in Total PAHs	N/A
Benzo(ghi)perylene	Included in Total PAHs	N/A
Benzo(k)fluoranthene	Included in Total PAHs	N/A
Benzyl alcohol	Infrequently detected	Unknown
Beryllium	Not enough hits	Minimal data shows no evidence of toxicity up to 1.5 mg/kg (maximum concentration detected)
beta-Endosulfan	Included in Total endosulfans	N/A
Bis(2-chloroethyl) ether	Infrequently detected	Unknown
Butyl benzyl phthalate	Modeling identified no toxicity	Up to a maximum concentration of 2800 µg/kg
Calcium	Crustal element	N/A
Caprolactam	Infrequently detected	Unknown
Carbon disulfide	Infrequently detected	Unknown
Chlordane	Included in Total chlordanes	N/A
Chlorobenzene	Infrequently detected	Unknown
Chloroform	Infrequently detected	Unknown
Chloromethane	Infrequently detected	Unknown
Chrysene	Included in Total PAHs	N/A
cis-1,2-Dichloroethene	Infrequently detected	Unknown
cis-Chlordane	Included in Total chlordanes	N/A
cis-Nonachlor	Included in Total chlordanes	N/A
Dehydroabietic acid	Infrequently detected	Unknown
delta-Hexachlorocyclohexane	Not enough hits	Minimal data suggests possible toxicity over 2.4 µg/kg
Dibenz(ah)anthracene	Included in Total PAHs	N/A
Dichloromethane	Infrequently detected	Unknown
Diethyl phthalate	Infrequently detected	Unknown
Dimethyl phthalate	Modeling identified no toxicity	Up to a maximum concentration of 580 µg/kg

Chemical Analyte	Reason for Screening	Maximum concentration for benthic organisms[a]
Dioxins/furans	No relationship to toxicity	Up to a maximum concentration of 28,000 ng/kg
Endosulfan sulfate	Included in Total endosulfans	N/A
Endrin	Not enough hits	Minimal data shows no clear toxicity up to 40 µg/kg (maximum detected value)
Endrin aldehyde	Infrequently detected	Unknown
Ethylbenzene	Infrequently detected	Unknown
Fluoranthene	Included in Total PAHs	N/A
Fluorene	Included in Total PAHs	N/A
gamma-Chlordane	Included in Total chlordanes	N/A
gamma-Hexachlorocyclohexane	Not enough hits	Minimal data shows no clear toxicity up to 11 µg/kg (maximum detected value)
gamma-Sitosterol	Infrequently detected	Unknown
Grain size	Physical parameter	N/A
Heptachlor	Included in Total chlordanes	N/A
Heptachlor epoxide	Included in Total chlordanes	N/A
Heptachlorodibenzofurans	Included in Dioxins/furans	N/A
Heptachlorodibenzo-p-dioxins	Included in Total dioxins/furans	N/A
Hexachlorobutadiene	Infrequently detected	Unknown
Hexachlorobenzene	No relationship to toxicity	Up to a maximum concentration of 260 µg/kg
Hexachlorodibenzofurans	Included in Dioxins/furans	N/A
Hexachlorodibenzo-p-dioxins	Included in Dioxins/furans	N/A
Hexachloroethane	No relationship to toxicity	Up to a maximum concentration of 1500 µg/kg
Indeno(123-cd)pyrene	Included in Total PAHs	N/A
Iron	Crustal element	N/A
Isophorone	Infrequently detected	Unknown
Isopimaric acid	Infrequently detected	Unknown
m,p-Xylene	Infrequently detected	Unknown
Magnesium	Crustal element	N/A
Manganese	Crustal element	N/A
MCPA	Infrequently detected	Unknown
MCPP	Infrequently detected	Unknown
Methoxychlor	No relationship to toxicity	Up to a maximum concentration of 34 µg/kg
Methyl iodide	Infrequently detected	Unknown
Methyl tert-butyl ether	Infrequently detected	Unknown

Chemical Analyte	Reason for Screening	Maximum concentration for benthic organisms[a]
Methylethyl ketone	Infrequently detected	Unknown
Mirex	Infrequently detected	Unknown
N-Nitrosodiphenylamine	Infrequently detected	Unknown
Naphthalene	Included in Total PAHs	N/A
o-Xylene	Infrequently detected	Unknown
o,p'-DDD	Included in Total DDDs	N/A
o,p'-DDE	Included in Total DDEs	N/A
o,p'-DDT	Included in Total DDTs	N/A
Octachlorodibenzofuran	Included in Dioxins/furans	N/A
Octachlorodibenzo-p-dioxin	Included in Dioxins/furans	N/A
Oxychlordane	Included in Total chlordanes	N/A
p,p'-DDD	Included in Total DDDs	N/A
p,p'-DDE	Included in Total DDEs	N/A
p,p'-DDT	Included in Total DDTs	N/A
Pentachlorodibenzofurans	Included in Dioxins/furans	N/A
Pentachlorodibenzo-p-dioxins	Included in Dioxins/furans	N/A
Perylene	Infrequently detected	Unknown
Phenanthrene	Included in Total PAHs	N/A
Phytol	Infrequently detected	Unknown
Pimaric acid	Infrequently detected	Unknown
Potassium	Crustal element	N/A
Pristane	Infrequently detected	Unknown
Pyrene	Included in Total PAHs	N/A
Retene	No relationship to toxicity	Up to a maximum concentration of 810,000 µg/kg
Sandaracopimaric Acid	Infrequently detected	Unknown
Sodium	Crustal element	N/A
Styrene	Infrequently detected	Unknown
TEQs (dioxin/furan/PCBs)	Derived parameter not applicable to benthos	N/A
Tetrachlorodibenzofurans	Included in Dioxins/furans	N/A
Tetrachlorodibenzo-p-dioxins	Included in Dioxins/furans	N/A
Thallium	Infrequently detected	Unknown
Toluene	Infrequently detected	Unknown

Chemical Analyte	Reason for Screening	Maximum concentration for benthic organisms[a]
Total benzofluoranthenes (b+j+k)	Included in Total PAHs	N/A
Total chlordanes	Modeling identified no toxicity	Up to a maximum concentration of 670 µg/kg
Total endosulfans	No relationship to toxicity	Up to a maximum concentration of 240 µg/kg
Total organic carbon	Natural material	N/A
Total solids	Physical parameter	N/A
trans-Chlordane	Included in Total chlordanes	N/A
trans-Nonachlor	Included in Total chlordanes	N/A
Trichloroethene	Infrequently detected	Unknown
Vanadium	Not enough hits	Minimal data shows no evidence of toxicity up to 41 mg/kg (maximum concentration measured)
Xylenes	Infrequently detected	Unknown

[a] Concentration below which no association with toxicity was observed in the data set used to calculate the SQVs. Does not address potential bioaccumulation toxicity to wildlife, fish, or humans.

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APPENDIX C

SELECTION OF BIOLOGICAL EFFECTS LEVELS

This appendix provides a detailed discussion of the selection of biological effects levels for each bioassay endpoint at both the SQS/SL1 and CSL/SL2 effects levels. Table 2-2 in the main report presents the parameters described below.

Hyalella azteca 10-day mortality bioassay

- **SQS/SL1 mortality:** A hit requires a statistically significant difference from control and a relative increase in mortality of >15% (test – control > 15%).
- **CSL/SL2 mortality:** A hit requires a statistically significant difference from control and a relative increase in mortality of >25% (test – control > 25%).

The ASTM protocols (ASTM 2005) originally established a control performance standard of 20% mortality, although in practice, the mean mortality observed in the control samples in round robin testing was approximately 10%. Recently, it has been suggested that the control performance standard be modified to 15% mortality (Ingersoll et al. 2008). Given this, the maximum mortality that would be observed at the SQS/SL1 level would be 30–35%, and would often be less, and the maximum mortality that would be observed at the CSL/SL2 level would be 40–45%, and would often be less. This SQS/SL1 level would be very similar in practice to the WA SMS marine SQS/SL1 level of 30% absolute mortality.

In ASTM round robin testing, the minimum detectable difference between the test and control sample ranged from 5 to 24%, with a mean of 11%. Within this range, statistical testing of commercial data from WA and OR determined that correlations between hit stations and toxicity improved at a threshold of 15% and did not increase substantially thereafter; thus, the 15% level was selected. Therefore, a detectable difference could occur at levels as low as 15% mortality, ranging in the worst case up to about 35% mortality, depending on the performance of the control samples and the degree of variability in the test replicates. In practice these thresholds should be statistically significant nearly all of the time, with the minimum detectable difference occasionally exceeding the SQS/SL1 numeric threshold, but not likely exceeding the CSL/SL2 numeric threshold.

Hyalella azteca 28-day mortality bioassay

- **SQS/SL1 mortality:** A hit requires a statistically significant difference from control and a relative decrease in mortality of >10% (test – control > 10%).
- **CSL/SL2 mortality:** A hit requires a statistically significant difference from control and a relative increase in mortality of >25% (test – control > 25%).

The ASTM protocols establish a control performance standard of 20% mortality, and the results of round robin testing reported that >90% of laboratories were able to meet that standard. Given this, the maximum mortality that would be observed at the SQS/SL1 level would be 30%, and would often be less, and the maximum mortality that would be observed at the CSL/SL2 level would be 45%, and would often be less.

In ASTM round robin testing, the minimum detectable difference between the test and control sample ranged from 2–20%, with a mean of 8%. Therefore, a detectable difference could occur at levels as low as 15% mortality, ranging in the worst case up to about 35% mortality, depending on the performance of the control samples and the degree of variability in the test replicates. In practice these endpoints should be statistically significant most of the time, with the minimum detectable difference at times exceeding the SQS/SL1 numeric threshold, but not likely exceeding the CSL/SL2 numeric threshold.

***Hyalella azteca* 28-day growth bioassay**

- **SQS/SL1 growth:** A hit requires a statistically significant difference from control and a relative decrease in weight of >25% (test/control < 75%).
- **CSL/SL2 growth:** A hit requires a statistically significant difference from control and a relative decrease in weight of >40% (test/control < 60%).

The SQS/SL1 and CSL/SL2 endpoints are based largely on the minimum detectable differences reported in ASTM round robin studies, since little additional information exists on which to base recommendations. The mean minimum detectable difference in weight in round robin studies was approximately 25%, with a range from 16–50%. Balancing these considerations are literature studies suggesting that reductions in growth of as little as 20–30% can cause significant reproductive effects and other physiological changes in aquatic species, including *Chironomus dilutus* and *Mytilus galloprovincialis* (ASTM 2005, Kagley et al. 1995, Widdows & Donkin 1992). The recommended endpoints above are a compromise between statistical reality and environmental policy objectives. The round robin studies suggest that the numeric level corresponding to the SQS/SL1 should be statistically significant about half the time, and the numeric level corresponding to the CSL/SL2 should be statistically significant about 80% of the time.

***Chironomus dilutus* 10-day mortality bioassay**

- **SQS/SL1 mortality:** A hit requires a statistically significant difference from control and a relative decrease in mortality of >20% (test – control > 20%).
- **CSL/SL2 mortality:** A hit requires a statistically significant difference from control and a relative increase in mortality of >30% (test – control > 30%).

The ASTM protocols establish a control performance standard of 30% mortality, although in practice, the mean mortality observed in the control samples in round robin testing was approximately 8%, with a range of 1–19%. Recently, it has been suggested that this be reduced to 20% (Ingersoll et al. 2008). Given this, the maximum mortality that would be observed at the SQS/SL1 level would be 40%, and would usually be less, and the maximum mortality that would be observed at the CSL/SL2 level would be 50%, and would usually be less.

In ASTM round robin testing, the minimum detectable difference between the test and control sample ranged from 2–12%, with a mean of 8%. However, statistical testing of commercial data from WA and OR determined that correlations between hit stations and toxicity improved at a threshold of 20% and did not increase substantially thereafter; thus, the 20% level was selected. Therefore, a detectable difference could occur at levels as low as 20% mortality, ranging in the worst case up to about 40% mortality, depending on the performance of the control samples and the degree of variability in the test replicates. In practice these numeric thresholds should be statistically significant most of the time.

***Chironomus dilutus* 10-day growth bioassay**

- **SQS/SL1 growth:** A hit requires a statistically significant difference from control and a relative decrease in weight of >20% (test/control < 80%).
- **CSL/SL2 growth:** A hit requires a statistically significant difference from control and a relative decrease in weight of >30% (test/control < 70%).

The SQS/SL1 and CSL/SL2 endpoints are based largely on the minimum detectable differences reported in ASTM round robin studies. The mean minimum detectable difference in weight in round robin studies was approximately 11%, with a range from 5–24%. This allows for more protective SQS/SL1 and CSL/SL2 levels than for either of the chronic growth tests. The round robin studies suggest that the numeric level corresponding to the SQS/SL1 should be statistically significant well over half of the time, and the CSL/SL2 levels should be statistically significant nearly all of the time. The numeric levels chosen span the range of growth rates associated with adverse reproductive or physiological effects in the literature, as discussed above.

The control performance standards established for the 10-day test are equal to or greater than 0.48 mg mean individual biomass at time final, and the recommended reference performance standard is at least 80% of the control.

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APPENDIX D

INTERIM MODEL RUNS

This appendix provides the results and discussion of interim model runs used to develop the final data set and modeling approach. In all cases, only the reliability results were calculated and presented to the workgroup, to preclude bias associated with the numeric results for individual chemicals. The reliability results are also presented here and an explanation is provided of the question being addressed and what decisions were made based on the results.

All of the results presented in this appendix are based on early versions of the data set, which did not have the same level of reliability as the final data set. As each quality assurance or database issue was worked through, the data set and/or the modeling approach incrementally improved, until the reliability goals were ultimately reached for each bioassay endpoint and effects level. Therefore, the results presented here are only for comparative purposes to illustrate the decisions that were made at the time.

D.1. Petroleum Hydrocarbons

The model was run using 1) total PAHs, 2) TPH-diesel and TPH-residual, and 3) both combined for two different data sets:

- The large data set included all data in the database, for which all stations had PAH data but only about 1/3 had TPH data. Because TPH alone could not predict toxicity in the other 2/3 of the stations, only PAH alone was compared with PAH + TPH combined.
- The small data set included only those stations that had both PAH and TPH data. For this data set, PAH alone, TPH alone, and PAH + TPH combined were compared.

For this modeling exercise, two representative bioassay endpoints were selected, Chironomus 10-day growth and Hyalella 28-day mortality. The results are shown in Table D-1 below.

For the large data set, the reliability was always improved by adding TPH over PAH alone, even though there were TPH data for only 1/3 of the stations. For the small data set, TPH was much more reliable than PAH alone, with very similar performance between TPH + PAH and TPH alone. Based on these results, it was agreed that both TPH and total PAHs would be used for the modeling, and that TPH should be analyzed more frequently at sediment sites where bulk petroleum may be an issue.

Table D-1. TPH vs. PAH Comparisons

a. CH10G Small Data Set SQS/SL1

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	42.6	100.0	57.4	24.8	100.0	62.7
5	2.9	36.1	97.1	63.9	27.4	99.4	68.0
10	8.6	28.5	91.4	71.5	31.1	98.3	73.9
15	14.3	21.3	85.7	78.7	36.1	97.5	79.6
20	20.0	16.5	80.0	83.5	40.6	96.7	83.1
25	22.9	13.3	77.1	86.7	45.0	96.4	85.6
30	28.6	5.6	71.4	94.4	64.1	95.9	91.5

TPH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	34.1	100.0	65.9	29.2	100.0	70.1
5	2.9	26.5	97.1	73.5	34.0	99.5	76.4
10	8.6	17.3	91.4	82.7	42.7	98.6	83.8
15	14.3	12.4	85.7	87.6	49.2	97.8	87.3
20	20.0	12.4	80.0	87.6	47.5	96.9	86.6
25	22.9	9.2	77.1	90.8	54.0	96.6	89.1
30	28.6	4.8	71.4	95.2	67.6	96.0	92.3

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	31.3	100.0	68.7	31.0	100.0	72.5
5	2.9	23.7	97.1	76.3	36.6	99.5	78.9
10	8.6	14.9	91.4	85.1	46.4	98.6	85.9
15	14.3	10.4	85.7	89.6	53.6	97.8	89.1
20	20.0	10.4	80.0	89.6	51.9	97.0	88.4
25	22.9	10.4	77.1	89.6	50.9	96.5	88.0
30	28.6	6.0	71.4	94.0	62.5	95.9	91.2

b. CH10G Small Data Set CSL/SL2

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	44.2	100.0	55.8	18.6	100.0	59.9
5	3.8	34.9	96.2	65.1	21.7	99.4	68.0
10	7.7	31.4	92.3	68.6	22.9	98.9	70.8
15	11.5	21.3	88.5	78.7	29.5	98.5	79.6
20	19.2	11.2	80.8	88.8	42.0	97.9	88.0
25	23.1	7.0	76.9	93.0	52.6	97.6	91.5
30	26.9	7.0	73.1	93.0	51.4	97.2	91.2

TPH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	32.2	100.0	67.8	23.9	100.0	70.8
5	3.8	16.7	96.2	83.3	36.8	99.5	84.5
10	7.7	14.7	92.3	85.3	38.7	99.1	85.9
15	11.5	11.6	88.5	88.4	43.4	98.7	88.4
20	19.2	4.3	80.8	95.7	65.6	98.0	94.4
25	23.1	2.3	76.9	97.7	76.9	97.7	95.8
30	26.9	2.3	73.1	97.7	76.0	97.3	95.4

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	32.2	100.0	67.8	23.9	100.0	70.8
5	3.8	16.7	96.2	83.3	36.8	99.5	84.5
10	7.7	14.7	92.3	85.3	38.7	99.1	85.9
15	11.5	11.6	88.5	88.4	43.4	98.7	88.4
20	19.2	4.3	80.8	95.7	65.6	98.0	94.4
25	23.1	2.3	76.9	97.7	76.9	97.7	95.8
30	26.9	2.3	73.1	97.7	76.0	97.3	95.4

c. HY28M Small Data Set SQS/SL1

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	58.7	100.0	41.3	18.2	100.0	48.1
5	3.7	40.3	96.3	59.7	23.9	99.2	63.9
10	7.4	30.6	92.6	69.4	28.4	98.6	72.1
15	14.8	24.3	85.2	75.7	31.5	97.5	76.8
20	18.5	16.5	81.5	83.5	39.3	97.2	83.3
25	22.2	11.7	77.8	88.3	46.7	96.8	87.1
30	29.6	9.2	70.4	90.8	50.0	95.9	88.4

TPH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	56.8	100.0	43.2	18.8	100.0	49.8
5	3.7	36.4	96.3	63.6	25.7	99.2	67.4
10	7.4	25.2	92.6	74.8	32.5	98.7	76.8
15	14.8	15.0	85.2	85.0	42.6	97.8	85.0
20	18.5	10.7	81.5	89.3	50.0	97.4	88.4
25	22.2	7.3	77.8	92.7	58.3	97.0	91.0
30	29.6	1.9	70.4	98.1	82.6	96.2	94.8

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	56.3	100.0	43.7	18.9	100.0	50.2
5	3.7	35.4	96.3	64.6	26.3	99.3	68.2
10	7.4	23.8	92.6	76.2	33.8	98.7	78.1
15	14.8	12.6	85.2	87.4	46.9	97.8	87.1
20	18.5	7.8	81.5	92.2	57.9	97.4	91.0
25	22.2	4.9	77.8	95.1	67.7	97.0	93.1
30	29.6	1.9	70.4	98.1	82.6	96.2	94.8

d. HY28M Small Data Set CSL/SL2

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	27.7	100.0	72.3	25.3	100.0	74.7
5	5.0	12.2	95.0	87.8	42.2	99.5	88.4
10	10.0	8.5	90.0	91.5	50.0	99.0	91.4
15	15.0	4.2	85.0	95.8	65.4	98.6	94.8
20	20.0	2.8	80.0	97.2	72.7	98.1	95.7
25	25.0	1.9	75.0	98.1	78.9	97.7	96.1
30	30.0	1.4	70.0	98.6	82.4	97.2	96.1

TPH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	24.9	100.0	75.1	27.4	100.0	77.3
5	5.0	7.5	95.0	92.5	54.3	99.5	92.7
10	10.0	2.3	90.0	97.7	78.3	99.0	97.0
15	15.0	1.4	85.0	98.6	85.0	98.6	97.4
20	20.0	0.9	80.0	99.1	88.9	98.1	97.4
25	25.0	0.5	75.0	99.5	93.8	97.7	97.4
30	30.0	0.5	70.0	99.5	93.3	97.2	97.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	24.9	100.0	75.1	27.4	100.0	77.3
5	5.0	7.5	95.0	92.5	54.3	99.5	92.7
10	10.0	2.3	90.0	97.7	78.3	99.0	97.0
15	15.0	1.4	85.0	98.6	85.0	98.6	97.4
20	20.0	0.9	80.0	99.1	88.9	98.1	97.4
25	25.0	0.5	75.0	99.5	93.8	97.7	97.4
30	30.0	0.5	70.0	99.5	93.3	97.2	97.0

e. CH10G Large Data Set SQS/SL1

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	58.7	100.0	41.3	19.4	100.0	48.6
5	4.6	47.8	95.4	52.2	22.0	98.8	57.5
10	9.2	41.7	90.8	58.3	23.5	97.8	62.3
15	13.8	40.2	86.2	59.8	23.2	96.8	63.0
20	20.0	35.9	80.0	64.1	24.0	95.8	66.1
25	24.6	33.9	75.4	66.1	23.9	95.0	67.2
30	29.2	27.6	70.8	72.4	26.6	94.6	72.2

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	58.0	100.0	42.0	19.6	100.0	49.1
5	4.6	47.6	95.4	52.4	22.1	98.8	57.7
10	9.2	41.3	90.8	58.7	23.7	97.8	62.7
15	13.8	39.8	86.2	60.2	23.4	96.9	63.4
20	20.0	33.5	80.0	66.5	25.2	95.9	68.2
25	24.6	29.6	75.4	70.4	26.5	95.3	71.0
30	29.2	24.3	70.8	75.7	29.1	94.8	75.0

f. CH10G Large Data Set CSL/SL2

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	54.8	100.0	45.2	15.8	100.0	50.3
5	4.1	43.5	95.9	56.5	18.5	99.3	60.2
10	8.2	37.0	91.8	63.0	20.4	98.7	65.7
15	14.3	36.8	85.7	63.2	19.4	97.7	65.3
20	18.4	30.9	81.6	69.1	21.4	97.3	70.3
25	24.5	25.6	75.5	74.4	23.3	96.7	74.5
30	28.6	20.8	71.4	79.2	26.1	96.4	78.5

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	54.8	100.0	45.2	15.8	100.0	50.3
5	4.1	43.5	95.9	56.5	18.5	99.3	60.2
10	8.2	37.0	91.8	63.0	20.4	98.7	65.7
15	14.3	36.8	85.7	63.2	19.4	97.7	65.3
20	18.4	30.9	81.6	69.1	21.4	97.3	70.3
25	24.5	23.3	75.5	76.7	25.0	96.8	76.6
30	28.6	18.3	71.4	81.7	28.7	96.5	80.8

g. HY28M Large Data Set SQS/SL1

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	59.2	100.0	40.8	23.0	100.0	49.7
5	4.3	53.2	95.7	46.8	24.2	98.4	54.2
10	8.5	40.8	91.5	59.2	28.5	97.5	64.1
15	14.9	26.0	85.1	74.0	36.7	96.6	75.6
20	19.1	21.1	80.9	78.9	40.4	95.9	79.2
25	23.4	13.2	76.6	86.8	50.7	95.4	85.3
30	29.8	6.8	70.2	93.2	64.7	94.6	89.7

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	50.9	100.0	49.1	25.8	100.0	56.7
5	4.3	38.5	95.7	61.5	30.6	98.8	66.7
10	8.5	26.8	91.5	73.2	37.7	98.0	76.0
15	14.9	14.3	85.1	85.7	51.3	97.0	85.6
20	19.1	10.6	80.9	89.4	57.6	96.3	88.1
25	23.4	9.8	76.6	90.2	58.1	95.6	88.1
30	29.8	6.0	70.2	94.0	67.3	94.7	90.4

h. HY28M Large Data Set CSL/SL2

PAH

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	33.3	100.0	66.7	22.1	100.0	69.6
5	3.7	13.7	96.3	86.3	40.0	99.6	87.2
10	7.4	10.9	92.6	89.1	44.6	99.2	89.4
15	14.8	7.7	85.2	92.3	51.1	98.5	91.7
20	18.5	4.9	81.5	95.1	61.1	98.2	93.9
25	22.2	3.5	77.8	96.5	67.7	97.9	94.9
30	29.6	1.8	70.4	98.2	79.2	97.2	95.8

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	30.2	100.0	69.8	23.9	100.0	72.4
5	3.7	9.8	96.3	90.2	48.1	99.6	90.7
10	7.4	6.0	92.6	94.0	59.5	99.3	93.9
15	14.8	3.5	85.2	96.5	69.7	98.6	95.5
20	18.5	2.8	81.5	97.2	73.3	98.2	95.8
25	22.2	2.1	77.8	97.9	77.8	97.9	96.2
30	29.6	1.8	70.4	98.2	79.2	97.2	95.8

D.2. Regional Differences

The model was run for the entire data set, as well as separately for the data east of the Cascades and west of the Cascades, although for HY10M there was not enough data east of the Cascades to calculate reliability. This approach reflects the widely differing geochemistry, industries, and analytes associated with these two areas and allowed evaluation of whether different SQVs would be appropriate for these geo-regions. The results are shown in Table D-2.

Overall, there were no consistent patterns among the results. For some endpoints/effects levels, west side data were more reliable than east side data, and vice versa. In many cases, patterns in the east side results suggested that there were too few data to conduct an effective reliability assessment, or that one survey was dominating the results. In many, but not all, of the cases the combined data were similar to or slightly better than the west side results alone.

Because no clear patterns could be discerned and the east-side database appears insufficient to stand alone at this time, the entire data set was combined and used to calculate state-wide SQVs. It may be possible in the future to develop regional SQVs once more data have been collected in a wider variety of east-side areas.

Table D-2. Geo-region Comparisons

a. CH10G SQS/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	53.3	100.0	46.7	22.0	100.0	53.7
5	4.8	41.2	95.2	58.8	25.8	98.8	63.6
10	9.7	40.9	90.3	59.1	24.9	97.6	63.2
15	14.5	33.7	85.5	66.3	27.6	96.8	68.8
20	19.4	28.3	80.6	71.7	29.9	96.1	72.8
25	24.2	25.4	75.8	74.6	30.9	95.4	74.7
30	29.0	21.1	71.0	78.9	33.6	94.8	77.9

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	34.0	100.0	66.0	15.8	100.0	68.0
5	0.0	34.0	100.0	66.0	15.8	100.0	68.0
10	0.0	34.0	100.0	66.0	15.8	100.0	68.0
15	0.0	34.0	100.0	66.0	15.8	100.0	68.0
20	0.0	34.0	100.0	66.0	15.8	100.0	68.0
25	0.0	34.0	100.0	66.0	15.8	100.0	68.0
30	0.0	34.0	100.0	66.0	15.8	100.0	68.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	58.7	100.0	41.3	19.4	100.0	48.6
5	4.6	47.8	95.4	52.2	22.0	98.8	57.5
10	9.2	41.7	90.8	58.3	23.5	97.8	62.3
15	13.8	40.2	86.2	59.8	23.2	96.8	63.0
20	20.0	35.9	80.0	64.1	24.0	95.8	66.1
25	24.6	33.9	75.4	66.1	23.9	95.0	67.2
30	29.2	27.6	70.8	72.4	26.6	94.6	72.2

b. CH10G CSL/SL2

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	53.0	100.0	47.0	17.2	100.0	52.2
5	4.3	40.7	95.7	59.3	20.5	99.2	62.9
10	8.5	40.4	91.5	59.6	19.9	98.5	62.7
15	14.9	32.2	85.1	67.8	22.5	97.6	69.5
20	19.1	28.5	80.9	71.5	23.8	97.1	72.4
25	23.4	24.1	76.6	75.9	25.9	96.7	76.0
30	29.8	16.1	70.2	83.9	32.4	96.2	82.5

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	35.4	100.0	64.6	10.5	100.0	66.0
5	0.0	35.4	100.0	64.6	10.5	100.0	66.0
10	0.0	35.4	100.0	64.6	10.5	100.0	66.0
15	0.0	35.4	100.0	64.6	10.5	100.0	66.0
20	0.0	35.4	100.0	64.6	10.5	100.0	66.0
25	0.0	35.4	100.0	64.6	10.5	100.0	66.0
30	0.0	35.4	100.0	64.6	10.5	100.0	66.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	54.8	100.0	45.2	15.8	100.0	50.3
5	4.1	43.5	95.9	56.5	18.5	99.3	60.2
10	8.2	37.0	91.8	63.0	20.4	98.7	65.7
15	14.3	36.8	85.7	63.2	19.4	97.7	65.3
20	18.4	30.9	81.6	69.1	21.4	97.3	70.3
25	24.5	25.6	75.5	74.4	23.3	96.7	74.5
30	28.6	20.8	71.4	79.2	26.1	96.4	78.5

c. CH10M SQS/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	96.1	100.0	3.9	27.2	100.0	29.3
5	4.4	81.9	95.6	18.1	29.6	92.0	38.6
10	9.5	74.0	90.5	26.0	30.5	88.4	43.1
15	14.6	67.2	85.4	32.8	31.4	86.2	46.7
20	19.7	61.2	80.3	38.8	32.1	84.6	49.8
25	24.8	56.7	75.2	43.3	32.3	82.9	51.7
30	29.9	48.3	70.1	51.7	34.3	82.8	56.6

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	76.5	100.0	23.5	38.1	100.0	48.0
5	0.0	76.5	100.0	23.5	38.1	100.0	48.0
10	6.3	58.8	93.8	41.2	42.9	93.3	58.0
15	6.3	58.8	93.8	41.2	42.9	93.3	58.0
20	18.8	32.4	81.3	67.6	54.2	88.5	72.0
25	18.8	32.4	81.3	67.6	54.2	88.5	72.0
30	18.8	32.4	81.3	67.6	54.2	88.5	72.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	97.3	100.0	2.7	27.5	100.0	28.9
5	4.6	83.4	95.4	16.6	29.7	90.8	37.9
10	9.8	71.8	90.2	28.2	31.7	88.6	44.9
15	14.4	63.4	85.6	36.6	33.2	87.4	49.8
20	19.6	52.0	80.4	48.0	36.3	86.9	56.7
25	24.8	46.0	75.2	54.0	37.6	85.5	59.7
30	29.4	40.7	70.6	59.3	39.0	84.5	62.3

d. CH10M CSL/SL2

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	52.8	100.0	47.2	19.9	100.0	53.3
5	5.0	42.8	95.0	57.2	22.5	98.9	61.6
10	10.0	33.0	90.0	67.0	26.3	98.1	69.7
15	15.0	23.6	85.0	76.4	32.1	97.5	77.4
20	20.0	19.4	80.0	80.6	35.0	96.9	80.5
25	25.0	17.7	75.0	82.3	35.7	96.2	81.5
30	30.0	13.1	70.0	86.9	41.2	95.7	84.9

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	25.6	100.0	74.4	38.9	100.0	78.0
5	0.0	25.6	100.0	74.4	38.9	100.0	78.0
10	0.0	25.6	100.0	74.4	38.9	100.0	78.0
15	14.3	18.6	85.7	81.4	42.9	97.2	82.0
20	14.3	18.6	85.7	81.4	42.9	97.2	82.0
25	14.3	18.6	85.7	81.4	42.9	97.2	82.0
30	28.6	11.6	71.4	88.4	50.0	95.0	86.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	50.9	100.0	49.1	20.8	100.0	55.1
5	4.5	42.7	95.5	57.3	23.0	99.0	61.8
10	9.0	37.1	91.0	62.9	24.7	98.1	66.2
15	14.9	29.1	85.1	70.9	28.1	97.3	72.5
20	19.4	20.8	80.6	79.2	34.2	96.8	79.4
25	23.9	18.0	76.1	82.0	36.2	96.3	81.3
30	29.9	13.0	70.1	87.0	42.0	95.6	85.0

e. HY10M SQS/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	93.7	100.0	6.3	30.6	100.0	33.7
5	4.8	78.7	95.2	21.3	33.3	91.5	42.9
10	9.5	71.7	90.5	28.3	34.3	87.8	46.5
15	14.3	65.0	85.7	35.0	35.3	85.6	49.9
20	20.0	54.7	80.0	45.3	37.7	84.6	55.4
25	24.8	40.2	75.2	59.8	43.6	85.4	64.3
30	29.5	36.2	70.5	63.8	44.6	83.9	65.7

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	95.7	100.0	4.3	30.7	100.0	32.8
5	4.6	82.9	95.4	17.1	32.8	89.8	40.4
10	9.2	72.4	90.8	27.6	34.7	87.7	46.4
15	14.7	60.7	85.3	39.3	37.3	86.3	53.0
20	19.3	49.8	80.7	50.2	40.7	86.0	59.3
25	24.8	46.7	75.2	53.3	40.6	83.5	59.8
30	29.4	44.7	70.6	55.3	40.1	81.6	59.8

f. HY10M CSL/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	59.4	100.0	40.6	21.0	100.0	48.7
5	4.1	57.4	95.9	42.6	20.9	98.5	49.9
10	8.2	55.2	91.8	44.8	20.8	97.2	51.3
15	14.3	48.7	85.7	51.3	21.8	95.8	56.0
20	18.4	44.5	81.6	55.5	22.5	95.0	59.1
25	24.5	30.0	75.5	70.0	28.5	94.8	70.8
30	28.6	23.2	71.4	76.8	32.7	94.4	76.0

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	69.1	100.0	30.9	19.3	100.0	40.7
5	3.8	54.5	96.2	45.5	22.6	98.6	52.7
10	9.6	49.0	90.4	51.0	23.4	97.0	56.6
15	13.5	35.4	86.5	64.6	28.8	96.7	67.8
20	19.2	32.2	80.8	67.8	29.4	95.5	69.7
25	25.0	25.8	75.0	74.2	32.5	94.7	74.3
30	28.8	24.5	71.2	75.5	32.5	94.0	74.9

g. HY28G SQS/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	83.1	100.0	16.9	33.2	100.0	41.2
5	4.1	74.0	95.9	26.0	34.8	93.9	46.4
10	9.6	62.1	90.4	37.9	37.5	90.5	53.2
15	13.7	58.8	86.3	41.2	37.7	88.0	54.4
20	19.2	48.6	80.8	51.4	40.7	86.7	60.0
25	24.7	43.5	75.3	56.5	41.7	84.7	62.0
30	28.8	42.9	71.2	57.1	40.6	82.8	61.2

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	54.5	100.0	45.5	36.8	100.0	58.6
5	0.0	54.5	100.0	45.5	36.8	100.0	58.6
10	7.1	27.3	92.9	72.7	52.0	97.0	77.6
15	14.3	25.0	85.7	75.0	52.2	94.3	77.6
20	14.3	25.0	85.7	75.0	52.2	94.3	77.6
25	21.4	15.9	78.6	84.1	61.1	92.5	82.8
30	28.6	11.4	71.4	88.6	66.7	90.7	84.5

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	79.6	100.0	20.4	33.1	100.0	42.9
5	4.6	74.7	95.4	25.3	33.5	93.3	45.1
10	9.2	70.6	90.8	29.4	33.6	89.0	46.8
15	14.9	63.8	85.1	36.2	34.4	86.0	50.0
20	19.5	62.0	80.5	38.0	33.8	83.2	50.0
25	24.1	58.4	75.9	41.6	33.8	81.4	51.3
30	29.9	57.0	70.1	43.0	32.6	78.5	50.6

h. HY28G CSL/SL2

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	28.6	100.0	71.4	11.5	100.0	72.4
5	0.0	28.6	100.0	71.4	11.5	100.0	72.4
10	0.0	28.6	100.0	71.4	11.5	100.0	72.4
15	11.1	28.6	88.9	71.4	10.4	99.4	72.0
20	11.1	28.6	88.9	71.4	10.4	99.4	72.0
25	22.2	10.8	77.8	89.2	21.2	99.1	88.8
30	22.2	10.8	77.8	89.2	21.2	99.1	88.8

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	12.2	100.0	87.8	60.0	100.0	89.7
5	0.0	12.2	100.0	87.8	60.0	100.0	89.7
10	0.0	12.2	100.0	87.8	60.0	100.0	89.7
15	11.1	4.1	88.9	95.9	80.0	97.9	94.8
20	11.1	4.1	88.9	95.9	80.0	97.9	94.8
25	22.2	4.1	77.8	95.9	77.8	95.9	93.1
30	22.2	4.1	77.8	95.9	77.8	95.9	93.1

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	36.2	100.0	63.8	14.6	100.0	65.9
5	0.0	36.2	100.0	63.8	14.6	100.0	65.9
10	5.6	36.2	94.4	63.8	13.9	99.5	65.6
15	11.1	23.8	88.9	76.2	18.8	99.1	76.9
20	16.7	17.9	83.3	82.1	22.4	98.8	82.1
25	22.2	9.7	77.8	90.3	33.3	98.5	89.6
30	27.8	6.6	72.2	93.4	40.6	98.2	92.2

i. HY28M SQS/SL1

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	64.2	100.0	35.8	20.5	100.0	44.9
5	2.8	53.2	97.2	46.8	23.2	99.0	53.9
10	8.3	37.2	91.7	62.8	28.9	97.9	66.9
15	13.9	27.1	86.1	72.9	34.4	97.0	74.8
20	19.4	20.2	80.6	79.8	39.7	96.1	79.9
25	25.0	14.2	75.0	85.8	46.6	95.4	84.3
30	27.8	10.1	72.2	89.9	54.2	95.1	87.4

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	25.5	100.0	74.5	47.8	100.0	79.3
5	0.0	25.5	100.0	74.5	47.8	100.0	79.3
10	9.1	25.5	90.9	74.5	45.5	97.2	77.6
15	9.1	25.5	90.9	74.5	45.5	97.2	77.6
20	18.2	21.3	81.8	78.7	47.4	94.9	79.3
25	18.2	21.3	81.8	78.7	47.4	94.9	79.3
30	27.3	21.3	72.7	78.7	44.4	92.5	77.6

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	59.2	100.0	40.8	23.0	100.0	49.7
5	4.3	53.2	95.7	46.8	24.2	98.4	54.2
10	8.5	40.8	91.5	59.2	28.5	97.5	64.1
15	14.9	26.0	85.1	74.0	36.7	96.6	75.6
20	19.1	21.1	80.9	78.9	40.4	95.9	79.2
25	23.4	13.2	76.6	86.8	50.7	95.4	85.3
30	29.8	6.8	70.2	93.2	64.7	94.6	89.7

j. HY28M CSL/SL2

West

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	29.9	100.0	70.1	25.0	100.0	72.8
5	4.3	13.9	95.7	86.1	40.7	99.5	87.0
10	8.7	9.5	91.3	90.5	48.8	99.1	90.6
15	13.0	6.5	87.0	93.5	57.1	98.6	92.9
20	17.4	4.8	82.6	95.2	63.3	98.2	94.1
25	21.7	3.5	78.3	96.5	69.2	97.8	94.9
30	26.1	2.2	73.9	97.8	77.3	97.4	95.7

East

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	5.6	100.0	94.4	57.1	100.0	94.8
5	0.0	5.6	100.0	94.4	57.1	100.0	94.8
10	0.0	5.6	100.0	94.4	57.1	100.0	94.8
15	0.0	5.6	100.0	94.4	57.1	100.0	94.8
20	0.0	5.6	100.0	94.4	57.1	100.0	94.8
25	25.0	5.6	75.0	94.4	50.0	98.1	93.1
30	25.0	5.6	75.0	94.4	50.0	98.1	93.1

Combined

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	33.3	100.0	66.7	22.1	100.0	69.6
5	3.7	13.7	96.3	86.3	40.0	99.6	87.2
10	7.4	10.9	92.6	89.1	44.6	99.2	89.4
15	14.8	7.7	85.2	92.3	51.1	98.5	91.7
20	18.5	4.9	81.5	95.1	61.1	98.2	93.9
25	22.2	3.5	77.8	96.5	67.7	97.9	94.9
30	29.6	1.8	70.4	98.2	79.2	97.2	95.8

D.3. Comparison to Reference vs. Control

The subset of the data set that includes reference data was used to evaluate the reliability of comparison to control vs. comparison to reference, to test the previous finding (SAIC and Avocet, 2003) that comparison to control provides similar or better reliability than comparison to reference. The results are shown in Table D-3 below. In these tables, green colored regions are those that performed better in a given table.

In all cases, comparison to control and reference were equally good or comparison to control was much better. Therefore, the workgroup chose to use comparison to control, in part due to these reliability evaluations and in part because there are far more data available to work with.

Table D-3. Comparison to Reference vs. Control

a. CH10G SQS/SL1

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	63.4	100.0	36.6	21.8	100.0	46.1
5	3.7	62.7	96.3	37.3	21.3	98.3	46.1
10	7.4	51.6	92.6	48.4	24.0	97.4	55.0
15	14.8	41.2	85.2	58.8	26.7	95.7	62.8
20	18.5	37.9	81.5	62.1	27.5	95.0	65.0
25	22.2	28.8	77.8	71.2	32.3	94.8	72.2
30	29.6	5.2	70.4	94.8	70.4	94.8	91.1

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	70.8	100.0	29.2	35.2	100.0	48.9
5	4.0	57.7	96.0	42.3	39.0	96.5	57.2
10	10.0	40.8	90.0	59.2	45.9	93.9	67.8
15	14.0	28.5	86.0	71.5	53.8	93.0	75.6
20	20.0	20.0	80.0	80.0	60.6	91.2	80.0
25	24.0	19.2	76.0	80.8	60.3	89.7	79.4
30	30.0	15.4	70.0	84.6	63.6	88.0	80.6

Conclusion: Neither is clearly better.

b. CH10G CSL/SL2

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	32.1	100.0	67.9	29.2	100.0	71.7
5	4.8	14.5	95.2	85.5	46.5	99.3	86.7
10	9.5	9.4	90.5	90.6	55.9	98.6	90.6
15	14.3	8.8	85.7	91.2	56.3	98.0	90.6
20	19.0	6.9	81.0	93.1	60.7	97.4	91.7
25	23.8	3.1	76.2	96.9	76.2	96.9	94.4
30	28.6	1.9	71.4	98.1	83.3	96.3	95.0

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	37.0	100.0	63.0	38.6	100.0	70.0
5	2.9	26.0	97.1	74.0	46.5	99.1	78.3
10	8.8	21.2	91.2	78.8	50.0	97.5	81.1
15	14.7	13.7	85.3	86.3	59.2	96.2	86.1
20	17.6	13.0	82.4	87.0	59.6	95.5	86.1
25	23.5	11.0	76.5	89.0	61.9	94.2	86.7
30	29.4	7.5	70.6	92.5	68.6	93.1	88.3

Conclusion: Control is clearly better.

c. CH10M SQS/SL1

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	72.4	100.0	27.6	43.3	100.0	53.4
5	4.1	59.7	95.9	40.3	47.0	94.7	60.1
10	9.5	53.0	90.5	47.0	48.6	90.0	62.5
15	14.9	47.8	85.1	52.2	49.6	86.4	63.9
20	18.9	43.3	81.1	56.7	50.8	84.4	65.4
25	24.3	35.8	75.7	64.2	53.8	82.7	68.3
30	29.7	26.9	70.3	73.1	59.1	81.7	72.1

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	64.5	100.0	35.5	17.5	100.0	43.3
5	4.0	61.7	96.0	38.3	17.5	98.6	45.2
10	8.0	56.8	92.0	43.2	18.1	97.5	49.0
15	12.0	54.6	88.0	45.4	18.0	96.5	50.5
20	20.0	47.5	80.0	52.5	18.7	95.0	55.8
25	24.0	40.4	76.0	59.6	20.4	94.8	61.5
30	28.0	37.2	72.0	62.8	20.9	94.3	63.9

Conclusion: Control is slightly better.

d. CH10M CSL/SL2

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	42.2	100.0	57.8	26.9	100.0	63.5
5	3.6	41.1	96.4	58.9	26.7	99.1	63.9
10	7.1	40.0	92.9	60.0	26.5	98.2	64.4
15	14.3	36.1	85.7	63.9	27.0	96.6	66.8
20	17.9	31.1	82.1	68.9	29.1	96.1	70.7
25	25.0	26.1	75.0	73.9	30.9	95.0	74.0
30	28.6	21.1	71.4	78.9	34.5	94.7	77.9

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	35.4	100.0	64.6	12.5	100.0	66.3
5	0.0	35.4	100.0	64.6	12.5	100.0	66.3
10	10.0	33.8	90.0	66.2	11.8	99.2	67.3
15	10.0	33.8	90.0	66.2	11.8	99.2	67.3
20	20.0	33.3	80.0	66.7	10.8	98.5	67.3
25	20.0	33.3	80.0	66.7	10.8	98.5	67.3
30	30.0	18.2	70.0	81.8	16.3	98.2	81.3

Conclusion: Neither is clearly better.

e. HY28G SQS/SL1

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	60.7	100.0	39.3	48.5	100.0	61.4
5	0.0	60.7	100.0	39.3	48.5	100.0	61.4
10	6.3	32.1	93.8	67.9	62.5	95.0	77.3
15	12.5	10.7	87.5	89.3	82.4	92.6	88.6
20	18.8	0.0	81.3	100.0	100.0	90.3	93.2
25	18.8	0.0	81.3	100.0	100.0	90.3	93.2
30	18.8	0.0	81.3	100.0	100.0	90.3	93.2

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	50.0	100.0	50.0	62.5	100.0	72.7
5	5.0	45.8	95.0	54.2	63.3	92.9	72.7
10	10.0	45.8	90.0	54.2	62.1	86.7	70.5
15	15.0	45.8	85.0	54.2	60.7	81.3	68.2
20	20.0	41.7	80.0	58.3	61.5	77.8	68.2
25	25.0	25.0	75.0	75.0	71.4	78.3	75.0
30	30.0	16.7	70.0	83.3	77.8	76.9	77.3

Conclusion: Control is clearly better.

f. HY28G CSL/SL2

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	7.7	100.0	92.3	62.5	100.0	93.2
5	0.0	7.7	100.0	92.3	62.5	100.0	93.2
10	0.0	7.7	100.0	92.3	62.5	100.0	93.2
15	0.0	7.7	100.0	92.3	62.5	100.0	93.2
20	20.0	5.1	80.0	94.9	66.7	97.4	93.2
25	20.0	5.1	80.0	94.9	66.7	97.4	93.2
30	20.0	5.1	80.0	94.9	66.7	97.4	93.2

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	40.6	100.0	59.4	48.0	100.0	70.5
5	0.0	40.6	100.0	59.4	48.0	100.0	70.5
10	8.3	34.4	91.7	65.6	50.0	95.5	72.7
15	8.3	34.4	91.7	65.6	50.0	95.5	72.7
20	16.7	15.6	83.3	84.4	66.7	93.1	84.1
25	16.7	15.6	83.3	84.4	66.7	93.1	84.1
30	16.7	15.6	83.3	84.4	66.7	93.1	84.1

Conclusion: Control is clearly better.

g. HY28M SQS/SL1

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	19.4	100.0	80.6	68.4	100.0	86.4
5	0.0	19.4	100.0	80.6	68.4	100.0	86.4
10	7.7	19.4	92.3	80.6	66.7	96.2	84.1
15	7.7	19.4	92.3	80.6	66.7	96.2	84.1
20	15.4	12.9	84.6	87.1	73.3	93.1	86.4
25	23.1	3.2	76.9	96.8	90.9	90.9	90.9
30	23.1	3.2	76.9	96.8	90.9	90.9	90.9

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	21.2	100.0	78.8	61.1	100.0	84.1
5	0.0	21.2	100.0	78.8	61.1	100.0	84.1
10	9.1	21.2	90.9	78.8	58.8	96.3	81.8
15	9.1	21.2	90.9	78.8	58.8	96.3	81.8
20	18.2	15.2	81.8	84.8	64.3	93.3	84.1
25	18.2	15.2	81.8	84.8	64.3	93.3	84.1
30	27.3	6.1	72.7	93.9	80.0	91.2	88.6

Conclusion: Control is clearly better.

h. HY28M CSL/SL2

Control

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	7.3	100.0	92.7	50.0	100.0	93.2
5	0.0	7.3	100.0	92.7	50.0	100.0	93.2
10	0.0	7.3	100.0	92.7	50.0	100.0	93.2
15	0.0	7.3	100.0	92.7	50.0	100.0	93.2
20	0.0	7.3	100.0	92.7	50.0	100.0	93.2
25	0.0	7.3	100.0	92.7	50.0	100.0	93.2
30	0.0	7.3	100.0	92.7	50.0	100.0	93.2

Reference

Nominal Percentiles	%False Negatives	%False Positives	Hit Reliability	NoHit Reliability	PredHit Reliability	PredNoHit Reliability	Overall Reliability
0	0.0	7.3	100.0	92.7	50.0	100.0	93.2
5	0.0	7.3	100.0	92.7	50.0	100.0	93.2
10	0.0	7.3	100.0	92.7	50.0	100.0	93.2
15	0.0	7.3	100.0	92.7	50.0	100.0	93.2
20	0.0	7.3	100.0	92.7	50.0	100.0	93.2
25	0.0	7.3	100.0	92.7	50.0	100.0	93.2
30	0.0	7.3	100.0	92.7	50.0	100.0	93.2

Conclusion: Both are the same.

D.4. Blank-Correction

It was determined during the quality assurance review that the data sets had not all been blank-corrected in the same manner. Furthermore, a number of chemicals known to be laboratory contaminants and not likely to be found in environmental sediments were associated with false positives in the data set, including acetone (5 false positives) and methylene chloride (57 false positives). This issue was resolved by applying EPA contract laboratory protocol blank-correction methods to all of the data in all of the historical data sets consistently, revising qualifier codes as necessary.

Following this step, the model was begun again to evaluate the effect of this change in the data set. It was immediately apparent that this requalification had improved the results, because the data set no longer contained acetone, methylene chloride, or isopropylbenzene, among other chemicals that are highly unlikely to be found in sediments but are common laboratory contaminants. These chemicals no longer had enough detections to pass the initial screening criteria. In addition, it is likely that some spurious results for chemicals that can be found in the environment but are also common laboratory contaminants were removed, leaving only those detections more likely to be associated with actual environmental concentrations.

Because this evaluation was conducted by examining the data set itself and the initial data screening results, reliability analysis was not conducted for this step alone. However, this process along with a number of other more minor quality assurance screening evaluations of the data significantly improved reliability in incremental steps.

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Appendix E - Case Studies

Human Health Case Studies

The human health cases studies presented in this section include:

1) A non-urban shoreline;
2) An urban shoreline;
3) Urban embayment;
4) Freshwater river; and
5) A comprehensive Puget Sound sediment quality dataset.

Selected chemicals or chemical groups from each of the first four case studies are used to develop cleanup levels based on each of the five proposed human health rule revision alternatives. Then, the cleanup levels derived from this exercise are collectively compared to the comprehensive Puget Sound sediment quality dataset as the fifth case study.

Cleanup Case Study 1 – Non-Urban Shoreline

Case Study 1 is a marine sediment cleanup site from a non-urban shoreline in Puget Sound, where contaminants of concern for human health protection include cadmium, cPAHs, and dioxin/furan congeners. Chemical concentration values are shown in Table E.1.

Table E.1 - Chemical Concentration Ranges, Case Study 1, Non-Urban Shoreline (Human Health Alternatives)

Contaminant	Carcinogen/NC	No. of Samples	Concentration		
			Minimum	Maximum	Mean
Dioxin/Furan Congeners	Carcinogen	10	0.34 ng/kg TEQ	2.48 ng/kg TEQ	1.06 ng/kg TEQ
Cadmium	NC	42	0.2 mg/kg	2.3 mg/kg	1.03 mg/kg
CPAH	Carcinogen	42	7.16 ug/kg	61.12 ug/kg	17.51 ug/kg

An analysis of this case study through each of the proposed five rule revision alternatives for protection of human health is provided below.

Alternative 1 - Original Rule (The No Action Alternative)

Under Alternative 1, sediment cleanup levels for human health protection were established on a site-specific basis per the original rule, using the applicable requirements in the MTCA rule. The approach is similar to the MTCA "one-tier" approach where the cleanup level is the highest of risk-based levels to human health, MTCA natural background, or PQL of the contaminant of concern.

Human Health Risk Evaluation. The likely human health exposure pathway for Case Study 1 contaminants was determined to be through ingestion of shellfish. Two reasonable maximum exposure (RME) scenarios were developed: the seafood ingestion scenario with the focus on shellfish ingestion, and the RME clamming scenario. The RME scenarios were developed based on a tribal use scenario, as allowed under MTCA. A daily shellfish consumption rate of 499 grams per day and adult body weight of 79 kilograms were used, for illustration purposes.

Carcinogenic risks and non-carcinogenic health effects were evaluated separately because of differences in assumptions about the mechanism of these toxic effects. The human health risk factors determined for cadmium, dioxin/furan congeners, and cPAHs under the RME seafood ingestion scenario, and derived sediment concentration levels at a risk level of 1E-06 or HQ greater than 1 are summarized in Table E.2. Derived risk sediment concentration levels under the RME clamming scenario were below the risk level of 1E-06 or the HQ was less than 1.

MTCA Natural Background. Natural background values for cadmium, dioxin/furan congeners, and cPAHs were determined from a subset of the OSV *Bold* dataset within the vicinity of the site using the 95 percent UCL on the mean assuming normal distribution (Table E.2).

PQL. The PQLs for cadmium, dioxin/furan congeners, and cPAHs as identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA are summarized in Table E.2.

Alternative 1 Cleanup Levels. Based on the statistical evaluation of risk drivers, the following sediment cleanup levels were established for Alternative 1, as shown in Table E.2:

- *Cadmium.* The selected cleanup level was set as the 95 percent UCL natural background sediment concentration of 0.97 mg/kg.
- *cPAHs.* The selected cleanup level was set as the 95 percent UCL natural background cPAH TEQ in sediment of 5.32 μg/kg.
- *Dioxin/Furan Congeners.* The selected cleanup level was set as the PQL for dioxin/furan in sediment of 5.0 ng/kg TEQ.

Table E.2 - Potential Cleanup Levels, Case Study 1, Non-Urban Shoreline (Human Health Alternatives)

Contaminant	Alternatives 1 - 5				PQL Concentration[2]	MTCA Natural Background Concentration[3]	Regional Background Concentration[4]
	Carcinogen		Non-carcinogen				
	HH (1E-06) Concentration[1]	HH (1E-05) Concentration[1]	Hazard Quotient[1]	HQ = 1 Concentration[1]			
Dioxin/Furan Congeners	0.0187 ng/kg	**0.187 ng/kg Alternative 2**	**--**	--	**5.0 ng/kg Alternative 1 Alternative 4 Alternative 5 (CSL & SCO)**	1.17 ng/kg	**1.17 ng/kg Alternative 3**
Cadmium	--	--	2	**0.466 mg/kg Alternative 2**	0.14 mg/kg	**0.97 mg/kg Alternative 1 Alternative 5 SCO[5]**	**0.97 mg/kg Alternative 3 Alternative 4 Alternative 5 CSL[5]**
cPAH	0.455 µg/kg	**4.55 µg/kg Alternative 2**	--	--	0.755 µg/kg	**5.32 µg/kg Alternative 1 Alternative 5 SCO[6]**	**5.32 µg/kg Alternative 3 Alternative 4 Alternative 5 CSL[6]**

[1]The human health-based levels for dioxin/furan congeners and cPAH were calculated based on two RME scenarios: the seafood ingestion scenario with the focus on shellfish ingestion, and the clamming scenario. Both were developed based on the EPA tribal framework document (EPA, 2007). For Alternatives 1 through 5, a daily shellfish consumption of 499 gram per day shellfish consumption and 79 kg body weight was used. It was assumed that the shellfish diet consisted of clams. In all cases, the risk-based level was lower using the seafood ingestion scenario than the value derived using the clamming scenario; therefore, calculated human health carcinogenic risk values for dioxin/furan congeners and cPAH, as well as the hazard quotient value for cadmium in the above table, are based on the seafood consumption scenario. Human health concentrations for dioxin/furan congeners and cPAH at the 1E-06 and 1E-05 risk levels, and for cadmium at the hazard index of 1.0 level, were calculated using equations presented earlier in this document.
[2]The PQLs were identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA was used.
[3] MTCA natural background levels for cadmium, dioxin/furan congeners, and cPAH were determined from a subset of the OSV Bold survey dataset (DMMP 2009) within the vicinity of the site using the 95th percent UCL on the mean assuming normal distribution (dioxin/furan congener and cPAH TEQ calculations used half of the detection limit for non-detected concentrations).
[4]Sediment data selected for regional background were determined on a case-by-case basis. For Case Study 1, there was not adequate data available to represent regional background. For this non-urban shoreline site, chemical concentrations in the outer portion of the site are low and comparable to MTCA natural background. Therefore, the MTCA natural background concentrations were adopted as the regional background concentrations for the purposes of this case study evaluation.
[5] Cleanup level for cadmium for Alternative 5 would be set somewhere in the range between the Cleanup Screening Level (in this case the CSL is the regional background concentration) and the Sediment Cleanup Objective (in this case the SCO is the MTCA natural background concentration), which are the upper and lower bounds of the two-tiered SMS Framework, respectively. For this case study both values are the same.
[6] Cleanup level for cPAH would be set somewhere in the range between the Cleanup Screening Level (in this case the CSL is the regional background concentration) and the Sediment Cleanup Objective (in this case the SCO is the MTCA natural background), which are the upper and lower bounds of the two-tiered SMS Framework, respectively. For this case study both values are the same.

Under this alternative, the total area of the Case Study 1 site identified for potential cleanup for the contaminants of concern is presented on Figure E.1 and summarized in Table E.3.

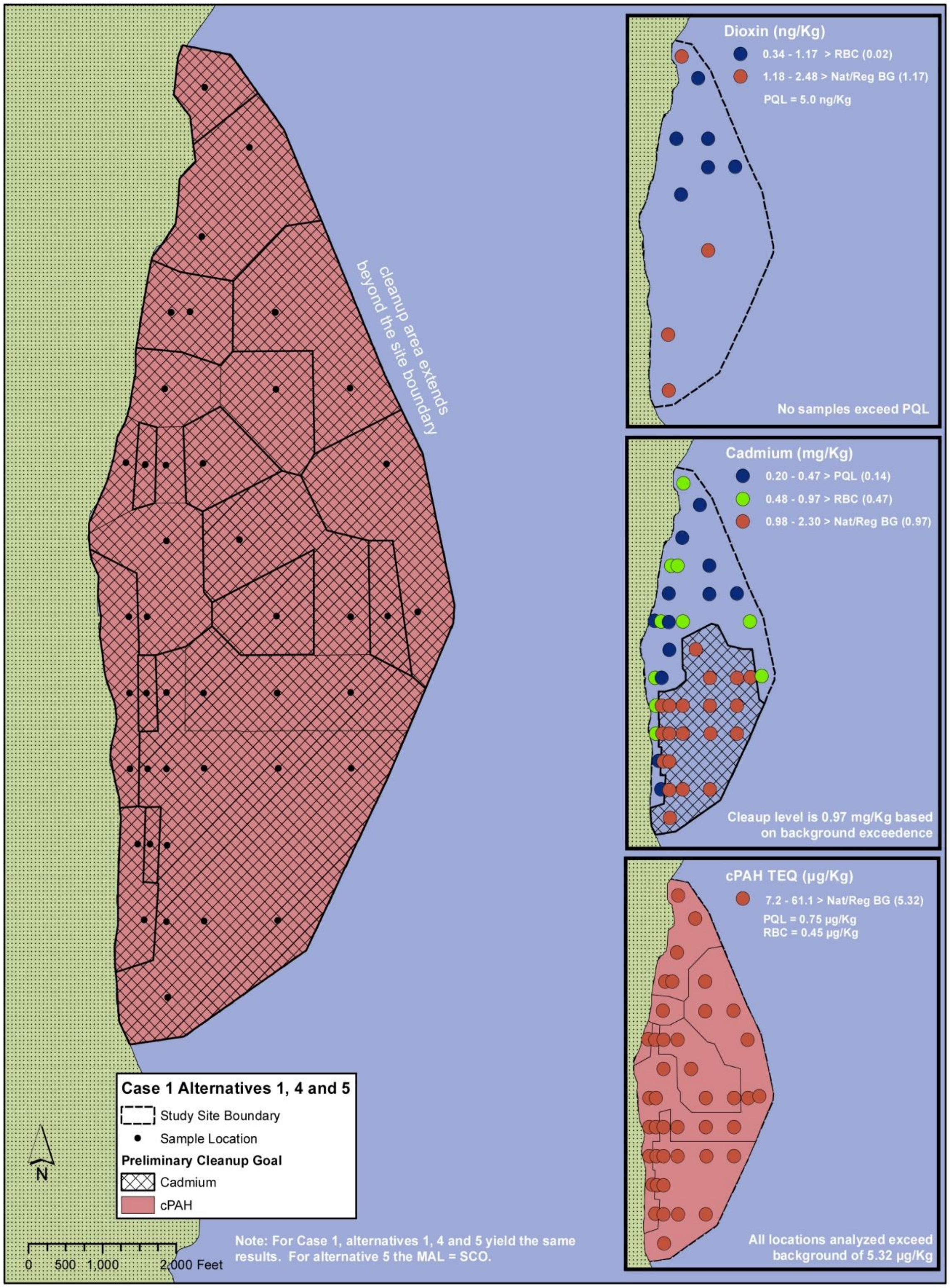


Figure E.1 - Case Study 1 - Areas Identified for Cleanup under Alternatives 1, 4, and 5

Table E.3 - Area Requiring Cleanup, Case Study 1, Non-Urban Shoreline (Human Health Alternatives)

Alternative	Acres Requiring Cleanup by Individual Contaminant[1]		
	Dioxin/Furan Congeners[2]	Cadmium[2]	cPAH[2]
Alternative 1	0	437.93	> 928.74
Alternative 2	299.30	627.26	> 928.74
Alternative 3	101.53	437.93	> 928.74
Alternative 4	0	437.93	> 928.74
Alternative 5	0	437.93[3]	> 928.74[3]

[1]Total number of acres in the Case Study 1 site was 928.74.
[2]If the cleanup level is set to natural background, cleanup acreage for dioxin/furan congeners = 101.53, cadmium = 437.93, cPAH = 928.74.
[3]The Cleanup Screening Level (CSL) and Sediment Cleanup Objective (SCO) are the same value, resulting in the same cleanup acreage.

Alternative 2 - Risk-Based Concentrations Based on Reasonable Maximum Exposure

Under Alternative 2, cleanup levels would be established solely on the basis of the human health risk assessment at a risk level of 1E-06 for single carcinogens, 1E-05 for multiple carcinogens, and a hazard quotient greater than 1 for non-carcinogenic chemicals. The RME scenarios used to evaluate human health risk as described in Alternative 1 would be the basis for cleanup levels established for cadmium, cPAH, and dioxin/furan congeners. Anticipated cleanup levels are summarized for Alternative 2 in Table E.2.

Under this alternative, the entire site (928.74 acres) would be identified as exceeding the cleanup levels for cPAHs (Figure E.2 and Table E.3). Site boundaries were established for illustration purposes to compare to other alternatives. However, given that the risk-based concentrations are below MTCA natural background levels, the sediment concentrations that exceed the human health risk-based cleanup levels would extend beyond the illustrated site boundaries for cPAHs. The locations sampled for dioxin/furan congeners exceeded the risk-based cleanup level but cleanup was represented only to the extent of analysis. See Case Study 5 for more detail on Puget Sound-wide concentrations.

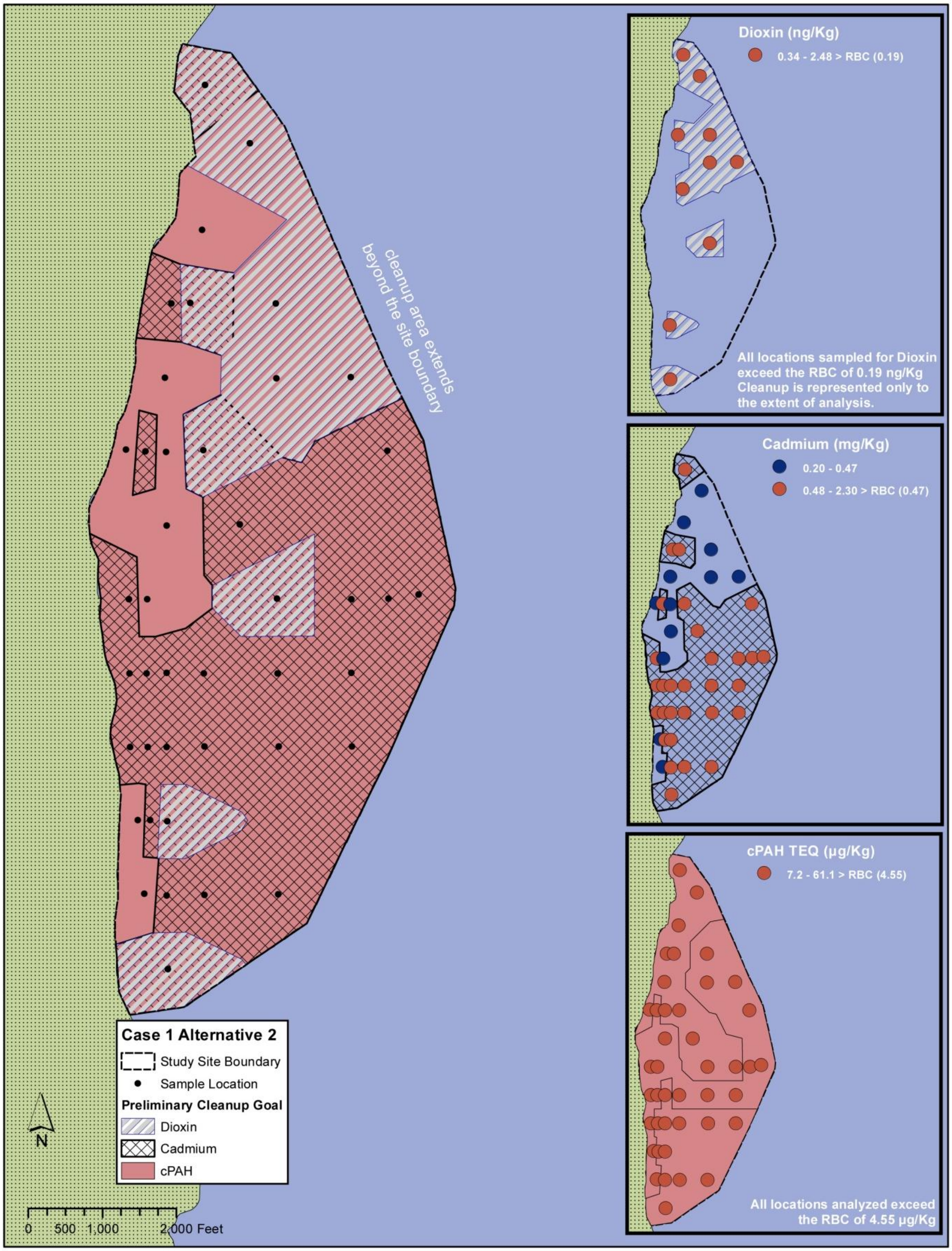


Figure E.2 - Case Study 1 - Areas Identified for Cleanup under Alternative 2

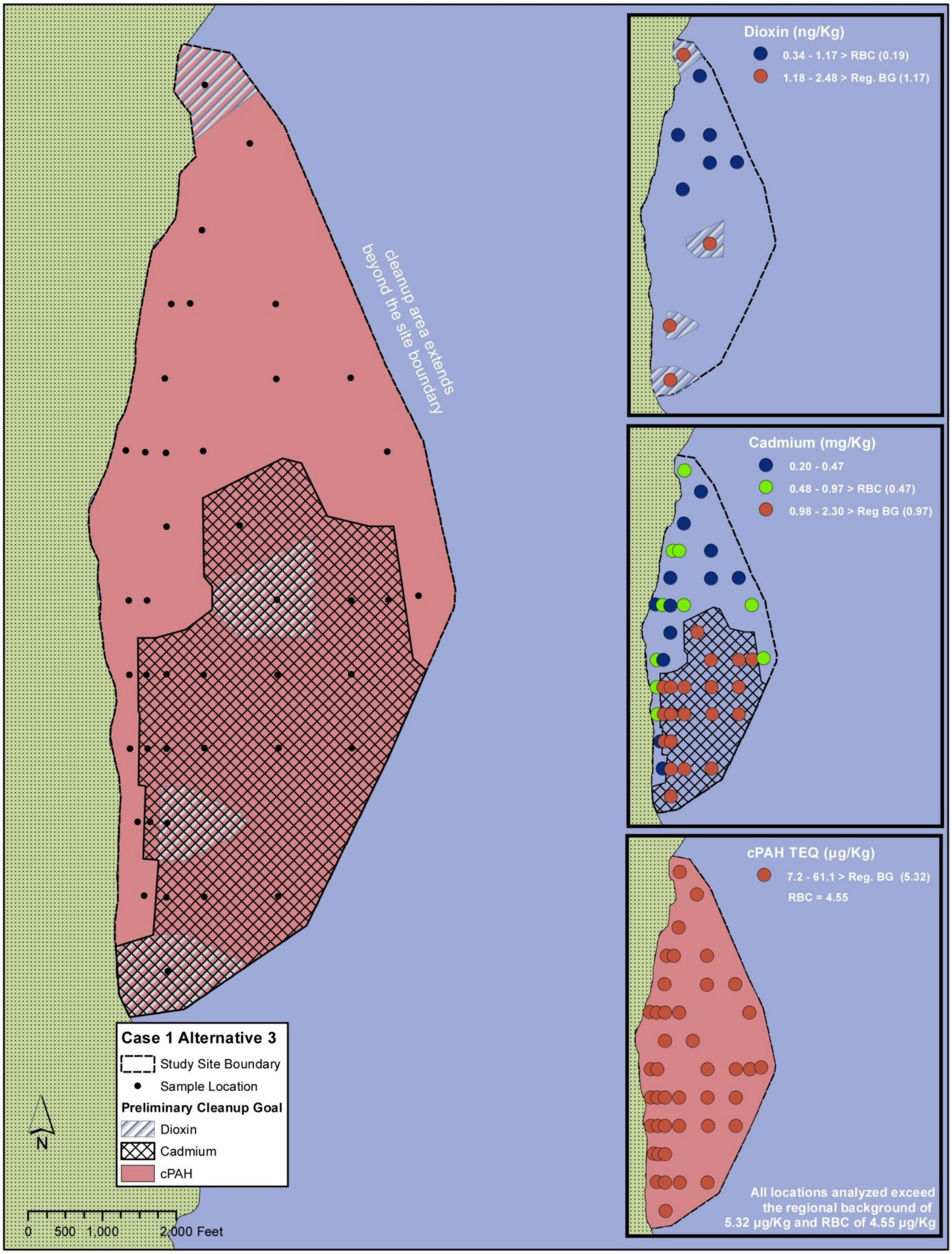


Figure E.3 - Case Study 1 - Areas Identified for Cleanup under Alternative 3

Alternative 3 - Risk-Based Concentrations Based on Federal Guidance or Regional Background

Under Alternative 3, cleanup levels for contaminants of concern would be established as the highest of risk-based concentrations based on federal guidance, or regional background (which is similar to EPA's anthropogenic background concept). Federal guidance specifies a one in ten thousand (1E-04) risk level for all of the carcinogenic chemicals combined and multiple exposure pathways.[44] For the purposes of these case study evaluations, a one in one hundred thousand (1E-05) risk level is assumed for any one carcinogenic chemical and single exposure pathway. Regional background would take into account ubiquitous, anthropogenic contamination as described in Chapter 3.

The risk-based concentrations at the 1E-05 risk level fall below the regional background concentrations (Table E.2). Therefore, the cleanup levels would be established at regional background concentrations under Alternative 3. Under Alternative 3, the total area of the Case Study 1 site is identified for potential cleanup for the contaminants of concern (Figure E.3 and Table E.3).

Alternative 4 - Regional Background and PQL

Under Alternative 4, cleanup levels for contaminants of concern would be established as the highest of regional background or the PQL. Regional background concentrations are higher than the PQLs for cadmium and cPAHs, and the PQL is higher than regional background for dioxin/furan congeners. For Case Study 1, the natural and regional background concentrations for the contaminants of concern were determined to be the same concentrations. Therefore, the proposed cleanup areas under Alternative 4 are the same as those for Alternative 1 (Figure E.1 and Table E.2).

Alternative 5 - Two-Tier Approach

Under Alternative 5, the cleanup level for Case Study 1 would be set within a range between an upper and lower bound consistent with the original two-tier SMS framework. The upper value would be referred to as the Cleanup Screening Level (CSL), which is defined to be the upper bound allowed as a cleanup level. This upper bound would be established as the highest of risk-based concentration (for human health it would be a risk of 1E-05 for total site risk), regional background, or PQL. The lower bound would be referred to as the Sediment Cleanup Objective (SCO). This lower bound concentration would be set as the highest of risk-based concentrations (for human health it would be a 1E-06 risk for a single carcinogen, total site risk of 1E-05 for multiple carcinogens, or HQ=1 for non-carcinogens), MTCA natural background, or PQL.

The site-specific cleanup level established for the site, based on protection of human health, would be somewhere in the range between the CSL (upper level) and SCO (lower level), and would be established on the basis of technical possibility and net adverse environmental impact. These cleanup levels are summarized in Table E.2. For this case study, the CSL was regional

[44] Environmental Protection Agency, Office of Solid Waste and Emergency Response, OSWER Directive 9355.0-30, 1991.

background and the SCO was the MTCA natural background for cadmium and cPAHs. For dioxin/furan congeners, the CSL and SCO were both determined to be the PQL.

The total area of the Case Study 1 site identified that exceeds the cleanup levels for the contaminants of concern would be the same as Alternative 1 (Table E.3 and Figure E.1).

Cleanup Case Study 2 – Urban Shoreline

Case Study 2 is a marine sediment site at an urban shoreline in Puget Sound, where the contaminants of concern for human health protection include arsenic and cPAHs. The urban shoreline supports various types of industries and has multiple potential sources of contamination. Chemical concentration values are shown in Table E.4.

Table E.4 - Chemical Concentration Ranges, Case Study 2, Urban Shoreline (Human Health Alternatives)

Contaminant	Carcinogen/NC	No. of Samples	Concentration		
			Minimum	Maximum	Mean
Arsenic	Carcinogen	65	3.0 mg/kg	53.0 mg/kg	10.59 mg/kg
cPAH	Carcinogen	65	1.09 ug/kg	3,700 ug/kg	167.37 ug/kg

An analysis of this case study through each of the proposed five rule revision alternatives for protection of human health is provided below.

Alternative 1 - Original Rule (The No Action Alternative)

Alternative 1 is the original rule and follows the MTCA "one-tier" approach where the cleanup level is the highest of risk-based levels to human health at a risk level of 1E-06 for single carcinogens or 1E-05 for multiple carcinogens, MTCA natural background, or PQL of the contaminant of concern.

Human Health Risk Evaluation. The likely human health exposure pathway for the contaminants listed in Table E.4 was determined to be through ingestion of seafood or sediment and dermal contact with sediment. The various exposure scenarios developed included seafood consumption, netfishing, beach play RME, and clamming. Seafood consumption rates were based on consumption studies representative of seafood harvest from other areas of Puget Sound. A seafood consumption rate of 97.5 grams per day and an adult body weight of 81.8 kilograms were used. The human health risk factors determined for arsenic and cPAHs under the RME seafood consumption scenario, and derived sediment concentration levels at a risk level of 1E-06 are summarized in Table E.5. Derived risk sediment concentration levels for the other RME scenarios were below the risk level of 1E-06.

MTCA Natural Background. Natural background values for arsenic and cPAHs were determined from the entire OSV *Bold* dataset using the 95 percent UCL of the mean assuming normal distribution and are summarized in Table E.5.

PQL. The PQLs for arsenic and cPAHs as identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA are summarized in Table E.5.

Alternative 1 Cleanup Levels. Based on the statistical evaluation of risk drivers, the following sediment cleanup levels were established for Alternative 1, as shown on Table E.5:

- *Arsenic.* The selected cleanup level was set as the natural background sediment concentration of 7.3 mg/kg.
- *cPAHs.* The selected cleanup level was set as the natural background cPAH TEQ in sediment of 8.48 μg/kg.

Under this alternative, the total area of the Case Study 1 site identified for cleanup for the contaminants of concern is presented on Figure E.4 and summarized in Table E.6.

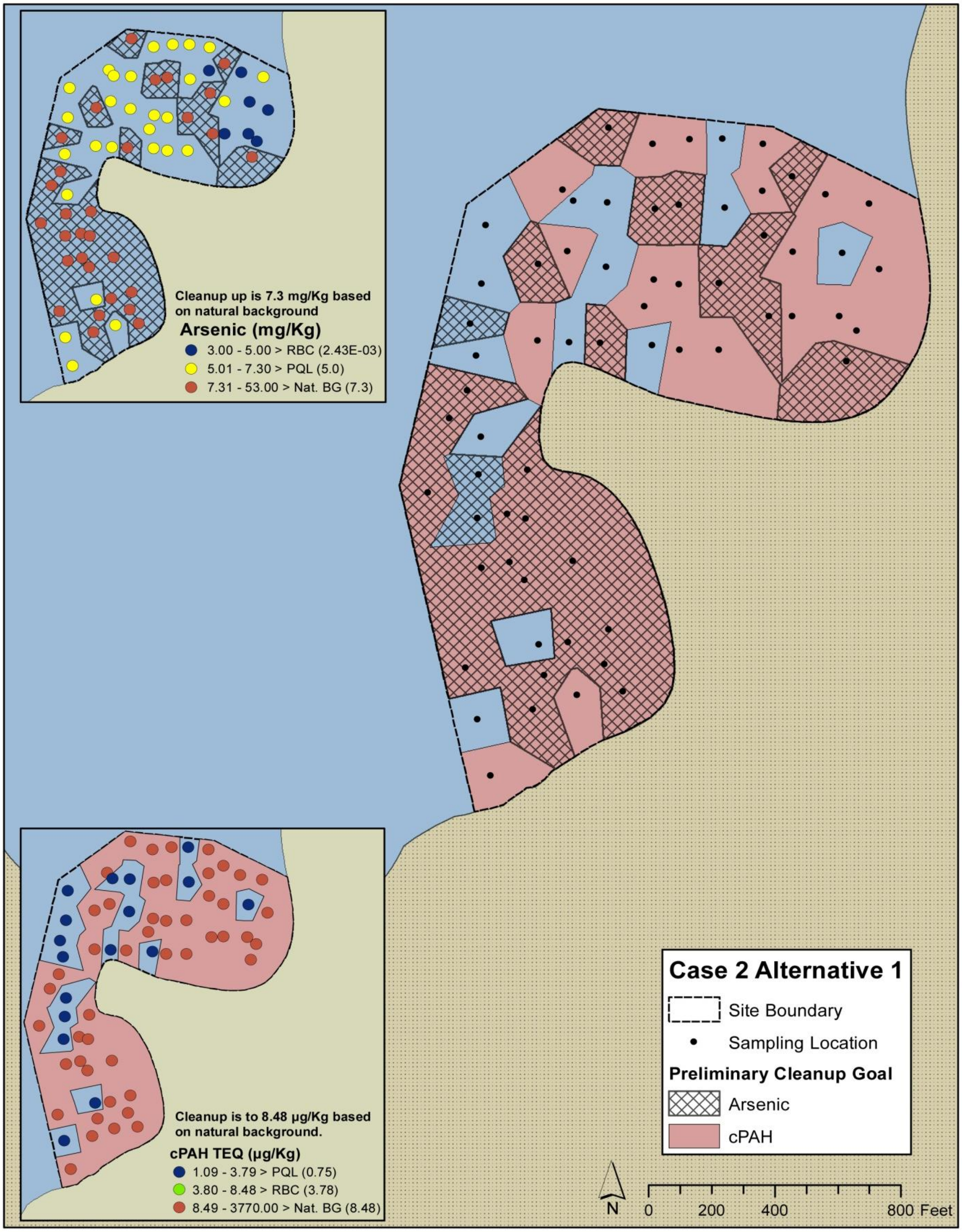


Figure E.4 - Case Study 2 - Areas Identified for Cleanup under Alternative 1

Table E.5 - Potential Cleanup Levels, Case Study 2, Urban Shoreline (Human Health Alternatives)

Contaminant	Carcinogen (Alternatives 1 – 5)		PQL Concentration[2]	MTCA Natural Background Concentration[3]	Regional Background Concentration[4]
	HH (1E-06) Concentration[1]	HH (1E-05) Concentration[1]			
Arsenic	2.43E-03 mg/kg	2.43E-02 mg/kg Alternative 2	5.0 mg/kg	7.3 mg/kg Alternative 1 Alternative 5 SCO[5]	7.3 mg/kg Alternative 3 Alternative 4 Alternative 5 CSL[5]
cPAH	3.79 µg/kg	37.9 µg/kg Alternative 2 Alternative 5 SCO[6]	0.755 µg/kg	8.48 µg/kg Alternative 1	42.59 µg/kg Alternative 3 Alternative 4 Alternative 5 CSL[6]

[1]The human health-based levels for arsenic and cPAH were calculated after evaluation of several exposure scenarios, including seafood ingestion, netfishing, beach play RME, and clamming. A daily seafood consumption of 97.5 gram per day and 81.8 kg body weight was used. It was assumed that the seafood diet consisted of benthic fish. In all cases, the risk-based level was lower using the seafood ingestion scenario than the value derived using other scenarios; therefore, calculated human health risk values for arsenic and cPAH in the above table are based on the seafood consumption scenario. Human health concentrations for arsenic and cPAH at the 1E-06 and 1E-05 risk levels were calculated using equations presented earlier in this document.

[2]The PQLs were identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA was used.

[3] MTCA natural background levels for Puget Sound sediments were taken from the Puget Sound background sediment database developed for the OSV Bold survey dataset (EPA, 2009). Report data from within the vicinity of the site were used, calculating the 95th percent UCL on the mean assuming normal distribution (cPAH TEQ calculations used half of the detection limit for non-detected concentrations).

[4]Sediment data selected for regional background were determined on a case-by-case basis. For Case Study 2, the regional background value was determined using the 95th percent UCL on the mean for the data (cPAH TEQ calculations used half of the detection limit for non-detected concentrations).

[5] Cleanup level for arsenic under Alternative 5 would be set somewhere in the range between the Cleanup Screening Level (in this case the CSL is regional background) and the Sediment Cleanup Objective (in this case the SCO is natural background), which are the upper and lower bounds of the two-tiered SMS Framework, respectively. For this case study, both values are the same.

[6]Cleanup level for cPAH would be set somewhere in the range between the Cleanup Screening Level (in this case the CSL is regional background) and the Sediment Cleanup Objective (in this case the SCO is the human health concentration based on a 1E-05 risk level), which are the upper and lower bounds, respectively, of the two-tiered SMS Framework.

Table E.6 - Area Requiring Cleanup, Case Study 2, Urban Shoreline (Human Health Alternatives)

Alternative	Acres Requiring Cleanup by Individual Contaminant[1]	
	Arsenic[2]	cPAH[2]
Alternative 1	22.84	36.07
Alternative 2	> 46.48	28.82
Alternative 3	22.84	27.37
Alternative 4	22.84	27.37
Alternative 5	22.84[3]	27.37[4] / 28.82[5]

[1]Total number of acres in the Case Study 2 site was 46.48
[2]If the cleanup level is set to natural background, cleanup acreage for arsenic = 22.84, cPAH = 37.72
[3]The Cleanup Screening Level (CSL) and Sediment Cleanup Objective (SCO) are the same, resulting in the same cleanup acreage
[4]Cleanup acreage if cleanup level is set at the CSL
[5]Cleanup acreage if cleanup level is set at the SCO

Alternative 2 - Risk-Based Concentrations Based on Reasonable Maximum Exposure

Under Alternative 2, cleanup levels would be established solely on the basis of the human health risk assessment at a risk level of 1E-06 for single carcinogens, 1E-05 for multiple carcinogens, or an HQ=1 for non-carcinogens. The RME scenarios used to evaluate human health risk as described in Alternative 1 would be the basis for cleanup levels established for arsenic and cPAHs (see Table E.5). Under this alternative the entire site (46.48 acres) would be identified as exceeding the cleanup levels for arsenic (Figure E.5 and Table E.6). Given the low levels of the risk-based concentrations, the sediment concentrations that exceed the human health risk-based cleanup levels would likely extend beyond the site boundaries given the known concentrations of these contaminants throughout Puget Sound.

Alternative 3 - Risk-Based Concentrations Based on Federal Guidance or Regional Background

Under Alternative 3, cleanup levels for contaminants of concern would be established as the highest of risk-based concentrations based on federal guidance (1E-05 for any one carcinogenic chemical for these case study evaluations), or regional background.

Risk-based concentrations for arsenic and cPAHs at a risk level of 1E-05 are summarized in Table E.5. For Case Study 2, the regional background concentrations for the contaminants of concern were determined using an area of the shoreline up current of the site, known to be unimpacted by the contaminants of concern from the site. Regional background concentrations were determined from the up current dataset using the 95th percentile UCL of the mean for arsenic and cPAHs. For arsenic, the method detection limit was used for non-detected concentrations. Non-detected concentrations were treated as half the detection limit for cPAH TEQ calculations.

Regional background concentrations for arsenic and cPAHs are higher than risk-based concentrations at a risk level of 1E-05, and, therefore, would be the identified cleanup levels. Under the Alternative 3 cleanup levels, the total area of the Case Study 2 site identified for potential cleanup for the contaminants of concern would be less than Alternative 1 (Figure E.6). The differences in cleanup area identified between alternatives are summarized in Table E.6.

Alternative 4 - Regional Background and PQL

Under Alternative 4, cleanup levels for contaminants of concern would be established as the highest of regional background or the PQL. Regional background concentrations for arsenic and cPAHs are higher than PQL; therefore, they would be the identified cleanup levels. Under the Alternative 4 cleanup levels, the total area of the Case Study 2 site identified for potential cleanup for the contaminants of concern would be similar to Alternative 3 (Figure E.7 and Table E.6).

Alternative 5 - Two-Tier Approach

Under Alternative 5, the site-specific cleanup levels for the Case Study 2 site would be set within a range between the CSL and the SCO consistent with the original two-tier SMS framework. Cleanup levels calculated for Alternative 5 are summarized in Table E.5.

For Alternative 5, the CSL was determined to be the regional background for arsenic and cPAHs, similar to Alternative 4. The SCO was determined to be MTCA natural background for arsenic and the risk-based concentration (risk level of 1E-05) for cPAHs (Table E.5). The SCO for cPAH was the risk-based concentration at a risk of 1E-05 because there was more than one carcinogen. The natural and regional background concentrations, PQLs, and risk-based concentrations for the contaminants of concern are summarized in Table E.5. The cleanup level would fall between the CSL and SCO and would be determined using site-specific final analyses, taking into account technical possibility and net environmental benefit.

The total area of the Case Study 2 site identified for potential cleanup action for Alternative 5 for the site-related contaminants of concern would fall between the areas calculated for the CSL and SCO (Figure E.8 and Table E.6).

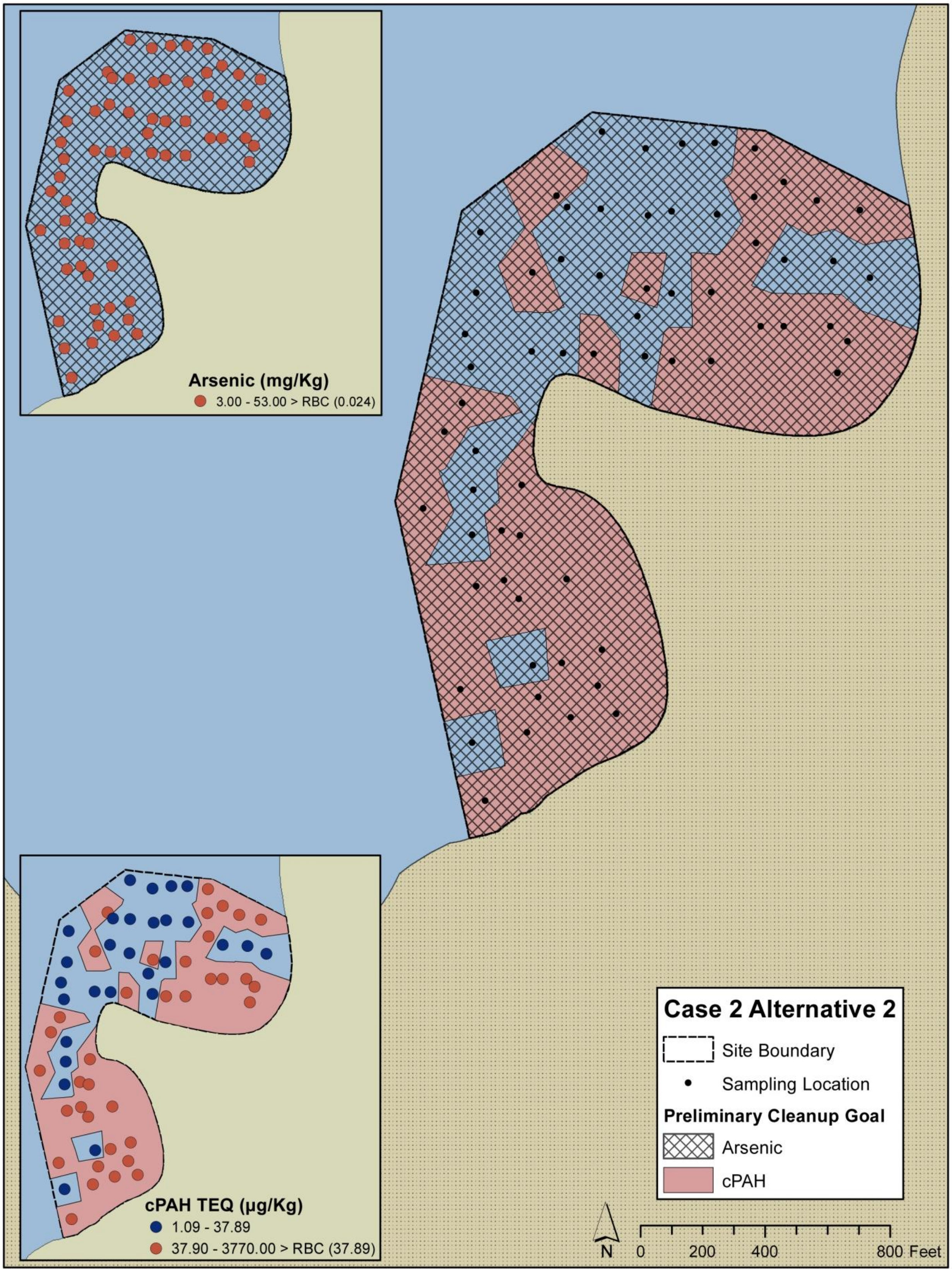


Figure E.5 - Case Study 2 - Areas Identified for Cleanup under Alternative 2

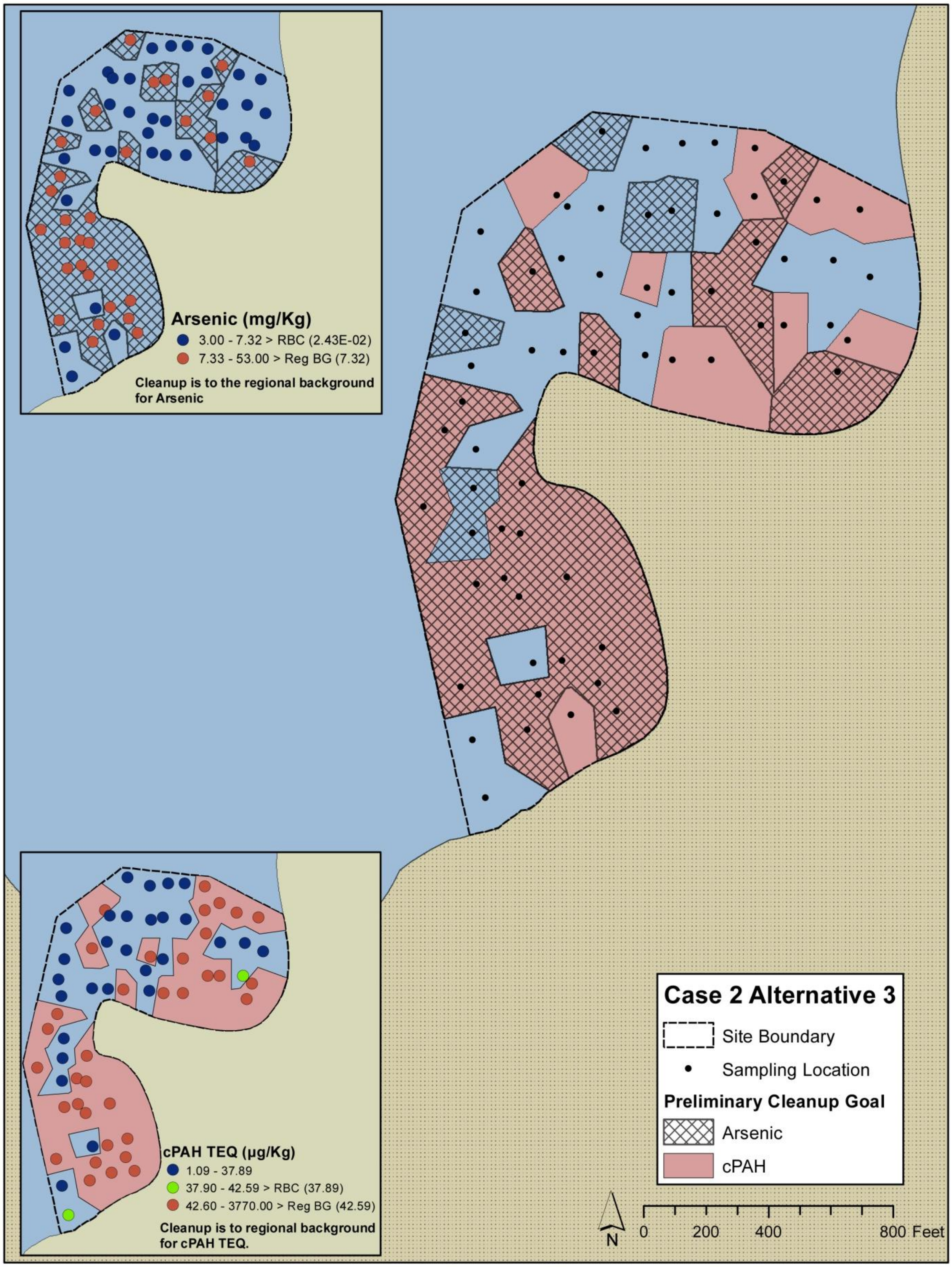


Figure E.6 - Case Study 2 - Areas Identified for Cleanup under Alternative 3

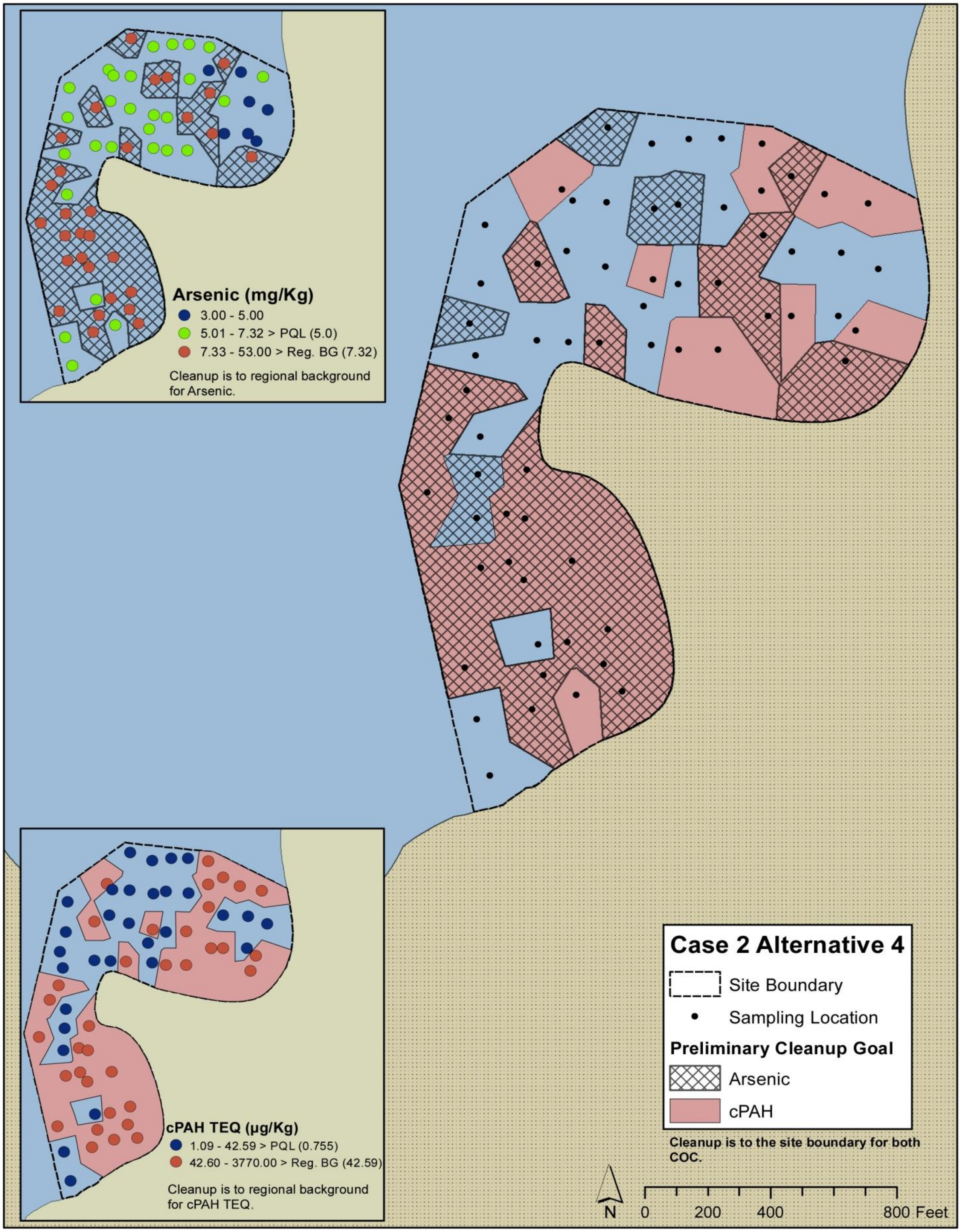


Figure E.7 - Case Study 2 - Areas Identified for Cleanup under Alternative 4

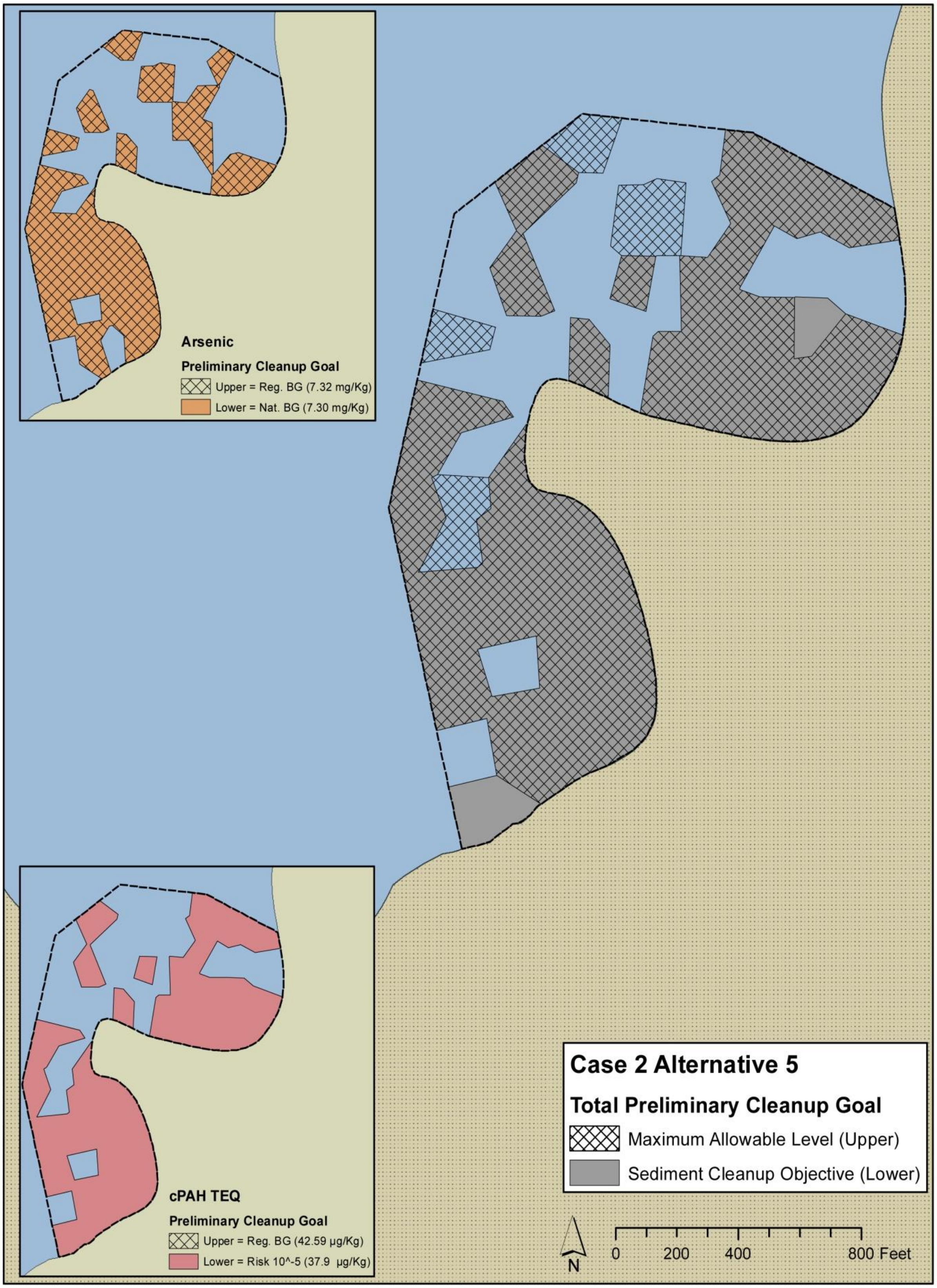


Figure E.8 - Case Study 2 - Areas Identified for Cleanup under Alternative 5

Cleanup Case Study 3 – Urban Embayment

Case Study 3 is a marine sediment embayment in Puget Sound, where contaminants of concern for human health protection include mercury and dioxin/furan congeners. The urban embayment supports various types of industries and has multiple potential sources of contamination along the shoreline. Chemical concentration values are shown in Table E.7.

Table E.7 - Chemical Concentration Ranges, Case Study 3, Urban Embayment (Human Health Alternatives)

Contaminant	Carcinogen/NC	No. of Samples	Concentration		
			Minimum	Maximum	Mean
Mercury	NC	149	0.025 mg/kg	7.6 mg/kg	0.42 mg/kg
Dioxin/Furan Congeners	Carcinogen	57	0.393 ng/kg TEQ	259 ng/kg TEQ	32.55 ng/kg TEQ

An analysis of this case study through each of the proposed five rule revision alternatives for protection of human health is provided below.

Alternative 1 - Original Rule (The No Action Alternative)

Alternative 1 is the original rule and follows the MTCA "one-tier" approach where the cleanup level is the highest of a human health risk-based level of 1E-06, MTCA natural background, or PQL of the contaminant of concern.

Human Health Risk Evaluation. The human health exposure pathway for the contaminants listed in Table E.7 was determined to be through ingestion of seafood (crab, bottom fish, and bivalves) and the risk assessment assumed 100 percent of the seafood intake from the site. An adult seafood consumption rate of 173 grams per day and adult body weight of 81.8 kilograms were used. The human health risk factors determined for mercury and dioxin/furan congeners under the RME seafood consumption scenario, and the derived sediment concentration levels at a risk level of 1E-06 are summarized in Table E.8. For mercury, it was assumed that 4 percent of the total in sediments was methylmercury for human health risk evaluation.

MTCA Natural Background. Natural background values for mercury and dioxin/furan congeners were determined from a subset of the OSV *Bold* dataset within the vicinity of the site using the 95th percent UCL assuming normal distribution (Table E.8).

PQL. The PQLs for mercury and dioxin/furan congeners as identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA are summarized in Table E.8.

Alternative 1 Cleanup Levels. Based on the statistical evaluation of risk drivers, the following sediment cleanup levels were established for Alternative 1, as shown in Table E.8:

- *Mercury.* The selected cleanup level was set at the MTCA natural background concentration in sediment of 0.104 mg/kg.

- *Dioxin/Furan Congeners.* The selected cleanup level was set as the PQL for dioxin/furan congeners in sediment of 5.0 ng/kg TEQ.

Under this alternative, the total area of the Case Study 3 site identified for cleanup for the contaminants of concern is presented on Figure E.9 and summarized in Table E.9.

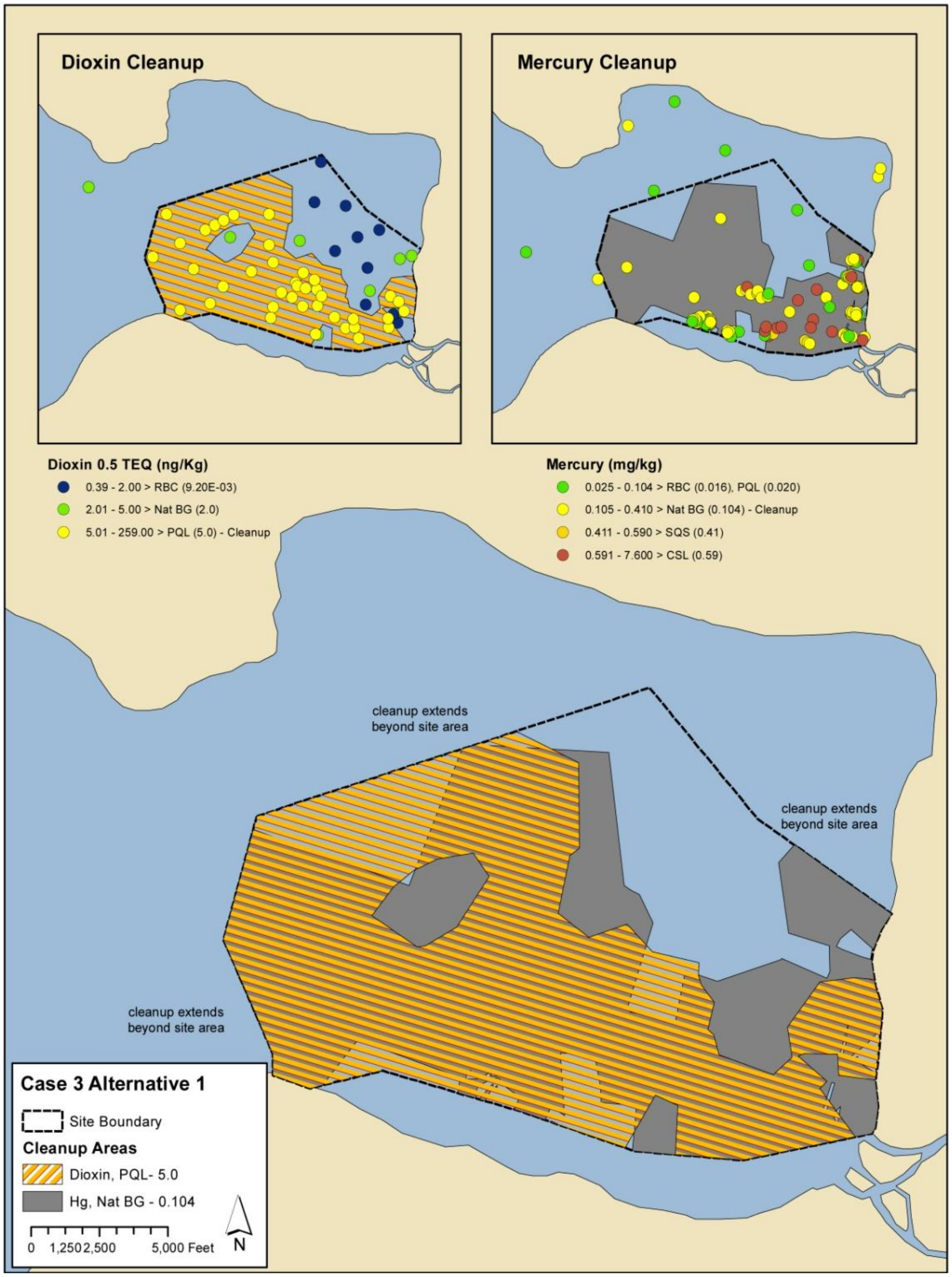


Figure E.9 - Case Study 3 - Areas Identified for Cleanup under Alternative 1

Table E.8 - Potential Cleanup Levels, Case Study 3, Urban Embayment (Human Health Alternatives)

Contaminant	Alternatives 1 - 5				PQL Concentration[2]	MTCA Natural Background Concentration[3]	Regional Background Concentration[4]
	Carcinogen		Non-carcinogen				
	HH (1E-06) Concentration[1]	HH (1E-05) Concentration[1]	Hazard Quotient[1]	HQ = 1 Concentration[1]			
Dioxin/Furan Congeners	9.21E-03 ng/kg Alternative 2	9.21E-02 ng/kg	--	--	5.0 ng/kg Alternative 1 Alternative 5 SCO[5]	2.0 ng/kg	14.6 ng/kg Alternative 3 Alternative 4 Alternative 5 CSL[5]
Mercury	--	--	3.5	0.016 mg/kg Alternative 2	2.0E-02 mg/kg	0.104 mg/kg Alternative 1 Alternative 5 SCO[5]	0.104 mg/kg Alternative 3 Alternative 4 Alternative 5 CSL[5]

[1]The human health-based levels for dioxin/furan congeners and for mercury were calculated based on the RME seafood ingestion scenario (assuming that 100 percent of the seafood intake was from the site). A daily seafood consumption rate of 173 gram per day and 81.8 kg body weight were used. It was assumed that the seafood diet consisted of Dungeness crab. For mercury, it was assumed that 4 percent of the total in sediments was methylmercury. Human health concentrations for dioxin/furan congeners at the 1E-06 and 1E-05 risk levels, and for mercury at the hazard index of 1.0 level, were calculated using equations presented earlier in this document.

[2]The PQLs were identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA was used.

[3] MTCA natural background levels for dioxin/furan congeners and mercury were determined from a subset of the OSV Bold survey dataset (DMMP, 2009) within the vicinity of the site using the 95th percent UCL on the mean assuming normal distribution (dioxin/furan congener TEQ calculations used half of the detection limit for non-detected concentrations).

[4] Regional background was calculated for dioxin based on a statistical analysis of existing data in the EIM database, and spatial contouring to determine dioxin regional background. The area believed to be regional background was delineated, and then samples excluded from areas near known point sources and areas suspected to be of a different population (e.g., cleanup sites). After removing trends from the data, Ecology then determined the extent of auto-correlation in samples from the background area. Upper-bound estimates (i.e., 90/90 UTL) were generated from the regional background area determined earlier. This was achieved by rendering the existing dataset independent by selecting a subset of samples that are further than the auto-correlated distance apart from one another. The dataset did not show evidence of significant auto-correlation among samples, so the complete dataset was used to calculate the 90/90 UTL. Ecology determined that it would be inappropriate to calculate a regional background for mercury, because at this specific embayment, mercury comes from specific, identified sources. Ecology determined that it was feasible to calculate a regional background for dioxin because of the influence of numerous non-point sources to the bay that were distinguishable from specific releases using best professional judgment. Regional background for mercury was determined to be the same as MTCA natural background. For mercury, the method detection limit was used for non-detected concentrations. Non-detected concentrations were treated as half the detection limit for dioxin/furan TEQ calculations.

[5]Cleanup levels for dioxin/furan congeners and for mercury under Alternative 5 would be set somewhere in the range between the Cleanup Screening Level and the Sediment Cleanup Objective, which are the upper and lower bounds of the two-tiered SMS Framework, respectively. For dioxin/furan congeners, the CSL and SCO were determined to be the regional background and PQL, respectively. For mercury, the CSL and SCO were determined to be the same; in this case, the MTCA natural background and regional background values are the same.

Table E.9 - Area Requiring Cleanup, Case Study 3, Urban Embayment (Human Health Alternatives)

Alternative	Acres Requiring Cleanup by Individual Contaminant[1]	
	Mercury[2]	Dioxin/Furan Congeners[2]
Alternative 1	4612	4276
Alternative 2	> 6554	> 6554
Alternative 3	4612	1262
Alternative 4	4612	1262
Alternative 5	4612[3]	1262[4] /4276[5]

[1]Total number of acres in the Case Study 3 site was 6554
[2]If the cleanup level is set to natural background, cleanup acreage for mercury = 4612, dioxin/furan congeners = 5056
[3]The Cleanup Screening Level (CSL) and Sediment Cleanup Objective (SCO) are the same, resulting in the same cleanup acreage
[4]Cleanup acreage if cleanup level is set at the CSL
[5]Cleanup acreage if cleanup level is set at the SCO

Alternative 2 - Risk-Based Concentrations Based on Reasonable Maximum Exposure

Under Alternative 2, cleanup levels would be established solely on the basis of the human health risk assessment at a risk level of 1E-06 (dioxin/furan congeners) and hazard quotient of 1.0 (mercury). The RME scenarios used to evaluate human health risk as described in Alternative 1 would be the basis for cleanup levels established for mercury and dioxin/furan congeners (see Table E.8). Under this alternative, the entire site (6,554 acres) would be identified as exceeding the cleanup levels for dioxin/furan congeners (Figure E.10 and Table E.9). Given the low levels of the risk-based concentrations, the sediment concentrations that exceed the human health risk-based cleanup levels would extend beyond the site boundaries given the known concentrations of these contaminants throughout the embayment and into Puget Sound.

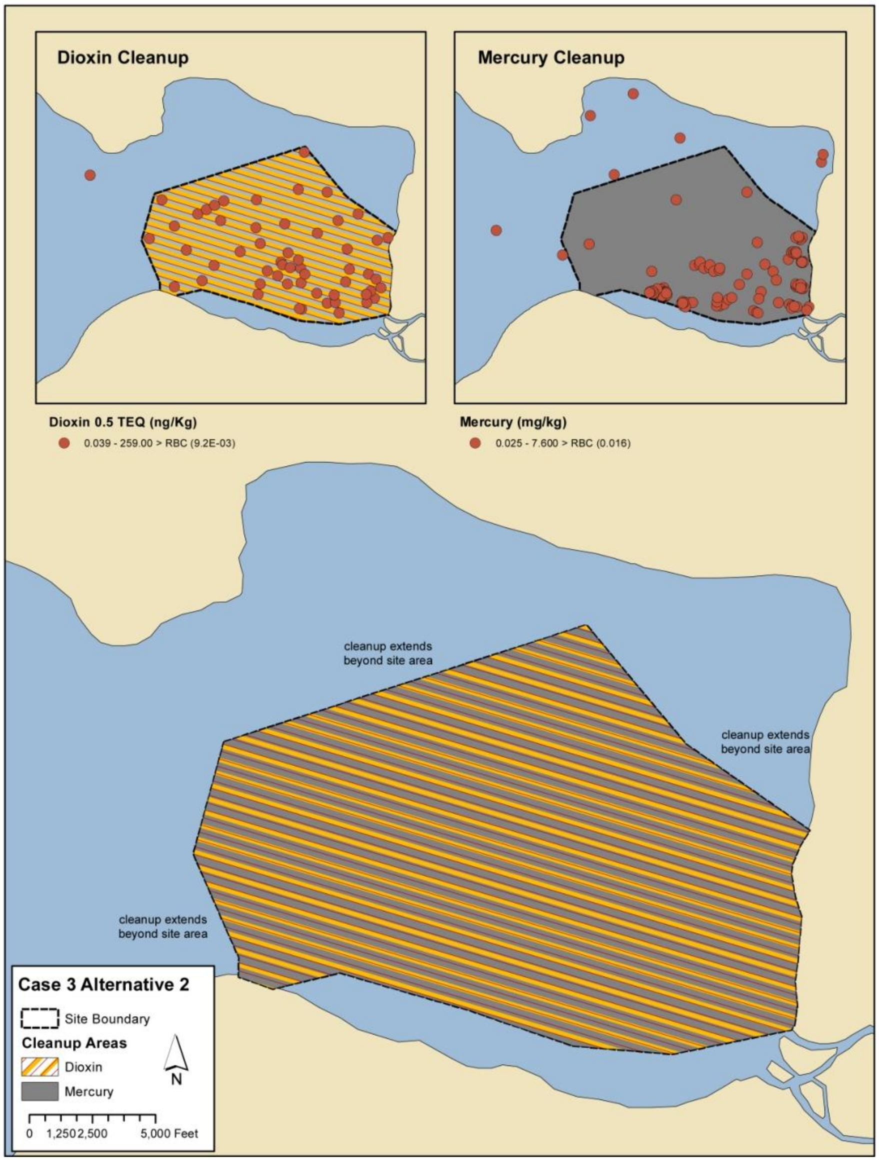


Figure E.10 - Case Study 3 - Areas Identified for Cleanup under Alternative 2

Alternative 3 - Risk-Based Concentrations Based on Federal Guidance or Regional Background

Under Alternative 3, cleanup levels for contaminants of concern would be established as the highest of risk-based concentrations based on federal guidance (1E-05 for any one carcinogenic chemical for these case study evaluations), or regional background. Risk-based concentrations for mercury and dioxin/furan congeners at a risk level of 1E-05 are summarized in Table E.10. For Case Study 3, the regional background concentrations for the contaminants of concern were determined by:

- Delineating the area believed to be regional background, and then excluding samples from areas near known point sources and areas suspected to be of a different population (e.g., cleanup sites).
- After removing trends from the data, the extent of auto-correlation in samples from the background area was determined.
- The upper bound estimates (i.e., 90/90 UTL) from the regional background area determine earlier were generated. This was done by rendering the existing dataset independent by selecting a subset of samples that were further than the auto-correlated distance apart from one another. The dataset did not show evidence of significant auto-correlation among samples, so the complete dataset was used to calculate the 90/90 UTL.

The regional background concentration for mercury was the same as MTCA natural background. For mercury, the method detection limit was used for non-detected concentrations. Non-detected concentrations were treated as half the detection limit for dioxin/furan TEQ calculations.

The regional background concentration for dioxin/furan congeners is higher than the risk-based concentrations at a risk level of 1E-05. The regional background concentration for mercury is also higher than the risk-based background. Under the Alternative 3 cleanup levels, the total area of the Case Study 3 site identified for potential cleanup for the contaminants of concern is identified in Table E.9 and on Figure E.11.

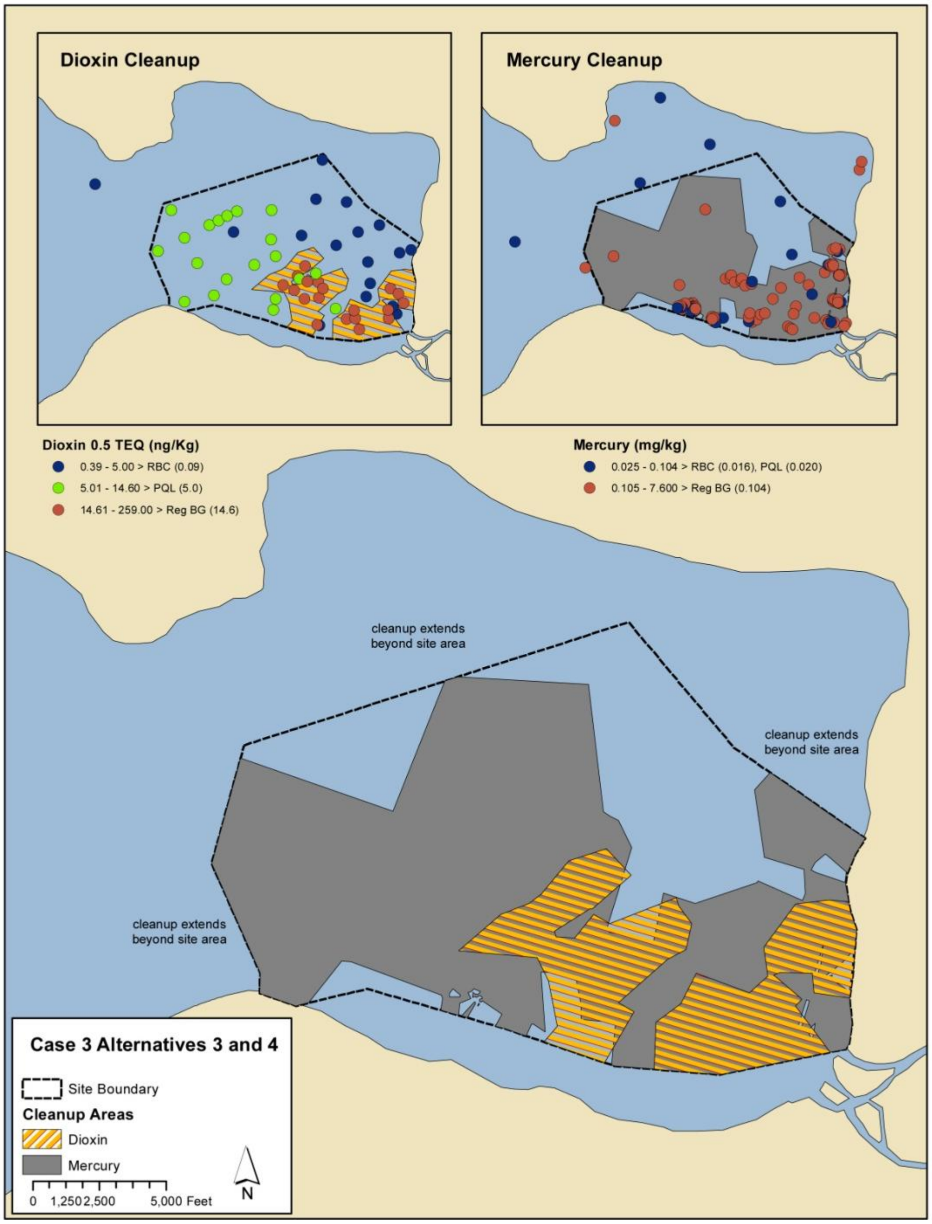


Figure E.11 - Case Study 3 - Areas Identified for Cleanup under Alternatives 3 and 4

Alternative 4 - Regional Background and PQL

Under Alternative 4, cleanup levels for contaminants of concern would be established as the highest of regional background or the PQL. The regional background for dioxin/furan congeners (14.6 ng/kg TEQ) was set as the cleanup level. For mercury, the regional background concentration was higher than the PQL and was set as the cleanup level. Cleanup levels for Alternative 4 are summarized in Table E.10. Under this alternative, the total area of the Case Study 3 site identified for potential cleanup for the contaminants of concern would be similar to Alternative 3 (Table E.9 and Figure E.11).

Alternative 5 - Two-Tier Approach

Under Alternative 5, the site-specific cleanup levels for the Case Study 3 site would be set within a range between the CSL and the SCO consistent with the original two-tier SMS framework. For dioxin/furan congeners, the CSL was determined to be regional background (14.6 ng/kg TEQ) and the SCO was determined to be the PQL (5.0 ng/kg TEQ). For mercury, the CSL and SCO were determined to be the same because the MTCA natural background and regional background are at the same concentration (0.104 mg/kg). Cleanup levels for Alternative 5 are summarized in Table E.8.

Under this alternative, the total area of the Case Study 3 site identified for potential cleanup for the contaminants of concern is summarized in Table E.9 and on Figure E.12.

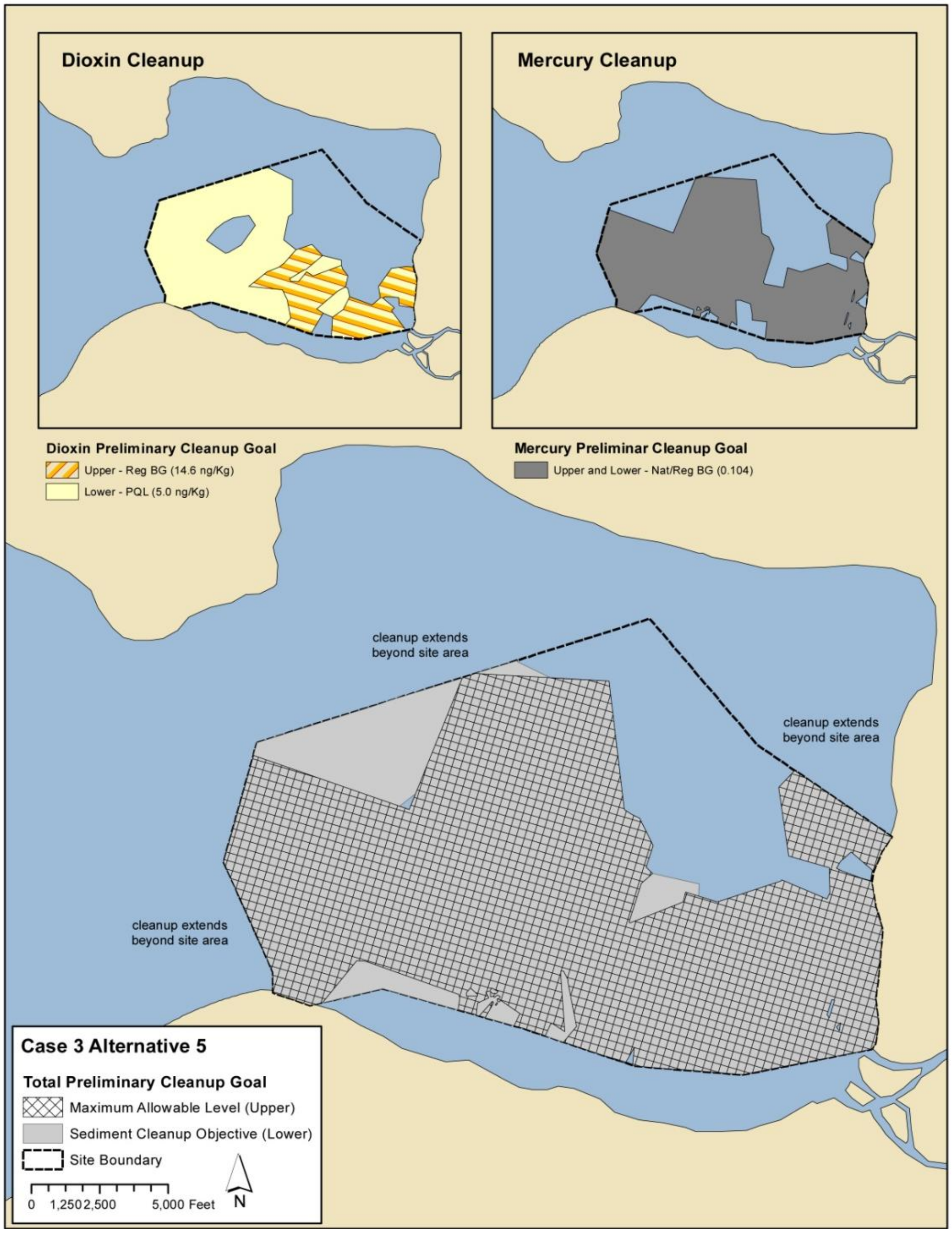


Figure E.12 - Case Study 3 - Areas Identified for Cleanup under Alternative 5

Cleanup Case Study 4 – Freshwater River

Case Study 4 is a site located along a freshwater river in Washington, where the contaminant of concern for human health protection is total PCB Aroclors. Various industries are located on the banks of the river both upstream and downstream of the site. Chemical concentration values are shown in Table E.10.

Table E.10 - Chemical Concentration Ranges, Case Study 4, Freshwater River (Human Health Alternatives)

Contaminant	Carcinogen/NC	No. of Samples	Concentration		
			Minimum	Maximum	Mean
Total PCB Aroclors	Carcinogen	57	1.4E-03 ng/kg TEQ	28E+03 ng/kg TEQ	701 ng/kg TEQ

An analysis of this case study through each of the proposed five rule revision alternatives for protection of human health is provided below.

Alternative 1 - Original Rule (The No Action Alternative)

Alternative 1 is the original rule and follows the MTCA "one-tier" approach where the cleanup level is the highest of risk-based levels to human health at a risk level of 1E-06, MTCA natural background, or PQL of the contaminant of concern.

Human Health Risk Evaluation. The contaminant of concern that is the risk driver for the Case Study 4 site is total PCB Aroclors. The human health exposure pathway was determined to be through ingestion of freshwater clams and the risk assessment assumed 25 percent of the diet intake from the site. A consumption rate of 81 grams of shellfish per day and adult body weight of 70 kilograms were used. The sediment concentration level of total PCB Aroclors at a risk level of 1E-06 under the RME ingestion scenario is provided in Table E.11.

MTCA Natural Background. The majority of PCB Aroclor measurements in freshwater systems throughout Washington have been undetected or measured at very low levels (less than 5 µg/kg). PCB Aroclor measurements in the freshwater river upstream and downstream of the Case Study 4 site are also mostly undetected. Therefore, the natural background value for total PCB Aroclors was determined to be less than the PQL of 5.5 µg/kg (Table E.11).

PQL. The PQLs for PCB Aroclors as identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA are summarized in Table E.11.

Table E.11 - Potential Cleanup Levels, Case Study 4, Freshwater River (Human Health Alternatives)

Contaminant	Alternatives 1 – 5				PQL Concentration[2]	MTCA Natural Background Concentration[3]	Regional Background Concentration[4]
	Carcinogen		Non-carcinogen				
	HH (1E-06) Concentration[1]	HH (1E-05) Concentration[1]	Hazard Quotient[1]	HQ = 1 Concentration[1]			
Total PCB Aroclors	1.20 µg/kg Alternative 2	12.0 µg/kg Alternative 3 Alternative 5 CSL[5]	--	--	5.5 µg/kg Alternative 1 Alternative 4 Alternative 5 SCO[5]	5.5 µg/kg	5.5 µg/kg

[1]The human health-based levels for total PCB Aroclors was calculated based on the RME clam ingestion pathway (assuming 25 percent of the clam diet was taken from the site). A shellfish consumption rate of 81 gram per day and 70 kg body weight were used. It was assumed that the seafood diet consisted of freshwater clams. Human health concentrations for total PCB Aroclors at the 1E-06 and 1E-05 risk levels were calculated using equations presented in Chapter 4.

[2]The PQLs were identified by Ecology's 2011 survey of analytical laboratory capabilities in support of sediment investigations under SMS and MTCA was used.

[3] The majority of PCB Aroclor measurements in freshwater systems throughout Washington have been undetected or measured at very low levels (less than 5 µg/kg). PCB Aroclor measurements in the freshwater river upstream and downstream of the Case Study 4 site are also mostly undetected. Therefore, the MTCA natural background value for total PCB Aroclors was determined to be less than the PQL value of 5.5 µg/kg.

[4] Based on natural transport of sediment down the river, total PCB concentrations in sediments fall to background levels a short distance away from the site. Therefore, it was determined that the regional background concentration of total PCB Aroclors is the same as the MTCA natural background concentration. For PCB Aroclors, the method detection limit was used for non-detected concentrations.

[5]Cleanup level for total PCB Aroclors under Alternative 5 would be set somewhere in the range between the Cleanup Screening Level (in this case the human health concentration based on a 1E-05 risk level) and the Sediment Cleanup Objective (in this case the human health concentration based on a 1E-06 risk level), which are the upper and lower bounds of the two-tiered SMS Framework, respectively.

Alternative 1 Cleanup Levels. Based on the statistical evaluation of risk drivers, the following sediment cleanup levels was established:

- *Total PCB Aroclors*.[45] The selected cleanup level was set at the PQL value of 5.5 µg/kg.

Under this alternative, the total area of the Case Study 4 site identified for cleanup for total PCB Aroclors is presented on Figure E.13 and summarized in Table E.12.

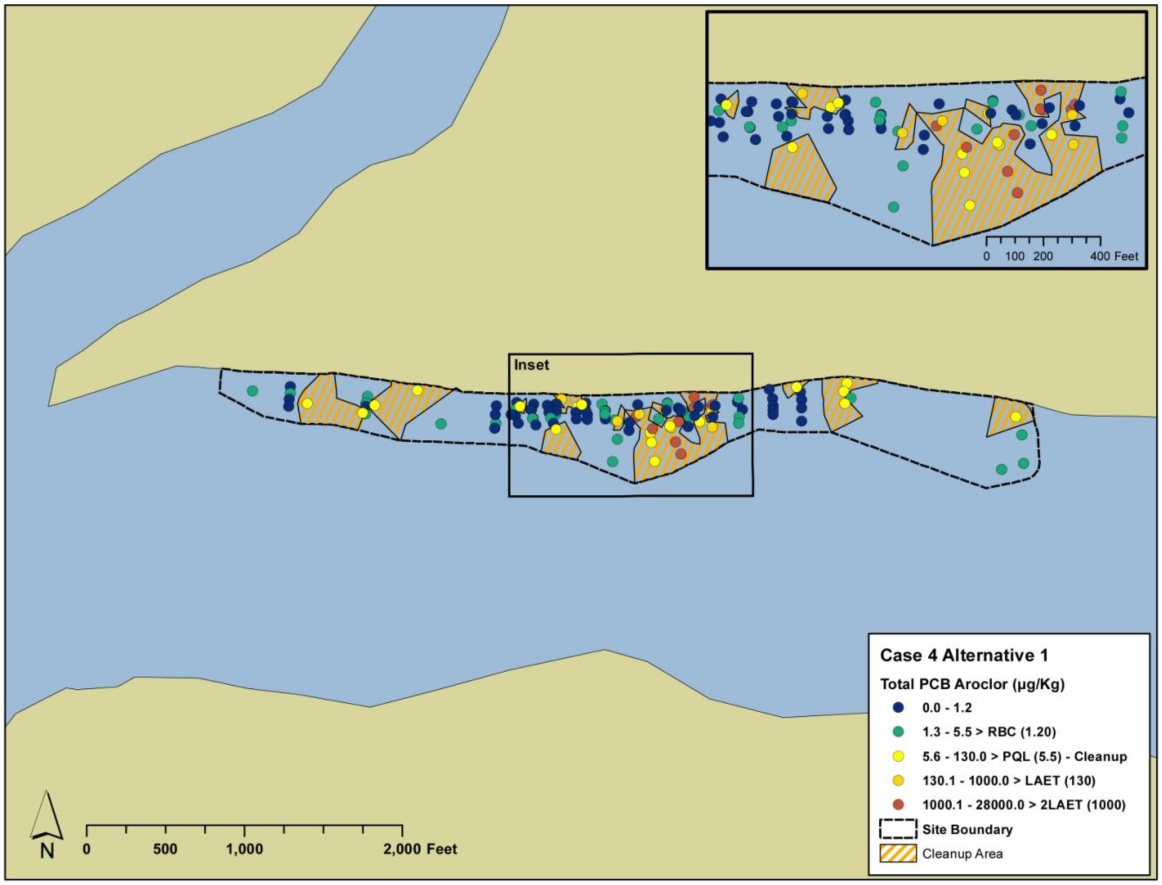


Figure E.13 - Case Study 4 - Areas Identified for Cleanup under Alternative 1

[45] Total PCB Aroclors analysis differs from PCB congener analysis, which affects how human health risk-based concentrations are determined. PCB Aroclors are assumed to be equitoxic, and total PCB Aroclors is represented as the sum of detected Aroclors regardless of the toxicity of the total mixture. Twelve of the 209 PCB congeners are considered to have dioxin-like properties and their toxicity is scaled relative to the toxicity of dioxins using TEF values.

Table E.12 - Area Requiring Cleanup, Case Study 4, Freshwater River (Human Health Alternatives)

Alternative	Acres Requiring Cleanup by Individual Contaminant[1]
	Total PCB Aroclors
Alternative 1	12.83[2]
Alternative 2	25.05
Alternative 3	8.09
Alternative 4	12.83[2]
Alternative 5	8.09[3]/12.83[4]

[1]Total number of acres in the Case Study 4 site was 46.09
[2] The majority of PCB Aroclor measurements in freshwater systems throughout Washington have been undetected or measured at very low levels (less than 5 µg/kg). PCB Aroclor measurements in the freshwater river upstream and downstream of the Case Study 4 site are also mostly undetected. Therefore, the MTCA natural background value for total PCB Aroclors was determined to be less than the PQL value of 5.5 µg/kg (cleanup acreage of 12.83).
[3]Cleanup acreage if cleanup level is set at the CSL
[4]Cleanup acreage if cleanup level is set at the SCO

Alternative 2 - Risk-Based Concentrations Based on Reasonable Maximum Exposure

Under Alternative 2, cleanup levels would be established solely on the basis of the human health risk assessment at a risk level of 1E-06. The RME scenarios used to evaluate human health risk as described in Alternative 1 would be the basis for cleanup levels established for total PCB Aroclors (see Table E.11). The total area identified for cleanup is shown in Table E.12 and on Figure E.14.

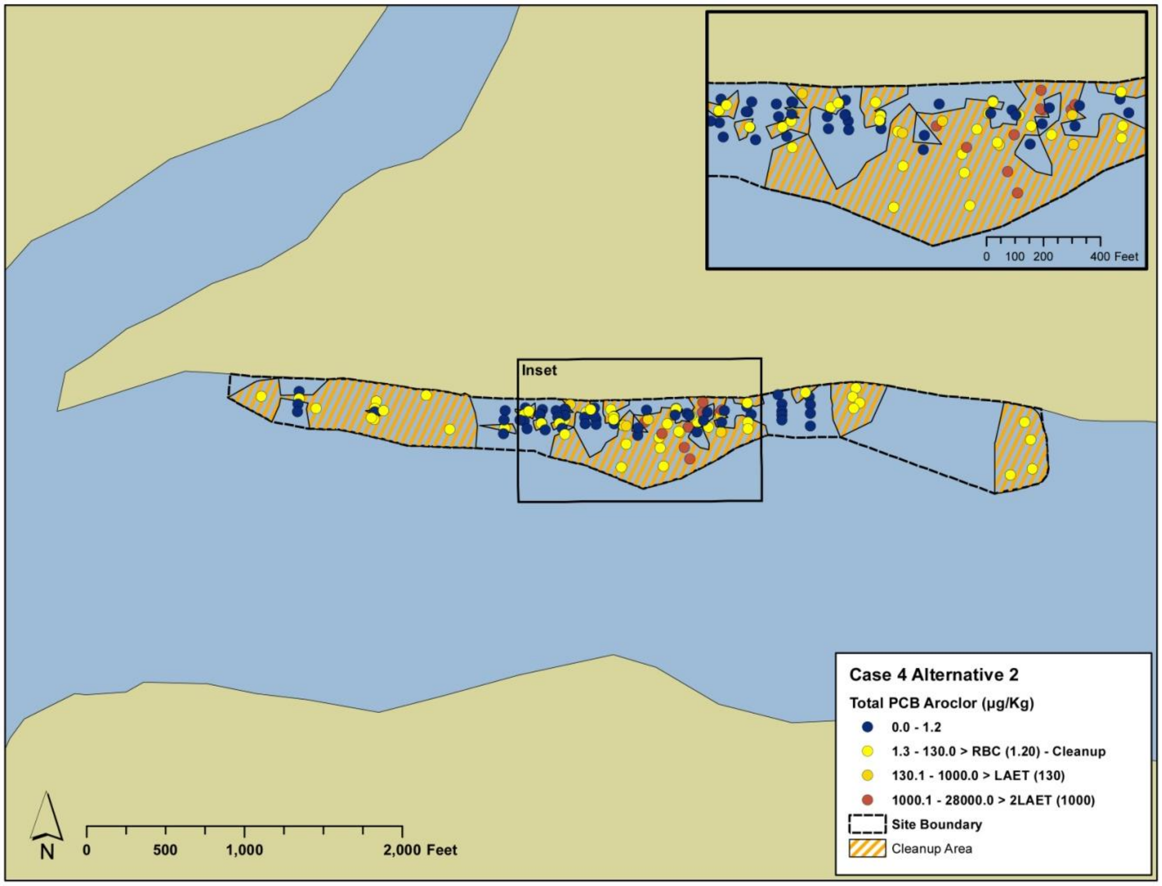


Figure E.14 - Case Study 4 - Areas Identified for Cleanup under Alternative 2

Alternative 3 - Risk-Based Concentrations Based on Federal Guidance or Regional Background

Under Alternative 3, cleanup levels for contaminants of concern would be established as the highest of risk-based concentrations based on federal guidance (1E-05 for any one carcinogenic chemical), or regional background. The risk-based concentration for total PCB Aroclors at a risk level of 1E-05 is 12 µg/kg (Table E.12). Based on the natural transport of sediment down the river, total PCB concentrations in sediments fall to background levels a short distance away from the site. Therefore, it was determined that regional background concentration of total PCB Aroclors is the same as the MTCA natural background concentration. For PCB Aroclors, the method detection limit was used for non-detected concentrations.

The risk-based concentration of total PCB Aroclors at a risk level of 1E-05 (12 µg/kg) is higher than regional background (5.5 µg/kg). Therefore, the risk-based concentration of 12 µg/kg would be the cleanup level for Alternative 3 and the total area of the Case Study 4 site identified for potential cleanup is shown on Figure E.15 and summarized in Table E.12.

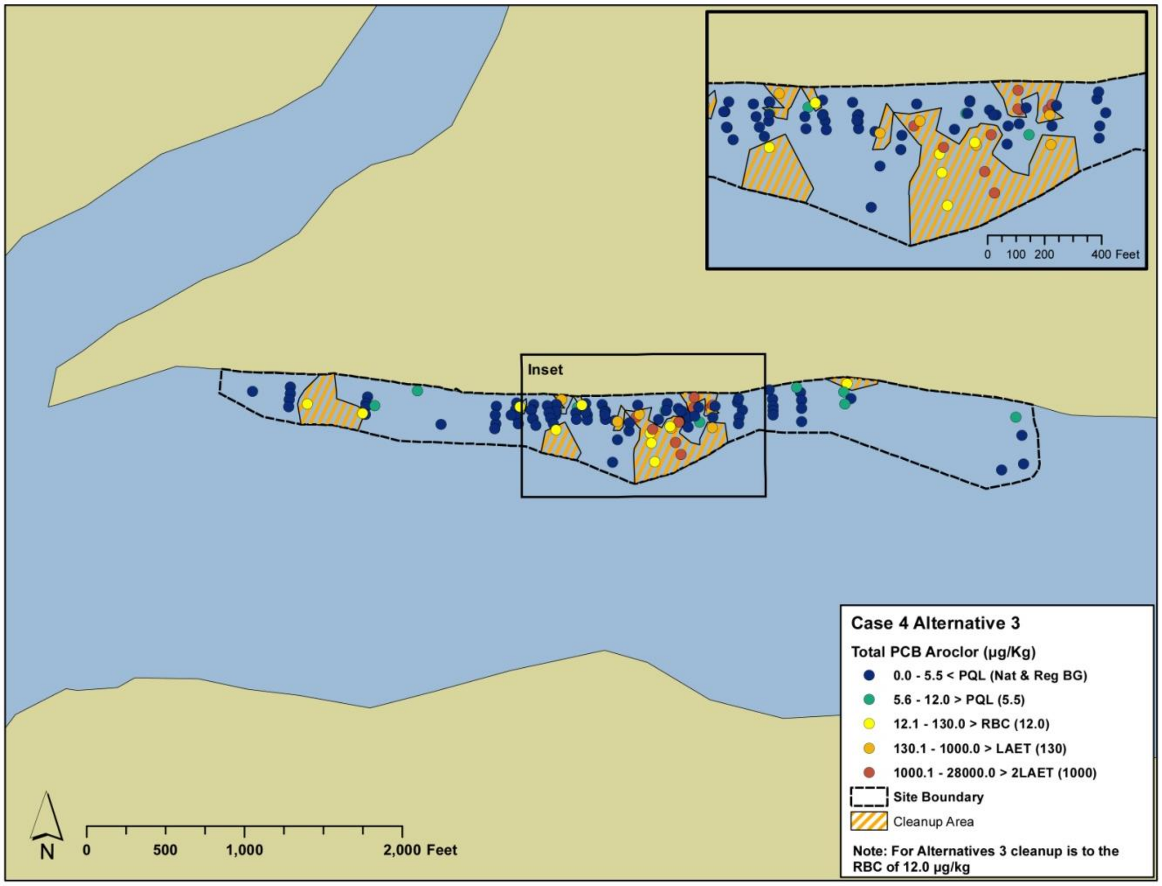


Figure E.15 - Case Study 4 - Areas Identified for Cleanup under Alternative 3

Alternative 4 - Regional Background and PQL

Under Alternative 4, cleanup levels for contaminants of concern would be established as the highest of regional background or the PQL. Regional and MTCA natural background concentrations of total PCB Aroclors fall below the PQL. Therefore, the PQL would be the cleanup level identified under this alternative. The total area of the Case Study 4 site identified for potential cleanup is greater than the previous alternatives and is shown on Figure E.16 and summarized in Table E.12.

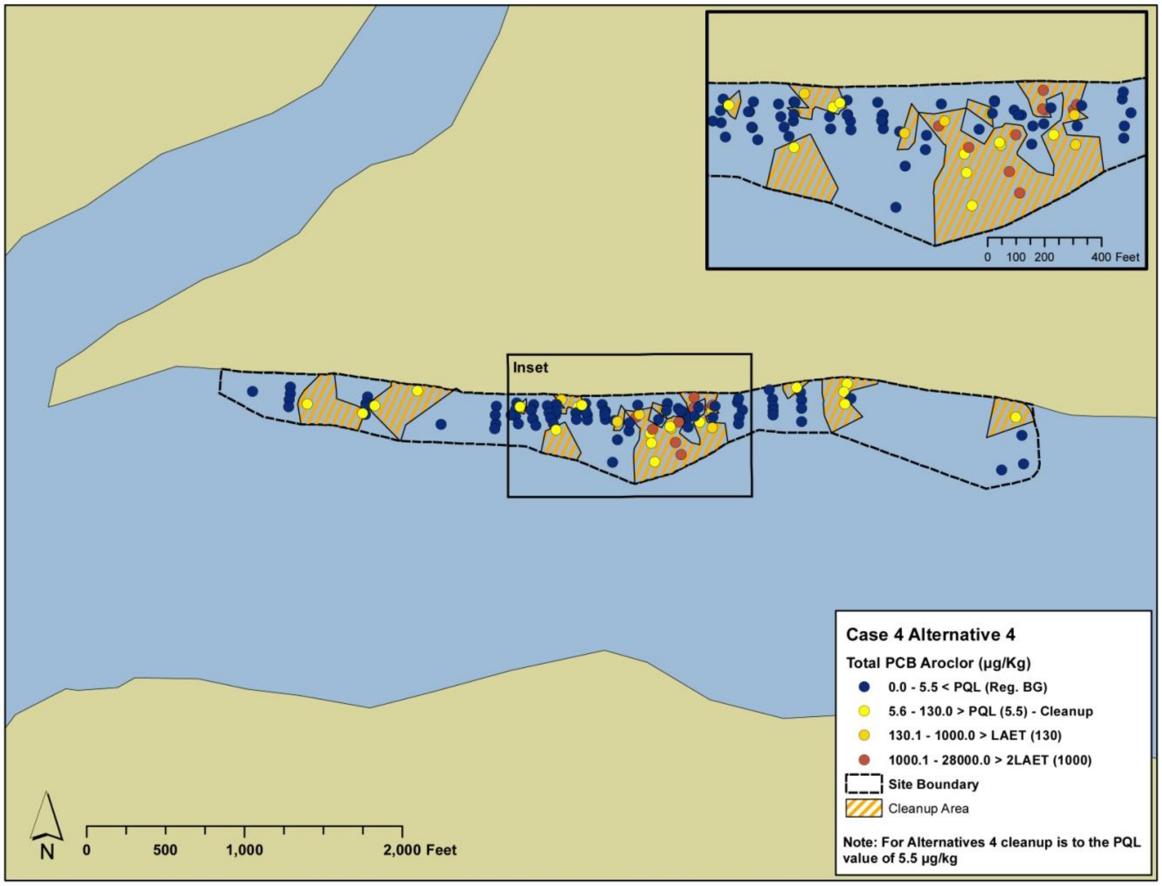


Figure E.16 - Case Study 4 - Areas Identified for Cleanup under Alternative 4

Alternative 5 - Two-Tier Approach

Under Alternative 5, the site-specific cleanup levels for the Case Study 4 site would be set within a range between the CSL and the SCO consistent with the original two-tier SMS framework. Cleanup levels calculated for Alternative 5 are summarized in Table E.12.

For Alternative 5, the CSL was determined to be the human health risk-based concentration of 12 µg/kg (risk level of 1E-05), which is higher than the PQL and regional background for total PCB Aroclors. The SCO was determined to be the PQL concentration of 5.5 µg/kg, which is higher than the risk-based level (risk level of 1E-06) and equal to MTCA natural background (Table E.11). The cleanup level would fall between the CSL and SCO and would be determined using site-specific final analyses, taking into account technical possibility and net adverse environmental impact. The total area of the Case Study 4 site identified for potential cleanup action for the site-related PCB Aroclors would fall between the areas calculated for the CSL and SCO, as summarized in Table E.12 and on Figure E.17.

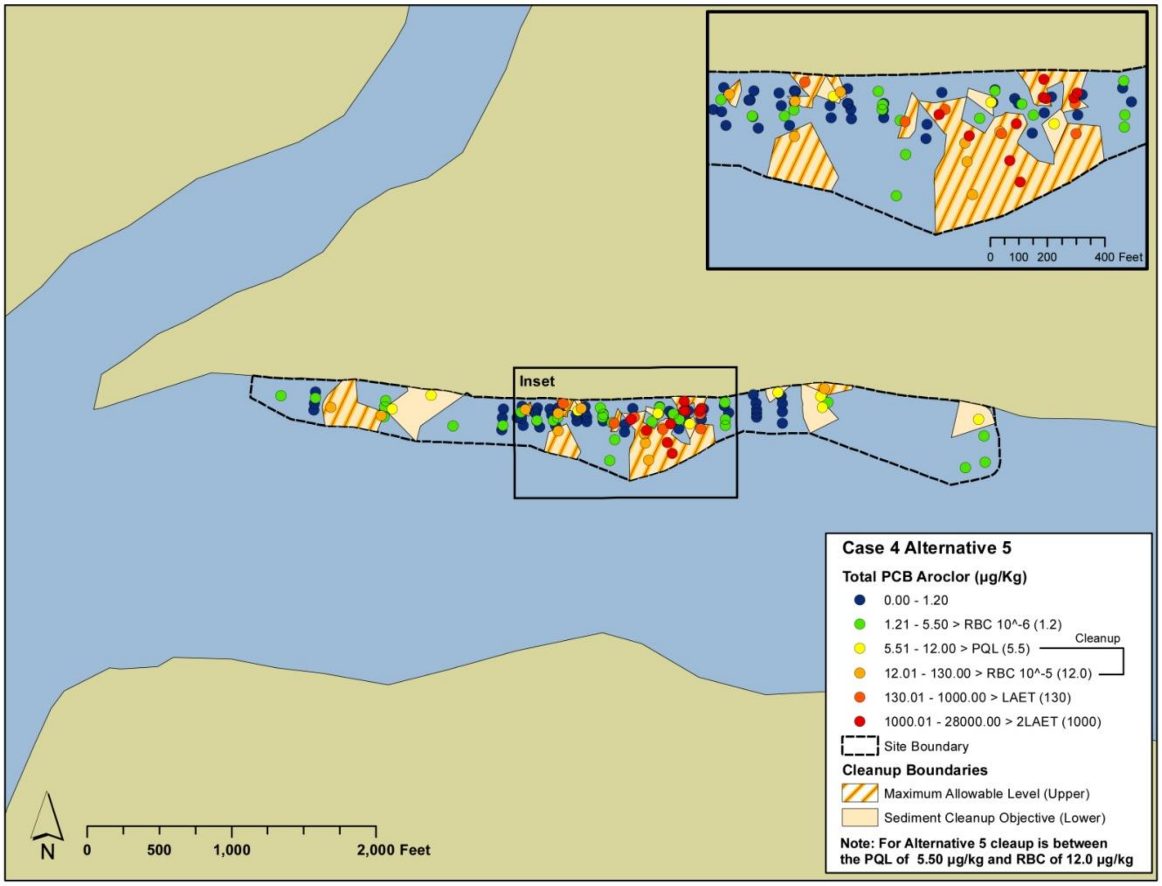


Figure E.17 - Case Study 4 - Areas Identified for Cleanup under Alternative 5

Cleanup Case Study 5 - Cleanup Levels Comparison to Puget Sound

For the Case Study 5 analysis, the cleanup levels developed as part of the alternatives analysis for Case Studies 1 through 4 were compared to the sediment chemistry data available in EIM to determine the percentage of Puget Sound-wide sediment sampling locations that would exceed a given cleanup level. EIM is Ecology's main database for environmental monitoring data collected in Washington State and contains records on physical, chemical, and biological analyses and measurements. The sediment component of EIM is derived from efforts representing different purposes, including known or suspected site characterization studies, dredging suitability studies, outfall monitoring, background studies, and ambient monitoring programs. The dataset may not be an unbiased representation of chemical levels in sediments throughout the Puget Sound because of the abundance of data from site characterization and cleanup actions in urban areas with potentially higher chemical concentrations. However, the database does include data from areas away from direct influence of known or suspected sources and reflects a full spectrum of concentrations from MTCA natural background levels to heavily contaminated levels.

For the Case Study 5 analysis, discussion is organized by contaminant type, with each case study associated with a particular contaminant, and its associated Alternatives 1 through 5 cleanup levels, presented to compare to Puget Sound EIM data. Contaminants of concern identified for Case Studies 1 through 4 include three metals (arsenic, cadmium, and mercury), cPAHs, dioxin/furan congeners, and total PCB Aroclors.

Arsenic Cleanup Levels

The cleanup levels for arsenic developed under Case Study 2 included the MTCA natural background or regional background concentration (7.3 mg/kg) for Alternatives 1, 3, 4, and 5, and a risk-based concentration at a risk level of 1E-05 (2.43E-02 mg/kg) for Alternative 2. Of the sediment chemistry data available in EIM for Puget Sound, 48 percent of the sampling locations exceed the background cleanup level and 100 percent exceed the risk-based cleanup level (Table E.13 and Figure E.18). In comparison with SMS criteria, 1.5 percent of the Puget Sound sampling locations exceed the benthic SCO for arsenic (57.0 mg/kg), and 1.0 percent exceed the benthic CSL (93.0 mg/kg).

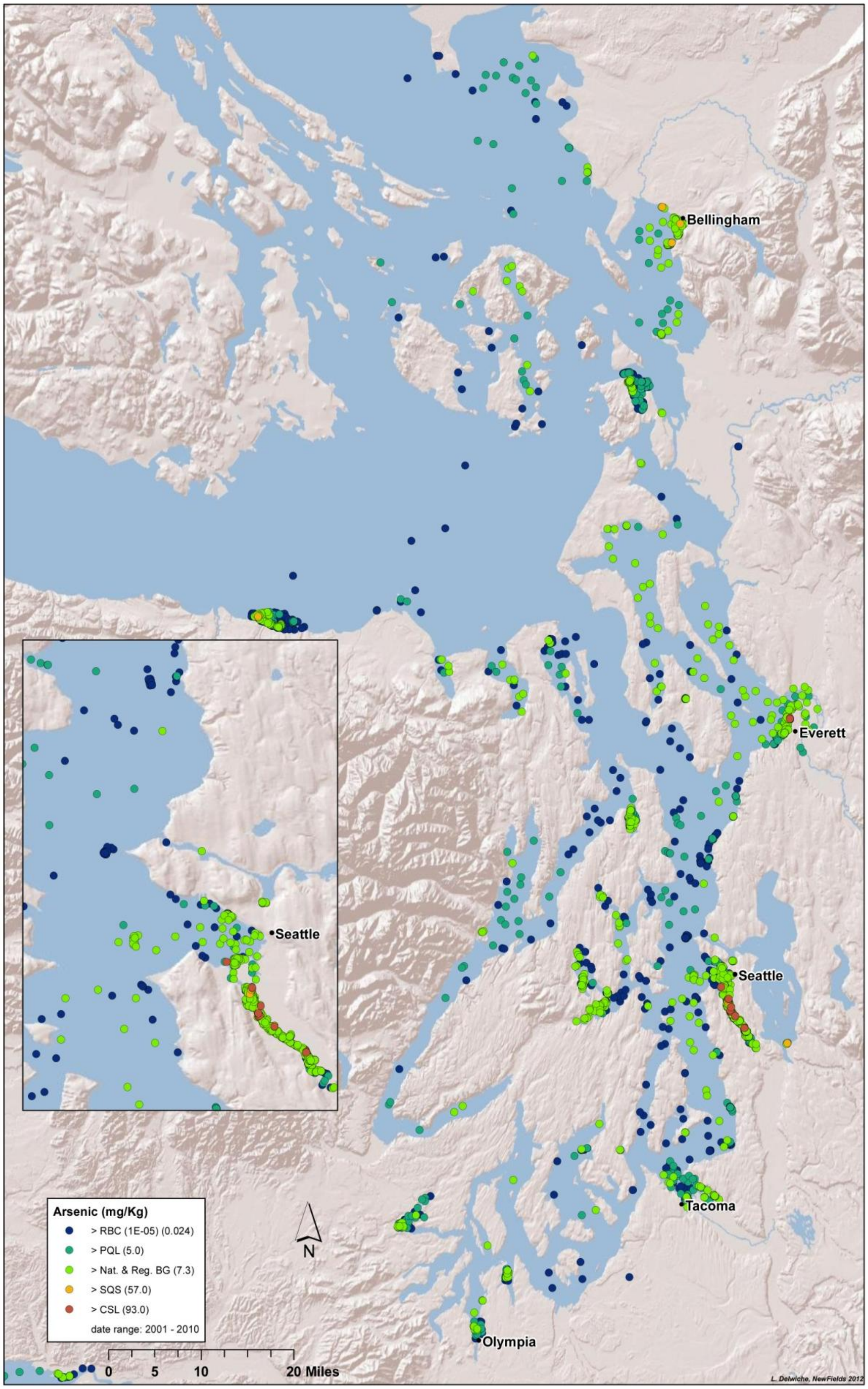


Figure E.18 - Arsenic Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

Table E.13 - Arsenic Cleanup Levels Compared to Puget Sound EIM Data

Case Study 2			
Alternatives	**Cleanup Level**	**Concentration (mg/kg)**	**Puget Sound EIM Data Locations Exceeding Level (%)**
1	MTCA Natural Background	7.3	48
2	Risk-Based (1E-05)	2.43E-02	100
3	Regional Background	7.3	48
4	Regional Background	7.3	48
5	Regional Background (CSL) MTCA Natural Background (SCO)	7.3 (CSL and SCO)	48
SMS	Benthic SCO	57.0	1.5
SMS	Benthic CSL	93.0	1.0

Cadmium Cleanup Levels

The cleanup levels for cadmium developed under Case Study 1 included the MTCA natural or regional background concentration (0.97 mg/kg) for Alternatives 1, 3, 4, and 5 and a risk-based concentration at a risk level of HQ=1 (0.466 mg/kg) for Alternative 2. Comparing the cleanup levels to the sediment chemistry data available in EIM for Puget Sound, 20 percent of the sampling locations exceed the natural/regional background cleanup level and 46 percent exceed the risk-based cleanup level (Table E.14 and Figure E.19). In comparison with SMS criteria, 1.7 percent of the Puget Sound sampling locations exceed the SCO for cadmium (5.1 mg/kg), and 1.5 percent exceed the CSL (6.7 mg/kg).

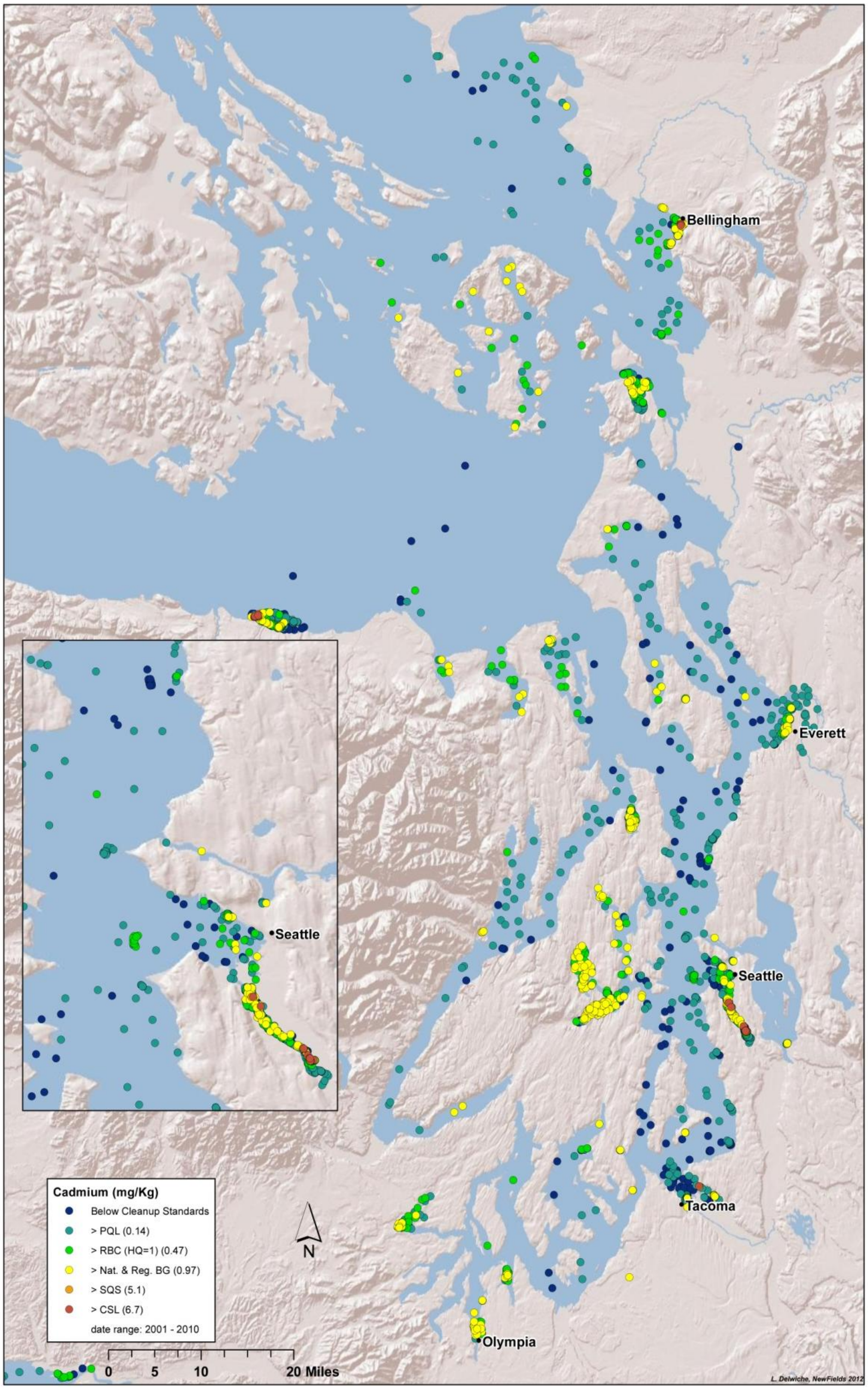


Figure E.19 - Cadmium Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

Table E.14 - Cadmium Cleanup Levels Compared to Puget Sound EIM Data

Case Study 1			
Alternatives	**Cleanup Level**	**Concentration (mg/kg)**	**Puget Sound EIM Data Locations Exceeding Level (%)**
1	MTCA Natural Background	0.97	20
2	Risk-Based (HQ=1)	0.466	46
3	Regional Background	0.97	20
4	Regional Background	0.97	20
5	Regional Background (CSL) MTCA Natural Background (SCO)	0.97 (CSL and SCO)	20
SMS	SCO	5.1	1.7
SMS	CSL	6.7	1.5

Mercury Cleanup Levels

Mercury cleanup levels were developed under Case Study 3 and included a risk-based concentration at a risk level of HQ=1 (0.016 mg/kg) for Alternative 2, a MTCA natural background concentration for Alternatives 1 and 5 (0.104 mg/kg), and a regional background concentration of 0.104 mg/kg for Alternatives 3, 4, and 5. Comparing the cleanup levels to the Puget Sound EIM sediment chemistry data, 96 percent of the sampling locations exceed the risk-based cleanup level and 51 percent exceed the regional background cleanup level (Table E.15 and Figure E.20). In comparison with SMS criteria, 21 percent of the Puget Sound sampling locations exceed the SCO for mercury (0.41 mg/kg), and 15 percent exceed the CSL (0.59 mg/kg).

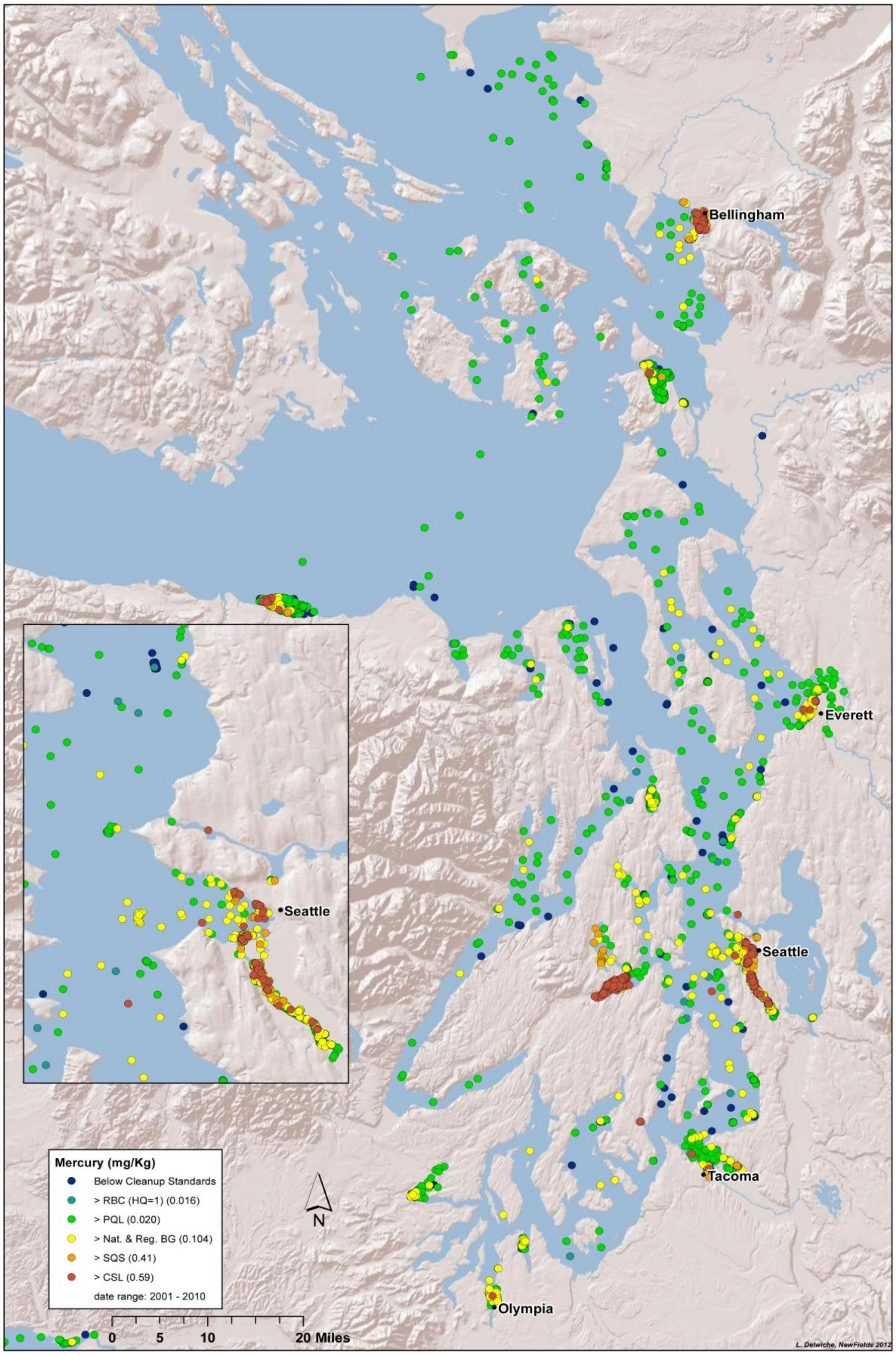


Figure E.20 - Mercury Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

Table E.15 - Mercury Cleanup Levels Compared to Puget Sound EIM Data

Case Study 3			
Alternatives	**Cleanup Level**	**Concentration (mg/kg)**	**Puget Sound EIM Data Locations Exceeding Level (%)**
1	MTCA Natural Background	0.104	51
2	Risk-Based (HQ=1)	0.016	96
3	Regional Background	0.104	51
4	Regional Background	0.104	51
5	Regional Background (CSL) MTCA Natural Background (SCO)	0.104 (CSL) 0.104 (SCO)	51 51
SMS	SCO	0.41	21
SMS	CSL	0.59	15

cPAH Cleanup Levels

Cleanup levels for cPAHs were developed for Case Studies 1 and 2. For Case Study 1, a non-urban shoreline, the cleanup levels included a natural/regional background concentration of 5.32 µg/kg for Alternatives 1, 3, 4, and 5, a risk-based concentration of 4.55 µg/kg (at a risk level of 1E-05) for Alternative 2. Comparing the cleanup levels to the sediment chemistry data available in EIM for Puget Sound, 87 percent of the sampling locations exceed the natural/regional background cleanup level and 89 percent exceed the risk-based cleanup level of 4.55 µg/kg (Table E.16 and Figure E.21).

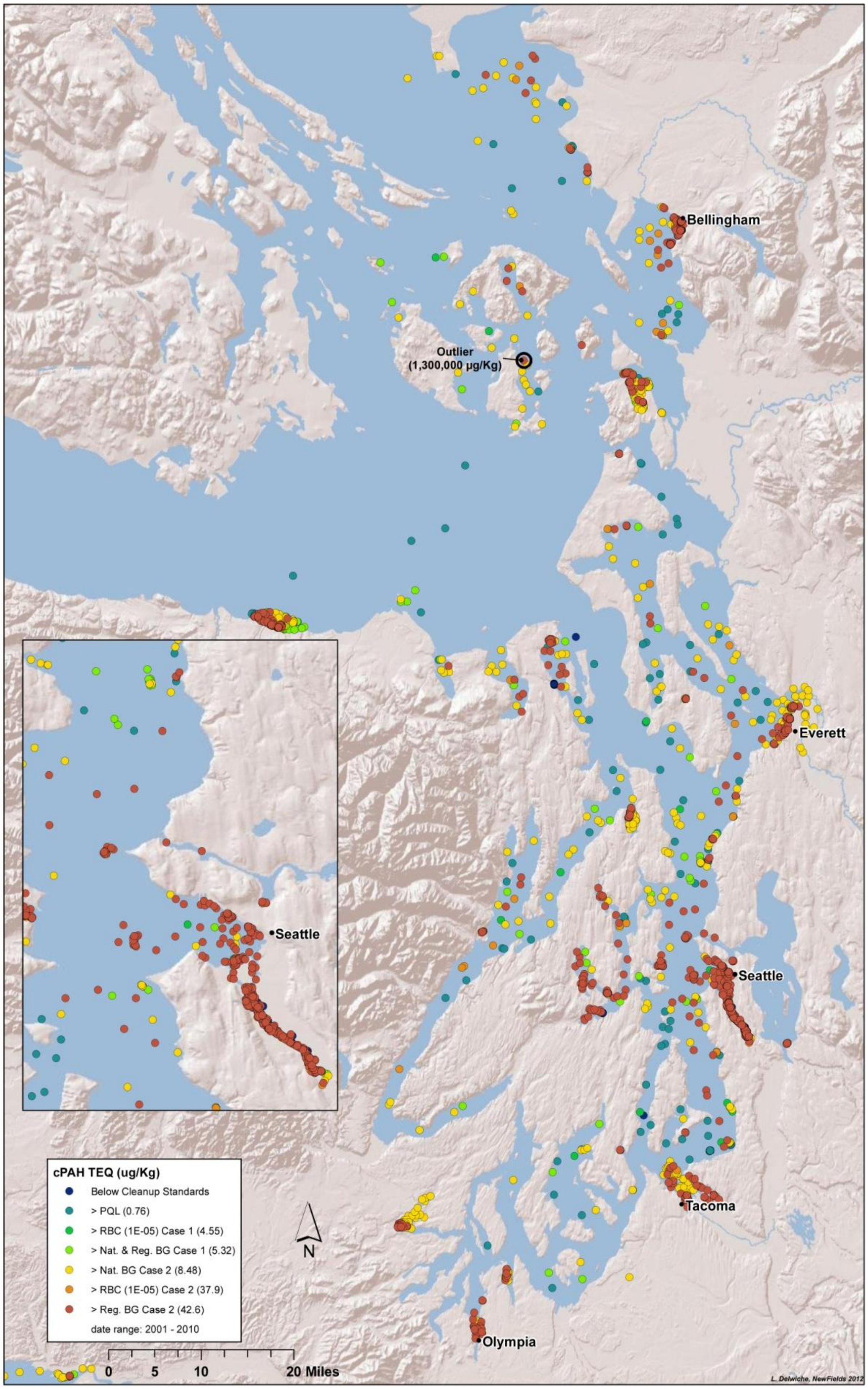


Figure E.21 - cPAH Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

For Case Study 2, an urban shoreline, the cleanup levels included a MTCA natural background concentration of 8.48 µg/kg for Alternative 1, a risk-based concentration of 37.9 µg/kg (at a risk level of 1E-05) for Alternatives 2 and 5, and a regional background concentration of 42.59 µg/kg for Alternatives 3, 4, and 5. Comparing the cleanup levels to the EIM data for Puget Sound, 81 percent of the locations exceed the MTCA natural background concentration, 55 percent exceed the risk-based cleanup level of 37.9 µg/kg, and 53 percent exceed the regional background cleanup level (Table E.16 and Figure E.21).

Table E.16 - cPAH Cleanup Levels Compared to Puget Sound EIM Data

Alternatives	Case Study 1			Case Study 2		
	Cleanup Level	Concentration (µg/kg)	Puget Sound EIM Data Locations Exceeding Level (%)	Cleanup Level	Concentration (µg/kg)	Puget Sound EIM Data Locations Exceeding Level (%)
1	MTCA Natural Background	5.32	87	MTCA natural background	8.48	81
2	Risk-Based (1E-05)	4.55	89	Risk-Based (1E-05)	37.9	55
3	Regional Background	5.32	87	Regional Background	42.59	53
4	Regional Background	5.32	87	Regional Background	42.59	53
5	Regional Background (CSL) MTCA Natural Background (SCO)	5.32 (CSL and SCO)	87	Regional Background (CSL) Risk-Based (1E-05) (SCO)	42.59 (CSL) 37.9(SCO)	53 55

Dioxin/Furan Congener Cleanup Levels

Cleanup levels for dioxin/furan congeners were developed for Case Studies 1 and 3. For Case Study 1, a non-urban shoreline, the cleanup levels included the PQL for dioxin/furan congeners for Alternatives 1, 4, and 5, a risk-based concentration of 0.187 ng/kg TEQ for Alternative 2, and a regional background cleanup level of 1.17 ng/kg TEQ for Alternative 3. Comparing the cleanup levels to the EIM data for Puget Sound, 48 percent of the locations exceed the PQL for dioxin/furan congeners, 95 percent exceed the risk-based cleanup level of 0.187 ng/kg TEQ, and 73 percent exceed the regional background cleanup level (Table E.17 and Figure E.22).

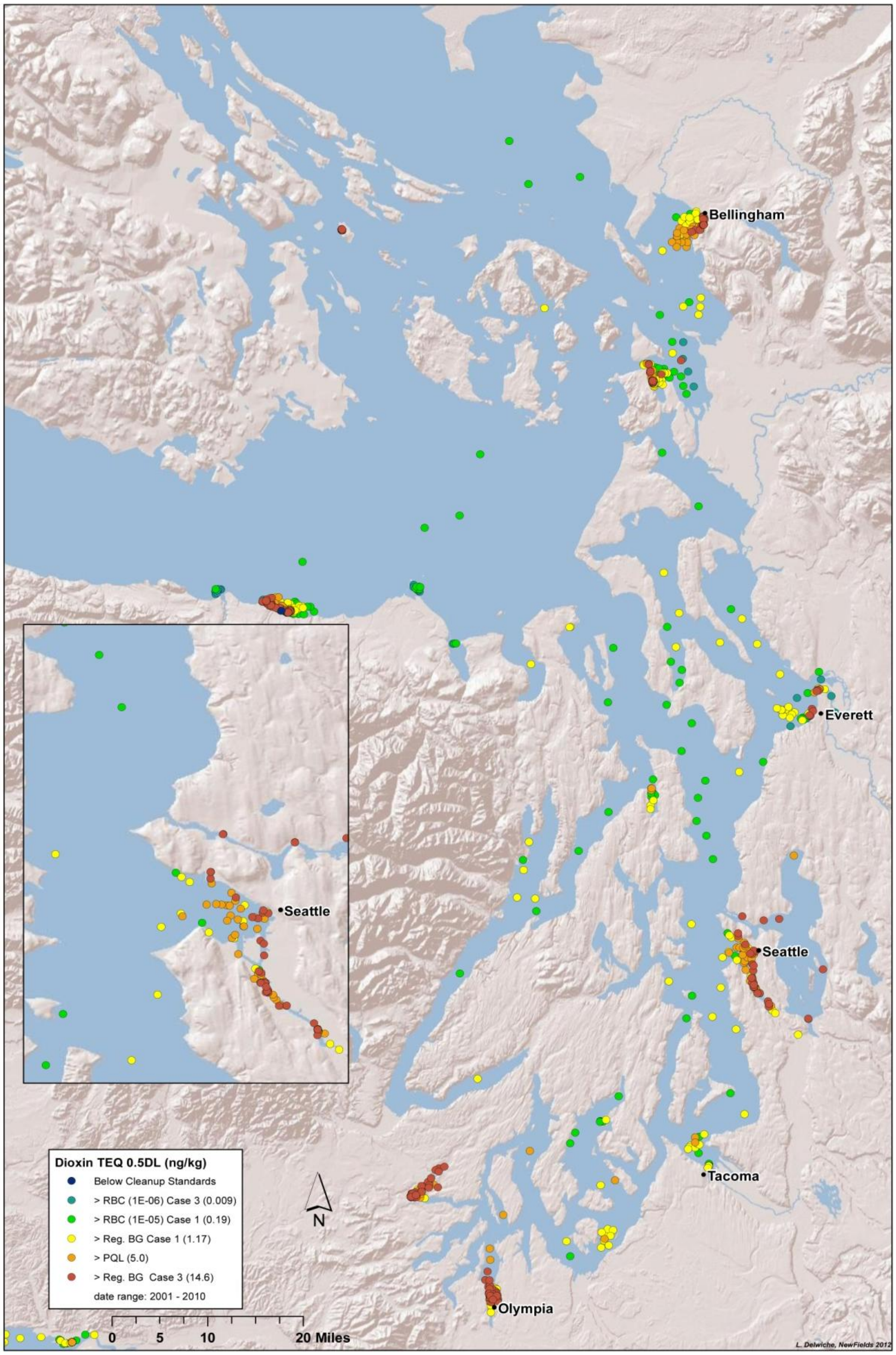


Figure E.22 - Dioxin Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

For Case Study 3, an urban embayment, the cleanup levels included the PQL for dioxin/furan congeners for Alternatives 1 and 5, a risk-based concentration of 9.21E-03 ng/kg TEQ for Alternative 2, and a regional background cleanup level of 14.6 ng/kg TEQ for Alternatives 3, 4, and 5. Comparing the cleanup levels to the EIM data for Puget Sound, 48 percent of the locations exceed the PQL for dioxin/furan congeners, 99.9 percent exceed the risk-based cleanup level, and 26 percent exceed the regional background cleanup level (Table E.17 and Figure E.22).

Table E.17 - Dioxin/Furan Congener Cleanup Levels Compared to Puget Sound EIM Data

Alternatives	Case Study 1			Case Study 3		
	Cleanup Level	Concentration (ng/kg TEQ)	Puget Sound EIM Data Locations Exceeding Level (%)	Cleanup Level	Concentration (ng/kg TEQ)	Puget Sound EIM Data Locations Exceeding Level (%)
1	PQL	5.0	48	PQL	5.0	48
2	Risk-Based (1E-05)	0.187	95	Risk-Based (1E-06)	9.21E-03	99.9
3	Regional Background	1.17	73	Regional Background	14.6	26
4	PQL	5.0	48	Regional Background	14.6	26
5	PQL (CSL and SCO)	5.0	48	Regional Background (CSL) PQL (SCO)	14.6 (CSL) 5.0 (SCO)	26 48

Total PCB Aroclor Cleanup Levels

Cleanup levels for total PCB Aroclors were developed for Case Study 4. For Case Study 4, a freshwater river, the cleanup levels included a risk-based concentration of 1.20 µg/kg at a risk level of 1E-06 for Alternative 2, a risk-based concentration of 12 µg/kg at a risk level of 1E-05 for Alternatives 3 and 5, and the PQL cleanup level for Alternatives 1, 4, and 5. Comparing the cleanup levels to the EIM data for Puget Sound, 99 percent of the locations exceed the risk-based cleanup level at a risk level of 1E-06, 73 percent of the locations exceed the risk-based cleanup level at a risk level of 1E-05, and 84 percent exceed the PQL cleanup level (Table E.18 and Figure E.23).

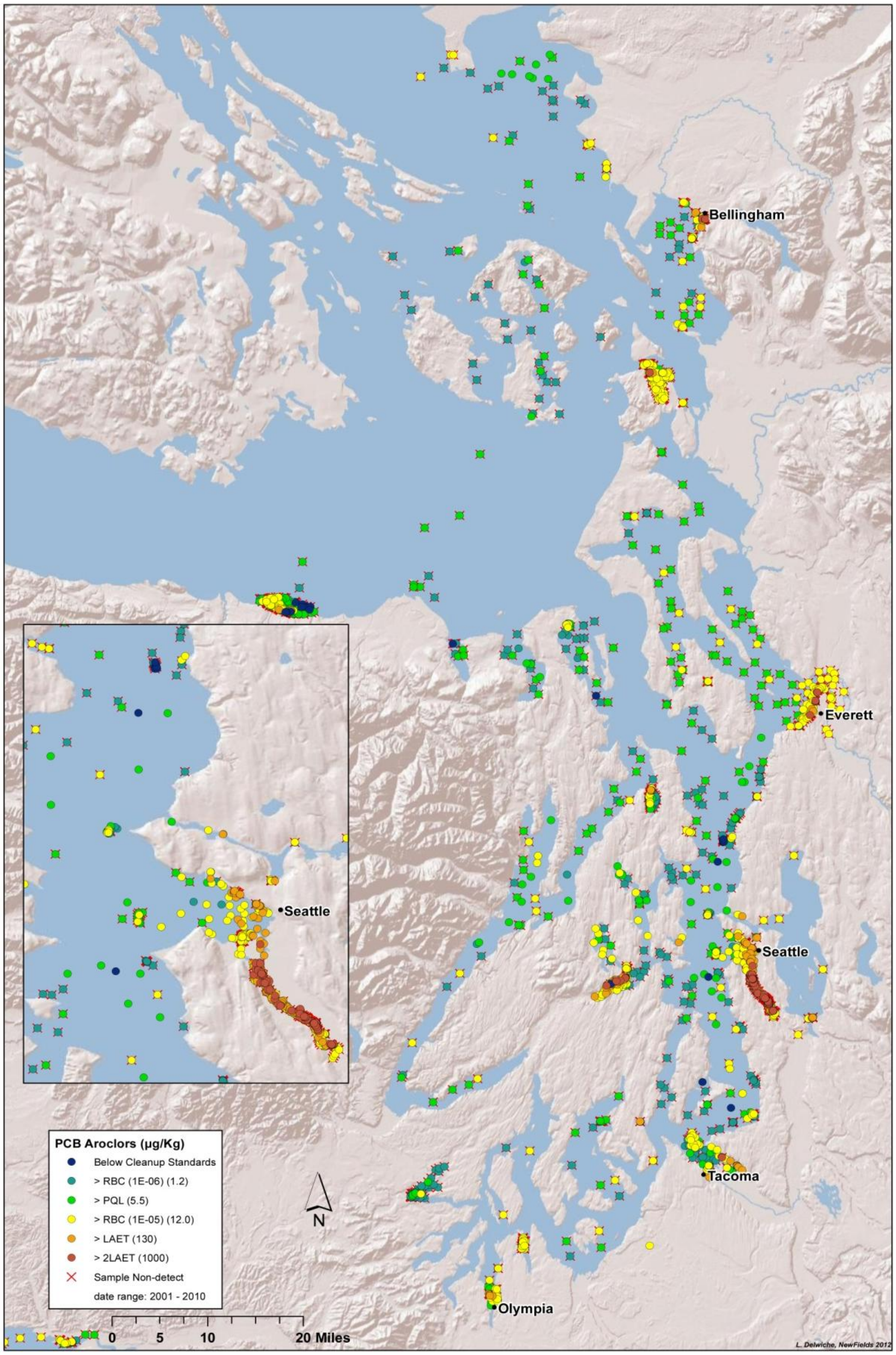


Figure E.23 - Total PCB Aroclor Cleanup Levels and SMS Criteria Compared to Puget Sound EIM Data

Table E.18 - Total PCB Aroclor Cleanup Levels Compared to Puget Sound EIM Data

Alternatives	Case Study 4		
	Cleanup Level	Concentration (µg/kg)	Puget Sound EIM Data Locations Exceeding Level (%)
1	PQL	5.5	84
2	Risk-Based (1E-06)	1.20	99
3	Risk-Based (1E-05)	12.0	73
4	PQL	5.5	84
5	Risk-Based (1E-05) (CSL) PQL (SCO)	12.0 (CSL) 5.5 (SCO)	73 84

Case Studies - Freshwater Sediment Cleanup Criteria

Three case studies are presented to evaluate the different freshwater sediment cleanup level alternatives. The first case study uses data in the EIM to evaluate the frequency of SCO and CSL exceedances across the state. The second case study uses datasets from different geographical areas to evaluate the reliability of the chemical SQVs to predict biological effects. Comparisons are made on a state-wide basis, as well as on a geographical area basis. The third case study evaluates how each of the alternatives would affect a specific cleanup site. For this case study, historical cadmium data were compared to each of the alternative cadmium SQVs and the predicted biological effects. The case studies are then summarized to rank the different alternatives.

Case Study 1 - Comparison of State-wide Sediment Chemistry to Proposed SQVs

To evaluate the proposed chemical levels, the freshwater sediment chemistry data within Ecology's EIM database were compared to each of the proposed criteria. In addition, metals concentrations observed in each station within the dataset were compared to Washington State background concentrations and practical quantitation limits (PQLs).

The dataset used for this evaluation included sediment analytical chemistry data from freshwater sites within Washington, as well as bordering areas in Oregon and Idaho, and includes urban and rural lake, river, and stream habitats. The database was screened for any unacceptable data (e.g., blank contamination) and included both detected and non-detected values. Background concentrations for metals were based on the state-wide average published in the report "Natural Background Soil Metals concentrations in Washington State" (Ecology, 1994). For metals that were not included in Ecology (1994), values from a USGS soil survey were used for comparison

(USGS, 2001). State-wide background values for organic contaminants of concern are more problematic because of differences in sources in the different geographical areas. For the purposes of these case studies, only metals SQVs are compared to background. Metals PQLs were based on a recent laboratory survey conducted by Hart Crowser in support of Ecology's SMS rule revisions (Appendix C of the Sediment HHRA guidance).

The sediment quality values for metals are presented in Table E.19. Comparisons of metals data from the different geographical areas to the SQVs defined in the five alternatives are presented in Table E.20. With the exception of selenium and silver the number of samples evaluated ranged from 2200 to 3600, with detected values in 75 percent or more of the samples. Selenium was included in fewer samples and was detected 46 percent of the time. Overall, EIM represents a strong dataset for evaluating the relative implications of the alternative screening levels. The background levels for metals and PQLs are presented in Table E.21.

The sediment quality values for organics are presented in Table E.22. Comparisons of organics data from the different geographical areas to the SQVs defined in the five alternatives are presented in Table E.23. The number of samples that included each of the organic contaminants ranged from 213 to 2801. A number of organics had high detection limits reported in the EIM, which were above either the SCO or CSL values (e.g., dieldrin and phenol). To avoid influence from elevated detection limits, non-detected values that were greater than median PQL were excluded for those compounds that have >50 percent non-detected values. Based on this censored dataset, most organics were detected in >50 percent of the samples. Exceptions included beta-hexachlorocyclohexane (beta-HCH), dieldrin, endrin ketone, monobutyltin, and the dichlorophenyltrichloroethane (DDT) analogs.

Alternative 1 - No Action Alternative

2003 Interim SQVs

Alternative 1 includes the 2003 Freshwater Interim SQVs (Michelsen, 2003), derived using the floating percentile method. This alternative does not include the modifications made between 2007 and 2011 to develop the SQVs proposed (Michelsen, 2011, provided in Appendix D of this document) in Alternatives 2 through 4 (inclusion of substantially more data from a broader geographic area and chronic endpoints for the toxicity tests). This alternative provides the advantage of being developed with data from the different geographical areas; however, it lacks some of the improved predictive ability that the larger 2007 - 2011 dataset provides. Additionally, based on the smaller dataset used in the development of the Interim SQVs, there are fewer chemicals represented.

Metals. SQVs were developed for nine of the 10 metals (no SQVs for selenium were generated). Chromium, lead, nickel, and silver concentrations exceeded the SCO in <10 percent of the stations. For these metals, there was also little difference in the proportion of stations that exceeded the SCO compared to the number of stations exceeding the CSL values. The frequency of SCO exceedances for arsenic, cadmium, copper, mercury, and zinc ranged between 13 and 40 percent. The percentage of stations exceeding the CSL guidance values for these analytes ranged from 3 to 25 percent, and all metals had more than 3 percent of the samples falling between the two SQVs, indicating an ability to distinguish between the "no-adverse" effects and "minor adverse" effects levels for these metals. All SQV levels were well above the background and PQL concentrations.

Organics. Ten of the 21 organic compounds being considered under the rule revisions have interim SQVs; many of the organochlorine pesticides and organotin compounds do not have interim SQVs. This was largely because of the limited data that were available in 2003. The Interim SQVs for benzoic acid, bis-2-ethylhexyl-phthalate, dieldrin, di-n-octyl-phthalate, and total Aroclors were generally conservative, with 34 to 58 percent of the stations exceeding the SCO values. The SCO value for dieldrin under this alternative is below the PQL; 57 percent of the samples exceeded the SCO value despite being detected in only 12 percent of the samples. For four of the ten compounds with SQVs, there was little distinction between the proportion of stations that exceed the SCO values compared to those that exceed the CSL values (less than 1 percent of the samples fall between the two values). This potentially indicates an inability to distinguish between screening and cleanup levels and may move a higher number of sites into cleanup.

TEC/PEC Values

The TEC/PECs are consensus values built on a number of marine and freshwater different guidance values including threshold and probable effects levels, freshwater apparent effects thresholds (AETs), and the Effects-Range Low and Median (ERL and ERM) values. The TEC values are generally low relative to background levels and there are few TEC/PEC values available for organics.

Metals. The metals TEC values predicted toxicity for a high number of samples within the EIM database (29 to 52 percent) with the highest percentage of exceedances for copper, nickel, and zinc. The TEC values for cadmium, chromium, copper, and nickel were equal to or above the background concentrations for Washington. Based on the PEC values, 2 to 20 percent of the stations were predicted to show toxicity. This was similar to the frequency of CSL failures based on the proposed SCO values, with the exception of copper, lead, nickel, and zinc.

Organics. There are limited organic analytes that have TEC/PEC values. SQG values have been developed for dieldrin, total Aroclors, the DDT analogs, and total PAHs. With the exception of total DDT (17 percent), there was a high percentage of stations that exceeded the TEC values (25 to 57 percent). Based on the small number of organic chemicals that have TEC/PEC values, they appear to have generally limited applicability for screening organic contaminants in freshwater sediments.

Alternative 2 - Minimize False Negative Rate (10% False Negative Rate)

Alternative 2 uses the FPM methodology with a low false negative rate (10 percent) to derive the SQVs, which minimizes the number of incorrect predictions of "no toxicity." While this alternative improved the predictive power for sites without toxicity, it may over-predict toxicity. As with the TECs/PECs, this option pushes SCO values for some metals below background or

PQL levels. However, use of the larger dataset allowed the development of the full set of SQVs (11 metals, 21 organic compounds).

Metals. Under Alternative 2, a high percentage of stations in the EIM exceed the SCO for arsenic, cadmium, nickel, selenium, and silver, ranging from 39 percent (cadmium) to 83 percent (selenium). There were few stations exceeding the SCO for lead and zinc (1 and 2 percent, respectively); and a moderate number of stations exceeding the SCO for chromium, copper, and mercury (7 to 15 percent). With the exception of lead and zinc, there was separation between the number of stations exceeding the SCO and CSL (5 to 70 percent of the values fell between the two values). The percentage of stations greater than CSL varied from low (1 to 2 percent for chromium, copper, and zinc) to high (39 percent of the samples for arsenic).

As with the TECs/PECs values, the SCO values in Alternative 2 are below the background levels for several metals, including arsenic, cadmium, nickel, and selenium. It is likely that this is associated with the high percentage of samples exceeding the SCO for these metals and is overly conservative for Washington State sediments. The SCO for selenium under this alternative is 0.29 mg/kg. While there is no selenium background value for soils in Washington State, this SCO value is below values reported in the USGS 22 element report (0.39 mg/kg; USGS, 2001) as well as the PQL of 0.6 mg/kg and is likely associated with the high number of stations with SCO exceedances.

Organics. As with metals, a high percentage of samples exceeded the SCO value for organic contaminants when the minimum false negative rate is used. The percentage of SCO hits was between 40 and 85 percent for 4-methylphenol, dibenzofuran, di-n-octyl phthalate, pentachlorophenol, tributyltin, and total aroclors. Nearly one-third of samples in the EIM exceeded the CSL for 4-methylphenol, phenol, tributyltin, total aroclors, and total PAHs. No samples exceeded the SCO for beta HCH. The Alternative 2 SCO values for di-n-octyl-phthalate, pentachlorophenol, and phenol were below the PQL, likely contributing to the high percentage of samples exceeding the SCOs for these compounds (42, 85, and 24 percent, respectively). With the exception of beta-HCH and di-n-butylphthalate, there was separation between the number of stations exceeding the SCO and CSL (3 to 74 percent of the values fell between the two values). Based on the large number of samples exceeding the SCO and CSL values for organic contaminants and the interactions with the PQLs for some compounds, the Alternative 2 SQVs appear to be conservative estimators of effects.

Alternative 3 - Minimize False Positive Rate (30% False Negative Rate)

The SQVs developed under Alternative 3 also used the FPM methodology, but allowed a higher rate of false negatives (30 percent) to minimize the number of false positive predictions of toxicity. This approach is intended to decrease the number of false positives and to minimize the potential for SCO values to fall below background or PQL levels. The use of the larger dataset allowed the development of the full set of SQVs (11 metals, 21 organic compounds).

Metals. The percentage of samples with metals concentrations exceeding the SCO values ranged from 3 to 38 percent, except for two metals (nickel and silver) having 20 percent or fewer samples above the SCO. Nickel (38 percent) had the highest percentage of samples exceeding the SCO, with the nickel SCO value below the background value for Washington State. Copper and zinc concentrations seldom exceeded the proposed SCO value for this alternative (3 percent). With the exception of silver, the percentages of samples exceeding the CSL were relatively low, ranging from 0 to 8 percent. There was generally a good separation between the number of samples exceeding the SCO and CSL criteria, indicating an ability to distinguish between no adverse and minor adverse effects, with the exceptions of zinc and copper, which both had only 1 percent of the samples falling between the two values.

Organics. With the exception of 4-methylphenol (47 percent), di-n-octyl-phthalate (42 percent), total aroclor (39 percent), and tributyltin (51 percent), the percentage of samples exceeding the SCO values was between 0 and 32 percent. None of the samples exceeded the SCO values for beta-HCH or for endrin ketone. In general, there was separation between the percentage of samples exceeding the SCO and CSL; however, the percentage of samples falling between the SCO and CSL hits was 2 percent or less for five contaminants (carbazole, dieldrin, di-n-butylphthalate, total DDDs, and PAHs). All organic SCO values were greater than their respective PQLs.

Alternative 4 - Balance False Negative and False Positive Rates (20% False Negative Rate)

The SQVs developed using the FPM methodology under Alternative 4 balance potential for false predictions of hits and no-hits by setting the false negative rate at 20 percent. Alternative 4 sets the SCO values at a level that best balances the potential false negatives and false positives, and also performs better by generating criteria that were above background and PQL levels. Again, the use of the larger dataset allowed the development of a more extensive set of SQVs (11 metals, 21 organic compounds).

Metals. The SCO values for Alternatives 3 and 4 are similar for a number of metals (arsenic, chromium, lead, mercury, nickel, selenium, and zinc). As such the number of samples exceeding the SCO and CSL criterion are similar (SCO exceedance range is 2 to 78 percent of the samples, except for three metals having fewer than 20 percent of the samples exceeding the SCO; the percentage of samples with concentrations above the CSL level remained the same (0 to 15 percent). As with the proposed SCO values for Alternatives 2 and 3, background concentrations were higher than the proposed SCO value for nickel, possibly indicating that these values may be conservative for Washington freshwater sediments. For this alternative, only zinc had SQVs with poor ability to discriminate between SCO and CSL hits.

Organics. A number of the SCO and CSL values under Alternative 4 are similar to that for Alternative 3, with some refinement. The percentage of samples with hits is between that of Alternatives 2 and 3. The percentage of samples exceeding the SCO values ranged from 0 percent (beta-HCH and endrin ketone) to 65 percent (tributyltin). The percentage of samples with SCO and CSL hits for TBT was 65 and 35 percent, respectively; this is likely a reflection of the nature of sites included in the EIM (e.g., shipping related sites in Portland Harbor and Salmon Bay). Similarly, nearly one-third of the samples in the EIM fail the CSL for 4-methylphenol and phenol under Alternative 4. Both organic contaminants have been associated the timber industry among other industrial activities. In general, there was reasonable separation between the percentage of samples exceeding the SCO and CSL values, with slightly improved separation relative to Alternative 3 (carbazole, dieldrin, di-n-butylphthalate, and total DDDs still had less that 2 percent of the samples between the SCO and CSL, but total PAHs were no longer on this list). All organic SCO values were greater than their respective PQLs.

Alternative 5 (Biological Criteria only)

Alternative 5 establishes SMS criteria only for the biological tests. Chemical screening of sediments would continue to be conducted on a site-by-site basis using either the 2003 Interim SQVs or the TEC/PECs. As such, the number of stations exceeding the chemical screening values would be similar for Alternatives 1 and 5.

Case Study 2 - Predictive Ability of Chemical SQVs

The ability for each of the alternatives to predict the outcome of the proposed toxicity tests was evaluated using an extensive compilation of synoptic chemical and biological data from freshwater sediment studies in Washington and Oregon (Michelsen, 2011).

As noted in Chapter 3, the different SQVs presented in each of the alternatives are based on the ability of sediment chemistry to predict the potential adverse effects to the benthic community. Consistent with the SMS marine sediment criteria, the freshwater sediment criteria developed by Ecology were developed to target no-adverse effects levels (SCO) and minor adverse-effects levels (CSL). The FPM was used with paired chemistry and toxicity testing data in EIM to develop SCO and CSL values. In total, 648 sediment samples with synoptic bioassay and chemistry data were evaluated and included the growth and mortality endpoints for the amphipod (*Hyalella azteca*) and midge (*Chironomus dilutus*). The SQVs for alternatives 1 (2003 Interim SQVs, only), 2, 3, and 4 were created by setting the maximum allowable false negative rate (calling a station non-toxic when it is actually toxic) at three different levels. If the false negative rate was set to a lower level (e.g., 10 percent FN), the number of false positive predictions (calling a station toxic when it is actually non-toxic) generally increased. Conversely, a higher false negative rate results in fewer false positive predictions. Ideally the false negative rate is set such that the number of correct predictions is maximized.

To evaluate the predictive accuracy of the different sets of SQVs, the synoptic dataset used in Michelsen (2011, Appendix D) was evaluated. The concentrations for each analyte from each sample were compared to each SQV to determine whether an SCO or CSL hit was predicted. That prediction was then compared to the bioassay results for that sample to determine whether the SQV correctly predicted the bioassay results. For each sample there were four possible outcomes:

1. False negative: Biological hits predicted as “no hits” by chemical SQVs
2. True Positive: Biological hits predicted as hits by chemical SQVs
3. True Negative: Biological “no-hits” predicted as “no-hits” by chemical SQVs
4. False Positive: Biological “no-hits” predicted as hits by chemical SQVs

A summary of the outcomes of those comparisons is presented in the plots on Figures E.24 and E.25. In the cross-plots, each bullet represents approximately 10 samples; solid bullets indicate hits; hollow bullets indicate non-hits. Green symbols indicate a correct (true) prediction; whereas a red symbol indicates an incorrect prediction.

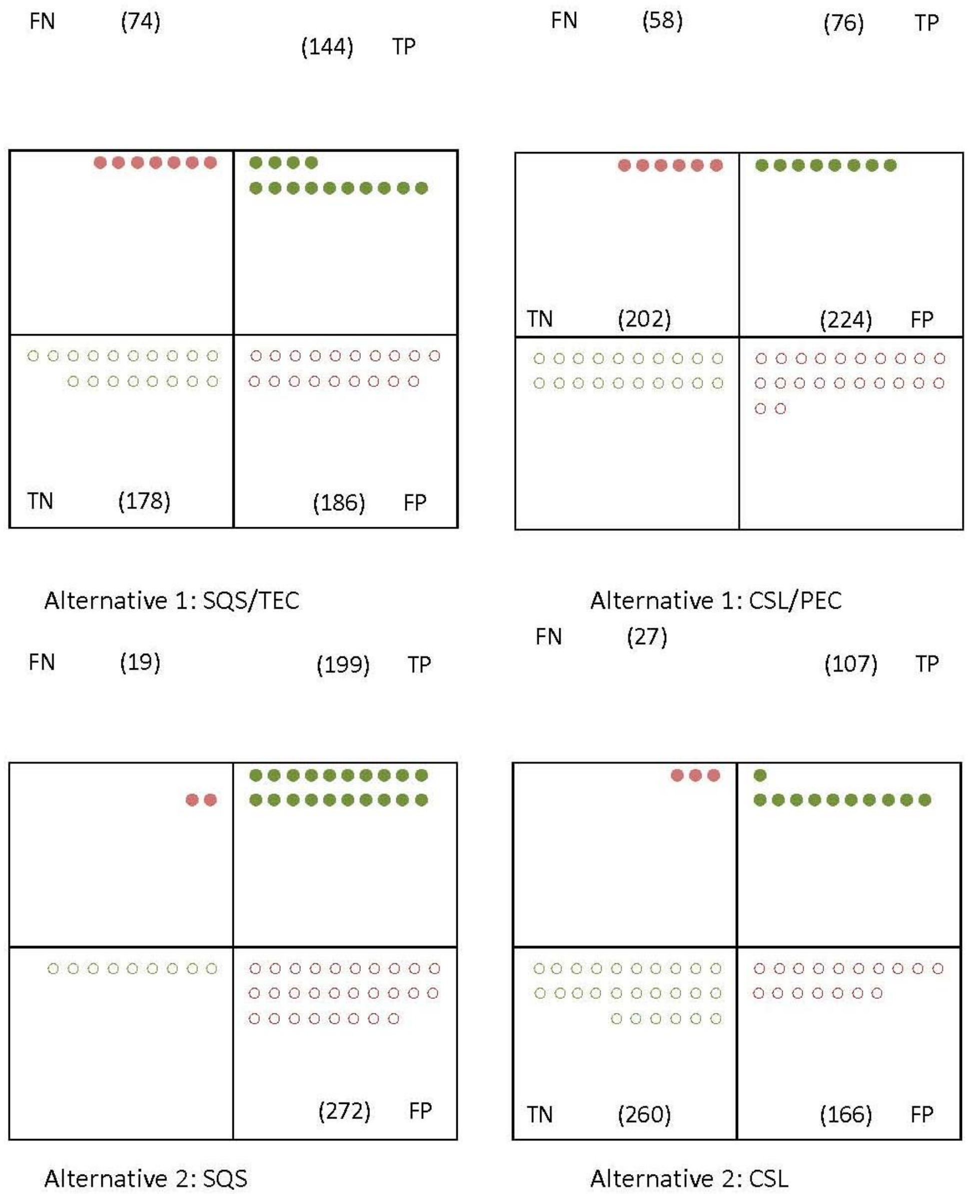


Figure E.24. Reliability Measures for Alternatives 1 and 2. Cells are defined as follows:

FN: False negative - Biological hits predicted as "no hits" by chemical SQVs
TP: True Positive - Biological hits predicted as hits by chemical SQVs
TN: True Negative - Biological "no-hits" predicted as "no-hits" by chemical SQVs
FP: False Positive - Biological "no-hits" predicted as hits by chemical SQVs

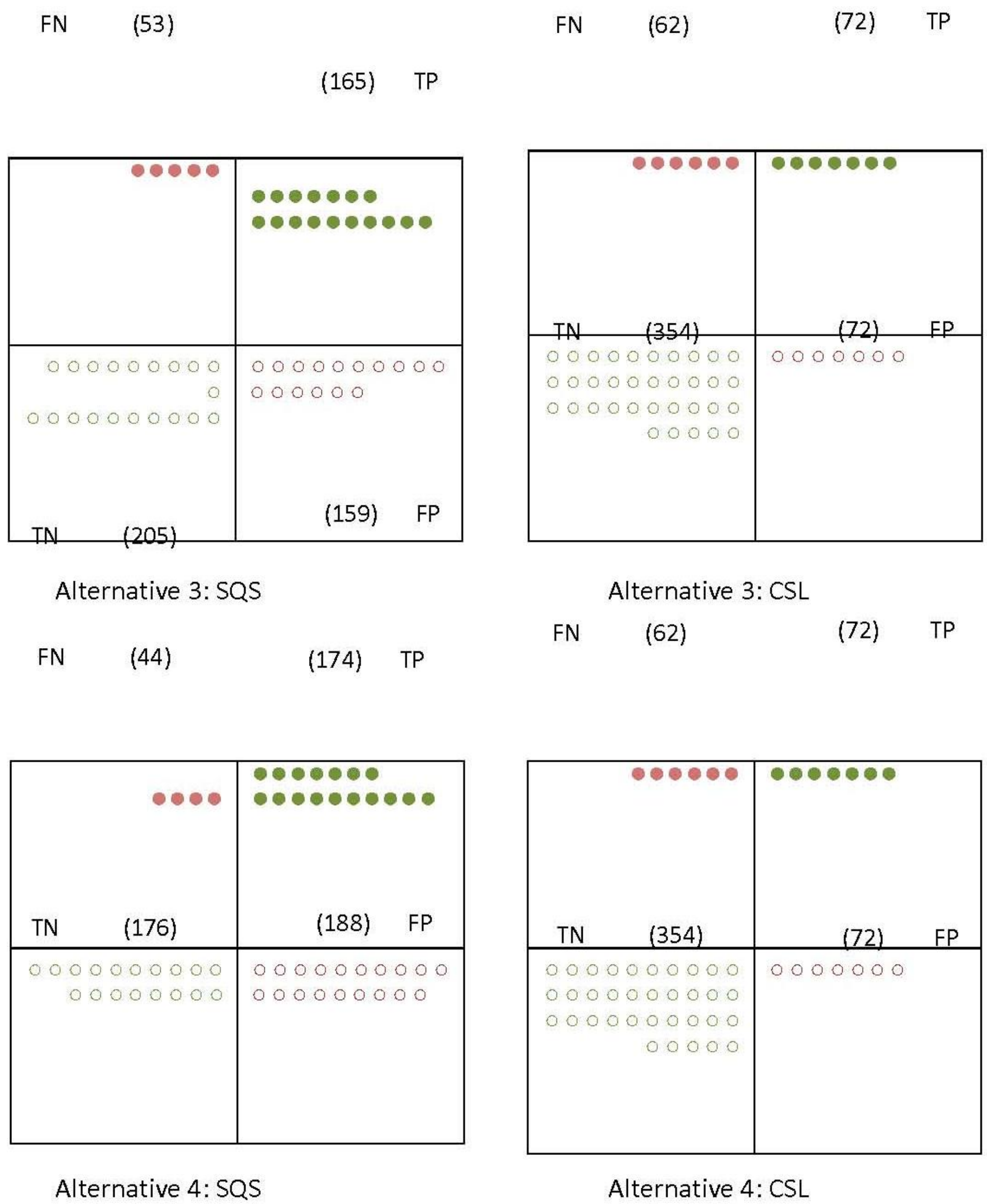
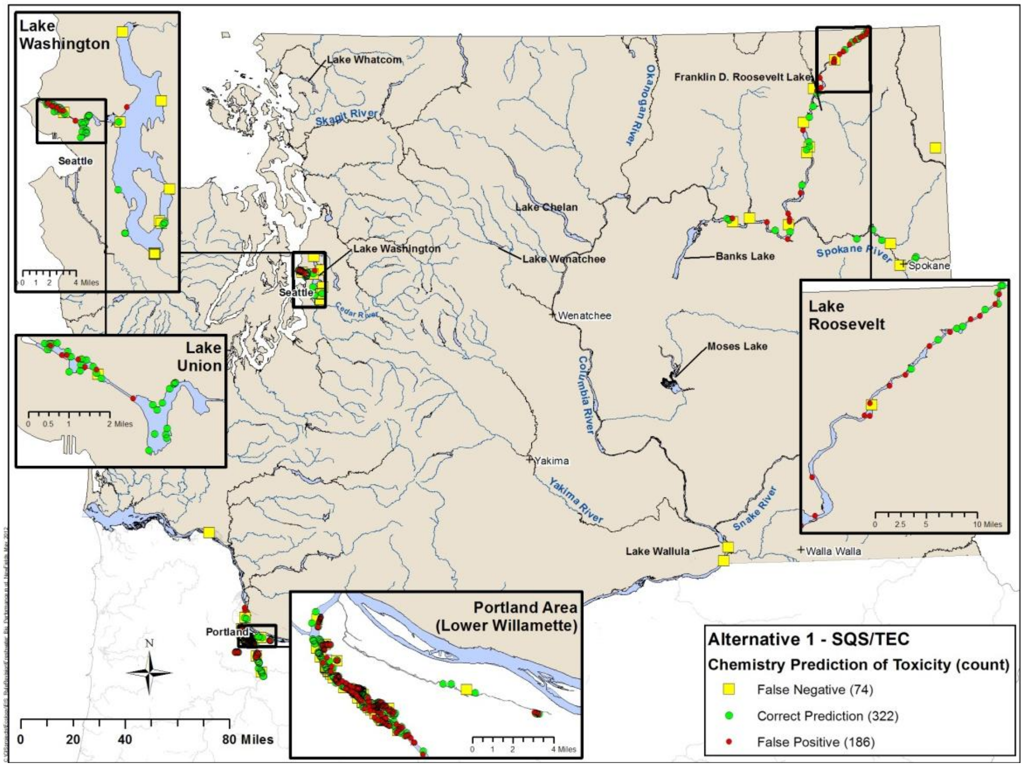


Figure E.25. Reliability Measures for Alternatives 1 and 2. Cells are defined as follows:

FN: False negative - Biological hits predicted as "no hits" by chemical SQVs
TP: True Positive - Biological hits predicted as hits by chemical SQVs
TN: True Negative - Biological "no-hits" predicted as "no-hits" by chemical SQVs
FP: False Positive - Biological "no-hits" predicted as hits by chemical SQVs

The geographic distribution of the predictive ability for the different alternatives is presented on Figures E.26 through E.29. The dataset used by Michelsen (2011) included stations with a variety of sediment types representing Puget Sound, the Lake Roosevelt/Lower Spokane River area, Lower Columbia River and the Portland Lower Willamette River area. Measured concentrations for all available COCs were compared to each of the respective criteria and were assessed for the number of correct, false negative (FN), and false positive (FP) predictions.



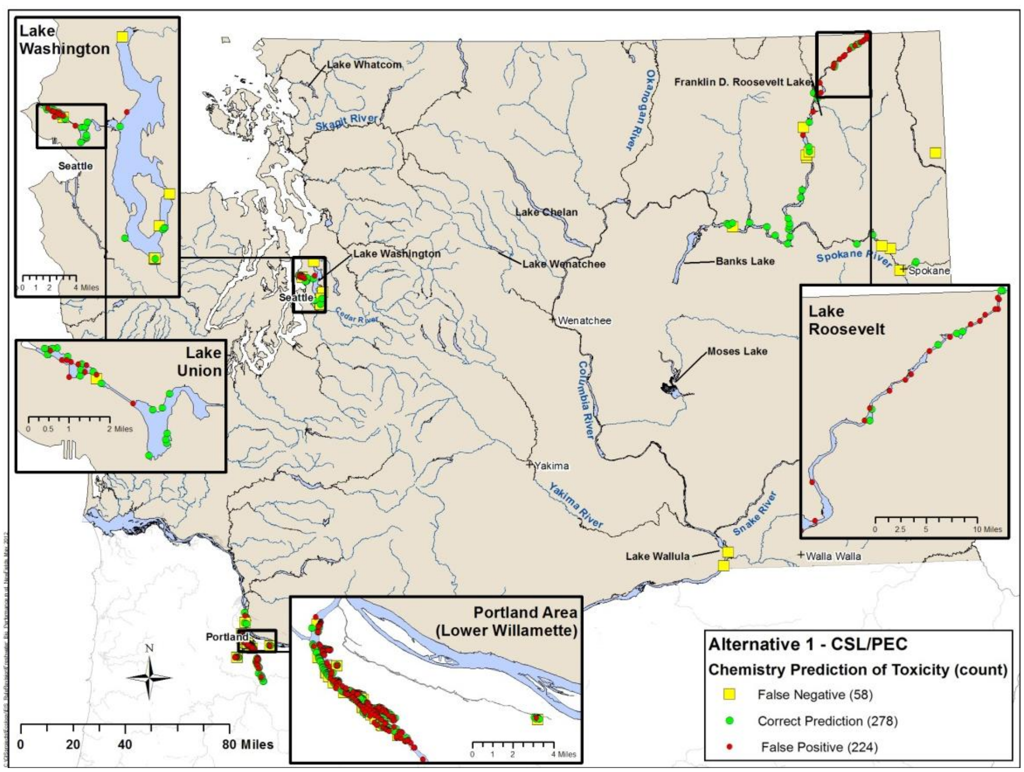


Figure E.26 - State-wide Distribution of Alternative 1 Predictive Ability

The different SQVs were also evaluated using measures of overall reliability, hit reliability, and no-hit reliability for each sample (Table E.24). Reliability was evaluated for all stations across the state, as well as separately for eastern and western Washington. Measures of reliability were defined as follows:

- *Predicted Hit Reliability.* Correctly predicted hits/total predicted hits
- *Predicted No-Hit Reliability.* Correctly predicted no-hits/total predicted no-hits
- *Overall Reliability.* Correct predictions/total stations

The reliability values in this table differ from those in the freshwater technical report (Ecology, 2011). The reliability analysis in the technical report was conducted for each endpoint individually, while Table E24 evaluates the reliability of the final SCO and CSL values in the proposed rule. To obtain the final values, the lowest (SCO) and second-lowest (CSL) of the values for all the endpoints were used, regardless of which endpoint set those values. The reliability of the combined criteria is affected in the following ways:

- Because these are the lowest of the available values, the no-hit reliability of the SCO and CSL criteria tends to increase, as it is more likely that a toxic station will be identified as such.

- On the other hand, the hit reliability is lower, because these lower criteria also result in more false positives (identifying a station as toxic when it isn't).

- There are many more non-toxic stations in Washington State sediments than toxic stations. Because of this, decreasing the hit reliability affects many more stations than improving the no-hit reliability, and therefore, the overall reliability declines. Because the overall reliability is so dependent on the relative percentage of toxic and non-toxic stations in the data set, it is a less useful measure than the other two.

- In summary, choosing the lowest of the endpoint values as the SCO and CSL criteria makes the criteria more conservative and protective, but at the cost of identifying some stations as toxic that are not actually toxic.

While differences in reliability appear to be present in the analysis of data from the different geographical areas between the east side and the west side of the Cascade Mountains, it is important to note that there are currently relatively few data for the east side (~10%). Most of the data sets for the east side had very limited analyte lists and could not be used in the analysis. Therefore, it is uncertain whether this comparison is representative of how the criteria will perform once more data become available.

The west side reliability values closely track those of the statewide analysis, likely because these data make up 90% of the data set. While hit reliability is higher for the east side, no-hit reliability is lower at the SCO level. However, the no-hit reliability for the proposed freshwater criteria is 20% higher than the no action alternative for the east side, assuming use of the TECs (MacDonald, 2000). The inability of either set of values to accurately predict toxicity in the few existing east side data sets may reflect chemicals not measured or not included in the criteria, physical toxicity associated with matrix effects (e.g., slag), unusual bioavailability due to factors such as water chemistry, etc. These results support the proposed rule language requiring the use of bioassays and/or site-specific chemical criteria when such factors are present.

Alternative 1 - No Action Alternative

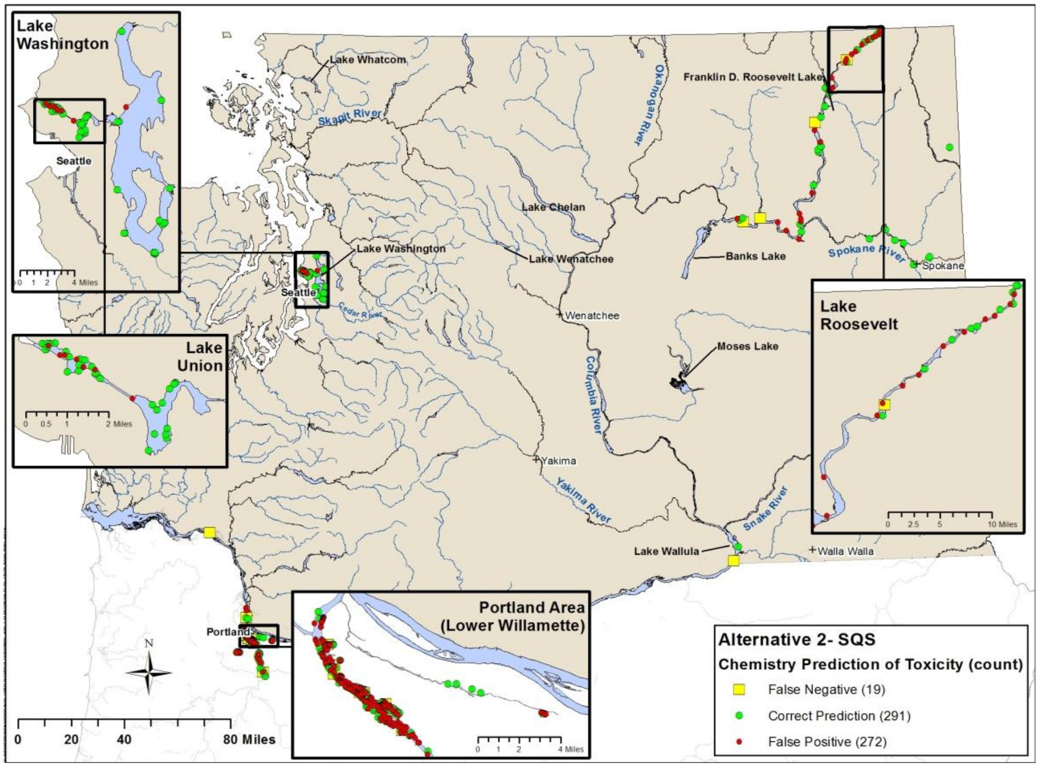
To evaluate the reliability and predictive ability for the no action alternative, comparisons in western Washington were made using the 2003 SQVs; comparisons in eastern Washington were made using the TEC/PECs. State-wide, the overall reliability of the combined SQVs was 55 percent for the SCO values and 50 percent for CSL values (Table E.24). For both the combined SCO/TEC and CSL/PEC criteria, the no-hit reliability was >70 percent; whereas, the hit reliability was quite low, at 44 and 25 percent, respectively. Hit reliability decreases with an increasing number of false positives. This is shown in the cross-plots which indicate an over-prediction of toxicity, as shown by the high number of stations with false positives (Figure E.24).

The distribution of the predictive ability for Alternative 1 is presented on Figure E.26. A high number of false positives were observed in Lake Roosevelt, Portland Harbor, and the Ship Canal west of Lake Union. The reliability for eastern and western Washington was generally similar. The overall reliability for the SCO/TEC criteria was lower for eastern Washington (Table E.24). This was driven by a low no-hit reliability for the TECs used in eastern Washington (35 percent) compared to 2003 SQV comparisons in western Washington (74 percent). It is important to note that the reliability estimate for no-hit reliability in eastern Washington was based on 20 stations, compared to 232 stations in western Washington. Thus, a small number of false negatives in eastern Washington may overly influence the reliability estimate. In general, Alternative 1 represented a highly conservative estimator of toxicity. Under this alternative, a higher number of sites would be identified for further characterization and require validation by further toxicity testing.

Alternative 2 - Minimize False Negative Rate (10% False Negative Rate)

The reliability of the Alternative 2 SQVs to predict toxicity was generally improved, relative to the Alternative 1, with overall reliability of 50 percent for SCO values and 66 percent for the CSL values. The no-hit reliability was higher for both the Alternative 2 SCO and CSL sediment quality values, at 83 and 91 percent, respectively. This was because of a lower false negative rate. Hit reliability was low for the SCO values, based on the high number of false positive predictions (272; Figure E.24). Because the false negative rates are set at 10 percent, the error is typically associated with predictions of toxicity. False positive rates for Alternative 2 averaged 40 percent for the SCO values and 30 percent for the CSL values. Under Alternative 2, a higher number of sites would be identified for further characterization and require validation by further toxicity testing; however, the number of false “no-hit” predictions would be lower when compared to alternatives with higher percent false negative rates.

The conservative nature of Alternative 2 is reflected in the geographic distribution, with false positive predictions occurring throughout the state (Figure E.27). This is the result in part of the SQVs for arsenic, nickel, and selenium falling below the background or PQL concentrations. The reliability in eastern and western Washington was improved relative to Alternative 1; however, hit reliability was in the 40 to 50 percent range for both eastern and western Washington, primarily because of the high false positive rates for this option.



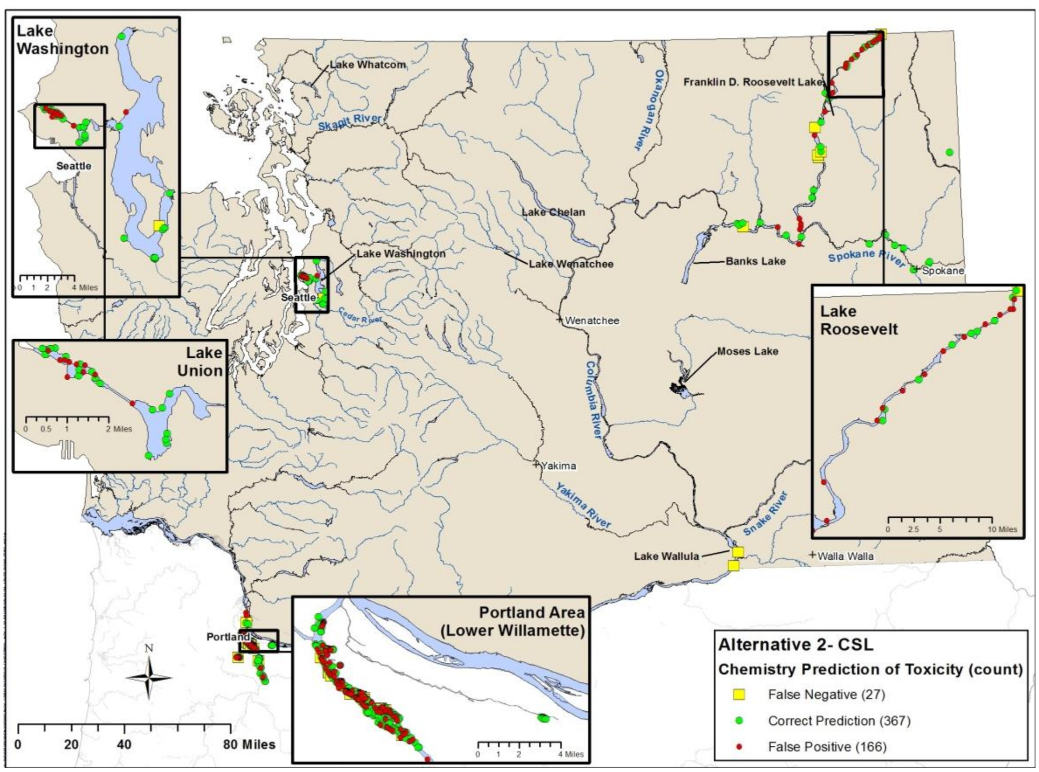


Figure E.27 - State-wide Distribution of Alternative 2 Predictive Ability

Alternative 3 - Minimize False Positive Rate (30% False Negative Rate)

The overall reliability for the Alternative 3 SQVs to predict toxicity was higher than those of both Alternatives 1 and 2, with overall reliability averaging 64 percent for the SCO values and 76 percent for the CSL values. Since the false negative rates were set at 30 percent (actual average false negative rates for both SCO and CSL values were both 29 percent), the false positive predictions were lowest for this alternative, particularly for the CSL values (Figure E.25). Consequently, the hit reliability was highest for this alternative.

Under this alternative, the number of correct predictions increased state-wide (Figure E.28), with overall reliability and no-hit reliability >75 percent for the CSL in both western and eastern Washington. SCO reliability was slightly less ranging from 50 to 83 percent. Hit reliability for the SCO in western Washington was low based in part to a high number of false positives in Portland Harbor. Under this alternative, the number of sites requiring further investigation and validation testing would be minimized; however, toxicity might be expected to be under-predicted.

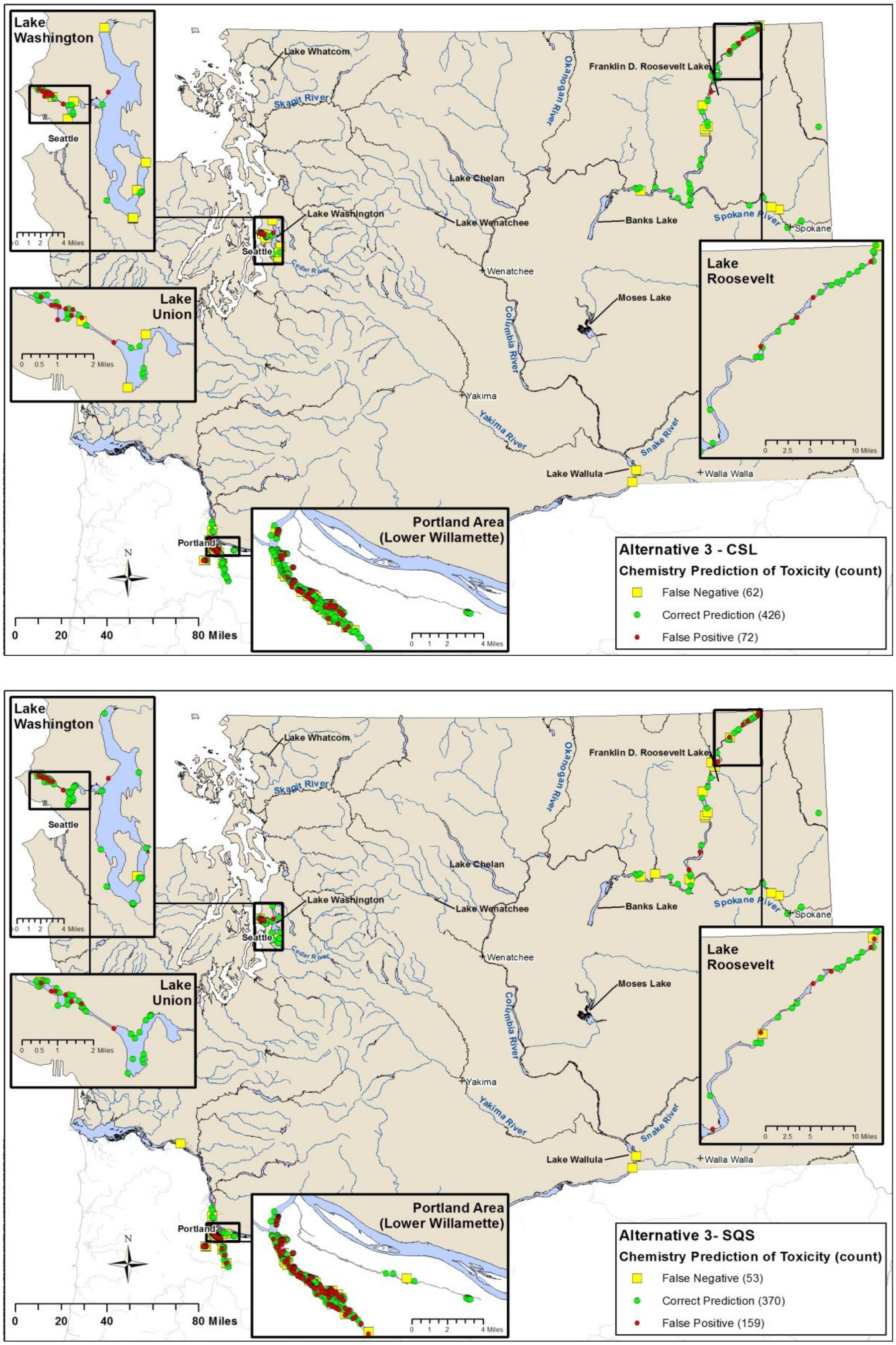


Figure E.28 - State-wide Distribution of Alternative 3 Predictive Ability

Alternative 4 - Balance False Negative and False Positive Rates (20% False Negative Rate)

Overall, the SQVs developed under Alternative 4 were the most balanced for predicting toxicity. Average overall reliability was 60 percent for SCO values and 76 percent for CSL values. While overall reliability was slightly below the Alternative 3 SQVs, there was improved balance in the false negative and false positive rates. False negative rates for SCO and CSL values were 19 and 20 percent, respectively, while false positives were 20 and 15 percent, respectively. Hit and no-hit reliability were among the highest of the alternatives for both SCO and CSL. Reliability was higher for no-hit predictions (80 to 85 percent) than for hit predictions (48 to 50 percent). This is due in part to a bias toward more protective values, particularly for the SCO level evaluations.

The state-wide distribution was similar to that of Alternative 3. False negatives were observed throughout the state; however, they represented a higher proportion of the stations in eastern Washington, resulting in a lower no-hit reliability in eastern Washington (Table E.24). Hit reliability in eastern Washington was similar to or higher than that of western Washington. Alternative 4 provided the best balance of false negatives and false positives while maintaining a higher overall reliability.

Alternative 5 (Biological Criteria only)

Because Alternative 5 would promulgate biological testing criteria only, the chemical screening criteria would be similar to that of Alternative 1. As such, the state-wide case studies would yield a similar distribution for stations requiring further characterization. While the distribution of stations exceeding the chemical screening values would be similar for Alternatives 1 and 5, the result of confirmatory testing would likely differ. Under Alternative 5, confirmatory tests would follow the proposed biological testing guidelines with the suite of tests recommended by the SMS Advisory Group and MTCA/SMS Science Panel. The specific changes in the distribution of cleanup sites on a state-wide basis would be difficult to predict. However, the advantage to this alternative would be a more predictable override step.

Case Study 3 - Specific Site Evaluation

To better understand how the different alternatives would affect a specific cleanup site, datasets in Lake Union were evaluated relative to each of the alternatives. For the purposes of this case study, the concentrations of cadmium were compared to the chemical screening values in each alternative. The areas within the lake that exceeded the SCO and CSL values were then calculated using Thiessen polygons. Thiessen polygons define the area of influence around an individual point in a set of points and were determined by the perpendicular bisectors between all surrounding points. The mean false positive rate (Michelson, 2011, see Appendix D) for each specific SQV was then applied to the respective area to estimate how the footprint for a cleanup action might be altered following confirmatory biological testing (the “confirmed” cleanup area). It is important to note that this application of the false-positive rate is for the purposes of this case study and not necessarily what might occur for an actual site. For the total area requiring cleanup (following confirmatory biological testing), the areas that exceeded either SCO or CSL were added together. Because of the sampling density in the northern portion of Lake Union, the areas represented by this vicinity were substantially smaller than individual stations in southern portion of the Lake where sampling densities were lower. Evaluations were based on readily available data and do not reflect site-specific cleanup decisions.

Cadmium concentrations within the Lake Union dataset ranged from 0.01 to 27 ppm, with approximately 30 percent of samples falling between the intervals of 0.01 to 0.99 ppm, 1.0 to 1.9 ppm, and 2.0 to 4.9 ppm. Approximately 10 percent of the samples were above 5.0 ppm. Based on the Thiessen polygons, the areas represented by the five sets of screening criteria area differed considerably (Table E.25; Figures E.30 through E.34).

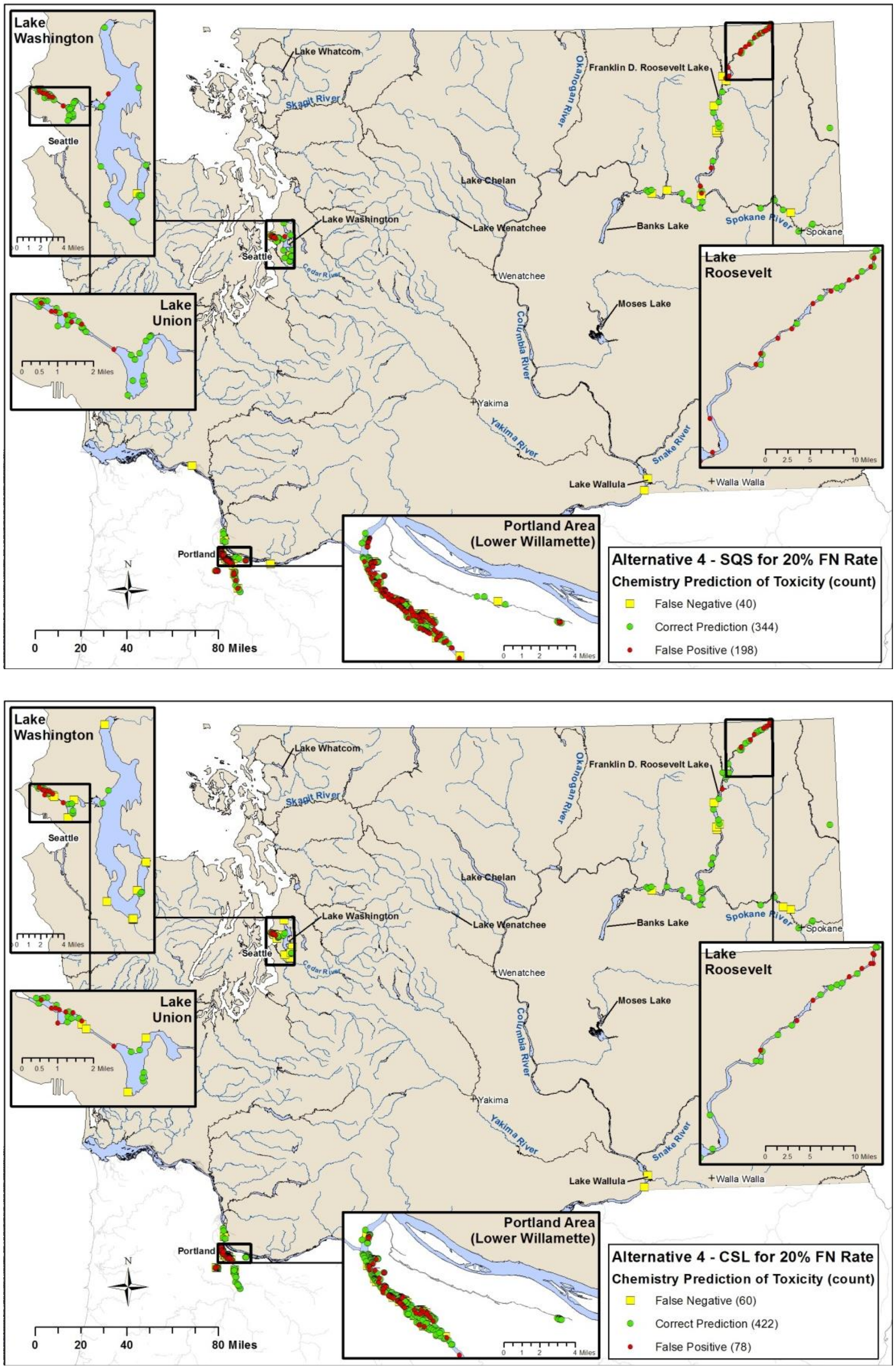


Figure E.29 - State-wide Distribution of Alternative 4 Predictive Ability

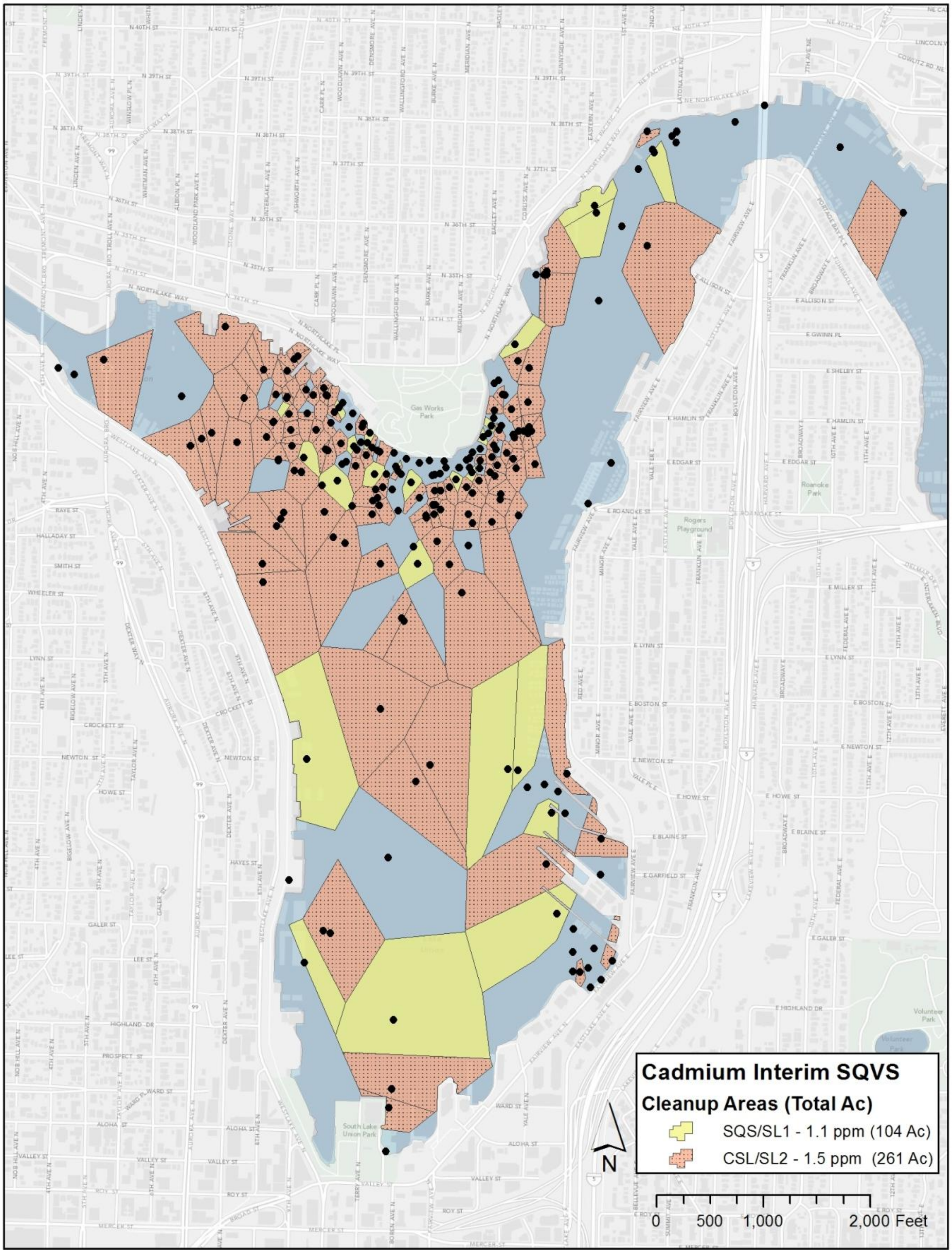


Figure E.30 - Distribution of Cadmium Concentrations that Exceed SCO and CSL Values - Alternative 1

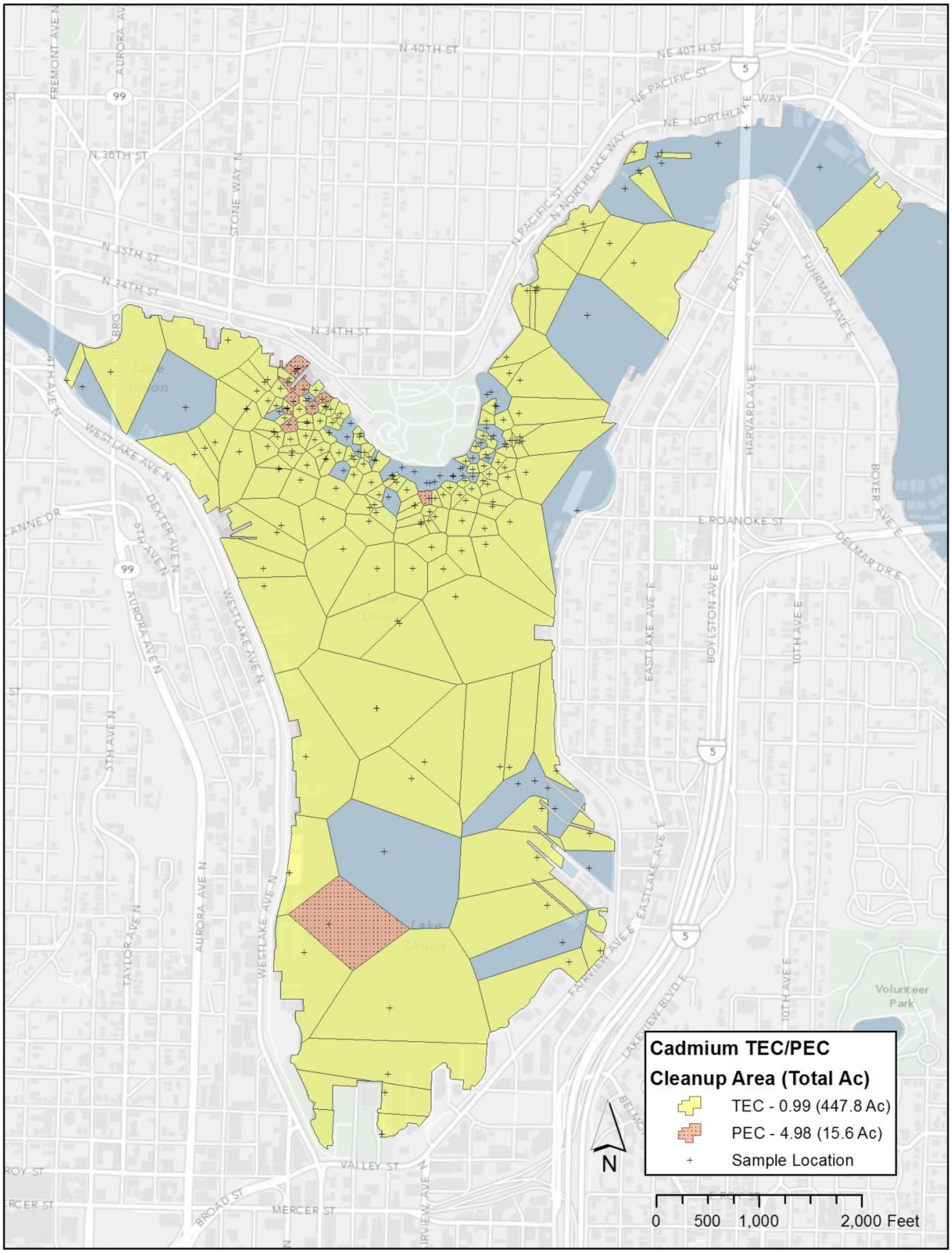


Figure E.31 - Distribution of Cadmium Concentrations that Exceed TEL and TEC Values - Alternative 1

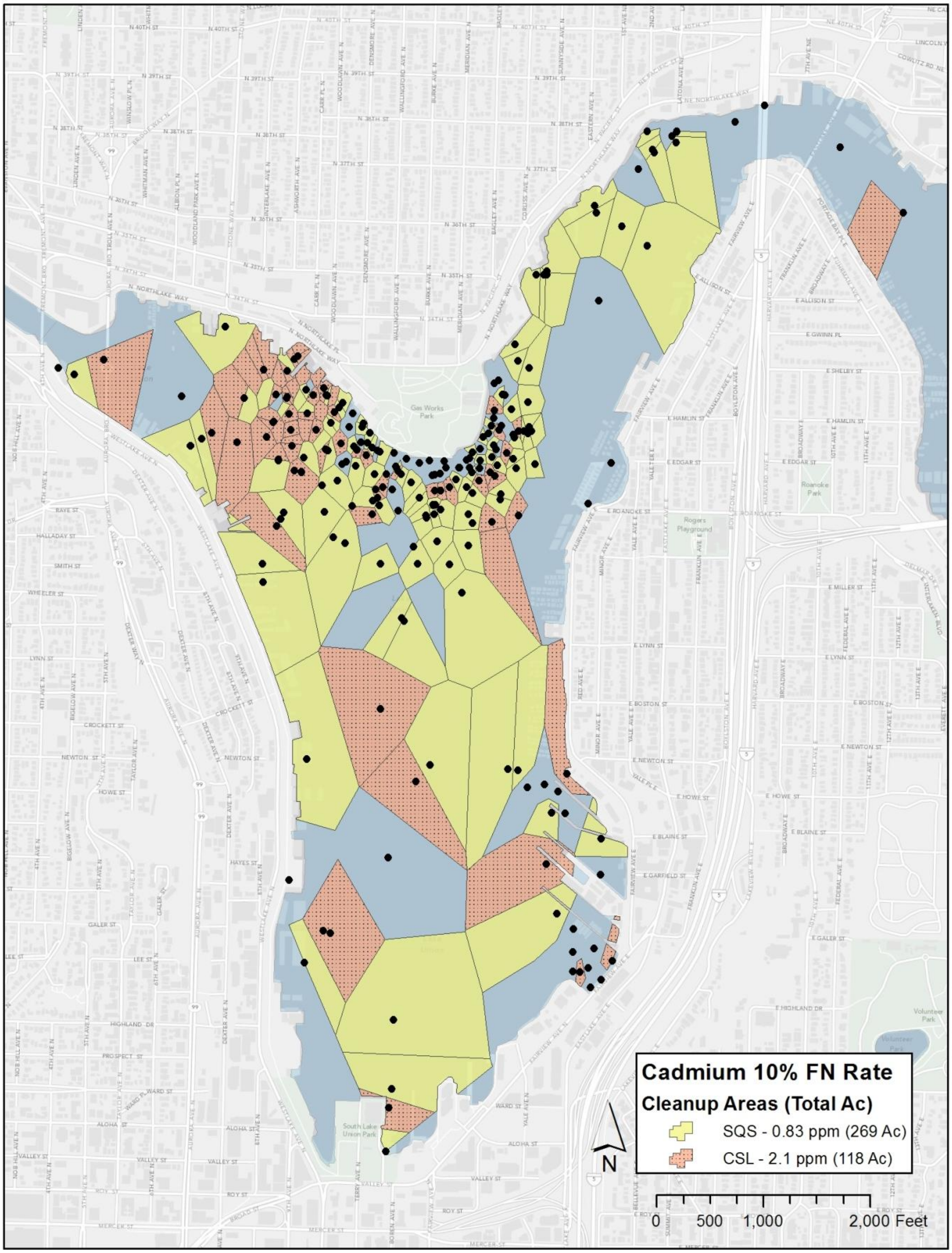


Figure E.32 - Distribution of Cadmium Concentrations that Exceed SCO and CSL Values - Alternative 2

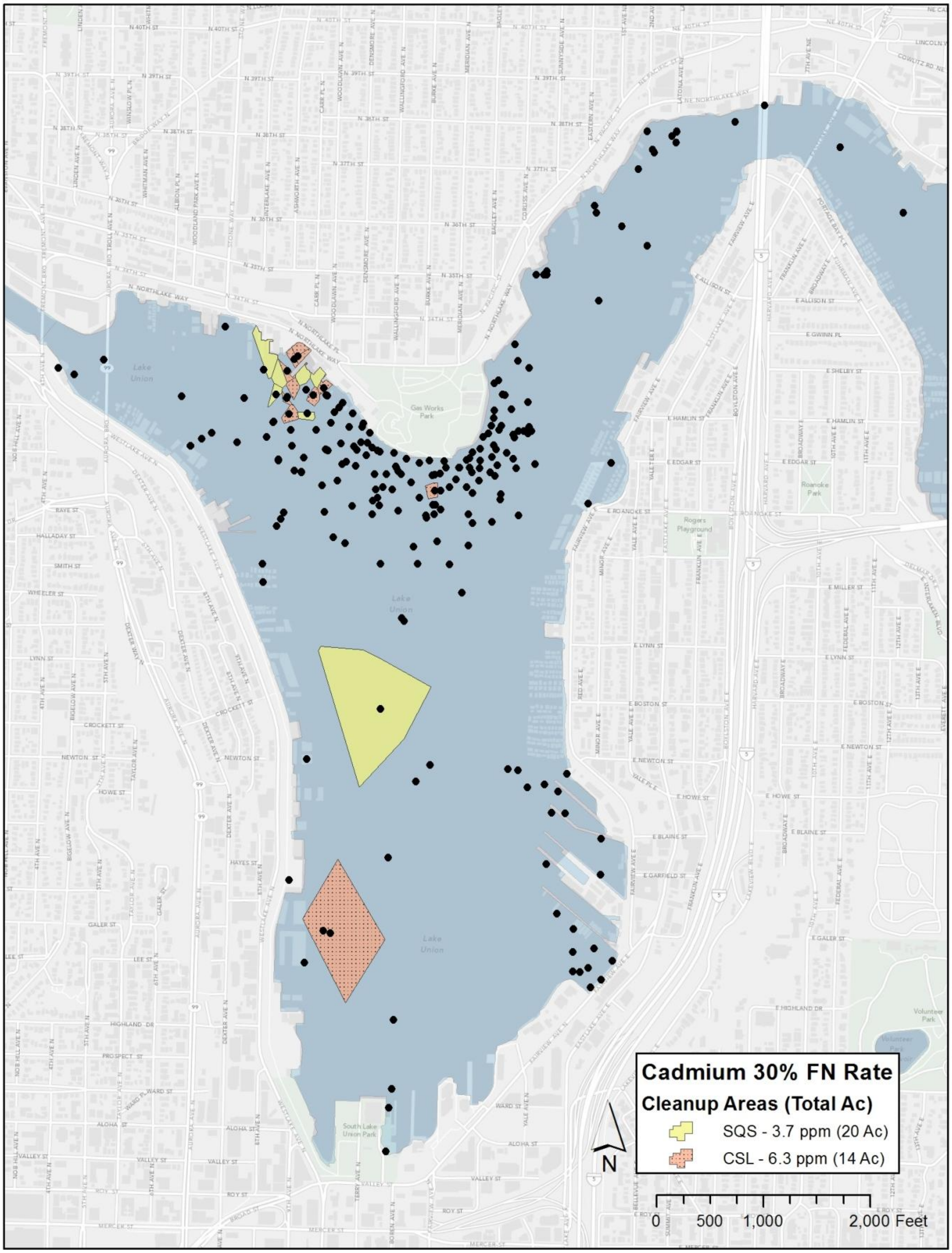


Figure E.33 - Distribution of Cadmium Concentrations that Exceed SCO and CSL Values - Alternative 3

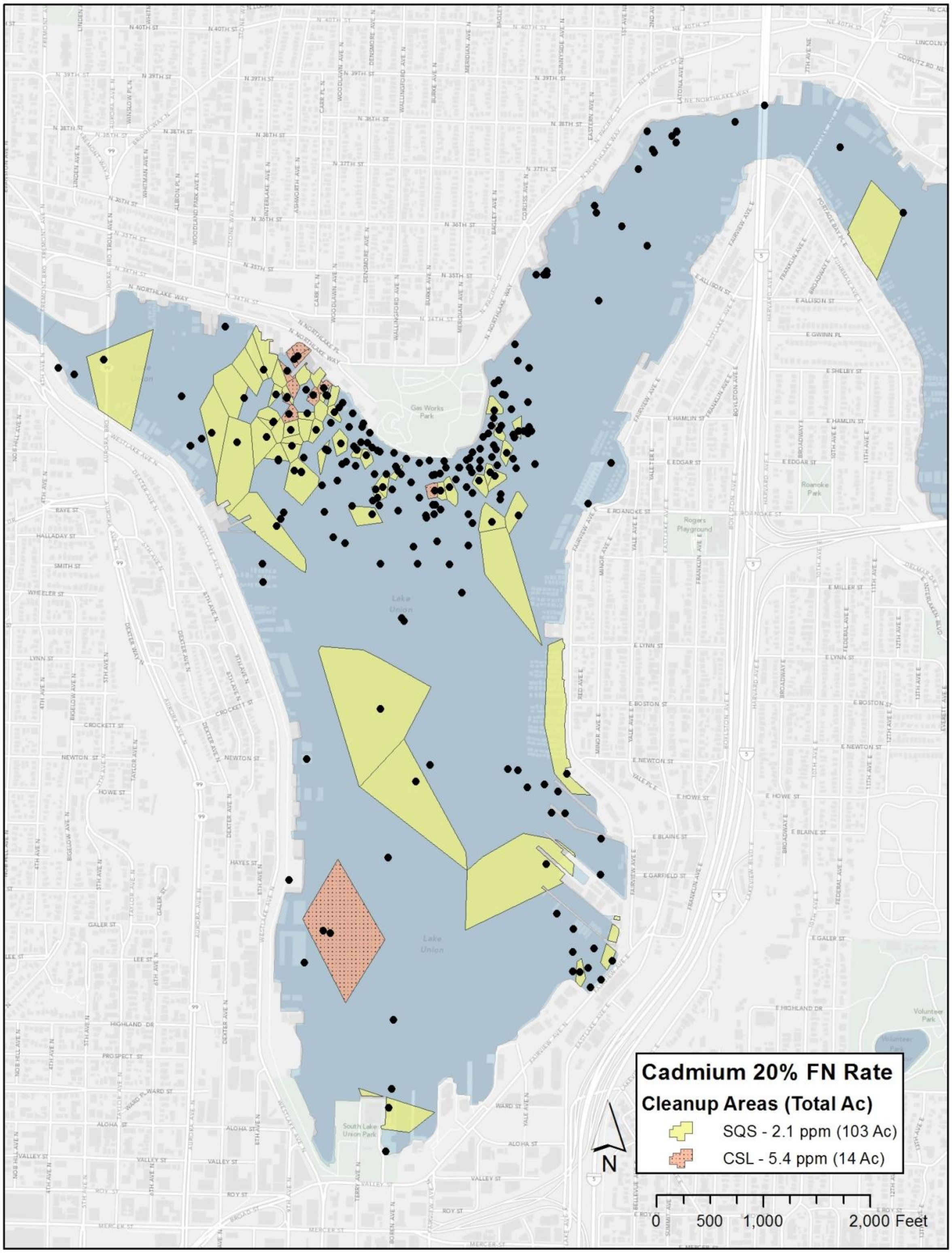


Figure E.34 - Distribution of Cadmium Concentrations that Exceed SCO and CSL Values - Alternative 4

Alternative 1 - No Action Alternative

Based on the 2003 Interim SQVs, concentrations over a substantial portion of the study area were above either the SCO or CSL values (Figure E.30). This high proportion of the area exceeding the SQVs may be the result in part to values that are close to the background concentrations of cadmium in Puget Sound soils (1 mg/kg; Table E.21). The area represented by stations exceeding the CSL (261 acres) was greater than for the SCO level (104 acres). This is likely because of the small difference between the SCO (1.1 ppm) and CSL (1.5 ppm) under this alternative.

Based on the mean false positive rate for the 2003 Interim SQVs, the overall areas requiring further action may be reduced up to 55 percent during confirmatory testing with a total estimated cleanup area of 159 acres. A number of stations fell below the SCO for cadmium and they were generally located in the northern lake where the polygons were smaller.

Under Alternative 1, extensive areas were triggered for cleanup based on CSL exceedances. While toxicity testing could potentially reduce this area by approximately 55 percent, an extensive toxicity testing effort would be required and based on the false positive rate an extensive area would still be slated for remedial action.

A comparison to the TEC value resulted in nearly the entire study area requiring further evaluation (Figure E.31), with a total of 447 acres exceeding the TEC values. The TEC value for cadmium was below the background concentration for cadmium, which likely contributed to the high proportion of chemical hits. Applying the high false positive rate (81 percent) may substantially reduce the footprint requiring cleanup; to an estimated area of 85 acres. The PEC resulted in a more refined estimate of impact, approximately 16 acres.

Alternative 2 - Minimize False Negative Rate (10% False Negative Rate)

The CSL (2.1 ppm) for Alternative 2 is slightly higher than for Alternative 1, consequently the overall area exceeding the CSL is lower (Figure E.32). There appeared to be an increased ability to delineate areas of cadmium contamination. However, a substantial portion of site exceeds the SCO value (0.83 ppm) for cadmium; likely because of an SCO value that is below the background value for cadmium. Such an overly conservative value would reduce the ability for this SCO to define site boundaries. Because this alternative represents the minimum false negative rate, the false positive rates were still somewhat high. Based on the false positive rates, the overall project area may be reduced to 244 acres during confirmatory testing.

Alternative 2 represents a highly conservative approach since a high number of stations exceed the sediment SQVs and fewer stations are expected to drop out compared to Alternative 1 due to the lower false positive rate.

Alternative 3 - Minimize False Positive Rate (30% False Negative Rate)

Alternative 3 allows for the highest false negative rate (30 percent) and consequently has higher SQVs for cadmium. The areas exceeding either SCO (3.7 ppm) or CSL (6.3 ppm) values were limited; 20 and 14 acres, respectively. This alternative delineates a well defined cleanup area located in the northern Bay (Figure E.33), as well as two areas in the central Bay. As a function of the higher false negative rate, the false positive rate under this alternative is relatively low, 15 percent for the SCO and 12 percent for the CSL. Following confirmatory testing, the overall cleanup area is estimated to be 29 acres.

Alternative 3 minimizes the level of effort related to site investigation and cleanup and appeared to effectively delineate a specific cleanup area. However, based on the higher false negative rate, there may be contaminated areas along the site boundaries that may have lower cadmium concentrations and associated toxicity.

Alternative 4 - Balance False Negative and False Positive Rates (20% False Negative Rate)

The areas with cadmium concentrations for Alternative 4 that exceed the SQVs are greater than that for Alternative 3, but lower than Alternative 2. There were more stations and a substantially larger area (103 acres) that exceeded the SCO value (2.1 ppm) for cadmium under Alternative 4 (Figure E.34). Using the false positive rate of 20.2 percent, the area of “confirmed” toxicity was reduced to 82 acres. While some of these areas were in the southern Bay, where they may be overemphasized by the larger polygons, many of the stations exceeding the SCO for cadmium are located in the northern embayment in the vicinity of the stations exceeding the CSL. The area represented by concentrations above the CSL value (5.4 ppm) was the same for Alternatives 3 and 4 (14 acres).

This alternative represents a compromise between the very conservative SQVs associated with Alternatives 1 and 2 and the less conservative SQVs presented in Alternative 3. The cadmium SQVs were able to delineate site boundaries, as well as identify boundary areas that may require further investigation. Based on the false positive rates of 20.2 percent for SCO and 15.6 percent for CSL, there would be some refinement expected in the cleanup area expected.

Alternative 5 (Biological Criteria only)

Because Alternative 5 would promulgate biological testing criteria only, the chemical screening criteria would be similar to that of Alternative 1. As such, the area requiring confirmatory testing after the chemical screening would be 365 to 463 acres. While this alternative provides predictable testing criteria, it is unclear how the overall area of the site would be directly affected. For the purposes of this Case Study, the area would be expected to be slightly lower than that of Alternative 1; however, it is not possible to estimate a potential change in the study area.

Summary

This section summarizes some of the patterns observed for each of the alternatives and is intended to support the comparative evaluation of the different alternatives in Chapter 5. Each alternative was ranked (Table E.26) based following criteria:

Reliability. The overall ability of the SQVs to predict toxicity;
False Negative Rates. The likelihood that predictions that sediments are non-toxic are incorrect;
False Positive Rates. The likelihood that predictions of toxicity are incorrect;
Background. Whether SQVs are set below background levels for soils in the state;
Inclusion of COCs. Whether most COCs have SQVs or important classes are missing;
PQL. Whether SQVs are set below the PQLs for some analytes;
Ability to Delineate a Site. The ability to delineate site boundaries;
Level of Effort. The level of effort to delineate a site; and
Consistency across the State. The consistency of criteria across the state.

Alternative 1- No Action Alternative. The original rule allowed the use of 2003 Interim SQVs or TEC/PECs in conjunction with biological testing as a "confirmatory" override. The specific suite of tests, as well as whether those tests will be compared to control or reference sediments is determined on a site-by-site basis. The reliability of the SQVs under this alternative was among the lowest for the different alternatives, with false negative and false positive rates that were relatively high. For some metals and organics, the SCO values were below the background or PQL, reducing the ability of the criteria to define a site. Although this option includes SQVs for more chemicals than the TEC/PECs, it is still missing important classes of organic contaminants of concern, such as organochlorine pesticides. While confirmatory testing allows further definition of the site, the lack of consistency in testing methods reduces the relative ability of criteria under this alternative to delineate sites.

The TEC and PEC values used under this alternative are consensus-based SQGs based on a subset of other SQGs, including the TEL and PEL values. The intent of consensus values was to increase their predictive ability. However, the TECs tended to over-predict toxicity with a high number of false positives. While the TEC/PECs include values for TPAH, there are few values for organics. This not only limits their applicability for certain sites, but can also overestimate the role of those analytes that have SQG values.

Based on the high false positive rates, it is expected that confirmatory testing will further refine site boundaries; however, the lack of consistency in testing methods reduces the relative level of confidence in the ability of criteria under this alternative to delineate sites. While the overall cleanup area under this alternative may be similar to that of other alternatives, the level of effort to reach the final site boundaries is high.

Alternative 2 – Minimize False Negative Rate (10% False Negative Rate). This alternative includes the promulgation of SQVs based on recent FPM analysis with a larger dataset, as well as biological criteria that define a suite of tests and biological performance criteria. While overall reliability increased with this group of SQVs, reliability was still 50 and 66 percent for the SCO and CSL, respectively. This was primarily because of a high false positive rate, a result of the low false negative rate. Indeed, a number of SQVs under this alternative were conservative and resulted in a very high percentage of stations exceeding both SCO and CSL values. As with Alternative 1, some metals and organics had SCO values below the background or PQL, reducing the ability of the criteria to define a site. This alternative includes SQVs for the full list of COCs. A high level of effort would be anticipated to refine site boundaries, with a substantial confirmatory testing program. Biological testing criteria would be established under this alternative, which would increase consistency and confidence in the eventual site delineation.

Alternative 3 – Minimize False Positive Rate (30% False Negative Rate). This alternative includes the promulgation of SQVs based on recent FPM analysis with a larger dataset, as well as biological criteria that define a suite of tests and biological performance criteria. Overall reliability was among the highest for the different alternatives, driven by a low false positive rate. The false negative rate was nearly 30 percent reducing the confidence in predictions of non-toxic sediments. Because values were set higher to reduce false positives, there were few SQVs that fell below background or PQL levels. This alternative includes SQVs for the full list of COCs. While the ability to delineate site was not diminished by interferences with background levels or PQL, the high false-negative rate may reduce the ability for SQVs to define moderately contaminated sites or site borders. Since this alternative has a high false-negative rate, toxicity tests are not triggered and the biological testing override is not used to correct predictions of toxicity. This alternative would not require excess effort in site evaluation and would create consistent criteria across the State.

Alternative 4 – Balance False Negative and False Positive Rates (20% False Negative Rate). This alternative includes the promulgation of SQVs based on recent FPM analysis with a larger dataset, as well as biological criteria that define a suite of tests and biological performance criteria. Overall reliability was among the highest for the four alternatives, driven by an acceptable low false negative and false positive rate. Because values are set higher to reduce false positives, there were few SQVs that fell below background or PQL levels. This alternative includes SQVs for the full list of COCs. Values under this alternative were optimized to reliably predict toxicity while moderating the level of effort.

Alternative 5 – Biological Criteria Only. This alternative would only promulgate biological criteria and using either the 2003 Interim SQVs or the TECs/PECs to establish a “reason to believe.” As with Alternative 1, the reliability, false positive rates, and false negative rates were relatively low. Conservative screening levels resulted in SQVs that fell below background levels or PQLs, resulting in widespread distribution of areas requiring further evaluation or clean up. While establishing biological criteria is expected to provide consistency across the state and improve the ability to delineate a site, the case studies are not able to show that improved ability. The level of effort associate with site evaluation is expected to be high as a large area is identified as exceeding the SQVs under this alternative.

Table E.19 - Sediment Quality Values for Metals (mg/kg)

Analyte (mg/kg)	Interim Freshwater (Alternative 1)		Other SQGs (Alternative 1)		10% False Negative Rate (Alternative 2)		20% False Negative Rate (Alternative 4)		30% False Negative Rate (Alternative 3)	
	SCO	**CSL**	**TEC**	**PEC**	**SCO**	**CSL**	**SCO**	**CSL**	**SCO**	**CSL**
Arsenic	20	51	9.79	33	5.9[a]	7.1	14	120	14	34
Cadmium	1.1	1.5	0.99	4.98	0.83	2.1	2.1	5.4	3.7	6.3
Chromium	95	100	43.4	111	72	220	72	88	72	220
Copper	80	830	31.6	149	320	1200	400	1200	970	1200
Lead	340	430	35.8	128	>1400	--	360	>1300	360	>1400
Mercury	0.28	0.75	0.18	1.06	0.41	0.66	0.66	0.8	0.66	0.8
Nickel	60	70	22.7	48.6	22	29	26	110	26	110
Selenium	--	--	--	--	0.29[a]	7.7	11	>20	11	>20
Silver	2.0	2.5	--	--	0.57	1.7	0.57	1.7	0.73	1.0
Zinc	130	400	121	459	3200	>4200	3200	>4200	2400	3200

[a] Value below the background or PQL.
-- =

Table E.20 - Percentage of SCO, CSL, and SQV Exceedances for Sites within the EIM Database

Analyte	Frequency of Detection			Frequency of SQV Exceedance (%)									
				Alternative 1				10 % FN Rate (Alternative 2)		20% FN Rate (Alternative 4)		30% FN Rate (Alternative 3)	
	Total Samples	Number	%	2003 SCO	2003 CSL	Other SQGs TEC	Other SQGs PEC	SCO	CSL	SCO	CSL	SCO	CSL
Arsenic	3316	2889	87	13	4	30	8	47	39	20	2	20	8
Cadmium	2946	2209	75	31	25	37	8	39	17	17	7	11	6
Chromium	2697	2668	99	4	3	24	2	8	1	8	4	8	1
Copper	3259	3241	99	21	3	52	14	7	2	6	2	3	2
Lead	3598	3431	95	8	6	38	20	1	--	7	1	7	1
Mercury	3372	2571	76	19	9	29	6	15	10	10	8	10	8
Nickel	2535	2515	99	7	5	49	11	50	38	38	2	38	2
Selenium	1313	609	46	--	--	--	--	83	13	7	0	7	0
Silver	2218	1374	62	8	7	--	--	41	15	41	15	33	24
Zinc	3158	3152	100	40	18	42	15	2	2	2	2	3	2

Table E.21 - Background Soil Values for Washington and Practical Quantitation Limits

Analyte in mg/kg		State Average	Puget Sound	Clarke County	Yakima	Spokane	USGS 22 Element Report	PQL
Arsenic	As	7	7	6	5	9		0.5
Cadmium	Cd	1	1	1	1	1		0.14
Chromium	Cr	42	48	27	38	38		0.35
Copper	Cu	36	36	34	27	27		0.35
Lead	Pb	17	24	17	11	11		0.15
Mercury	Hg	0.07	0.07	0.04	0.05	0.05		0.001
Nickel	Ni	38	38	21	46	46		0.35
Selenium	Se	--	--	--	--	--	0.39	0.6
Silver	Ag	--	--	--	--	--		0.2
Zinc	Zn	86	85	96	79	66		1.6

Table E.22 - Sediment Quality Values for Organics

Analyte	Alternative 1				Alternative 2		Alternative 4		Alternative 3	
	2003 SQV		Other SQGs		10 % FN Rate		20% FN Rate		30% FN Rate	
	SCO	CSL	TEC	PEC	SCO	CSL	SCO	CSL	SCO	CSL
Organic Chemicals (µg/kg)										
4-Methylphenol	670	670	--	--	180	260	260	2000	260	510
Benzoic acid	650	650	--	--	2900	3800	2900	3800	2900	3800
beta-HCH	--	--	--	--	7.2	11	7.2	11	11	--
bis(2-Ethylhexyl)phthalate	230	32	--	--	460	22000	500	22000	1100	31000
Carbazole	--	--	--	--	1100	1400	900	1100	1100	1400
Dibenzofuran	400	440	--	--	38	680	200	680	680	3800
Dieldrin	1.9[c]	3.5	1.9	61.8	4.9	22	4.9	9.3	4.9	9.3
Di-n-butyl phthalate	1400	1400	--	--	380	450	380	1000	380	450
Di-n-octyl phthalate	26	45	--	--	39	>1100	39	> 1100	39	>1100
Endrin ketone	--	--	--	--	2.7	8.5	8.5	--	8.5	--
Pentachlorophenol	400[bc]	690[bc]	--	--	1200	>1200	1200	> 1200	1200	>1200
Phenol	420	1200	--	--	120	210	120	210	120	210
Monobutyltin	--	--	--	--	540	>4800	540	> 4800	52	540
Dibutyltin	--	--	--	--	910	130000	910	130000	910	130000
Tributyltin	--	--	--	--	47	200	47	320	110	320
Tetrabutyltin			--	--	97	>97	97	> 97	97	>97
Total Aroclors	60	120	59.8	676	110	250	110	2500	120	1700
Total DDDs	--	--	4.88	28	310	2500	310	860	110	310
Total DDEs	--	--	3.16	31.3	21	910	21	33	21	910
Total DDTs	--	--	4.16	62.9	15	8100	100	8100	100	8100
Total PAHs	--	--	1610	22800	4500	10000	17000	30000	26000	35000
Bulk Petroleum Hydrocarbons (mg/kg)										
TPH-Diesel	--	--	--	--	340	1700	340	510	390	1700
TPH-Residual	--	--	--	--	810	4400	3600	4400	3600	4400

SCOSCO = Sediment Cleanup Objective, CSL = Cleanup Screening Level

> "greater than" value indicates that the toxic level is unknown, but above the concentration shown

[a]The selected value is the Threshold Effects Concentration (TEC) or Threshold Effects Level (TEL) from McDonald et al., 20

[b]The value selected is the SMS marine sediment quality value.

[c]The value is below the PQL for that analyte.

Table E.23 - Percentage of SCO or CSL Exceedances for Sites within the EIM Database

Analyte	Total Samples	Frequency of Detection			Frequency of SQV Exceedance (%)									
					Alternative 1				10 % FN Rate Alternative 2		20% FN Rate Alternative 4		30% FN Rate Alternative 3	
		Total Qualified Samples	n	%	2003 SCO	2003 CSL	TEC	PEC	SCO	CSL	SCO	CSL	SCO	CSL
4-Methylphenol	1318	497	494	99	19	19	--	--	57	47	47	4	47	27
Benzoic acid	1381	368	346	94	34	34	--	--	8	5	8	5	8	5
beta-HCH	1131	64	26	41	--	--	--	--	0	0	0	0	0	--
bis(2-e,h)phthalate	1531	917	916	100	58	50	--	--	38	2	37	2	26	1
Carbazole	1073	317	317	100	--	--	--	--	14	12	15	14	14	12
Dibenzofuran	2120	847	847	100	27	26	--	--	59	21	36	21	21	8
Dieldrin	1370	781	94	12	57	4	57	0	4	1	4	3	4	3
Di-n-butyl phthalate	1557	625	318	51	3	3	--	--	7	7	7	3	7	7
Di-n-octyl phthalate	1647	218	215	99	49	39	--	--	42	9	42	9	42	9
Endrin ketone	619	418	3	1	--	--	--	--	39	0	0	--	0	--
Pentachlorophenol	1852	305	300	98	28	19	--	--	85	11	11	--	11	--
Phenol	1638	287	284	99	11	5	--	--	32	24	32	24	32	24
Monobutyltin	213	249	84	34	--	--	--	--	9	2	9	2	32	9
Dibutyltin	352	225	200	89	--	--	--	--	8	0	8	0	8	0
Tributyltin	494	413	399	91	--	--	--	--	65	41	65	35	51	35
Tetrabutyltin	280	141	82	58	--	--	--	--	7	--	7	--	7	--
Total Aroclors	2031	909	901	99	53	39	54	14	40	28	40	6	39	7
Total DDDs	1335	1538	564	37	--	--	25	15	4	1	4	2	6	4
Total DDEs	1362	1538	568	37	--	--	26	7	10	1	10	7	10	1
Total DDTs	1360	1538	377	25	--	--	17	6	11	1	5	1	5	1
Total PAHs	2801	2255	2255	100	--	--	49	23	36	29	25	20	21	19

Table E.24 - Average False Negative, False Positive Rates, and Overall Reliability for Alternatives

Alternative	SCO Hit Reliability (%)	SCO No Hit Reliability (%)	SCO Overall Reliability (%)	CSL Hit Reliability (%)	CSL No Hit Reliability (%)	CSL Overall Reliability (%)
Statewide Evaluation of Reliability						
1 No Action	44	71	55	25	78	50
2 10% FN Rate	42	83	50	39	91	66
3 30% FN Rate	51	79	64	50	85	76
4 20% FN Rate	48	80	60	50	85	76

Geographical Area Evaluations of Reliability	SCO Hit Reliability East	SCO Hit Reliability West	SCO No Hit Reliability East	SCO No Hit Reliability West	SCO Overall Reliability East	SCO Overall Reliability West	CSL Hit Reliability East	CSL Hit Reliability West	CSL No Hit Reliability East	CSL No Hit Reliability West	CSL Overall Reliability East	CSL Overall Reliability West
1 No Action	45	43	35	74	42	57	32	25	66	79	50	50
2 10% FN Rate	53	41	55	86	53	50	35	40	69	93	50	67
3 30% FN Rate	63	50	56	83	50	67	67	48	78	86	75	76
4 20% FN Rate	56	47	52	85	53	61	67	48	78	86	75	76

Table E.25 - Comparison of Cleanup Areas for Cadmium, Lake Union Case Study

Alternative		SQV (mg/kg Cd)	Area Exceeding Threshold (acres)	False Positive Rate (%)	"Confirmed" Cleanup Area[a] (acres)	Total Cleanup Area (acres)*
Alternative 1	SCO	1.1	104	51	47	159
	CSL	1.5	261	49	112	
	TEC	0.990	447	81	85	96
	PEC	4.98	16	32	11	
Alternative 2	SCO	0.83	269	40	161	244
	CSL	2.1	118	30	83	
Alternative 3	SCO	3.7	20	16	17	29
	CSL	6.3	14	12	12	
Alternative 4	SCO	2.1	103	20	82	94
	CSL	5.4	14	15	12	

[a]Confirmed cleanup area = area exceeding the threshold – (area exceeding threshold * false positive rate)
* Value is the sum of the area exceeding the SCO and CSL or TEC and PEC values.

Table E.26 - Ranking Criteria for Alternatives Based on Case Studies

Measure	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
	Interim SQV TEC/PECs	10% FN	30% FN	20% FN	Biological Criteria
Reliability	🔴	🔴	🟢	🟢	🔴
Low false negative	🟡	🟢	🟢	🟡	🟡
Low false positive	🔴	🔴	🟢	🟢	🔴
Background	🔴	🔴	🟡S,N	🟡 S,N	🔴
Inclusion of COCs	🔴	🟢	🟢	🟢	🔴
PQL issues	🟡	🟡	🟡	🟡	🟡
Ability to delineate site	🔴	🔴	🟢	🟢	🔴
Level of Effort	🟡	🔴	🟢	🟢	🟡
Consistency across State	🔴	🟢	🟢	🟢	🟡

🔴 Poor
🟡 Adequate
🟢 Good
S,N: Proposed SQVs are below the background level for selenium and nickel only.

Appendix F – The Affected Environment

Introduction

The affected environment includes the physical, biological, and human environment elements. Each of these environmental elements is described in the following sections. Impacts of the proposed alternatives (human health and freshwater sediments) for rule revision on each element of the affected environment are discussed in Chapter 5 of this document.

Physical Environment

This section describes components of the physical environment, which includes sediment, water, and air quality.

Sediment Quality

Sediments, the sand and mud that lie on the bottom of Puget Sound, freshwater lakes, ponds, and rivers and streams, perform many important functions in the aquatic ecosystem, including provision of shelter, habitat, and rearing grounds for plants and animals. In both marine and freshwater environments, the nearshore sediments support the foundation of the aquatic food web.

A wide array of toxic chemicals end up in state waterways and in receiving water sediments. Wastewater, stormwater, and runoff from land can contain many types of chemicals, depending on the industry or municipal treatment plant from which they are discharged, the type of land use of the drainage area, the weather, and the time of year. The bottom sediments receive an ever-changing mixture of chemicals from the complex variation of chemical contributions and interactions that occur between the contaminants, particulates, and water. In general, nearshore areas exhibit higher levels of sediment contamination, increased toxicity to test organisms, higher levels of contaminant uptake in fish tissue, and greater incidences of impaired communities of benthic organisms (Long, 1985).

Suspended particles in effluent discharges and surface runoff carry contaminants into waterways. Much of the particulate material and associated contaminants that enter waterways via stormwater do not dissolve into the water column; rather, they settle to the bottom to become part of the sediment of the receiving water. Sediment deposition and accumulation in a receiving water body are subject to natural variations over time and place. In Puget Sound, measurements of sediment deposition in the main sub-basin, determined by radioactive isotope dating of subsurface core samples, show that approximately 0.18 to 1.20 grams of sediment per square centimeter of the bottom accumulate in a year (Crecelius et al., 1984).

Geology, climate, and vegetation influence water chemistry as it migrates through different portions of the watershed. As a result, sediment deposition rates, chemical availability, and toxicity can also vary substantially between different water bodies within a watershed and between watersheds. Background concentrations for some metals vary naturally across the state in part as a result of the complex geologic origins of the soils in Washington (Ecology 1994). Climate and vegetation can influence water pH, hardness, and alkalinity, which can further alter the chemical nature of soils and freshwater sediment. As such, a chemical concentration that is considered acceptable in one portion of the state for freshwater sediment may differ from that of a different part of the state. Similarly, freshwater sediment guidance values that are based on national datasets may not necessarily apply to Washington State freshwater sediment (Michelson, 2011).

The complexity of Washington State's surface waters is further modified by the hydrologic regime. Even over a small area, a single water body can have remarkably diverse characteristics including fast-flowing rapids and riffles, slow moving waters in shallow or deep pools, and long glides that include sand or mud flats (Skidmore, 2006). The fate and transport of characteristics for contaminated sediments in these areas can also differ considerably.

Water Quality

Marine waters of the state include Puget Sound and its inlets, as well as portions of the Strait of Juan de Fuca and shoreline areas in the Pacific Ocean. Fresh water bodies in the state include all inland lakes, ponds, rivers, and streams. The state is divided into eight drainage basins, of which the Puget Sound and Upper Columbia are the largest. East of the Cascade Mountains (70 percent of the total land area), surface water drains primarily into the Columbia River. West of the Cascade Mountains and east of the Olympic Mountains (20 percent of the total land area), surface water drains into Puget Sound. West of the Olympics (10 percent of the total land area), surface water drains into the Pacific Ocean. The average annual runoff statewide is 26 inches per year. There are 40,838 miles of rivers in Washington and over 8,000 lakes (Wash. St. et al., 1989).

Chapter 173-201 WAC designates water quality standards for all waters of the state according to use as follows:

- Areas where special resources must be protected against contamination [AA (extraordinary) and A (excellent)]; and
- Areas where the waters have been degraded by human activities [B (good) and C (fair)].

Wetland areas are provided special protection by various state and federal laws, including Section 404 of the Clean Water Act. In addition, surface waters used as drinking water sources are of special interest.

In general, the quality of the marine waters and freshwater features in the state are high, with the exception of some urban bays and rivers. Several studies have been performed on concentrations of contaminants in urban bays. Human activities in both urban and rural areas have influenced water quality. Although controls on large discharges of municipal sewage and industrial effluent through the National Pollutant Discharge Elimination System (NPDES) permit program have succeeded in reducing high biochemical oxygen demand and improving water quality, isolated fish kills still occur in localized areas of Puget Sound. Historically, concentrations of lead, copper, and zinc in Elliott Bay near Seattle have exceeded water quality criteria. Subsequently, because of pollution abatement programs, the concentrations of these contaminants have decreased to below 1 μg/L for copper and lead and below 5 μg/L for zinc; well below water quality criteria for these metals (Paulson et. al., 1989). As with marine waters, contaminants related to urban and heavy residential activities, such as metals, PCBs, and petroleum hydrocarbons have been detected at elevated concentrations in some freshwater systems (e.g., Duwamish River or Spokane River; EPA, 2010; Ecology, 2001). However, rural activities, such as agriculture, mining, and the timber industry, can be equally important sources of contamination in freshwater systems, particularly for pesticides, metals, and wood waste-related chemicals (e.g., Lake Roosevelt; EPA, 2006).

Air Quality

Air quality in Washington is highly variable and is a complex function of population density, emission sources and rates, and climate. In general, air quality is better in rural areas than in more populated urban areas. The Puget Sound area experiences nighttime inversions in the winter, often lasting well into the day, that trap pollutants emitted from urban areas near the ground. The Cascade Range also blocks pollutant transport, causing the buildup of air contaminants along the western foothills of the Cascades (Ecology, 1990).

Sources of toxic air contaminants in Washington include transportation, industry, manufacturing, and energy-related sources. Prevailing air currents in western Washington originate from the northern Pacific Ocean and move eastward across the state. These air masses pick up moisture from the Pacific Ocean and lose most of it in the form of rain or snow while crossing the Olympics and Cascades. Rain and snow pick up contaminants in the air during formation and carry them to the ground. This pattern of precipitation makes wet deposition the primary mechanism of atmospheric contaminant deposition in western Washington.

Biological Environment

This section describes components of the biological environment, which includes small and large aquatic organisms and plants as well as nearshore terrestrial organisms and plants.

Plankton, Algae, and Other Small Aquatic Organisms

The main sub-basin of Puget Sound has one of the highest phytoplankton production rates of all deep-water estuaries in the world (Strickland, 1983). This production is a major contributor to the highly productive food web of Puget Sound. However, phytoplankton populations can affect and be affected by water quality, which in turn can be affected by sediment quality, particularly in quiescent environments. Puget Sound also contains a diverse and abundant population of zooplankton. The copepods (*Corycaeus* spp., *Pseudocalanus* spp., and *Microcalanus* spp.,) are most numerous, while the greatest biomass comes from larger copepods (*Calanus* spp.), euphausids (*Euphausa pacifica*), and amphipods. There are also a number of planktonic larvae that are an important component of water-column food webs, including larval crab, shrimp, barnacles, and larval fish (ichthioplankton). Zooplankton abundance is closely associated with algal blooms, with an increase in the abundance of secondary and tertiary consumers following that of the zooplankton. This is an important factor in the timing of salmon and rock fish fry emergence and early development. Zooplankton actively fed on by juvenile and adult fish, birds, and marine mammals. Zooplankton resources in the upper surface layers of the water column (the "microlayer") are critical to the life cycle stages of many important marine organisms in Puget Sound, and are also among the most sensitive species to the effects of surface water contaminants (Word et al., 1986)

Algae provide the base of the aquatic food chain in freshwater systems. Freshwater algae include free-floating cells, attached communities that can appear as submerged aquatic plants, or algal mats that grow along the bottom of lakes, rivers, or streams. Algae are an integral part of the nutrient cycle, absorbing nitrogen and phosphorus to grow and providing an important source of nutrients and carbon for primary consumers, such as zooplankton. Algae can be an important factor in balancing nutrient input related to residential and agricultural activities; however, algal blooms can affect dissolved oxygen concentrations and have been linked to fish kills in some parts of the state, such as the Yakima River (Ecology, 2012a). The most commonly encountered groups of freshwater algae are green algae, diatoms, and blue-green algae (cyanobacteria).

Aquatic Plants

Kelp and eelgrass are the primary aquatic plants in the marine environment. Kelp are common seaweeds that attach to rocky sediments in intertidal and subtidal zones and includes both the floating kelp (bull kelp and giant kelp) as well as 21 species of non-floating kelp, such as *Laminaria* sp Kelp beds provide habitat for all or part of the life cycle of many marine inhabitants. For example, kelp beds provide feeding and nursery grounds for juvenile salmon, rock fish, and other fish, as well as food and refuge for many marine invertebrates that form the base of the benthic food web (Mumford, 2007).

Eelgrass is the dominant marine plant species in the shallow subtidal, soft-bottom communities of Puget Sound. Eelgrass meadows are present throughout Puget Sound, with extensive beds in protected areas such as Padilla Bay and in the vicinity of Dungeness Spit. These highly productive marine habitats have been estimated to support 191 invertebrate species, 76 fish species, and 86 bird species (Phillips, 1984; Mumford, 2007). Eelgrass provides food in the form of detritus or direct forage for small crustaceans. In addition, eelgrass beds are considered to be critical fish habitat, supporting the larval and juvenile stages of many types of commercial and sport fish[46]. The Washington Department of Natural Resources estimates that there are approximately 26,000 acres of eelgrass in Puget Sound (WDNR, 2011). Anecdotal information indicates that there have been significant eelgrass losses in some areas, such as the Snohomish delta, and gains in other areas, such as Padilla Bay.

[46] http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm

Freshwater aquatic plants are present in most lakes, streams, and rivers in Washington. They range from tiny floating plants that can form mats on a lake surface to reed-like plants that grow 2 meters above the water's surface, and are generally classified into three types of growth: shoreline, surface, and submerged (Hamel et al., 2001). Shoreline plants, such as sedges, rushes, and canary grass, grow along nearshore and riparian corridors. They are closely associated with nearshore sediments, acting as traps for suspended sediments and source materials, and controlling sediment erosion. Floating plants can be rooted or free-floating and can form mats (pondweed, duck weed, and water hyacinth) or single leafy structures (water lilies) at the surface. Submerged plants include those forms that grow entirely underwater and can include stalk-like plants that provide vertical structure or surface algae that grow along rocky bottoms and sediment at the bottom (Hamel et al., 2001).

Aquatic plants are an important part of freshwater environments, providing food and shelter for a wide variety of insects, amphibians, fish, reptiles, mammals, and birds. Aquatic plants help to stabilize shorelines and nearshore habitat and provide nursery grounds for juvenile fish and invertebrates. They also form an important link in nutrient cycles and can sequester contaminants altering chemical availability. Floating plants provide shelter to aquatic fish and insects from predation, provide habitat for amphibians and insects, and are an important food source for water fowl.

Benthic Invertebrates

Bottom or benthic marine and freshwater habitats support a diverse assemblage of organisms that vary depending on the texture or particle size of the sediment bed, as well as on the degree of tidal influence (in the case of a marine environment).

The marine and estuarine benthic community is a critical component of the food web in Puget Sound (Simenstad et al., 1979). A diverse assemblage of hundreds of species from every marine phyla live in or on bottom sediments and rocky structures. Benthic species include marine amphipods, polychaete worms, small clams and snails, cnidarians, echinoderms (sea stars, urchins, sand dollars, and sea cucumbers), and small crustaceans. Benthic infauna and epifauna include primary consumers that feed on marine algae, secondary consumers that feed on other benthic fauna, and scavengers that feed on detritus and organic debris. In addition, there are smaller forms of benthic invertebrates, the meiofauna and microfauna, that live in the interstitial spaces of sediments and provide a key function in cycling nutrients from detritus back into the food web. These include bacteria, ciliates, amebas, and flagellates.

The benthic community is a key food source for many of the larger species, such as salmonids, flat fish, and otters (Fresh et al., 1981). It provides an important link for benthic carbon and nutrients to water column species and serves as a pathway for contaminants from sediment into higher trophic levels (Simenstad et al., 1979; Preikshot and Beattie, 2001). Because benthic fauna are closely associated with sediment, they have a high potential to accumulate certain contaminants into their tissues. Fish and other higher vertebrates feeding along the bottom can in turn be exposed to those contaminants through their diet. In this regard, the marine benthic community can act as a sentinel to marine pollution (Ecology, 2008b). Because of their proximity to sediments and their sensitivity to contaminants, changes in benthic community structure can provide an early indication of the decline of water or sediment quality.

In Puget Sound, the soft, fine-grained intertidal mudflats are vital habitats for many highly prized species of shellfish, including clams, mussels, scallops, geoducks, crab, shrimp, and urchins. Puget Sound provides a multi-million dollar commercial and recreational fisheries resource to the area and the abundance of shellfish plays an important role in the cultural tradition of the tribal communities (WDFW, 2008). Shellfish are vulnerable to degradation of the Puget Sound environment. Bivalve shellfish, such as clams, oysters, mussels, and geoduck, spend their adult lives in one spot on the bottom of the sound and filter large quantities of water to extract nourishment from plankton and debris. Their sedentary nature and filtering process place bivalves at risk from contaminants in the water column, as well as contaminants in resuspended sediments. Other shellfish such as crab and shrimp consume plants, animals, and debris from the floor of Puget Sound. Crab and bottom-scavenging shrimp can accumulate chemicals from contaminated sediments as they range for sustenance.

Freshwater benthic invertebrates include insects, crayfish, and mollusks (clams, snails, and mussels), which are important components of the aquatic food web (Morin, 1999). For some insect species, such as the midge, caddisfly, or mayfly, early development occurs in the aquatic environment. Larval or naiad forms can remain on stream or lake bottoms for up to a year, followed by a hatch of the adult life form. The adult stage can last a very short time. Aquatic insects are a critical component of fish diets, particularly trout and anadromous salmonids (Groot and Margolis, 1991). Amphipods, crayfish, polychaetes, oligochaetes, clams, and snails also live in close association with freshwater sediments, living and feeding on algae, small invertebrates, and detritus. These benthic invertebrates are particularly sensitive to changes in water and sediment quality and are sentinel species for toxicity or bioaccumulation (Burton Jr., 1992).

Washington State has several freshwater benthic invertebrate species that are considered “Species of Concern.” This includes the mussel, *Anodonta californiensis*, and the Columbia River spire snail (*Fluminicola columbiana*) that is a Federal Species of Concern, as well as Columbia pebblesnail and the Giant Columbia River Limpet.

Marine and Freshwater Fish

There are more than 220 species of fish in Puget Sound, including salmon, ground or bottom fish, herring, and smelt. The various types of fish live in a variety of habitats and occupy many different positions in the food web. There are more than 70 families of resident and anadromous fish in Washington State, which migrate to feed in marine waters and return to fresh water to spawn. Washington fishes include a number of important resource and non-resource species, such as anadromous and resident salmon, trout, char, sturgeon, the Pacific lamprey, walleye, char, whitefish, burbot, minnows, catfish, sunfish, and suckers.

- *Native Resident Salmonid*
    - Include rainbow trout (including redband trout), cutthroat trout, bull trout, and mountain whitefish.

  - Remain in freshwater habitat for their entire life cycle.
  - Require clean, cool water to thrive.
  - Typically feed on plankton, insects, other invertebrates, and small fish.
  - Some populations are declining, with the decline attributed to a number of factors (loss of suitable rearing habitat, water quality degradation, and loss of clean spawning gravels).
- *Native Anadromous Salmonid*
  - Include Chinook, coho, chum, and sockeye salmon; steelhead and sea-run coastal cutthroat trout; and native char (bull trout and Dolly Varden).
  - Habitat extends from the smallest inland streams to the Pacific Ocean and consists of a vast network of freshwater, estuarine, and ocean habitats.
  - Freshwater habitats are used for spawning, incubation, and juvenile rearing. In estuarine habitats, juvenile salmonid fish experience rapid growth and chemical changes as they transition between fresh water and salt water.
  - Feed on a variety of freshwater invertebrate organisms and fishes, while being fed on by a variety of parasites, predators, and scavengers. Juvenile salmon feed on salmon carcasses, eggs, and invertebrates, caddisflies, stoneflies, and midges.
  - Populations have substantially declined over past decades as a result of over-fishing, habitat loss, and the effects of hydropower facilities.

There are a number of native fish that are listed as threatened or endangered that interact with sediments, including Bull Trout, a number of anadromous salmonids, several rockfish species, herring, and Green sturgeon[47]. The declines are a result of a combination of natural and anthropogenic pressures (Puget Sound Partnership, 2010). Fisheries managers cannot easily separate the effects on fish populations of contamination and related disease from effects of habitat loss, poor environmental conditions, and overfishing. Significant efforts are being made to preserve and restore the threatened and endangered runs of sturgeons, lampreys, as well as salmonids in Washington State (Skidmore, 2006).

Aquatic Mammals and Birds

Twenty-one species of marine mammals live in Puget Sound (PSWQA, 1990). Some species, such as the harbor seal (*Phoca vitulina*), minke whale (*Balaenoptera acutorostrata*), Dall's porpoise (*Phocoenoides dalli*), and killer whale (*Orcinus orca*), are considered year-round residents, while other species are seasonal, accidental, or rare visitors. Table F.1 lists rare, threatened, and endangered mammals that have been sighted in Washington State.

[47] http://wdfw.wa.gov/conservation/endangered/list/Fish/

Table F.1 - Rare, Threatened, and Endangered Species Associated with the Marine Environment

Marine Mammals	Water Birds
Sea otter	Great blue heron
Grey whale	Black-crowned night heron
Sei whale	Osprey
Fin whale	Bald eagle
Blue whale	Arctic tern
Hump-backed whale	Marbled murrelet
Black right whale	Snowy plover
Sperm whale	Upland sandpiper
Orca whale	

Marine mammals feed on an array of organisms, such as benthic invertebrates, small fish, squid, and herring, and may be exposed to contaminated fish, shellfish, and sediments during feeding. For example, the grey whale filters large quantities of sediment to obtain benthic organisms living in the sediment. The sea otter feeds primarily on shellfish.

Several species of resident marine mammals may use the habitats in and near contaminated sites for feeding or resting purposes. Discharges of contaminants into a water body can impact aquatic mammals by the accumulation of contaminants in their tissue (Puget Sound Partnership, 2010). Similarly, a decline in food sources can directly impact these residents. While resident marine mammal populations are thriving, biologists have seen some recent changes in their distribution and numbers, and have observed some reproductive problems. The causes and significance of these effects are unclear.

Marine waterfowl and birds provide quarry for hunters and as attractions for birdwatchers. Many are residents of the region, while an even greater number use the sound seasonally as a stopping and feeding ground along the Pacific flyway migratory routes (PSWQA, 1990). Twenty-six species of ducks, ten species or subspecies of geese, and two species of swans use Puget Sound for some portion of the year.

Despite many years of monitoring surveys for birds, there have been very few population estimates of marine birds and waterfowl. Marine birds in Puget Sound appear to be generally more vulnerable to human disturbances than are waterfowl. Marine birds are entirely dependent on the marine environment for food, and many spend much of their lives on the water and wading in sediments. Investigations of the relationship between reproductive problems and contamination in marine birds have shown eggshell thinning and reproductive failures in a number of species (Calambokidis et al., 1985).

There are a wide variety of mammalian species living near freshwater bodies in Washington State, partly a result of the habitat diversity throughout the state. There are over 140 species of mammals ranging from small herbivorous rodents to larger top-level carnivores. The level of interaction with freshwater bodies varies; however, a number of species interact in significant ways with aquatic ecosystems. Raccoons, river otters, and bears directly consume fish and shellfish, as well as having significant direct contact with aquatic sediments. Other mammals, such as mice, deer, and fox live along the riparian corridor and are likely to have more incidental contact with freshwater sediments, while having direct contact with surface waters. Other important species, such as the federally listed gray wolf, have more incidental contact with contaminated sediment.

Of the mammal species included on the state's Species of Concern list, the Pacific marsh shrew is most closely associated with aquatic environments, living in marsh, stream, and beach habitats of the coastal rain forest. The marsh shrew dives into the water to catch aquatic insect larvae (Hammerson, 2008 in IUNC, 2012). Thus, the Pacific marsh shrew has both ingestion and direct contact pathways to sediment-associated contaminants.

The freshwater habitats are primary habitat for a number of birds, including waterfowl and birds of prey, such as Bald eagles and osprey. Resident and migratory ducks and geese are common in Washington waters. Dabbling ducks, such as mallards, widgeons, and teals, feed on aquatic plants. Omnivorous ducks, such as mergansers and canvasback ducks, have a diverse diet eating fish and shellfish, as well as aquatic insects. Larger birds of prey that feed on freshwater fish include herons, eagles, and osprey. Birds that are listed as federal or state species of concern include the Black swift, American white pelican, Bald eagle, Golden eagle, and Common loon[48].

Because some aquatic birds are often higher trophic level consumers, they have a high potential to accumulate certain contaminants that have passed through the food chain. This can in turn affect the health of the individual bird or its reproductive success.

Terrestrial Plants and Animals

Plants and animals of concern are present throughout the terrestrial environment of Washington State and the Pacific Northwest region. Geographic areas of concern are those in which threatened or endangered species are present, or where the Washington Department of Fish and Wildlife has listed sensitive species in its non-game database. Endangered species are those in danger of becoming extinct throughout all or a significant portion of their ranges. Threatened species are those that may become endangered in the foreseeable future. Impacts on these and all other terrestrial plants, wildlife, and birds would primarily result with disposal of contaminated material in upland locations. However, some terrestrial species may be exposed to sediments in intertidal and freshwater environments.

Human Environment

This section describes components of the human environment, which includes human health, economics, fishing, cultural resources, transportation, noise and aesthetics, water use, and land use.

[48] http://wdfw.wa.gov/conservation/endangered/list/Birds/

Human Health

Fish and shellfish can accumulate contaminants present in sediment. One of the major concerns associated with contaminated fish and shellfish is the threat that they pose to humans who consume them. Public health officials are concerned about the risk to humans from eating contaminated freshwater fish and seafood. Many aquatic and terrestrial animals (including birds, other fish, and mammals) eat fish. These animals can accumulate toxicants and pass them up the food chain, which can pose an additional health risk to humans.

Humans may be at risk for illness and serious disease if they consume enough contaminated fish. However, it is difficult to estimate risk to human health. In general, health risks associated with a given chemical are proportional to the dose, or intake of that chemical. Thus, fish with high concentrations of a given chemical in their tissues pose greater human health risks when eaten than do those with low concentrations. An EPA study has shown that the potential lifetime cancer risk from eating about 30 servings per year of Puget Sound bottomfish from contaminated areas is similar to the risk from eating other foods that are known to contain carcinogens (Tetra Tech, 1988).

Washington residents consume locally caught fish and seafood, and many subpopulations, such as tribes and some Asian groups, as well as some recreational fisherman, eat large amounts of locally caught fish and shellfish. As Table F.2 illustrates, between 1.4 and 3.8 million Washington adults and approximately 290,000 Washington children (0 to 18 years of age) are fish consumers. These estimates were prepared based on both National Survey Data, as well as data from a survey completed by the Washington Department of Health (Ecology, 2012b). Population projections illustrate that estimates of total number of fish consumers in Washington are expected to increase as the population grows.

Table F.2 - Estimated Washington State Fish Consumers Based on Washington DOH Survey Data

Years for Projected Population Estimates	Estimated number of Washington Adults who Consume:		
	Store-bought Fish	Fish from Local Stores or Markets	Salmon
2010	3,805,958 [49]	2,931,616 [50]	1,674,622
2030	4,876,809	3,756,461	2,899,725

As previously noted, there are sizable subgroups within the state that are considered “high fish consumers”. An adult “high fish consumer” is considered an individual who consumes more than 250 grams of fish and/or shellfish per day, and a child “high fish consumer” is considered an individual who consumes at least 190 grams of fish and/or shellfish per day (for both values, the 90th percentile fish consumption rate reported in the national consumption survey conducted by EPA in 2002). Tables F.3 and F.4 summarize the number of high fish consumers (adults and

[49] This estimate assumes 74 percent of the total adult population consuming store-bought fish, per the DOH 2004 data.

[50] This estimate assumes 57 percent of the total adult population consuming fresh fish from local stores or markets, per Ecology (2012b) data.

children, respectively) estimated to live in Washington State at present, and population projections for 2030.

Table F.3 - Estimates of Fish Consumption among the Washington Adult Population

Year	Total Population (Adults)	Estimates of All WA Adult Fish Consumers		Estimates of WA Adult High Fish Consumers (over 250 g/day)	
		Low (28%)	High (74%)	Low	High
2010	5,143,185	1,440,092	3,805,958	144,009	380,596
2030	6,590,283	1,845,279	4,876,809	184,528	487,680

Table F.4 - Estimated Number of Washington Children High Fish Consumers

Year	Total Population of Children (18 and younger)	Estimated Number of Children Who Consume Some Amount of Fish and Shellfish	High Fish Consumers: Estimated Number of Children Who Consume over 190 g/day
2010	1,708,318	290,000	29,000
2030	2,063,883	351,000	35,100

Additional information on the methods used to evaluate the data collected in the Department of Health Survey are presented in the DRAFT 2012 Ecology document *Fish Consumption Rates, Technical Support Document* (Ecology 2012b).

Additional exposure to contaminated sediments may occur through direct contact or ingestion of contaminated sediments during recreational activities such as wading, fishing, and water sports. Inhalation of volatile contaminants released by sediments is also a potential exposure route. Although these exposure routes are generally not expected to contribute greatly to human health risks compared to consumption of seafood, they may be important at some sites and would be considered as part of a site-specific risk assessment preceding a cleanup decision.

Economics

Population growth continues in most Puget Sound counties, placing additional development pressure on shoreline resources to ensure continued economic growth. According to the Washington State Office of Financial Management (OFM), the population of Washington State as of April 1, 2003, was 6,724,540.[51] King County is the largest county in the state, with a

[51] U.S. Census Bureau, Census 2000 Redistricting Data (Public Law 94-171) Summary file, Table PL1, and 2010 Census Redistricting Data (Public Law 94-171) Summary file, Table P1. [Provided by Washington State's Office of Financial Management at http://www.ofm.wa.gov/pop/census2010/data.asp]

population of 1,875,519 in July 2008. Population growth over the last decade has been caused by a variety of economic factors including expansion by local industry including high technology companies and the development of Seattle as a regional center and focus for Pacific Rim trade. Population forecasts by OFM predict that the population of the state will increase to 8,544,700 by the year 2030, with a projected population in King County of 2,548,112 by that time. Major port development continues to occur along Elliott Bay and along the lower Duwamish River.

Fishing

Some of the most important natural resources commercially harvested in Washington come from the state fisheries. The Washington Department of Fish and Wildlife (WDFW), in concert with other state and federal agencies, manage natural resources for fishing. The state's diverse water resources sustain recreational, commercial, and tribal fishing. The state has more than 500 miles of Pacific coast shoreline, and over 2,700 combined miles of Puget Sound, San Juan Islands, Strait of Juan de Fuca, and Hood Canal shoreline. This shoreline provides habitat for marine fish and shellfish. Washington State also has 4,000 rivers and streams, stretching over 50,000 miles, and more than 7,000 lakes with over 2,500 lakes at alpine elevations, and over 200 reservoirs that provide for a variety of fishing opportunities. Many of Washington's freshwater areas are open for fishing year around.

There are a large variety of fish and shellfish available for harvesting in Washington State.[52] WDFW has identified over fifty freshwater species of edible fish and almost as many in marine waters.[53] The fish species of highest commercial value include salmon, black cod, sole, flounder, Pollock, and halibut. Most rivers and streams throughout Washington are managed to produce wild trout, coastal and westslope cutthroat, salmon, and steelhead.[54]

Governor Gregoire requested a study designed to summarize the economic benefits of Washington's non-treaty commercial and recreational fisheries for 2006.[55] This study provides information on the valuation and numbers of commercial and recreational fish and shellfish harvested throughout Washington State for 2006. There were more than 109 million pounds of commercial fish landings from Washington non-treaty fisheries in 2006. The Washington

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[52] IBID.

[53] IBID.

[54] Washington Department of Fish and Wildlife. 2012 Washington Fishing Prospects. Web location: http//www.wdfw.wa.gov/fish/prospects/index.htm

[55] Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. Final Report. Washington Department of Fish and Wildlife. December 2008. Web location: http://wdfw.wa.gov/commission/econ_analysis.html

Coastal area is the largest contributor to commercial fish harvesting accounting for 85 percent of total pound landed.[56]

Washington State's commercial fishery is structured around a multi-species fishery including groundfish, Pacific halibut, coastal pelagic species, highly migratory species, salmon, other anadromous species and eggs, and shellfish. In 2006, non-tribal commercial fish landings from Washington fisheries totaled approximately 109.4 million pounds. This total consisted of the following:

- Salmon is the major contributor to Washington State's commercial fishing industry, with salmon landings from Washington waters totaled about 11 million pounds landing accounting for about 10 percent of the commercial catch in 2006.
- Groundfish represented Washington State's largest commercial fishery in 2006, accounting for 54 percent of the commercial catch from Washington State waters with approximately 59.2 million pounds landed.
- Shellfish landings represented Washington State's next largest commercial fishery accounting for almost 25 percent of the commercial catch from Washington State waters with approximately 25.8 million pounds landed in 2006.

The traditional start of Washington State's most intense freshwater recreational fishing occurs the last weekend in April. Freshwater recreational fish inhabit more than 4,000 rivers and streams extending over 50,000 miles, 7,000 lakes, and 200 reservoirs. Based on estimates from WDFW, over 300,000 anglers are fishing on opening weekend of fishing season. To meet this level of demand on fish-related resources, WDFW annually stocks about 19 million trout and kokanee fry, and 3 million catchable trout are planted in lakes and streams. In addition, large numbers of lakes throughout the state receive additional plants of sterile triploid rainbow trout.

According to the 2008 Economic Analysis of Fisheries:

- An estimated total of 824,000 anglers fished (both finfishing and shellfishing) in Washington in 2006.
- An estimated 725,000 anglers (88 percent of the total) were Washington State residents who fished about 8.5 million days in 2006 representing 93 percent of all fishing days available for licensed recreational sport fishing.

Marine recreational fishing and shellfishing occurs along more than 500 miles the Pacific Coast shoreline and more than 2000 combined miles of shoreline throughout Puget Sound, San Juan Islands, Strait of Juan de Fuca, and Hood Canal. Dungeness crab taken from north Puget Sound waters accounted for more than 85 percent of the 2006 state-wide harvest. Razor clams are only harvested from coastal beaches, and tens of thousands of recreational sport clammers harvest razor clams on weekends when razor clamming is open along coastal beaches.[57]

[56] IBID.

[57] IBID.

Cultural Resources

The Puget Sound fishing industry is an important part of cultural resources, as well as the local economy. Fishing played a key role in sustaining tribal communities in the Puget Sound basin, attracted early settlers to the area, and continues as an important factor today. Native American tribes throughout the area harvest fish and shellfish in commercial and subsistence fisheries. Salmon and steelhead fisheries are important tribal commercial harvests. Tribal harvest includes commercial, ceremonial, and subsistence uses. Native American treaty rights to access traditional fishing grounds for subsistence and ceremonial purposes is an important component in the state's responsibilities to the Tribes. Lack of access to these fishing grounds because of contaminated sediments would be a significant loss for Tribes. Fishing also provides benefits to other communities (e.g., southeast Asians) for sustenance, spiritual and religious activities, and recreational activities. The presence of sediment cleanup standards that are accurate would both provide an appropriate level of protection and maximize access to the resource.

Additional cultural resources in and around Puget Sound that could be affected by remediation or land-based disposal of sediments include sites of archaeological or historic importance. Historically significant sunken vessels and aircraft could also be affected by remediation or aquatic disposal of sediments.

Transportation

The Washington shoreline, primarily within Puget Sound is home to a significant number of ports and supports significant marine vessel traffic. Navigational development has occurred in most of the major urban embayments since the early 1900s. Navigation in Puget Sound ranges from large bulk cargo and container ships to barges, tugboats, and ferries. Smaller, inland water bodies, such as lakes and rivers, support recreational vessel traffic. Upland areas adjacent to marine ports are typically highly developed, industrial areas with significant transportation infrastructure. The amount of development quantity/type of transportation infrastructure adjacent to smaller water bodies varies with location.

Noise and Aesthetics

The marine and fresh waters of the state represent an invaluable aesthetic and recreational resource for both residents and tourists. People have a strong desire to live near the water, and the value of this resource is reflected in the high property values of shoreline residences. Marine and fresh waters are used increasingly for activities, such as recreational boating and the viewing of aquatic and terrestrial birds and mammals. The aesthetic qualities of surface water features in the state and associated amenities are also enjoyed by boaters, many of whom use local marinas for moorage.

Water Use

Water use falls into two distinct categories, use of surface waters for navigation, and use of groundwater and some surface water as a drinking water supply. The navigational use of the waters of surface water is addressed above under Transportation.

One of the most important resources in the human environment is drinking water. Drinking water sources in Washington are both groundwater and surface water. Surface water supplies for drinking water are located in areas that have not been impacted by sediment contamination and are highly protected to prevent future problems. The potential for groundwater contamination by contaminated sediments exists only in locations where contaminated sediments would be disposed of at nearshore or upland disposal facilities.

Land Use

Land use in areas surrounding the Puget Sound basin and freshwater lakes, rivers, and streams in the state encompass a wide variety of land types including urban development; suburban, rural, and resource uses; and protected parks, open spaces, wilderness areas, sanctuaries, and wildlife refuges. Marine and freshwater shorelines are used for myriad water-dependent, water-related, and water-enjoyment uses. Significant portions of the Puget Sound shoreline are dominated by industrial use (the Lower Duwamish Waterway, Commencement Bay, and Sinclair inlet). Roughly one-third of the Puget Sound marine shoreline has been modified with armoring and docks. Other common shoreline use is residential, marinas, waterfront resorts, shellfish farms, hatcheries, and waterfront parks. Zoning varies widely throughout the state according to existing and expected land use. Shoreline designations vary widely by jurisdiction and by individual shoreline reach.