WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Final
Environmental Impacts Statement
For the Washington State
Sediment Management Standards

Chapter 173-204 WAC

December 1990
Publication # 90-50

[Note: The electronic version of this document was released on Oct 30, 1998. Some of the contents of the original document may be rearranged or missing in this electronic version of the document.]

Table of Contents

List of Figures

Note to viewers of electronic file version: Although the text of this document is available in electronic format, most of the figures and tables are not available in electronic format at this time. We hope to make them available in the near future. If you would like to view some of the figures in particular, please contact Brenden McFarland at bmcf461@ecy.wa.gov

List of Tables

List of Acronyms

AET	apparent effects threshold
2AET	second lowest apparent effects threshold
AKART	all known available and reasonable methods of prevention, control, and treatment
ARAR	applicable or relevant and appropriate requirement
the Authority	Puget Sound Water Quality Authority
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CFR	Code of Federal Regulations
CRQL	contract-required quantification limit
CSL	cleanup screening level
Ecology	Washington Department of Ecology
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
HAET	highest apparent effects threshold
HCB	hexachlorobenzene
HPAH	high molecular weight polycyclic aromatic hydrocarbon
LAET	lowest apparent effects threshold
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MCUL	minimum cleanup level
MTCA	Model Toxics Control Act
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PQL	practical quantification limit
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
PSWQA Plan	Puget Sound Water Quality Management Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SARA	Superfund Amendments and Reauthorization Act
SEPA	State Environmental Policy Act
SIZ_{max}	sediment impact zone maximum allowable contaminant level
SMS	Sediment Management Standards
Superfund	Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
WAC	Washington Administrative Code
WASP4	Water Quality Analysis Simulation Program 4 (used in sediment impact zone modeling)

Fact Sheet

Name of Proposal
Sediment Management Standards, Chapter 173-204 WAC

Nature of Proposal
The proposed action is to adopt statewide Sediment Management Standards for contaminant source control and cleanup activities in Washington. The source control standards include authorization, maintenance, and closure of sediment impact zones (i.e., sediment dilution zones, limited areas in which dischargers are permitted to contribute higher contaminant levels for limited periods of time). The cleanup standards include a decision process designed to meet the sediment quality goals identified in the Sediment Management Standards.

The proposed Sediment Management Standards also incorporate sediment quality standards that establish a "no effects" goal for the chemical and biological quality of sediment. The sediment quality standards have previously undergone review and are not evaluated in this environmental impact statement.

Location of Proposal
The Sediment Management Standards are proposed as a statewide rule. The qualitative requirements of the source control, cleanup, and sediment quality standards will apply statewide. Currently, the rule proposes quantitative source control, cleanup, and sediment quality standards (i.e., chemical values and biological effects levels) only for Puget Sound. Source control, cleanup, and sediment quality standards for all other state marine, low salinity, and freshwater sediments shall be determined on a case-by-case basis until quantitative standards applicable to these sediments are established. Like the Puget Sound sediment standards, the development of these other standards will be subject to all applicable public review and State Environmental Policy Act requirements.

Alternatives
This document evaluates four alternatives for determining the maximum degree of sediment contamination to be allowed in Puget Sound during implementation of three sediment management activities related to the following three sets of standards:

Source control standards— The maximum degree of sediment contamination (measured by chemical quality and biological effects) allowed in sediments impacted by ongoing discharges (i.e., the sediment impact zone maximum allowable contamination level)
Screening standards— The maximum degree of sediment contamination allowed before a contaminated sediment site cleanup is required (i.e., the cleanup screening level)
Cleanup standards— The maximum degree of sediment contamination allowed to be left in place after active cleanup (i.e., a minimum cleanup level).

The four sediment management alternatives evaluated in this document represent increasing degrees of adverse environmental effects along a scale of decreasing costs. The four alternatives are:

Alternative 1— Under Alternative 1, defined as the no-action alternative, source control standards and cleanup standards would require all discharges and cleanup decisions to meet the long-term sediment quality goal previously established for Puget Sound. Alternative 1 is the "no effects" level established by the sediment quality standards, that is, no significant effects in any of the biological tests used to establish the standards. Alternative 1 represents the lowest biological effects level and the highest cost of the four alternatives.
Alternative 2—Alternative 2 is the level at which significant effects are identified in one but not two of the four biological tests used to establish the sediment quality standards. This alternative is defined as allowing "minor adverse effects." Alternative 2 represents an increased biological effects level and lower cost than Alternative 1.
Alternative 3—Alternative 3 is the level at which significant effects are identified in three but not all four of the biological tests used to establish the sediment quality standards. This alternative is defined as allowing "moderate adverse effects." Alternative 3 represents an increased biological effects level and lower cost than Alternative 2.
Alternative 4—Alternative 4 is the higher of the level defined in Alternative 3 and the level at which significant effects are identified in all the biological tests used to establish the sediment quality standards. This alternative is defined as allowing "severe adverse effects." In general, Alternative 4 represents an increased biological effects level and lower cost than Alternative 3.

Lead Agency
Washington State Department of Ecology

Responsible Official
Greg Sorlie
Central Programs
Washington State Department of Ecology
Mail Stop PV-11
Olympia, WA 98504-8711

Contact Person
Brett Betts
Central Programs
Washington State Department of Ecology
Mail Stop PV-11
Olympia, WA 98504-8711

Subsequent Environmental Review
Individual contaminated sediment site cleanup actions will be reviewed pursuant to State Environmental Policy Act, Chapter 43.21C RCW requirements.

Authors and Principal Contributors
Washington State Department of Ecology
Central Programs
Mail Stop PV-11

Olympia, WA 98504-8711

PTI Environmental Services
15375 S.E. 30th Place, Suite 250
Bellevue, WA 98007

Required Approvals
Adoption by the Washington State Department of Ecology

Comment Period
The comment period extended from 5 October 1990 to 5 November 1990.

Public Meetings
Public hearings were held in Bellingham, Washington on 23 October 1990 and in Seattle, Washington on 24 October 1990.

Date of Final Action
Effective January 1991 (date may be subject to change).

Location of Background Information
Responsiveness Summary Appendix with comment letters and technical documents cited in this final environmental impact statement are available through:

Washington State Department of Ecology
Central Programs
Mail Stop PV-11
Olympia, WA 98504-8711

Cost of Document
This final environmental impact statement is available at no charge with a limit of one per person. Additional copies may be purchased for the cost of reproduction.

Executive Summary

Need for Sediment Management Standards

Sediments in several areas of Puget Sound and throughout Washington state have been identified as contaminated with toxic substances such as petroleum-derived compounds, chlorinated organic compounds, and metals. Sediment contamination has been associated with impacts on animals living in the sediments and the development of tumors and other abnormalities in bottom-feeding fish. In addition, fish, crabs, and clams have been observed to accumulate pollutants in areas with sediment contamination. In several of these areas, local health departments have advised residents to limit their consumption of seafood.

Authority

The proposed Sediment Management Standards (SMS) acknowledge the Water Pollution Control Act (Chapter 90.48 RCW) and the Model Toxics Control Act (Chapter 70.105D RCW) as the primary authorizing legislation for establishing sediment source control and cleanup standards, respectively. The Washington Department of Ecology (Ecology) also cites several other state laws as providing authority for the adoption of the SMS. The laws and Ecology's intent in citing each law within the authority section of the SMS are described in Chapter 1.

Objective of the Proposal

The objective of the proposed action is to adopt statewide sediment management standards for source control and cleanup activities. The source control standards include authorization, maintenance, and closure of sediment impact zones (i.e., sediment dilution zones, limited areas in which dischargers are permitted to contribute higher contaminant levels for limited periods of time). The cleanup standards include a decision process designed to meet the sediment quality goals identified in the rule. This decision process includes procedures to screen contaminated sediment areas for consideration of active cleanup, to rank contaminated sediment sites based on the relative risk they pose to human and environmental health, and to select a site-specific cleanup standard.

The rule also includes sediment quality standards that establish a "no effects" goal for the chemical and biological quality of sediments. The sediment quality standards have previously undergone review and are not evaluated in this document.

Although the rule is proposed for statewide application, only the qualitative portions of the source control, cleanup, and sediment quality standards will apply to the sediments in all waters of the state. The quantitative source control, cleanup, and sediment quality standards currently set forth in the rule (i.e., the chemical values and biological effects levels) apply only to Puget Sound sediments. Source control, cleanup, and sediment quality standards for all other state marine, low salinity, and freshwater sediments shall be determined on a case-by-case basis until quantitative standards applicable to these sediments are established. Like the Puget Sound sediment standards, the development of these other standards will be subject to all applicable public review and State Environmental Policy Act requirements.

A separate, companion environmental impact statement (Ecology 1990b) that documents the incorporation by reference of the SMS into the Model Toxics Control Act cleanup regulation is available for review.

Purpose of the Environmental Impact Statement

The purpose of this environmental impact statement is to evaluate four alternatives for determining the maximum degree of sediment contamination to be allowed during implementation of three sediment management activities related to the following three sets of standards:

- **Source control standards**—The maximum degree of sediment contamination (chemical quality/biological effects) allowed in sediments impacted by ongoing discharges [i.e., the sediment impact zone maximum allowable contamination level (SIZ_{max})]
- **Screening standards**—The maximum degree of sediment contamination allowed before a contaminated sediment site cleanup is required [i.e. the cleanup screening level (CSL)]
- **Cleanup standards**—The maximum degree of sediment contamination allowed to be left in place after active cleanup [i.e., a minimum cleanup level (MCUL)].

This document addresses the environmental trade-offs associated with programmatic adoption of each of the four alternative contamination levels identified for the SIZ_{max}, CSL, and MCUL. Site-specific environmental impacts are not defined, but this document is intended to encourage and facilitate public involvement in decisions regarding the impacts on the environment from selection of any one of the alternatives. 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.

Description of the Alternatives

Four alternative approaches to establishment of the SIZ_{max}, CSL, and MCUL are evaluated in this environmental impact statement. The four sediment management alternatives generally represent increasing degrees of adverse environmental effects along a scale of decreasing costs. In the process of formulating the SIZ_{max}, CSL, and MCUL alternatives, Ecology determined that in order to maintain integrity and consistency between the various portions of the rule, the same chemical concentration and biological effects levels should be established for the SIZ_{max}, CSL, and MCUL. The alternative contamination levels to be considered are described below:

- **Alternative 1**—Under Alternative 1, defined as the no-action alternative, source control standards and cleanup standards would require all discharges and cleanup decisions to meet the long-term sediment quality goal previously established for Puget Sound. Alternative 1 is the "no effects" level established by the sediment quality standards, that is, no significant effects in any of the biological tests used to establish the standards. Alternative 1 represents the lowest biological effects level and the highest cost of the four alternatives.
- **Alternative 2**—Alternative 2 is the level at which significant effects are allowed in one but not two of the biological tests used to establish the sediment quality standards. This alternative is defined as allowing "minor adverse effects." Alternative 2 represents an increased biological effects level and lower cost than Alternative 1.
- **Alternative 3**—Alternative 3 is the level at which significant effects are allowed in three but not all four of the biological tests used to establish the sediment quality standards. This

alternative is defined as allowing "moderate adverse effects." Alternative 3 represents an increased biological effects level and lower cost than Alternative 2.

- **Alternative 4**—Alternative 4 is the higher of the level defined in Alternative 3 and the level at which significant effects are identified in all the biological tests used to establish the sediment quality standards. This alternative is defined as allowing "severe adverse effects." Alternative 4 represents an increased biological effects level and lower cost than Alternative 3.

Background Information

Areas of contaminated sediments and associated adverse effects have been identified in Washington state since the early 1980s. Sediment contamination has been associated with impacts on animals living in the sediment, and the development of tumors and other abnormalities in bottom-feeding fish. In addition, fish, crabs, and clams have been observed to bioaccumulate pollutants in areas with sediment contamination.

Contamination in sediments comes from numerous sources, including both historical practices and ongoing point and nonpoint discharges. Rules currently in place that regulate discharges to waters of the state are primarily concerned with water quality rather than sediment quality and therefore do not directly address the problems associated with sediment contamination. Since toxicants from the water column can concentrate in sediments, harmful sediment contamination can occur even when the water column is not seriously contaminated.

Prior to the adoption of the 1987 Puget Sound Water Quality Management Plan (the PSWQA Plan), the regulation of discharges; the management of dredging and disposal of dredged material; and the identification, ranking, and cleanup of contaminated sediment sites were hampered by the lack of coordinated goals and policies addressing the prevention of sediment contamination. The absence of any adopted sediment quality standards added to the difficulty in consistent protection of sediment quality. During this time, regulation of sources of toxicants through permit programs generally addressed the quantity, not quality, of sediment particles suspended in effluents that could ultimately affect the quality of impacted sediments. State and federal water quality, hazardous waste, and cleanup laws were often in disagreement concerning the need for the protection of sediments, the level of protection necessary, and the appropriate scientific methods for measuring the chemical and biological quality of sediments.

The PSWQA Plan, which was formally adopted by the Puget Sound Water Quality Authority in 1987, presents goals, strategies, and work elements for 12 program areas to improve and protect the quality of Puget Sound. The municipal and industrial discharges program and the contaminated sediments and dredging program specifically address the identification and management of contaminated sediments. These programs direct Ecology to develop Puget Sound sediment quality standards, source control standards including discharge sediment dilution zones, and contaminated sediment cleanup standards. In response to the PSWQA Plan and ongoing environmental and human health concerns relative to sediment contamination, Ecology developed the SMS, Chapter 173-204 WAC, to comprehensively address the management of sediments in Washington state waters.

Ecology's Rule-Making Approach

Throughout the development of the rule, Ecology conducted numerous public involvement and education activities. These activities were conducted to establish a better public understanding concerning technical and policy issues involved in the development of the rule and to address concerns and opinions from a wide range of interest groups on these issues.

During 1988, Ecology distributed two early drafts of the rule to obtain public comments on key needs and issues. Four public workshops were conducted in 1988 to obtain comment on these drafts of the rule. A major comment received from the public workshops was the need for a representative committee to discuss key policy issues identified from early drafts of the rule.

In response to public request, Ecology formed the Sediment Advisory Group, which then met routinely from August 1988 through February 1990. This committee's effort led Ecology to develop an issue paper on six major policy issues identified by the committee (Ecology 1989b). The issue paper discusses the key issues identified regarding the proposed standards and contains Ecology's conclusions on each issue, which were finalized after consideration of all written comments submitted by committee members.

During 1989, Ecology conducted additional briefing and development activities as follows:

- Response to the U.S. Environmental Protection Agency Science Advisory Board report on the review of the apparent effects threshold method (this method was used by Ecology in the development of sediment quality standards for Puget Sound)
- Briefing of the Washington State Science Advisory Board on the proposed rule
- Development of the December 1989 Interim Sediment Quality Evaluation Process guidance document, which incorporates the sediment quality values into the implementation guidance developed for use by multiple Ecology programs.

In March 1990, Ecology formed an additional policy advisory committee, the Sediment Management Standards Work Group. This work group focused on the development of sediment impact zone and contaminated sediment cleanup standards. Ecology summarized and provided responses to the work group's recommendations concerning the rule on 24 May 1990. Comments on the draft rule were accepted from the public and the work group through the end of July 1990. Ecology incorporated changes into the rule as a result of these comments, and filed the proposed rule with the Office of the Code Reviser on 18 September 1990. The draft rule was officially issued as a proposed rule in the State Register on 3 October 1990. The final rule, the environmental impact statement, and the responsiveness summary incorporate and address the comments received during the public review period.

Affected Environment

The affected environment includes the physical, biological, and human environment of Washington state. The following specific elements of the environment may be affected by the selected alternative for the SIZ_{max}, CSL, and MCUL.

Physical Environment

- Sediment quality

- Water quality
- Air quality

Biological Environment

- Plankton species
- Macrophytic plants
- Benthic macroinvertebrates and megainvertebrates
- Anadromous and demersal fish
- Marine mammals and water birds
- Terrestrial plants and animals

Human Environment

- Human health
- Economics
- Fishing
- Cultural resources
- Transportation
- Noise and aesthetics
- Water use
- Land use.

Each of these elements of the environment is discussed in detail in Chapter 3.

Case Studies

Chapter 4 describes case studies conducted to evaluate the applicability of the source control and sediment cleanup standards to environmental conditions in Puget Sound. The results of three sediment impact zone case studies, along with 10 cleanup standards case studies to which the four alternatives have been applied, provide more specific information with regard to when and where a sediment impact zone might be needed, and the area and location of contaminated sediments that may require active cleanup.

The following key conclusions can be drawn from the results of the sediment impact zone case study analysis:

- The potential for contaminants to accumulate in sediments adjacent to the point of discharge is highly dependent on the loading rate of contaminants and the energetics (i.e., currents, waves, and tides) of the receiving water.
- Sediment impact zones are most likely to be needed when the point of discharge is to a calm receiving-water environment, such as an urban bay.
- At a constant loading rate, a balance between contaminant discharge and surface sediment accumulation (i.e., steady state) was typically achieved in the surface 2-cm of the sediments adjacent to the discharge outfall within 10 years.

For the 10 cleanup case study sites, application of the Alternative 1 CSL in the cleanup decision process would retain all sites for further cleanup consideration, the Alternative 2 CSL would screen out two sites from further cleanup consideration, and the Alternatives 3 and 4 CSL would each screen out the same five sites from further cleanup consideration. A similar relationship was demonstrated among the alternatives for determining sediment areas that exceed MCULs (i.e., the area of sediments requiring cleanup within the study sites). The number of sites and the area of sediments requiring cleanup under Alternatives 3 and 4 were so similar that the impacts of these two alternatives were generally not evaluated separately in the discussion of impacts.

Environmental Impacts of the Alternatives

There are fewer types of impacts associated with implementation of the source control standards than with implementation of the cleanup standards because, unlike the cleanup standards, the identification and authorization of a sediment impact zone does not require the implementation of remedial action activities. The discussion of environmental impacts associated with sediment impact zones focuses only on the varying degrees of impact that would be associated with the different SIZ_{max} values. The impacts associated with varying sizes of impact zones is reflected in the impacts associated with the four alternatives as applied in the cleanup standards.

The following significant impacts on the physical, biological, and human environment have been identified:

- Alternatives 2-4 would allow some sediments to remain in place that have chemical concentrations exceeding sediment quality standards. These sediments would be confined to sediments within impact zones and to sediments within cleanup sites that would be expected to naturally recover over a period of time to the sediment quality standards, once source control is achieved or cleanup is accomplished. Because these sediments are allowed to remain in place, biological impacts are likely to occur during the period that a sediment impact zone is allowed and/or until sediments remaining at cleanup sites recover naturally to levels of the sediment quality standards. Under Alternative 2, these biological impacts are expected to be minor. Under Alternatives 3 and 4, the potential biological impacts are considered significant.
- Impacts on commercial, recreational, and tribal fisheries and cultural resources are directly tied to potential biological and human health impacts. Because the biological impacts under Alternatives 3 and 4 are potentially significant, there may be impacts on fisheries and cultural resources under these alternatives. These impacts would be localized to the vicinity of sediment impact zones and contaminated sediment sites. However, considered cumulatively, these impacts potentially could be significant. Although human health-based sediment quality standards are still under development, the rule contains a provision requiring site-specific assessments of risks to human health. These assessments should mitigate human health impacts on a site-specific basis.
- During cleanup of contaminated sediment sites, there is a potential for short-term impacts on water quality, aquatic life, noise levels, aesthetics, land use, water use, transportation, and human health, regardless of the alternative chosen. These impacts will likely be greater if more stringent alternative cleanup standards are chosen. Because of the high level of impact associated with increased traffic, resource use, and need for landfill capacity that would be associated with cleanups under Alternative 1, short-term remedial impacts for this alternative are considered adverse and significant. These impacts will be more fully assessed for each individual site in site-specific environmental impact statements.
- Under any of the alternatives, the cost of cleaning up contaminated sediment sites is

considered significant. However, the costs (both at individual sites and from a program-wide perspective) associated with more stringent alternatives increase. Additionally, the proposed rule will result in additional permitting and monitoring costs for sediment impact zones. However, these costs are not considered significant (i.e., less than 1 percent of sales).

Evaluation of the Alternatives

In Chapter 6 the alternatives are evaluated according to several criteria, divided into the following three classes:

- **Threshold criteria** include protection of human health, protection of the environment, and compliance with applicable or relevant and appropriate requirements (ARARs). These criteria reflect requirements and compliance with the Model Toxics Control Act and the PSWQA Plan, and thus receive the most weight in the evaluation.
- **Balancing criteria** include technical feasibility, scientific certainty, and cost effectiveness. These criteria represent practical considerations that affect how easily an alternative can be implemented under the source control and cleanup standards. These criteria receive less weight than the threshold criteria in the evaluation.
- **Modifying criteria** reflect issues of public and agency concern and perceptions. Regulatory precedence is the modifying criterion considered in this evaluation. This criterion is given less weight in the evaluation but may affect the outcome if the alternatives are ranked similarly under the preceding sets of criteria.
- The results of the alternative evaluations under the threshold, balancing, and modifying criteria are set forth in Chapter 6. Based on the results of these evaluations, Ecology prefers Alternative 2 over the other alternatives for establishing the SIZ_{max}, CSL, and MCUL values.

1 Introduction

1.1 Need for Sediment Management Standards

Sediments in several areas of Puget Sound and throughout Washington state have been identified as contaminated with toxic substances such as petroleum-derived compounds, chlorinated organic compounds, and metals. Many contaminants are present at much higher concentrations in sediments than in water because the contaminants do not dissolve easily and they tend to adhere to sediment particles that are settling or have already settled to the bottom. Sediment contamination has been associated with impacts to animals living in the sediments, and the development of tumors and other abnormalities in bottom-feeding fish. In addition, fish, crabs, and clams have been observed to accumulate pollutants in areas with sediment contamination. In several of these areas, local health departments have advised residents to limit their consumption of seafood.

The ability of the Washington Department of Ecology (Ecology) to address sediment contamination issues in Washington state is contingent on existing laws and proposed regulations. The Water Pollution Control Act, Chapter 90.48 RCW, provides Ecology with the ability to regulate and manage existing and proposed discharges to control any impacts of the discharges upon sediment quality. Likewise, the Model Toxics Control Act (MTCA), Chapter 70.105D RCW, enables Ecology to address necessary environmental cleanups. However, Ecology's ability to implement necessary source control and cleanup actions to prevent adverse effects on biological resources or significant threats to human health via protection of sediment quality is hampered by the lack of a uniform set of sediment management standards for source control and cleanup.

1.2 Authority

The proposed Sediment Management Standards (SMS) were filed with the Office of the Code Reviser on 18 September 1990, beginning the formal public adoption process for the rule. In addition to Chapters 90.48 and 70.105D RCW, Ecology cites several other state laws as providing authority for the adoption of the rule. All of these laws, and Ecology's intent in citing each law within the authority section of the SMS, are described below:

- Chapter 43.21C RCW, the State Environmental Policy Act (SEPA) includes broad policy mandates for multiple environmental protection objectives, e.g., "Attain the widest range of beneficial uses of the environment without degradation. . .", which are to be implemented by state agencies.
- Chapter 90.48 RCW, the Water Pollution Control Act, establishes key permitting and regulatory authority for source control activities that enable Ecology to implement the SMS rule. This law also requires permitted discharges to meet sediment quality values and dilution zone requirements.
- Chapter 70.105D RCW, the Model Toxics Control Act, establishes requirements for Ecology to identify cleanup procedures and standards that are protective of human health and the environment. Ecology has not yet included sediment cleanup levels in the amendments to the MTCA cleanup regulations, Chapter 173-340 WAC. The SMS establish such requirements for marine, low salinity, and freshwater sediments, and it is Ecology's intent to incorporate these standards by reference into the MTCA cleanup regulations. Once adopted, the SMS will thus become applicable requirements under MTCA. The draft rule acknowledges Ecology's intent by referencing MTCA as authorizing legislation for establishing cleanup standards for all

sediments.

- Chapter 90.52 RCW, the Pollution Disclosure Act of 1971, establishes authority for Ecology to implement all known available and reasonable methods of prevention, control, and treatment (AKART) to protect sediment quality statewide.
- Chapter 90.54 RCW, the Water Resource Act, establishes additional authority for Ecology to implement AKART to protect sediment quality statewide.
- Chapter 90.70 RCW, the Puget Sound Water Quality Act, establishes authority for Ecology to adopt regulations to implement the intent of the Puget Sound Water Quality Management Plan (PSWQA 1988). This law also authorizes adoption of such regulations on less than a statewide basis.

1.3 Rule Development

Ecology proposed the comprehensive sediment management rule known as the Sediment Management Standards (Chapter 173-204 WAC) in response to ongoing environmental and human health concerns relative to sediment contamination. The rule defines sediment quality standards, sediment source control standards, and sediment cleanup standards. The SMS represent the culmination of cooperative planning and scientific investigations carried out by Ecology and other state and federal agencies throughout the 1980s. These efforts include:

- The Commencement Bay Superfund investigations
- The Puget Sound Dredged Disposal Analysis
- The Puget Sound Estuary Program
- The Puget Sound Water Quality Management Plan.

1.3.1 Commencement Bay Superfund Investigation

A remedial investigation begun in 1983 under the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), known as Superfund, revealed 25 major sources contributing to sediment contamination in Commencement Bay, Tacoma. The magnitude of sediment contamination was characterized using the apparent effects threshold (AET) method, based on matched (synoptic) chemical analyses and biological effects indicators for sediment samples. At the Commencement Bay site, the AET method was used to evaluate cleanup options. Ecology then selected this scientific approach for establishing sediment quality values as the primary method to develop sediment quality standards for Puget Sound.

1.3.2 Puget Sound Dredged Disposal Analysis (PSDDA)

In 1985, PSDDA was initiated to develop environmentally safe and publicly acceptable guidelines for unconfined, open-water disposal of dredged material. PSDDA is a cooperative program conducted under the direction of the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the Washington Department of Natural Resources, and Ecology. To date, PSDDA has established sites for unconfined, open-water disposal of dredged material, and produced a management plan specifying procedures and criteria for evaluation of dredged material.

1.3.3 Puget Sound Estuary Program (PSEP)

PSEP was begun in 1984-1985 by the U.S. Environmental Protection Agency (EPA) Office of Puget Sound and Ecology, with the substantial participation of the Puget Sound Water Quality Authority (the Authority) and other state agencies and local government. The PSEP Urban Bay Action Program activities focus on the identification of problem areas in urban bays (predominantly based on receiving-water sediment contamination), the identification of potential contaminant sources, the development of an action plan for source control, and the formation of an action team for plan implementation. Problem areas are identified and ranked based on a comparison with unpolluted reference area sediment quality. Under the direction of PSEP, the action plan is scheduled for adoption as the joint federal and state comprehensive source control plan for Puget Sound.

1.3.4 Puget Sound Water Quality Management Plan (PSWQA Plan)

In 1987, the PSWQA Plan was adopted by the Authority. The PSWQA Plan presents goals, strategies, and work elements for 12 program areas to improve and protect the quality of Puget Sound. The municipal and industrial discharges program and the contaminated sediments and dredging program specifically address the identification and management of contaminated sediments. The most important aspects of these programs that relate to the management of contaminated sediments include the following:

- Element P2 of the municipal and industrial discharges program directs Ecology to develop and adopt sediment quality standards for identifying and designating sediments that have acute or chronic adverse effects on biological resources or pose a significant health risk to humans. The standards represent a "no adverse impact" goal for the quality of sediments throughout Puget Sound over the long term.
- Elements P2 and P3 of the municipal and industrial discharges program direct Ecology to develop a process and technical criteria for the establishment of sediment impact zones, i.e., sediment dilution zones. Establishment of a sediment impact zone acknowledges technical feasibility or cost constraints in meeting the long-term sediment quality goal for Puget Sound. For example, a discharger may be unable to reduce the amount of contaminants discharged in the effluent enough to prevent an exceedance of the sediment quality standards in sediments impacted by the effluent discharge.
- Element S7 of the contaminated sediments and dredging program directs Ecology to establish a uniform decision process for managing contaminated sediments. The decision process is to include procedures for the consideration of time, cost, and technical feasibility in establishing priorities for contaminated sediment cleanup actions.
- The PSWQA Plan envisions several uses of the sediment quality standards. The standards will be used as the sediment quality goal for several discharge permit programs including the municipal and industrial discharges program, the stormwater and combined sewer overflow program, and the nonpoint source discharge control program. Discharge permits issued by Ecology will include discharge monitoring and treatment requirements and effluent limitations sufficient to prevent exceedances of the sediment quality standards in sediments impacted by the effluent, while taking into account the discharger's need for a sediment impact zone.

The PSWQA Plan also recommends establishment of an inventory of locations or stations where sediment contamination levels exceed the applicable standards. The cleanup standards developed under Element S7 will identify, screen, rank, and prioritize contaminated sediment sites for cleanup actions, which may include source control, active sediment cleanup, or both. The cleanup standards will also identify acceptable cleanup levels for sediments.

1.3.5 Technical Studies

Ecology has used an extensive Puget Sound sediment quality database, developed to a large extent by PSDDA and PSEP, to conduct further technical analyses for the development of sediment quality standards and the identification of alternatives for sediment source control and cleanup action levels.

Ecology conducted multiple technical reviews and studies to support the development of the SMS rule. Some of the key efforts are outlined below:

- Contractor studies were performed on a wide variety of technical issues related to the proposed rule. More than a dozen reports have been completed (see Appendix A) and are available for public review.
- Ecology supported EPA Region 10 with presentations and response to the EPA Science Advisory Board review and report on the AET method in 1989.
- Ecology gave presentations on the SMS to the Washington State Science Advisory Board in 1989 and 1990.
- Ecology conducted expert workshops on computer modeling of sediment impact zones and chronic/sublethal bioassays with followup technical reports to support the proposed rule.
- Ecology participated in and made presentations to the PSEP Sediment Criteria Committee and Technical Advisory Committee on the technical development of the SMS.
- 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 contained within the SMS.

1.4 Objective of the Proposal

The proposed Sediment Management Standards address three main issues.

First, the standards identify a long-term goal for the quality of sediments in Puget Sound, embodied in definitive sediment quality standards. Sediment standards for other areas of the state are reserved for future development. Source control and cleanup standards for these environments will be considered on a case-by-case basis until quantitative standards are established.

Quantitative chemical contaminant levels are stipulated in the sediment quality standards for 47 contaminants or groups of contaminants of concern in Puget Sound. The sediment quality standards for other Puget Sound contaminants of concern will be added to the Sediment Management Standards once adequate information is available. It will be necessary to consider such chemicals on a case-by-case basis until quantitative values are established. This document does not discuss selection of the levels for the sediment quality standards included within the proposed rule because these standards represent a "no effects" level in the environment.

Second, when implementing the long-term sediment quality goals in Puget Sound, provision is made for current and future dischargers who may not be able to meet the goals due to technical limitations or unreasonable cost. For these discharges, the SMS rule allows the establishment of an area in the receiving-water sediments (sediment impact zone) where the discharger is permitted to contribute a higher contamination level. The alternatives for establishing a maximum contamination level in these zones (SIZ_{max}) are addressed in this document.

Third, the rule includes a decision process for identifying contaminated sediment areas and determining appropriate cleanup responses. The cleanup decision process includes screening procedures that are designed to focus limited resources on areas of sufficient concern to warrant consideration of active cleanup. This document addresses the alternatives for determining when contaminated sediments warrant such consideration.

It is also recognized that in some cases the environmental disruption resulting from contaminated sediment removal actions or the cost of cleanup may outweigh the adverse environmental effects of leaving sediments in place. For these reasons the rule establishes a long-term sediment quality goal, but allows case-by-case consideration of technical limitations and cost in setting the standard for the quality of sediments left in place after cleanup. The alternatives for establishing the maximum degree of contamination allowed to remain after cleanup are also addressed in this document.

All of the source control and cleanup standard alternatives being considered are based on chemical concentration and biological effects levels equal to or higher than those established as the sediment quality standards in the rule. In the process of formulating the source control, screening, and cleanup criteria, Ecology determined that in order to maintain integrity and consistency between the source control and cleanup parts of the rule, the same chemical concentration and biological effects levels should be established for each criterion. Ecology also recognized the importance of integrating the approach to management of source control and cleanup standards with the PSDDA program to preclude the creation of conflicts between the management and disposal of contaminated sediments. Thus, Ecology has identified a preferred alternative that is functionally equivalent to the guidelines established by the PSDDA program for unconfined, open-water disposal of contaminated sediments (i.e., PSDDA Site Condition II).

A separate, companion environmental impact statement (Ecology 1990b) that documents the incorporation by reference of the SMS into the MTCA cleanup regulation is available for review.

1.5 Purpose of the Environmental Impact Statement

The purpose of this document is to evaluate four alternatives for determining the maximum degree of sediment contamination to be allowed during implementation of three sediment management activities within the Sediment Management Standards. These three sediment management activities are related to the following three sets of standards:

- **Source control standards**—The maximum degree of sediment contamination (measured by chemical quality and biological effects) allowed in receiving-water sediments in the zone of an ongoing discharge source, termed the *sediment impact zone maximum allowable contaminant level* (SIZ_{max})
- **Screening standards**—The maximum degree of sediment contamination allowed before a contaminated sediment site cleanup is required, termed the *cleanup screening level* (CSL)
- **Cleanup standards**—The maximum degree of sediment contamination allowed to be left in place after active cleanup, termed the *minimum cleanup level* (MCUL).
-

This document addresses the environmental trade-offs associated with programmatic adoption of each of the four alternative contamination levels identified for the SIZ_{max}, CSL, and MCUL. Site-specific environmental impacts are not defined, but this document is intended to encourage and facilitate public involvement in decisions regarding the impacts on the environment from selection of any one of the alternatives. 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. Ecology evaluated several approaches to formulating SIZ_{max}, CSL, and MCUL criteria before establishing the framework set forth in the proposed rule. In Chapter 2 of this document, the major provisions of the SMS rule are described, focusing particularly on the activities relevant to the use of the SIZ_{max}, CSL, and MCUL. Background information addressing the rationale for selecting the four SIZ_{max}, CSL, and MCUL alternatives being considered is then provided, and the four alternatives are defined.

In Chapter 3, the affected environments are described, and in Chapter 4, three sediment impact zone case studies and 10 cleanup decision process case studies are discussed. Based on all available information, including the data derived from the case study analyses, the potentially significant environmental impacts associated with each of the four alternatives are examined in Chapter 5.

In Chapter 6, the four SIZ_{max}, CSL, and MCUL alternatives are evaluated, and the minor adverse biological effects level (Alternative 2) is identified as the preferred alternative for all three purposes. The evaluation of alternatives includes consideration of the potential environmental impacts identified in Chapter 5, as well as other criteria developed by Ecology and described in Chapter 6.

The discussion in Chapter 7 focuses on the relationship between the four alternatives and existing laws and regulations. Chapter 8 describes public involvement and education activities conducted by Ecology in concert with development and adoption of the rule. Remaining opportunities for public participation in sediment management decisions are also described. Finally, Chapter 9 contains a list of references cited in this document.

2 Description of the Sediment Management Process and the Alternatives

In this chapter, the processes for establishing sediment impact zones and for making sediment cleanup decisions contained in the proposed Sediment Management Standards are described. The descriptions provide a context for the development and evaluation of the SMS alternatives. Four alternatives are presented for addressing maximum levels of contamination in sediment impact zones and maximum contamination levels allowed following cleanup actions under the contaminated sediment cleanup decision process, which also includes provisions for sediment recovery zones. The proposed standards and alternatives were developed after consideration of a number of issues, which are also discussed in this chapter.

2.1 Sediment Management Process

2.1.1 Introduction

The Sediment Management Standards proposed by Ecology (Chapter 173-204 WAC) include procedures for the authorization of a sediment impact zone and a cleanup decision process for managing contaminated sediments. A summary of these procedures is provided below to facilitate an understanding of how the SMS alternatives were developed and to describe how the SIZ_{max}, CSL, and MCUL will be used after rule adoption. It is recognized that implementation of the rule is based on an evolving data set. The rule will be reviewed and modified as new information becomes available. In addition, in implementing the source control and cleanup provisions of the rule, the antidegradation policy set forth in Chapter 120 WAC provides for protection of pristine areas to more stringent standards than the applicable sediment quality standards and also provides for the protection of beneficial uses.

2.1.2 Source Control Standards and Sediment Impact Zones

The process for establishing a sediment impact zone begins with the review of an authorization or permit application (as applicable) for a stormwater or wastewater discharge. Through evaluation of the discharge effluent quality and available field monitoring data as well as the use of modeling, Ecology will determine whether the discharge may result in exceedance of the sediment quality standards. If an exceedance is predicted, and the discharger is applying AKART or best management practices (as applicable) to the discharge, a sediment impact zone may be approved as one provision of a discharge permit or other agency authorization. The degree of contamination allowed will be as low as possible based on modeling predictions, but shall in no case exceed the SIZ_{max} identified in the rule. The models will be used to estimate the impact of a discharge on the receiving waters and surface sediment quality for a period of 10 years, beginning from the later of the date of application for an impact zone or the starting date of the discharge.

The size of the allowable sediment impact zone will also be as small as practicable, based on modeling predictions and the department's best professional judgment. In designating impact zones, Ecology will avoid areas requiring special protection, such as shellfish beds and other areas identified in the rule, whenever possible. Although impact zones from different discharges may overlap, they may not together exceed the SIZ_{max} as described below.

The SIZ_{max} represents the highest chemical concentration for each chemical of concern that will be allowed in an impact zone due to the discharge. However, specifically identified acute and chronic biological effects tests conducted pursuant to the procedures set forth in the rule can be used to confirm or override the results of the chemical contamination analyses. 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. Ecology response to noncompliance with permit requirements ranges from an alteration in the permit conditions to closure of the impact zone. To ensure recovery of impacted sediments to levels allowed under the rule, closure requirements may include continued monitoring and active cleanup.

The need for an impact zone will be reevaluated during the permit renewal process for the discharge. Once the zone is no longer required, monitoring may be required to continue until the zone has recovered to the level of the sediment quality standards.

2.1.3 Contaminated Sediment Cleanup Standards

The sediment management process as set forth in the proposed rule is shown in Figure 2.1. The first step is to identify all locations in Puget Sound where sediment chemical concentration levels exceed the sediment quality standards. Each location where a sediment sample is collected or a measurement is taken is referred to as a *station*. Ecology will prepare and maintain an inventory of the results of all chemical and biological analyses performed on sediment samples taken from all stations.

Using the information contained in the inventory, Ecology will identify groups of stations that meet the chemical and biological criteria identified in the rule, to be defined as *station clusters of potential concern*, or *station clusters of low concern*. A station cluster of potential concern is defined when the contamination levels of the station cluster exceed the identified CSL.

This screening process is intended to efficiently determine whether a cluster of stations is of sufficient concern to merit further evaluation via additional review of existing information for the station cluster in a *hazard assessment* step. The screening procedures are not designed to identify the most highly contaminated stations. This identification occurs later during site ranking or during a cleanup study. Instead, screening removes marginally contaminated areas from consideration of active cleanup. Nonetheless, if these areas, which are returned to the station inventory, are related to ongoing discharge sources, they may be subject to other source control evaluations and requirements.

Following the screening step, a hazard assessment is performed on all identified station clusters of potential concern. During this stage, additional existing information is assembled to further characterize the clusters. Using the new information, the clusters are put through chemical and biological testing reviews similar to those performed during the screening stage. Clusters that continue to exceed the CSL are then defined as cleanup sites. Site boundaries are determined based on the area of sediments that exceed the sediment quality standards. The boundaries may be established by determining the nearest stations that meet the standards, although these boundaries may be adjusted later as warranted by new information.

Next, identified cleanup sites proceed to the ranking stage of the sediment cleanup process. The objective of ranking is to assess the relative hazard posed by different contaminated sediment sites to both human health and the environment, in order to efficiently allocate resources to remediate contaminated sediments that pose the greatest environmental and public health threat.

The final step in the contaminated sediment management process is to select the appropriate cleanup alternative(s) for those sites determined to warrant such action(s). As part of this step, a site may be divided into discrete units that are distinguishable in terms of habitat, resource values, or other unique characteristics. A unique cleanup standard is then developed for the site as a whole, or for each identified site unit as appropriate.

The cleanup standard for each unit or the site as a whole is always as close as practicable to the cleanup objective (i.e., the sediment quality standards), based on a consideration of the potential for natural recovery of the sediments over time, and the cost and engineering feasibility of the available remedial action alternatives. In all cases, the MCUL defines the upper constraint on the unit-specific or site-specific cleanup standard. The MCUL is defined in the SMS as the maximum allowable chemical concentration and biological effects level permissible at the cleanup site to be achieved by 10 years after the completion of active site cleanup. A 10-year time of compliance is consistent with that used at existing cleanup sites (e.g., Commencement Bay) and allows efficient coordination with MTCA and Superfund site reviews, which are required every 5 years when contaminants are left in place at a site. The incorporation of the 10-year compliance criterion into the definition of the MCUL further enhances the flexibility available in implementing the rule, by specifically allowing the potential for natural recovery to be considered in defining the appropriate active cleanup action for a particular site.

The level of contamination may vary between identifiable site units, and for technical or economic reasons it may not be appropriate to require cleanup of all units or the site as a whole. For areas of sediment contamination that fall between the sediment quality standards and the site-specific cleanup standard as determined above, the rule provides for the designation of sediment recovery zones. In these zones, the sediments will be allowed to recover naturally. Ongoing monitoring of the recovery zone and the recovery process may be included as a requirement within a cleanup decision.

2.2 Focusing the Environmental Impact Issues

In the process of developing the Sediment Management Standards, Ecology recognized that the program could be formulated in several ways. Ecology considered the following general issues for the source control requirements and cleanup decision process:

- Should sediment impact zones be established, and if so, what maximum degree of contamination should be allowed?
- Should areas of marginal contamination be screened from consideration of active cleanup? If so, how should this be accomplished?
- Should a higher level of contamination (i.e., a minimum cleanup level) exceeding the sediment quality goal be allowed as a cleanup standard when conducting cleanup actions? If so, what should that minimum cleanup level be?

The manner in which these issues were addressed and resolved, thereby leading to the approach identified in the proposed rule, is discussed below.

2.2.1 Maximum Allowable Contamination in a Sediment Impact Zone

As noted in Chapter 1, the PSWQA Plan acknowledges that after the implementation of AKART there may still be instances where a discharger is unable to sufficiently reduce the amount of contaminants in the effluent discharged to meet the sediment quality standards, due to technical or economic constraints. In order to stay in operation, this discharger may require some form of variance from the sediment quality standards for the sediment area impacted by the effluent. Ecology considered the following three alternative approaches to address this issue:

- Do not allow a sediment impact zone, requiring the discharge to meet the sediment quality standards.
- Rather than implementing the sediment impact zone concept, develop multiple sediment quality standards for different geographic areas. The sediment quality criteria for use in an urban bay would recognize existing contamination and ongoing human uses, thereby factoring technical feasibility and costs directly into the sediment quality standards. The sediment quality criteria for use in cleaner areas would be protective enough to maintain the quality of these areas, even in pristine areas requiring standards more stringent than the sediment quality standards.
- Allow a sediment impact zone with an established maximum allowable contamination level.

The first general alternative was eliminated because the sediment quality standards were developed based solely on scientific and technical information, and did not accommodate the essential consideration of cost and technical feasibility needed for regulatory decisions. As a result, this alternative would be inflexible and could result in unreasonable costs and economic impacts. The PSWQA Plan accepts the concept of sediment dilution zones and provides a specific reference for Ecology to include sediment impact zones.

The second approach, establishing multiple sediment quality standards, was rejected for several reasons. First, a relaxed standard applying to a relatively large geographical region would not protect cleaner areas within that region. Second, the expense and time necessary to establish the number of standards needed to adequately protect all areas of Puget Sound would be prohibitive, substantially exceeding available resources. Third, a relaxed sediment quality standard in a given location would not provide accountability for specific dischargers. Fourth, urban bays, where the most severe contamination is located, are also vital to the sensitive life stages of important aquatic species and therefore may deserve greater protection than other less contaminated areas. Fifth, EPA Region 10 has indicated that the multiple criteria approach would likely be reviewed and would be disapproved on the basis of nonprotection of existing designated beneficial uses. Such a rejection by EPA would reduce or restrict Ecology's use of the criteria in federal effluent discharge permit programs and federal cleanup programs. Finally, the cleaner areas of Puget Sound are already protected by the existing antidegradation policy of state clean water laws.

With the third approach, the sediment impact zone requirements would provide for a degree of flexibility necessary to effectively and efficiently implement the contaminated sediment management program. An impact zone would be implemented only by permit or departmental approval and would be accountable to specific dischargers. The size of an allowable zone would be determined on a site-specific basis using modeling predictions and field monitoring data. A single SIZ_{max} for each chemical of concern would be developed, based on adverse biological effects. Biological testing could then be used to confirm or override the results of the chemical analyses as needed on a case-by-case basis. Monitoring would be required to assure that neither the size nor degree of allowable contamination is exceeded. Establishment of a maximum contamination level would assist in ensuring the underlying protection of environmental and human health for the discharge areas.

In permitting a sediment impact zone, the technical feasibility and cost associated with reducing the contaminant(s) in the discharge in excess of AKART to a level sufficient to meet the sediment quality standard would be considered. These considerations would also be subject to discharge-specific agency and public review. Upon closure of the impact zone (for noncompliance or because the zone is no longer needed), the affected area would remain accountable to the discharger. The sediments previously impacted by a closed impact zone may require active cleanup or be allowed to recover naturally, as determined appropriate based on the degree of residual contamination.

Based on these considerations, Ecology selected the third approach set forth above, that is, allow sediment impact zones, but only to an identified maximum allowable chemical contamination level, as measured by chemical and biological tests.

The key environmental impact issue related to the completion of the source control portion of the rule is: what level of contamination should be allowed in an impact zone? The alternative chemical contamination levels being evaluated for this purpose are identified and defined later in this chapter.

2.2.2 The Cleanup Screening Level

In formulating the contaminated sediment cleanup standards, Ecology considered the following approaches to address whether areas of marginal contamination (slightly above the sediment quality standards) should be screened from consideration of cleanup:

- Do not screen any contaminated sediment areas from consideration of active cleanup.
- Screen out contaminated sediment areas based on degree of contamination (measured by chemical concentration and biological response) associated with the sediments.

Though highly contaminated sediments are present in some areas of Puget Sound, they are often surrounded by large expanses of relatively low-level contamination. While these marginally contaminated sediments do not meet the sediment quality standards, the adverse environmental consequences of active cleanup of all sediments exceeding the sediment quality standards, in concert with the high costs, can outweigh the benefits of cleanup actions. Recognizing that it may not be economically feasible or environmentally desirable to clean up all sediments exceeding the sediment quality standards, Ecology concluded that it would be appropriate to screen out sites of minimal concern in order to focus resources on areas posing a more significant threat to aquatic resources and human health. These sediment areas of low concern will remain on the inventory, and any associated discharges may be subject to additional source control requirements.

In addition to active cleanup, the long-term goal for sediment quality can also be achieved through natural recovery and ongoing or increased source control activities. This approach is consistent with the PSWQA Plan requirement that Ecology consider the potential for natural recovery and the costs of the cleanup standards. These considerations led to eliminating the first approach set forth above from further consideration.

Consequently, Ecology determined that the process of screening out areas of minimal contamination should be based on the threat posed by these levels of contamination to human and environmental health. This consideration led to the selection of the second alternative set forth above as the preferred method for addressing the need to screen contaminated sediment areas, using a cleanup screening level. In order to maintain a consistent technical approach among the various provisions of the rule, the CSL, like the MCUL and SIZ_{max}, would be based on adverse biological effects as defined by chemical criteria. Biological testing would then be available to confirm the level of adverse effects associated with the sediment.

2.2.3 The Cleanup Standard—The Minimum Cleanup Level

Ecology evaluated three approaches to setting cleanup standards for contaminated sediment sites:

- Use the sediment quality standards as the cleanup standards in all cases.
- Establish a degree of contamination exceeding sediment quality standards as the cleanup standards in all cases.
- Develop a range of cleanup standards varying from the sediment quality standards up to some identified higher limit of contamination (i.e. a minimum cleanup level). The cleanup standard for any particular site would then be established somewhere within this range as determined by a consideration of site-specific factors.

As noted above, the sediment quality standards have been identified in the PSWQA Plan as the long-term goal for sediment quality in Puget Sound. Ecology has determined that it is appropriate and consistent with this goal to consider the sediment quality standards as the cleanup objective for contaminated sediments in all cases where remedial action is being considered. Based on this determination, Ecology removed from further consideration the approach that would set the cleanup standard in all cases at some contamination level greater than sediment quality standards.

Next, Ecology acknowledged that while the sediment quality standards should be based solely on scientific criteria aimed at protecting human health and the environment, considerations of cost and technical feasibility must be considered when applying the standards to individual contaminated sites. Based on this determination, the approach that would set the cleanup standards at the sediment quality standards in all cases was also removed from further consideration.

However, Ecology also reasoned that there should be an upper constraint on contamination left in place, a MCUL, in order to ensure an acceptable level of environmental and human health protection for all cleanups. Therefore, the third approach to setting cleanup standards was selected. The cleanup standards would be determined on a site-specific basis and would be as close as practicable to the cleanup goal, but would in no case exceed an identified MCUL. The

MCUL would be defined as the maximum allowable chemical concentration and biological effects level permissible at a cleanup site, to be achieved within 10 years after completion of active site cleanup. As with the application of the CSL and SIZ_{max}, the designation of sediments as exceeding the MCUL would be based on chemical analysis, with biological testing available to confirm the adverse biological effects expected at the MCUL chemical concentrations.

Sediments containing chemicals at concentrations between the sediment quality standards and the MCUL do not meet the long-term goal for Puget Sound. However, the adverse environmental consequences of active cleanup of all sediments exceeding sediment quality standards (e.g., dredging most of an embayment), in combination with the high costs, can outweigh the benefits. A site-specific cleanup standard between the sediment quality standards and the MCUL would be based on a consideration of the environmental effects anticipated from alternative actions (including natural recovery), the cost of alternative cleanup scenarios, the technical feasibility of alternative cleanup scenarios, and the potential for natural recovery down to the MCUL within a maximum of 10 years after completion of cleanup activities (i.e., a period of compliance).

The CSL and MCUL are linked as two steps in the same cleanup decision process. The second issue evaluated in this document is, therefore: what contamination level should be used to screen sites from consideration of active cleanup, and what level of contamination should be allowed to remain in the sediments following the completion of cleanup actions?

2.2.4 Relation Between SIZ_{max}, CSL, and MCUL

During development of the SMS, Ecology evaluated the interrelationship of the various portions of the rule to ensure that source control requirements, cleanup requirements, and related dredging programs could be implemented without conflict and would complement each other. As a result of this evaluation, Ecology concluded that:

- Permitted sediment impact zones should not result in areas that will require future active cleanup. Therefore, SIZ_{max} should be established at or below 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, SIZ_{max} should be established at or below the current PSDDA disposal guidelines used for open-water disposal sites.
- The quality of dredged material that meets current disposal guidelines for unconfined, open-water disposal should not result in the need for future active cleanup. Therefore, the CSL should be established at or above the current PSDDA disposal guidelines.
- 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 all should be based on comparable statutory mandates for environmental protection and human health.

The net effect of these conclusions is illustrated schematically in Figure 2.2, which shows that only one alternative for SIZ_{max}, CSL, and MCUL need be selected.

2.3 *Definition of the Alternatives*

Four alternative effects levels for the SIZ_{max}, CSL, and MCUL are evaluated in this document. In general, these alternatives represent increasing degrees of adverse environmental effects and human health risk along a scale of decreasing costs. In the process of formulating the SIZ_{max}, CSL, and MCUL alternatives, Ecology determined that in order to maintain integrity and consistency among the various portions of the rule, the same chemical concentration and biological effects levels should be established for the SIZ_{max}, CSL, and MCUL.

To provide a better understanding of how the candidate alternatives relate to the sediment quality standards, a brief discussion of the derivation of the sediment quality standards is provided in the following section. Subsequent sections define and describe the alternative environmental effects levels considered in this study.

2.3.1 The Sediment Quality Standards - An Environmental Effects-Based Approach

As noted above, quantitative sediment quality standards for Puget Sound marine sediments have been established by Ecology for 47 contaminants or groups of contaminants of concern. The sediment quality standards for other Puget Sound contaminants of concern will be added to the Sediment Management Standards once adequate information is available. It will be necessary to consider such chemicals on a case-by-case basis until quantitative values are established.

With the exception of phenanthrene, which was derived using the equilibrium partitioning approach (Read et. al. 1989; U.S. EPA 1988b), the standards established for the 47 contaminants of concern were derived through application of the AET method. AET stands for *apparent effects threshold*, defined as the threshold above which adverse biological effects always occur, in the database of samples used to derive these values.

The AET method uses chemical and biological tests on field-collected sediments to establish sediment quality values. The method was originally developed to identify areas of contaminated sediments in the Commencement Bay Nearshore/Tideflats Superfund site located in south-central Puget Sound. This method has also been used by PSDDA to define the range of chemical contamination over which biological testing is used to determine the acceptability of dredged material for disposal at designated unconfined open-water sites.

The AET method associates chemical concentrations in sediments with adverse biological responses. The sediment quality standards are based on the lowest AET value established for up to four biological indicators from a database of over 300 Puget Sound sediment samples. A sampling station that exhibits a statistically significant adverse biological response relative to reference conditions is defined as an impacted station for a particular biological indicator. A sampling station that does not exhibit a significant response is defined as a nonimpacted station for that biological indicator.

AET values can be used to derive sediment quality values for any biological indicator including both acute and chronic effects. The existing AET values derived for Puget Sound have been determined on a chemical-specific basis using lethal and sublethal bioassays and indigenous biota analyses for as many as four biological indicators. The specific biological tests used to derive Puget Sound AET values include bioassays for amphipod mortality, oyster larvae abnormality, and Microtox® bioluminescence, and the *in situ* abundance of benthic macro-invertebrates (Table 2.1).

By collecting data for these four biological indicators on samples that have been chemically analyzed, four distinct AET values can be determined for each chemical measured. These AET values for one chemical may be the same for two or more of the biological indicators. The sediment quality standard for each tested chemical (except phenanthrene, which was established using the equilibrium partitioning approach) is set at the lowest AET (LAET) value for these four biological indicators. For more general information on the derivation of the sediment quality standards or the associated biological tests, see Becker et. al. (1989), Williams et. al. (1986), Johns (1988), Pastorok and Becker (1989), and Becker et al. (1988). For more specific information on the derivation and application of the AET method, see U.S. EPA (1988a) and Barrick et al. (1988). For more specific information on the derivation of alternative SIZ_{max}, CSL, and MCUL values see PTI (1990b).

In practice, sediments first will be chemically analyzed to determine if they exceed the sediment quality standards. However, it is recognized that local conditions such as chemical speciation and certain chemical or physical associations may influence the bioavailability of chemical contaminants. Therefore, when a sediment area is judged too contaminated for a sediment impact zone, or cleanup is deemed necessary under the cleanup standards, an affected party can accept this designation or opt to confirm the level of adverse effects with direct biological testing. Specific guidance for performing these tests is set forth in the proposed rule. Results of the biological testing override the results of the chemical evaluation.

All of the SIZ_{max}, CSL, and MCUL alternatives evaluated in this document represent differing degrees of biological effects in sediment. More specifically, the alternatives comprise varying chemical concentrations that reflect varying degrees of effects measured by selected biological tests. As with the sediment quality standards, these chemical values are subject to biological testing to confirm or override the indications of the chemical tests. Thus, the SIZ_{max}, CSL, and MCUL are defined by both chemical concentration criteria and biological testing interpretation.

Chemical concentrations for each alternative are summarized in Table 2.2. Values for additional contaminants of concern will be added as adequate information becomes available. In advancing from Alternative 1 to Alternative 4, the concentration of each chemical either increases or remains constant (different alternatives can have the same concentration for a contaminant if the AET values for two or more biological indicators are the same). The chemical concentrations for the contaminants being regulated, corresponding to alternatives ranging from no effects to severe biological effects, are encompassed within 2 orders of magnitude. For more than 70 percent of the contaminants being regulated, the alternatives fall within 1 order of magnitude. All the alternative concentrations generally fall in the upper range of sediment concentrations measured in Puget Sound.

The numerical concentrations listed in Table 2.2 apply only to sediments in Puget Sound, although the biological effects level on which the concentrations are based will apply to the whole state. Numerical cleanup standards for other areas of the state based on these effects levels will be derived at a later date.

The SIZ_{max}, CSL, and MCUL alternatives under consideration are intended to be protective of environmental health. Standards that are protective of human health will be determined on a case-by-case basis until quantitative human health standards are developed. Like the biologically based standards being evaluated here, development of the human health-based standards will be subject to all applicable public participation and review requirements.

2.3.2 Alternative 1 - No Adverse Effects

Under Alternative 1, source control standards and cleanup standards would require all discharges and cleanup decisions to meet the long-term sediment quality goal previously established for Puget Sound. Alternative 1 is the "no effects" level established by the sediment quality standards, i.e., no significant effects in any of the biological tests used to establish the standards (Table 2.1). Alternative 1 represents the lowest biological effects level and the highest cost alternative.

For the purposes of this document, Alternative 1 represents the no-action alternative because no SIZ_{max}, CSL, or MCUL would be formulated. Under Alternative 1, an effluent would be required to immediately meet the long-term goal for Puget Sound defined by the sediment quality standards, because there would be no sediment impact zone or SIZ_{max}. Permits would require discharges causing sediment contamination above sediment quality standards to be discontinued or additionally treated in excess of AKART. Similarly, with no CSL or MCUL, all sites exceeding the sediment quality standards would be cleaned up to levels established by the sediment quality standards, as measured by the chemical concentration criteria and biological effects tests. Alternative 1 is thus defined by the sediment quality standards as the level of "no significant acute or chronic adverse effects" on biological resources.

2.3.3 Alternative 2 - Minor Adverse Effects

Alternative 2 is the level at which significant effects are allowed in one but not two of the biological tests used to establish the sediment quality standards, and is defined as allowing "minor adverse effects." Alternative 2 represents an increased biological effects level and lower cost than Alternative 1.

This alternative is comparable to PSDDA Site Condition II disposal guidelines currently in use at Puget Sound nondispersive unconfined, open-water disposal sites. Under PSDDA Site Condition II, material is considered unacceptable for unconfined, open-water disposal under either of the following conditions (PSDDA 1989):

- The amphipod and juvenile infaunal species show statistically significant acute toxic responses relative to reference
- Either the amphipod or juvenile infaunal species mortality is significantly greater than reference (greater than 30 percent absolute) and statistically significant relative to reference.

The second lowest AET (2AET) value is used to define the chemical concentration that approximates this level of biological effect. The 2AET value is defined as the chemical concentration at which one but not two of the biological tests used to establish AET values exhibits adverse biological effects. Above this concentration, adverse effects may be exhibited in two or more of the biological tests. The level of biological effects associated with a mixture of chemicals at concentrations equal to 2AET values is equal to or higher than that associated with the sediment quality standards.

2.3.4 Alternative 3 - Moderate Adverse Effects

Alternative 3 is the level at which significant effects are allowed in three, but not all four, of the biological tests used to establish the sediment quality standards, and is defined as allowing "moderate adverse effects." Alternative 3 represents an increased biological effects level and lower cost than Alternative 2.

This level of biological effects is represented by the highest AET (HAET) value. The HAET is defined as the chemical concentration at which no more than three of the four biological tests used to establish the AET values exhibit adverse biological effects. Above the HAET value, adverse effects may be expected in all four biological tests. The HAET value for a series of biological indicators was also selected by PSDDA for use in setting the upper end of the range of chemical contamination above which biological testing is used to determine the acceptability of dredged material for disposal at designated unconfined, open-water sites. The level of biological effects associated with a mixture of chemicals at concentrations equal to HAET values is equal to or higher than that associated with Alternative 2.

2.3.5 Alternative 4 - Severe Adverse Effects

Alternative 4 is the higher of the level defined in Alternative 3 and the level at which significant effects are identified in all four biological tests used to establish the sediment quality standards. This alternative is defined as allowing "severe adverse effects." In general, Alternative 4 represents an increased biological effects level and lower cost than Alternative 3.

Alternative 4 is defined by the higher of the HAET value or the highest severe effects AET value. The HAET value is defined in the previous section. The severe effects AET value refers to the chemical concentration above which the biological indicator shows a high magnitude of response that is considered severe relative to any response found in reference areas. For example, 50 percent mortality in the amphipod bioassay is considered severe relative to the 0-25 percent response that may be found in reference areas. Likewise, 50 percent abnormality in the larvae bioassay is considered severe relative to the 0-20 percent response that may be found in reference areas. Statistically significant depressions in the abundance of more than one major taxon is considered a severe response for the benthic abundance test. A criterion for a severe response in the Microtox® bioassay has not been established; therefore, a severe effects AET value for this biological indicator has not been determined. The highest severe effects AET value for a chemical would then be the highest of the severe effects AET values for that chemical established by either the amphipod mortality, larvae abnormality, or benthic abundance test. The level of biological effects associated with a mixture of chemicals at concentrations equal to the higher of the severe effects AET or HAET values is generally equal to or higher than that associated with Alternative 3.

Additional definition of these alternatives is provided in the sections below. With the exception of Alternative 1, all of these alternatives in most cases represent chemical concentrations in sediment that are greater than the level allowed by the sediment quality standards. All four alternatives represent sediment chemical concentrations associated with varying degrees of adverse biological effects.

2.3.6 An Exception - The SIZ_{max}, CSL, and MCUL for Phthalates

It has been recognized that AET values for some phthalate esters may be unrealistically low because of their observed toxicity in laboratory experiments and because the pattern of AET values among different phthalate esters does not reflect their relative physicochemical characteristics. In addition, phthalate esters are common laboratory contaminants, and the influence of this factor cannot be fully assessed in some of the historical data sets used to generate AET values. For these reasons, Ecology has decided that it would be appropriate to set the standard at a higher chemical concentration for phthalate esters. Thus, regardless of which $SIZ_{max,}$ CSL, and MCUL alternative is selected for all other contaminants of concern, the alternative for phthalate esters will be set at the HAET value in all cases. This approach to phthalate esters is consistent with the dredged material disposal guidelines used by the PSDDA program.

2.4 Potential Alternatives Dropped from Consideration

The four SIZ_{max}, CSL, and MCUL alternatives described above were selected from a longer list of potential alternatives following extensive discussion between Ecology and interested representatives of industries, environmental groups, and other agencies. The work of the Sediment Management Standards Work Group was particularly instrumental in narrowing the list of potential alternatives to those evaluated in this study. Participants in the work group included representatives from industry, environmental groups, Indian tribes, and affected or interested state and federal agencies. The work group met several times early in 1990 and helped to finalize several aspects of the rule in addition to assisting Ecology in narrowing the list of potential SIZ_{max}, CSL, and MCUL alternatives.

The potential alternatives that were eliminated from further consideration include:

- Chemical levels 1.5 times the sediment quality standards
- Chemical levels 2 times the sediment quality standards
- The maximum chemical level associated with PSDDA Site Condition III
- Standards derived by various other field-based approaches
- Standards derived by various laboratory-based and theoretical approaches (exception: the equilibrium partitioning approach was used to establish the sediment quality standards chemical value for phenanthrene).

The first two alternatives listed above represent arbitrarily selected sediment chemical concentrations above the sediment quality standards. These multiples of sediment quality standards were intended to include a factor to account for possible uncertainties in the derivation of the AET values. However, a single multiplicative factor cannot account for differences in possible dose-response relationships among different chemicals and biological effects. Arbitrarily selected higher chemical concentrations such as these potential alternatives were removed from consideration based on the conclusion reached by the work group that, like the sediment quality standards, the SIZ_{max}, CSL, and MCUL should be defined by some degree of biological effect that is reflective of some specific level of environmental health protection.

PSDDA Site Condition III represents a series of specific bioassay response conditions and bioaccumulation in tissues not exceeding human health guidelines described by PSDDA (1988). The bioassay conditions include potential acute responses for a single bioassay that could exceed response levels 70 percent over reference conditions. Following discussions with interested parties, Ecology removed this potential alternative from further consideration based on the conclusion that it would not provide sufficient protection of human and environmental health.

Field-based methods rely on empirical information, i.e., chemical or biological measurements of sediments, to establish sediment quality values. Some of these approaches are purely chemical (e.g., the reference area approach) or biological (e.g., the field-collected sediment bioassay approach). Other methods such as screening level concentration, sediment quality triad, and AET correlate biological responses (e.g., bioassays on field-collected sediment, *in situ* biological effects observed in organisms associated with sediments) with chemical concentrations measured in sediments to develop sediment quality values. Laboratory-based and theoretical methods rely on extrapolation of water quality criteria to sediments, models of environmental fate of chemicals (e.g., equilibrium partitioning), or extrapolation of laboratory cause/effect studies (e.g., spiked sediment bioassays) to develop sediment quality values.

Following an evaluation of these field-based, laboratory-based, and theoretical approaches, Ecology selected the AET method as the preferred approach for developing the SIZ_{max}, CSL, and MCUL. This approach is consistent with the development of the sediment quality standards and, as noted above, was supported by the work group. The AET method was selected over other alternatives for several reasons. First, the AET method has a relatively high reliability in classifying Puget Sound sediment samples as adversely impacted or not impacted. Second, the AET method can be used to provide sediment quality values for the greatest number and widest range of chemicals of concern in Puget Sound. Finally, the method also incorporates the widest range of biological indicators that are directly applicable to sediment conditions. Details of the evaluation of the AET method and the other approaches can be found in Becker et. al. (1989).

3 Affected Environment

The Sediment Management Standards (Chapter 173-204 WAC) include sediment quality standards, sediment source control standards, and sediment cleanup standards that will apply to all surface sediments in marine, low-salinity, and freshwater environments of the state of Washington. While the general approach to sediment management issues is the same for surface sediments in all of these environments, numerical sediment quality standards have been developed to date only for marine sediments in Puget Sound [as defined in WAC 173-204-200(16)]. Development of sediment quality standards applicable to non-Puget Sound marine sediments, low-salinity sediments, and freshwater sediments is deferred. In the absence of numerical criteria applicable to such sediments, Ecology will determine on a case-by-case basis the criteria, methods, and procedures necessary to manage sediments in such environments.

The State Environmental Policy Act defines elements of the environment to be considered in an environmental impact statement (EIS). The elements of the environment that are expected to be affected by implementation of the SMS rule include features of the physical environment, the biological environment, and the human environment. Each of these elements of the affected environment is discussed in the following sections. The focus is on effects on the environment associated with implementation of the rule in Puget Sound sediments, because the present lack of numerical sediment management standards applicable to other sediments precludes an evaluation of the affected environment in each of those cases. The affected environment and impacts on the affected environment associated with sediment management standards for other areas of the state will be addressed in a supplemental EIS.

3.1 Physical Environment

3.1.1 Sediment Quality

Sediments, the sand and mud that lie on the bottom of Puget Sound, perform many important functions in the marine ecosystem. They provide shelter and rearing grounds for marine plants and animals. The nearshore organic detritus and deep sediments support a major branch of the food web of the sound. Suspended particles in effluent discharges and surface runoff carry contaminants into the sound. Much of the particulate material and associated contaminants do not dissolve into the water column; instead, they settle to the bottom to become part of the sediment of Puget Sound. The health of the benthic communities that live in and on Puget Sound sediments is an indicator of the contaminant level of the substrate. Sediments and benthic communities have been extensively studied in the urban bays of Puget Sound. In general, nearshore areas of urban bays show higher levels of sediment contamination, greater sediment toxicity to test organisms, higher levels of contaminants in fish tissue, and greater incidences of abnormal communities of benthic animals than those in less developed areas (Long 1985).

Sediment deposition and accumulation in Puget Sound are subject to natural variations over time and from place to place. Measurements of sediment deposition in the main subbasin, made by dating a radioactive isotope of lead in core samples, show that approximately 0.18-1.20 grams of sediment accumulate in a year on 1 cm^2 of the bottom (Crecelius et al. 1984).

A wide array of toxic chemicals find their way into Puget Sound. 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 area drained, the weather, and the time of year. The bottom sediments receive an ever-changing mixture of chemicals due to the complex variation of chemical contributions and the chemical interactions that occur between the contaminants and seawater.

3.1.2 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. Chapter 173-201 WAC designates water quality standards for all waters of the state as follows:

- Areas where special resources must be protected against contamination [AA (extraordinary) and A (excellent)]
- Areas where the waters have been degraded by human activities [B (good) and C (fair)].

In general, the quality of the marine waters in the state is high, except in urban bays.
Several studies have been performed on concentrations of contaminants in urban bays. 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, due to 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).

3.1.3 Air Quality

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 1990b). One of the many sources of toxic air contaminants in the Puget Sound region is vehicle air emissions. Of volatile organic compounds measured in the region, approximately 75 percent are transportation-related. Approximately 15 percent of sources of toxic air contaminants are transportation-related (Ecology 1990b). Toxic air pollutants are also released by a variety of industrial and commercial 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.

3.2 Biological Environment

3.2.1 Plankton Species

The main subbasin 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. The presence of blooms, while not well understood, may be related to anthropogenic nutrient contributions or hydrologic factors. Paralytic shellfish poisoning, which causes a serious potential human health threat, is associated with red tide phytoplankton blooms. The neurotoxin produced by the phytoplankton bioaccumulates in shellfish and other organisms and can cause paralysis leading to death in humans eating tainted shellfish (Saunders 1984). Paralytic shellfish poisoning is regulated in Washington state by the Department of Health through shellfish harvesting regulations and shellfish bed closures.

Zooplankton are quite diverse and abundant in areas of Puget Sound. 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. Other nearshore zooplankton are represented by crab larvae (zoea), cnidaria (jellyfish), and fish eggs and larvae. Several of these zooplankton including amphipods, crab larvae, and fish eggs and larvae live in the sediments for all or part of their life cycles and can bioaccumulate or be impacted by contaminants in sediments. Zooplankton are actively fed upon 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. Microlayer contamination could thus impact the life cycle stages of many commercially and ecologically important species.

3.2.2 Macrophytic Plants

3.2.2.1 Kelp Beds

Kelp is a common seaweed that attaches to rocky sediments in intertidal and subtidal zones of Puget Sound. The typical intertidal zone contains large rocks and rubble, while the subtidal zone can include silt and sand, coarse gravel and shell debris, or gravel/cobble/boulder beds. Kelp beds support many marine inhabitants during parts of their life cycles. For example, these habitats provide feeding and nursery grounds for juvenile salmon and other fish, as well as food and refuge for many marine invertebrates that form the base of the benthic food web.

The kelp plant has shown an overall increase in Puget Sound, possibly due to the building of bulkheads and seawalls that alter the natural movement of water and sediment near the shoreline. Other possible reasons for the increased abundance of kelp may be its perennial growth pattern, its relative tolerance to pollution, or its ability to rapidly dominate shallow subtidal areas.

3.2.2.2 Eelgrass Beds

Eelgrass is the dominant plant species in the shallow subtidal, soft-bottom communities of Puget Sound. Extensive eelgrass meadows are still found in 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). Eelgrass provides food in the form of detritus or direct forage for small crustaceans. In addition, eelgrass beds support the larval and juvenile stages of many types of commercial and sport fish.

While there are no quantitative data on the extent of eelgrass meadows throughout Puget Sound, anecdotal information indicates that there have been losses in some areas such as the Snohomish delta and gains in other areas such as Padilla Bay. Unlike kelp, eelgrass has shown signs of physiological stress. However, no direct correlations between pollution and habitat loss have been documented.

3.2.3 Benthic Macroinvertebrates and Megainvertebrates

Bottom or benthic habitats support a diverse assemblage of organisms that vary depending upon the texture or particle size of the floor of the sound, as well as on the degree of tidal influence. The soft, fine-grained intertidal mudflats are vital habitats for many highly prized species of shellfish. Puget Sound shellfish, including clams, mussels, scallops, geoducks, crab, and shrimp, are a multi-million dollar commercial and recreational fisheries resource to the area. The abundance of shellfish plays an important role in the cultural tradition of the communities of native American people. 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 (PSWQA 1990).

3.2.4 Anadromous and Demersal Fish

There are more than 220 species of fish in Puget Sound, including salmon, groundfish, herring, and smelt. Salmon is the most important component of the tribal and commercial sport fisheries. The various types of fish live in a variety of habitats and occupy many different positions in the food web. Anadromous fish, which migrate to feed in marine waters and return to fresh water to spawn, include salmon, steelhead, and searun trout. Marine fish can either live on one reef throughout their entire life cycle or range widely within marine or estuarine waters.

Some species of fish are thriving in Puget Sound, while populations of other species are declining. While salmon and other types of anadromous fish, such as lingcod, are flourishing in fish hatcheries and enhancement programs, wild stocks of anadromous fish and some marine fish, such as cod and whiting, are declining (Schmitt 1990). The declines are a result of a combination of natural and anthropogenic pressures. 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.

3.2.5 Marine Mammals and Water 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 3.1 lists rare, threatened, and endangered mammals that have been sighted in Washington state. Of these, only the sea otter and the grey whale are typically found in Puget Sound.

Marine mammals feed on an array of organisms such as benthic invertebrates, small fish, squid, and herring (PSDDA 1989) and may be exposed to contaminated fish, shellfish, and sediments during feeding. For example, the grey whale filters large quantities of sediment in order to retain 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 Puget Sound waters can impact marine mammals by the accumulation of contaminants in their tissue. Similarly, a decline in food sources can directly impact these residents. While resident Puget Sound 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.

Water birds provide diverse types of enjoyment to the people of the Puget Sound region, as quarry for hunters and as attractions for birdwatchers. Many marine birds and waterfowl 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, 10 species or subspecies of geese, and two species of swans use Puget Sound for some portion of the year. Rare, threatened, and endangered water birds are listed in Table 3.1.

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).

3.2.6 Terrestrial Plants and Animals

Plants and animals of concern are found throughout the terrestrial environment of Washington state and the Pacific Northwest region. Plants and animals existing on or adjacent to upland disposal facilities that would receive dredged material from contaminated sediment cleanup sites have the greatest potential to be impacted. If an upland disposal site is created, existing habitats for terrestrial birds and other wildlife could be destroyed and vegetation could be removed during construction activity.

Geographic areas of concern are those in which threatened or endangered species are found, or where the Washington Department of Wildlife has listed sensitive species in its nongame 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 (Ecology 1990b). 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 environments.

3.3 Human Environment

3.3.1 Human Health

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 toxicants 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. 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 1988b). Subpopulations who eat large amounts of locally caught fish and shellfish may face greater risks, such as some recreational fishermen, some native Americans, and some Asian groups.

Public health officials at the state Department of Health sampled a number of recreational shellfish sites in Puget Sound in 1988 and found high levels of fecal coliform bacteria at a few sites, and high bacterial levels in shellfish near the urban bays and all along the eastern shore of the main basin of Puget Sound. The same study found low levels of toxic organic compounds and metals in shellfish meat from most areas (Faigenblum 1988). Beaches at Eagle Harbor have been closed to shellfish harvesting because of high chemical concentrations in sediments.

Additional exposure to contaminated sediments may occur in intertidal areas through direct contact or ingestion of contaminated sediments during recreational activities such as wading, fishing, clamming, 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 should be considered as part of a site-specific risk assessment.

3.3.2 Economics

Various locations in the region could be affected economically by the source control or sediment cleanup standards. Population growth continues in most Puget Sound counties, placing additional development pressure on shoreline resources to ensure continued economic growth.

For example, under Alternative 1, Elliott Bay in the Seattle metropolitan area would require remediation of over 7,500,000 square yards of sediment. King County is the largest county in the state, with a population of 1,346,400 in 1985. Population growth over the last decade has been caused by a variety of economic factors including expansion by the Boeing Company, establishment of other high technology companies, and the development of Seattle as a regional center and focus for Pacific Rim trade. Population forecasts by the state Office of Financial

Management predict that the population of King County will increase to 1,601,700 by the year 2000. Major port development continues to occur along Elliott Bay and along the lower Duwamish River. Waterborne commerce through Seattle Harbor has increased from 15,008,000 short tons in 1975 to 20,300,000 short tons in 1984.

3.3.3 Fishing

Some of the most important natural resources commercially harvested in Washington come from the state fisheries. Commercial and recreational salmon fishing takes place throughout the Puget Sound region. The fish species of highest commercial value include salmon, black cod, sole, flounder, pollock, and halibut. The 1987 values of the commercial harvest of these fish totaled $80,884,000 for salmon, $10,589,000 for other anadromous fish, and $44,173,000 for other marine fish (DOF 1987).

The human population in the Puget Sound basin has centered largely around bays with large navigable rivers. Pollution from industrial development and upland runoff is concentrated in the sediments and water of these urban bays. Fish that live in the urban bays are more likely to be exposed to degraded habitats and contamination than those that live in less contaminated areas. University of Washington researchers have found higher levels of some contaminants in the tissues of Pacific cod than in most other Puget Sound species examined (Landolt et al. 1987). Pacific cod populations in both central and southern Puget Sound have seriously declined, although fisheries biologists are uncertain to what degree, if any, contamination is responsible for this decline.

3.3.4 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 the early native American people in the Puget Sound basin, attracted early settlers to the area, and continues as an important factor today. Fishing provides benefits to native Americans, southeast Asians, and other communities for sustenance, spiritual and religious activities, and recreational activities.

Native American tribes throughout the area harvest fish and shellfish in commercial and subsistence fisheries. Salmon and steelhead fisheries are the most important tribal commercial harvest. In 1987, 4,500,000 salmon were harvested in Washington state by Indian tribes, accounting for approximately 50 percent of the total salmon harvest in Washington state. This tribal harvest included commercial, ceremonial, and subsistence uses (Ecology 1990b).

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 historical importance. Historically significant sunken vessels and aircraft could also be affected by remediation or aquatic disposal of sediments.

3.3.5 Transportation

Terrestrial areas where transportation may be affected are defined by the relationship between the physical distribution of contaminated sediment sites undergoing cleanup actions where upland disposal is a preferred option for disposing of contaminated sediments 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. Though contaminated sediment sites are located throughout Puget Sound, many are found 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 (Ecology 1990b).

Navigation through marine waters may also be affected by site cleanup activities. Vessels traveling the waters in the vicinity of cleanup sites can vary from large bulk cargo and container ships to barges, tugboats, ferries, and assorted other craft. Navigational development has occurred in most of the major urban embayments since the early 1900s.

To improve federal and state management of open-water disposal sites, PSDDA 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. About 60 percent of the material dredged between 1970 and 1985 was deposited at upland and nearshore disposal sites (PSDDA 1988). During the past 15 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.

3.3.6 Noise and Aesthetics

Dredging equipment and marine vessels, including tugs and barges, can contribute to increased noise levels in the vicinity of the contaminated sediment site where active cleanup is occurring.
The marine waters of the Puget Sound basin 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.

The 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 bays. Potentially affected activities include recreational boating and the viewing of wetlands, marine mammals, and seabirds. The aesthetic qualities of Puget Sound and associated amenities are also enjoyed by boaters, many of whom use local marinas for moorage.

3.3.7 Water Use

Water use falls into two distinct categories, use of Puget Sound waters for navigation, and use of groundwater as a drinking water supply. The navigational use of the waters of Puget Sound is addressed above under *Transportation*. Generally, navigation in the vicinity of sediment remedial action sites could range from large bulk cargo and container ships to barges, tugboats, ferries, and other assorted craft.

One of the most important resources in the human environment is drinking water. Based on data for drinking water systems with 100 or more connections, 69 percent of the drinking water in Washington comes from groundwater (DOH 1989). 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.

3.3.8 Land Use

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 upon 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. Land use would also be affected in areas designated for nearshore or upland disposal of sediments too contaminated for aquatic disposal.

The marine receiving environment in the vicinity of municipal and industrial outfall pipes will be affected by the chosen alternatives for sediment impact zones. Many of the pollution problems in Puget Sound are associated with both past and current discharges, and these discharges are often associated with industrialized areas subject to multiple land use pressures. Once the pollutants are discharged from the ends of pipes, they are much more difficult to control as they become dispersed in water, sediment, and biota. Depending upon the chosen alternative, sediment impact zones will affect bottom sediment at various sites throughout Puget Sound.

4 Sediment Impact Zone And Cleanup Decision Process Case Studies

Case studies were conducted to evaluate the impact of the source control standards and the sediment cleanup standards on environmental conditions in Puget Sound. Figures 4.1 through 4.14 provide a graphic depiction of the locations in Puget Sound that exceed the sediment quality standards in general and each of the four alternatives in particular. Figures are based on data from over 900 sediment chemistry sampling stations throughout Puget Sound, shown in Figure 4.1. These data are intended to provide a broad overview of sediment chemistry in Puget Sound; many recent site-specific studies are not represented.

Figure 4.2 provides a sound-wide look at stations that exceed the sediment quality standards. As this figure illustrates, known contaminated areas are located primarily near urban areas, particularly in Bellingham Bay, Elliott Bay, the Everett-Port Gardner area, and Commencement Bay (these areas have also been most heavily sampled). Figures 4.3 through 4.14 provide a closer look at three of these embayments. For each embayment, four figures show the stations that exceed the four alternatives. These figures provide a general sense of the areas that might require sediment impact zones or might be subject to the cleanup standards under the four alternatives.

The results of three sediment impact zone case studies provide more specific information with regard to when and where impact zones might be needed. The 10 cleanup decision process case studies in turn illustrate the area and location of contaminated sediments that may require active cleanup (i.e., capping, dredging, and confined disposal). These case studies are discussed in the sections below. These sections first set forth the manner in which the case studies were selected. Next, the underlying assumptions and simplifications used in applying the source control and cleanup standards procedures are described. Finally, the results and implications associated with incorporating the four alternatives into the source control and cleanup standards are highlighted.

The case study evaluations are included to illustrate the range of possible conclusions for the alternatives. The case studies were based on readily available data and do not reflect site-specific final analyses. Additional evaluations would be required for actual site application of the proposed rule.

4.1 Sediment Impact Zone Case Studies

A discharger who cannot reduce the amount of contaminants in the discharge sufficiently to avoid violation of the sediment quality standards may apply for a sediment impact zone. Permit conditions will not apply directly to limit the discharge of specific contaminants. Rather, the maximum allowable concentration in sediments within the zone will be limited by the SIZ_{max} values identified in the rule.

The primary vehicle for authorizing a sediment impact zone will be through the NPDES and state waste discharge permit procedures. In such cases, an impact zone will be authorized only after AKART and best management practices have been implemented. The rule also provides that Ecology may authorize impact zones for other discharges not subject to the NPDES permitting requirements (e.g., some stormwater discharges), but only after the implementation of AKART and best management practices, as determined by the department.

Computer modeling was conducted as part of the three sediment impact zone case studies to assist in evaluation of the conditions in which impact zones would be appropriate under each of the four alternatives. Of several models available for simulating the fate and transport of contaminants in surface waters, the Water Quality Analysis Simulation Program 4 (WASP4) was selected to model sediment impact zones in the case study sites. WASP4 is a dynamic compartment modeling program that considers both the water column and the underlying sediments. The program subdivides a surface water body and sediments into segments (or compartments) into which and from which contaminants migrate. The model can be applied in one, two, or three dimensions, given adequate information on the transport (flux) of water and contaminants between the segments defined for the surface water body and underlying sediments. WASP4 is described in more detail by U.S. EPA (1988d).

The WASP4 model was applied to three discharges in Puget Sound to test its applicability to the sediment impact zone designation process and to generally evaluate the circumstances (e.g., discharge rate, contaminant concentration, current rate, tidal exchange rate) under which an impact zone would be needed under the four alternatives. These case studies are intended as illustration only and do not necessarily incorporate all available site data. The case studies are used to help determine the types of environments in which sediment impact zones are most likely to be needed. Site-specific modeling may be needed to determine whether an impact zone is needed in a particular location.

4.1.1 Site Selection Process

Each case study includes a potential contamination source that discharges to Puget Sound through an outfall and a receiving environment that includes water column and underlying sediment. The sites were chosen by an Ecology internal work group that convened on 9 January 1990. Sites were selected on the basis of site representativeness and data availability. The three case study sites (Figure 4.15) are:

- A municipal sewage treatment plant outfall located in Commencement Bay
- Two major storm drains located at the head of Foss Waterway (formerly City Waterway), Tacoma
- An industrial outfall located in Bellingham Bay.

The receiving environments represent the broad range of conditions encountered in Puget Sound, including both confined waterways with limited circulation (the storm drains in Foss Waterway), and enclosed or open bay areas with less confined circulation (the industrial outfall in Bellingham Bay and the sewage treatment plant outfall in Commencement Bay).

4.1.2 Assumptions and Simplifications

The WASP4 model was used to simulate the relationship between source discharge and sediment accumulation for each of the three case studies. A 20-year period of constant loading was simulated for all case studies. (When used under the rule to estimate the impact of the discharge on receiving water and surface sediment quality, the model will be applied only for a 10-year period.) Up to three indicator chemicals were used to represent the most likely contaminants associated with the various sources. The initial sediment concentrations of these indicator chemicals were assigned on the basis of measured reference values or nearby area values. Typically, indicator chemicals were metals (e.g., copper, lead, zinc, chromium). However, an organic chemical, 3,4,5-trichloroguaiacol, was included as an indicator chemical for the industrial outfall. The effluents in all case studies were characterized in terms of loading data for total flow, concentrations of indicator chemicals, and total suspended solids as determined from NPDES permits and agency studies. A 10-cm mixing zone was simulated. Near the outfall this mixing zone was subdivided into a 2-cm surface zone and an 8-cm subsurface zone.

The goal of applying the model to these three case studies was to determine if exceedances of sediment quality standards would be predicted in the vicinity of the discharge, thus requiring a sediment impact zone. However, the actual need for impact zones at each of these locations will be determined by Ecology, using all available information, once the alternative for setting SIZ_{max} is chosen.

4.1.3 Results and Conclusions

The results presented here are abstracted from the more detailed case study results presented by PTI (1990a).

The concentrations of indicator chemicals in sediments adjacent to the sewage treatment plant outfall and the industry outfall were not predicted to exceed the sediment quality standards, indicating that sediment impact zones would probably not be required for these sources. Sediments adjacent to the storm drain discharges in Foss Waterway were predicted to exceed sediment quality standards for both copper and zinc over approximately half the waterway, suggesting that an impact zone may be necessary if AKART and best management practices do not significantly reduce the contaminant load. These results are qualitatively consistent with currently available sediment measurements, which portray elevated metal concentrations at levels exceeding Alternative 2 only for sediments in the Foss Waterway site. Foss Waterway, the only case study where sediment quality standards were exceeded, is the only site where a significant proportion of the total load of copper discharged into the site was retained within the site boundaries (i.e., resident copper represents 25 percent of the total copper discharged to the waterway over 20 years, while resident copper for the other two case studies represents 1 percent or less).

It is also useful to compare the relative importance of currents and tides as offsite transport processes. Advection (i.e., water current) effectively transports offsite most of the copper discharged by the sewage treatment plant outfall in Commencement Bay. By contrast, dispersion (i.e., tides) is the most important offsite transport process in Foss Waterway, a relatively stagnant environment of Commencement Bay. The Bellingham Bay site represents yet another mixture of physical processes, where dispersion and advection are both responsible for significant transport of copper offsite, but with tidal dispersivity dominating.

These case study evaluations provide valuable information about the general need for sediment impact zones in Puget Sound and the utility of using a model to support implementation of the source control standards. The following conclusions can be drawn from the results of this case study analysis:

- The potential for contaminants to accumulate in sediments adjacent to the point of discharge is highly dependent on the loading rate of contaminants (i.e., effluent discharge and contaminant/particle loading) and energetics of the receiving water (i.e., net current flow and tidal flow). Particle size is also an important factor but was not explicitly assessed in the model runs.

- Sediment impact zones are most likely to be needed in quiescent receiving environments (i.e., confined waterways or embayments) if the contaminant loads are high or particles are large or dense. For a large part of Puget Sound, impact zones will probably not be needed because of naturally high-energy receiving waters. However, parts of many urban bays are relatively quiescent and also experience a high contaminant load. Based on the results of this modeling, urban bays are expected to require the most sediment impact zones and accordingly will experience the highest environmental impacts.
- A significant portion of the contaminant load is transported offsite (i.e., outside the area modeled), particularly in active environments. Because these contaminants are highly dispersed, they are not likely to cause sediment quality problems in the receiving environment.
- At a constant loading rate, a balance between contaminant discharge and surface sediment accumulation (i.e., steady state) was typically achieved in the surface 2 cm of the sediments adjacent to the outfalls within 10 years.
- The size of the sediment impact zone in quiescent environments (e.g., stagnant waterways, channels, or berths) will be very sensitive to values assigned to key physical and chemical parameters, and site-specific refinement of these variables should be conducted as information becomes available (e.g., from monitoring data).

These conclusions are directly applicable to the evaluation of the environmental impacts of designating sediment impact zones in Puget Sound. Results suggest that impact zones will not be extensively applied in Puget Sound except in urban bays. The evaluation of environmental impacts will focus on these areas.

4.2 Cleanup Decision Process Case Studies

The sediment cleanup decision process is divided into several stages: 1) inventory of stations, 2) screening of station clusters of potential concern, 3) hazard assessment and site identification, 4) site ranking, 5) cleanup study, 6) selection of a cleanup standard, and 7) cleanup action decision. The purpose of the case study analysis is to provide some indication of the area and volume of sediment in Puget Sound that would require active cleanup (i.e., remedial action) when the various CSL and MCUL alternatives are applied in the cleanup decision process. The case study analysis focuses only on the stages where these alternatives are specifically applicable (i.e., station cluster screening and site identification, and site cleanup).

4.2.1 Station Cluster Screening and Site Identification

The identification of station clusters of potential concern is based on an assessment of geographic proximity of stations and the common occurrence of specific contaminants. Single, geographically isolated stations that exhibit elevated chemical concentrations are screened out in the initial stages of the process but may be included at a later time when additional data from newly sampled, adjacent stations become available. The process of screening station clusters from further consideration of cleanup involves, first, determining the average concentration of a particular chemical (or chemicals) at the three stations within the cluster that exhibit the highest concentration of that chemical (or chemicals). If the average concentration of any chemical exceeds the CSL, the cluster is defined as a "site" and proceeds through the cleanup decision process. If the average concentration does not exceed the CSL, the cluster is defined as a cluster of low concern and is not considered further for active cleanup unless warranted by new information. In this way, an individual station that exceeds the CSL may be excluded from further cleanup consideration.

4.2.2 Site Cleanup

Once a site is defined and has reached the remedy selection stage of the decision process, a site-specific cleanup standard will be determined. That cleanup level will always fall somewhere within the range between the sediment quality standards and the MCUL, although time of compliance may be as long as 10 years. Once source control is in place, the use of a 10-year time of compliance allows natural recovery to take place, decreasing the area that must be actively remediated. Natural recovery mitigates sediment contamination by decreasing surface sediment concentrations through burial and mixing with clean sediment and degradation of contaminants.

4.2.3 Selection of Case Study Sites

The case study sites were selected by evaluating the geographical distribution of problem chemicals in Puget Sound. First, all stations in Puget Sound with available chemical data were compared to the sediment quality standards. At each station, the three chemicals exceeding the standards by the greatest factor were identified. The names of these chemicals were plotted on a map of Puget Sound at the station's location. Station clusters were identified by visual examination of the maps. Cluster formation was based on the physical proximity of stations with identical or related chemicals. Rather than relying on absolute distances, proximity was judged in relation to stations without exceedances or without exceedances of the same group of characteristic chemicals. Where two or more station clusters with similar chemicals were separated by distances greater than the diameter of either cluster, with no data available on the gap, the clusters were regarded as separate sites.

Ten station clusters were selected for further characterization based upon the distinctness of their boundaries and the degree of similarity of stations within the clusters. These 10 sites include approximately 5 percent of the stations sampled in Puget Sound. Finally, the total area of each site was calculated.

Notes: First, the area encompassed by each station within a cluster was computed by determining a Thiessen polygon for each station. Any point within a Thiessen polygon for a station is closer to that station than to any other station. To complete the polygons for stations at the edge of the site where there are no onsite stations beyond, control points were artificially introduced. These control points were placed as far from the boundary stations as the boundary stations are from other cluster stations. Cluster boundaries were then established outside the outermost stations of a cluster at a distance controlled either by the adjacent shoreline (if any), the nearest noncluster station, or the average distance between cluster stations where there are no noncluster stations. The cluster boundary was established halfway between each outermost cluster station and the closest noncluster station. If noncluster stations were not proximate to the site, the outer cluster boundary was established at a distance beyond the outermost cluster station equivalent to half the separation between cluster stations. The area of Puget Sound estimated to require cleanup under the four alternatives was determined by first estimating the area represented by each station in Puget Sound. This average (or representative) area was determined from the distribution of station areas represented by the Thiessen polygons generated for the case studies. The area in Puget Sound that exceeds each alternative was calculated by multiplying the total number of stations that exceed the alternative by the representative station area.

4.2.4 Assumptions and Simplifications

Discrimination of site boundaries was most difficult in those portions of urban bays containing stations with a large number of exceedances and a large variety of problem chemicals and potential sources. For this reason, the 10 case studies selected for this analysis tended to avoid complicated areas that exhibited these characteristics (e.g., the Duwamish River near Harbor Island in Elliott Bay), although case study sites are probably biased toward relatively contaminated areas and may not adequately represent relatively small clusters that could be screened out during the early stages of the decision process.

By focusing only on the decision process stages where the CSL and MCUL are specifically applied, this analysis overestimates the area of sediments requiring cleanup, because screening can also occur during site ranking and prioritization. Furthermore, by not explicitly considering recovery factors when estimating the area or volume of sediments requiring cleanup, the estimates tend to be conservative (i.e., larger areas than actually expected). The approach used to estimate site areas may also have been conservative. Because simplifying assumptions were used, these case studies are intended for illustration only and are not intended to predict the exact volume of sediments that would require cleanup in any of these locations. Site-specific analyses, using the full screening and prioritization process, will be performed to determine the amounts and locations of sediments to be cleaned up under MTCA.

Notes: The use of Thiessen polygons to represent the distribution of chemical concentrations represents a major simplification. The Thiessen polygons assume that the concentration of each contaminant is homogenous within each polygon and that variation occurs only at the borders, contrary to the continuously variable nature of sediment chemistry concentrations. In addition, the area of the polygons, and thus the area of a site, is highly dependent on station spacing. For example, the size of a very small contaminated sediment area is exaggerated using the Thiessen polygon technique if adjacent stations are relatively far apart, because the polygon boundary is constructed at half the distance between the hot spot station and adjacent stations. Alternatively, the Thiessen polygon technique underestimates the area of contaminated sediments if the concentration gradient between two stations steepens abruptly adjacent to the lower-concentration station. In this case, the polygon associated with the higher-concentration station represents the higher concentration as extending midway between the stations, when in fact it extends into the adjacent, low-concentration polygon.

4.2.5 Results and Conclusions

The 10 case studies, shown in Figure 4.16, include Bellingham Bay, Elliott Bay (outer bay), Eagle Harbor, Everett Harbor, Hylebos Waterway, the head of Hylebos Waterway, Magnolia Bluff (in Elliott Bay), Ruston Shoreline, Sinclair Inlet, and Sitcum Waterway. Hylebos Waterway and a subarea, the head of Hylebos Waterway, were included to evaluate the results of dividing an initially identified area of contiguous contamination into a smaller, discrete subarea.

The following discussion focuses on two key stages: 1) screening of station clusters, and 2) identification of cleanup areas. Throughout this analysis, two categories of sediments are of interest: 1) sediments left in place to recover naturally, and 2) sediments that would require active cleanup (i.e., either confinement in place or removal and disposal elsewhere). Each of these categories of sediments is associated with characteristic impacts. For sediments left in place, some degree of biological effects are predicted due to exceedances of the sediment quality standards. Both short- and long-term impacts are associated with confining or removing sediments.

The sites that were retained after applying the alternative screening levels are set forth in Table 4.1, which shows that under Alternative 1 all sites would be retained for further consideration. When the average concentration of a particular chemical (or chemicals) at the three most contaminated stations exceeds the value (or values) representing Alternative 2, two sites are screened from further consideration of cleanup. When the average concentrations exceed the values representing Alternatives 3 and 4, three additional sites (five sites total) are screened from further consideration. Assuming that these 10 sites are representative of Puget Sound as a whole, use of Alternative 2 as the screening level would thus screen out 20 percent of the clusters being evaluated for possible cleanup, and Alternatives 3 and 4 would each screen out 50 percent of the clusters being considered for possible cleanup.

For each of the 10 case study sites, the area within the site that exceeded each of the four alternatives was calculated in order to estimate the areas requiring remedial action. When corrected for screening, the estimated areas represent rough approximations of the actual sediment areas that would require cleanup under the various alternatives. These estimates are considered only roughly approximate because site-specific cleanup values were not developed, and the mitigating effects of natural recovery were not incorporated into the analysis.

Table 4.2 lists the areas (estimated as described above) within each of the 10 sites that exceed the four alternative MCULs. The areas exceeding Alternatives 3 and 4 are similar, reflecting the similarity between the MCULs for Alternatives 3 and 4. This similarity results from the fact that in most cases severe effects data are not available for all test types. Because the areas requiring cleanup and the MCULs under Alternatives 3 and 4 would not be very different, it is not generally possible to distinguish between the environmental impacts expected with one of these alternatives as opposed to the other. Therefore, in the following chapters, Alternatives 3 and 4 are considered separately only when required by the context of specific discussions.
An illustration of the ways in which the areas to be remediated typically vary under the alternatives is provided in Figure 4.17, using the Eagle Harbor case study. This evaluation does not include Eagle Harbor data collected during the Eagle Harbor remedial investigation. The case studies were conducted before the remedial investigation data became available. Case study results would differ with the more recent information. For example, localized contamination adjacent to the south shoreline is not illustrated. Figures showing the other case study sites are provided in Appendix B.

Finally, Table 4.3 shows the areas of sediments within the 10 case study sites whose concentrations fall between the MCULs for Alternatives 1 and 2, 2 and 3, and 3 or above. These areas represent increasing degrees of biological effects that may be associated with sediments that will remain in place. Based on this information, if the MCUL is set at Alternative 2, 43 percent of the sediments that exceed the sediment quality standards within the 10 sites would be considered for active cleanup (and 57 percent would not be considered), because under the rule the active cleanup would not be required unless sediment concentrations exceed the MCUL. On the other hand, if the MCUL is set at Alternative 3 or 4, only approximately 5 percent of the sediments that exceed the standards within the 10 sites would be considered for active cleanup. In either case, the total amount of sediments considered for active cleanup will be further modified by the averaging requirements implemented at the cluster screening and hazard assessment stages.

In the next chapter, a discussion is presented of the environmental impacts that would be expected to occur in Puget Sound as a result of implementing each of the four alternatives for sediment impact zones and cleanup standards.

5 Environmental Impacts Associated with the Four Alternatives

The types of environmental impacts related to the source control standards and contaminated sediment cleanup standards discussed in this chapter are set forth in Table 5.1. There are fewer types of impacts associated with implementation of the source control standards than with implementation of the cleanup standards because, unlike the cleanup standards, the identification and authorization of a sediment impact zone does not require the implementation of cleanup actions. Those environmental impacts associated specifically with the implementation of cleanup actions therefore do not apply to the source control portions of the rule. The discussion of environmental impacts associated with sediment impact zones focuses only on the varying degrees of impacts associated with the different SIZ_{max} values.

Because the alternatives represent varying chemical concentrations to be used in the implementation of source control and cleanup standards, and not different approaches to dealing with the source control and cleanup issues, the types of impacts are the same for each alternative, varying only by a matter of degree. In this chapter, the types and significance of impacts associated with the alternatives are discussed.

The first three sections below address impacts on the physical, biological, and human environments that are associated with residual contamination left in place in a sediment impact zone or after implementation of the cleanup standards. The fourth section addresses additional impacts associated only with cleanup actions. The next section addresses the impacts on other state programs and resources that would result from the four alternatives. The final section provides a summary of unavoidable adverse impacts.

While some impacts apply to both residual contamination and cleanup action, 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 sediments. These different kinds of human health impacts are discussed separately in the two sections on residual contamination and cleanup under subsections entitled *Human Health Impacts*. This approach has also been used with cultural resource impacts.

This document provides only a brief discussion of mitigation options for the impacts associated with the source control and cleanup standards. Necessary mitigation features will be considered routinely during site-specific review of impacts. Additionally, regardless of the alternative chosen, implementation of the rule is intended to increase environmental protection and reduce impacts of current source control activities and cleanup programs.

5.1 Impacts on the Physical Environment from Residual Contamination

This description of the impacts on the physical environment is limited to impacts resulting from residual contamination left in place following implementation of the source control and cleanup standards procedures. In general, impacts on the physical environment include those on sediment, water, and air quality, and on land use. Air quality and land use impacts are at issue only in relation to cleanup activities, which are discussed in the fourth section of this chapter. This first section is limited to a discussion of the impacts on sediment and water quality that would result from leaving contaminated sediments in the environment. Generally, as the action alternatives (Alternatives 2-4) allow a greater quantity of contaminated sediments to remain in the environment, the impacts associated with this residual contamination will increase relative to Alternative 1.

5.1.1 Sediment Quality Impacts

Impacts on sediment quality within a sediment impact zone or at a contaminated site following the implementation of cleanup actions under the four alternatives would be reflected in the biological impacts associated with each alternative. These impacts are discussed in terms of biological test results under the definitions of the alternatives in Chapter 2 above. Generally, sediment quality would decrease from Alternative 1 through Alternative 4. However, assuming natural recovery of sediment quality over time, the concentrations of many contaminants under Alternatives 2-4 would be expected to improve to the levels of Alternative 1 in the long term.

Impacts on sediment quality in the vicinity of a sediment impact zone or near a cleanup site would depend on whether local currents are strong enough to move the sediments outside of the zone or site boundaries. However, potential resuspension of sediment is one factor that will be taken into account in establishing the boundaries of the zone. In addition, as discussed in Chapter 4, impact zones are anticipated to be necessary only in relatively quiescent environments. Therefore, only a minor quantity of contaminated sediment is expected to be transported from within the zone boundaries to outside the boundaries. Significant degradation of sediment quality outside the zone boundaries is therefore not anticipated under any of the alternatives.

Sediments from cleanup sites may migrate offsite when adequate current rates prevail. Again, the potential for resuspension of contaminated sediment is a factor that will be taken into account during the ranking and cleanup study steps. If conditions are appropriate for sediment capping, the cap will be designed to withstand expected current action. Relocation of a minor amount of clean capping material will not degrade nearby sediment quality. If the contaminated sediments are removed by dredging, offsite transport of sediments will be a function of the dredging technique, water currents, and the grain size distribution of the residual sediment. Coarse-grained sediment is less likely than fine-grained sediment to be transported offsite. Offsite impacts would be expected only if the residual sediments are substantially finer-grained than the contaminated sediment that has been dredged and only if water currents are of sufficient velocity to resuspend and transport the exposed material. These factors will be taken into account in site-specific evaluations of cleanup actions. Preventing significant degradation of sediment quality outside the boundaries of a cleanup site will be a general regulatory requirement, and degradation is thus not anticipated under any of the alternatives.

5.1.2 Water Quality Impacts

Water quality in the vicinity of a sediment impact zone could be impacted by the continuous contribution to the surface waters of contaminants in the effluent and by contaminant release from sediments within the zone. Any water quality impacts associated with an impact zone would be smaller under the lower-concentration alternatives (Alternatives 1 or 2) than with the higher-concentration alternatives (Alternatives 3 or 4). As noted in the case study discussion in Chapter 4, discharges where the receiving waters circulate adequately are not expected to require an impact zone, while discharges into quiescent waters may require one. In addition, water quality criteria are not often exceeded in Puget Sound for the contaminants of concern in sediments, even in areas that accumulate contaminated sediments from effluent discharges. Because attainment of AKART or best management practices is required prior to the approval of an impact zone, the severity of impacts is not expected to be significant under any of the alternatives. The quality of receiving water for all discharges will continue to be regulated and monitored by NPDES and state waste discharge permits.

Long-term water quality impacts associated with sediments left in place under the cleanup standards would occur only when and if the sediments become resuspended in the water column, or if significant pore water fluxes of contaminants are present (more likely in areas of limited water circulation). Strong currents or ship passage may periodically resuspend contaminated sediments in many areas throughout Puget Sound.

The precise impacts on water quality that would result under each of the four alternatives would depend on site conditions. However, sediments containing the PSDDA Site Condition II level of chemicals are considered acceptable for disposal in nondispersive aquatic environments. PSDDA Site Condition II is defined as causing ". . . minor adverse impacts on biological resources due to sediment chemicals . . . " (PSDDA 1988). In nondispersive environments, sediments containing this level or less (Alternatives 1 and 2) would not be expected to result in significant adverse water quality impacts. In highly dispersive environments, transport of contaminants out of the area would occur so quickly that water quality problems would not be expected. The highest potential for water quality impacts would occur in relatively quiescent environments where contaminants are continually released from sediments into the water column because of propeller wash or other mechanical disturbances or where there is a significant flux of contaminants through the sediments (e.g., groundwater seeps).

5.2 Impacts on the Biological Environment from Residual Contamination

This section addresses the potential impacts on plant and animal communities and human health resulting from contaminants remaining in the sediments either in a sediment impact zone, or from residual contamination following cleanup actions under the cleanup standards.

5.2.1 Assessing the Degree of Biological Effects

There are two factors that must be considered in a discussion of the biological impacts from residual contamination expected under each of the four alternatives. The first is the variation in degree or magnitude of impacts. The second is the area of contamination to which biological resources may be exposed under each of the alternatives. The four alternatives for cleanup levels are based on biological responses in selected biological tests. The organisms used in these biological tests were chosen because they are indigenous to Puget Sound and are relatively sensitive to contaminants. Therefore, measures of biological effects based on these tests are expected to be protective of the wider range of organisms present in Puget Sound.

By definition, no adverse biological impacts are expected to result from long-term exposure to sediments containing residual levels of contamination allowed under Alternative 1.

Residual sediment contamination allowed under Alternative 2 is functionally equivalent to the sediment quality considered acceptable by PSDDA for unconfined, open-water disposal. Some species may suffer varying levels of adverse effects from long-term exposure to sediments containing this level of contamination. However, by definition, this contaminant level would allow on average only minor adverse effects on biological resources (PSDDA 1988).

Residual contamination under Alternatives 3 and 4 would result in substantially more adverse biological impacts. While Alternative 2 would allow an adverse impact in only one biological test, Alternative 3 would allow varying degrees of adverse biological impact in three of the tests. Alternative 4 would allow a significant percentage response (50 percent) in all four biological tests. Based on these biological response levels, it is clear that the degree or magnitude of biological resource protection will decrease as the alternatives allow higher contaminant levels to remain in the sediments.

In the 10 case studies, the areas of contaminated sediment that exceed each of the four alternatives (Table 4.3) indicate the difference in area that would remain contaminated under each alternative. Under Alternative 2, 43 percent of the area that exceeds the sediment quality standards would be cleaned up, leaving sediments in 57 percent of the area within these 10 case study sites in place at a contamination level between the sediment quality standards and Alternative 2 standards. Under Alternatives 3 and 4, approximately 5 percent of sediments exceeding the sediment quality standards would be cleaned up. In that case, approximately 95 percent of the area within these 10 case study sites would remain in place at contamination levels between the sediment quality standards and the higher levels allowed under these alternatives. Thus, a larger area of sediment contaminated above the sediment quality standards would remain under Alternatives 3 and 4 than under Alternative 2. Until sediments can recover naturally, this larger area implies a greater spatial extent of residual biological impacts under Alternatives 3 and 4 than under Alternative 2.

Table 4.3 can also be used to assess the degree of residual impact that might be expected on a site-specific basis under a particular alternative. For example, in Elliott Bay, 100 percent of the area exceeding the sediment quality standards would be cleaned up under Alternative 1, and 27 percent of this area would be cleaned up under Alternative 2. Under Alternative 3 or 4, only 3 percent of the area would be cleaned up. Therefore, most of the sediments at this site are contaminated at levels between Alternative 1 and Alternative 2. Even if the site were cleaned up under Alternative 3, the residual contamination would be characterized primarily as resulting in minor adverse biological effects.

By contrast, the degree of contamination in the Sinclair Inlet site is significantly greater, because all the sediments are contaminated at levels between Alternatives 2 and 3. If Alternative 3 were chosen, the residual contamination at this site would be characterized primarily as resulting in moderate biological impacts. Based on the characterization of sediment quality in the 10 case studies, cleanup under Alternative 3 would result in approximately 57 percent of the original area exhibiting no more than minor adverse biological impacts and 38 percent exhibiting moderate adverse biological impacts. Cleanup under Alternative 2 would result in 57 percent of the original area exhibiting no more than minor adverse biological impacts, and no sediments exhibiting moderate adverse biological impacts.

It is clear that both the area of residual contamination and the overall degree of biological impacts will increase in choosing the higher numbered alternatives as cleanup levels. However, it is difficult to determine a quantitative relationship between each of the biological test results and cumulative biological impacts in the environment. The following sections provide a general discussion of the types of biological impacts that would be expected to result from sediment contamination in the natural environment. These impacts are expected to be of greater concern at the higher-concentration alternatives.

5.2.2 Identifying Biological Effects

Chronic exposure of benthic invertebrates and demersal 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) found elevated prevalences 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 sediments. Adult anadromous fish, shore birds, marine mammals, and endangered species may be impacted through contamination of the food chain.

Impacts on individuals 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 plants to residual contaminants can result in reduced growth, failure to reproduce, or death.

Comparison of Figures 4.2 through 4.13 with Figures 5.1 through 5.14 provides general information on the location of recreationally, commercially, and ecologically important species relative to contaminated sediment areas in Puget Sound. Because these maps do not provide detailed, up-to-date information on specific areas in Puget Sound, site-specific inventories of aquatic resources will be developed in each area before permitting a sediment impact zone or beginning cleanup at a site. The following resources may be at risk in the areas indicated:

- Figures 5.1 and 5.2 indicate that the substrate of eelgrass beds might be contaminated in Elliott Bay, Commencement Bay, and Everett Harbor, and that kelp could be exposed in Elliott Bay and perhaps to a small degree in Commencement Bay and Eagle Harbor
- Figure 5.3 indicates that Dungeness crab (which would be directly exposed to sediment contamination) would be exposed to contamination in Everett Harbor and Bellingham Bay
- Figures 5.4 and 5.5 indicate that both commercial and recreational salmon harvesting take place in all of the major urban bays
- Figure 5.6 shows that major groundfish resources are located in Everett Harbor, Bellingham Bay, Dyes Inlet, and Eagle Harbor

- Figures 5.7 through 5.9 indicate that herring and smelt may be impacted by sediment contamination in Dyes Inlet and Bellingham Bay
- Figures 5.10 through 5.14 indicate that shrimp, geoduck, intertidal clams, and oysters in Puget Sound are not expected to be impacted by the sediment contamination in urban bays.

The extent to which resources will be impacted under each of the four 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 in a sediment impact zone or after cleanup activities have been undertaken. No adverse biological impacts are expected under Alternative 1. No more than minor adverse biological impacts are expected under Alternative 2. The greatest degree of biological impact is expected under either Alternative 3 or 4 relative to Alternative 1.

5.3 Impacts on the Human Environment from Residual Contamination

Impacts on the human environment resulting from residual contamination left in place include health impacts, economic impacts, fishing impacts, impacts on cultural resources, and land use impacts. These impacts differ from impacts resulting directly from cleanup activities. Each of these impacts is discussed in the following sections; corresponding impacts resulting from cleanup activities are discussed in the fourth section of this chapter.

5.3.1 Human Health Impacts

The primary risk to human health resulting from residual concentrations of contaminants remaining in the sediments, either in a sediment impact zone or as a result of cleanup action, is the risk associated with consuming fish or shellfish contaminated by direct exposure to those sediments (or indirect exposure in the case of edible fish consuming other organisms that have been directly exposed). Less significant risks to human health are associated with dermal exposure to water or sediments, incidental ingestion of contaminated water or sediments during recreational activities, and inhalation of vapors released by contaminated sediments. Each of these potential impacts is discussed in turn below.

The potentially adverse health effects associated with consumption of contaminated marine animals are typically divided into carcinogenic and noncarcinogenic effects. In characterizing the potential for carcinogenic effects to occur, it is assumed there is no safe exposure threshold; that is, even a low dose of a carcinogenic contaminant carries with it some degree of risk.

In characterizing noncarcinogenic effects, a threshold exists below which exposure poses no health risk. Residual concentrations of chemicals remaining in the sediments that result in exposure to levels below the threshold dose pose a negligible risk to human health. Above the threshold, and as the extent of exposure increases, noncarcinogenic effects of contaminants can range from subtle biochemical or physiological changes to more severe effects, including death.

A direct quantitative comparison of the human health risks associated with the four alternatives is not possible because the alternatives 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 sediments would be based primarily on consumption of contaminated fish and shellfish. EPA has developed a method for assessing the risk to human health from concentrations of contaminants in fish and shellfish tissue. However, the relationship between concentrations of contaminants in sediment and concentrations in fish and shellfish is not well understood. Therefore, it is not currently possible to estimate the risk to human health from a carcinogen in sediments or to determine a threshold concentration for noncarcinogens in sediments below which adverse impacts on humans will not occur.

The alternatives do, however, represent a rough approximation of increasing concentrations of contaminants and areal extent of contaminants in sediments that can be related to human health impacts. In general, increasing concentrations of contaminants in sediments, 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 the four alternatives represent increasing concentrations of toxins in sediments, those alternatives may also be associated with increasing 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.

The significance of the carcinogenic human health risk varies with the type of cancer. In particular, cancers range from those that are generally simple to cure (e.g., most skin cancers), to those that generally show good recovery when treated (e.g., some leukemias), to those that are generally fatal whether treated or not (e.g., most lung cancers). Some of the more serious noncarcinogenic effects include reproductive impairment; developmental deficits in the fetus, infant, or young child; and neurological or immunological dysfunction. Human 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 sediments
- Exposure rate—Amount of fish or shellfish consumed, or frequency of contact with sediments
- Dose—Levels of contaminant concentrations in edible tissues of fish and shellfish and in sediments.

These exposure factors are related to the contaminant concentrations in sediments and to the areal extent of elevated contaminant concentrations. As the area of sediment contamination increases, a larger (and perhaps entire) portion of the fish or shellfish's foraging territory will likely be centered in the contaminated area, increasing the contaminant concentration in fish and shellfish tissues and the human health risks associated with ingestion of those tissues. 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. As the areal extent of contamination increases, the number of fish and shellfish likely to be exposed increases, thus increasing the likelihood of human exposure.

Persons involved in recreational activities (e.g., fishing, wading, clam digging) in intertidal zones may be exposed via dermal contact and incidental ingestion of contaminants in sediments or released as water-soluble components. As contaminant concentrations increase, exposures may be more severe. Further, as the area of contamination increases, the likelihood of exposure increases.

The quantity of contaminated fish and shellfish consumed depends on the degree of access to contaminated source areas. Many of the contaminated sediments in Puget Sound are located in shoreline and nearshore areas (see Figures 4.2 through 4.14) where people could come into physical contact with contaminated sediments. However, the potential risks to human health are limited because many contaminated areas tend to be situated near industrial or business districts where people do not tend to swim or recreate. In addition, shellfish are not likely to be harvested in most areas of concern (e.g., urban bays) because of the health risks posed by bacterial contamination. 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 be exposed to contaminants in sediments, water, and tissues of fish and shellfish.

The only means of limiting the human health impacts associated with consumption of contaminated seafood is to restrict consumption of seafood that comes from a contaminated area. The impacts associated with direct dermal exposure may be similarly mitigated by limiting access to or placing warning signs on contaminated beach areas.

Ecology is currently working with the Washington Department of Health to coordinate the development of human health criteria for contaminated sediments. It is anticipated that the development of human health criteria will begin in 1991. Until human health criteria for sediments are developed, the section of the rule dealing with human health-based standards is reserved, and a site-specific evaluation of risks to human health will be required. During the development of the human health criteria, substantial opportunity for public review and involvement in development of the standards will be provided.

5.3.2 Economic Impacts

Expected economic costs in relation to the SIZ_{max}, the CSL, and the MCUL have been evaluated in an economic impact assessment issued in conjunction with this EIS (Ecology 1990a). Implementation of source control standards could result in substantial economic impacts, depending on additional effluent treatment activities that would be required for compliance with AKART and best management practices specified in the proposed rule. These impacts would be the same under all the alternatives. However, more stringent alternatives could require some dischargers to treat effluent to levels below AKART, or reduce or discontinue the discharge.

Another major factor influencing compliance costs for the proposed rule is the cost of monitoring, much of which may be attributable to evolving NPDES requirements. For the purpose of the economic impact assessment for the proposed rule, compliance with AKART is assumed equivalent to federal requirements already established in NPDES permits. Therefore, the economic analysis is based on the assumption that there will be no additional costs of attaining AKART in complying with the proposed rule. In addition, any cleanup cost associated with closing a sediment impact zone is attributed to the cleanup standards portion of the rule.

Under Alternative 2, the remaining compliance costs for establishing and maintaining an impact zone range from approximately $27,000 to $232,000 for a 5-year permit. These costs are insignificant (less than 1 percent of sales) for the industrial categories examined in detail (Ecology 1990a). Except for the costs of attaining AKART, corresponding costs for establishing and maintaining a sediment impact zone under the other alternatives are expected to be similar to those associated with Alternative 2.

If it is not technically feasible to reduce effluent contaminant concentrations to the levels allowed by the proposed rule, Ecology may limit the amount of contaminants reaching the sediments by implementing waste load allocation requirements. This action could result in substantial economic impacts by requiring reduced production sufficient to meet waste load allocations, or alternative disposal methods for that portion of the wastewater effluent not allowed to be discharged into Puget Sound under the allocation. These impacts would increase as the SIZ_{max} alternatives become more stringent.

The economic impacts resulting from implementation of the cleanup standards will also increase as the CSL/MCUL becomes more stringent, because a larger quantity of sediment will require cleanup. Economic analyses of cleanup costs were first conducted under Alternative 2. A wide range of low, medium, and high compliance costs was estimated based on a range of actions that may be required for different sites in Puget Sound. At the lower range of costs for the cleanup standards (including cleanup actions and monitoring), dischargers may have total costs of up to approximately $256,000. The middle range of total costs (approximately $256,000 to $10,800,000) also encompasses the range of costs that have been estimated for cleanup action and monitoring at each of eight cleanup sites within Commencement Bay. At the upper range of costs for this process, dischargers could have total costs of approximately $10,800,000 to $56,000,000. Two major factors affecting these ranges in costs include the type of cleanup action (e.g., capping vs. upland disposal of contaminated sediments) and the total amount of contaminated sediment at any one site. These costs could result in significant economic impacts.

The range of costs observed for different types of cleanup sites around Puget Sound using Alternative 2 encompasses the typical costs of site cleanup estimated for the other alternatives. Cleanup costs for Alternative 1 are typically higher than for Alternative 2; costs for Alternatives 3 and 4 are lower than for Alternative 2. Estimated cleanup costs for a typical small site are approximately $200,000 for Alternative 3, $256,000 for Alternative 2, and $340,000 for Alternative 1. For a typical medium-sized cleanup site, costs are estimated at approximately $530,000 for Alternative 3, $3,400,000 for Alternative 2, and $8,200,000 for Alternative 1. For a typical large site, Alternative 3 cleanup costs are estimated at approximately $17,000,000, compared to $32,000,000 for Alternative 2 and $55,000,000 for Alternative 1.

5.3.3 Fishing Impacts

As indicated in Figures 5.4 and 5.5, commercial and recreational salmon fishing take place throughout the Puget Sound region. Because adult salmon do not consume benthic organisms, it is doubtful that salmon would become sufficiently tainted through indirect exposure to residual contamination (i.e., through consumption of food sources that are directly exposed) to pose a significant health risk to humans. Therefore, residual sediment contamination under any of the alternatives would not be expected to adversely affect the commercial, native, or recreational salmon fisheries in Puget Sound.

Commercially and recreationally important demersal fishes (e.g., English sole, rock sole, starry flounder, several species of rockfish) and shellfish would be directly exposed to residual sediment contamination. Consumption of these resources could pose a health risk to humans (see *Human Health Impacts* above). The potential for bioaccumulation of contaminants to levels that pose a human health risk has been recognized. For example, the eastern shoreline of Puget Sound from Commencement Bay to Meadowdale is permanently closed to the commercial harvest of shellfish because of the presence of numerous biological and chemical contaminant sources.

Some fish and shellfish that are harvested recreationally from Commencement Bay, Elliott Bay, and Eagle Harbor have also been significantly 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.

Impacts on demersal and shellfish fisheries associated with existing contamination levels in Puget Sound will be mitigated to a degree under any of the four alternatives. The degree of protection provided by the alternatives increases in the order of Alternative 3 or 4, Alternative 2, and finally, Alternative 1, which should result in no adverse impacts on fisheries.

5.3.4 Cultural Resource Impacts

Puget Sound is a cultural resource to all residents of the state to the extent that its amenities are an important component of their lifestyles. For many native Americans, high cultural values are associated with Puget Sound and its living resources, which are incorporated into many tribal activities including 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 ethnic 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 any of the alternatives. The specific types of cultural resource impacts that may be expected are discussed below.

Cultural resources may be adversely impacted if aquatic resources are diminished or if people avoid harvesting seafood 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 contaminated areas. 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 four alternatives. A more detailed discussion of health risks from consumption of fish and shellfish is presented above.

Source controls and cleanup action will help mitigate the impacts currently resulting from sediment contamination. In addition, the mitigation options discussed for human health and biological impacts apply to the cultural resource impacts discussed here as well.

5.3.5 Land Use Impacts

Establishment of a sediment impact zone requires an evaluation of whether the zone would conflict with existing or potential human uses of the area outside and near the discharge. Because many discharge outfalls already exist, and many are located in industrialized areas currently associated with historic sediment contamination areas, most impact zones are not expected to conflict with other uses of the shoreline environment. For new outfalls, existing shoreline management requirements will address the acceptability of the discharge location. The proposed rule also contains other locational criteria for establishing impact zones. Where unacceptable conflicts arise, the zones will not be established.

Cleanup actions at an aquatic site can restore or enhance opportunities for land use of the shoreline environment. If residual contamination is left to natural recovery after active cleanup, some types of land use may be precluded during the recovery period (e.g., fishing piers). Higher degrees of contamination (under Alternatives 3 and 4) could discourage recreational or bottom harvesting activities for longer periods of time due to increased environmental and human health risks. Current and potential land uses will be one factor in determining the site-specific cleanup standards during application of the Sediment Management Standards.

5.4 Impacts Associated with Site Cleanup

The severity or extent of environmental impacts associated with site cleanup will depend in part on the quantity of sediments requiring cleanup. As discussed in Chapter 2, the four candidate alternatives considered in this study represent different chemical concentration levels, which in turn reflect varying degrees of biological effects in selected biological tests. Thus, as allowable chemical concentrations increase under the four alternatives, the area of sediments requiring cleanup will decrease.

In general, as the volume of sediment requiring cleanup decreases under the alternatives with higher cleanup levels, the short-term impacts associated with the implementation of cleanup action activities also decrease, and the long-term impacts associated with allowing this greater quantity and level of contaminated sediments to stay in place increase.

Cleanup-related impacts also vary depending on the type of action taken. In general, the cleanup action alternatives applicable to contaminated sediments are limited to in-place capping and removal. Sediments removed from the site would be taken to another aquatic location for capping, or they would be disposed of in confined nearshore or upland locations. When sediments are disposed of on land, 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 placed in aquatic locations, there may be impacts on benthic species and marine fish and on human health through consumption of chemically contaminated seafood.

Impacts associated with the implementation of cleanup activities include impacts on water and air quality, plants and animals, human health, cultural resources, land and water use, noise and aesthetics, and transportation. The nature of these impacts would be the same for all the alternatives. The extent of these impacts will vary in relation to the amount of sediments cleaned up and the disposal method used. Each of these impacts is discussed briefly below. Because impacts related to cleanup action do not apply to establishment of sediment impact zones, the impacts discussed below apply only to implementation of the cleanup standards.

5.4.1 Water and Air Quality Impacts

Some short-term water quality impacts at cleanup sites and at aquatic disposal sites are anticipated from dredging sediment at contaminated sites and dumping sediments through the water column at 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 sediments disturbed during cleanup activities). While these impacts are expected to be temporary under all four alternatives, they would be of longer duration under the more stringent standards, which would require cleanup 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.

No significant air quality impacts are anticipated as a result of contaminated sediment cleanup activities under any of the four alternatives. 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 sediments may release volatile contaminants into air and water. While the impacts associated with such releases would be greater under the more stringent cleanup standards, they are expected to be insignificant under all four of the alternatives.

5.4.2 Plant and Animal Impacts

Sediment excavation or capping may result in habitat destruction and removal or burial of benthic organisms. The benthic environment following cleanup activities may not be hospitable for species previously present. In general, the types of impacts on plants and animals resulting from cleanup activities will be the same under the four alternatives. However, it is expected that activities required to meet a more stringent alternative (i.e., Alternative 1 or 2) would result in greater short-term impacts on plants and animals. Specific types of impacts are discussed below.

5.4.2.1 Plankton Species

Material suspended through the water column during cleanup operations could impact marine phytoplankton by either promoting or inhibiting primary production. Mixtures of organic and inorganic material suspended in the water column can interfere with photosynthesis by shielding light and can stimulate growth by raising inorganic nutrient levels above ambient levels. Suspended materials can also adhere to cell surfaces, thereby interfering with gas and nutrient transport across the cell wall, possibly leading to mortality of affected organisms. Finally, contaminants released during cleanup operations could inhibit photosynthesis by interfering with metabolic pathways.

In addition, zooplankton could be impacted during cleanup activities in two ways. First, suspended particles may physically interfere with feeding mechanics. Second, suspended particles may dilute the concentration of food particles available to zooplankton in the water column. Because turbid conditions associated with cleanup actions are of short duration, the impacts on plankton at the cleanup sites would be localized and of short duration under all four alternatives. Further, because only a small percentage of plankton on an areawide basis would be affected, the impact on the plankton community as a whole is expected to be minimal under all alternatives.

5.4.2.2 Macrophytic Plants

Possible impacts on intertidal and subtidal macroalgae and eelgrass include inhibition of photosynthesis due to reductions in available light and smothering by settling particles. These impacts are expected to be temporary and minimal under all four alternatives. However, physical destruction of macroalgae and eelgrasses resulting from cleanup activities could result in long-term impacts.

Comparisons of Figures 5.1 and 5.2 with Figures 4.2 through 4.14 suggest that areas in which sediment contamination may require cleanup action overlap areas in which major kelp and eelgrass beds are found (e.g., Ruston Shoreline, Eagle Harbor, Everett-Port Gardner). The total area of eelgrass and kelp beds intentionally or otherwise removed during cleanup operations under the four alternatives is not expected to be substantial. However, a greater area will be impacted at sites with more stringent cleanup objectives. Kelp beds can be expected to recover in clean habitats within 6 months to a year following physical disturbance (Foster 1975). Eelgrass is less likely to recover from physical damage. If sediments are altered or if plants suffer extensive damage to rhizomes, the seagrass ecosystem may require 5 years or more of recovery time (Zieman et al. 1984). Because seagrasses and macroalgae provide numerous critical habitat functions for a variety of commercially important fish and invertebrates, mitigative actions to minimize impacts on eelgrass and kelp beds will be addressed in site-specific EISs.

5.4.2.3 Benthic Macroinvertebrates and Megainvertebrates

Benthic macroinvertebrates and mobile bottom-dwelling megainvertebrates such as shrimp and crab may be removed from the sediments during dredging activities or buried during capping activities. In addition, particles suspended during cleanup operations could also accumulate in the gills of local crabs and shrimp, thereby interfering with gill function. Comparisons of Figures 5.3 and 5.10 with Figures 4.2 through 4.14 suggest that major Dungeness crab populations in Bellingham, Everett, and Elliott bays and off Magnolia Bluff may be affected by contaminated sediment cleanup actions, but that major shrimp populations are not at risk in these areas.
It is anticipated that during capping, most mobile bottom-dwelling megainvertebrates will avoid burial by moving out of the area. It is further anticipated that following dredging activities, partial recovery of the benthic macroinvertebrate community will occur rapidly due to recruitment and migration of organisms from surrounding unimpacted areas. Cleanup-related

impacts on these macroinvertebrate communities are expected to be temporary. Impacts will be more significant under the more stringent alternatives.

5.4.2.4 Anadromous and Demersal Fish

During cleanup actions, anadromous and demersal fish may suffer inhibited oxygen exchange resulting from suspended solids clogging gill surfaces. Slightly lowered concentrations of dissolved oxygen availability may be expected due to elevated oxygen demand caused by sediments suspended in the water column during cleanup operations. However, fish are unlikely to suffer toxic effects from exposure to chemicals associated with suspended sediments. Contaminants sorbed to sediment particles are not readily available for absorption across gill surfaces. In general, all of these impacts would be insignificant under all alternatives because fish would typically move away from the cleanup sites.

The food sources of demersal fish located at a site targeted for cleanup action could be temporarily lost due to sediment burial or removal during cleanup operations. The impact of food scarcity on demersal fish populations is expected to be minor because most demersal fish will leave the site during cleanup activities and seek food elsewhere. As previously stated, it is anticipated that the benthic organisms that serve as food to demersal fish will partially recover in a short time following completion of cleanup activities. In addition, dredge and fill activities could be scheduled for periods when juvenile anadromous fish are not feeding and when adults are not migrating through urban bays.

5.4.2.5 Marine Mammals and Water Birds

Because marine mammals generally avoid human activity, they are unlikely to stay at a contaminated site when cleanup operations are ongoing. It is therefore unlikely that any significant impacts on marine mammals would result from cleanup operations under any of the alternatives.

Cleanup activities may impact water birds as a result of temporarily elevated turbidity levels (thereby limiting visibility and making feeding difficult) and loss of prey organisms in the intertidal zone due to effects of suspended sediment material. Because most of the contaminated areas are located in the nearshore environment, these impacts would be most significant on shorebirds. However, birds are highly mobile, and the cleanup site area for any particular cleanup effort represents a small portion of the total available feeding area in Puget Sound. Cleanup impacts on water birds are thus expected to be minimal under all alternatives.

5.4.2.6 Terrestrial Species

Additional upland disposal facilities may be needed if a substantial volume of sediments require upland disposal. In general, the construction of additional upland disposal sites would become more likely as more contaminated sediments require upland disposal.

Impacts on terrestrial plants, wildlife, and birds would result only from the disposal of contaminated sediment material in upland locations. If an upland disposal site is created, existing habitats for terrestrial birds and other wildlife would be destroyed and vegetation would be removed. Sublethal chronic impacts on terrestrial birds could still result from the ingestion of plants and animals that have accumulated contaminants present in the sediment material disposed of at the site. Terrestrial species impacted by disposal site construction would vary with the location of the disposal site. The significance of the impacts would depend on whether there are other similar plants in the general vicinity and whether there is adequate habitat available in the area to assimilate the displaced wildlife.

5.4.2.7 Additional Factors Affecting Impacts on Plants and Animals

The extent of impacts on plants and animals expected to result from cleanup activities should be assessed on a site-by-site basis by performing an ecological inventory of the area to be disturbed. This assessment would be especially useful in identifying any species, particularly any threatened or endangered species, that may suffer adverse impacts from implementation of cleanup activities.

The impacts on plants and animals may be mitigated by restoring the physical and chemical environment of the site to conditions amenable to the original community. Impacts may also be minimized by scheduling cleanup activities to avoid interfering with seasonal uses of critical habitats (e.g., halting cleanup activities during the period when a sensitive species is breeding at the site, when salmon are migrating to spawn, or when juvenile salmon are outmigrating) or by limiting cleanup activities in sensitive habitat areas or in areas where species have difficulty recolonizing.

5.4.3 Human Health Impacts

Onsite 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. Offsite populations may be exposed to contaminants released during cleanup activities.

The impacts on onsite workers can be substantially mitigated through the implementation of site-specific health and safety plans. If significant impacts on offsite populations 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 all 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, transportation-related injuries or fatalities may be a factor at sites requiring long-distance hauling of contaminated sediments from the site 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 sediments in this study. The 4 million ton figure is thus applied here to estimate the number of fatalities that might be expected as a result of cleanup operations under the four alternatives.

Like the Ecology (1990b) analysis, this analysis relies on the following assumptions:

- Fatal accidents involving trucks in Washington state occur at the rate of approximately 1.8 per 100 million miles traveled (DOT 1989)
- The distance traveled during a typical site cleanup is estimated at 300 miles (or 600 miles round-trip), based on the distance from Seattle to the nearest hazardous waste disposal facility in Arlington, Oregon (since most dredged material is not designated as "hazardous waste," this assumption provides a highly conservative analysis)
- The trucks used to transport the contaminated material will carry 22 tons of soil or waste at a time (Cook 1989).

In addition, the following two assumptions are made on the minimum volume of dredged material and choice of a disposal area:

- One dredge-lift of approximately 3 feet (or 1 meter) would be required to remove all contaminated sediments
- All contaminated sediments that are cleaned up are disposed of in upland locations.

In conducting this analysis, an estimation of the volume of sediment requiring cleanup for Puget Sound as a whole was calculated. Using the information developed for the analysis of the 10 case studies, the calculation assumed that the average area per station in Puget Sound equals 190,594 square yards. Multiplying this number by the number of contaminated stations under each of the four alternatives, the following results are obtained:

- 418 stations exceed Alternative 1 levels, for a total of approximately 80 million square yards (418 x 190,594)
- 288 stations exceed Alternative 2 levels, for a total of approximately 55 million square yards (288 x 190,594)
- Approximately 129 stations exceed Alternative 3 and 4 levels, for a total of approximately 25 million square yards (129 x 190,594).

Assuming that all of these contaminated sediments are dredged to a depth of approximately 1 yard and transported to upland sites, the resulting volumes correspond to approximately 100 million tons, over 68 million tons, and over 30 million tons of contaminated sediments, respectively. Assuming that 4 million tons would be transported before one fatality would occur (Ecology 1990b), these amounts of transported materials could result in 25, 17, and 7 traffic-related deaths, respectively. All of these impact levels are considered significant in an absolute sense. Relative to one another, the impacts associated with Alternative 1 are considered more significant than those of Alternative 2, and Alternative 2 impacts would be considered more significant than impacts of Alternatives 3 and 4.

On the other hand, as noted above, the assumptions specific to this analysis result in probable overestimates of the sediment volumes to be transported to upland sites. It is reasonable to assume that the quantity of sediment requiring upland disposal will be smaller than the figures used here, for three reasons. First, because the cost of aquatic disposal will in most cases be significantly less than the cost of upland disposal, aquatic disposal will be used when deemed appropriate on a case-by-case basis. Second, appropriate upland disposal sites are not likely to be available for all sediments to be disposed of in this manner, especially considering recent land-ban restrictions (40 CFR 268.30-.34). Third, as discussed in Chapter 2, sediments that will recover naturally to the MCUL within 10 years may be allowed to do so. Thus, in many cases minimally contaminated sediments may not require any cleanup action.

In addition, while these estimates imply that all contaminated sediments in Puget Sound will be cleaned up as one site, this is not a realistic scenario. Rather, there are many sites in Puget Sound that will addressed individually. The 10 case studies discussed in Chapter 4 provide estimates for the traffic-related injuries or fatalities that might be expected on a site-specific basis. Referring again to Table 4.3, the smallest case-study site (head of Hylebos Waterway) that is retained as a site under the four alternatives contains 386,808 square yards of sediments that exceed Alternative 1 standards. Assuming again that all sediment would be disposed of in upland locations, approximately 480,000 tons of sediment would require transport. Based on 4 million tons transported per traffic fatality, no transportation-related impacts associated with remediating this site under the most stringent cleanup alternative are expected. The risk of transportation-related fatalities would be correspondingly less under the other alternatives requiring less cleanup.

On the other hand, for the largest case-study site (Elliott Bay), over 7,500,000 square yards would require cleanup under Alternative 1. Cleanup of this site could result in over 9,300,000 tons of sediment requiring upland transport. Based on 4 million tons transported per traffic fatality, transport of this quantity of sediment would be expected to result in two traffic-related fatalities. This level of human impact is considered significant. Under Alternative 2 (requiring cleanup of 2,600,000 tons of sediment), and Alternatives 3 and 4 (requiring cleanup of 300,000 tons of sediment), no adverse traffic-related human health impacts would be expected. 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.

5.4.4 Cultural Resource Impacts

Site cleanup may result in impacts on cultural resources to the extent that cleanup activities (e.g., dredging and capping) lower the quality of experience derived from activities such as tribal fishing and shellfish harvesting. However, the impacts resulting from these activities will probably be minimal or completely absent under all the alternatives because of existing regulatory requirements that govern dredge and fill operations. For example, the state departments of Fisheries 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.

Cultural resources such as historical or archeological sites could be affected by land-based disposal of sediments. However, recent 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 sediments. Therefore, impacts on these cultural resources are expected to be minimal. Potential impacts on these cultural resources and means of mitigating and preserving historic properties affected by site cleanup will be addressed in site-specific EISs.

5.4.5 Land Use Impacts

Some impacts on land use would result from the need to store vehicles and equipment close to cleanup sites, and from cleanup activities conducted directly from land when a site is adjacent to the shoreline or within a narrow waterway (e.g., in Commencement Bay). While the duration of these impacts would be greater under the more stringent alternatives, impacts are expected to be temporary and insignificant under all four 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 sediments is of increasing concern to Ecology and the public. Thus, it is likely that a substantial amount of sediments 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 sediments removed during a cleanup action may not be suitable for other economic uses.

5.4.6 Water Use Impacts

Cleanup activities could disrupt the normal uses of the waters of Puget Sound 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, shipping vessels could go around the cleanup equipment. However, cleanup activities in spatially constricted locations, such as near Harbor Island in Elliott Bay (see Figures 4.3 through 4.6), or within the waterways of Commencement Bay (see Figures 4.11 through 4.14) could severely or totally limit the ability of vessels to avoid a cleanup site. Further, Washington state ferry traffic patterns in Elliott Bay and in the vicinity of Eagle Harbor would very likely require rerouting during cleanup activities (see Figures 4.3 through 4.14).

While these impacts would be of a shorter duration under Alternatives 3 or 4, they would be of the same nature under all four alternatives. The only means of mitigating these impacts is to conduct cleanup operations from shore when possible, thereby keeping the shipping lanes and normal ferry routes as clear as possible. However, shore-based cleanup may not be possible when a site is located some distance from shore (e.g., outer Elliott Bay). Further, the decision to work from the shore would in turn increase land use impacts.

The disposal of contaminated sediments on land could also adversely impact groundwater and possibly drinking water supplies. These impacts can be mitigated by careful siting of disposal sites, development of design specifications to limit the transport of contaminants into the environment, and groundwater monitoring. Disposal facility siting and design will be in conformance with all applicable state and federal laws.

5.4.7 Noise and Aesthetic Impacts

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.

Although dredging equipment and marine vessels including tugs and tug-barge combinations may increase noise levels in the vicinity of a contaminated sediment site, it is anticipated that noise 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 EISs.

As shown in Figures 4.2 through 4.14, the areas of sediment contamination tend to be relatively close to the shoreline and near urban areas. Persons located along various shorelines or bluff areas and in many office buildings will therefore be able to view cleanup activities. Aesthetic impacts will be the same under all the alternatives and cannot be easily mitigated. Although the sight of cleanup activities may not be a positive aesthetic experience for some viewers, others will likely view the scene in a more positive sense as both interesting and educational.

5.4.8 Transportation Impacts

In addition to potential traffic fatality impacts discussed above, the disposal of contaminated sediments in upland locations may impact transportation patterns and volumes. 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. 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 all the alternatives, although the extent of impact could increase as more sediments are 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.

The impacts that might be associated with long-distance trucking can be estimated by comparing normal traffic volume statistics with the number of truckloads needed to haul the waste from a contaminated site. For the purpose of illustration, the figures set forth in the largest case study (outer Elliott Bay) are used for this analysis.

Relying on the analysis of traffic volume statistics developed by Ecology (1990b), it is estimated that an approximate total of 980,000 combination trucks pass any point on Interstate-5 each year. As noted above, if all contaminated sediments were disposed of in upland locations, the case study for outer Elliott Bay would require the transport of over 9 million tons of material under Alternative 1, approximately 2.6 million tons under Alternative 2, and approximately 300,000 tons under Alternatives 3 and 4. Assuming that a typical truck carries 22 tons of material (Cook 1989), the alternatives would result in an estimated 400,000, 100,000, and 13,500 truckloads of material, respectively, requiring transport to disposal facilities. It is estimated that a minimum of 5 years would be required for cleanup of a large site such as outer Elliott Bay.

Based on these figures, Alternative 1 could result in a significant increase (8 percent) in traffic volume along Interstate-5 or other major transportation routes. Alternative 2 could result in a smaller but still significant (2 percent) increase. Finally, Alternatives 3 and 4 could result in a minimal but not significant (0.3 percent) increase in traffic volume. This analysis is conservative because it is highly unlikely that these quantities of sediment would be disposed of in upland locations, for the reasons discussed above in relation to traffic injury and fatality impacts.

Site cleanups may also have impacts on commercial shipping and ferry traffic patterns. These impacts are discussed in more detail under *Water Use Impacts* above.

5.5 Programmatic Impacts

Impacts on other state programs and state resource use resulting from incorporation of the four alternatives into the source control and cleanup standards are referred to as *programmatic impacts*. These impacts vary with the stringency of the various alternatives, which in turn influences the extent and type of source control or cleanup to be undertaken.

Depending on the alternative selected for the source control standards and cleanup standards, unconfined, open-water disposal under PSDDA could be impacted. The biological and chemical criteria defining sediments as acceptable for unconfined, open-water disposal are described in further detail in Chapter 2.

Alternative 1 defines lower chemical concentration and biological response levels than those allowed at PSDDA open-water disposal sites. Therefore, if Alternative 1 is selected, some or all of the PSDDA disposal sites would be considered contaminated sites requiring consideration of cleanup under the contaminated sediment cleanup standards. Alternative 2 defines chemical concentration and biological response levels approximately equivalent to those allowed at PSDDA disposal sites. Selection of this alternative would therefore be consistent with existing PSDDA guidelines. Finally, Alternatives 3 and 4 define chemical and biological response levels that in most cases are less stringent than those at PSDDA disposal sites. The selection of either one of these alternatives could result in adverse effects on navigation dredging by allowing sediment impact zones that overlap navigation lanes to accumulate sediments exceeding PSDDA disposal guidelines.

Although in-place capping or other aquatic disposal activities can occur in a contaminated sediment cleanup action, it is likely that at least a portion of the contaminated sediments will require upland disposal at approved disposal facilities. There are relatively few disposal locations available for this material. Disposal of sediments in upland locations would thus result in competition for disposal space with solid and hazardous wastes generated from ongoing activities or from the cleanup of land-based hazardous waste sites.

The stringency of the selected alternative may affect the timing of source control and cleanup activities because of demands on state resources. The more stringent alternatives would put a greater demand on limited state personnel and monetary resources because the adequacy of source controls for a greater number of discharges would require investigation and monitoring. Similarly, under more stringent alternatives, 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 discharges and sites posing the greatest risks to human and environmental health. However, all discharges and sites considered contaminated under the selected alternative would require some time and money initially, in order to determine their priority ranking relative to the other discharges and sites of concern.

The stringency of the selected alternative may also affect the willingness of the liable parties to accept the need for additional source controls or to participate in site cleanup. Standards that are perceived as unnecessarily strict could inhibit voluntary source control and cleanup response actions. 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 also result in a delay in responding to the contamination problem.

5.6 Summary of Unavoidable Adverse Impacts

The following unavoidable adverse impacts have been identified in the preceding discussion:

- Alternatives 2-4 would allow some sediments to remain in place that have chemical concentrations exceeding sediment quality standards. These sediments would be confined to sediment impact zones and to sediments within cleanup sites that would be expected to recover naturally over a period of time to the sediment quality standards, once source control is achieved or cleanup is accomplished. Because these sediments are allowed to remain in place, biological impacts are likely to occur during the period that a sediment impact zone is allowed and/or until sediments remaining at cleanup sites recover naturally to sediment quality standards. Under Alternative 2, these biological impacts are expected to be minor. Under Alternatives 3 and 4, the potential biological impacts are considered significant.
- Impacts on commercial, recreational, and tribal fisheries and cultural resources are directly tied to potential biological and human health impacts. Because the biological impacts under Alternatives 3 and 4 are potentially significant, there may be impacts to fisheries and cultural resources under these alternatives. Although these impacts would be localized to the vicinity of sediment impact zones and contaminated sediment sites, considered cumulatively the impacts could be significant. Although human health-based sediment quality standards are still under development, the rule contains a provision requiring site-specific assessments of risks to human health that are intended to mitigate human health impacts on a site-specific basis.
- 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 standards are chosen. Because of the high level of impacts resulting from increased traffic, resource use, and need for landfill capacity associated with cleanups under Alternative 1, short-term remedial impacts under this alternative are considered adverse and significant. These impacts will be more fully assessed in environmental impact statements prepared for each individual site.
- Under any 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. The proposed rule will also result in additional permitting and monitoring costs for sediment impact zones. These costs are not considered significant (i.e., less than 1 percent of sales).

6 Evaluation of the Alternatives

6.1 Introduction

In this chapter the four alternatives for implementation of the Sediment Management Standards are evaluated. Based on this evaluation, a preferred alternative is selected. Each alternative is discussed under several discrete criteria and is assigned a score of high, medium, or low depending on how well the requirements of each criterion are met. The results of this evaluation are then used as the basis for selecting the preferred alternative. A tabular summary of the scores assigned under each set of criteria is provided at the end of this chapter.

The criteria used in this evaluation are divided into three categories. First are the threshold criteria, which include protection of human health, protection of the environment, and compliance with applicable or relevant and appropriate requirements (ARARs). Because these criteria reflect requirements or goals of MTCA and the PSWQA Plan, they receive the most weight in the evaluation.

The second set of criteria are referred to as balancing criteria. These criteria include technical feasibility, scientific certainty, and cost effectiveness. These criteria represent practical considerations that arise when implementing an alternative in the source control and cleanup standards. Although recognized as important, these criteria receive less weight in the evaluation than the threshold criteria.

Regulatory precedence is the final criterion considered in the evaluation. This criterion is referred to as a modifying criterion, and it relates to the defensibility of the rule and its consistency with other regulations. This criterion 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.

Under most of these criteria, a single evaluation of an alternative applies equally to both the source control and cleanup standards sections of the rule. However, when appropriate, an alternative is evaluated separately for each of these processes.

6.2 Threshold Criteria

In this section, the four alternatives are evaluated with respect to requirements or goals of MTCA and the PSWQA Plan, expressed by three threshold criteria for protection of human health, protection of the environment, and compliance with ARARs.

6.2.1 Protection of Human Health

The chemical concentrations identified under the four alternatives are based on associations with adverse biological effects. As noted earlier, these environmental effects have not been correlated to human health effects. Even under Alternative 1, an analysis of human health risks would necessitate some site-specific analysis. For example, contaminants such as PCBs or mercury may bioconcentrate in aquatic species without causing adverse biological effects, yet these elevated contaminant concentrations may pose health risks to humans consuming fish and shellfish from contaminated areas. Alternatively, contaminants such as copper are highly toxic to aquatic organisms, yet have low toxicity to humans.

Although Alternative 1 is likely more protective of human health than Alternative 4, no definitive statement on absolute health risks of the alternatives can be made. However, it is reasonable to conclude that as chemical concentrations of carcinogens increase, risks to human health increase as well. Similarly, it is reasonable to assume that as more sediments require cleanup, the risks to human health associated with cleanup activities also increase.

Because the degree to which any of the alternatives is protective of human health 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 human health risks associated with cleanup activities are also considered. However, it is assumed that the human health risk associated with exposure to residual contamination is greater than the risk associated with cleanup activities, because the risk associated with cleanup activities can be mitigated to some extent by site health and safety plans. Thus, the human health risk associated with exposure to residual contamination receives a greater weight than that associated with remedial activities.

Table 2.2 shows the alternative concentrations for contaminants that exceed the sediment quality standards in Puget Sound. For over 70 percent of these contaminants, all four alternative concentrations fall within an order of magnitude of one another (for five contaminants, the standards would be the same under all four alternatives). The alternative concentrations for the remaining 30 percent of contaminants (13) fall within 2 orders of magnitude of one another.

Assuming constant exposure, models for assessing carcinogenic risks to human health (including those models proposed for use under MTCA for soils and groundwater) typically assume a linear relationship between increasing chemical concentrations and increasing risks to human health (U.S. EPA 1989b). Because human health risk assessment contains many assumptions and uncertainties, differences in estimated risk of less than an order of magnitude are not generally considered significant (Food Safety Council 1980). Therefore, for the 70 percent of contaminants for which the alternative concentrations fall within an order of magnitude of one another, the relative human health risks of the alternatives cannot be distinguished. For the remaining 30 percent of contaminants, the relative risks associated with the alternatives are expected to increase with increasing chemical concentration. The alternatives for this 30 percent are ranked using the following scores:

- **Low:** The human health protection provided by the alternative is unknown, but health risks associated with consumption of resources chronically exposed to sediments with this level of chemical contamination are more than an order of magnitude greater than under other alternatives for many contaminants. The removal or capping of sediments requiring cleanup under the alternative could pose a substantial risk to human health.
- **Medium:** The human health protection provided by the alternative is unknown, but health risks associated with consumption of resources chronically exposed to sediments with this level of chemical contamination are more than an order of magnitude greater than under other alternatives for a few contaminants. The removal or capping of sediments requiring cleanup under the alternative could pose a moderate risk to human health.
- **High:** The human health protection provided by the alternative is unknown, but health risks associated with consumption of resources chronically exposed to sediments with this level of

chemical contamination are among the lowest of the alternatives for all contaminants. The removal or capping of sediments requiring remediation could pose little risk to human health.

By definition, Alternative 1 (the sediment quality standards) represents the level of contamination at which no significant adverse biological effects are expected. Direct effects on human health may also be limited by implementation of this alternative. While this alternative is not necessarily fully protective of human health, it is the most protective of the four alternatives, because the standard for each contaminant would be set at a concentration equal to or lower than that allowed under the other alternatives. However, implementation of this alternative could result in remediation of a substantial area of contaminated sediments, potentially up to 80 million square yards, with a coincident elevated threat to human health resulting from cleanup activities. Combining these positive and negative aspects, Alternative 1 is assigned a high value for protection of human health from effects of residual contamination, and a low value for protection of human health during cleanup activities. Therefore, Alternative 1 is assigned a combined score of medium under this criterion.

Alternative 2 represents the level of contamination at which no more than minor adverse biological effects are expected. For a few contaminants, health risks under Alternative 2 would be more than an order of magnitude greater than under Alternative 1. However, implementation of this alternative would result in cleanup of a smaller area of contaminated sediments (potentially a maximum of 55 million square yards) relative to Alternative 1, resulting in a significantly decreased threat to human health from cleanup activities. Combining these two factors, Alternative 2 is also assigned a score of medium for protection of human health.

Alternatives 3 and 4 are based on the chemical concentrations above which sediments in all four biological tests would exhibit adverse biological effects of varying degrees. In many cases, these chemical concentrations are more than an order of magnitude higher than those of either Alternative 1 or 2. The potential for human health effects from consumption of contaminated seafood or direct exposure to contaminated sediments increases as well. The quantity of sediments that may require cleanup under Alternatives 3 and 4 is substantially less than under Alternative 2 (e.g., approximately 25 million square yards may be affected by Alternative 3), but could still result in human health risk during cleanup. Therefore, these two alternatives are assigned a low score for protection of human health.

6.2.2 Protection of the Environment

For the purposes of this analysis, the alternatives are evaluated in terms of the degree to which they provide long-term environmental protection, as measured by biological test results. The alternatives are ranked using the following scores:

Low: The chemical concentrations allowed under the alternative correspond to at least a moderate degree of adverse biological effects as measured by biological test results
Medium: The chemical concentrations allowed under the alternative correspond to a minor degree of adverse biological effects as measured by biological test results
High: The chemical concentrations allowed under the alternative correspond to very low, if any, adverse biological effects as measured by biological test results.

As noted above, no significant adverse biological effects are associated with the chemical concentrations representing Alternative 1 (the sediment quality standards) as determined by the four biological tests performed to date on Puget Sound sediments. Alternative 1 is therefore assigned a high score for protection of the environment.

No more than minor adverse biological effects are expected under Alternative 2, which is assigned a score of medium. Alternatives 3 and 4 are assigned a score of low because both alternatives could result in at least moderate (and in some cases severe) adverse biological effects in Puget Sound.

6.2.3 Compliance with ARARs

This criterion is used to evaluate whether the alternatives would allow chemical concentration levels that are at least as stringent as levels associated with available ARARs addressing source control and contaminated sediment cleanup standards. The alternatives are ranked using the following scores:

- **Low:** The alternative would be less stringent than all available ARARs
- **Medium:** The alternative would not be as stringent as some available ARARs
- **High:** The alternative would be at least as stringent as all available ARARs.

Federal laws and regulations have not yet been adopted to designate national sediment quality standards, allowances for sediment dilution zones or impact areas around source discharges, or sediment contamination cleanup levels. Site-specific cleanup standards have been developed for the Commencement Bay Superfund project and are being developed for the Eagle Harbor Superfund project. These site-specific values are not specifically ARARs but have been considered in the development of the alternatives. For example, the sediment quality objective for the Commencement Bay Superfund site is comparable to the sediment quality standards. A remedial action level was determined for this site by allowing for a 10-year recovery factor, which ranged between 1.2 and 2.9 times the sediment quality objective. The concentrations identified in the record of decision (U.S. EPA 1989a) for this remedial action level generally range between the Alternative 2 and 3 levels, depending on the specific chemical and problem area.

Note: All sediment quality objectives listed in the Commencement Bay record of decision (U.S. EPA 1989a) for nonpolar organic compounds are expressed in terms of µg/kg dry weight of sediment. The sediment quality standards for this class of compounds are expressed as mg/kg organic carbon.

Note: Exceptions are high molecular weight polycyclic aromatic hydrocarbons (HPAH) and PCBs, for which the remedial action levels established in the Commencement Bay record of decision (U.S. EPA 1989a) lie between the sediment quality standards and the Alternative 2 values.

In addition, PSDDA has established disposal guidelines for unconfined, open-water disposal sites that have been addressed in an EIS (PSDDA 1988). The PSDDA guidelines are not ARARs that apply to sediment cleanup standards, but they have been considered in the development of SIZ_{max} alternatives. At the state level, specification of sediment management guidelines and standards is limited to that described in this EIS, except as generally provided for in the PSWQA (1988) Plan. Thus, beyond the provisions addressing these issues in the Sediment Management Standards developed pursuant to the PSWQA Plan and MTCA, there are currently no other ARARs that apply to these issues.

Setting the sediment quality standards as the SIZ_{max} and cleanup standards would maintain sediment quality throughout Puget Sound at a level at least as stringent as those of precedent cleanup decisions. Therefore, Alternative 1 is assigned a high score for compliance with ARARs.

Setting the SIZ_{max} or cleanup standard at concentrations higher than the sediment quality standards, as would be the case with the other three alternatives, would not necessarily establish the standard at levels less stringent than available ARARs. Specifically, the PSWQA Plan recognizes that sediment impact zones or cleanup standards less stringent than sediment quality standards may be necessary to account for technical feasibility. It is also reasonable to evaluate Alternatives 2, 3, and 4 in terms of their consistency with guidelines that address related contaminated sediment issues, such as the PSDDA guidelines for unconfined, open-water disposal of dredged material.

Under PSDDA guidelines, sediments are considered acceptable for disposal at unconfined, open-water sites if they meet the biological criteria of Site Condition II (PSDDA 1989). The PSDDA guidelines are not intended to identify contaminated sediments requiring cleanup. However, this site condition is approximated by the chemical values specified in Alternative 2 and the confirmatory biological testing set forth in the proposed rule. Setting the SIZ_{max}, CSL, and MCUL chemical concentrations and confirmatory biological test results at a level equivalent to that in dredged material considered acceptable for unconfined, open-water disposal under PSDDA would provide for a degree of consistency between these two programs. This consistency would not only be desirable, but may in fact be necessary to successfully implement both programs. Therefore, Alternative 2 is also assigned a high score for compliance with ARARs.

Alternative 3 is conceptually similar to the maximum chemical levels used by PSDDA to identify material for which there is reason to believe that unconfined, open-water disposal may be unacceptable. Dredged material that is contaminated at levels approaching the maximum chemicals levels requires standard biological testing to confirm the acceptability of the material at unconfined, open-water disposal sites. It is anticipated that some of this material would not meet the requirements of Site Condition II specified for these sites. By implementing Alternative 3 as the SIZ_{max}, CSL, and MCUL, sediments could be left in place that later, because of maintenance or other dredging needs, may not be acceptable for disposal at PSDDA unconfined, open-water sites. Because this constraint would reduce the flexibility for managing sediments in Puget Sound, Alternative 3 is assigned a medium score for compliance with ARARs.

Finally, Alternative 4 is assigned a score of low for compliance with existing ARARs or consistency with related programs. The severe biological effects that could occur under this alternative are not consistent with post-remedial action conditions that have been approved in Superfund projects in Puget Sound or with acceptable conditions at PSDDA disposal sites.

6.3 Balancing Criteria

In this section, the four alternatives are evaluated with respect to practical considerations associated with rule implementation. These considerations, defined as balancing criteria, include technical feasibility and enforceability, scientific certainty, and cost effectiveness. The cross-media impacts associated with the effects of sediment contamination on the underlying water column were considered for evaluation as a fourth balancing criterion. However, this criterion was eliminated from the evaluation because short- and long-term impacts on water quality from sediment contamination are expected to be minimal under all alternatives.

6.3.1 Technical Feasibility and Enforceability

Several technical factors will influence the ability to implement the Sediment Managements Standards. For example, the ability to define the size and contamination level of a sediment impact zone will depend in part on the sophistication of modeling. The ability to maintain a particular contaminant level within the confines of a defined impact zone will in turn depend on physical conditions, including local water and sediment dynamics. Monitoring success will depend in part on the ability to distinguish different sources of contamination. The feasibility of cleaning up a contaminated site also will be influenced by physical conditions at the site. For example, the ability to clean up a contaminated site may be limited by water depth, by the influence of currents on capping material, or by wave action on dredging equipment. Further, in sensitive intertidal areas or in shipping lanes, capping may not be a feasible response option.

Although all of these factors are important, they are not evaluated here because they generally apply to all of the alternatives. Contamination equivalent to the levels specified in each alternative occurs at a variety of sites in Puget Sound. Most sites will require a further evaluation of technical feasibility in selecting appropriate actions during implementation of the rule. However, the alternatives differ with regard to the ability to accurately measure compliance with the contamination level allowed in a sediment impact zone, or compliance with a cleanup standard. Thus, technical feasibility is evaluated in terms of whether chemical concentrations identified in the alternatives can be feasibly measured within the authorized impact zone, or in surface sediments following completion of a cleanup plan using best available analytical techniques. (Completion of the cleanup plan may incorporate a 10-year time of compliance, as allowed in the rule.) The enforceability of the source control and cleanup standards would in part be a function of the ability to measure this compliance. These concerns for technical feasibility apply primarily to the measurement of organic compounds. The concentrations for metals specified in Table 2.2 can be readily measured for all alternatives. The alternatives are ranked using the following scores:

- **Low:** The technical feasibility of measuring compliance is limited because many of the chemical concentration levels identified under the alternative fall below practical quantification limits (PQLs) recommended by PSEP for marine sediments, or some chemical levels fall below standard limits of detection (thus special analytical services are required at most sites)

- **Medium:** It is moderately feasible to measure compliance because most chemical concentration levels identified under the alternative fall between the PQLs recommended by PSEP and the contract-required quantification limits (CRQLs) specified by the EPA Contract Laboratory Program (thus special analytical services may be needed at some sites)
- **High:** It is highly feasible to measure compliance because all chemical concentration levels identified under the alternative are higher than the CRQLs used for low-level hazardous waste analyses by the EPA Contract Laboratory Program (thus no more than routine analytical services would be needed at any site).

Quantification limits refer to the ability to measure sediment chemical concentrations with a high degree of analytical confidence. For most organic compounds, the PQL recommended by PSEP is 200 g/kg dry weight or approximately 10 mg/kg organic carbon (assuming an organic carbon content of approximately 2 percent in sediment). The CRQL used for most organic compounds by the EPA Contract Laboratory Program is approximately 600 g/kg dry weight (assuming 50 percent water in sediment) or approximately 30 mg/kg organic carbon. 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. Quantification limits for low-level hazardous waste in the EPA Contract Laboratory Program are routinely achieved by most laboratories and are therefore highly feasible. Quantification limits recommended by PSEP can be achieved by many laboratories but require some additional effort in sample preparation beyond that routinely required under the Contract Laboratory Program. Detection of chemicals at concentrations less than the PQL recommended by PSEP is still feasible (1-2 orders of magnitude additional sensitivity can be readily achieved for many chemicals), but the potential for random error is higher than at the PQL.

All of the values for the 47 chemicals or chemical groups listed in Table 2.2 are higher than limits of detection recommended by PSEP. The values listed in Table 2.2 for three chlorinated benzenes are lower than the PQL (on an organic carbon basis) for all alternatives, and the values for 2-methylphenol are lower than the PQL (on a dry weight basis) for all alternatives. The values for eight chemicals (i.e., 2-methylphenol, 2,4-dimethylphenol, the four chlorinated benzenes, hexachlorobutadiene, and N-nitrosodiphenylamine) fall below the CRQL for all alternatives. These compounds are not widely detected in Puget Sound.

Taking these measurement values and error concerns into consideration, Alternatives 3 and 4 are assigned a medium-high score for technical feasibility. With the eight exceptions noted above for all alternatives, most of the 47 chemical values for Alternatives 3 and 4 exceed the CRQL (adjusted for organic carbon content), often by a significant margin.

Alternative 2 is assigned a medium score for technical feasibility. With the eight exceptions noted for all alternatives, plus values for benzyl alcohol, most of the 47 chemical values for Alternative 2 exceed the CRQL (adjusted for organic carbon content), often by a significant margin. Benzyl alcohol has been detected in several urban bays and is more difficult to measure at low levels than many other organic compounds. In addition to the exceptions noted for all alternatives, the values for benzyl alcohol and 2,4-dimethylphenol under Alternative 2 do not exceed the PQL. Therefore, the technical feasibility of measuring compliance with this alternative is somewhat lower than for Alternatives 3 and 4.

Finally, Alternative 1 is assigned a low score for technical feasibility. In addition to the exceptions noted for other alternatives, the value for hexachlorobenzene (HCB) is below normal limits of detection recommended by PSEP (i.e., approximately 0.5 mg/kg organic carbon assuming 2 percent organic carbon content). The value for butyl benzyl phthalate is also below the PQL, and the value for dibenzofuran is below the CRQL (adjusted for organic carbon content). In addition, the values for acenaphthene and fluorene fall below the CRQL (adjusted for organic carbon content) but above the PQL. Both of these compounds are widely distributed in Puget Sound.

Note: Two percent organic carbon content is an approximate average for all of Puget Sound. However, the organic carbon content of sediments where HCB has been detected in Puget Sound has been substantially higher than 2 percent. This higher organic carbon content resulted in an ability to detect HCB at levels that exceed PSEP guidelines for the limits of detection.

Note: The value for PCBs under Alternative 1 is below the CRQL (adjusted for organic carbon content) for most other organic compounds. However, the quantification limit for PCBs is lower because a more sensitive technique is routinely used for PCB analyses.

6.3.2 Scientific Certainty

As discussed in Chapter 1, the sediment quality standards are identified in the PSWQA Plan as the long-term goal for sediment quality in Puget Sound. The alternative selected for incorporation into the proposed rule should thus be capable of achieving this goal. The criterion of scientific certainty is used to evaluate the alternatives with respect to whether this long-term goal is expected to be reached in an acceptable period of time.

There are several situations in which contaminated sediments will remain in place and be allowed to recover naturally, by either necessity or design. For example, following any cleanup action under Alternative 2, 3, or 4, some residual contamination exceeding the sediment quality standards will be left at a site. Further, the sediment cleanup decision process allows the incorporation of natural recovery into a site cleanup plan, as deemed appropriate by Ecology. This allowance for natural recovery could result in sediments contaminated above the sediment quality standards remaining in place for a reasonable time period even under Alternative 1. Allowance for a sediment impact zone would also result in exceedance of the sediment quality standards for a defined time period under Alternatives 2, 3, and 4. Some sediment contamination may remain in place once the impact zone variance is discontinued.

The scientific certainty that a site will achieve the long-term sediment quality goal within a reasonable period of time is assessed by considering the concentration represented by each of the alternatives. This assessment 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 quality standards, play a major role in determining recovery rate.

To conduct this analysis, a generalized and simplified recovery rate was estimated from an assumed definition of an acceptable time frame for natural recovery and from a general knowledge of sedimentation rates in Puget Sound. Based on case study results, previous work on Commencement Bay contaminated sediments, and the best professional judgment of Ecology, the agency defined 10 years as an acceptable time frame for natural recovery. This value was converted to a recovery factor of approximately 2 on the basis of general conditions observed and evaluated in Commencement Bay (Tetra Tech 1988a). This recovery factor implies that any chemical concentration within a factor of 2 of the sediment quality standards (i.e., 2 times the sediment quality standards) would be expected to achieve the sediment quality standards within 10 years, given typical conditions of natural recovery.

Based on these simplified assumptions, the alternatives are ranked using the following scores:

- **Low:** It is likely that sediments contaminated to the level of the alternative will not recover to the levels of the sediment quality standards in a reasonable time frame (scientific certainty is low)
- **Medium:** It is likely that sediments contaminated to the level of the alternative will recover to the levels of the sediment quality standards in a reasonable time frame (scientific certainty is moderate)
- **High:** It is likely or certain that sediments contaminated to the level of the alternative will recover to the levels of the sediment quality standards at or shortly following remedial action (scientific certainty is high).

Alternative 1 is assigned a high score because this alternative is represented by the sediment quality standards, and there is thus a high scientific certainty that compliance with the long-term sediment quality goal will be achieved. Alternative 2 is also assigned a high score because, for most chemicals, values defined by Alternative 2 are well within a factor of 2 of the sediment quality standards. Therefore, there is a high scientific certainty that implementation of this alternative will result in compliance with the long-term sediment quality goal within a reasonable period of time. Alternative 3 is assigned a score of medium because the values of several chemicals under this alternative exceed the sediment quality standards by more then a factor of 2, and there is only moderate scientific certainty that the sediment quality standards can be achieved within an acceptable period of time. Alternative 4 is assigned a score of moderate to low because the chemical values under this alternative are either equal to or greater than the values under Alternative 3.

6.3.3 Cost Effectiveness

Cost effectiveness is evaluated by comparing the cost or economic consequences associated with implementation of the source control and cleanup standards alternatives. The alternatives are ranked using the following scores:

- **Low:** The alternative could result in a significant economic burden on those bearing the cost of applying for and maintaining a sediment impact zone or those bearing the cost of cleaning up contaminated sites
- **Medium:** The alternative could still result in an economic burden on those bearing the cost of applying for or maintaining a sediment impact zone or those bearing the cost of cleaning

up contaminated sites, but the burden is less than half that for alternatives ranked as low

- **High:** The alternative would not result in a substantial economic burden on those bearing the cost of applying for or maintaining a sediment impact zone or those bearing the cost of cleaning up contaminated sites.

The economic impacts associated with implementation of the Sediment Management Standards are evaluated in an economic impact statement (Ecology 1990a) issued in conjunction with this EIS. As discussed previously, economic impacts associated with sediment impact zones are not expected to be significant under any of the alternatives. Therefore, each of the alternatives is ranked high in cost effectiveness for the source control portion of the rule.

The economic costs associated with implementation of the cleanup decision process will always be significant, no matter which alternative is ultimately selected. Therefore, none of the alternatives is assigned a high score for cost effectiveness of the cleanup portion of the rule. Relying on some basic assumptions regarding the average cost per square yard to cap or remove sediments for disposal, and an average contaminated area per station, an analysis was performed to assess the magnitude and range of cleanup costs.

This analysis was conducted for Alternatives 1, 2, and 3. A quantitative analysis of costs under Alternative 4 has not been performed. However, Alternative 4 is expected to result in a cost slightly lower than or approximately equal to the cost of Alternative 3. Cleanup under Alternative 2 is expected to be approximately 2.2 times the cost of cleanup under Alternative 3. Cleanup under Alternative 1 is expected to be approximately 3.2 times the cost of cleanup under Alternative 3. Because the total costs that could be incurred throughout Puget Sound could exceed $400 million under any of the alternatives, these differences of a factor of 2-3 are considered significant. Therefore, Alternative 1 is ranked low and Alternative 2 is ranked medium in cost effectiveness. Alternatives 3 and 4 are lower in cost than Alternative 2, but the economic burden of cleanup efforts under these alternatives could still be significant. Therefore, these alternatives have been ranked medium-high in cost effectiveness.

The range in costs among alternatives is smaller than the range in costs associated with the specific selection of remedial action under any one of the alternatives. For example, estimates of the total cost for capping versus upland disposal vary by a factor of approximately 4-7. Therefore, site-specific decisions on required remedial actions will be a major factor in determining the final economic impact.

6.4 Modifying Criterion

In this section, the four alternatives are evaluated with respect to public concerns and perceptions, which are addressed through the single modifying criterion of regulatory precedence. Other criteria for public concerns and perceptions are not addressed in this study, because the four alternatives are similar, for example, in their understandability and consistency of application.

6.4.1 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 Sediment Management Standards. A detailed discussion of federal, state, and local laws and regulations related to the proposed rule is provided in Chapter 7. The alternatives are ranked using the following scores:

- **Low:** The alternative is innovative and has not been used in environmental legislation or other environmental programs
- **Medium:** The alternative has been incorporated into environmental legislation or other environmental programs that have somewhat different goals than those in the proposed rule
- **High:** The alternative has been incorporated into environmental legislation or other environmental programs that have the same goals as those in the proposed rule.

Alternative 1 is assigned a high score because no federal regulations designating national sediment quality standards, sediment impact zone standards, or contaminated sediment cleanup standards have yet been adopted, and such efforts at the state level are limited to the sediment quality standards. Thus, to set the SIZ_{max}, CSL, and MCUL values at the same level of chemical contamination as that set forth in the sediment quality standards would be consistent with the long-term sediment quality goal.

Alternative 2 is also assigned a high score for regulatory precedence because of its consistency with other sediment management programs. Although PSDDA does not address source control and site cleanup, it does address issues relevant to the management of contaminated sediments. By setting the SIZ_{max}, CSL, and MCUL values at a level that is functionally equivalent to PSDDA Site Condition II, which is the functional equivalent of Alternative 2, a goal of no more than minor adverse effects would be established for both unconfined, open-water disposal sites and for sites to be regulated under the proposed rule.

Alternative 3 is assigned a medium score for regulatory precedence. The HAET concept has been used by PSDDA to identify a maximum level of contamination that is supported by a preponderance of evidence for adverse biological effects. This maximum level is intended to define the chemical concentrations above which confirmatory biological testing is required under PSDDA (1988). However, this approach has not been used as the basis for cleanup decisions. In particular, remedial action levels established for the Commencement Bay Superfund site are generally lower chemical concentrations than the values that would be established by Alternative 3.

Finally, Alternative 4 is assigned a low score for regulatory precedence because this application of the AET approach (i.e., the severe effects AET, which is defined as a greater than 50 percent response in selected biological tests) has no precedent in any environmental legislation related to sediment management or in other sediment management programs.

6.5 Selection of the Preferred Alternative

The results of the evaluation of alternatives under the threshold, balancing, and modifying criteria are summarized in Table 6.1. Selection of the preferred alternative was made in accordance with procedures outlined in Superfund guidance documents (U.S. EPA 1988c). Based on the conclusions reached in the evaluation process, Alternative 2 was selected for the $SIZ_{max,}$ CSL, and MCUL.

Because the threshold criteria reflect requirements or goals of MTCA and the PSWQA Plan, they receive the most weight in selecting the preferred alternative. Alternatives that clearly do not meet these requirements or goals are considered unsuitable and are not evaluated further. The remaining alternatives are then compared according to their scores under the balancing criteria. Additional alternatives will be removed from further consideration if they do not perform as well as other alternatives under the threshold and balancing criteria. Finally, if appropriate, the scores under the modifying criterion are considered, and the final alternative selection is made.

Both Alternatives 1 and 2 perform well under the threshold criteria, scoring either medium or high in all cases. Both alternatives represent chemical concentrations that reflect adequate environmental protection as evidenced by minimal adverse effects in selected biological tests. Because protection of human health is unpredictable with these alternatives, neither receives a high score under this criterion. However, because of lower residual levels of contamination, Alternatives 1 and 2 are expected to present a lower risk to human health than either of the remaining two alternatives. Finally, while there are few ARARs pertaining to sediment cleanup decisions, both Alternatives 1 and 2 score high in compliance with ARARs. Selection of Alternative 1 as the SIZ_{max}, CSL, and MCUL would be consistent with the sediment quality standards, and selection of Alternative 2 would provide a basis for management of biological effects similar to that of the PSDDA dredged disposal guidelines. Alternatives 1 and 2 are thus retained for further evaluation under the other criteria.

Alternative 3 scores low under two of the threshold criteria. For protection of human health, Alternative 3 receives a relatively low score, because higher risks (ranging from less than 1 order of magnitude to greater than 2 orders of magnitude) may be associated with direct or indirect exposure to sediment contamination under this alternative than under either Alternative 1 or 2. Moderate adverse effects on the environment are expected under this alternative. The level of biological impact allowed under Alternative 3 exceeds that of either Alternative 1 or 2. With regard to its compliance with ARARs, although HAET values were used in developing PSDDA guidance, the associated level of contamination approaches a level that in most cases is unacceptable for unconfined, open-water disposal. Because Alternative 3 scores consistently lower than Alternative 1 or 2 under each of the threshold criteria, which express the basic purposes of the Sediment Management Standards, Alternative 3 is removed from further consideration.

For the same reasons discussed under Alternative 3, Alternative 4 scores low for protection of human health. Alternative 4 also scores low for protection of the environment because of the potential for severe adverse biological effects that could be allowed. Finally, Alternative 4 scores low for compliance with ARARs, because it generally allows higher chemical concentrations than levels allowed by existing guidance for dredged material management or remedial action levels established for a National Priorities List site in Puget Sound. Because Alternative 4 meets none of the primary goals of the Sediment Management Standards, it is removed from further consideration.

Under the balancing criteria, both Alternatives 1 and 2 receive a high score for scientific certainty in achieving the long-term sediment goal for Puget Sound. However, Alternative 2 is stronger than Alternative 1 with respect to technical feasibility and cost effectiveness. These two factors weigh strongly in establishing a flexible sediment management program that can be successfully implemented in Puget Sound. Therefore, Alternative 2 scores higher than Alternative 1 under the balancing criteria. These considerations temper the advantages demonstrated by Alternative 1 under the threshold criteria.

Because regulatory precedence is similar for both Alternatives 1 and 2, Ecology did not find adequate reason to consider the modifying criterion in the evaluation.

Through the evaluation process described above, Alternative 2 was selected over the other alternatives for the SIZ_{max}, CSL, and MCUL standards. The same alternative is selected for each of these sets of standards as a further means of ensuring that related decisions on sediment management are made in a consistent manner. Alternative 2 best meets the stated objectives of the proposal, as described in Chapter 1.

Note: However, the cost effectiveness of all of the alternatives is considered equally high with respect to implementation of source control measures (i.e., sediment impact zones). Differences in cost effectiveness arise primarily because of differences in the volumes of contaminated material that could require cleanup action under the various alternatives.

7 Relationship of Existing Laws and Regulations to the Sediment Management Standards

Many federal, state, and local laws, regulations, and ordinances affect the implementation of the Sediment Management Standards. Some of these programs directly address the management of contaminated material, dredged material, or sediment. Other programs impose requirements that impact the manner in which the rule will be implemented. In addition, the rule will be incorporated into several state programs. The relationship of the rule to each of these types of programs is discussed in the following sections.

7.1 Federal Programs

7.1.1 Federal Water Pollution Control Act (Clean Water Act)

The goal of the Clean Water Act (42 U.S.C. 1251 et seq.) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Several requirements of the statute and the implementing regulations apply to the implementation of both the cleanup standards and the source control standards under the proposed rule. The most relevant requirements are discussed in the following sections.

7.1.1.1 Section 401

Clean Water Act Section 401 requires the state to certify that any project (e.g., dredging and dredged material disposal) that may result in any discharge into navigable waters will comply with the effluent limitations required under the statute [401(1)]. The permit may also be conditioned to assure compliance with state water quality standards [401(2)].

State certification under Section 401 is granted (or denied) by Ecology. Chapter 173-201 WAC sets forth the details of the state water quality standards. With the exception of federal Superfund sites, a Section 401 certification is required for active cleanup of contaminated sites. The Sediment Management Standards will be applied through the 401 certification to this type of cleanup action.

7.1.1.2 Section 402

Clean Water Act Section 402 establishes requirements for point-source discharge permits (i.e., NPDES permits) for pollutant discharges into navigable waters. In general, point-source discharges must be conditioned not to exceed the effluent limitations set forth in the statute. The NPDES permits are implemented through regulations codified at 40 CFR 122. Effluent limitations and standards for toxic pollutant effluents are codified at 40 CFR 129.

Ecology currently administers the federal NPDES permit program (for nonfederal facilities, Chapter 173-220 WAC). Dischargers are required to obtain a discharge permit under either the federal NPDES permit process or the state effluent discharge permit process (Chapter 173-216 WAC; see Water Pollution Control Act under *State Programs* below). For discharges requiring a sediment impact zone, the authorization, conditions, and monitoring requirements will be included in the discharge permit.

7.1.1.3 Section 404

Clean Water Act Section 404 establishes guidelines and requirements pertaining to the discharge or disposal of dredged material into specified disposal sites in waters of the United States. Under

Section 404(a), a permit is required for the discharge of dredged or fill material into navigable waters at specified disposal sites, which are to be designated in accordance with guidelines established pursuant to Section 404(b) (40 CFR 230). The guidelines for issuing permits for discharges of dredged or fill material are specified in 33 CFR 320-330.

Except for federal Superfund actions, the Section 404 permit will be required in the case of capping a contaminated sediment site (i.e., dredged material discharge) or when contaminated sediments removed from a site are disposed of in aquatic or nearshore environments. The U.S. Army Corps of Engineers also has responsibility for processing the dredging permits required under Section 10 of the Rivers and Harbors Act of 1899 (discussed below).

7.1.2 Comprehensive Environmental Response, Compensation and Liability Act

CERCLA (42 U.S.C 9601 et seq.), as amended by the Superfund Amendments and Reauthorization Act (SARA), establishes a program for investigation and response to the release or threatened release of hazardous substances from inactive hazardous waste sites, on both land and water. The purpose of these activities is to ensure that contaminated sites are cleaned up by responsible parties when possible. When a responsible party cannot be located or cannot complete the cleanup, CERCLA/SARA provides for cleanup to be conducted by the government. CERCLA/SARA sets up a hazardous substance trust fund (Superfund) that provides up-front money to pay for cleanup actions. CERCLA/SARA also sets forth enforcement and cost recovery provisions that enable the public trustees to pursue recovery of cleanup costs from responsible parties.

Section 121, Cleanup Standards, contains the primary CERCLA/ SARA provisions addressing cleanup issues. This section defines the basic requirements to be met by cleanup actions, i.e., protection of human health and the environment, cost effectiveness, and compliance with the National Contingency Plan. Treatment of hazardous substances to reduce their volume, toxicity, and mobility is a preferred cleanup response. Under MTCA, state cleanup standards must be at least as stringent as all applicable state and federal laws. In particular, the state cleanup standards must be at least as stringent as these developed pursuant to CERCLA Section 121 [70.105D.030(2)(d) RCW].

A Superfund contaminated sediment site that is receiving federal funding and cleanup assistance (e.g., Commencement Bay, Harbor Island, Eagle Harbor) must meet all CERCLA/SARA cleanup requirements. In addition, the SMS rule will become an ARAR for federal Superfund sites and will thus apply to all federal sites in the state as well.

The proposed rule will also be incorporated by reference in the sediment section of the MTCA cleanup rule. Thus, the requirements of the SMS will apply to the cleanup of those contaminated sediment sites that are subject to MTCA, the state Superfund statute.

7.1.3 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901 et seq.), as amended by the Hazardous and Solid Waste Amendments of 1984 (40 CFR 280), and implemented under federal regulations (including, primarily, 40 CFR 260-40 CFR 271), creates the federal program for managing solid and hazardous wastes. This program identifies materials to be considered hazardous wastes and regulates the generation, treatment, storage, and disposal of both solid wastes and identified hazardous wastes. CERCLA Section 121(d)(2)(A)(i) identifies RCRA as an ARAR for evaluating the appropriateness of cleanup actions at a contaminated site. Ecology has responsibility for implementing most aspects of the federal RCRA program.

Washington state has also enacted legislation and implementing regulations that address the management of solid, hazardous, and dangerous wastes. Responsibility for implementing most of the solid waste aspects of the state program has been delegated to local governments. 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. However, because the requirements of the state program are, in some respects, more stringent than those of the federal program, only the state requirements apply in most cases. The state solid and hazardous waste management program is discussed in more detail under *State Programs* below.

7.1.4 Coastal Zone Management Act

The Coastal Zone Management Act of 1972 as amended (16 U.S.C 1451 et seq.) establishes a national policy to preserve, protect, develop, and, where possible, restore or enhance the resources of the nation's coastal zone. This statute establishes a framework for states to develop and implement state shoreline management programs (e.g., the Shoreline Management Act, Chapter 90.58 RCW). The state in turn has the authority to delegate this responsibility to local governments (e.g., the Tacoma Shoreline Master Program). When a state has its shoreline master program approved by the federal government, this program then supersedes the requirements of the Coastal Zone Management Act. The Shoreline Management Act has been approved and therefore supersedes the requirements of the Coastal Zone Management Act. The requirements of this act (and the local programs) as they apply to the SMS rule are discussed under *State Programs* below.

7.1.5 River and Harbors Act

The most important portion of the River and Harbors Act of 1899 (33 U.S.C. 401 et seq.) for the purposes of the proposed rule is Section 10, which prohibits the unauthorized obstruction or alteration of any navigable waters of the United States. Section 10 requires a recommendation from the Chief of Engineers and authorization from the Secretary of the Army (who has delegated approval authority to the Chief of Engineers) for any work affecting the course, location, condition, or physical capacity of a waterway. Of particular importance, a Section 10 permit is required for any dredging activity in navigable waters, regardless of the aquatic or upland location of the dredged material disposal site. This requirement contrasts with that of Clean Water Act Section 404 permits.

Contaminated sediment site cleanup actions that may require either dredging in navigable waters or the alteration of navigable waters will require a Section 10 permit. The U.S. Army Corps of Engineers administers both Clean Water Act Section 404 permits (discussed above) and Rivers and Harbors Act Section 10 permits.

7.1.6 Other Federal Laws

The following federal laws and regulations are more tangentially related to implementation of the proposed rule. In general, it is anticipated that source control and cleanup actions conducted pursuant to the rule will meet the requirements of these laws. However, some provisions of these laws may be relevant to the cleanup of particular sites and therefore will need to be considered as appropriate on a case-by-case basis.

- Toxic Substances Control Act (TSCA) (15 U.S.C. 2601 et seq.)
- Safe Drinking Water Act, as amended (42 U.S.C. 300 et seq.)
- Clean Air Act, as amended (42 U.S.C. 7401 et seq.)
- Federal rules for the transportation of hazardous materials
- Occupational Safety and Health Act (OSHA) (29 U.S.C. 651 et seq.)
- Historic Sites, Buildings, and Antiquities Act (16 U.S.C. 461 et seq.)
- Archeological and Historic Preservation Act of 1974 (16 U.S.C. 469 et seq.)
- Abandoned Shipwreck Guidelines (54 Federal Register 13642-658, 4 April 1989)
- Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.)
- Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.)
- Fish and Wildlife Improvement Act of 1978, and Fish and Wildlife Act of 1956 (16 U.S.C. 742 et seq.)
- Fish and Wildlife Conservation Act of 1980 (16 U.S.C. 2901 et seq.)
- Wetlands Protection [33 CFR 320.4(b) and Executive Order 11990, 24 May 1977]
- Protection and Enforcement of the Cultural Environment (Executive Order 11593, 15 May 1971)
- Flood Plain Management (Executive Order 11988).

7.2 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.

7.3 Regional Programs

7.3.1 Puget Sound Water Quality Act

The PSWQA Plan was adopted pursuant to the Puget Sound Water Quality Act (Chapter 90.70 RCW) in December 1986 and was updated in 1989. The PSWQA Plan includes guidelines for the development of a contaminated sediment management program (in particular, Elements P2, P3, S4, S6, S7, and S8). The requirements of the PSWQA Plan that relate to the management of contaminated sediments provide a primary authority for the development of the proposed Sediment Management Standards.

7.3.2 Puget Sound Dredged Disposal Analysis

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. Much of the material removed during dredging is disposed of in Puget Sound. 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 procedures, led in part to the PSDDA (1990) study.

PSDDA establishes guidelines for unconfined, open-water disposal sites for dredged material.

PSDDA has developed comprehensive procedures for the sampling, testing, and evaluation of dredged material to ensure that the dredged material is acceptable for unconfined, open-water disposal. Dredged material that does not meet the chemical and biological guidelines set forth by PSDDA is not accepted for unconfined, open-water disposal. These evaluation procedures are used to assess projects conducted under Clean Water Act Section 401 and 404 guidelines described above.

PSDDA also addresses siting and monitoring requirements for Puget Sound disposal sites. Specific unconfined, open-water disposal site locations are being evaluated, and several have been selected. PSDDA also establishes disposal site management plans to address navigation and discharge conditions of disposal permits. The monitoring requirements set forth by PSDDA are intended to ensure that acceptable conditions at the site are not exceeded and to provide a basis for any necessary adjustments to the PSDDA management plan.
The PSDDA disposal sites are intended for the disposal of routine dredged materials. Therefore, it is unlikely that any sediments excavated as part of a contaminated sediment site cleanup operation would be disposed of at a PSDDA site, unless Alternative 1 were chosen.

7.4 State Programs

7.4.1 Model Toxics Control Act

The MTCA (Chapter 70.105C RCW), the state statute paralleling CERCLA, is designed primarily for the cleanup of sites contaminated by hazardous substances. Like CERCLA, MTCA includes schemes for allocating liability for cleanup costs among parties responsible for releases of 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). The MTCA provides authority for adoption of the Sediment Management Standards 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.

7.4.2 Water Pollution Control Act

Washington state has an antidegradation policy for surface water quality under Chapter 90.48 RCW. Under the authority of Chapter 90.48 RCW and the Clean Water Act, 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 Clean Water Act goals. As noted above, Clean Water Act 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 (see discussion of Clean Water Act above).

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 Clean Water Act 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 proposed rule will be used by Ecology in establishing the necessary levels of environmental protection when issuing wastewater discharge permits. In particular, the potential impacts to receiving-water sediment quality will be considered in establishing permit treatment requirements and permit effluent limitations. In all cases, all effluent discharges must be conditioned with AKART in order 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 and to assess potential impacts on the environment from wastewater, stormwater, combined sewer overflow, and nonpoint discharges.

Washington also has an antidegradation policy for groundwater quality under Chapter 90.48 RCW. Generally, 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).

7.4.3 Aquatic Lands Act

The Aquatic Lands Act (Chapter 79.90 RCW) gives the Department of Natural Resources 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. The department approves the use of an open-water disposal site if a) there is no practical upland disposal alternative, or aquatic disposal would be beneficial (e.g., beach enhancement), b) all necessary federal, state, and local permits have been acquired, and c) the material has been found acceptable for in-water disposal.

The Department of Natural Resources also manages a lease program for state-owned aquatic lands. 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.

7.4.4 Hydraulics Act

The Hydraulics Act (Chapter 75.20 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 departments of Fisheries 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. If contaminated sediment cleanup activities would result in such impacts, a hydraulic project approval would be required.

7.4.5 Shoreline Management Act and Local Shoreline Master Programs

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.

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

7.4.6 Solid and Hazardous Waste Management Laws

The state program applicable to management of waste sediment depends on the categorization of the waste. 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. 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). Priorities for waste management and state grant funding are established in the following order:

- Waste reduction
- Recycling
- Treatment
- Energy recovery or incineration
- Solidification
- Landfilling.

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. 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 Clean Water Act 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. Ecology is currently preparing revised rules addressing dredging and disposal of sediments. These rules would modify current disposal procedures and requirements.

Unlike the solid waste regulations, the dangerous waste regulations (Chapter 173-303 WAC) require generators of dangerous waste to comply with labeling, manifesting, tracking, reporting, and recordkeeping requirements. If contaminated sediments are designated dangerous, the manner in which they are handled and disposed of would be regulated under the Hazardous Waste Management Act (Chapter 70.105 RCW) and implementing regulations.

7.4.7 Archeological Sites and Resources Act

Some provisions of the Washington State Archeological Sites and Resources Act (Chapter 27.53 RCW) 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.

7.5 Local Ordinances And Permit Requirements

As discussed above under *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, local health department regulations) that will be applicable to implementation of the Sediment Management Standards. Because the type and number of these permits and ordinances varies from jurisdiction to jurisdiction, requiring evaluation on a case-by-case basis, these permit and ordinance requirements are not discussed in this document.

8 Public Participation

Ecology encourages the public to actively participate in the development of all rules. To facilitate public comment on the Sediment Management Standards, the department has conducted a wide variety of public activities in an attempt to raise public awareness and secure meaningful involvement early and throughout the development process. These activities have included:

- Public presentations and workshops
- Mailings of information sheets, early versions of the draft rule, and related technical reports
- Participation through several technical and policy work groups.

Ecology will continue to pursue public review and involvement in sediment management activities prior to and after rule adoption.

8.1 Public Participation in Development of the Sediment Management Standards and Environmental Impact Statement

8.1.1 Early Public Review

Public involvement in the Sediment Management Standards began during development of the PSWQA Plan. In 1986, the Authority convened an advisory committee to assist in the preparation of a plan to address contaminated sediments and dredging activities in Puget Sound. Preparation of an EIS and public review of the draft PSWQA Plan were key events that helped shape later Ecology sediment management activities.

Although Ecology became active in sediment management programs in the late 1970s, rule development efforts did not begin until 1987. Initial public comment on the rule development work was requested via a March 1988 preliminary draft of the sediment rule. Four public workshops were held during 1988 to obtain comments on the proposed rule. One of these workshops was dedicated to discussing and obtaining technical comments on the draft rule. Using the comments from the workshops, Ecology distributed a revised draft of the rule for public comment in September 1988.

During this time, Ecology developed a mailing list of individuals and organizations interested in sediment management activities. The list is used to distribute meeting notices, information updates, technical reports, and draft rules.

8.1.2 Work Groups and Advisory Groups

As a result of comments received during the 1988 workshops, Ecology convened the Sediment Advisory Group to address issues raised by the draft rule. The group met regularly between August 1988 and February 1990 as an open forum attended by representatives of agencies, tribes, cities, industry, and environmental groups, as well as legal and technical consultants. In addition to reviewing development reports, the group assisted Ecology in defining and evaluating key policy issues for the rule. Ecology prepared an issue paper to respond to these issues (Ecology 1989b).

Early versions of the sediment rule contained only the sediment quality standards (i.e., chemical values and biological response levels) and did not address the use of these standards in source control (i.e., discharge permits) or contaminated sediment cleanup actions. In the course of the Sediment Advisory Group meetings, Ecology decided to expand the scope of the rule to address source control and cleanup, which led to the decision to prepare an EIS for the rule.

The public was notified of the intent to prepare an EIS by distribution of a notice to those on the mailing list and by publication of a declaration of significance in the 7 July 1989 SEPA Register. Public scoping meetings were held in August 1989 to obtain comments on the alternatives and possible environmental consequences to be evaluated in the draft EIS.

In December 1989, Ecology distributed the *Interim Sediment Quality Evaluation Process* (Ecology 1989a), an agency policy document that established interim technical guidance for sediment-related decisions pending completion and adoption of the rule.

To assist in preparing the proposed rule, Ecology established the Sediment Management Standards Work Group in March 1990. Select members of the Sediment Advisory Group were asked to participate in final resolution of rule policy and language issues. The group included a balanced representation of environmental protection and economic development interests. Ecology prepared a written response to all work group recommendations and included all consensus views in the proposed rule (Ecology 1990c).

Ecology has actively coordinated with tribal nations interested in Puget Sound sediment management activities. Comments on development documents and the draft rule have been requested routinely from tribal interests. A workshop for Puget Sound tribes was conducted in March 1990, and one tribe has participated consistently in Ecology's sediment advisory groups. In addition to the activities described above, presentations and workshops on sediment management activities have been conducted for a wide variety of groups over the past 2 years.

8.1.3 Coordination with Other Ecology Programs

During development of the proposed rule, Ecology has worked to ensure close coordination among the various programs managed by the department. Through this coordination, Ecology has attempted to establish rule requirements that will work efficiently and effectively among all programs.

An implementation plan has been developed that describes the use of the sediment rule in Ecology programs for water quality, shorelands, solid and hazardous waste management, toxics cleanup, and environmental investigations. The rule has been reviewed and revised to ensure consistency with Ecology's rules for groundwater quality, surface water mixing zones, and the MTCA process and cleanup standards. The relationship of the rule to dredging and dredged material disposal programs (e.g., PSDDA) has also been clarified in the rule.

8.2 Public Review of the Proposed Rule and the Environmental Impact Statement

Ecology began formal review of the proposed Sediment Management Standards on 24 September

1990. The draft EIS and the draft economic impact statement for the proposed rule (Ecology 1990a) received concurrent public review. The deadline for written comments was 5 November 1990. Verbal comments were received at public hearings in Bellingham on 23 October 1990 and in Seattle on 24 October 1990.

The draft EIS was prepared to inform the public about the environmental consequences of the proposed rule and to request public comment on the alternatives being considered for the rule. Before development of the final rule, all comments were reviewed and considered by Ecology. A summary of the comments received by Ecology and Ecology's responses to the comments are available in conjunction with this EIS.

8.3 Future Opportunities for Public Involvement

After rule adoption, public review and participation will be an ongoing and important feature of sediment management decisions.

Use of the Sediment Management Standards in source control programs will result in public review of sediment monitoring requirements and sediment impact zone conditions contained in draft NPDES and state waste discharge permits. The rule also will require public review of proposed cleanup decisions at contaminated sediment sites. In addition, Ecology will maintain an inventory of sediment quality conditions in Puget Sound that will be distributed to the public via periodic reports.

To ensure consistent and effective implementation of the rule, Ecology will develop implementation guidance documents to help Ecology permit writers and site cleanup managers with sediment-related decisions. Ecology will establish an external advisory group to assist in preparing these documents. Representatives of industry, municipalities, tribes, environmental groups, and other agencies will be asked to participate in this advisory group.

9 References

Barrick, R.C., D.S. Becker, L. Brown, H. Beller, and R.A. Pastorok. 1988. Sediment quality values refinement: 1988 update and evaluation of Puget Sound AET. Volume 1. Final report. Prepared for Tetra Tech, Inc. and the U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA. PTI Environmental Services, Bellevue, WA. 74 pp. + appendices.

Becker, D.S., T.C. Ginn, and G.R. Bilyard. 1988. Field validation of sediment bioassays at a marine Superfund site: Commencement Bay, Washington. pp. 323-328. In: Superfund '88: Proceedings of the Ninth National Conference. Hazardous Materials Control Research Institute, Washington, DC.

Becker, D.S., R.A. Pastorok, R.C. Barrick, P.N. Booth, and L.A. Jacobs. 1989. Contaminated sediments criteria report. Prepared for Washington Department of Ecology, Olympia, WA. PTI Environmental Services, Bellevue, WA. 97 pp. + appendices.

Beckman Instruments. 1982. Microtox system operating manual. Beckman Publication No. 015-555879. Beckman Instruments, Inc., Carlsbad, CA.

Bulich, A.A., M.W. Greene, and D.L. Isenberg. 1981. Reliability of the bacterial luminescence assay for determination of the toxicity of pure compounds and complex effluents. pp. 338-347. In: Aquatic Toxicology and Hazard Assessment: Proceedings of the Fourth Annual Symposium. ASTM STP 737. American Society for Testing and Materials, Philadelphia, PA.

Calambokidis, J., S.M. Speich, J. Peard, G.H. Steiger, and J.C. Cubbage. 1985. Biology of Puget Sound marine mammals and marine birds: Population health and evidence of pollution effects. NOAA Technical Memorandum NOS OMA 18. National Oceanic and Atmospheric Administration, Rockville, MD. 159 pp.

Chapman, P., and J. Morgan. 1983. Sediment bioassays with oyster larvae. Bull. Environ. Contam. Toxicol. 31:438-444.

Cook, A. 21 November 1989. Personal Communication (telephone conversation with R. Schoof, PTI Environmental Services, Bellevue, WA). Chemical Processors, Inc., Seattle, WA.

Crecelius, E.A., N.S. Bloom, and J.M. Gurtisen. 1984. Chemical analysis of sediment cores from the East Waterway (Everett, Washington). Final Report. PNL-5045. Prepared for U.S. Army Corps of Engineers. Pacific Northwest Laboratory, Battelle Memorial Institute, Sequim, WA. 31 pp.

Dinnel, P.A., and Q.J. Stober. 1985. Methodology and analysis of sea urchin embryo bioassays. Circular No. 85-3. University of Washington, Fisheries Research Institute, Seattle, WA. 19 pp.

DOF. 1987. 1987 fisheries statistical report. Washington State Department of Fisheries, Olympia, WA. 88 pp.

DOH. 1989. Public water supply system listing. Washington State Department of Health, Office of Environmental Health, Olympia, WA.

DOT. 1989. Truck data on interstates and state routes. Database retrieval. Washington State Department of Transportation, Olympia, WA.

Ecology. 1989a. Interim sediment quality evaluation process. December 1989. Washington Department of Ecology, Olympia, WA.

Ecology. 1989b. Issue paper: Sediment quality standards for Puget Sound. October 1989. Washington Department of Ecology, Olympia, WA. 32 pp. + exhibits.

Ecology. 1990a. Economic impact statement for proposed Sediment Management Standards. Public review draft. Prepared by PTI Environmental Services for Washington Department of Ecology, Sediment Management Unit, Olympia, WA.

Ecology. 1990b. Draft environmental impact statement: Cleanup standards (plus technical appendices). Washington Department of Ecology, Toxics Cleanup Program, Olympia, WA.

Ecology. 1990c. Response to Sediment Management Standards work group recommendations. Unpublished Document. Washington Department of Ecology, Olympia, WA. 17 pp.

Faigenblum, J. 1988. Chemicals and bacteriological organisms in recreational shellfish. Prepared for U.S. Environmental Protection Agency by Washington Department of Social and Health Services. 109 pp. + appendices.

Food Safety Council. 1980. Quantitative risk assessment. Food & Cosmetics Toxicology 18:711-734.

Foster, M.S. 1975. Regulation of algal community development in *Macrocystis pyrifera* forest. Mar. Biol. 32:331-342.

Johns, D.M. 1988. Puget Sound Dredged Disposal Analysis sublethal test demonstration. Prepared for U.S. Army Corps of Engineers, Seattle District. PTI Environmental Services, Bellevue, WA. 94 pp. + appendix.

Johns, D.M., T.C. Ginn, and D.J. Reish. 1989. Interim protocol for juvenile *Neanthes* bioassay. Draft Report. Prepared for U.S. Environmental Protection Agency Region 10, Office of Puget Sound. PTI Environmental Services, Bellevue, WA.

Landolt, M.L., D.L. Kalman, A. Nevissi, G. van Belle, K. Van Ness, and F.R. Hafer. 1987. Potential toxicant exposure among consumers of recreationally caught fish from urban embayments of Puget Sound. Final Report. NOAA Technical Memorandum NOS OMA 33. National Oceanic and Atmospheric Administration, Rockville, MD. 111 pp.

Long, E.R. 1985. Status and trends in sediment toxicity in Puget Sound. pp. 919-925. In: Oceans '85: Conference Record. Vol. 2. Marine Technology Society, Washington, DC.

Malins, D.S., B.B. McCain, D.W. Brown, S.L. Chan, M.S. Myers, J.T, Landahl, P.G. Prohaska, A.J. Friedman, L.G. Rhodes, D.G. Burrows, W.D. Gronlund, and H.O. Hodgins. 1984. Chemical pollutants in sediments and diseases of bottom-dwelling fish in Puget Sound, Washington. Environ. Sci. Tech. 18:705-713.

Pastorok, R.A., and D.S. Becker. 1989. Comparisons of bioassays for assessing sediment toxicity in Puget Sound. Final report. Prepared for U.S. Environmental Protection Agency. PTI Environmental Services, Bellevue, WA. 54 pp. + appendices.

Paulson, A.J., R.A. Feely, H.C. Curl, J., E.A. Crecelius, and G.P. Romberg. 1989. Decreased fluxes of Pb, Cu, and Zn from Elliott Bay. Proceedings of the Sixth Symposium on Coastal and Ocean Management. Charleston, SC, 11-14 July 1989. 15 pp.

Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: A community profile. Seattle Pacific University, Seattle, WA.

Preston, Thorgrimson. 1989. Analysis of key laws directly affecting the management and disposal of contaminated sediments in Puget Sound. Prepared for Parametrix, Inc. and Washington Department of Ecology. Preston, Thorgrimson, Ellis & Holman, Seattle, WA. 36 pp.

PSDDA. 1988. Final environmental impact statement: Unconfined open-water disposal sites for dredged material–Phase I (central Puget Sound), and Evaluation procedures technical appendix– Phase I (central Puget Sound). Puget Sound Dredged Disposal Analysis, Seattle, WA.

PSDDA. 1989. Management plan report: Unconfined, open-water disposal of dredged material–Phase II (north and south Puget Sound). Puget Sound Dredged Disposal Analysis, Seattle, WA.

PSDDA. 1990. Record of decision for unconfined, open-water disposal of dredged material–Phase II (north and south Puget Sound). Puget Sound Dredged Disposal Analysis, Seattle, WA.

PSEP. 1987a. Puget Sound environmental atlas. Prepared by Evans-Hamilton, Inc. and D.R. Systems, Inc. for Puget Sound Estuary Program. U.S. Environmental Protection Agency, Puget Sound Water Quality Authority, and U.S. Army Corps of Engineers.

PSEP. 1987b. Recommended protocols for sampling and analyzing subtidal benthic macroinvertebrate assemblages in Puget Sound. Prepared by Tetra Tech, Inc. for Puget Sound Estuary Program, U.S. Environmental Protection Agency, Seattle, WA.

PSEP. (In press). Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Prepared by PTI Environmental Services for Puget Sound Estuary Program, U.S. Environmental Protection Agency, Seattle, WA.

PSWQA. 1988. 1989 Puget Sound Water Quality Management Plan. Puget Sound Water Quality Authority, Seattle, WA. 276 pp.

PSWQA. 1990. Puget Sound update: First annual report of the Puget Sound ambient monitoring program. May 1990. Puget Sound Water Quality Authority, Seattle, WA. 89 pp.

PTI. 1990a. Recommended sediment impact and recovery zone models. Final report. Prepared for Washington Department of Ecology. PTI Environmental Services, Bellevue, WA.

PTI. 1990b. Status report: Evaluation of candidate CSL, MCUL, and SIZ_{max} values. Prepared for Washington Department of Ecology. PTI Environmental Services, Bellevue, WA.

Read, L.B., M.A. Jacobson, R.C. Barrick. 1989. Application of equilibrium partitioning sediment quality criteria to Puget Sound. Prepared for Washington Department of Ecology, Sediment Management Unit. PTI Environmental Services, Bellevue, WA. 21 pp. + appendices.

Saunders, R.S. 1984. Shellfish protection strategy. WDOE 84-4. Washington Department of Ecology, Olympia, WA. 38 pp.

Schmitt, C. 1990. Marine fish users and managers: How are we doing? pp. 118-141. In: Status and Management of Puget Sound's Biological Resources. J.S. Armstrong and A.E. Copping (eds). EPA 910/9-90-001. U.S. Environmental Protection Agency, Seattle, WA.

Strickland, R.M. 1983. The fertile fjord: Plankton in Puget Sound. University of Washington Press, Seattle, WA. 145 pp.

Swartz, R.C., W.A. DeBen, J.K. Phillips, J.O. Lamberson, and F.A. Cole. 1985. Phoxocephalid amphipod bioassay for marine sediment toxicity. pp. 284-307. In: Aquatic Toxicology and Hazard Assessment: Seventh Symposium. R.D. Cardwell, R. Purdy, and R. Bahner (eds). ASTM STP 854. American Society for Testing and Materials, Philadelphia, PA.

Tetra Tech. 1988a. Commencement Bay nearshore/tideflats feasibility study (with appendices). Public review draft. Prepared for Washington Department of Ecology and U.S. Environmental Protection Agency. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1988b. Health risk assessment of chemical contamination in Puget Sound seafood. Prepared for U.S. Environmental Protection Agency. Tetra Tech, Inc., Bellevue, WA. 102 pp + appendices.

U.S. EPA. 1988a. The apparent effects threshold approach. Briefing report to the EPA Science Advisory Board. Prepared by PTI Environmental Services for U.S. Environmental Protection Agency, Office of Puget Sound, Puget Sound Estuary Program. 57 pp.

U.S. EPA. 1988b. Equilibrium partitioning approach to generating sediment quality criteria. Briefing report to the EPA Science Advisory Board. U.S. Environmental Protection Agency.

U.S. EPA. 1988c. Hazardous waste management in the Pacific Northwest: Findings and recommendations. Final Report. Prepared by U.S. Environmental Protection Agency Region 10 and the states of Alaska, Idaho, Oregon, and Washington.

U.S. EPA. 1988d. WASP4: A hydrodynamic and water quality model. Model theory - user's manual and programmer's guide. EPA/600/3-87/039. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1989a. Commencement Bay nearshore/tideflats record of decision. Prepared by PTI Environmental Services for U.S. Environmental Protection Agency, Seattle, WA. 133 pp. + appendices.

U.S. EPA. 1989b. Risk assessment guidance for Superfund: Human health evaluation manual. Part A. Interim Final. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

Williams, L.G., P.M. Chapman, and T.C. Ginn. 1986. A comparative evaluation of sediment toxicity using bacterial luminescence, oyster embryo, and amphipod sediment bioassays. Mar. Environ. Res. 19:225-249.

Zieman, J.C., R. Orth, R.C. Phillips, G. Thayer, and A. Thorhaug. 1984. The effects of oil on seagrass ecosystems. pp. 37-64. In: Restoration of Habitats Impacted by Oil Spills. J. Cairns, Jr. and A.L. Buikema, Jr. (eds). Butterworth Publishers, Stoneham, MA.

APPENDICES

APPENDIX A – LIST OF TECHNICAL REPORTS RELATED TO THE SEDIMENT MANAGEMENT STANDARDS

SEDIMENT QUALITY STANDARDS

1988 Update and Evaluation of Puget Sound AET—Sediment Quality Values Refinement: Volume 1 and Data Appendices (produced for the Puget Sound Estuary Program). Barrick, R., S. Becker, L. Brown, H. Beller, and R. Pastorok. September 1988.

Application of Equilibrium Partitioning Sediment Quality Criteria to Puget Sound. Read, L., M. Jacobson, and R. Barrick. PTI Environmental Services. June 1989.

Contaminated Sediments Criteria Report. Becker, D., R. Pastorok, R. Barrick, P. Booth, and L. Jacobs. PTI Environmental Services. April 1989.

Development of Sediment Quality Values for Puget Sound. Tetra Tech, Inc. September 1986.

Evaluation of Growth as an Indicator of Toxicity in Marine Organisms (*Neanthes* Sublethal Bioassay Interpretation Guidelines Report). PTI ENVIRONMENTAL SERVICES. JUNE 1989.

Evaluation of the Apparent Effects Threshold (AET) Approach for Assessing Sediment Quality. Report of the EPA Science Advisory Board Sediment Criteria Subcommittee. July 1989.

Interim Performance Standards for Puget Sound Reference Areas. Pastorok, R., R. Sonnerup, J. Greene, M. Jacobson, L. Read, and R. Barrick. PTI Environmental Services. June 1989.

Interim Sediment Quality Evaluation Process. Department of Ecology. December 1989.

Protocol for Juvenile *Neanthes* Sediment Bioassay. PTI ENVIRONMENTAL SERVICES. JUNE 1990.

The Apparent Effects Threshold Approach: Briefing Report to the EPA Science Advisory Board (produced for the Puget Sound Estuary Program). PTI Environmental Services. September 1988.

Issue Paper: Sediment Quality Standards for Puget Sound. Washington Department of Ecology. October 1989. 32 pp. (plus exhibits).

SEDIMENT IMPACT ZONES

Puget Sound Contaminated Sediments Impact and Recovery Zones—Workshop Summary. PTI Environmental Services. October 1989.

Recommended Sediment Impact and Recovery Zone Models—Draft Report. PTI Environmental Services. February 1989.

SEDIMENT CLEANUP

Application of SEDQUAL to Selected Problem Areas of the Commencement Bay Superfund Site—Cost Analysis. PTI Environmental Services. June 1989.

Recommended Guidelines for Contaminated Sediment Cleanup Decisions—Draft Report. PTI Environmental Services. June 1989.

Sediment Ranking System. PTI Environmental Services. January 1990.

MISCELLANEOUS

Data Validation Guidance Manual for Selected Sediment Variables—Draft Report. PTI Environmental Services. June 1989.

Evaluation of Candidate CSL, MCUL, and SIZ_{max} Values. PTI Environmental Services. July 1990.

APPENDIX B – RESULTS OF CLEANUP SITE CASE STUDIES

The following figures illustrate the results of applying the EIS alternative cleanup standards (i.e., the cleanup screening levels) to several case study sites in Puget Sound. The methods applied during the case studies are described in Chapter 4 of the EIS.

The case study results were prepared to illustrate the range of possible consequences from the EIS alternatives. The case studies do not reflect the more in-depth site-specific analyses that would be conducted in later application of the Sediment Management Standards rule.