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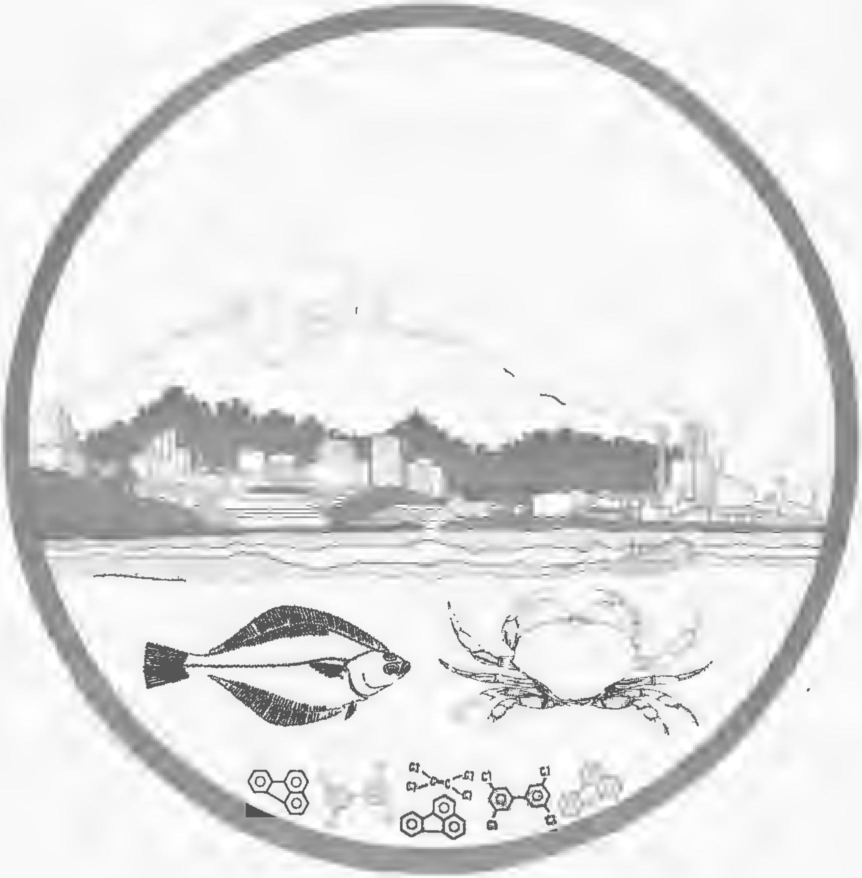
Public Review Draft

COMMENCEMENT BAY NEARSHORE/TIDEFLATS FEASIBILITY STUDY

Volume 1



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TETRA TECH

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COMMENCEMENT BAY NEARSHORE/TIDEFLATS FEASIBILITY STUDY

VOLUME 1

by

Tetra Tech, Inc.

for

Washington Department of Ecology
and
U.S. Environmental Protection Agency

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CONTENTS

	Page
LIST OF FIGURES	xii
LIST OF TABLES	xvii
1.0 INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.2 FEASIBILITY STUDY PURPOSE AND APPROACH	1-4
1.3 SITE BACKGROUND	1-6
1.3.1 Study Area Description	1-6
1.3.2 Site History	1-6
1.3.3 Natural Environment	1-8
1.3.4 Nature and Extent of Contamination	1-8
1.3.5 Identification of Problem Chemicals and Problem Areas	1-11
1.4 FEASIBILITY STUDY REPORT OVERVIEW	1-16
2.0 TECHNICAL AND INSTITUTIONAL BASIS FOR REMEDIATION	2-1
2.1 FEASIBILITY STUDY TECHNICAL FRAMEWORK	2-1
2.1.1 Field Investigations	2-4
2.1.2 Development of Sediment Cleanup Goals	2-4
2.1.3 Response of Sediments to Source Control	2-5
2.1.4 Feasibility of Source Control	2-6
2.1.5 Identify and Screen Sediment Remedial Alternatives	2-6
2.1.6 Identification of Preferred Alternatives	2-8
2.1.7 Integrated Action Plan	2-8
2.2 IDENTIFICATION OF LONG-TERM CLEANUP GOALS	2-9
2.2.1 Background	2-9
2.2.2 Evaluation of Environmental Effects	2-10
2.2.3 Evaluation of Human Health Effects	2-32
2.2.4 Administrative Definition of the Long-term Goal	2-49
2.2.5 Review/Use of New Information	2-54

2.3 USE OF THE LONG-TERM SEDIMENT CLEANUP GOAL 2-55

2.3.1 Defining the Extent of Areas of Concern 2-55
2.3.2 Defining Source Control Needs 2-56
2.3.3 Prioritizing Areas for Remedial Action 2-57
2.3.4 Identifying Sediments Requiring Remediation 2-57
2.3.5 Definition of a Reasonable Sediment Recovery Time 2-58
2.3.6 Sediment Volume Refinement Process 2-58

2.4 RELATIONSHIP BETWEEN THE FEASIBILITY STUDY AND EXISTING REGULATORY PROGRAMS 2-65

2.4.1 Relationship Between the PSDDA Program and the Commencement Bay Superfund Project 2-65
2.4.2 Relationship Between the PSWQA Management Plan Elements and the Commencement Bay Superfund Project 2-68
2.4.3 Relationship Between PSEP and the Commencement Bay Superfund Project 2-71

2.5 ROUTINE DREDGING WITHIN COMMENCEMENT BAY 2-72

2.5.1 Regulatory Requirements for Routine Dredging Projects in Puget Sound 2-73
2.5.2 Regulatory Requirements for Routine Dredging Projects in the High Priority Areas of Commencement Bay 2-76
2.5.3 Relationship Between Routine Dredging and Sediment Cleanup Actions 2-76
2.5.4 Conclusions 2-77

3.0 REMEDIAL TECHNOLOGIES FOR DEVELOPMENT OF AREA-WIDE SEDIMENT REMEDIAL ALTERNATIVES 3-1

3.1 GENERAL RESPONSE ACTIONS FOR SEDIMENTS 3-2

3.1.1 No Action 3-2
3.1.2 Institutional Controls 3-4
3.1.3 In Situ Containment 3-4
3.1.4 Removal 3-4
3.1.5 Treatment 3-8
3.1.6 Disposal Options 3-19
3.1.7 Summary of Preliminary Screening of Sediment Remedial Technologies 3-31

3.2 SOURCE CONTROLS 3-31

3.2.1 Groundwater 3-33
3.2.2 Surface Water 3-39
3.2.3 Soil 3-45
3.2.4 Air 3-48

3.3 DEVELOPMENT OF SEDIMENT REMEDIAL ALTERNATIVES 3-50

3.3.1 No Action 3-51
3.3.2 Institutional Controls 3-51
3.3.3 Containment 3-52
3.3.4 Removal 3-52
3.3.5 Treatment 3-52
3.3.6 Disposal 3-55

3.4 IDENTIFICATION OF CANDIDATE REMEDIAL ALTERNATIVES 3-55

3.4.1 No Action 3-56
3.4.2 Institutional Controls 3-57
3.4.3 In Situ Capping 3-57
3.4.4 Removal/Confined Aquatic Disposal 3-58
3.4.5 Removal/Nearshore Disposal 3-59
3.4.6 Removal/Upland Disposal 3-61
3.4.7 Removal/Solidification/Upland Disposal 3-62
3.4.8 Removal/Incineration/Upland Disposal 3-63
3.4.9 Removal/Solvent Extraction/Upland Disposal 3-63
3.4.10 Removal/Land Treatment 3-64

4.0 DEVELOPMENT OF SEDIMENT REMEDIAL ACTION EVALUATION CRITERIA 4-1

4.1 EFFECTIVENESS CRITERIA 4-2

4.1.1 Short-Term Protectiveness 4-2
4.1.2 Timeliness 4-2
4.1.3 Long-Term Protectiveness 4-3
4.1.4 Reduction in Toxicity, Mobility, or Volume 4-4

4.2 IMPLEMENTABILITY CRITERIA 4-4

4.2.1 Technical Feasibility 4-4
4.2.2 Institutional Feasibility 4-5
4.2.3 Availability 4-22

4.3 COST CRITERIA 4-26

4.4 IDENTIFICATION OF PREFERRED ALTERNATIVES 4-27

4.4.1 Short-Term Protectiveness 4-28
4.4.2 Timeliness 4-29
4.4.3 Long-Term Protectiveness 4-29
4.4.4 Reduction in Contaminant Toxicity, Mobility, or Volume 4-30
4.4.5 Technical Feasibility 4-30
4.4.6 Institutional Feasibility 4-31
4.4.7 Availability 4-31
4.4.8 Cost 4-32

5.0	HEAD OF HYLEBOS WATERWAY	5-1
5.1	WATERWAY DESCRIPTION	5-1
5.1.1	Nature and Extent of Contamination	5-2
5.1.2	Recent and Planned Dredging Projects	5-8
5.2	POTENTIAL SOURCES OF CONTAMINATION	5-8
5.2.1	Kaiser Aluminum	5-12
5.2.2	U.S. Gypsum	5-15
5.2.3	B&L Landfill	5-16
5.2.4	Pennwalt	5-17
5.2.5	General Metals, Inc.	5-22
5.2.6	Log Sorting Yards	5-23
5.2.7	Tacoma Boatbuilding Company	5-25
5.2.8	Storm Drains	5-26
5.2.9	Loading Summary	5-29
5.3	EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION	5-31
5.3.1	Feasibility of Source Control	5-31
5.3.2	Evaluation of the Potential Success of Source Control	5-34
5.3.3	Source Control Summary	5-38
5.4	AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION	5-39
5.5	DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES	5-39
5.5.1	Assembly of Alternatives for Analysis	5-39
5.5.2	Evaluation of Candidate Alternatives	5-41
5.6	PREFERRED SEDIMENT REMEDIAL ALTERNATIVE	5-49
5.7	CONCLUSIONS	5-52
6.0	MOUTH OF HYLEBOS WATERWAY	6-1
6.1	WATERWAY DESCRIPTION	6-1
6.1.1	Nature and Extent of Contamination	6-3
6.1.2	Recent and Planned Dredging Projects	6-4
6.2	POTENTIAL SOURCES OF CONTAMINATION	6-7
6.2.1	Occidental Chemical Corporation	6-10
6.2.2	Loading Summary	6-13

6.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 6-13

6.3.1 Feasibility of Source Control 6-14
6.3.2 Evaluation of the Potential Success of Source Control 6-15
6.3.3 Source Control Summary 6-17

6.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 6-19

6.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 6-20

6.5.1 Assembly of Alternatives for Analysis 6-20
6.5.2 Evaluation of Candidate Alternatives 6-21

6.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 6-29

6.7 CONCLUSIONS 6-32

7.0 SITCUM WATERWAY 7-1

7.1 WATERWAY DESCRIPTION 7-1

7.1.1 Nature and Extent of Contamination 7-1
7.1.2 Recent and Planned Dredging Projects 7-3

7.2 POTENTIAL SOURCES OF CONTAMINATION 7-6

7.2.1 Port of Tacoma Terminal 7 Ore Unloading Facilities 7-8
7.2.2 Storm Drains 7-9

7.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 7-13

7.3.1 Feasibility of Source Control 7-14
7.3.2 Evaluation of the Potential Success of Source Control 7-15
7.3.3 Source Control Summary 7-17

7.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 7-19

7.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 7-20

7.5.1 Assembly of Alternatives for Analysis 7-20
7.5.2 Evaluation of Candidate Alternatives 7-21

7.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 7-29

7.7 CONCLUSIONS 7-32

8.0 ST. PAUL WATERWAY 8-1

8.1 WATERWAY DESCRIPTION 8-1

8.1.1 Nature and Extent of Contamination 8-3
8.1.2 Recent and Planned Dredging Projects 8-3

8.2 POTENTIAL SOURCES OF CONTAMINATION 8-6

8.2.1 Simpson Tacoma Kraft Pulp Mill 8-6
8.2.2 Storm Drains 8-11
8.2.3 Loading Summary 8-14

8.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 8-14

8.3.1 Feasibility of Source Control 8-15
8.3.2 Evaluation of the Potential Success of Source Control 8-16
8.3.3 Source Control Summary 8-19

8.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 8-19

8.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 8-19

8.5.1 Assembly of Alternatives for Analysis 8-19
8.5.2 Evaluation of Candidate Alternatives 8-21

8.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 8-29

8.7 CONCLUSIONS 8-30

9.0 MIDDLE WATERWAY 9-1

9.1 WATERWAY DESCRIPTION 9-1

9.1.1 Nature and Extent of Contamination 9-1
9.1.2 Recent and Planned Dredging Projects 9-3

9.2 POTENTIAL SOURCES OF CONTAMINATION 9-6

9.2.1 Ship Repair Facilities 9-6
9.2.2 Storm Drains 9-9

9.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 9-11

9.3.1 Feasibility of Source Control 9-11
9.3.2 Evaluation of the Potential Success of Source Control 9-13
9.3.3 Source Control Summary 9-16

9.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 9-16

9.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 9-17

9.5.1 Assembly of Alternatives for Analysis 9-17
9.5.2 Evaluation of Candidate Alternatives 9-18

9.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 9-26

9.7 CONCLUSIONS 9-29

10.0 HEAD OF CITY WATERWAY 10-1

10.1 WATERWAY DESCRIPTION 10-1

10.1.1 Nature and Extent of Contamination 10-1
10.1.2 Recent and Planned Dredging Projects 10-5

10.2 POTENTIAL SOURCES OF CONTAMINATION 10-9

10.2.1 Storm Drains 10-11
10.2.2 Martinac Shipbuilding 10-20
10.2.3 Groundwater 10-21
10.2.4 American Plating 10-22

10.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 10-22

10.3.1 Feasibility of Source Control 10-23
10.3.2 Evaluation of the Potential Success of Source Control 10-26
10.3.3 Source Control Summary 10-29

10.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 10-31

10.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 10-31

10.5.1 Assembly of Alternatives for Analysis 10-31
10.5.2 Evaluation of Alternatives 10-32

10.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 10-40

10.7 CONCLUSIONS 10-42

11.0 WHEELER-OSGOOD WATERWAY 11-1

11.1 WATERWAY DESCRIPTION 11-1

11.1.1 Nature and Extent of Contamination 11-1
11.1.2 Recent and Planned Dredging Projects 11-4

11.2 POTENTIAL SOURCES OF CONTAMINATION 11-4

11.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 11-10

11.3.1 Feasibility of Source Control 11-10
11.3.2 Evaluation of the Potential Success of Source Control 11-11
11.3.3 Source Control Summary 11-13

11.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 11-15

11.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 11-15

11.5.1 Assembly of Alternatives for Analysis 11-15
11.5.2 Evaluation of Alternatives 11-16

11.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 11-25

11.7 CONCLUSIONS 11-26

12.0 MOUTH OF CITY WATERWAY 12-1

12.1 WATERWAY DESCRIPTION 12-1

12.1.1 Nature and Extent of Contamination 12-1
12.1.2 Recent and Planned Dredging Projects 12-3

12.2 POTENTIAL SOURCES OF CONTAMINATION 12-3

12.2.1 D Street Petroleum Storage Facilities 12-7
12.2.2 Storm Drains 12-10

12.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 12-10

12.3.1 Feasibility of Source Control 12-10
12.3.2 Evaluation of the Potential Success of Source Control 12-11
12.3.3 Source Control Summary 12-14

12.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 12-14

12.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 12-15

12.5.1 Assembly of Alternatives for Analysis 12-15
12.5.2 Evaluation of Alternatives 12-16

12.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 12-20

12.7 CONCLUSIONS 12-21

13.0 RUSTON-PT. DEFIANCE SHORELINE 13-1

13.1 WATERWAY DESCRIPTION 13-1

13.1.1 Nature and Extent of Contamination 13-3
13.1.2 Recent and Planned Dredging Projects 13-7

13.2 POTENTIAL SOURCES OF CONTAMINATION 13-7

13.2.1 American Smelting and Refining Company 13-7
13.2.2 Loading Summary 13-14

13.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION 13-15

13.3.1 Feasibility of Source Control 13-15
13.3.2 Evaluation of the Potential Success of Source Control 13-16
13.3.3 Source Control Summary 13-20

13.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION 13-21

13.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES 13-22

13.5.1 Assembly of Alternatives for Analysis 13-22
13.5.2 Evaluation of Alternatives 13-24

13.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE 13-32

13.7 CONCLUSIONS 13-34

14.0 SUMMARY OF PREFERRED ALTERNATIVES 14-1

14.1 PREFERRED ALTERNATIVES 14-1

14.1.1 Removal/Confined Aquatic Disposal 14-1
14.1.2 Removal/Nearshore Disposal 14-3
14.1.3 In Situ Capping 14-3
14.1.4 Institutional Controls 14-4

14.2 COST ANALYSIS 14-4

14.3 NATURAL SEDIMENT RECOVERY 14-11

14.4 HABITAT RESTORATION 14-11

14.4.1 Benthic Habitat in Problem Areas 14-14
14.4.2 Intertidal Habitat in Problem Areas 14-14
14.4.3 Benthic Habitat in Confined Aquatic Disposal Areas 14-14
14.4.4 Intertidal Habitat in Nearshore Disposal Areas 14-14
14.4.5 Habitats at or adjacent to Upland Disposal Sites 14-14

15.0 REFERENCES 15-1

VOLUME 2 - APPENDICES

APPENDIX A. EVALUATION OF SEDIMENT RECOVERY

APPENDIX B. DETAILS OF DREDGING AND CAPPING TECHNOLOGIES

APPENDIX C. SPECIFICATIONS OF MAJOR ARARs AND TBCs

APPENDIX D. METHOD FOR ESTIMATING COSTS OF SEDIMENT REMEDIAL ALTERNATIVES

APPENDIX E. SOURCE LOADING DATA

APPENDIX F. SAMPLING STATION LOCATIONS

APPENDIX G. FIELD SURVEY DATA REPORT - MAY 1986

FIGURES

Number		Page
1-1	Commencement Bay Nearshore/Tideflats study area	1-7
1-2	Waterway segments defined during the remedial investigation for the Commencement Bay study area	1-12
1-3	Relationship between problem areas identified during the remedial investigation and those studied for the feasibility study	1-17
2-1	Relationships among programs to identify and correct sediment contamination problems in the Commencement Bay N/T site	2-2
2-2	Measures of reliability (sensitivity and efficiency)	2-17
2-3	The AET approach to sediments tested for lead and 4-methylphenol concentrations and amphipod mortality during bioassays	2-19
2-4	Hypothetical example of dose-resonse relationship resulting from laboratory exposure to single chemicals X and Y	2-22
2-5	Hypothetical example of toxic response resulting from exposure to environmental samples of sediment contaminated with chemicals X and Y	2-23
2-6	Hypothetical example of AET calculation for chemical X based on classification of significant and nonsignificant responses for environmental samples contaminated with both chemicals X and Y	2-24
2-7	Hypothetical dose-response relationships for a carcinogen and a noncarcinogen	2-35
2-8	Graphical risk characterization for PCBs in seafood	2-42
2-9	Refinement of sediment cleanup volume estimates	2-60
2-10	Theoretical relationships among AET, long-term cleanup goals, and short-term cleanup goals	2-62
3-1	Response action, technology types, and process options for remediation of contaminated sediments	3-3

3-2	Confined aquatic disposal of contaminated dredged material	3-20
3-3	Confined nearshore disposal of contaminated dredged material	3-23
3-4	Confined upland disposal (a) and components of a typical diked upland disposal site (b)	3-24
3-5	Potential Commencement Bay disposal sites identified by Phillips et al. (1985)	3-27
3-6	Potential sediment remedial technologies and process options that are retained for further evaluation	3-32
3-7	Comparative pollutant removal of urban best management practice (BMP) designs, as determined by Schueler (1987)	3-41
3-8	Dredge water chemical clarification facility	3-54
5-1	Head of Hylebos Waterway - existing industries and businesses	5-3
5-2	Areal and depth distributions of arsenic in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal	5-5
5-3	Areal and depth distributions of HPAH in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal	5-6
5-4	Areal and depth distributions of PCBs in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal	5-7
5-5	NPDES-permitted and nonpermitted discharges to Hylebos Waterway	5-11
5-6	Surface water drainage pathways to the head of Hylebos Waterway	5-13
5-7	Drainage basin for Morningside Ditch	5-28
5-8	Sediments at the head of Hylebos Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	5-37
6-1	Mouth of Hylebos Waterway - existing industries and businesses	6-2

6-2 Areal and depth distributions of PCBs in sediments at the mouth of Hylebos Waterway, normalized to long-term cleanup goal 6-5

6-3 Areal and depth distributions of hexachlorobenzene in sediments at the mouth of Hylebos Waterway, normalized to long-term cleanup goal 6-6

6-4 NPDES-permitted and nonpermitted discharges to Hylebos Waterway 6-8

6-5 Sediments at the mouth of Hylebos Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control 6-18

7-1 Sitcum Waterway - existing industries, businesses, and discharges 7-2

7-2 Areal and depth distributions of copper in sediments of Sitcum Waterway, normalized to long-term cleanup goal 7-4

7-3 Areal and depth distributions of arsenic in sediments of Sitcum Waterway, normalized to long-term cleanup goal 7-5

7-4 Surface water drainage pathways to Sitcum Waterway 7-10

7-5 Sediments in Sitcum Waterway not meeting cleanup goals at present and 10 yr after implementing feasible source control 7-18

8-1 St. Paul Waterway - existing industries, businesses, and discharges 8-2

8-2 Areal and depth distributions of 4-methylphenol in sediments of St. Paul Waterway, normalized to long-term cleanup goal 8-4

8-3 Remedial actions at the Simpson Tacoma Kraft Company facility 8-5

8-4 Proposed stormwater control areas at the Simpson Tacoma Kraft Company facility 8-12

8-5 Surface water drainage pathways to St. Paul Waterway 8-13

8-6 Sediments in St. Paul Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control 8-18

9-1 Middle Waterway - existing industries, businesses, and discharges 9-2

9-2	Areal and depth distributions of mercury in sediments of Middle Waterway, normalized to long-term cleanup goal	9-4
9-3	Areal and depth distributions of copper in sediments of Middle Waterway, normalized to long-term cleanup goal	9-5
9-4	Surface water drainage pathways to Middle Waterway	9-10
9-5	Sediments in Middle Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	9-15
10-1	Head of City Waterway - existing industries and businesses	10-2
10-2	Areal and depth distributions of HPAH in sediments at the head of City Waterway, normalized to long-term cleanup goal	10-4
10-3	Areal and depth distributions of cadmium in sediments at the head of City Waterway, normalized to long-term cleanup goal	10-6
10-4	Areal and depth distributions of lead in sediments at the head of City Waterway, normalized to long-term cleanup goal	10-7
10-5	Areal and depth distributions of mercury in sediments at the head of City Waterway, normalized to long-term cleanup goal	10-8
10-6	Surface water drainage pathways to the head of City Waterway	10-12
10-7	Drainage basins for City Waterway	10-13
10-8	Sediments at the head of City Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	10-28
11-1	Wheeler-Osgood Waterway - existing businesses and industries	11-2
11-2	Areal and depth distributions of HPAH in sediments of Wheeler-Osgood Waterway, normalized to long-term cleanup goal	11-3
11-3	Areal and depth distributions of zinc in sediments of Wheeler-Osgood Waterway, normalized to long-term cleanup goal	11-5
11-4	Surface water drainage pathways to Wheeler-Osgood Waterway	11-7

11-5	Sediments in Wheeler-Osgood Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	11-14
12-1	Mouth of City Waterway - existing industries and businesses	12-2
12-2	Areal and depth distributions of HPAH in sediments at the mouth of City Waterway, normalized to long-term cleanup goal	12-4
12-3	Areal and depth distributions of mercury in sediments at the mouth of City Waterway, normalized to long-term cleanup goal	12-5
12-4	Surface water drainage pathways to the mouth of City Waterway	12-6
12-5	Sediments at the mouth of City Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	12-13
13-1	Ruston-Pt. Defiance Shoreline - existing industries, businesses, and discharges	13-2
13-2	Areal and depth distributions of arsenic in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal	13-4
13-3	Areal and depth distributions of mercury in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal	13-5
13-4	Areal and depth distributions of LPAH in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal	13-6
13-5	Sediments along the Ruston-Pt. Defiance Shoreline not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control	13-19
14-1	Estimated remediation costs related to sediment volume for preferred alternatives in each problem area	14-10

TABLES

Number		Page
1-1	Final ranking of problem areas in the Commencement Bay remedial investigation	1-15
1-2	Revised designations for problem areas in the Commencement Bay Nearshore/Tideflats site	1-19
2-1	Approaches evaluated for establishing sediment quality values	2-13
2-2	Potential guideline concentrations for PCBs in fish tissue, Commencement Bay N/T Feasibility Study	2-43
2-3	Predicted vs. observed PCB concentrations in fish tissue from Commencement Bay	2-45
2-4	Sediment quality values that are expected to result in background concentrations of PCBs in fish of Commencement Bay	2-46
2-5	Average sediment PCB concentrations achieved with alternative cleanup levels	2-48
2-6	Cleanup goal options considered for Commencement Bay N/T Feasibility Study	2-52
2-7	Biological disposal guidelines for alternative site management conditions	2-75
3-1	Potential sites for contaminated dredged material disposal	3-28
4-1	Selected potential chemical-specific ARARs for problem area chemicals	4-13
4-2	Selected potential chemical-specific TBCs	4-15
4-3	Selected potential location-specific ARARs for candidate remedial alternatives	4-17
4-4	Selected potential action-specific ARARs for candidate remedial alternatives	4-23
5-1	Head of Hylebos Waterway - source status	5-9

5-2	Effectiveness of source control for head of Hylebos Waterway	5-32
5-3	Head of Hylebos Waterway summary of sediment recovery calculations	5-36
5-4	Remedial alternatives evaluation matrix for the head of Hylebos Waterway problem area	5-42
5-5	Evaluation summary for head of Hylebos Waterway	5-44
6-1	Mouth of Hylebos Waterway - source status	6-9
6-2	Mouth of Hylebos Waterway summary of sediment recovery calculations	6-16
6-3	Remedial alternatives evaluation matrix for the mouth of Hylebos Waterway problem area	6-22
6-4	Evaluation summary for mouth of Hylebos Waterway	6-24
7-1	Sitcum Waterway - source status	7-7
7-2	Storm drains discharging into Sitcum Waterway	7-11
7-3	Sitcum Waterway summary of sediment recovery calculations	7-16
7-4	Remedial alternatives evaluation matrix for the Sitcum Waterway problem area	7-22
7-5	Evaluation summary for Sitcum Waterway	7-24
8-1	St. Paul Waterway - source status	8-7
8-2	St. Paul Waterway summary of sediment recovery calculations	8-17
8-3	Remedial alternatives evaluation matrix for the St. Paul Waterway problem area	8-22
8-4	Evaluation summary for St. Paul Waterway	8-24
9-1	Middle Waterway - source status	9-7
9-2	Middle Waterway summary of sediment recovery calculations	9-14
9-3	Remedial alternatives evaluation matrix for the Middle Waterway problem area	9-19
9-4	Evaluation summary for Middle Waterway	9-21
10-1	Head of City Waterway - source status	10-10

10-2	Commercial discharges to storm drains CN-237 and CS-237 identified during sewer utility business inspections	10-15
10-3	Commercial discharges to storm drain CI-230 identified during sewer utility business inspections	10-18
10-4	Effectiveness of source control for head of City Waterway	10-24
10-5	Head of City Waterway summary of sediment recovery calculations	10-27
10-6	Average percent reductions needed to achieve long-term cleanup goal concentrations of indicator chemicals in storm drain effluent particulate matter or sediments	10-30
10-7	Remedial alternatives evaluation matrix for the head of City Waterway problem area	10-33
10-8	Evaluation summary for the head of City Waterway	10-35
11-1	Wheeler-Osgood Waterway - source status	11-6
11-2	Storm drains discharging into Wheeler-Osgood Waterway	11-9
11-3	Wheeler-Osgood Waterway summary of sediment recovery calculations	11-12
11-4	Remedial alternatives evaluation matrix for the Wheeler-Osgood Waterway problem area	11-17
11-5	Evaluation summary for Wheeler-Osgood Waterway	11-20
12-1	Mouth of City Waterway - source status	12-8
12-2	Mouth of City Waterway summary of sediment recovery calculations	12-12
12-3	Remedial alternatives evaluation matrix for the mouth of City Waterway problem area	12-17
12-4	Evaluation summary for mouth of City Waterway	12-19
13-1	Ruston-Pt. Defiance shoreline - source status	13-8
13-2	Ruston-Pt. Defiance shoreline summary of sediment recovery calculations	13-18
13-3	Remedial alternatives evaluation matrix for the Ruston-Pt. Defiance shoreline problem area	13-25
13-4	Evaluation summary for Ruston-Pt. Defiance shoreline	13-27

14-1	Alternatives evaluated for each problem area	14-2
14-2	Summary of remedial sediment surface areas and volumes	14-5
14-3	Cost summary for preferred alternatives	14-6
14-4	Sediment cleanup summary for Commencement Bay	14-7
14-5	Factors affecting cost estimates	14-8
14-6	Sediment recovery factors	14-12
14-7	Maximum enrichment ratios that are predicted to recover to acceptable levels in a given time period	14-13
14-8	Estimated intertidal surface areas and volumes to be disturbed by sediment remedial action	14-15

1.0 INTRODUCTION

This report documents the feasibility study (FS) prepared for the waterways/shoreline portion of the Commencement Bay Nearshore/Tideflats (N/T) Superfund site in Tacoma, Washington. The purpose of the FS was to develop and evaluate the most appropriate remedial strategies for correcting the human health and environmental impacts associated with contaminated sediments in the Commencement Bay N/T site.

1.1 BACKGROUND

The feasibility study represents the end of the Superfund investigation and evaluation phase. This phase began in October 1981, when Commencement Bay was listed as the highest priority site for action in the State of Washington on an interim priority list developed by the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The Commencement Bay site was initially divided into four areas: deepwater, nearshore, tideflats industrial, and the South Tacoma Channel. On a subsequent priority list published on 30 December 1982, the nearshore and tideflats industrial areas of Commencement Bay were designated as a discrete Superfund site, as was the South Tacoma Channel. The deepwater area was eliminated as a priority site because water quality studies indicated less severe contamination in that area than was initially suspected. On 6 September 1983, the U.S. EPA published and promulgated the first official National Priorities List (NPL) of hazardous waste sites. This list included the Commencement Bay N/T site. Earlier that year, on 13 April 1983, the U.S. EPA announced that an agreement had been reached with the Washington Department of Ecology (Ecology) to conduct a remedial investigation/feasibility study (RI/FS) of the hazardous substance contamination in the N/T site. The RI/FS comprises two distinct parts: metals contamination of the upland environment near the American Smelting and Refining Company (ASARCO) smelter (the Ruston/Vashon task), and chemical contamination and its effects in the marine environment (waterways/shoreline tasks). This report addresses only the waterways/shoreline tasks. References herein to Commencement Bay problem areas and reports are also limited to the waterways/shoreline tasks of the Commencement Bay Nearshore/Tideflats RI/FS.

Under the Superfund remedial program, long-term remedial response actions are undertaken to stop or substantially reduce actual or threatened releases of hazardous substances that are serious, but not immediately life-threatening. A remedial response has two main phases: an RI/FS, and a remedial design/remedial action (RD/RA) phase. During the RI/FS, conditions at the site are studied, problems are characterized, and alternative methods to clean up the site are evaluated. In the RD/RA phase, the recommended cleanup strategy is refined via further sampling and testing, an approach is designed and engineered, and final construction and cleanup are undertaken.

Ecology was designated as the lead agency for the RI/FS. Ecology contracted with Tetra Tech, Inc. to perform the RI and the FS. The RI phase was initiated in 1983, and the final results were published in August 1985 (Tetra Tech 1985a,b). Results presented in the RI included identification of nine high priority problem areas in the Commencement Bay N/T site, identification of problem chemicals within the nine problem areas, and identification of potential sources of the problem chemicals.

Following the completion of the RI, two approaches were developed to address sediment contamination problems in Commencement Bay. First, Ecology and EPA expanded ongoing source control efforts in the Commencement Bay area. These expanded efforts focused on controlling or eliminating the ongoing release of chemicals into the high priority problem areas. The source control effort involved a number of programs, and individual actions have been taken using the most appropriate program mechanism [e.g., enforcement under the Clean Water Act (CWA), and the Resource Conservation and Recovery Act (RCRA)]. Examples of source control actions undertaken in Commencement Bay include the investigation and control of surface water runoff from several log sorting yards in the area.

The second major effort that was initiated following the completion of the RI was the FS. This effort includes the identification, evaluation, and recommendation of corrective measures for each of the nine high priority problem areas. The preferred alternatives recommended for each problem area integrate source control and sediment remedial actions, and include natural recovery of sediments (i.e., degradation or burial of contaminated surface sediments beneath clean material) as a component of the remedial alternative.

An Integrated Action Plan (IAP) was developed to integrate feasible source controls and the results of the FS to correct sediment contamination problems in Commencement Bay. The plan presents the required actions, prioritizes those actions, and provides a schedule for their implementation (PTI 1988a).

The purpose of this FS, led by Ecology under a cooperative agreement with U.S. EPA, is to develop and evaluate the most appropriate remedial strategies for correcting the documented biological and human health impacts associated with contaminated sediments at the Commencement Bay N/T site. Completion and publication of this FS report is an important milestone in the long-term response action being conducted at the site, because it represents a transition from a study phase to an active cleanup phase.

This transition is highlighted by and dependent on one of the most important opportunities for public participation in the Superfund process: the public comment period. During the public comment period, the FS is made available for review, and comments on cleanup alternatives, including the agencies' proposed plan, are actively solicited. Following the public comment period, the agencies will prepare a responsiveness summary describing and responding to significant community comments on the proposed remedial action and the other alternatives considered. Finally, based on both the information developed in the FS and on the public comments discussed in the responsiveness summary, the agencies will select a remedial action plan.

This plan will be described in a Record of Decision (ROD) document. The Commencement Bay ROD will be performance-based as a result of detailed site investigations and area by area evaluations of remedial alternatives. A performance-based ROD is more flexible than the usual technology-based ROD that assumes certain remedial technologies will be used under a given set of environmental circumstances. The flexibility of the performance-based ROD is due to the potential to vary from the recommended alternative if future technologies contribute to new alternatives that become preferred over presently recommended alternatives. The ROD will be the blueprint for continuation of the long-term remedial response action at the Commencement Bay N/T site under the Superfund remedial program. Post-ROD activities will be implemented according to the IAP (PTI 1988a) (Section 2.1.6).

The FS was conducted in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. However, given the large study area, the multiplicity of contaminant sources, and the diversity of ongoing activities within the Commencement Bay N/T site, the development of the FS and the plans for implementing the recommended remedial strategies differ in many respects from the reports and implementation strategies at more traditional Superfund sites. Of particular importance are the following distinctions:

- Correction of sediment contamination problems will be accomplished through the implementation of these measures:

  1) Source control measures to reduce or eliminate ongoing releases of hazardous substances

  2) Natural recovery through chemical degradation, deposition of clean sediments, and diffusive loss to overlying water

  3) Institutional controls such as public warnings to reduce potential human exposure

  4) Routine dredging, which will result in the removal of contaminated sediments and their subsequent disposal at appropriate facilities (i.e., those designed for sediments with a given level of contamination)

  5) Sediment remedial actions (e.g., removal, capping, treatment) for highly contaminated sediments.

- Correction of sediment contamination problems will be implemented over a period of several years. In the short term, regulatory efforts will focus on measures to reduce or eliminate the ongoing release of contaminants. These measures, in conjunction with natural processes such as biodegradation and sedimentation, will reduce exposure to contaminated sediments. During this initial timeframe, it is anticipated that routine dredging projects will continue to occur. Regulatory requirements for dredging in high priority areas are presented in Section 2.5.2. These activities will have the net effect of removing some contaminated sediments from the waterways. After source control measures are implemented and monitoring is performed to verify the effectiveness of such controls and natural sediment recovery, actions to remediate areas of high sediment contamination will be initiated. This remediation will proceed in two phases: 1) detailed sediment sampling to refine the estimates of areal extent of individual problem areas and 2) implementation of the appropriate remedial measures.

- Correction of sediment contamination problems will be implemented by several agencies using a wide variety of existing regulatory authorities. Wastewater discharges will continue to be regulated under state and federal water quality laws. Stormwater and industrial pretreatment requirements will be implemented under federal, state, and local laws and regulations. The Commencement Bay Action Team will continue to oversee implementation of source control. Routine dredging projects will continue to be regulated under the federal Clean Water Act Section 404 program. Remediation of highly contaminated sediments will be required under state and federal Superfund laws.

- Correction of sediment contamination problems will be implemented using a performance-based cleanup plan (performance-based Record of Decision). Each completed cleanup will be required to satisfy performance criteria (i.e., specific cleanup levels). A performance-based cleanup provides flexibility in selecting cleanup options because the specific techniques to be used for each area will be defined during the detailed engineering design phase. This approach provides the flexibility to use the most appropriate techniques available at the time cleanup occurs. Since sediment cleanup (i.e., source control and sediment remedial actions) may span 5 to 15 yr, new, and possibly more effective, techniques may be available in the future. Consequently, the preferred alternative 10 yr from now may differ substantially from those identified in this report.

1.2 FEASIBILITY STUDY PURPOSE AND APPROACH

The purpose of the FS was to develop and evaluate the most appropriate remedial strategies for correcting short- and long-term hazards associated with contaminated sediments in the Commencement Bay N/T site. The remediation strategies, which were developed to protect human health and the environment, are based upon an analysis of the actual and potential hazards at the site. Each remedial strategy addresses source control/natural sediment recovery, institutional controls, routine dredging, and sediment cleanup. This comprehensive approach is designed to ensure that long-term solutions to the existing sediment problems are implemented in a timely and cost-effective manner.

The feasibility of institutional controls and sediment cleanup actions were evaluated using the standard Superfund evaluation approach. The objective of this evaluation was to determine cleanup activities necessary to meet the long-term goal (LTG) of sediments causing no adverse biological impacts. Areas and volumes of contaminated sediments were estimated based upon an analysis of sediment chemistry and observed biological effects, and upon the predicted results of source controls and natural recovery processes. Alternatives were developed and analyzed in accordance with the most recent U.S. EPA (1988) guidance. The evaluation process involved consideration of the effectiveness, implementability, and costs of various remedial alternatives.

The FS report does not contain a detailed engineering and cost evaluation for individual source control measures. Many of the source control actions identified herein are currently being implemented by local industries in response to enhanced Ecology and U.S. EPA regulatory efforts during the last several years. This enhanced effort began in the fall of 1985, when Ecology created the Commencement Bay Action Team. This Action Team, based in Ecology's Southwest Regional Office, has utilized a multi-programmatic approach to controlling sources. The four members of this team have utilized permitting mechanisms, enforcement orders, consent orders and decrees, or court action to control sources of toxic contaminants. Many of the sites being handled by the Action Team were identified as high priority sites in the RI (Tetra Tech 1985a,b). Regulatory actions have resulted in the collection of additional data that have been incorporated into the FS evaluations. Upon completion of the FS, source control actions will continue to be handled under these existing regulatory programs.

The FS report provides an overall framework for performing detailed evaluation of source control actions. Existing sediment contamination data and current knowledge of source inputs were used to determine the levels of source control required to maintain long-term sediment quality at acceptable levels. These source control requirements were compared to the estimated levels of source control achievable through the use of all known, available, and reasonable technologies. The source control evaluation consists of the following components:

- Identifying major sources
- Estimating source loadings
- Examining the relationships between sources and sediment contamination
- Estimating the degree of source control needed to allow natural recovery of sediment contamination problems
- Identifying available control technologies

- Estimating the degree of source control obtainable through the implementation of all known, available, and reasonable methods of treatment

- Recommending source control investigations and actions to correct ongoing problems.

The preferred alternative for each problem area addresses both source control and sediment remedial measures. The overall framework for implementing the preferred alternative is described in a separate document, the "Commencement Bay Nearshore/Tideflats Integrated Action Plan" (PTI 1988a).

1.3 SITE BACKGROUND

1.3.1 Study Area Description

Commencement Bay covers approximately 9 mi^2 in southern Puget Sound, Washington (Figure 1-1). The bay opens to Puget Sound in the northwest, with the City of Tacoma situated on the south and southeast shore. A number of waterways and the Puyallup River adjoin Commencement Bay. The drainage area for the Puyallup River is approximately 950 mi^2.

The N/T Superfund site includes 10-12 mi^2 of shallow water, shoreline, and adjacent land. The Commencement Bay Nearshore is defined as the area along the Ruston shoreline from the head of City Waterway to Pt. Defiance. It includes all water with depths of less than 60 ft below mean lower low water (MLLW). The maximum depth of the study area along the Ruston-Pt. Defiance shoreline was increased to 200 ft when sediments with contaminant concentrations that exceeded cleanup goals were found at depths greater than 200 ft. The 200 ft depth contour was selected because some dredging techniques are capable of dredging to that depth. The Tideflats area includes Hylebos, Blair, Sitcum, Milwaukee, St. Paul, Middle, Wheeler-Osgood, and City Waterways; the Puyallup River upstream to the Interstate-5 bridge; and the adjacent land areas. The landward boundary of the Tideflats is defined by drainage pathways rather than political boundaries.

The land, water, and shorelines within the study area are owned by various parties, including the State of Washington, the Port of Tacoma, the City of Tacoma, Pierce County, the Puyallup Tribe of Indians, and numerous private entities. Much of the publicly owned land is leased to private and industrial enterprises. The names and locations of many of these enterprises are presented in Chapters 5-13 of this report.

1.3.2 Site History

At the time of urban and industrial development in the late 1800s, the south end of Commencement Bay was composed largely of tideflats formed by the Puyallup River delta. Dredge and fill activities have significantly altered the estuarine nature of the bay since the 1920s. Intertidal areas were covered, and meandering streams and rivers were channelized. Numerous industrial and commercial operations have located in the filled areas of the

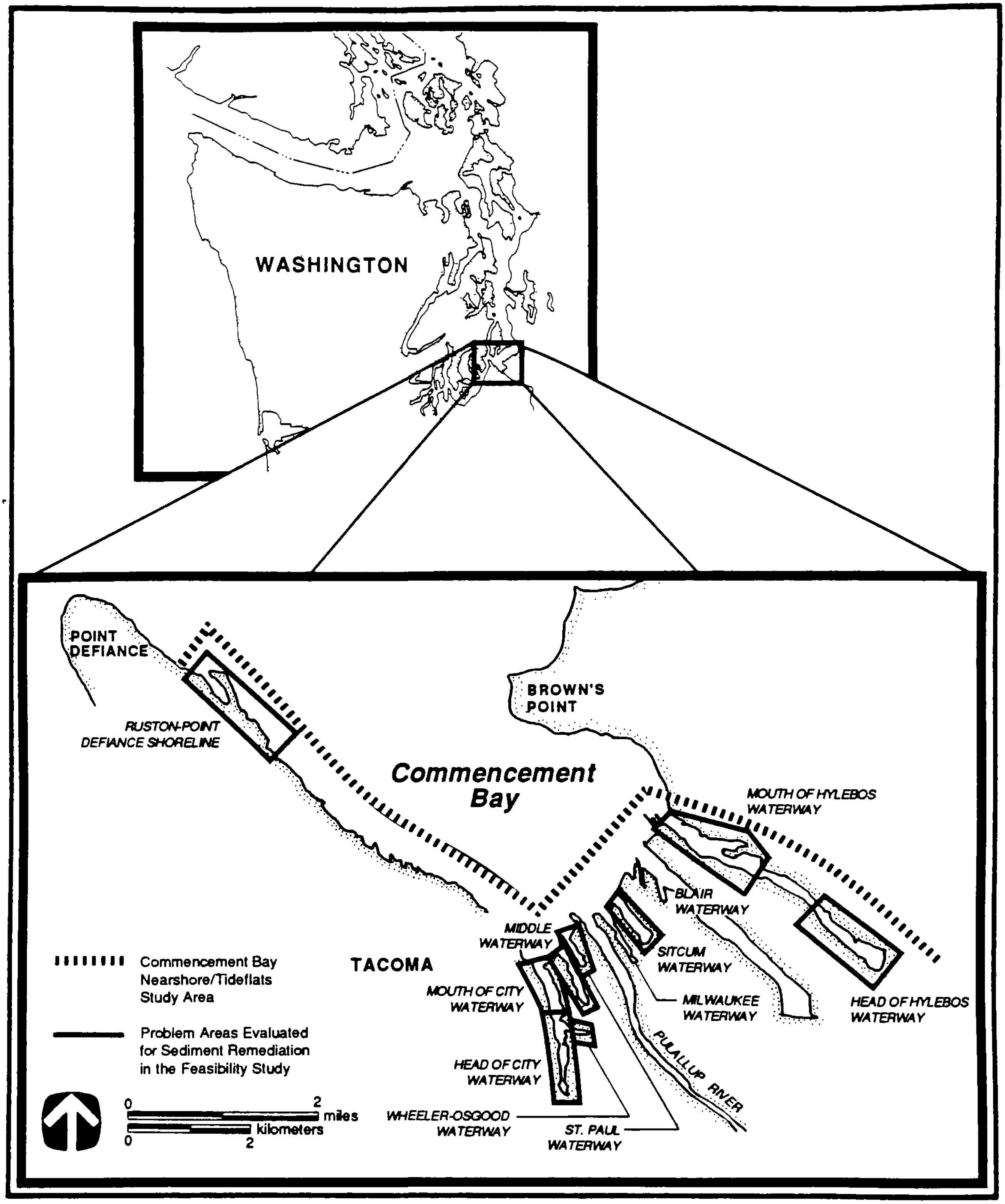


Figure 1-1. Commencement Bay Nearshore/Tideflats study area.

bay for purposes of shipbuilding, chemical production, ore smelting, oil refining, food preserving, transportation, and other urban activities.

Since initial industrialization of the Commencement Bay area, hazardous substances and waste materials have been released into the environment. As a result of these various uses and releases of waste materials, the chemical quality of the waters and sediments in many areas of Commencement Bay has been altered. Contaminants found in the area include arsenic, lead, zinc, cadmium, copper, mercury, and a variety of organic compounds [e.g., polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAH)].

Contaminants in the Commencement Bay area originate from both point and nonpoint sources. Industrial surveys conducted by the Tacoma-Pierce County Health Department and the Port of Tacoma indicate that there are more than 281 industrial activities in the Commencement Bay N/T area. Approximately 34 of these are National Pollutant Discharge Elimination System (NPDES)-permitted dischargers, including two sewage treatment plants. Nonpoint sources include two creeks; the Puyallup River; numerous storm drains, seeps, and open channels; groundwater seepage; atmospheric deposition; and spills. The Tacoma-Pierce County Health Department has identified approximately 480 point and nonpoint sources that empty into the Commencement Bay N/T area (Rogers et al. 1983).

1.3.3 Natural Environment

Commencement Bay, like much of Puget Sound, supports important fishery resources. Four salmonid species (i.e., chinook, coho, chum, and pink) and steelhead occupy Commencement Bay for part of their life cycle. These anadromous species have critical estuarine migratory and rearing habitat requirements. Adults pass through the bay enroute to their spawning grounds, and juveniles reside in nearshore estuarine areas. Recreational and commercial harvesting of these species occur in the bay. The Commencement Bay area also supports extensive inshore marine fish resources. Flatfish, including English sole, rock sole, flathead sole, c-o sole, sand sole, starry flounder, and speckled sanddab, are most abundant within the waterways. Rock sole, c-o sole, and several species of rockfish are most abundant along the outer shoreline. Although there is an advisory against the consumption of fish, shellfish, and crabs caught within the study area, recreational harvesting of many of these species occurs primarily within City Waterway and along the Ruston-Pt. Defiance shoreline.

1.3.4 Nature and Extent of Contamination

There is considerable variability in the types and concentrations of chemical contaminants in Commencement Bay sediments. The primary objective of the RI was to define the nature and extent of sediment contamination. That investigation involved the compilation and evaluation of existing data and an extensive field sampling effort to collect additional data. The distribution of sediment contaminants is presented in the RI report (Tetra Tech 1985a). The RI findings are summarized below and incorporated into Chapters 5-13.

Sediment Contamination--

Investigations of the nearshore waters of Commencement Bay have demonstrated the existence of sediment contamination by toxic pollutants, accumulation of some of these substances by biota, and possible pollution-associated abnormalities in indigenous biota (Crecelius et al. 1975; Riley et al. 1980, 1981; Malins et al. 1980, 1982; Gahler et al. 1982; Tetra Tech 1985a, 1988; Parametrix 1987). The highest concentrations of certain metals (i.e., arsenic, copper, lead, and mercury) have been found in sediments in the waterways, along the southwest shore, and near the ASARCO smelter. Sediment contamination by persistent organic compounds (e.g., PCBs) was detected in the heavily industrialized waterways (e.g., Hylebos Waterway) and along the Ruston-Pt.Defiance Shoreline.

During the Commencement Bay N/T RI, four inorganic and six organic contaminants were detected at concentrations 1,000 times as great as reference conditions (i.e., those in sediments from nonindustrialized areas of Puget Sound). Those concentrations were detected in samples from stations located off the Ruston-Pt. Defiance Shoreline, Hylebos Waterway, and St. Paul Waterway. Twenty-eight chemicals or chemical groups had concentrations 100-1,000 times as great as reference conditions. Contaminants of concern include metals (e.g., arsenic, lead, mercury, zinc), PCBs, PAH, and total organic carbon.

Sediment Toxicity--

A number of laboratory tests are available to evaluate the potential toxicity of contaminated sediments to marine organisms. Many of these tests are discussed in Chapter 2. The toxicity of Commencement Bay sediments was initially studied using amphipod bioassays (Swartz et al. 1982a,b). The waterways were found to contain toxic and nontoxic sediments with heterogenous spatial distributions. Sediments with the highest toxicity were detected near docks, drains, and ditches associated with pollutant sources. Higher toxicities were observed in intertidal sediments of the waterways than in sediments from mid-channel and subtidal stations.

During the RI, sediment toxicity was tested using the amphipod and oyster larvae bioassays. Sediments from 24 of the 52 stations tested had statistically significant toxicities for one or both of the bioassays when compared with the reference area (i.e., Carr Inlet). Sediments from 10 of the stations were toxic in both bioassays. These stations were located in Hylebos Waterway, City Waterway, St. Paul Waterway, and along the Ruston-Pt. Defiance Shoreline. In some areas (e.g., Stations SP-14, RS-18, RS-19, CI-11; see Appendix F for station locations), the sediments were toxic to the extent that a 90 percent dilution was not sufficient to reduce amphipod toxicities to reference levels.

Benthic Infauna--

Examination of the benthic community structure provides an in situ measure of pollution impacts. In the Commencement Bay waterways, the overall benthic community is regulated by the physical characteristics (e.g., grain size) of the sediment or by environmental stress that may be associated with toxic contamination or sediment disturbance. However, the overall high abundances of a mixed polychaete-mollusc assemblage indicate that severe effects to benthic communities were localized. Areas having depressed abundances of at least two major taxonomic groups included the head and middle of Hylebos Waterway, St. Paul Waterway, the head of City Waterway, Wheeler-Osgood Waterway, and the Ruston-Pt. Defiance Shoreline. In Sitcum Waterway, single benthic depressions were found at two of three stations.

Fish Histopathology--

Many recreationally and commercially important species live in contact with the bottom sediments, resulting in a high potential for uptake of sediment associated contaminants. The incidence of liver lesions is greatest in fish from areas with the highest concentrations of sediment-associated contaminants (Malins et al. 1980). The prevalence of abnormalities in organs of shrimp and crabs from Commencement Bay waterways was particularly high compared with other areas in Puget Sound (Malins et al. 1980).

Histopathological analyses were conducted on the livers of English sole during the RI. These analyses indicate that prevalences of liver abnormalities such as preneoplastic nodules, megalocytic hepatosis, and nuclear pleomorphism were significantly elevated compared to prevalences in the reference area (i.e., Carr Inlet). In comparisons among the eight Commencement Bay RI study areas, prevalences of preneoplastic nodules and nuclear pleomorphism were significantly elevated only in Middle Waterway, and prevalences of megalocytic hepatosis were significantly elevated in Hylebos, Blair, Milwaukee, and Middle Waterways. The prevalence of fish having one or more of the four hepatic lesions was significantly elevated in Hylebos, Blair, Sitcum, Milwaukee, and Middle Waterways.

Bioaccumulation--

Concentrations of metals in English sole muscle tissue were relatively homogeneous among study areas in the Commencement Bay N/T site. The maximum average concentrations of most metals in fish were less than 2 times the average reference concentrations. However, the concentrations of copper in fish tissue were significantly elevated (3-9 times) in fish from Sitcum and St. Paul Waterways and the Ruston-Pt. Defiance Shoreline. Concentrations of lead and mercury were elevated in Dungeness crab muscle. Maximum concentrations of these metals were about 5 times the reference concentrations. PCBs were detected in all fish and crabs sampled. Maximum concentrations of PCBs in English sole, which were found in fish from Hylebos and City Waterways, were about 10 times as great as those found in English sole caught in the reference area, Carr Inlet.

Concerns exist over the potential human health impacts from the consumption of local seafood. The Tacoma-Pierce County Health Department issued a notice in January 1983 advising against the consumption of bottom fish from Hylebos Waterway and against regular consumption of fish from the other waterways. A second advisory was issued in April 1985 which expanded the advisory coverage to include the Ruston-Pt. Defiance Shoreline and Carr Inlet. Data generated in 1984 showed that muscle tissue from English sole collected at the reference stations in Carr Inlet had low concentrations of contaminants (Tetra Tech 1985a). Because these data failed to show abnormal contaminant concentrations, these data were considered suitable for use as reference data.

1.3.5 Identification of Problem Chemicals and Problem Areas

Sediments in all parts of the N/T area contain concentrations of one or more toxic contaminants that exceed levels commonly found in Puget Sound reference areas. During the RI, a multistep decision-making process was used to 1) define problem sediments and identify areas containing problem sediments, 2) identify problem chemicals, and 3) prioritize problem areas for remedial action evaluations. This process resulted in the identification of 11 high priority problem areas (subsequently consolidated into 9 areas), which are addressed in this FS report. The decision-making process is summarized below.

Identification of Problem Areas--

To facilitate the identification of problem areas, the Commencement Bay waterways and the Ruston-Pt. Defiance Shoreline were divided into 20 segments based on apparent trends in sediment contamination (Figure 1-2). In order to characterize each of these 20 segments, indices of contamination were calculated for each environmental indicator (e.g., sediment contamination, sediment toxicity, and biological effects). Elevation above reference (EAR) indices were calculated as the ratio of the value of an indicator in a particular Commencement Bay segment to the value of that indicator in the reference area. For example, the average concentration of arsenic in Sitcum Waterway sediments (37 mg/kg) was 11 times as great as that in the reference area, resulting in an EAR of 11.

Carr Inlet was selected as the primary reference area for the Commencement RI/FS. The selection of Carr Inlet for reference values was based on the proximity of the inlet to Commencement Bay, and the overall lack of contamination at the reference stations. In addition to Carr Inlet, uncontaminated stations in Blair Waterway provided reference data for benthic infauna. Because the physical characteristics of the stations in Blair Waterway were more similar to those in the problem waterways than to those in Carr Inlet, Blair Waterway was a more appropriate reference area for benthic infauna.

EAR values for five indicators (i.e., sediment chemistry, sediment toxicity, benthic infauna, fish histopathology, and bioaccumulation) were calculated for each segment. Significant elevations in any three of these indicators resulted in a segment being designated as a problem area. Use of this guideline resulted in the designation of problem areas in all Commencement Bay N/T areas and segments.

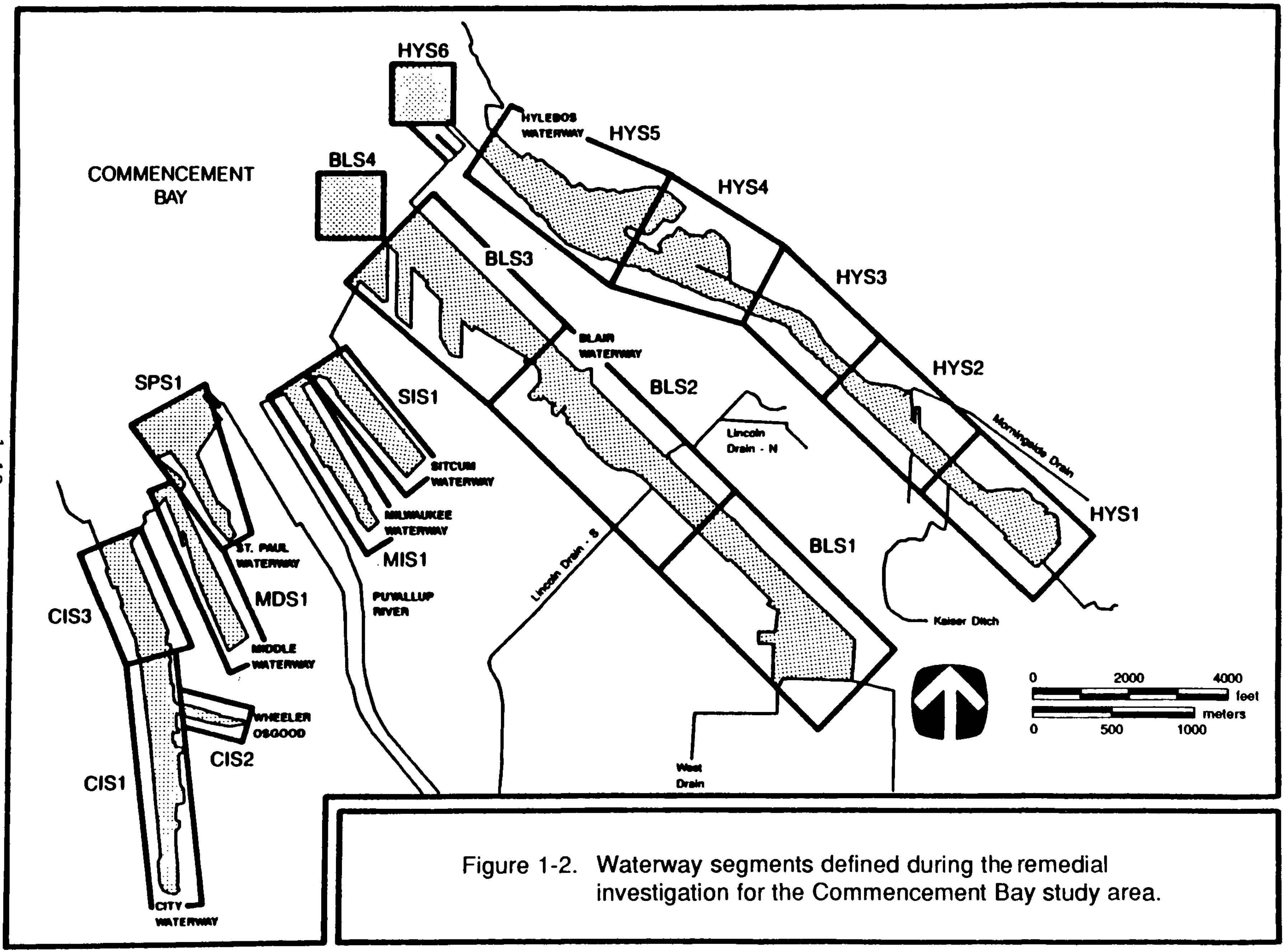


Figure 1-2. Waterway segments defined during the remedial investigation for the Commencement Bay study area.

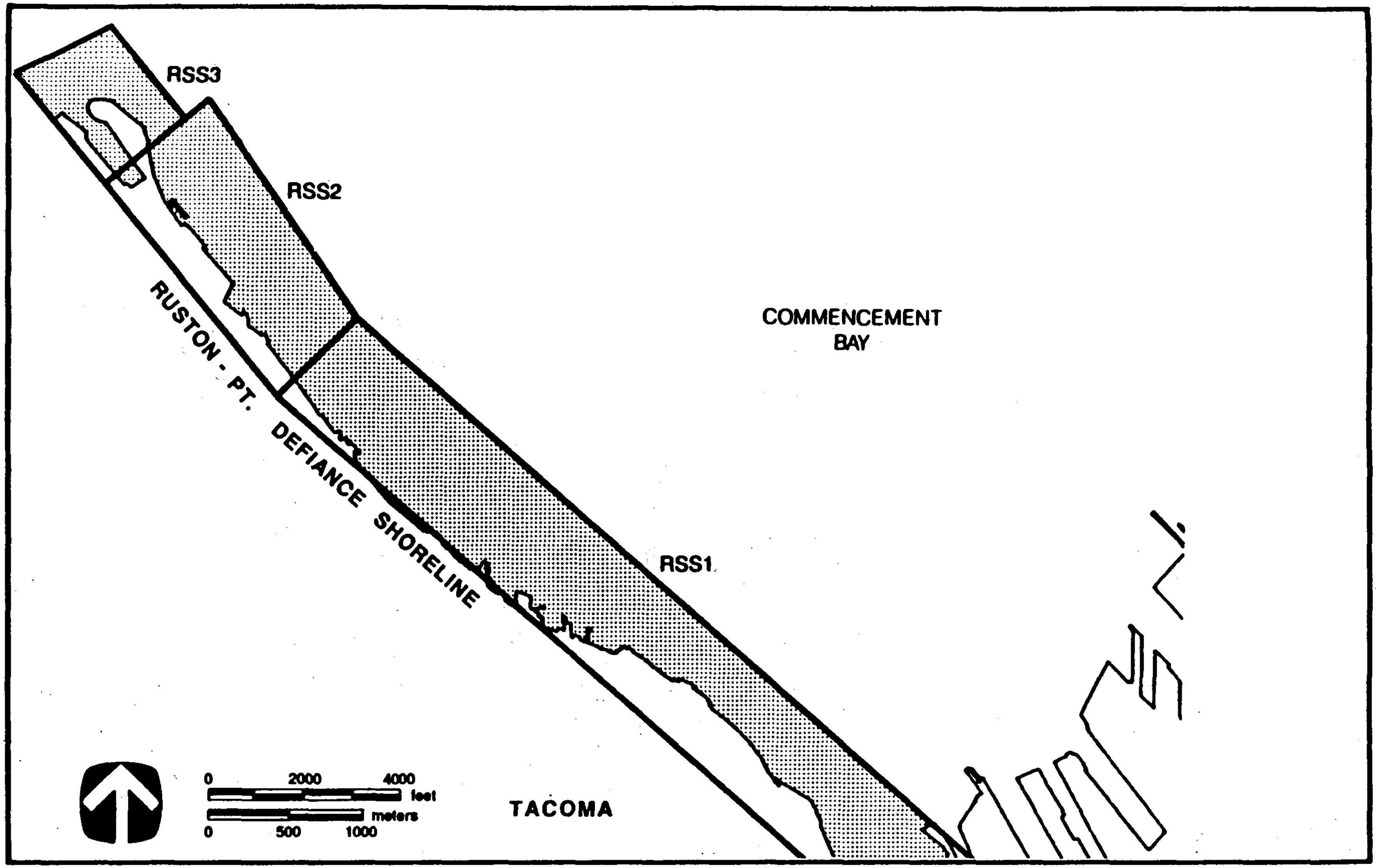


Figure 1-2. (Continued).

Identification of Problem Chemicals--

Synoptic sediment chemistry, sediment toxicity, and benthic infaunal data were used to predict the concentration of contaminants above which biological effects would be expected. A sediment toxicity "apparent effects threshold" (AET) is defined as the contaminant concentration above which statistically significant toxicity would always be expected. A benthic AET value is defined as the contaminant concentration above which statistically significant benthic effects would always be expected. Both values measure sediment quality as related to observed biological effects. Toxicity and benthic AET values were defined for each contaminant of concern (i.e., chemicals that exceeded all reference conditions) in the N/T area (Tetra Tech 1985a). The AET values were used to predict the occurrence of biological effects at sampling stations with only sediment chemistry data (i.e., sediment toxicity and/or benthic infaunal data were not collected). Further discussion of AET is provided in Sections 2.2.2.

Problem chemicals within each problem area were assigned a priority on the basis of two factors: correlation with observed biological effects and number of stations where concentrations exceeded an AET. Priority 1 chemicals were detected at concentrations greater than an AET and the spatial distributions of these chemicals corresponded to gradients of observed toxicity or benthic effects. Priority 2 chemicals were detected at concentrations greater than an AET at more than one station in a problem area, but either showed no particular spatial relationship with gradients of observed toxicity or benthic effects, or insufficient data were available to evaluate their correspondence with concentration gradients. Priority 3 chemicals were detected at concentrations greater than an AET at only a single station in a problem area. Chemicals detected at concentrations below an AET at all stations were not considered problem chemicals.

Prioritization of Areas for Remedial Action Evaluations--

Final prioritization of problem areas for remedial action was determined on the basis of three criteria:

- Environmental significance
- Spatial extent of contamination
- Confidence in source identification.

Each problem area received a score for each of the three criteria. The possible scores ranged from 1 to 4, with 4 indicating the highest priority for potential remedial action. The problem areas with the highest scores were determined to warrant evaluation of potential/sediment remedial actions under Superfund guidelines. Eleven problem areas characterized by high levels of sediment contamination were assigned the highest priority during the RI. The final ranking of the problem areas is shown in Table 1-1. Sediment remedial actions have been evaluated for these problem areas.

TABLE 1-1. FINAL RANKING OF PROBLEM AREAS IN THE COMMENCEMENT BAY REMEDIAL INVESTIGATION[a]

Segment Containing Problem Area[b]	Environmental Significance	Spatial Extent	Confidence of Source Identification	Total Score
RSS2	4	4	4	12
SPS1	4	3	4	11
CIS1	4	3	4	11
HYS5	4	3	4	11
SIS1	4	4	3	11
HYS1	4	4	3	11
HYS2	4	1	4	9
CIS2	4	1	3	8
MDS1	3	3	2	8
RSS3	1	3	4	8
CIS3	3	2	2	7
---[c]				
HYS4	3	2	1	6
RSS1a (RS-13)	3	1	1	5
BLS2	2	1	1	5
MIS1	2	1	1	4
RSS1b (RS-15)	1	1	1	3
HYS3	1	1	1	3
BLS1	1	1	1	3
HYS6	1	1	1	3
BLS3	1	1	1	3
BLS4	1	1	1	3

[a] The possible scores assigned to environmental significance, spatial extent, and confidence of source identification ranged from 1 to 4. A 4 indicates the highest priority for potential remedial action.

[b] Problem areas did not always encompass an entire segment. Problem areas in the segments indicated are listed in order of their total score of environmental significance, spatial extent, and confidence of source identification.

[c] Identification of potential remedial technologies was conducted for problem areas with a total score greater than 6 (Tetra Tech 1986b).

Reference: Tetra Tech (1985a).

Areas not identified as high priority areas were characterized by less severe environmental hazard as indicated by lower levels of contamination, reduced toxicities, and limited biological effects; smaller areas of elevated problem chemical concentrations (generally less than 10 ac, as compared to eight of the high priority areas, which were found to have spatial extents greater than 50 ac); and a limited number of identified sources. Further discussion of the evaluation process is provided in Tetra Tech (1985a).

Following further investigation during the FS, the 11 problem areas were recombined into 9 discrete areas of sediment contamination or areas where contamination can be attributed to a single source or a group of sources (Figure 1-3). The problem areas discussed in the RI as Hylebos Waterway Segments 1 and 2 (referred to hereafter as the head of Hylebos Waterway) have been combined, because the sediment contamination is contiguous and is attributable, in many cases, to common sources. Part of Hylebos Waterway Segment 4 was combined with Segment 5 (referred to hereafter as mouth of Hylebos Waterway) for similar reasons. Segments 2 and 3 of the Ruston-Pt. Defiance Shoreline (referred to hereafter as Ruston-Pt. Defiance Shoreline) have also been combined because sediment contamination is attributable to a single ultimate source (i.e., the ASARCO smelter). The revised designations for problem areas are summarized in Table 1-2.

1.4 FEASIBILITY STUDY REPORT OVERVIEW

Chapter 2 of this FS provides the technical and institutional basis for evaluating remediation requirements in Commencement Bay N/T. Section 2.1 provides a description of the technical framework that served as the basis for the RI/FS process. Section 2.2 provides an indepth discussion of the establishment of long-term cleanup goals, including goals based on both environmental and human health risks. Section 2.3 describes how long-term goals were used to estimate areas and volumes of sediment requiring remediation. The relationship between the FS and existing regulatory programs is addressed in Section 2.4. A discussion of future routine dredging programs in Commencement Bay is provided in Section 2.5.

Potentially applicable technologies for the remediation of contaminated media are presented and assembled into alternatives in Chapter 3. Both sediment and source remediation technologies are addressed, with emphasis on the former. Sediment remediation technologies are presented in Section 3.1. Source control technologies for contaminated surface water, groundwater, soil, and air are discussed in Section 3.2. In Sections 3.3 and 3.4, the various technologies are assembled into sediment remedial alternatives and the process options within each technology are described. Each alternative represents a plausible combination of remedial actions for the Commencement Bay N/T sediment remediation effort. As a whole, the set of alternatives encompasses the range of general response actions and represents all viable technologies and process options. Ten remedial alternatives appropriate to one or more of the nine Commencement Bay N/T problem areas are identified. The most appropriate alternative for each problem area was recommended from the ten candidate alternatives.

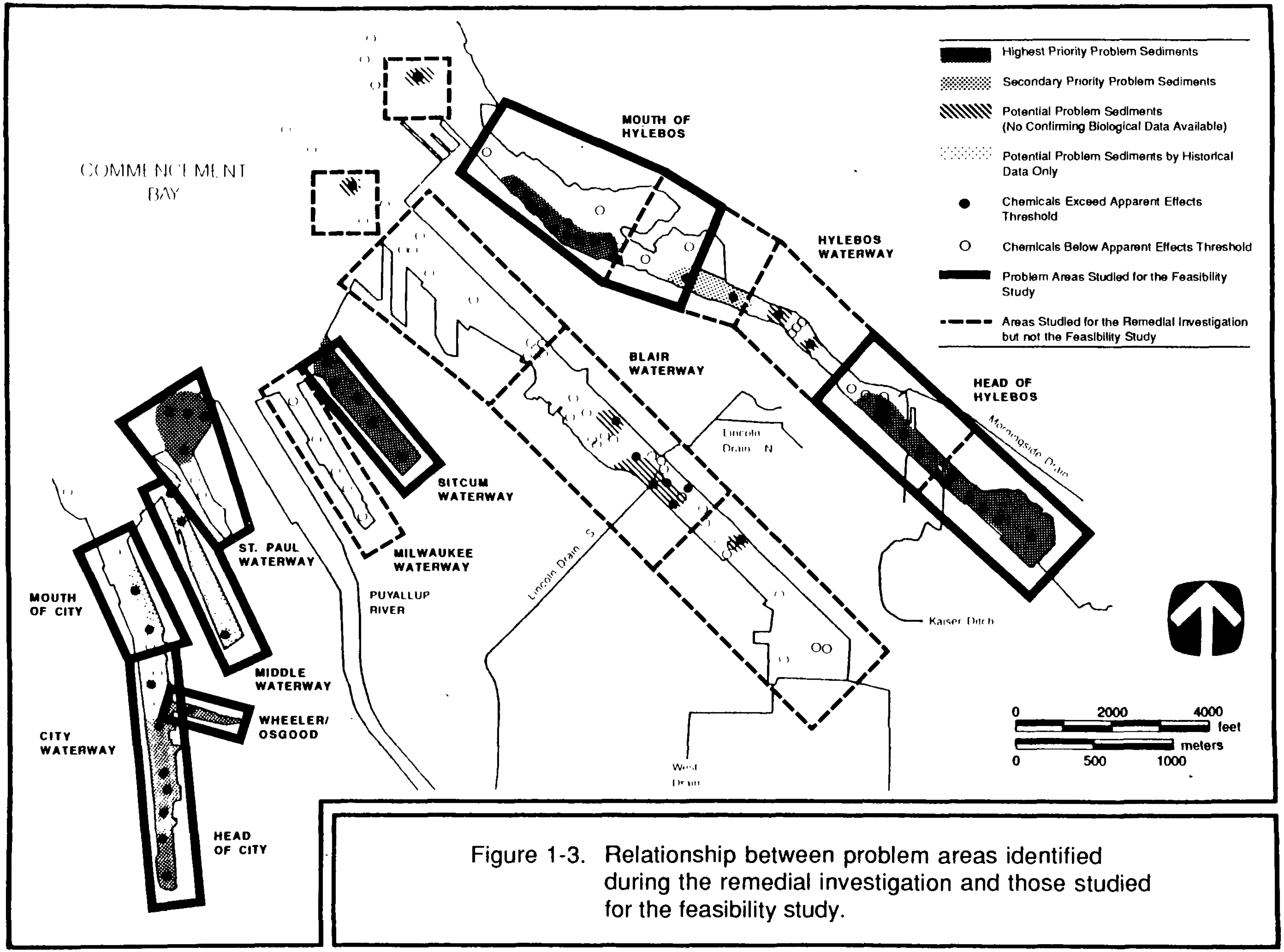


Figure 1-3. Relationship between problem areas identified during the remedial investigation and those studied for the feasibility study.

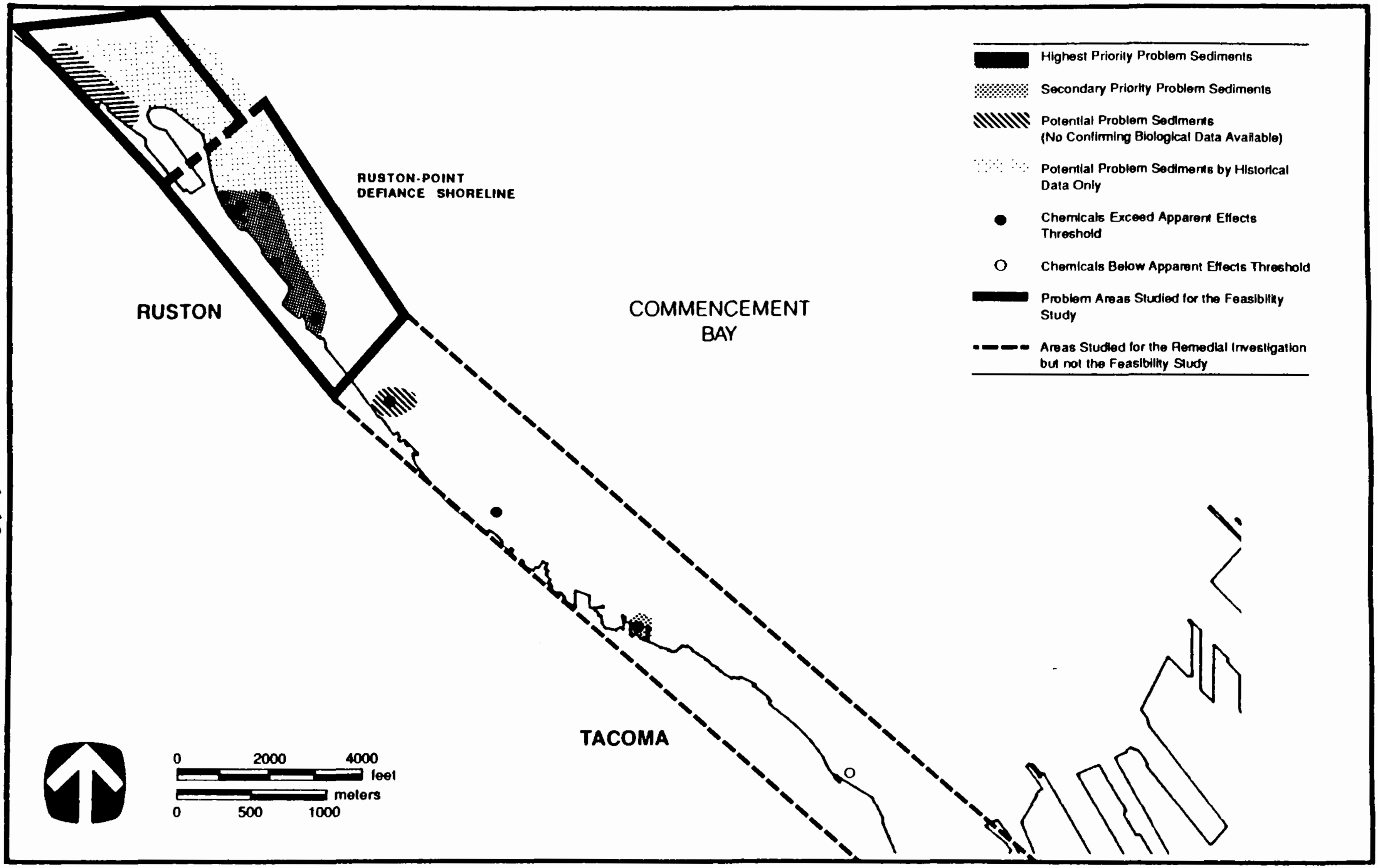


Figure 1-3. (Continued).

TABLE 1-2. REVISED DESIGNATIONS FOR PROBLEM AREAS IN THE COMMENCEMENT BAY NEARSHORE/TIDEFLATS SITE

Previous Designation[a]	Revised Designation
Hylebos Waterway Segments 1 and 2 (HYSI and HYS2)	Head of Hylebos Waterway
Hylebos Waterway Segment 3 and part of Segment 4 (HYS3 and HYS4)	Low Priority - Not included in FS
Part of Hylebos Waterway Segment 4 and Hylebos Waterway Segment 5 (HYS4 and HYS5)	Mouth of Hylebos Waterway
Hylebos Waterway Segment 6 (HYS6)	Low Priority - Not included in FS
Blair Waterway Segments 1-4 (BLS1-BLS4)	Low Priority - Not included in FS
Sitcum Waterway Segment 1 (SIS1)	Sitcum Waterway
Milwaukee Waterway Segment 1 (MIS1)	Low Priority - Not included in FS
St. Paul Waterway Segment 1 (SPS1)	St. Paul Waterway
Middle Waterway Segment 1 (MDS1)	Middle Waterway
City Waterway Segment 1 (CIS1)	Head of City Waterway
City Waterway Segment 2 (CIS2)	Wheeler-Osgood Waterway
City Waterway Segment 3 (CIS3)	Mouth of City Waterway
Ruston-Pt. Defiance Shoreline Segment 1 (RSS1a and RSS1b)	Low Priority - Not included in FS
Ruston-Pt. Defiance Shoreline Segments 2 and 3 (RSS2 and RSS3)	Ruston-Pt. Defiance Shoreline

[a] Tetra Tech (1985a).

Chapter 4 introduces the framework for the detailed analysis of sediment remedial alternatives. Effectiveness, implementability, and cost criteria are defined in Sections 4.1, 4.2, and 4.3, respectively. Section 4.4 presents the framework for identifying the preferred sediment remedial alternative.

Chapters 5-13 describe the following information for nine high priority problem areas in the study area:

- A description of the nature and extent of sediment contamination

- An overview of the major sources, with emphasis on the status of ongoing remedial activities

- An evaluation of the potential success of source control

- A detailed assessment of candidate sediment remedial alternatives

- A discussion of the selection process and indication of the recommended alternative

- Integration of source control and sediment remedial action into an overall cleanup strategy.

Chapter 14 provides a summary discussion of the preferred alternatives and the sources of uncertainty associated with the assessment procedures and data used in the FS. References are listed in Chapter 15.

Detailed explanations of certain methods and approaches are presented in Volume 2 (appendices). Appendix A presents details of the sediment recovery model, SEDCAM. Appendix B provides detailed descriptions of dredging and capping technologies. Appendix C provides a summary of specifications from applicable or relevant and appropriate requirements (ARARs) used to evaluate potential remedial activities. The method and assumptions used to estimate costs of the various remedial alternatives are described in Appendix D. Source loading data are summarized in Appendix E. Estimated rates of input for each Priority 1 and Priority 2 chemical are presented by problem area, retaining area designations of the RI (Tetra Tech 1985a). Appendix F is a set of maps showing the locations of sediment sampling stations in the subject study area. Appendix G presents the raw sediment data collected for the FS. Sample collection and laboratory analysis methods are also included in Appendix G.

The overall framework for implementing the preferred alternative for each problem area is described in a separate document, the "Commencement Bay Nearshore/Tideflats Integrated Action Plan" (PTI 1988a). These strategies were formulated by integrating the proposed sediment remedial action with recommended source control measures.

2.0 TECHNICAL AND INSTITUTIONAL BASIS FOR REMEDIATION

Chapter 2 provides the technical and institutional basis for evaluating remediation requirements in the Commencement Bay N/T area. Section 2.1 provides a description of the technical framework that served as the basis for the RI/FS process. Section 2.2 provides a detailed discussion of the development and use of long-term cleanup goals. Goals based on both environmental and human health assessments are described. Section 2.3 describes how long-term goals were used to estimate areas and volumes of sediment requiring remediation. The relationship between the FS and existing regulatory programs is addressed in Section 2.4. A discussion of future routine dredging programs in Commencement Bay is provided in Section 2.5.

2.1 FEASIBILITY STUDY TECHNICAL FRAMEWORK

The Commencement Bay N/T Superfund program is a multistep program involving a remedial investigation, a feasibility study, source control, and an integrated action plan. The relationships among these programs are shown in Figure 2-1.

The Commencement Bay RI was completed in August 1985. Its major objectives were threefold:

- To identify problem sediments in the waterways and along the Ruston-Pt. Defiance shoreline
- To identify the particular chemicals associated with those problem sediments
- To identify potential sources of problem chemicals.

Based on the results of the RI, 11 high priority problem areas were identified for potential remedial action. These areas were consolidated into nine problem areas for the Commencement Bay FS evaluation. Although source identification was somewhat limited by available data, a number of ongoing sources of contamination were identified.

Following the completion of the RI, two approaches were developed to address Commencement Bay problems. First, Ecology and U.S. EPA expanded ongoing source control efforts in the Commencement Bay area. These expanded efforts focus on controlling or eliminating the ongoing release of chemicals into high priority problem areas. The source control effort involves a number of programs, and individual actions have been taken using the most appropriate program mechanism [e.g., enforcement under the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA)]. Examples of source control actions undertaken in Commencement Bay include the investi-

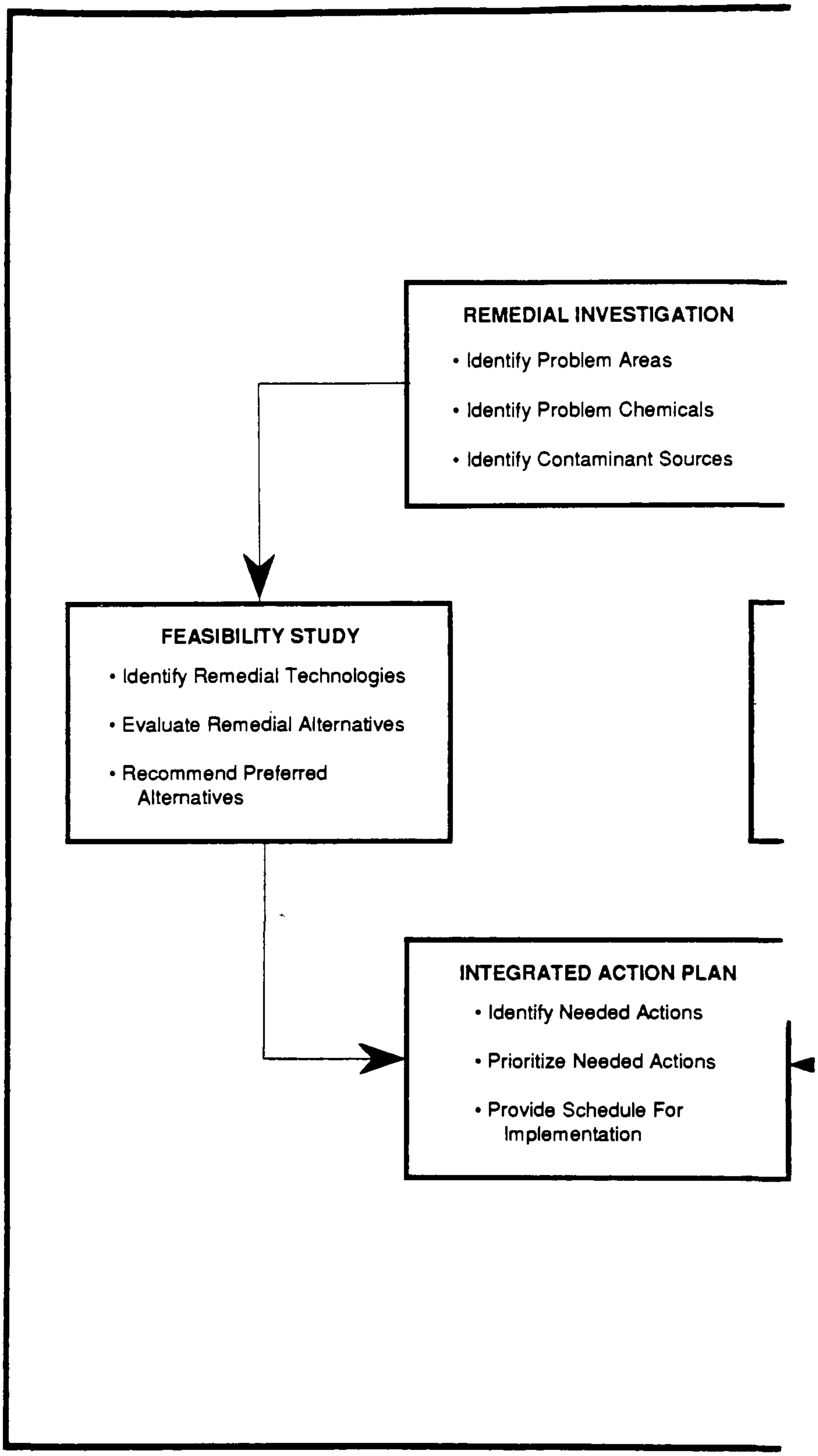


Figure 2-1. Relationships among programs
sediment contamination problem
Commencement Bay N/T site.

gation and control of surface water runoff from several log sorting yards in the area.

The second major effort initiated following the completion of the RI was the FS. This effort includes the identification, evaluation, and recommendation of corrective measures for each of the nine high priority problem areas. The preferred alternatives recommended for each problem area integrate source control and sediment remedial actions. Natural recovery of sediments (i.e., degradation or burial of contaminated surface sediments beneath clean material) is included as a component of the remedial alternative.

The feasibility of institutional controls and sediment cleanup actions were evaluated using the standard Superfund evaluation approach. Areas and volumes of contaminated sediments were estimated based upon an analysis of sediment chemistry and observed biological effects, and upon the predicted results of source controls and natural recovery processes. Alternatives were developed and analyzed in accordance with the most recent U.S. EPA (1988) guidance. The evaluation process involved consideration of the effectiveness, implementability, and costs of various remedial alternatives.

This report does not contain detailed engineering and cost evaluations for individual source control measures. Many of the source control actions identified herein are currently being implemented by local industries in response to enhanced Ecology and U.S. EPA regulatory efforts during the last several years. Regulatory actions have resulted in the collection of additional data that have been incorporated into the FS evaluations. Upon completion of this FS, source control actions will continue to be handled under these existing regulatory programs.

The technical approach used in the FS to assess remedial alternatives for sediment problem areas includes the following components:

- Conduct field investigations to fill data gaps
- Develop sediment cleanup goals
- Develop an analytical approach to 1) establish the relationship between source loading and sediment accumulation of problem chemicals, and 2) evaluate natural recovery of sediments following control of sources
- Estimate the feasibility of source control
- Identify and screen candidate sediment remedial alternatives
- Identify preferred alternatives
- Prepare an integrated action plan.

Components of the technical approach are discussed briefly in the following sections.

2.1.1 Field Investigations

The RI (Tetra Tech 1985a) revealed several major data gaps. During the FS, several approaches were used to collect additional information.

Sediment core data were collected to help distinguish historical from current sources and to estimate sedimentation rates. Sediment cores were collected in May 1986 at 22 locations in the high priority problem areas. Sediment coring locations are identified in Appendix F. These cores were analyzed for chemical contaminants and 210-Pb. Chemical concentrations were used to determine depth of contamination and to help define the chronology of historical contamination in the problem areas. The 210-Pb data were used to plot radioactive 210-Pb decay curves, which were then used to estimate sedimentation rates for the selected areas. The summary data report is included as Appendix G.

Supporting field investigations were conducted to provide additional information on sources of contamination in the receiving environment. Ecology's Water Quality Investigation Section investigated the following four topics, with QA/QC support provided by Tetra Tech, Inc.:

- Potential sources of PCB contamination in Hylebos Waterway (Stinson et al. 1987)
- Concentration of metals in ASARCO discharges and receiving waters (Stinson and Norton 1987a)
- Contaminants in Wheeler-Osgood drains and sumps (Stinson and Norton 1987b)
- 4-Methylphenol in marine sediments of Commencement Bay (Norton et al. 1987).

Results have been incorporated into the evaluations of individual problem areas (see Chapters 5-13).

2.1.2 Development of Sediment Cleanup Goals

Under Section 121 of CERCLA/SARA, U.S. EPA is required to select a remedial action that ". . . attains a degree of cleanup . . . which assures protection of human health and the environment . . . ." Protection of human health and the environment is to be achieved at least in part, by compliance with the ". . . appropriate standard, requirement, criteria, or limitation for contaminants that will remain at the site . . . ." These legally applicable or relevant and appropriate requirements (ARARs) include federal, state, local, and tribal laws and regulations. Similar statutory requirements are contained in the Washington State Model Toxics Control Act. Under state law, Ecology is required to select those actions that will attain a degree of cleanup that is protective of human health and the environment. As with the federal law, remedial actions must, at a minimum, meet the substantive requirements of other state and federal laws, regulations, and rules.

Translating these general directives into specific requirements for the Commencement Bay N/T project was complicated by the lack of definitive standards, guidelines, or criteria for defining acceptable levels of contaminants in marine sediments. The technical approach used to establish sediment cleanup goals and requirements included the following components:

- Define an acceptable level of environmental and human health protection
- Develop an approach for translating this conceptual definition into an administrative framework
- Develop an approach for translating the long-term sediment cleanup goal into site-specific cleanup requirements
- Define procedures for reviewing cleanup requirements and incorporating new information to refine estimates of sediment areas and volumes requiring remediation.

2.1.3 Response of Sediments to Source Control

Following source control, surface sediments will tend to recover (i.e., concentrations of contaminants and the composition of biological communities will not differ statistically from those in similar uncontaminated areas) naturally through contaminant degradation, diffusive loss to overlying water, and deposition of clean sediments. In certain circumstances, source control and natural recovery of contaminated sediments may represent an appropriate response to existing sediment contamination problems. Where it can be shown that the depositional environment and the existing level of contamination would allow natural recovery, this option would allow gradual recovery of the benthic community. This option would also minimize possible adverse impacts associated with redistribution of contaminated sediments during dredging operations, and would minimize the costs and technical problems associated with the disposal of contaminated dredged material. This option is consistent with the guidelines for sediment cleanup decisions section of the Puget Sound Water Quality Authority's 1989 Management Plan (PSWQA 1988).

Areas of contamination that, following source control, would be expected to return to acceptable levels in a reasonable timeframe were predicted using a mathematical model (SEDCAM). Sediment recovery over 5-yr, 10-yr, and 25-yr timeframes were estimated as was long-term sediment recovery. The technical approach developed to establish the relationship between source control and sediment recovery includes the following components:

- Establishing a mathematical relationship between source loadings and the level of contamination in surface sediments

- Characterizing the depth of the biologically active sediment surface layer and the natural sedimentation rates in each of the waterways and along the Ruston-Pt. Defiance Shoreline using 210-Pb techniques

- Evaluating chemical-specific losses due to biodegradation and diffusion across the sediment-water interface.

To apply this model, it was necessary to estimate the degree of source control that is feasible for individual problem areas. Details of the model and implicit assumptions are described in Appendix A and Tetra Tech (1987a).

2.1.4 Feasibility of Source Control

Before sediment remedial alternatives can be implemented, it will be necessary to control the sources of contamination. Potential sources of contamination are identified and source control technologies are discussed in the FS report. However, preferred source control alternatives are not identified. Instead, estimates are provided for the degree of source control that may be feasible in each problem area. These values were used to calculate natural sediment recovery following implementation of source controls.

Estimates of the degree of source control that is feasible for each problem area were based on known or potential pathways of contamination and the probable success of implementing all known, available, and reasonable control technologies. Factors considered in the evaluation include the number of sources and pathways, the resolution with which these sources and pathways of contamination were defined, the frequency of contaminant detection in source monitoring efforts, and average loading values (developed as the product of observed concentrations and flow volumes).

The feasibility of source control was assumed to be highest for chemicals with well-defined migration pathways to the problem area. A maximum of 95 percent source control was assumed feasible for chemicals discharged from a single source with a well-identified contaminant reservoir and environmental pathway. A maximum of 80 percent source control was assumed feasible for chemicals discharged from multiple well-identified sources, or from a single source with multiple potential migration pathways. A 70 percent source control level was assumed feasible for chemicals associated with poorly defined or questionable sources. A 60 percent source control level was assumed feasible for contaminants associated with storm drain inputs where major point sources have not been identified in the drainage basin, and for contaminants from poorly defined sources where it is unclear whether inputs are ongoing or historical.

2.1.5 Identify and Screen Sediment Remedial Alternatives

Sediment remedial alternatives were developed through the following steps:

- Develop a thorough list of available remedial technologies for the isolation, excavation, treatment, and disposal of contaminated sediments

- Conduct an initial screening of available remedial technologies to identify candidate technologies that may be appropriate for the project area

- Develop specific combinations of appropriate technologies to define a range of complete sediment remedial alternatives

- Screen candidate sediment remedial alternatives for each individual problem area to develop a discrete and concise set of alternatives appropriate for that problem area.

Remedial technologies and corresponding process options were identified within six response action categories: no action, institutional controls, in situ containment, removal, treatment, and disposal. Through an initial screening process, several technologies and many process options were eliminated as not being appropriate at this time for Commencement Bay N/T problem areas. The sediment remedial technologies and process options that passed the initial screening were combined to form 10 remedial alternatives within five general categories, as follows:

- No action

- Institutional controls

- In situ containment (capping)

- Removal and disposal

  - Removal/confined aquatic disposal

  - Removal/nearshore disposal

  - Removal/upland disposal

- Removal, treatment, and disposal

  - Removal/solidification/upland disposal

  - Removal/solvent extraction/upland disposal

  - Removal/incineration/upland disposal

  - Removal/land treatment.

These 10 alternatives were then evaluated to develop a specific set of alternatives for each problem area.

2.1.6 Identification of Preferred Alternatives

A detailed analysis of sediment remedial alternatives and identification of preferred alternatives is the final stage of the FS process. Evaluation criteria for the detailed analysis can be grouped into three general categories: effectiveness, implementability, and cost. For the Commencement Bay N/T FS, there are four effectiveness criteria: short-term protectiveness; timeliness; long-term protectiveness; and reduction in contaminant toxicity, mobility, or volume. Three implementability criteria have been included: technical feasibility, institutional feasibility, and availability of disposal facilities. Cost criteria were divided into initial costs, and operation and maintenance (O&M) costs. Initial costs include those for design, preparation of specifications, and construction. O&M costs include those for environmental monitoring. A cost analysis was performed to estimate the initial costs of each alternative and the present value of a 30-yr monitoring program.

A full analysis of effectiveness and implementability of each alternative is presented in a narrative matrix for each problem area. Summary tables, in which each alternative is rated high, moderate, or low in the seven major evaluation criteria have also been prepared. Costs are shown in the latter tables. Based on this evaluation, a preferred alternative was identified and proposed for sediment remediation in each problem area.

The preferred alternatives will be evaluated during a public review period. Following public review, correction of sediment contamination problems will be implemented according to a performance-based Record of Decision (ROD). The ROD will specify performance criteria (e.g., attainment of specific cleanup criteria), but will not require that a specific technology be used to conduct the cleanup. Since sediment cleanup (i.e., source control and sediment remedial action) may span 5 to 10 yr, new and possibly more effective techniques may become available after the ROD. In addition, smaller projects (e.g., pier development or maintenance dredging) within problem areas are anticipated prior to scheduled remedial action under Superfund. These smaller projects would need to be conducted in a manner consistent with the performance criteria specified in the ROD, but not necessarily according to the recommended technology. This approach provides the flexibility to use the most appropriate technology available at the time cleanup occurs as long as it can be shown, during the detailed engineering phase of the project, that the technology will be at least as effective in attaining the cleanup criteria as the technology recommended in the ROD. Post-ROD activities will be implemented according to the Integrated Action Plan (PTI 1988a) (Section 2.1.6).

2.1.7 Integrated Action Plan

Development and implementation of preferred sediment remedial alternatives must be coordinated with source control to maintain acceptable sediment quality following remediation. Institutional requirements, source control measures, and sediment remedial actions are incorporated in the Commencement Bay Integrated Action Plan (IAP) (PTI 1988a) to identify, prioritize, and integrate remedial activities. The overall objective of the plan is to ensure that risks to human health and the environment are eliminated in a timely and cost-effective manner.

2.2 IDENTIFICATION OF LONG-TERM CLEANUP GOALS

2.2.1 Background

The purpose of Superfund actions is to protect human health and the environment from hazards associated with the release or threatened release of hazardous substances. A major issue in developing sediment cleanup goals for the Commencement Bay N/T Superfund site is the determination of the degree of protection that is necessary and appropriate.

Translating the guidance regarding ARARs provided under Section 121 of the CERCLA/SARA (see Section 2.1.2) into specific requirements for the Commencement Bay N/T project was complicated by the lack of definitive standards, guidelines, or criteria for defining acceptable levels of contaminants in marine sediments. However, the Puget Sound Water Quality Authority Management (1989) Plan (PSWQA 1988) specified a number of goals and policies that are applicable to the Commencement Bay area. For purposes of defining sediment cleanup goals and requirements, two program elements are of particular importance: Standards for Classifying Sediments Having Adverse Effects (Element P-2), and Guidelines for Sediment Cleanup Decisions (Element S-7).

Element P-2 requires Ecology to develop and adopt by regulation, standards for identifying and designating sediments that have observable acute or chronic adverse effects on biological resources or pose a significant health risk to humans. The standards for defining "sediments that have acute or chronic adverse effects" may use chemical, physical, or biological tests, and shall clearly define pass/fail standards for any tests. Initial standards may deal exclusively with biological effects, but shall be revised to include human health concerns as this information becomes available. The standards are to be used to limit discharges through the NPDES (Element P-7), stormwater (Element SW-4), and nonpoint programs; to identify sites with sediment contamination (Element S-8); and to limit the disposal of dredged material (Element S-4). Element S-7 requires Ecology to develop guidelines for deciding when to implement sediment remedial actions. The guidelines should consider deadlines for making decisions, natural recovery of sediments, procedures for determining priorities for action (including consideration of costs), and trigger levels for defining sediments that require expedited remedial action. Trigger levels may be higher than the sediments-having-adverse-effects levels developed under Element P-2.

The sediment quality goal in Element P-2 (no acute or chronic adverse effects on biological resources or significant health risk to humans) was used to define the long-term sediment quality goal in Commencement Bay. As in other parts of Puget Sound, this sediment cleanup goal is meant to establish levels of sediment contamination that would be acceptable throughout Commencement Bay. It is a long-term goal to be achieved through numerous actions over a period of 10 to 15 yr. The long-term goal has not been modified to take into consideration factors such as cost and technical feasibility. Consequently, it serves as a yardstick for evaluating and selecting the requirements for individual actions where these and other factors are considered. The methods and factors associated with translating this goal into individual requirements will vary depending on the type of action, statutory authorities, and site-specific considerations, as discussed in Section 2.3.

There are a number of technical approaches for defining sediments that meet the long-term cleanup goal. Available approaches have been divided into the following two groups: 1) those concerned with environmental effects (Section 2.2.2), and 2) those concerned with human health effects (Section 2.2.3).

2.2.2 Evaluation of Environmental Effects

The sediments of Commencement Bay host a large diversity of benthic organisms that may be directly influenced by sediment contaminants. Sediment contaminants may result in acute or chronic impacts to those organisms. In addition to potential impacts to benthic organisms, fish and crabs that live in close association with the sediment and perhaps feed on benthic organisms may be affected. Therefore, the evaluation of environmental effects on resident biota provides a suitable basis for development of long-term sediment quality goals. Approaches for development of long-term goals based on environmental effects (i.e., benthic communities, and sediment toxicity) are summarized below. The technical approach selected for use in the FS (i.e., the AET), and the rationale for selecting it are described in Section 2.2.2. Administrative procedures that will be used to define the long-term goal are described in Section 2.2.4. This discussion addresses chemical and biological testing requirements and interpretation guidelines. Procedures for reviewing cleanup estimates and incorporating new information to refine estimates of sediment areas and volumes requiring remediation are described in Section 2.2.5.

Sediment Quality Goals - Review of Available Approaches--

Ideally, sediment quality values and sediment management decisions would be supported by definitive cause-and-effect information relating specific chemicals to biological effects in various aquatic organisms and to quantifiable human health risks. However, to date, very little information of this type is available, and it is unlikely that additional information will be available in the near future. In the interim, in the interest of protecting human health and the environment, regulatory agencies must proceed with sediment management decisions based on the best information available.

The ability to develop sediment cleanup goals for the Commencement Bay N/T site was initially limited due to a lack of appropriate regulatory standards or guidelines for evaluating the quality of the marine environment. The ability to assess sediment quality in a technically reliable and legally defensible manner was considered a necessary component of a complete plan for remedial action, and was required to make the following management decisions:

- Identify problem chemicals

- Establish a link between contaminated sediments and sources

- Provide a predictive tool for cases in which site-specific biological testing results were not available

- Enable designation of problem areas within the site

- Provide a consistent basis on which to evaluate sediment contamination and to separate acceptable from unacceptable conditions

- Provide an environmental basis for triggering sediment remedial action

- Provide a reference point for establishing a cleanup goal

- Evaluate the need for and success of source control.

In the past decade, several federal, regional, and state agencies have developed numerical criteria or assessment methods for evaluating contamination in sediments and dredged material. Most early efforts at developing criteria were based on comparing chemical concentrations in contaminated areas to those in reference areas, and did not directly consider biological effects. More recently, approaches to evaluating sediment quality have focused on determining relationships between sediment contaminant concentrations and adverse biological impacts.

Various approaches were evaluated for possible use in guiding management decisions under PSDDA (Tetra Tech 1986a). The conclusions of this independent study have been reviewed in the context of the Commencement Bay N/T project, and have also been reviewed for application in other Puget Sound programs (Tetra Tech 1986a; Lyman et al. 1987; Battelle 1988; and Chapman, in review). The following approaches were evaluated:

- Field-based approaches

  - Reference area

  - Field-collected sediment bioassay

  - Screening level concentration (SLC)

  - Sediment quality triad (Triad)

  - Apparent effects threshold (AET)

- Laboratory/theoretically-based approaches
    - Water quality criteria/interstitial water
    - Equilibrium partitioning (sediment-water)
    - Equilibrium partitioning (sediment-biota)
    - Spiked sediment bioassay.

These approaches are briefly described in Table 2-1. Field-based approaches rely on empirical chemical and/or biological measurements of sediments to establish sediment quality values. Some of these approaches are either purely chemical (reference area approach) or biological (field-collected sediment bioassay approach) in nature. Other approaches such as SLC, Triad, and AET correlate biological responses (e.g., field-collected sediment bioassays, in situ biological effects observed in organisms associated with sediments) and chemical concentrations measured in sediments to develop sediment quality values. Laboratory/theoretically-based approaches rely on extrapolation of water quality criteria to sediments, models of environmental interactions (e.g., sediment-water equilibrium partitioning) or extrapolation of laboratory cause-effect studies to develop sediment quality values.

In the 1986 study, the water quality criteria, spiked bioassay, and field bioassay approaches were not considered appropriate for further consideration as stand-alone methods. Water quality criteria are integrated into the sediment-water equilibrium partitioning approach. The field bioassay approach was considered as part of the AET approach and could not generate chemical-specific criteria in its simplest form. Sufficient data were not available to evaluate the spiked bioassay approach. The remaining five approaches were evaluated, using several management and technical criteria (Tetra Tech 1986a). For the Commencement Bay N/T project, the following criteria were used:

- Management considerations
    - Applicability to existing and anticipated sediment management programs at the site
    - Feasibility of full implementation in the very near term
    - Environmental protectiveness (i.e., reliability in predictions of adverse effects)
    - Regulatory defensibility (i.e., supporting weight of evidence)
    - Cost of initial sediment quality value development
    - Cost of routine application as a regulatory tool

TABLE 2-1. APPROACHES EVALUATED FOR ESTABLISHING SEDIMENT QUALITY VALUES

Approach	Concept
Reference Area	Sediment quality values are based on chemical concentrations in a pristine area or an area with acceptably low levels of contamination.
Field Collected Sediment	Relationships between chemical concentrations and biological responses are established by exposing test organisms to field-collected sediments with measured contaminant concentrations.
Screening Level Concentration (SLC)	The SLC approach estimates the sediment concentration of a contaminant above which less than 95 percent of the total enumerated species of benthic infauna are present. SLC values are empirically derived from paired field data for sediment chemistry and species-specific benthic infaunal abundances.
Sediment Quality Triad (Triad)	The Triad approach consists of coincident measurements of sediment contamination, sediment toxicity, and benthic infauna community structure. This approach is based upon the observation that each component complements and adds to the information provided by the other two components in assessments of pollution-induced environmental degradation. The hypothesis underlying this concept is that no individual component of the triad can be used to predict the results of the measurements of the other components.
Apparent Effects Threshold (AET)	An AET is the sediment concentration of a contaminant above which statistically significant biological effects (e.g., amphipod mortality in bioassays, depressions in the abundance of benthic infauna) would always be expected. AETs are empirically derived from paired field data for sediment chemistry and a range of biological effects indicators.
Water Quality Criteria/ Interstitial Water	Contaminant concentrations in interstitial water are measured directly and compared with U.S. EPA water quality criteria.

TABLE 2-1. (Continued)

Equilibrium Partitioning (Sediment-Water)	A theoretical model is used to describe the equilibrium partitioning of a contaminant between sedimentary organic matter and interstitial water. A sediment quality value for a given contaminant is the organic carbon normalized concentration that would correspond to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant.
Equilibrium Partitioning (Sediment-Biota)	Acceptable contaminant body burdens for benthic organisms are based on existing regulatory limits. Sedimentary contaminant concentrations that would correspond to these body burdens under thermodynamic equilibrium are established as sediment quality values.
Spiked Sediment Bioassay	Dose-response relationships are established by exposing test organisms to sediments that have been spiked with known amounts of chemicals or mixtures of chemicals. Sediment quality values are determined for sediment bioassays in the manner that aqueous bioassays were used to establish U.S. EPA water quality criteria.

- Technical considerations

  - Data requirements for initial sediment quality value development and the current availability of data

  - Data requirements for routine application as a regulatory tool

  - Ability to develop chemical-specific sediment quality values

  - Ability to develop sediment quality values for a wide range of chemicals (e.g., metals; nonionic organic compounds; ionizable organic compounds)

  - Current availability of values for a wide range of problem chemicals in Commencement Bay

  - Ability to incorporate influence of chemical mixtures in sediments

  - Ability to incorporate a range of biological indicator organisms

  - Ability to incorporate direct measurement of sediment biological effects

  - Applicability of predictions to historical sediment chemistry data

  - Ease and extent of field verification in Puget Sound.

Three approaches were identified as most promising in the Tetra Tech (1986a) study and selected for further evaluation. They included the SLC, AET, and sediment-water equilibrium partitioning approaches. These remaining approaches were compared in a field verification test designed to assess their ability to predict observed adverse impacts in actual environmental samples collected from Puget Sound. Field verification using diverse environmental samples was an important element of the evaluation of each approach because none of the available approaches are fully capable of addressing all concerns about interactive effects among chemicals and other factors that may be important in field-contaminated sediments. Sediment quality values were generated according to each approach, and were compared to biological effects data developed for the sediment samples. The SLC approach could not be adequately tested using the existing data, and was subjected to a limited evaluation.

Specific measures of predictive reliability were developed to objectively assess the approaches to sediment quality value generation. The measures focused on the binary (i.e., impacted vs. nonimpacted) predictions of sediment quality values (if, for a given station, one or more chemicals exceeded their sediment quality values, then the station was predicted to have impacts). The measures of reliability were defined as follows:

- Sensitivity in detecting environmental problems (i.e., are all biologically impacted sediments identified by the predictions of the chemical sediment criteria?)

- Efficiency in screening environmental problems (i.e., are only biologically impacted sediments identified by the predictions of the chemical sediment criteria?).

As a measure of reliability, sensitivity was defined as the proportion of all stations exhibiting adverse biological effects that are correctly predicted using sediment quality values. Efficiency was defined as a proportion of all stations predicted to have adverse biological effects that actually are impacted. The concepts of sensitivity and efficiency are illustrated in Figure 2-2.

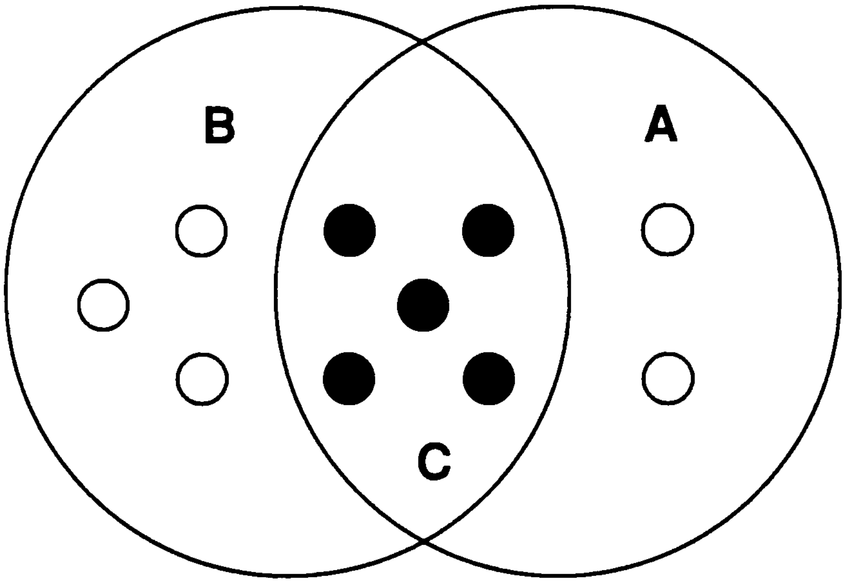
The sediment quality values developed according to the AET approach were found to provide greater overall predictive reliability than those derived by the equilibrium partitioning approach. For example, depending on the biological indicator being tested, the AET approach correctly identified between 54 and 94 percent of the field stations exhibiting biological impacts (sensitivity), and had an efficiency of 33-100 percent. In comparison, the equilibrium partitioning approach correctly predicted from 13 to 43 percent of the impacted stations (sensitivity), and had an efficiency of 33-100 percent. A recent study of the AET approach using a larger data set (PTI 1988c) demonstrated sensitivity similar to that observed in 1986, but with generally higher efficiency (typically >60 percent).

The AET Approach--

Rationale for Selection of AET--Based on consideration of management and technical criteria and on results of the verification exercise with field-collected data, the AET approach has been selected and confirmed as the preferred method for developing sediment quality goals in Commencement Bay. At this time, the AET approach can be used to provide chemical-specific sediment quality values for the greatest number and widest range of chemicals of concern in Commencement Bay and throughout Puget Sound. AET can also be developed for a range of biological indicators, including laboratory-controlled bioassays and in situ benthic infaunal analyses (the indicators for which data are available are discussed later in this section). An additional advantage of using existing AET for the Commencement Bay N/T FS is that RI data constitute a relatively large proportion of the data set used to generate AET values. The AET approach has also been selected for application in other Puget Sound regulatory programs, including the PSWQA Plan, PSDDA, and PSEP (Section 2.4).

AET Development--An AET is defined as the sediment concentration of a given chemical above which statistically significant ($P<0.05$) biological effects are always expected. In this section, the procedure for developing

MEASURES OF RELIABILITY



SENSITIVITY = C/B x 100 = 5/8 x 100 = 63%
EFFICIENCY = C/A x 100 = 5/7 x 100 = 71%

FOR A GIVEN BIOLOGICAL INDICATOR:

A All stations predicted to be impacted

B All stations known to be impacted

C All stations correctly predicted to be impacted

Figure 2-2. Measures of reliability (sensitivity and efficiency).

chemical-specific AET is described, and the AET concept is discussed as it relates to the interpretation of chemical and biological data in field-collected sediments. AET generation is a conceptually simple process that incorporates some of the complexity of biological-chemical relationships in the environment without relying upon assumptions about the mechanistic (i.e., cause-and-effect) nature of these relationships. The concept of the AET is presented in this section with little reference to specific chemicals or specific biological tests, because the approach is not inherently limited to specific subsets of these variables.

The focus of the AET approach is on identifying concentrations of contaminants that are associated exclusively with sediments exhibiting statistically significant biological effects relative to reference sediments. As follows, the calculation of the AET for each chemical and biological indicator is straightforward:

1) Collect "matched" chemical and biological effects data--Conduct chemical and biological effects tests on subsamples of the same field sample (to avoid unaccountable losses of benthic organisms, benthic infaunal and chemical analyses are conducted on separate samples collected concurrently at the same location)

2) Identify "impacted" and "nonimpacted" stations--Statistically test the significance of adverse biological effects relative to suitable reference conditions for each sediment sample and biological indicator; suitable reference conditions are established by sediments containing very low or undetectable concentrations of any toxic chemicals

3) Identify AET using only "nonimpacted" stations--For each chemical, the AET can be identified for a given biological indicator as the highest detected concentration among sediment samples that does not exhibit a statistically significant effect (if the chemical is undetected in all nonimpacted samples, then no AET can be established for that chemical and biological indicator)

4) Check for preliminary AET--Verify that statistically significant biological effects are observed at a chemical concentration higher than the AET; otherwise the AET is only a preliminary estimate or may not exist

5) Repeat steps 1 through 4 for each biological indicator.

A pictorial representation of the AET approach for two chemicals is presented in Figure 2-3 based on results for the amphipod toxicity bioassay. Two subsets of the data from all sediments chemically analyzed and subjected to an amphipod bioassay are represented by bars in the figure. The following information is presented in Figure 2-3:

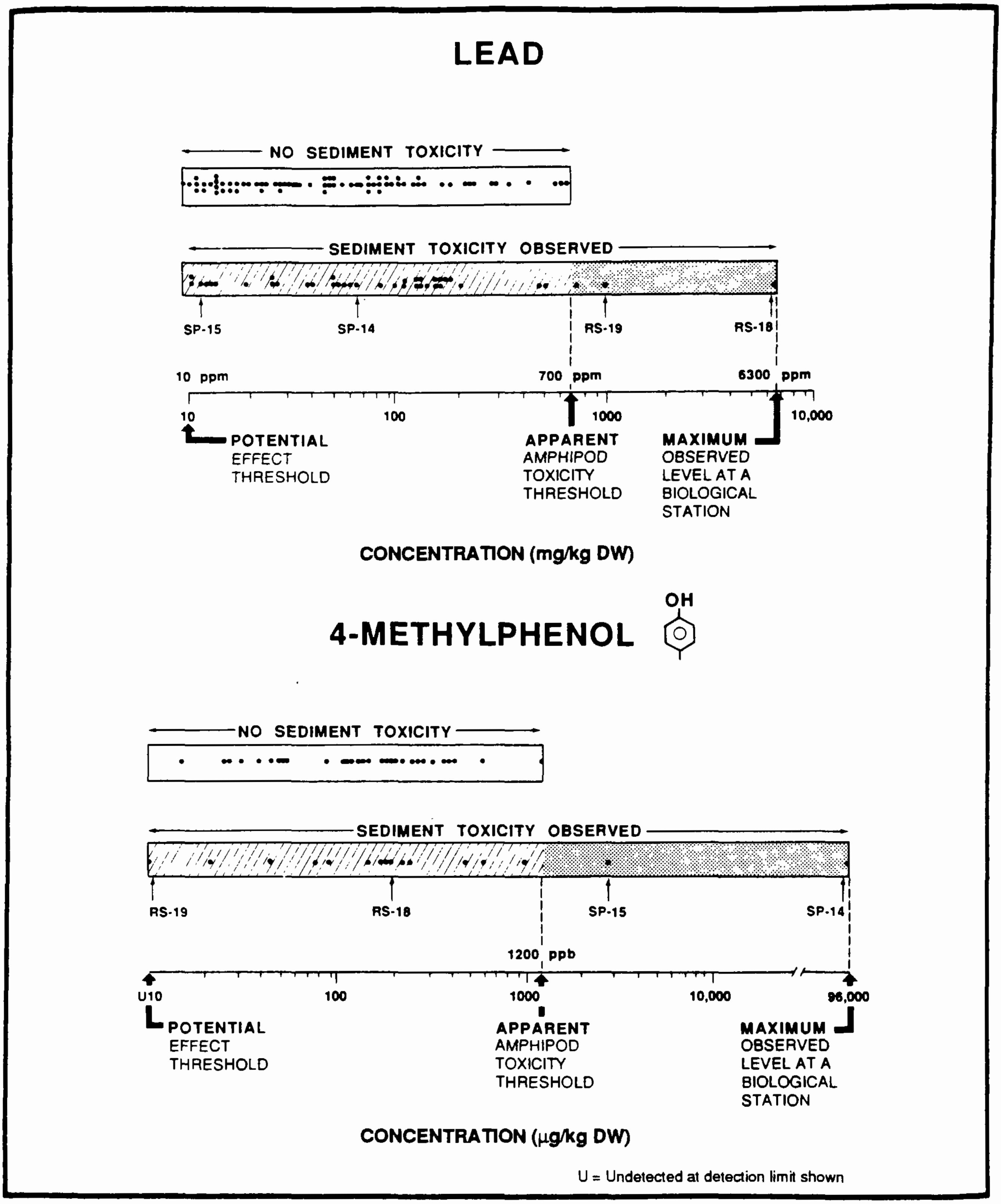


Figure 2-3. The AET approach to sediments tested for lead and 4-methylphenol concentrations and amphipod mortality during bioassays.

- Sediments that did not exhibit statistically significant (P=0.05) amphipod toxicity relative to reference conditions ("nonimpacted" stations)

- Sediments that did exhibit statistically significant (P=0.05) amphipod toxicity in bioassays relative to reference conditions ("impacted" stations).

The horizontal axes in Figure 2-3 represent sediment concentrations of chemicals (lead or 4-methylphenol) on a log scale. The AET is established by the highest concentration at a station without observed biological effects. For the toxicity bioassay under consideration, the AET for lead is the highest lead concentration corresponding to sediments that did *not* exhibit significant toxicity (the top bar for lead in Figure 2-3). Above this AET for lead, significant amphipod toxicity was *always* observed in the data set. The AET for 4-methylphenol was determined analogously.

Interpretation of the AET--An AET corresponds to the sediment concentration of a chemical above which *all* samples for a particular biological indicator were observed to have adverse effects. Thus, the AET is based on noncontradictory evidence of biological effects. Data are treated in this manner to reduce the weight given to samples in which factors other than the contaminant examined (e.g., other contaminants, environmental variables) may be responsible for the biological effect.

Using Figure 2-3 as an example, sediment from Station SP-14 exhibited severe toxicity, potentially related to a greater elevated level of 4-methylphenol (7,400 times reference levels). The same sediment from Station SP-14 contained a relatively low concentration of lead that was well below the AET for lead (Figure 2-3). Despite the toxic effects associated with the sample, sediments from many other stations with higher lead concentrations than SP-14 exhibited no statistically significant biological effects. These results were interpreted to suggest that the effects at Station SP-14 were potentially associated with 4-methylphenol (or a substance with a similar environmental distribution), but were less likely to be associated with lead.

A converse argument can be made for lead and 4-methylphenol in sediments from Station RS-18. In this manner, the AET approach helps to identify measured chemicals that are potentially associated with observed effects at each biologically impacted site and eliminates from consideration chemicals that are less likely to be associated with effects (i.e., the latter chemicals have been observed at higher concentrations at other sites without associated biological effects). Based on the results for lead and 4-methylphenol, effects at two of the impacted sites shown in the figure may be associated with elevated concentrations of 4-methylphenol, and effects at three other sites may be associated with elevated concentrations of lead (or similarly distributed contaminants).

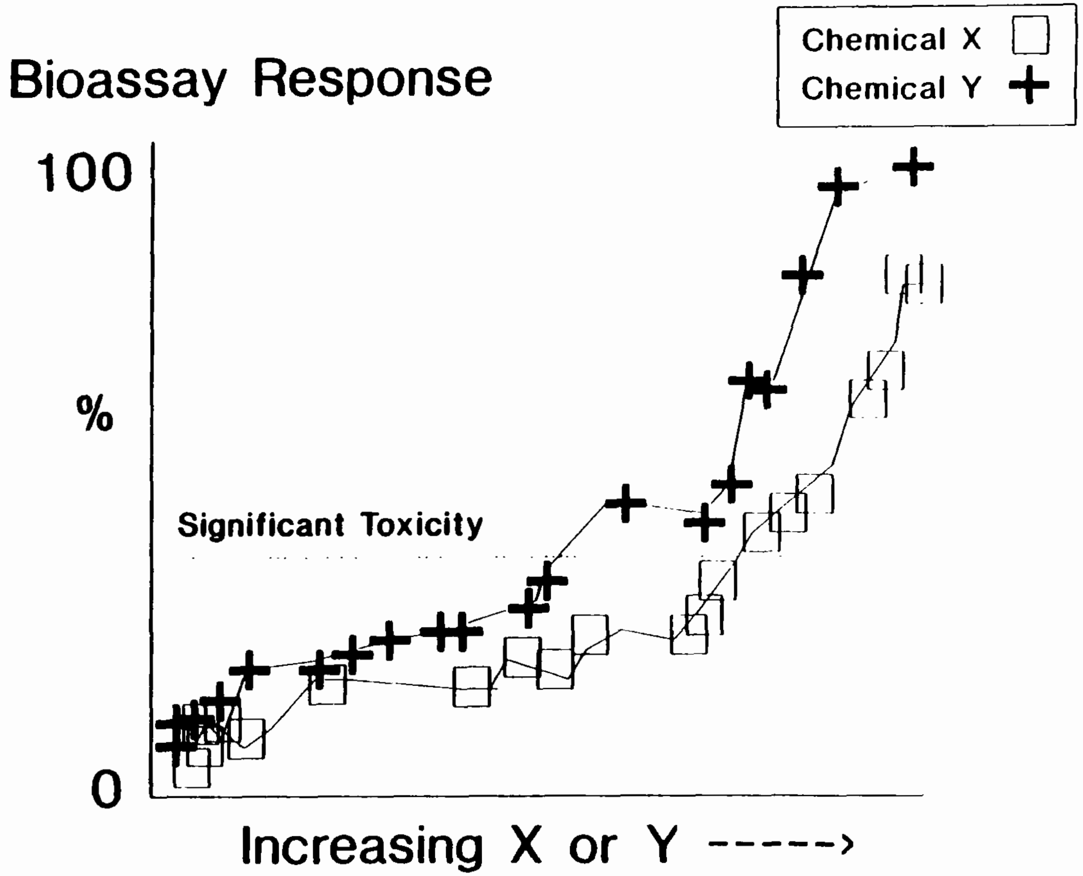
These results illustrate that the occurrence of biologically impacted stations at concentrations below the AET of a single chemical does not imply that AET in general are not protective against biological effects, only that single chemicals may not account for all stations with biological effects. By developing AET for multiple chemicals, a high percentage of all stations with biological effects are accounted for with the AET approach, as has been demonstrated in validation tests with large matched biological and chemical data sets (Tetra Tech 1986a; PTI 1988b,c).

Dose-Response Relationships and AET--The AET concept is consistent with empirical observations in the laboratory of dose-response relationships between increasing concentrations of individual toxic chemicals and increasing biological effects. A simple hypothetical example of such single-chemical relationships is shown for chemicals X and Y in Figure 2-4. In the example, data are shown for laboratory exposures of a test organism to sediment containing only increasing concentrations of chemical X, and independently, for exposures to sediment containing only increasing concentrations of chemical Y. The magnitude of toxic response in the example differs for the two chemicals, and occurs over two different concentration ranges. It is assumed that at some level of response (e.g., >25 percent) the two different responses can be distinguished from reference conditions (i.e., responses resulting from exposure to sediments containing very low or undetectable concentrations of any toxic chemicals).

These single-chemical relationships cannot be proven in the field because organisms are exposed to complex mixtures of chemicals in environmental samples. In addition, unrelated discharges from different sources can result in uncorrelated distributions of chemicals in environmental samples. To demonstrate the potential effects of these distributions, response data are shown in Figure 2-5 for random association of chemical X and Y using the same concentration data as in Figure 2-4. The data have been plotted according to increasing concentrations of chemical X, and the same dose-response relationship observed independently for the two chemicals in the laboratory has been assumed. The contributions of chemicals X and Y to the toxic response shown for these simple mixtures is intended only for illustration purposes to enable direct comparison to the relationships shown in Figure 2-4; interactive effects are not considered in this example.

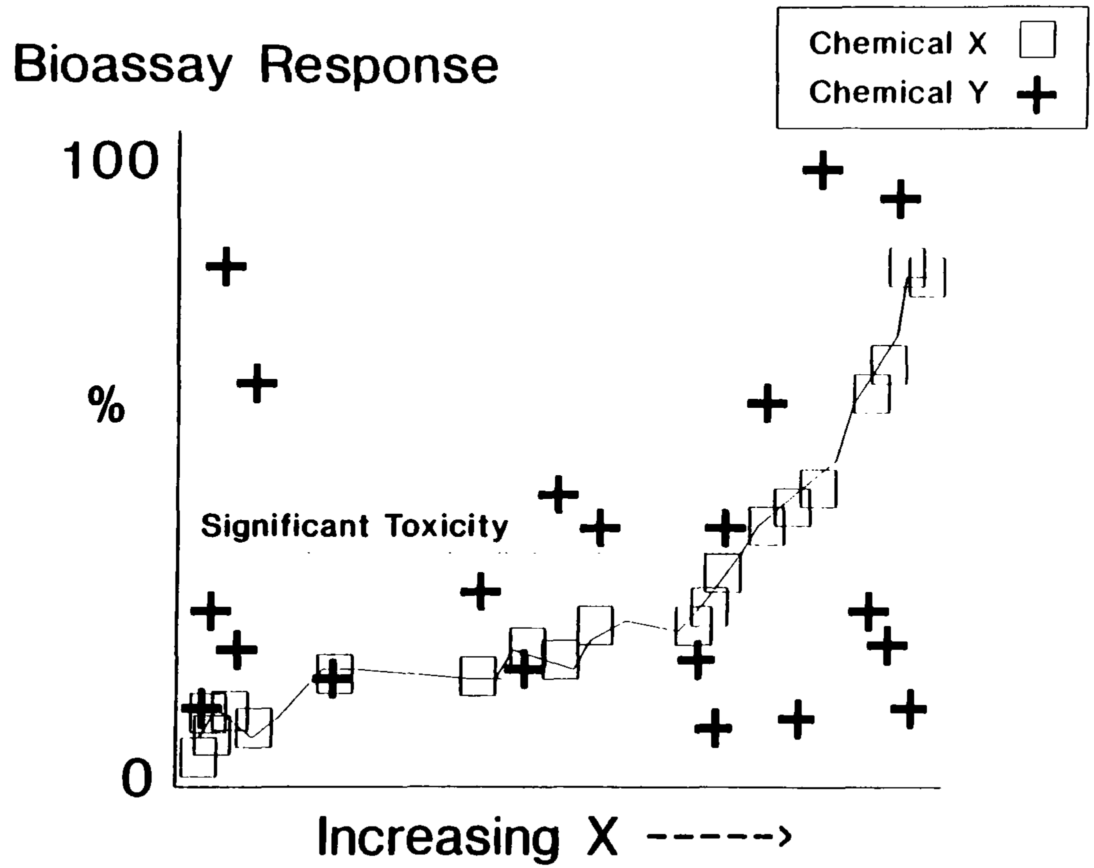
In Figure 2-5, a significant response relative to reference conditions would result whenever elevated concentrations of either chemical X or chemical Y occurred in a sample. Because of the random association of Y with X in these samples, the significant responses would appear to occur randomly over the lower concentration range of chemical X. The classification of the responses shown in Figure 2-5 into significant and nonsignificant groups (i.e., >25 percent response for either chemical) results in generation of Figure 2-6.

Figure 2-6 represents the appearance of the environmental results when ranked according to concentrations of chemical X using these data. Below the AET for chemical X, significant toxicity is produced by elevated concentrations of chemical Y, which is randomly associated with the distribution of chemical X. Above the AET for chemical X, significant toxicity is always produced by elevated concentrations of chemical X, although in some samples, elevated concentrations of chemical Y also contribute to the overall toxicity. The AET for chemical X corresponds



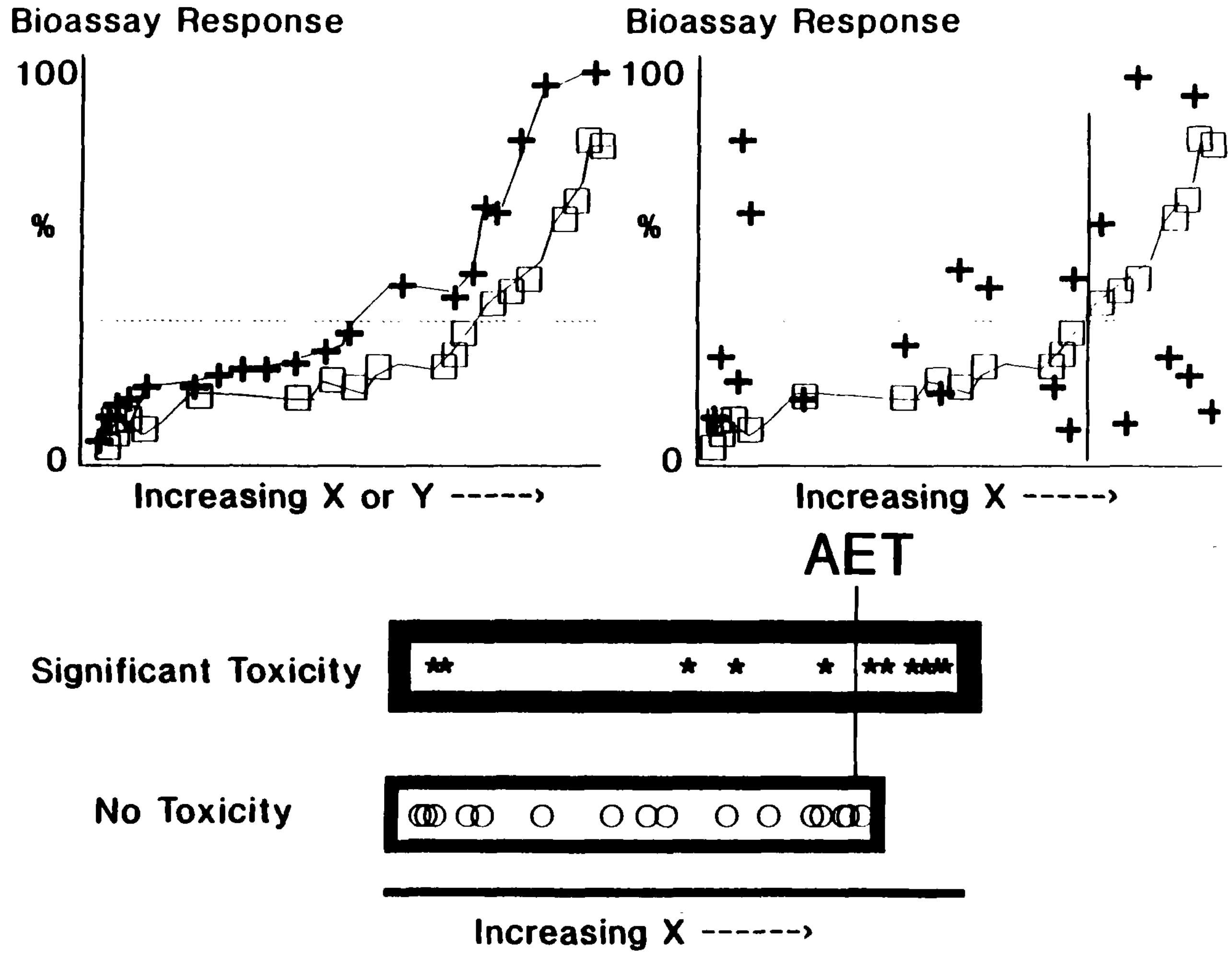
Reference: PTI (1988c).

Figure 2-4. Hypothetical example of dose-response relationship resulting from laboratory exposure to single chemicals X and Y.



Reference: PTI (1988c).

Figure 2-5. Hypothetical example of toxic response resulting from exposure to environmental samples of sediment contaminated with chemicals X and Y.



NOTE: Figures 2-4 and 2-5 are shown for comparison; dashed line indicates level of significant toxicity.

Reference: PTI (1988c).

Figure 2-6. Hypothetical example of AET calculation for chemical X based on classification of significant and nonsignificant responses for environmental samples contaminated with both chemicals X and Y.

conceptually, in this simple example, to the concentration in Figure 2-4 at which a significant difference in response was observed in the laboratory for chemical X.

In environmental samples that contain complex mixtures of chemicals, a monotonic dose-response relationship such as in this simple two-chemical example may not always apply. For example, a consistently increasing biological response may not always occur at increasing concentrations of a chemical above its AET. Such observations could indicate that the AET is coincidental (i.e., that the observed toxicity in some or all samples above the AET is unrelated to the presence of that chemical), or that changing environmental factors in samples exceeding an AET obscure a monotonic dose-response relationship. Such factors are discussed in the following section.

<u>Influence of Environmental Factors on AET Interpretation</u>--Although the AET concept is simple, the generation of AET values based on environmental data incorporates many complex biological-chemical interrelationships. For example, the AET approach incorporates the net effects of the following factors that may be important in field-collected sediments:

- Unmeasured chemicals and other unmeasured, potentially adverse variables
- Interactive effects of chemicals (e.g., synergism, antagonism, and additivity)
- Matrix effects and bioavailability [i.e., phase associations between contaminants and sediments that affect bioavailability of the contaminants, such as the incorporation of polycyclic aromatic hydrocarbons (PAH) in soot particles].

The AET approach cannot distinguish and quantify the contributions of unmeasured chemicals, interactive effects, or matrix effects in environmental samples, but AET values may be influenced by these factors. To the extent that the samples used to generate AET are representative of samples for which AET are used to predict effects, the above environmental factors may not detract from the predictive reliability of AET. Alternatively, the infrequent occurrence of the above environmental factors in a data set used to generate AET could detract from the predictive reliability of those AET values. If confounding environmental factors render the AET approach unreliable, this should be evident from validation tests in which biological effects are predicted in environmental samples. Tests of AET values generated from Puget Sound data (Tetra Tech 1986a; PTI 1988c) indicate that the approach is relatively reliable in predicting biological effects despite the potential uncertainties of confounding environmental factors.

Although the environmental factors discussed above can influence the generation of field-based sediment quality values such as AET, they may also influence the application of all sediment quality value approaches for the prediction of adverse biological effects. For example, sediment quality values based on laboratory sediment bioassays spiked with single chemicals would not be susceptible to the effects of the environmental factors listed above. However, in applying such values to field-collected samples, predictions of biological effects could be less successful to the extent that interactive effects, unmeasured chemicals, and matrix effects occur in the environment. The nature of the relationships between AET values and confounding environmental factors is discussed in the remainder of this section.

Unmeasured Toxic Chemicals and AET--In general, the effect of unmeasured chemicals on the predictive success of the AET approach is a function of the degree of covariance (i.e., similarity in environmental distribution) of measured and unmeasured chemicals.

If an unmeasured chemical (or group of chemicals) varies consistently in the environment with a measured chemical, then the AET established for the measured contaminant will indirectly apply to, or result in the management of, the unmeasured contaminant. In such cases, a measured contaminant would act as a surrogate for an unmeasured contaminant (or group of unmeasured contaminants). Because all potential contaminants cannot be measured routinely, management strategies must rely to some extent on "surrogate" chemicals.

If an unmeasured toxic chemical (or group of chemicals) does not always covary with a measured chemical (e.g., if a certain industry releases an unusual mixture of contaminants), then the effect should be mitigated if a sufficiently large and diverse data set is used to establish AET. Use of a data set comprising samples with diverse chemical assemblages and wide-ranging chemical concentrations would decrease the likelihood that an unrealistically low AET would be set. Because AET are set by the highest concentration of a given chemical in samples without observed biological effects, AET will not be affected by less contaminated samples in which unmeasured contaminants cause biological effects.

If an unmeasured toxic chemical does not covary with any of the measured chemicals, then it is unlikely that the AET (or any other chemical-specific approach) could predict impacts at stations where the chemical is inducing toxic effects. The frequency of occurrence of stations with biological effects but no chemicals exceeding AET has been the subject of extensive validation tests (Tetra Tech 1986a; PTI 1988c).

Interactive Effects and AET--AET uncertainty is increased by the possibility of interactive effects; the increase in uncertainty is expected to be less pronounced when large data sets collected from diverse areas are used to generate AET. Additivity and synergism can produce a comparatively low AET for a given chemical by causing impacts at concentrations that would not cause impacts in the absence of these interactive effects. This would effectively reduce the pool of nonimpacted stations used to generate AET. This effect should be reduced if a diverse database is used such that chemicals occur over a wide range of concentrations at stations where additivity and synergism are not operative. For chemicals that covary regularly in the environment (e.g., fluoranthene and pyrene), even a large, diverse database will not reduce the effects of additivity and/or synergism on AET generation. The resulting AET values for such chemicals may be reliable in predicting biological effects in environmental samples although not representative of the toxicities of the chemicals acting independently.

Antagonism will produce comparatively high AET values if (and only if) the AET is established at a station where antagonism occurs. A large, diverse database could not rectify this elevation of AET if the station at which antagonism occurred was the nonimpacted station with the highest concentration (i.e., the station setting an AET). An AET set by a station at which antagonism occurred would not be representative of the toxicity of the chemical acting independently.

Empirical approaches such as the AET do not provide a means for characterizing interactive effects. Only laboratory-spiked sediment bioassays offer a systematic and reliable method for identifying and quantifying additivity, synergism, and antagonism. A great deal of research effort would be required to test the range of chemicals potentially occurring in the environment (both individually and in combination), a sufficiently wide range of organisms, an a wide range of sediment matrices to establish criteria. In addition, the applicability of bioassays conducted with laboratory-spiked sediments to environmentally-contaminated sediments requires further testing.

Matrix Effects and Bioavailability--Geochemical associations of contaminants with sediments that reduce bioavailability of those contaminants would affect AET analogously to antagonistic effects (i.e., they would increase AET relative to sediments in which this factor was not operative). Sediment matrices observed in Commencement Bay that may reduce bioavailability of certain contaminants include slag material (containing high concentrations of various metals and metalloids, such as copper and arsenic), and coal or soot (which may contain high concentrations of largely unavailable PAH, as opposed to oil or creosote, in which PAH would be expected to be far more bioavailable). Many kinds of matrices may occur in the environment and a large proportion may be difficult to classify based upon appearance or routinely measured sediment variables. Hence, the use of matrix-specific data sets to generate AET, although desirable, would be difficult to implement. Data treatment guidelines to address the possibility of matrix effects are discussed in PTI (1988c).

<u>The AET Database</u>--AET can be expected to be most predictive when developed from a large database with wide ranges of chemical concentrations and a wide diversity of measured contaminants. During the RI, AET were generated for a combined measure of sediment toxicity (i.e., either amphipod mortality or oyster larvae abnormality), and benthic infaunal depressions (at phylum or class levels of taxonomic classification). These AET values were based on data from 50-60 stations. In a more recent project for PSDDA and PSEP, AET were generated with a larger database (190 samples, including Commencement Bay data) for individual measures of toxicity (i.e., amphipod mortality, oyster larvae abnormality, and Microtox bioluminescence bioassays), and benthic infaunal depressions (at phylum or class taxonomic levels) (Tetra Tech 1986a). During the Eagle Harbor Preliminary Investigation (Tetra Tech 1986b), matched biological and chemical data from 10 Eagle Harbor stations were added to the existing 190-sample Puget Sound database.

Additional data sets from Elliott Bay, Everett Harbor, and associated reference areas have most recently been incorporated into the AET database (PTI 1988c). AET developed from this 334-sample data set were used to establish sediment cleanup goals and to assess the feasibility of sediment remedial actions in Commencement Bay. Detailed descriptions of data treatment for this data set (including the statistical analyses used for each biological indicator) are presented in PTI (1988b,c).

The following is an overview of the four biological tests used to generate AET and their ecological relevance:

- Field Test: Benthic Macroinvertebrate Assemblages--

  Overview: Apparent depressions in the abundances of indigenous benthic infauna are in situ assessments of chronic and acute effects of contaminated sediments. These tests generally involve the collection of sediment samples using a bottom grab or box corer and the sieving of the samples through a screen having a mesh size of 1.0 mm. The organisms retained on the screen are collected, preserved using formalin, and later identified and counted in the laboratory. The kinds of species and numbers of individuals present at each station are then evaluated to determine whether the overall benthic assemblage appears to be altered. At each station, four to five replicate field samples are generally collected and analyzed.

  Ecological Relevance: The ecological relevance of alterations of benthic macroinvertebrate assemblages generally is high. Because these organisms live in close contact with bottom sediments and are relatively stationary, they have one of the highest potentials for exposure to sediment contaminants in marine and estuarine ecosystems. In addition, benthic assemblages typically include organisms that are very sensitive to chemical toxicity (e.g., amphipods). The high exposure potential and inclusion of sensitive species make benthic organisms an excellent indicator group. If sediment-associated adverse effects are not detected in these organisms, then it is unlikely that they are present in most other components of the ecosystem. The evaluation of major taxonomic groups of benthic infauna (e.g., Crustacea, Mollusca, Polychaeta) has been used to provide in situ measurements of chronic and/or acute biological effects in sediments by making statistical comparisons to reference areas in Puget Sound.

- Bioassay--Amphipod Mortality Test (*Rhepoxynius abronius*)

  Overview: The amphipod mortality bioassay is an indicator of acute lethal toxicity in whole sediments. This bioassay involves a 10-day exposure of adult organisms to a 2-cm layer of bedded (i.e, settled) test sediment (Swartz et al. 1985, 1988). For each field sample, 20 organisms are tested in each test chamber. The primary endpoint is mortality.

  Ecological Relevance: The test species, *Rhepoxynius abronius*, is a resident of Puget Sound and represents a group that forms an important component of the diet of numerous juvenile and adult fishes (Simenstad et al. 1979; Wingert et al. 1979). As an amphipod, it is a member of a pollution-sensitive group (Bellan-Santini 1980), although the adult life stage typically used in sediment bioassays probably is not the most sensitive stage in the organism's life cycle. The potential for exposure of the test organisms to sediment contaminants is high because they burrow into the sediment and feed upon material found naturally in the sediment. The primary endpoint (i.e., mortality) has relatively clear ecological meaning. That is, if adult organisms cannot survive in an environment, it is likely that severe alterations of benthic assemblages will be found.

- Bioassay--Oyster Larvae Abnormality Test (Crassostrea gigas)

Overview: The oyster larvae abnormality bioassay is an indicator of acute sublethal toxicity in sediments elutriates. This bioassay involves a 48-h exposure of embryos (2 h after fertilization) to 15 g of bedded test sediment [Chapman and Morgan 1983; American Society for Testing and Materials (ASTM) 1985]. For each field sample, 20,000-40,000 developing embryos are tested in each of five test chambers. The primary endpoint is larval abnormality or failure to develop to the fully shelled stage.

Ecological Relevance: The test species is a resident of Puget Sound, although it was originally introduced from Japan (Kozloff 1983). As a bivalve, it represents a group of organisms that supports commercial and recreational fisheries in Puget Sound (i.e., clams, mussels, oysters, and scallops) (PSWQA 1988). The life stages evaluated (embryo and larva) represent two of the most sensitive stages in the life cycle of the organism. The potential for exposure of the test organisms to sediment contaminants is moderate because although bedded sediments are present in each test chamber, bivalve embryos and larvae reside primarily in the water column and therefore rarely are in direct contact with bedded sediments. The primary endpoint (i.e., abnormality) has a relatively clear ecological meaning for the test species and other species that rely primarily on larval recruitment to colonize areas (i.e., species with relatively sedentary juvenile and adult stages). That is, abnormal larvae are unlikely to survive and the establishment of adult assemblages would thereby by prevented. The ecological relevance of the test for motile organisms that can colonize a contaminated area in the juvenile and adult stages is less certain, because successful embryonic and larval development could occur in areas removed from contamination.

- Bioassay--Microtox Saline Extract (Photobacterium phosphoreum)

Overview: The Microtox (or bacterial luminescence) bioassay is an indicator of acute sublethal effects in sediment elutriates. This bioassay involves a 15-min exposure of bacteria to a 500-uL aliquot of saline extract from 13-26 g of test sediment (Bulich et al. 1981; Beckman Instruments 1982; Williams et al. 1986). For each field sample, a series of four dilutions is evaluated. Two replicate measurements are made for each dilution. Bioluminescence is measured using an automated toxicity analyzer system with a temperature-regulated photometer equipped with a photomultiplier. The primary endpoint, decrease in luminescence, represents an indication of change in cellular metabolic function (Hastings and Nealson 1977).

Ecological Relevance: The test species is a member of the estuarine and marine pelagic communities (Holt 1977). As a bacterium, it is representative of the group of organisms that forms the base of detrital-based food webs (Steele 1974). That is, bacteria play a major role in decomposing organic matter (i.e., detritus) and making it available to higher organisms (e.g., benthic macroinvertebrates). The potential for exposure of the test organisms to sediment contaminants is limited by the fact that the bioassay is conducted on a saline extract of the test sediment (i.e., sediment is not present in the test chamber). The saline extraction will tend to remove only water-soluble contaminants from the test sediment and therefore may not be representative of the full range of contaminants to which the organisms would be exposed if they were in direct contact with the test sediment. Although this test appears to be very sensitive to the influence of chemical contaminants, it is unknown whether changes in metabolic function have serious consequences for the organisms, or for the ecological role of the bacteria. However, if this ecological role is impeded, it could deprive certain higher organisms of their primary food source and thereby alter the ability of these higher organisms to survive.

Three other AET were also developed for the Commencement Bay N/T RI/FS. They include a bioaccumulation AET for evaluation of PCB contamination in relation to public health risk (Section 2.2.3) and two AET based on additional biological indicators: depressions in abundances of six individual benthic species, and fish histopathology.

Species-level benthic AET were found to be of similar magnitude to higher-taxa benthic AET even though they were based on considerably less data. For the purposes of this FS, the higher-taxa AET are preferred over species-level AET for two reasons: 1) they are currently supported by a much larger Puget Sound database than species-level AET, and 2) they represent a more broadly based measure of benthic effects than do the six available species-level AET. Because of limitations in available data, the species-level AET were not used in developing cleanup goals for the FS.

Although fish histopathology AET were developed, they were not considered appropriate for establishing cleanup goals in the Commencement Bay N/T area for the following three reasons: 1) the available volume of data were relatively limited, 2) the relationship between sediment contamination and fish exposure was uncertain because fish were not limited to confined exposure to specific sediments, and 3) the relationship between the chemicals of concern and the liver lesions was uncertain. Fish histopathology AET may be worthy of further investigation as more data become available.

Summary Considerations--Taken as a whole, the AET approach provides a powerful predictive tool for characterizing sediment quality at the Commencement Bay N/T site. The AET approach and the AET values generated from available Puget Sound data present advantages and limitations in their application to the development of cleanup goals and remedial strategies. The AET approach and existing AET offer the following advantages:

- Applicability to a wide range of chemicals (allowing for application to a variety of sources present on the site)
- Applicability to a wide range of biological effects indicators (allowing for protection against a wide range of environmental impacts)
- Reliance on objective statistical criteria to determine adverse biological effects relative to Puget Sound reference conditions (which enhances the technical defensibility of AET over approaches that rely on professional judgment to determine impacts)
- Supported by noncontradictory evidence of adverse biological effects above the AET for a database comprising over 300 samples (including 287 amphipod bioassay stations, 201 benthic infauna stations, 56 oyster larvae bioassay stations, and 50 Microtox bioassay stations)
- Extensive validation with field-collected sediment samples (Tetra Tech 1986a; PTI 1988c), including 50-60 samples from the Commencement Bay N/T RI
- Consistency with methods and approaches being used by other Puget Sound sediment management programs.

The AET approach and the existing AET database also have the following limitations or sources of uncertainty:

- Extensive data requirements (not a major disadvantage for the Commencement Bay N/T RI/FS because AET have already been developed in Puget Sound)
- Not supported by definitive cause-and-effect data (only the spiked sediment bioassay approach is based on such data)
- AET have not been generated for a definitive indicator of chronic effects (although benthic infauna AET may represent chronic effects to some extent)
- Uncertainty can be increased by certain factors in field-collected samples, most notably, interactive effects, unmeasured toxic chemicals, and geochemical matrix effects (discussed previously)

- Uncertainty related to the probability of statistical classification error (alpha or beta) (Tetra Tech 1986a; PTI 1988c)

- Uncertainty related to data distributions (in particular, the magnitude of concentration gaps between the station setting an AET and the adjacent impacted and nonimpacted stations) (Tetra Tech 1986a).

Although the above sources of uncertainty are of concern, detailed validation tests of AET with field-collected data (Tetra Tech 1986a; PTI 1988c) indicate that the approach is relatively reliable in predicting biological effects despite these potential uncertainties and confounding factors. Based on validation tests with the existing Puget Sound database of over 300 samples, AET were from 86 to 96 percent reliable in predicting adverse effects when they did occur and in not predicting effects when none were observed (PTI 1988c).

Although the AET has shown a relatively high degree of reliability, it must be recognized that the database will continue to be refined over time as new information is made available. Thus, sediment management decision-making process at the site includes an opportunity to evaluate the validity of predicted effects by allowing, and in some cases requiring, direct biological testing of field samples. These administrative considerations are discussed in more detail in Sections 2.2.4 and 2.2.5.

2.2.3 Evaluation of Human Health Effects

Human exposure to contaminants in Commencement Bay sediments is possible via a number of pathways. The pathway of greatest concern is the ingestion of fish or shellfish contaminated by chemicals from the water or sediments. Other potential exposure pathways include dermal absorption or ingestion of chemicals as a result of direct contact with sediments, ingestion or dermal absorption of contaminants in the water, and inhalation of contaminants that volatilize from sediments or water.

Health risk assessments are designed to evaluate the nature, magnitude, and probability of adverse impacts to human health resulting from these types of exposure. The risk assessment process can be divided into four major steps:

- Hazard identification

- Exposure assessment

- Dose-response assessment (often combined with hazard identification)

- Risk characterization.

A baseline assessment of risks associated with the consumption of seafood from Commencement Bay was performed as part of the remedial investigation

(Versar 1985). The baseline evaluation is a risk assessment of the current conditions and, as such, represents an evaluation of the "no action" alternative. The results of this assessment are summarized in Section 2.2.3.

The Versar (1985) report is limited to an evaluation of the health risks associated with observed levels of contamination in fish tissue. During the FS, two approaches for extrapolating from contaminant concentrations in sediments to contaminant concentrations in fish tissue (and health risks) were evaluated, as described in Section 2.2.3. These two approaches can be used to estimate the level of risk reduction associated with various proposed cleanup levels. Overall health risk conclusions are presented in Section 2.2.3.

Baseline Public Health Assessment--

The public health assessment prepared by Versar (1985) was designed to determine if there were significant health risks associated with the consumption of contaminated seafood from the study area. This assessment considered three types of exposure: consumption of fish muscle tissue, consumption of fish livers, and consumption of crab muscle tissue. Assessment methods, major study findings, and general conclusions are summarized below.

<u>Method</u>--The risk assessment procedures used by Versar (1985) were divided into three main tasks: exposure assessment, hazard assessment (including hazard identification and dose-response assessment), and risk characterization.

Exposure Assessment--The first step in the exposure evaluation was to estimate the size of the exposed population (i.e., individuals consuming fish or shellfish from Commencement Bay). Based on the results of a survey conducted by the Tacoma-Pierce County Health Department (Pierce et al. 1981), it was estimated that there are 4,070 shore and boat anglers in the Commencement Bay area. Assuming an average family size of 3.74 persons, an estimated 15,200 persons consume fish or shellfish from Commencement Bay.

The second step in the exposure evaluation was to calculate the quantity of fish consumed by the exposed population. Information in the Tacoma-Pierce County Health Department catch-consumption survey was used to estimate the frequency of fishing. That value was multiplied by the average catch per trip of nonsalmonid fish intended for consumption. These calculations indicate that a small proportion of the exposed population (i.e., 30 of 15,220 or 0.2 percent) consumes fish at the highest estimated rate of 1 lb/day (454 g/day). These calculations also indicate that 82 percent of the exposed population consumes less than 1 lb/mo (15 g/day) and that more than half the population (57 percent) consumes Commencement Bay fish at the lowest rate of 1 lb/yr (1.2 g/day). Consumption of crabs was assumed to follow a similar distribution.

Consumption of fish livers was considered a potential problem for a small portion of the exposed population. However, no data were available on consumption rates. Therefore, it was assumed that all persons who eat fish livers eat them from all the fish they catch. It was also assumed that the liver mass was proportional to the liver-to-muscle ratio (12 percent) of Commencement Bay fishes. Therefore, at the maximum estimated fish consumption rate of 1 lb/day, the corresponding maximum liver consumption rate would be 0.12 lb/day.

The final step in the exposure evaluation was to multiply the estimated seafood consumption rates by the concentrations of contaminants in fish and crab tissue, and divide this product by an assumed value for human body weight. Tissue contaminant data for English sole (Parophrys vetulus) collected as part of the RI (Tetra Tech 1985a) were used for that analysis. English sole was used as an indicator species for potential human exposure to contaminants in nonsalmonid fishes for three reasons:

- They are more bioaccumulative than other species
- They are seasonal residents in areas where they are caught
- They may be representative of contaminant bioaccumulation associated with the sediment environment at specific locations in Commencement Bay.

Hazard Assessment--The dose-response variables for each contaminant were reviewed in this stage of the risk assessment. A generalized illustration of the role of these variables in dose-response relationships for carcinogens and noncarcinogens is shown in Figure 2-7. The carcinogenic potency factor [expressed in units of $(mg/kg/day)^{-1}$] is typically determined by the upper 95 percent confidence limit of slope of the linearized multistage model which expresses excess cancer risk as a function of dose. The model is based on high to low dose extrapolation, and also assumes that there is no threshold for the initiation of toxic effects. The reference dose (RfD, expressed in units of mg/kg/day) is an estimated single daily chemical intake rate that appears to be without risk if ingested over a lifetime. It is usually based on the relationship between the dose of a noncarcinogen, and the frequency of systemic toxic effects in experimental animals or humans. It also assumes that a threshold exists for the initiation of toxic effects. The threshold of observed effects is divided by an uncertainty factor to derive an RfD that is protective of the most sensitive members of the population. The general source for this information was the supporting literature for standards and criteria, carcinogenic potency factors, and RfD values.

Risk Characterization--Risk characterization is the process of estimating the magnitude of potential adverse health effects under various conditions defined in the exposure assessment. The risk characterization integrates the information developed during the exposure and hazard assessment to yield a characterization of potential health effects. Potential risks associated with each carcinogenic chemical of concern in various exposure media were estimated as the probability of excess cancer using the equation:

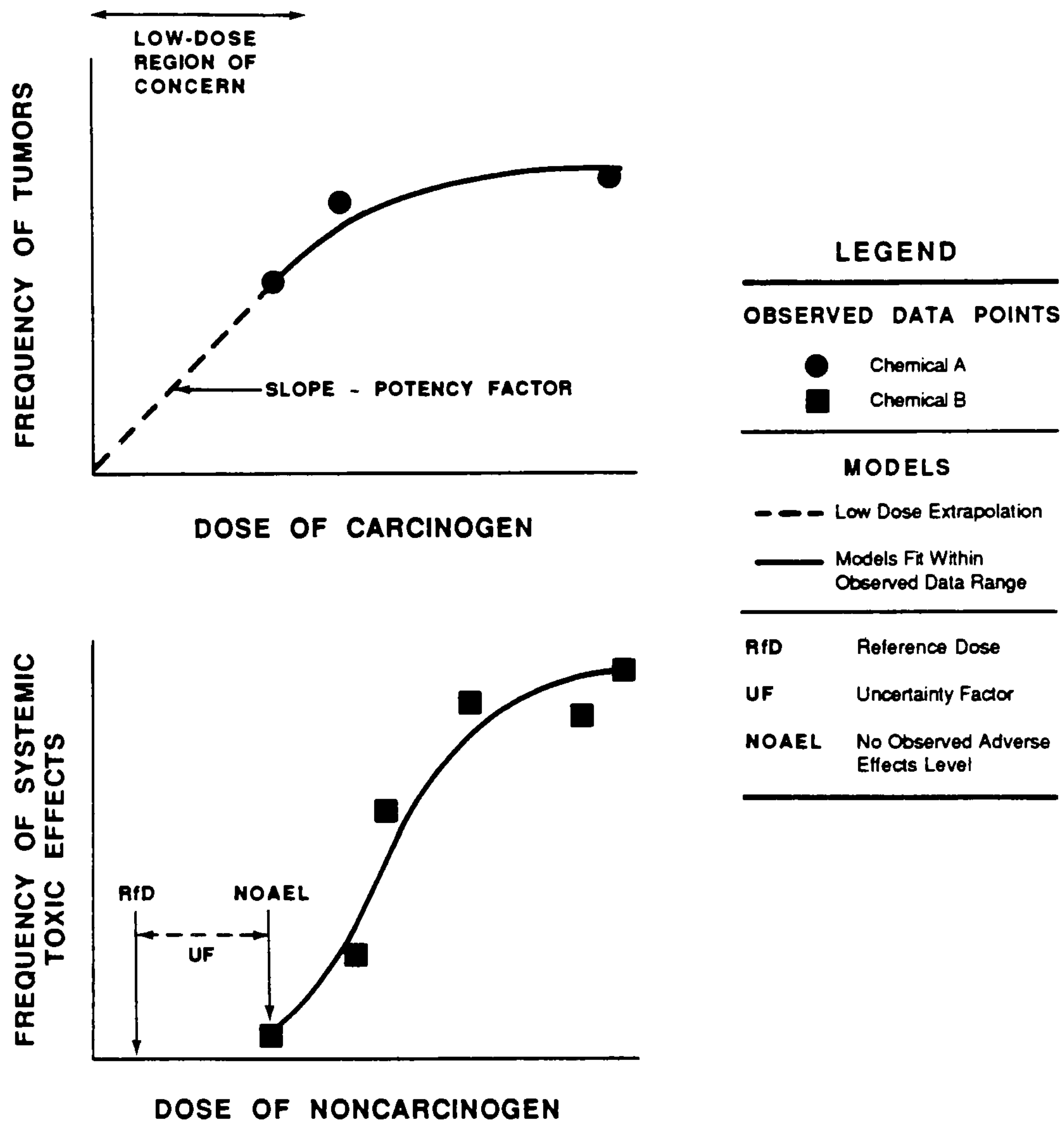


Figure 2-7. Hypothetical dose-response relationships for a carcinogen and a noncarcinogen.

$$R_{ij} = 1 - \exp(-P_i \times D_{ij})$$

where:

R_{ij} = Risk associated with chemical i in medium j
P_i = Carcinogenic potency factor for chemical i $(mg/kg/day)^{-1}$
D_{ij} = Dose of chemical i in medium j (mg/kg/day).

Attributes of carcinogenic potency factors and methods of dose estimation are as described above. Nonprobabilistic hazards associated with ingestion of noncarcinogenic chemicals were expressed as a ratio:

$$RI_{ij} = D_{ij}/RfD_i$$

where:

RI_{ij} = Risk index for chemical i in medium j
D_{ij} = Dose of chemical i in medium j (mg/kg/day)
RfD_i = Reference dose for chemical i (mg/kg/day)

Characteristics of the RfD and methods of dose estimation are described above.

Results of Public Health Assessment--

<u>Fish Consumption</u>--At the maximum consumption rate of 1 lb/day (454 g/day) of nonsalmonid fish from Commencement Bay, the estimated individual lifetime cancer risks exceed 1 in 1 million for six carcinogens: PCBs, arsenic, hexachlorobenzene, hexachlorobutadiene, bis(2-ethylhexyl)phthalate, and tetrachloroethene. At a fish consumption rate of 1 lb/mo (15 g/day), only PCBs and arsenic would exceed the 1 in 1 million risk level. For a given consumption rate, estimated individual risks from consuming Commencement Bay fish muscle tissue exceed those for consuming Carr Inlet (reference area) fish for three of the above six compounds: PCBs, bis(2-ethylhexyl)phthalate, and tetrachloroethene. For PCBs, individual risks from consuming Commencement Bay fish are about 5 times as high as the risks associated with consuming Carr Inlet fish. For arsenic, estimated individual risks from consuming Commencement Bay fish and Carr Inlet fish are similar.

Fish tissue concentrations and the associated risk for consuming nonsalmonid fish varied among the Commencement Bay waterways. Fish consumed from City and Hylebos Waterways represent the greatest individual risk from PCB contamination. Risk associated with consumption of those fish was 10 times as high as that associated with fish from Carr Inlet.

Much of the shore fishing in Commencement Bay occurs on piers along the Ruston-Pt. Defiance Shoreline. Therefore, contamination of fish in this area is of special concern relative to possible public health impacts. The available data indicate that individual risks for all chemicals in the Pt. Defiance area are similar to those in the Carr Inlet reference area.

Antimony, lead, and mercury were present in fish muscle tissue at levels that would cause exposure to exceed the RfD values at the 1 lb/day consumption rate. Tissue concentrations of these chemicals were very similar among project areas and at the Carr Inlet reference site. At the lower consumption rate of 1 lb/mo, however, estimated exposure does not exceed the RfD values.

Twenty-one chemicals were detected in a nonsalmonid fish liver composite sample from Commencement Bay. Four of the detected chemicals are carcinogens: PCBs, hexachlorobenzene, hexachlorobutadiene, and arsenic. At the maximum consumption rate of 0.12 lb/day (56 g/day), consumption of PCBs in fish liver would result in a predicted individual lifetime risk of 2 in 100. This risk is higher than the corresponding risk associated with consumption of PCBs in fish muscle tissue (6 in 1,000) because of the much higher PCB concentrations in fish livers. The predicted risk level for PCBs in Commencement Bay fish livers is about 15 times as high as the corresponding risk for fish livers from Carr Inlet.

Maximum estimated carcinogenic risks for hexachlorobenzene and hexachlorobutadiene in fish liver were about the same as the corresponding risks for fish muscle (i.e., 1 in 10,000 and 1 in 100,000). All other estimated carcinogenic risks were much lower than these levels.

All calculated exposures for the noncarcinogens present in fish livers from Commencement Bay were less than 10 percent of the corresponding average daily intakes (ADIs). Therefore, even at the maximum consumption rate of 0.12 lb/day, no human health effects attributable to these noncarcinogens would be expected.

Of the chemicals detected in fish livers from Commencement Bay, PCBs pose the greatest potential risk to public health. Although the maximum estimated risk of 2 in 100 is associated with a high consumption rate, much less frequent consumption of fish livers would still result in a substantial predicted risk.

Crab Consumption--A risk assessment was also conducted for consumption of crabs harvested in Commencement Bay. For PCBs and arsenic, the estimated individual risks from eating crabs only were approximately the same as those for eating fish. Risk associated with consumption of PCB-contaminated crabs from Commencement Bay were 3 times as great as those associated with crabs from Carr Inlet.

Calculated exposures from consumption of crab muscle at the maximum rate of 1 lb/day (454 g/day) exceeded the ADI for the following contaminants: antimony, lead, silver, zinc, and mercury. ADIs were exceeded for crabs from both Commencement Bay and Carr Inlet for these metals. For most of the metals, the risk difference between Commencement Bay and Carr Inlet was slight. By limiting consumption of crabs from either Commencement Bay or Carr Inlet to 1 lb/wk (65 g/day), all noncarcinogenic exposures would be below the ADI.

Relationship Between Sediment Contamination and Health Risks Associated With Consumption of Contaminated Fish--

Fish in the Commencement Bay area come into contact with the sediments, and bioaccumulation of contaminants occurs to varying degrees. To evaluate the risk reductions associated with various remedial alternatives, contaminant concentrations in sediments must be extrapolated to concentrations in edible tissues of fish and shellfish. The following two approaches were used to evaluate this relationship:

- Apparent effects threshold approach
- Equilibrium partitioning approach.

Bioaccumulation Apparent Effects Threshold--The AET approach establishes sediment quality values empirically by determining the sediment concentrations of specific contaminants above which statistically significant ($P<0.05$) elevations of contaminant concentrations in fish tissue relative to a reference level of the contaminant are expected. (A detailed discussion of the AET approach is described in Section 2.2.2). The advantages of this approach are twofold: it is potentially applicable to a wide range of contaminants, and the emphasis is on empirical field data rather than theoretical predictions. Disadvantages include the large data requirements, the need to assume that fish are exposed to sediments within a known, specified area, and the related assumption that increasing sediment concentrations correspond to increasing tissue concentrations in field-collected fish.

Method--More than 70 contaminants were detected in fish and crab tissue during the RI (Tetra Tech 1985a). Bioaccumulation AET values were developed for contaminants that satisfied the following criteria:

- Estimated health risks associated with long-term consumption of seafood caught in Commencement Bay at a rate of 1 lb/mo (15 g/day) exceeded a cancer risk level of 10^{-6} or the ADI
- Observed tissue concentrations exceeded tissue concentrations from fish caught from Puget Sound reference areas (i.e., Carr Inlet).

Of the 70 contaminants, observed concentrations of PCBs and arsenic were associated with lifetime cancer risks of 10^{-6} or greater at a consumption rate of 1 lb/mo. Because mean concentrations of arsenic in English sole muscle tissue were greater in Carr Inlet than in all Commencement Bay transects, it was considered inappropriate to establish an AET for arsenic bioaccumulation. Therefore, only PCB data were used to establish a bioaccumulation AET.

Significant bioaccumulation was determined by statistically comparing pollutant concentrations in each Commencement Bay transect to concentrations in Carr Inlet (i.e., reference area) transects. PCBs in English sole muscle and sediments from 12 fish trawl transects in the Commencement Bay waterways

(Tetra Tech 1985a) were used to generate bioaccumulation AET values for PCBs. Fish trawl transects along open shorelines (i.e., Ruston Shoreline) were not included in AET generation, because associations between sediment and fish contaminant concentrations were assumed to be stronger for fish collected in waterways. It was assumed that fish in waterways experienced a more confined exposure to local sediment contamination than fish that were collected along an open shoreline.

English sole muscle tissue data were evaluated for statistically significant PCB bioaccumulation using the following steps:

- PCB bioaccumulation data were evaluated for normality with the Kolmogorov-Smirnov (K-S) test (Sokal and Rohlf 1981; SPSS 1986). The data were not normally distributed ($P<0.05$), but instead appeared to have a log-normal distribution.

- PCB bioaccumulation data were log10-transformed and re-evaluated for normality with the K-S test. The transformed data were normally distributed ($P<0.05$).

- The mean and standard deviation of the log10-transformed data from each trawl were calculated.

- Results from each potentially impacted trawl were statistically compared with Carr Inlet conditions using pairwise analysis.

- An F-max test was used to test for homogeneity of variances between each pair of mean values.

- If variances were homogeneous, then a t-test was used to compare the two means.

- If variances were not homogeneous, then an approximate t-test was used to compare means.

- Error rates for significance were adjusted for multiple comparisons using Bonferroni's technique (Miller 1981). An error rate of 0.004 (i.e., 0.05 divided by 12) was used for each pairwise comparison.

Results--The bioaccumulation AET for PCBs was 140 ug/kg dry weight sediment. However, due to the large uncertainty associated with using AET values on a non-site-specific basis and because of limited volume of available data with which to apply the AET approach, the bioaccumulation AET was not used as the sole basis for establishing a sediment cleanup goal for PCBs. However, it is useful for indicating a potential level of concern.

<u>Equilibrium Partitioning</u>--In the equilibrium partitioning (sediment-biota) approach, the sediment concentrations associated with a selected human health guideline for edible fish tissue are calculated by assuming that chemical concentrations in sediment, interstitial water, surface water, and

fish are in thermodynamic equilibrium (Battelle 1985a). Acceptable fish tissue concentrations are based on existing regulatory limits (e.g., U.S. FDA action limits or tolerances), site-specific risk calculations, or background (reference area) concentrations. The sediment contaminant levels that would correspond to these body burdens under thermodynamic equilibrium are established as the sediment quality values.

This approach has been investigated by the U.S. EPA/Environmental Research Laboratory-Narragansett, the U.S. Army Corps of Engineers, and Battelle (1985 and 1988) as a tool for estimating bioaccumulation potential. The advantages of this approach are that 1) it has a well-developed theoretical basis, 2) it utilizes available toxicological databases, and 3) it applies to a wide variety of sediment types (i.e., a wide range of organic carbon content). Disadvantages are that 1) it is limited to nonpolar, nonionic organic compounds, 2) it assumes multiphase equilibrium, and 3) it assumes that individuals are exposed to sediments within a known, specified area.

The equilibrium relationship used to establish sediment quality values is based on:

$$K_{ibs} = C_{ib}/C_{is}$$

where:

K_{ibs} = Partition coefficient between biota and sediment for chemical i
C_{ib} = Lipid normalized concentration of chemical i in biota (mg chemical/kg lipid)
C_{is} = Organic carbon normalized concentration of chemical i in sediments (mg chemical/kg organic carbon).

There are a number of assumptions inherent in the use of this approach:

1) Thermodynamic equilibrium exists among sediment, fish/shellfish, and interstitial water.

2) Hydrophobic pollutants associate predominantly with lipids in all aquatic organisms, and the affinity of lipids for these pollutants is equivalent for all organisms; similarly, hydrophobic pollutants associate predominantly with organic carbon in all sediments and the affinity of organic carbon for these pollutants is equivalent in all sediments.

3) The equilibrium distribution of hydrophobic organic pollutants between lipids and sedimentary organic carbon (i.e., the partitioning coefficient) is constant regardless of the type of organism or sediment and regardless of the specific compound.

Method--Sediment quality values for PCBs were established using a five-step approach. Each step of the procedure is discussed below.

Step 1. Determine Acceptable Fish Tissue Concentrations--There are three primary approaches available for defining acceptable concentrations of contaminants in fish tissue: promulgated regulations or guidelines, background (reference) concentrations, and risk assessments.

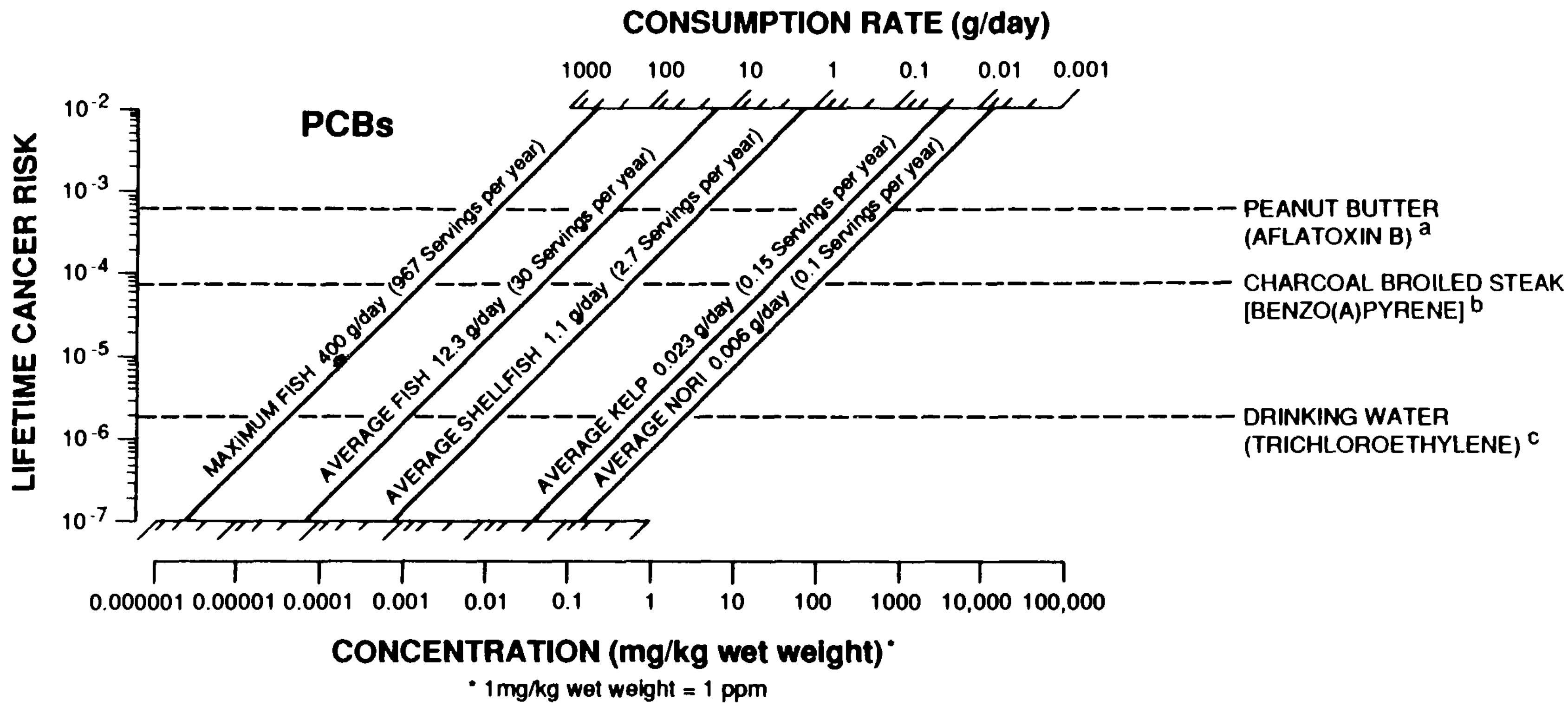
- Regulations/Guidelines: The FDA has stated that levels of "no effect" or "allowable daily intake" cannot be established for PCBs and therefore any potential exposures should be reduced as low as possible. The FDA tolerance level for PCBs in fish and shellfish is 2 mg/kg. This tolerance level is applicable only to fish shipped in interstate commerce.

- Puget Sound Background Concentrations: The 2 mg/kg tolerance level is substantially higher than the PCB concentrations found in fish tissue from nonindustrial areas of Puget Sound. "Background" levels in fish tissue range from 7 to 70 ug/kg wet weight (Tetra Tech 1986a). The average PCB concentration in Carr Inlet fish tissue was 36 ug/kg wet weight (Tetra Tech 1985a).

- Cancer Risk Levels: Fish tissue guidelines can also be developed using standard risk assessment data and methods. Tetra Tech (1988) has developed a graphical method for characterizing health risks associated with a wide range of chemical concentrations and consumption rates for a variety of seafoods. For example, at a fish consumption rate of 12.3 g/day, a PCB concentration of 100 ug/kg (wet weight) is associated with an excess lifetime cancer risk of approximately 10^{-4} (Figure 2-8).

For purposes of the FS evaluation, the mean Carr Inlet tissue concentration (36 ug/kg) was selected as the guideline tissue concentration. This level corresponds to an excess lifetime cancer risk of approximately 4×10^{-5}. This is within the range of risks (10^{-4} to 10^{-7}) generally considered acceptable in Superfund cleanups. Potential guideline concentrations for PCBs in fish tissue are summarized in Table 2-2.

Step 2. Determine Sediment and Fish Characteristics--Two key environmental factors and characteristics of fish and sediments that affect the equilibrium partitioning between sediment, water, and fish are sediment organic carbon content and fish lipid concentration. The organic content of the sediments is one of the most important environmental variables in predicting partitioning of organics such as PCBs between sediments and the water column. In Commencement Bay, average organic carbon content varies from 1.4 percent in Blair Waterway to 6.2 percent in Middle Waterway. Carr Inlet sediments contain an average organic carbon content of 0.3 percent (Tetra Tech 1985a).



a Four tablespoons per day
b 100 steaks per year
c 2 L per day at the U.S. EPA limit (0.005 mg/L)

Figure 2-8. Graphical risk characterization for PCBs in seafood.

TABLE 2-2. POTENTIAL GUIDELINE CONCENTRATIONS FOR PCBs IN FISH TISSUE, COMMENCEMENT BAY N/T FEASIBILITY STUDY

Description	Concentration (ug/kg)
U.S. FDA tolerance	2,000
10^{-4} risk level[a]	81
Background (Carr Inlet)	36
10^{-5} risk level	8
10^{-6} risk level	0.8

[a] Risk calculations were based on the following assumptions:

Carcinogenic potency factor = 7 $(ug/kg/day)^{-1}$

Ingestion rate = 12.3 x 10^{-3} kg fish/day

Human body weight = 70 kg.

Neutral compounds such as PCBs are distributed primarily in the lipids of exposed organisms. A correlation between the lipid concentration and the steady-state PCB concentration in the various tissue types has been shown by several researchers. Because muscle tissue contains the lowest lipid concentration, it can be expected to have lower PCB concentrations than the other tissue types. In Commencement Bay, lipid concentrations in fish muscle tissue ranged from 2.1 to 3.1 percent (mean = 2.6 percent) (Tetra Tech 1985a).

Step 3. Define Equilibrium Relationships--There are several available methods for predicting the partitioning of neutral chemicals between sediment and fish. The equilibrium equation used in this evaluation was developed by the U.S. Army Corps of Engineers (1987) Waterways Experiment Station to predict the maximum bioaccumulation potential that could occur from a given sediment contaminant level. The equation is as follows:

$$Ct = 1.72 \times (Cs/fOC) \times fL$$

where:

Ct = Predicted fish tissue concentration (ug/kg wet weight)
Cs = Sediment contamination level (ug/kg dry weight)
fOC = Decimal fraction of the sediment organic carbon content (%)
fL = Decimal fraction of an organism's lipid content (%)

In essence, this equation states that the ratio of lipid-normalized tissue concentration to organic carbon-normalized sediment concentration is constant (i.e., 1.72). In order to check the utility of this method for the Commencement Bay area, the above equation was used to predict the fish tissue concentrations in each of the waterways. This predicted value was then compared with the observed values. As shown in Table 2-3, the predicted values ranged from 12 to 250 percent of the observed values.

Step 4. Calculate Range of Sediment Quality Values--Using the equilibrium relationships developed by the U.S. Army Corps of Engineers, a range of sediment quality values were calculated. These sediment quality values represent sediment concentrations predicted to be in equilibrium with background (Carr Inlet) fish tissue concentrations (36 ug/kg wet weight). Sediment quality values were calculated for each waterway and the Ruston-Pt. Defiance Shoreline based on the average sediment organic carbon content for that particular area. An average fish lipid concentration of 2.6 percent was used for all areas. Sediment quality values that are expected to result in background PCB concentrations in fish from each waterway are identified in Table 2-4.

Step 5. Determine Sediment Cleanup Goals--In order to evaluate various sediment cleanup levels, sediment PCB concentrations representative of a range of potential post-cleanup conditions were derived and used to estimate long-term health risks associated with the consumption of PCB-contaminated seafood. The method used to derive post-cleanup conditions was based on considerations of available remedial technologies and potential sediment action levels.

TABLE 2-3. PREDICTED VS. OBSERVED PCB CONCENTRATIONS IN FISH TISSUE FROM COMMENCEMENT BAY

Location	Predicted PCB Concentration[a] (ug/kg wet weight)	Observed PCB Concentration[b] (ug/kg wet weight)	Predicted/ Observed (%)
Hylebos Waterway	410	332	123
Blair Waterway	107	253	42
Sitcum Waterway	130	172	76
Milwaukee Waterway	90	100	90
St. Paul Waterway	77	40	193
Middle Waterway	35	170	21
City Waterway	44	354	12
Ruston-Pt. Defiance Shoreline	180	68	265
Average	134	186	72

[a] Based on methods in U.S. Army Corps of Engineers (1987) and McFarland (1984).

[b] From Tetra Tech (1985a).

TABLE 2-4. SEDIMENT QUALITY VALUES THAT ARE EXPECTED TO RESULT IN BACKGROUND CONCENTRATIONS OF PCBs IN FISH OF COMMENCEMENT BAY[a]

Location	Concentration (ug/kg dry weight)
Hylebos Waterway	30
Blair Waterway	11
Sitcum Waterway	15
Milwaukee Waterway	16
St. Paul Waterway	45
Middle Waterway	50
City Waterway	48
Ruston-Pt. Defiance Shoreline	27
Commencement Bay	30

[a] Background concentration is 36 ug/kg wet weight, based on samples of English sole from Carr Inlet (Tetra Tech 1985a).

The primary remedial technologies considered appropriate to contaminated sediments in the Commencement Bay area involve either removal or capping with clean sediments. Both of these measures can be assumed to result in essentially background conditions. Consequently, in estimating average post-cleanup sediment concentrations, the general approach was to assume that all sediments with concentrations greater than a potential action level are removed and replaced by sediments with concentrations equal to Puget Sound reference areas. For a given sediment action level, the resulting post-cleanup concentration was assumed to be the geometric mean of sediments that would be remediated because they exceeded the action level, and those remaining sediments that would not be remediated because they were less than the action level. In order to identify an acceptable post-cleanup level, a reference concentration of 20 ug/kg dry weight was assumed, and seven potential sediment action levels (i.e., 50, 100, 150, 200, 250, 500, and 1,000 ug/kg dry weight) were evaluated as described below.

Geometric mean values for various cleanup levels were calculated in a systematic, iterative manner. All of the sediment concentrations within a particular area were rank-ordered by PCB concentration. The rank order of sediments represents the cleanup priorities for that area (i.e., sediments with the highest observed PCB concentrations have the highest priority for cleanup). Beginning with the maximum rank-ordered PCB concentration, a range of possible post-cleanup concentrations was determined in the following manner:

- First, PCB concentration of 20 ug/kg (Puget Sound reference) was substituted for all of the observed values that exceeded the highest potential action level of 1,000 ug/kg dry weight

- Second, an overall post-cleanup concentration was determined by calculating a geometric mean for the entire data set using the substituted values and the remaining unsubstituted values

- This process was repeated for each of the remaining potential wet action levels (i.e., 50, 100, 150, 200, 250, and 500 ug/kg dry weight.

The geometric mean concentration at each step in this process represents the average residual concentration in the entire waterway following the removal/capping/treatment of sediments that exceeded the specified potential action levels.

Results--Post-cleanup evaluations were performed for Hylebos Waterway, which had the highest observed PCB levels, and for Commencement Bay as a whole. Results of the Hylebos Waterway evaluations are summarized in Table 2-5. The results for Commencement Bay as a whole are very similar to those for Hylebos Waterway. Not unexpectedly, the mean post-cleanup sediment concentrations are reduced as the stringency of the cleanup increases. Based on available data, remediation of sediments exceeding a PCB concentration of 150 ug/kg dry weight will reduce average sediment concentrations in Hylebos Waterway to 30 ug/kg dry weight. At this sediment concentration,

TABLE 2-5. AVERAGE SEDIMENT PCB CONCENTRATIONS ACHIEVED WITH ALTERNATIVE CLEANUP LEVELS

Cleanup Level (ug/kg dry weight)	Mean Residual Sediment Concentration (ug/kg dry weight)	Mean Predicted Fish Concentration (ug/kg wet weight)	Predicted Fish Concentration as a Percent of Reference[a]
1,000	150	186	515
500	105	130	360
250	62	77	213
200	48	60	166
150	30	37	102
100	24	30	83
50	22	27	75

[a] Average reference concentration is 36 ug/kg wet weight based on fish in Carr Inlet (Tetra Tech 1985a).

the predicted PCB fish tissue concentrations (37 ug/kg wet weight) would be essentially equivalent to those in Carr Inlet (36 ug/kg wet weight). Similar results are expected for Commencement Bay as a whole.

Conclusions of Human Health Assessment--

The most significant human health risks from contaminated sediments in Commencement Bay appear to be related to the elevated concentrations of PCBs in sediment and fish tissue (Tetra Tech 1985a, Versar 1985). Sediment concentrations range from 6 to 2,000 ug/kg dry weight, with a mean concentration of 140 ug/kg. In most cases, these levels are significantly higher than the sediment concentrations in Carr Inlet, where the average concentration is 6 ug/kg dry weight. Average fish tissue concentrations vary from waterway to waterway. The highest average values were found in fish from City (354 ug/kg wet weight) and Hylebos Waterways (332 ug/kg wet weight). These contamination levels are associated with excess lifetime cancer risks of approximately 4.0×10^{-4}.

The AET and equilibrium partitioning approaches were used to develop PCB sediment cleanup levels that address human health protection. The bioaccumulation AET defines the sediment concentrations above which statistically significant increases in fish tissue concentrations (relative to Carr Inlet) would be predicted. The bioaccumulation AET for PCBs is 140 ug/kg dry weight.

Using the equilibrium partitioning approach, sediment concentration levels predicted to be in equilibrium with fish tissue concentrations from Carr Inlet were calculated. For purposes of the FS, PCB levels in Carr Inlet fish tissue were considered to be representative of PCB levels in fish tissue in Puget Sound reference areas. A sediment quality value of 30 ug/kg was calculated using this approach. Remediation of sediments with concentrations greater than 150 ug/kg would result in average post-cleanup sediment concentrations of approximately 30 ug/kg dry weight. Following implementation of source control measures and sediment remediation, average concentrations of PCBs in surface sediments would be expected to be reduced further by natural sedimentation and biodegradation.

Taken together, the two approaches provide a reasonable basis to establish sediment cleanup levels. For the purpose of evaluating cleanup alternatives in Commencement Bay, the proposed sediment cleanup level for PCBs is 150 ug/kg dry weight. This sediment concentration is predicted to result in fish tissue concentrations of PCBs that are similar to those in fish from Carr Inlet.

2.2.4 Administrative Definition of the Long-Term Goal

Achievement of the long-term goal for remediation of the nine Commencement Bay N/T sediment problem areas requires a management plan that utilizes the power of the AET approach while recognizing its limitations. A two-step approach has been developed to help translate the long-term goal from a conceptual definition into an administrative framework. It is important to recognize that the AET database is being considered for application as a sediment management tool within a larger management strategy for the site. Thus, its predictive power may help define the extent of a particular problem area and streamline confirmatory sediment sampling operations. However, this approach is fundamentally based on the results of direct environmental sampling and subsequent chemical and biological analysis that have been used to document the nine Commencement Bay N/T problem areas described in the RI/FS. These results confirmed significant environmental degradation in each of the problem areas, based on a combination of chemical and biological analyses. The chemical analyses indicated concentrations of contaminants that are hundreds to thousands of times as great as those in reference areas. The biological testing indicated significant impact to indigenous benthic species, bottom-feeding fish, and shellfish. However, the spatial extent of the problem areas requires considerable refinement, which can be effectively accomplished through appropriate use of the AET database.

Management Approach--

The two-step management approach proposed for use at the Commencement Bay N/T site continues to rely on a combination of chemical and biological testing to assess sediment quality. In the first step, the long-term goals are defined in terms of chemical-specific values derived from the AET database. Numerical sediment quality values were established for each of the 64 Commencement Bay N/T chemicals of concern, and existing sediment chemical data from the site were evaluated to identify areas with chemical concentrations that do not meet the long-term goal. This step allows the problem areas to be defined in terms of spatial extent and volume, based on chemistry, for the purpose of the FS. In addition, it will facilitate future sampling required to better define each problem area prior to remedial action, and to monitor the effectiveness of the cleanup after remedial action. Another advantage of this approach is that sediment sampling operations based primarily on chemical analysis (related to the long-term goal) may be more cost-effective and have a quicker return of data than biological testing.

The second step in the Commencement Bay N/T sediment management approach provides the flexibility to administratively define the long-term goal in terms of chemical or biological testing. Because the AET database is being used as a predictive tool, a degree of uncertainty is inherent in chemical-specific sediment quality values defined by the AET approach. Therefore, it may [redacted] be appropriate to confirm predicted sediment toxicity via direct biological testing in order to prevent the unnecessary remediation of sediments within problem areas that are not accurately characterized by the existing AET database. This is discussed in Section 2.4.

Long-Term Goals Based on Chemistry--

If the long term goal for the site is driven by a mandate requiring no "acute or chronic adverse effects", as suggested in Section 2.2.1, then the lowest AET value for a given chemical (LAET) may be an appropriate way to administratively define that goal, provided all the tests are accepted as sufficiently sensitive, reliable, and environmentally relevant.

As part of the FS, the following three options were evaluated to define contaminant concentrations that provide protection of human health and the environment (described in PTI 1988c):

1) The lowest AET for a range of four biological indicators (amphipod, oyster larvae, benthic infauna and Microtox)

2) The lowest AET for a range of three biological indicators (amphipod, oyster larvae, and benthic infauna)

3) The lower of either the maximum AET value for three indicators (amphipod, oyster larvae, and benthic infauna) or the lowest severe effects AET for the same indicators. Severe effects in biological tests are defined as ≥50 percent bioassay response or benthic infaunal depressions in more than one major taxonomic group.

In establishing a cleanup goal for PCBs, the bioaccumulation AET and the equilibrium partitioning approach were also included among the indicators considered. For Option 2, the EP value for PCBs (i.e., 150 ug/kg) was lower than AET established by other biological indicators. Consequently, it was used to define the long-term goal for PCBs. The sediment quality values corresponding to each of the three options are provided in Table 2-6.

Option 2 was selected to define the long-term goal based on chemical-specific sediment quality values for the Commencement Bay N/T site. The biological indicators included in Option 2 are considered sufficiently sensitive, reliable, and environmentally relevant to establish a cleanup goal for the site that is protective of the environment. By including the EP value for PCBs, Option 2 is also considered protective of human health, and therefore consistent with CERCLA Section 121. The use of the lowest AET for the three biological indicators (amphipod, oyster larvae, and benthic infauna), which measure acute, and to a degree, chronic effects, is protective of adverse biological effects in Puget Sound, and is therefore consistent with the requirements contained in the Puget Sound Water Quality Authority's 1989 Management Plan and Ecology's current efforts to fulfill those requirements. By including the benthic infauna AET, Option 2 provides some measure of protection against chronic effects in the environment. It therefore provides the most appropriate administrative definition of the long-term goal of the approaches currently available.

Option 1 was not selected for several reasons. First, the Microtox AET was not considered as an appropriate component of the chemically based long-term goals. Although there are a number of technical considerations supporting the use of the Microtox bioassay in setting cleanup goals, several considerations have caused agencies in a number of different programs to limit its use as a stand-alone biological indicator of sediment toxicity. The test is often perceived as overly sensitive when compared to tests using higher organisms. It is also difficult to extrapolate the results of the Microtox test to effects in marine microbial communities. Use of the Microtox AET was also found to reduce the efficiency of defining impacted sediments while providing only small improvements in sensitivity. Although

TABLE 2-6. CLEANUP GOAL OPTIONS CONSIDERED FOR COMMENCEMENT BAY N/T FEASIBILITY STUDY
(ug/kg dry weight for organics; mg/kg dry weight for metals)

	Option 1	Option 2	Option 3
Low molecular weight PAH	5,200[a,e]	5,200[a]	5,200[g]
naphthalene	2,100[a,e]	2,100[a,d]	2,100[g]
acenaphthylene	1,300[c,d]	1,300[c,d]	1,300[c,d]
acenaphthene	500[a,e]	500[a]	500[g]
fluorene	540[a,e]	540[a]	540[g]
phenanthrene	1,500[a,e]	1,500[a]	2,300[g]
anthracene	960[a,e]	960[a]	960[a,e,g]
High molecular weight PAH	12,000[e]	17,000[a]	30,000[g]
fluoranthene	1,700[e]	2,500[a]	3,900[g]
pyrene	2,600[e]	3,300[a]	4,300[g]
benz(a)anthracene	1,300[e]	1,600[a]	2,300[g]
chrysene	1,400[e]	2,800[a]	2,800[g]
benzofluoranthenes	3,200[e]	3,600[a]	9,900[c]
benzo(a)pyrene	1,600[a,e]	1,600[a]	3,600[c]
indeno(1,2,3-c,d)pyrene	600[e]	690[a]	2,600[c]
dibenzo(a,h)anthracene	230[a,e]	230[a]	970[c]
benzo(g,h,i)perylene	670[e]	720[a]	2,600[c]
Total PCBs	130[e]	150[b]	1,500[f]
Chlorinated organic compounds			
1,3-dichlorobenzene	>170[a,c,d,e]	>170[a,c,d]	>170[a,c,d,f,g,h]
1,4-dichlorobenzene	110[c,e]	110[c]	120[a,d,f]
1,2-dichlorobenzene	35[e]	50[a,c]	63[f]
1,2,4-trichlorobenzene	31[e]	51[d]	64[a,c,f]
hexachlorobenzene (HCB)	22[c]	22[c]	230[a,f]
Phthalates			
dimethyl phthalate	71[e]	160[a]	>1,400[c,d,f,h]
diethyl phthalate	200[c]	200[c]	>1,200[d,f,h]
di-n-butyl phthalate	1,400[a,d,e]	1,400[a,d]	1,500[h]
butyl benzyl phthalate	63[e]	900[c,d]	900[c,d]
bis(2-ethylhexyl)phthalate	1,300[c]	1,300[c]	1,300[c,f]
di-n-octyl phthalate	6,200[d]	6,200[d]	6,200[c]
Pesticides			
p,p'-DDE	9[c]	9[c]	9[c,f]
p,p'-DDD	16[c]	16[c]	43[d]
p,p'-DDT	34[c]	34[c]	34[c,f]

TABLE 2-6. (Continued)

	Option 1	Option 2	Option 3
Phenols			
phenol	420[a]	420[a]	1,200[c,d,e,g,h]
2-methylphenol	63[a,d]	63[a,d]	72[c,f,h]
4-methylphenol	670[a,e]	670[a]	1,200[g]
2,4-dimethylphenol	29[a,e]	29[a]	210[c,h]
pentachlorophenol	360[d]	360[d]	690[c,f,h]
Miscellaneous extractables			
hexachlorobutadiene	11[c]	11[c]	270[a]
dibenzofuran	540[a,e]	540[a]	540[a,e,g]
benzyl alcohol	57[e]	73[a]	130[g]
benzoic acid	650[a,c,e]	650[a,c]	650[f]
N-nitrosodiphenylamine	28[c]	28[c]	130[a,h]
Volatile organics			
tetrachloroethene	57[c]	57[c]	140[a,e,f]
ethylbenzene	10[c]	10[c]	37[a,f]
total xylenes	40[c]	40[c]	120[a,f]
Metals			
antimony	150[c]	150[c]	200[d,f]
arsenic	57[c]	57[c]	700[a,e,h]
cadmium	5.1[c]	5.1[c]	9.6[a,e,h]
copper	390[a,e]	390[a]	1,300[d,h]
lead	450[c]	450[c]	660[a,d]
mercury	0.41[e]	0.59[a]	2.1[c,d,h]
nickel	>140[c,d]	>140[c,d]	>140[c,d,f,h]
silver	6.1[d]	6.1[d]	6.1[d]
zinc	410[c]	410[c]	1,600[a,e,f,g,h]

[a] Oyster larvae bioassay AET.

[b] English sole muscle tissue bioaccumulation AET.

[c] Benthic infauna (higher taxa) AET.

[d] Amphipod bioassay AET.

[e] Microtox bioluminescence.

[f] Severe benthic infauna AET.

[g] Severe oyster larvae bioassay AET.

[h] Severe Amphipod bioassay AET.

[i] The criteria shown are set by the crustal abundance of nickel (based on Turekian and Wedepohl 1961). The AET values for nickel were below crustal abundance levels, and were thus considered inappropriate. Addition of data with a wider range of nickel is needed.

[j] A detection limit value would be applied according to the procedure for selecting target and alternative criteria; however, detection limit values are not considered appropriate as a criterion.

Microtox may be included as a component in Ecology's approach for inventorying potential problem areas in the sound [Element S-8 of the Puget Sound Water Quality Management Plan (PSWQA 1988)], it is unlikely to be included as a factor in defining sediment remedial actions.

Option 3 was not selected because it was not considered environmentally protective and is inconsistent with Ecology's efforts to develop Puget Sound-wide sediment quality goals. It was used, however, to establish a lower range of the areas and volumes of sediment requiring remediation. These calculations are provided in Chapter 14.

For the purposes of the FS, cleanup goals and estimates of areas and volumes not meeting those goals are based on sediment chemistry values. During the remedial design phase, which precedes remedial actions, chemical testing will be required and biological testing may or may not be required to refine area and volume estimates and to verify the predictions based on chemical AET values. Procedures for additional testing are presented in PTI (1988a).

2.2.5 Review/Use of New Information

The technical approaches for evaluating the quality of marine sediments have undergone rapid development during the last several years. It is anticipated that continued research, evaluation of the various technical approaches, and practical experience in their application may lead to future modifications. In recognition of the evolving nature of the various technical approaches, the Superfund process includes several provisions for ensuring the timely incorporation of important new scientific evidence during the cleanup phases of the project:

- Superfund Five-Year Reviews - Under SARA, U.S. EPA is required to review remedial actions where hazardous substances are left onsite at intervals of no less than 5 yr. These reviews will provide the opportunity to incorporate additional scientific information that becomes available during the previous 5-yr interval.

- Remedial Design Testing - For each problem area, potentially responsible parties (PRPs) will be required to perform additional sediment sampling and analysis to refine the estimates of the areal extent of contamination based on the AET approach. The proposed refinement procedures are described in Section 2.3.6 and PTI (1988a). The testing procedures and data interpretations will incorporate new scientific evidence as appropriate.

- Source Control Requirements - Many of the source control measures being implemented under various water quality programs are being implemented in a phased manner. This will provide a great deal of flexibility to incorporate new information on sediment quality values into future regulatory decisions.

2.3 USE OF THE LONG-TERM SEDIMENT CLEANUP GOAL

The long-term sediment cleanup goal defines a level of sediment contamination that would be acceptable throughout Commencement Bay. As referenced in Section 2.2.1, the long-term goal has not been modified to take into account factors such as technical feasibility and cost. However, these and other factors are often important considerations when translating the long-term cleanup goals into individual requirements for sources of contamination, routine navigation dredging projects, and sediment remedial actions.

In evaluating measures to correct sediment contamination problems in Commencement Bay, the long-term sediment cleanup goal has been used as a tool in making the following types of management decisions:

- Defining extent and relative priority of problem areas
- Defining source control needs
- Prioritizing areas for remedial action
- Identifying sediment areas requiring remediation.

These uses of the long-term goal are summarized in Sections 2.3.1-2.3.4. Section 2.3.5 provides a definition of a reasonable sediment recovery time. The remedial design procedures for refining estimates of sediment areas and volumes requiring remediation are discussed in Section 2.3.6.

2.3.1 Defining the Extent of Areas of Concern

During the FS, the long-term cleanup goal was used to estimate the extent of contamination in each problem area. This was accomplished by first defining a set of "indicator chemicals" for each problem area. Indicator chemicals represent a subset of all of the chemicals identified in a particular area and were identified by first separating the problem chemicals into groups that appeared to have a common source (or sources), and then selecting the chemicals that were most representative of each source group. These chemicals were selected on the basis of the following three criteria: 1) they had the highest ratio of observed sediment contamination to long-term cleanup goal (termed the enrichment ratio), 2) they were present at concentrations higher than the long-term goal over the greatest area, and 3) they resist degradation.

The sediment areas of concern were estimated by mapping the enrichment ratios for the indicator chemicals for all sampling stations in a problem area. Boundaries for the surface area requiring remediation were drawn by linear interpolation between sampling stations where sediment concentrations exceeded the long-term goal and those where the sediment levels did not exceed the goal. Depth of contamination, estimated from available sediment profiles within the problem area, was slightly overestimated to account for tolerances of the various dredging techniques and to be environmentally protective. For each indicator chemical, area and depth data were used to calculate sediment volumes of concern. In problem areas with two or more indicator chemicals, the separate volume estimates were integrated to obtain a total problem area sediment volume. Maps showing the areas of concern are included in Chapters 5-13.

The use of the long-term goal to define the extent of contamination in a problem area should be distinguished from the process of identifying high priority problem areas requiring remedial action evaluations. Criteria for triggering an evaluation of sediment remedial action are described in Section 1.3.5.

2.3.2 Defining Source Control Needs

The long-term goal was used to define acceptable levels of contamination in ongoing discharges and to identify the need for additional source control measures to protect sediment quality. The general approach involved the following steps:

1) Estimating current discharge loadings for major sources

2) Estimating the percent source control required to reach the long-term goal

3) Estimating the degree of source control achievable through the implementation of all known, available, and reasonable methods of treatment.

For the FS, contaminant concentrations from the three most contaminated stations in a problem area were averaged to derive an estimate of the current level of contamination in freshly deposited sediments. Two assumptions were inherent in these estimates: 1) contaminants discharged by sources are associated or become associated with particulate material that accumulates primarily as sediments, and 2) source discharges are in steady-state with sediment accumulation. The quantitative relationships between long-term sediment cleanup goals and contaminant concentrations in the effluent particulates were evaluated using a mathematical model (SEDCAM) which incorporates site-specific and chemical-specific variables. Examples of site-specific variables include suspended particle loadings of effluents, sedimentation rate, and depth of the mixed layer in sediments near the source. Examples of chemical-specific variables include particle affinity and susceptibility to biodegradation.

Estimates on the degree of source control achievable through the use of all known, available, and reasonable methods of treatment were based on a general evaluation of sources, discharges, and pollution control technologies. These estimates will be refined as part of detailed engineering and cost evaluations by owners and operators of individual facilities. In evaluating and implementing individual source control actions, Ecology will utilize a phased approach. First, sources will be required to install all known, available, and reasonable methods of treatment. Source and sediment monitoring will be performed to determine whether violations of the sediment criteria are occurring. Based on this information, Ecology will then determine the need for either additional control measures or a "sediment impact zone" (sediment dilution zone). This is consistent with the general approach being developed by Ecology to fulfill the requirements of the Puget Sound Water Quality Management Plan. Ecology and U.S. EPA will require that final source control actions are consistent with the sediment remedial action requirements specified in the Superfund Record of Decision for the Commencement Bay N/T site.

2.3.3 Prioritizing Areas for Remedial Action

In developing the Commencement Bay N/T Integrated Action Plan (PTI 1988a), the long-term goal was one of several factors used to prioritize sources and areas for further investigation, source control, or remedial action. Relative rankings were based on three criteria: environmental significance, effectiveness of source control, and status of action. For source rankings, environmental significance for an individual source is based on a consideration of contaminant types, magnitude and spatial extent of sediment areas not meeting the long-term goal, and the relative contribution of each individual source to the sediment contamination. For area rankings, environmental significance scores were based on an intercomparison of spatial extent and persistence of sediments not meeting the long-term goal. Spatial extent is defined as the area of surface sediments whose contaminant concentrations exceed the long-term goal. Persistence is defined as the relative proportion of contaminated sediments that is expected to exceed the long-term goal 10 yr after a 70 percent source control level is achieved.

2.3.4 Identifying Sediments Requiring Remediation

Under the proposed Commencement Bay approach, PRPs will be required to remediate sediments in areas where contamination problems are not corrected by source control and natural recovery, within a reasonable timeframe or through navigational dredging. The long-term sediment cleanup goal is used as the basis for determining when a sediment problem has been successfully corrected.

The contaminant concentrations requiring remediation (i.e., removal, capping, treatment) are higher than the long-term goal used to define the areas of concern. The multipliers used to define those levels vary from waterway to waterway and are a function of the types of sources, source control effectiveness, waterway characteristics (e.g., sedimentation rates, navigational dredging) and the length of time required for natural recovery.

The multipliers are chemical- and area-specific. They were calculated using a mathematical model (SEDCAM). This model (described in Appendix A) was used to estimate the highest level of sediment contamination that would naturally recover within 5 yr, 10 yr, and 25 yr after the implementation of source control measures. Natural recovery is defined to include reduction in surface sediment concentrations due to sedimentation, diffusive loss to overlying water, and biodegradation. Sediment concentrations that could naturally recover were then used to estimate the sediment areas requiring remediation.

2.3.5 Definition of a Reasonable Sediment Recovery Time

The longer the recovery period following source control, the smaller the area requiring remediation. The 10-yr timeframe was selected as a "reasonable" recovery period based on the following factors:

1) Precedent - A 10-yr period is similar to legislatively mandated timeframes under other environmental legislation. For example, the 1972 Federal Water Pollution Control Act stated it was a national goal to attain fishable and swimmable waters by 1983.

2) Environmental Protection - CERCLA Section 121 requires that in assessing remedial alternatives, the agencies must take into account ". . . the potential threat to human health and the environment associated with excavation, transportation, and redisposal, and containment . . . ." The use of the 10-yr recovery sediment volumes provides an optimal balance by minimizing remediation-related adverse impacts while protecting natural resources in Commencement Bay.

3) Monitoring Practicality - Additional monitoring will be required to confirm modeling predictions. It is unlikely that significant changes in contaminant concentrations would be observed in timeframes of less than 10 yr.

4) Costs and Technical Feasibility - The PSWQA 1987 and 1989 Management Plans direct Ecology to develop sediment remedial action guidelines. Ecology is required to consider natural recovery, cost, and technical feasibility in developing those guidelines. Use of a 10-yr recovery period will enable natural recovery of less contaminated areas, thereby reducing volumes and associated costs.

2.3.6 Sediment Volume Refinement Process

Intensive sampling within individual problem areas was not performed as part of the Commencement Bay N/T FS. The volume of contaminated sediments requiring cleanup was estimated using available chemical and biological data. Consequently, additional sampling will be required during the remedial design/remedial action phases of the Superfund process to ensure cost-effective and appropriate implementation of sediment remedial actions. Data from the remedial design sampling will be used for the following purposes:

- Refine estimates of the areal extent and depth of contamination to be addressed by the remedial alternative

- Confirm predicted adverse biological impacts

- Identify temporal changes in problem chemical concentrations resulting from sedimentation and source control actions since the RI/FS sampling phase. Documented changes will then be used to refine predictions of the rate of problem area recovery and to re-evaluate the need for the remedial alternative

- Provide a baseline assessment to support subsequent monitoring of the success of remedial action.

The steps in refining estimates of sediment cleanup volumes during remedial design are shown in Figure 2-9. These steps may involve only collection and evaluation of chemical data or a combination of chemical and biological data. Following final determination of the cleanup volume, the sediment remedial alternative will be implemented. Major changes in the estimated sediment cleanup volume may require modification of the remedial alternative.

Chemical Characterization--

Unless biological testing is included in remedial design site characterization, a chemical sampling program for analysis of all identified problem chemicals in the problem area is required. Guidance on chemical sampling and analysis is provided in PTI (1988a). The results of this sampling program will be used to establish the depth and areal extent of the final cleanup volume. Long- and short-term cleanup goals serve as a basis for the evaluation of chemical data. Long-term cleanup goals are used to characterize the spatial extent of contaminated sediments, and short-term cleanup goals are used to identify the volume of sediments subject to remedial action (i.e., the cleanup volume). The cleanup volume is defined horizontally and vertically by the location of the sample, at which contamination consistently no longer exceeds any short-term cleanup goal for any problem chemical in a given problem area. Short-term cleanup goals are equivalent to the chemical concentrations in present-day sediments that will attain the long-term cleanup goal after 10 yr of source control and natural recovery. Long- and short-term cleanup goals for each problem area are described in Chapters 5-13.

Biological Characterization--

Biological testing can be either optional or, in selected instances, mandatory. A PRP has the option to conduct biological testing to refine estimates of sediment cleanup volumes rather than accept the prediction of biological effects based solely on chemical data. The option to appeal the predictions of AET is provided in recognition that site-specific factors could anomalously influence predictions of biological effects. The site-specific results of biological tests will replace all predictions based on chemical data. Because source control and natural recovery cannot be incorporated into biological test results, the long-term cleanup goal (i.e., the biological effect represented by the lowest AET) will define the areal extent of contamination when the biological testing option is exercised. Remedial design results will not immediately be used to modify predictions

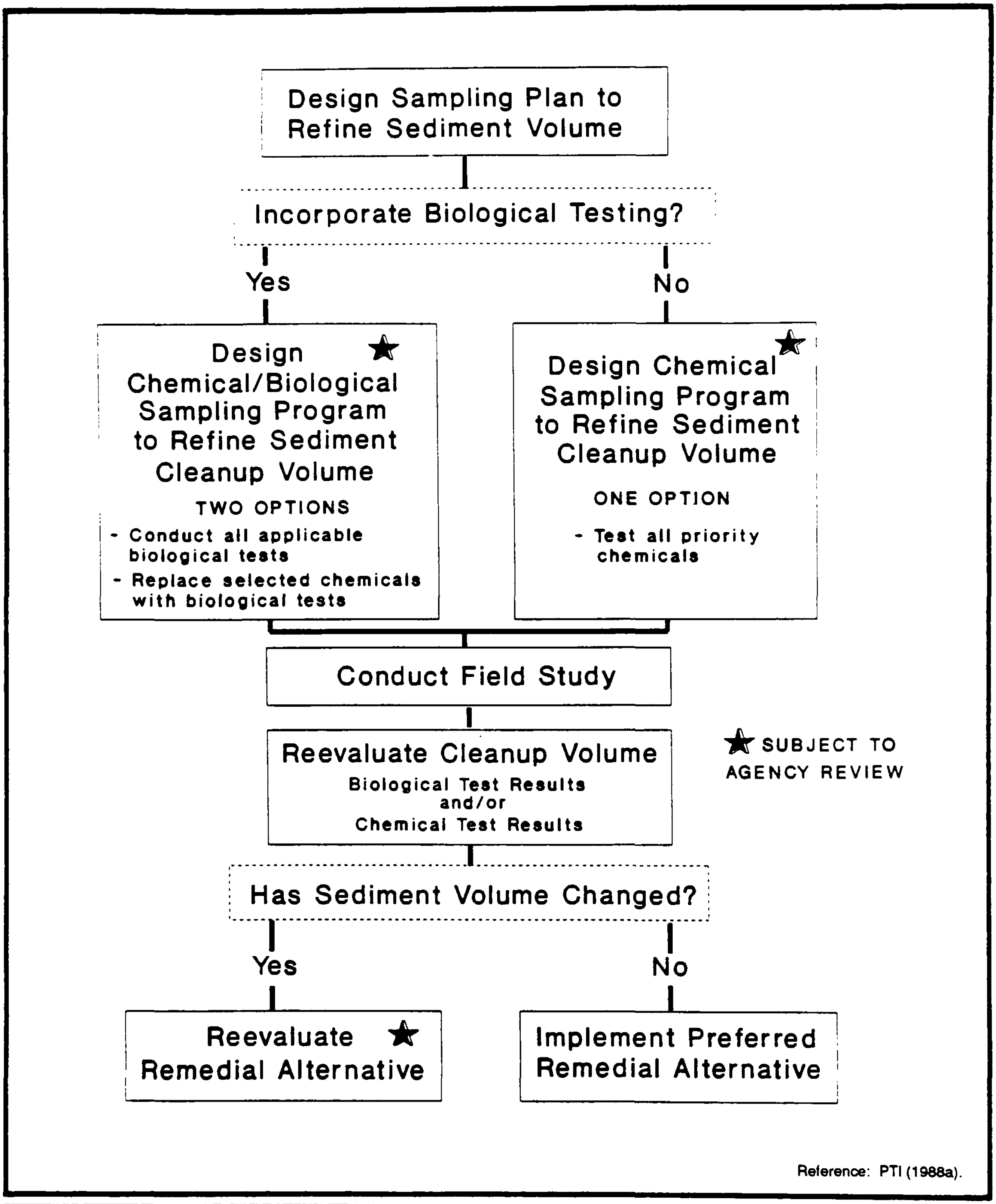


Figure 2-9. Refinement of sediment cleanup volume estimates.

at other sites, but may be used to modify predictions in the future after general review.

Guidance on biological sampling and analysis is provided in PTI (1988a) for all conventional biological effects tests (i.e., amphipod mortality, oyster larvae abnormality, benthic infauna depressions). Because the PCB cleanup goal is developed from a human health risk assessment, standardized biological tests do not apply. The option to appeal the PCB cleanup goal can still be exercised by conducting laboratory tests that evaluate the PCB content of fish exposed to contaminated sediment. Protocols for this type of test have not yet been developed.

The option to focus on biological/bioaccumulation tests can be fully exercised only in appealing the areal extent of the cleanup volume (and not the cleanup depth), because benthic infauna analyses cannot be used to test subsurface sediments. If the depth component of the cleanup volume is appealed, bioassays must be performed in combination with chemical tests for all priority chemicals. The results of the chemical tests must be compared against cleanup goals established for benthic infauna analysis.

The PRP may elect to conduct some, but not all, of the biological tests that apply to the problem area in question. As in the previous option, benthic infauna analyses can be used only to test surface sediments. Chemical cleanup goals are used to predict results for each biological indicator that is not used in the testing program. The selection of appropriate biological indicators for testing may depend on the relative cost of biological and chemical analyses, as well as site-specific concerns of the PRPs as to which biological predictions may be anomalous.

The strategy for selecting candidate biological tests that would be incorporated into remedial testing for a given problem area would also depend in the following factors:

- The problem chemical identified

- The relationship between AET for individual problem chemicals or chemical classes (i.e., which biological effect is associated with the lowest AET for a given chemical or chemical class)

- The net effect of source control and natural recovery on the relationship between short-term cleanup goals and the biological effects represented by AET.

Alternative ways in which the short-term cleanup goals may relate to AET [i.e., oyster (O), amphipod (A), and benthic infauna (B)] are illustrated in Figure 2-10. The solid axis depicts differing relationships among AET (Cases 1, 2, and 3). The AET with the lowest value is defined as the long-term cleanup goal (e.g., B in Case 3). The dashed arrows depict how the long-term cleanup goal may be adjusted to define the short-term cleanup goal, depending on the degree of source control and the potential for

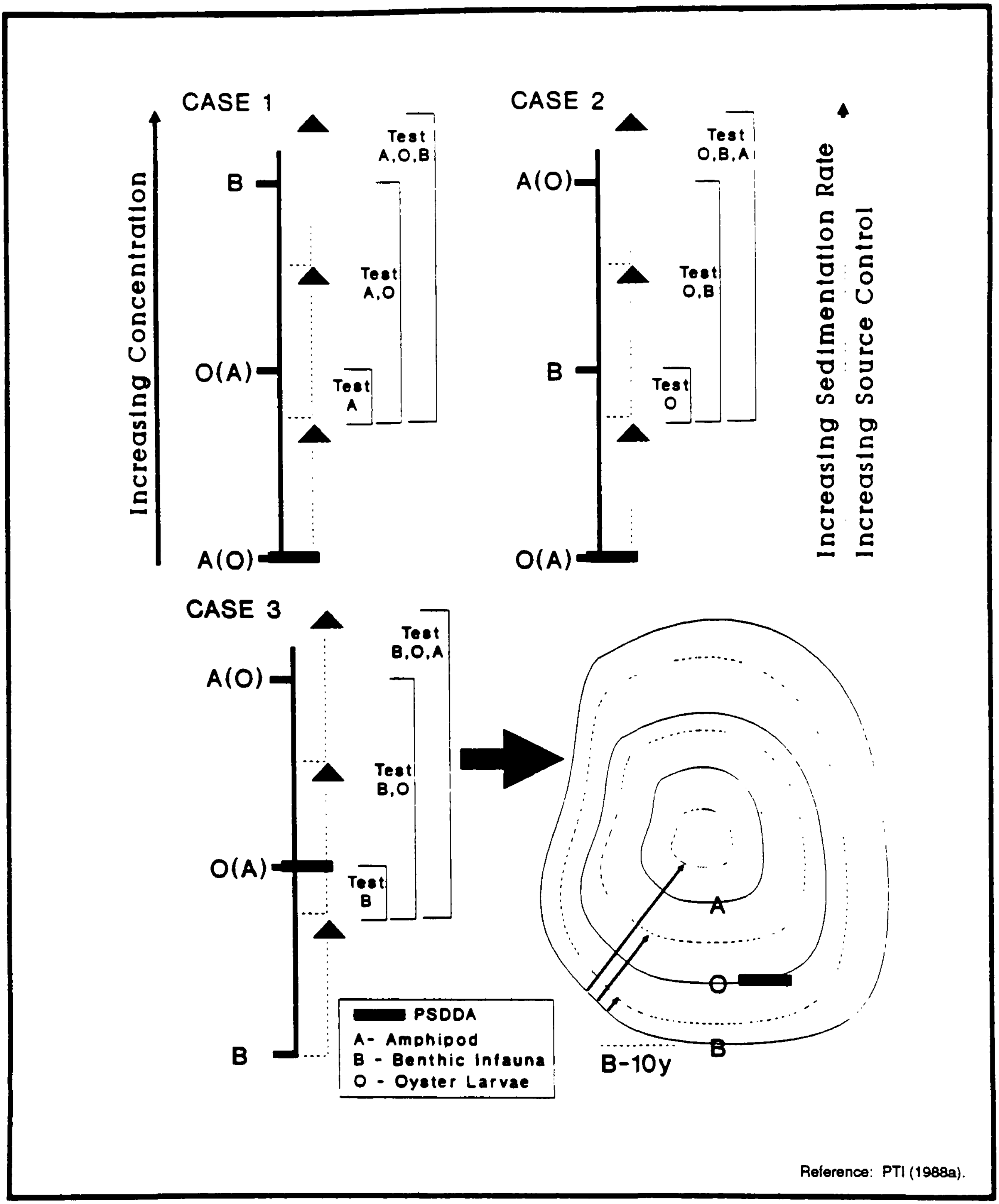


Figure 2-10. Theoretical relationships among AET, long-term cleanup goals, and short-term cleanup goals.

natural recovery. The brackets indicate the types of biological tests that would be appropriate to conduct over selected concentration ranges.

The optional biological testing program in the remedial design phase is generally consistent with the intent of regional contaminated sediment management programs, including PSDDA. Comparable tests and test protocols are used, and site-specific biological information overrides predictions of biological effects based on chemical data. Some specific differences among regional programs in the interpretation of biological test results may exist because of differing program goals (e.g., cleanup of nearshore sediments in a multi-use environment vs. assessment of the suitability of potentially contaminated material for disposal at a designated deepwater site).

Benthic infauna testing may be mandatory when any portion of the cleanup volume is defined exclusively by benthic infauna AET (i.e., when the benthic infauna AET is the lowest AET for one or more problem chemicals). Benthic infauna testing is not a component of the PSDDA evaluation procedures for dredged material. Because the PSDDA evaluation procedures do not consider in situ benthic effects, it is theoretically possible that sediments designated for remedial action also could be acceptable for unconfined, open-water disposal. This situation occurs when the short-term goal defined by the benthic infauna AET (which is modified for natural recovery) is lower than the long-term goal defined by oyster larvae abnormality or amphipod mortality. This is most likely to occur in problem areas where the highest priority problem chemicals have benthic infauna depressions as their lowest AET and where sedimentation rates are relatively low. This possibility is illustrated as Case 3 in Figure 2-10.

Should the PRP choose to conduct biological testing, then the PRP must use the following definitions of impacted station:

- 10-day amphipod mortality bioassay (Rhepoxynius abronius) - Impacted stations will be defined as stations where 1) the test sample mortality is statistically significant (pairwise alpha of 0.05) relative to the reference sample, and 2) the test sample absolute mortality exceeds 25 percent. Results will be classified as inconclusive if the standard deviation is greater than 15 or if the statistical power of the test is <0.6.

- Bivalve larvae abnormality bioassay (i.e., 4-day oyster larvae or 2- to 4-day mussel larvae bioassays) - Impacted stations will be defined as stations where 1) the test sample absolute combined mortality/abnormality is statistically significant (pairwise alpha of 0.05) relative to the reference sample; 2) the test sample absolute, combined mortality/abnormality is greater than 10 percent over reference; and 3) the test sample absolute, combined mortality/abnormality is greater than 20 percent over control.

- Benthic infaunal abundance test (for surface sediments) - Impacted stations will be defined as stations where 1) the test sediment demonstrates a statistically significant effect (pairwise alpha of 0.050) when compared to the reference sediment sample; and 2) the test sediment demonstrates greater than a 50 percent depression in the abundance of the major taxa of Polychaeta, Mollusca, or Crustacea when compared to the reference sediment sample.

- Laboratory exposure studies of PCB bioaccumulation in fish- Because protocols to conduct these exposure studies have not yet been developed, the criteria to define impacted stations are unavailable.

Use of Additional Data to Define Areas of Concern--

Results of the additional chemical and biological testing will be used to redefine areas of concern that exceed the long-term sediment quality goal and will be evaluated using the following criteria:

- Areas of concern will be defined to include all sediments where chemical contamination exceeds the long-term goal. The chemical long-term goal is defined as the lowest AET exclusive of Microtox (i.e., Option 2 in Section 2.2.4).

- Areas of concern will be defined to include all sediments with demonstrated impacts on the benthic communities. Impacted stations will be defined as described above.

- Areas of concern will be defined to include all sediments with significant adverse effects in either the 10-day amphipod mortality bioassay, or bivalve larvae abnormality bioassay. Significant adverse effects will be defined as described above.

Use of Additional Data to Define Sediment Cleanup Volumes--

Results from the additional chemical and biological testing will be used to determine which sediments require remediation and will be evaluated using the following interpretation criteria:

- Sediments containing chemical contamination concentrations that exceed the long-term goal (adjusted for 10 yr recovery) will require remediation.

- Sediments with demonstrated impacts on indigenous benthic infauna will require remediation. Impacted stations will be defined as described above.

- Sediments with significant adverse effects in either of the following laboratory bioassays: 10-day amphipod mortality bioassay, or bivalve larvae abnormality bioassay. Significant adverse effects will be defined as described above.

2.4 RELATIONSHIP BETWEEN THE FEASIBILITY STUDY AND EXISTING REGULATORY PROGRAMS

Sediment contamination in the Commencement Bay N/T area is the result of contaminant discharges from many different sources over an extended period of time. These sources are regulated under a number of environmental programs. Excavation, capping, and other treatment of the sediments are also subject to a number of existing regulatory requirements. In both cases, the applicable requirements vary with respect to source, activity, location, contaminant type, and contaminant concentration.

These existing programs and requirements will provide the basic regulatory framework for the reduction or elimination of ongoing releases of toxic materials to the marine environment. For example, wastewater discharges from industrial and municipal facilities have been, and will continue to be regulated under the NPDES and state waste discharge permit programs. Releases of hazardous substances have been and will continue to be regulated under the state and federal hazardous waste management laws. In most cases, discharge requirements will be similar to requirements for comparable facilities in other parts of Puget Sound.

With respect to sediment remedial actions, greater reliance will be placed on the CERCLA requirements and procedures. It is currently planned that this type of remedial work will be performed by PRPs under conditions specified in consent decrees. These negotiated agreements will be developed in a phased approach according to priorities for action described in the Integrated Action Plan (PTI 1988a). At a minimum, these types of corrective measures will be performed in compliance with the substantive requirements of existing environmental rules and regulations.

The approach being used for the Commencement Bay N/T FS is consistent with and supportive of the major sediment quality management initiatives and programs of the Puget Sound Dredged Disposal Analysis (PSDDA), the Puget Sound Water Quality Authority (PSWQA), and the Puget Sound Estuary Program (PSEP). Many of the proposed actions in Commencement Bay are dependent upon the successful implementation of these programs. The relationships between each of these major programs and the Commencement Bay N/T Superfund Project are described below.

2.4.1 Relationship Between the PSDDA Program and the Commencement Bay Superfund Project

The Puget Sound Dredged Disposal Analysis is a comprehensive interagency effort to develop a process for making decisions regarding the unconfined disposal of dredged material in deep waters in Puget Sound. It is a cooperative effort undertaken by the U.S. Army Corps of Engineers, U.S. EPA, the Washington Department of Natural Resources (DNR), and Ecology. The study, which began in April 1985, is a 4-yr effort being conducted in two overlapping phases, each about 3 yr in length. Phase I covers central Puget Sound, including the major urban centers of Tacoma, Seattle, and Everett. Phase II, initiated in April 1986, covers north and south Puget Sound. During the Superfund process, consistency with the PSDDA evaluation procedures and decision guidelines has been identified as a major issue. In the following sections, the similarities and distinctions between the two approaches are described.

Program Objectives--

The main study objectives are to 1) identify acceptable public multiuser unconfined, PSDDA open-water disposal sites; 2) define consistent and objective procedures by which to determine the suitability of dredged material for disposal at those sites; and 3) formulate site use management plans that will ensure adequate controls and program accountability. In contrast, the objective of the Superfund activities at the Commencement Bay N/T site is to correct existing sediment contamination problems through source control and sediment remedial actions.

Evaluation Procedures--

As part of the PSDDA effort, the Evaluation Procedures Work Group (EPWG) was formed to develop a consistent decision-making framework for evaluating dredged material and making a determination on whether the material is acceptable for open-water disposal. The procedures developed by this group include three tiers:

- Tier 1 - Assess existing sediment information
- Tier 2 - Conduct chemical testing if necessary
- Tier 3 - Conduct biological testing if necessary.

PSDDA and the Commencement Bay N/T FS process share two common elements:

- Use of chemical and biological testing data in the decision-making process
- Use of the AET approach in defining sediment quality.

Use of Chemical and Biological Testing Data--The multistep PSDDA evaluation process begins with the evaluation of existing information on sediment contamination and sources of contamination. If there is reason to believe that the sediments contain elevated concentrations of chemical contaminants, then additional chemical testing of the sediments is required. Results from this testing are used to identify sediments that are expected to be of very high toxicity (above the PSDDA maximum level, ML) or very low toxicity (below the PSDDA screening level, SL).

When sediment chemical concentrations fall between the SL and ML concentrations, biological testing of the sediments is required. The required tests include the amphipod bioassay, the juvenile bivalve larvae test, Microtox test, and a 30-day bioaccumulation test.

A similar approach is being proposed for use in the Commencement Bay N/T FS. Initial estimates of cleanup areas and sediment volumes have been based on chemical contamination. Additional chemical testing will be required during the remedial design phase to refine sediment area and volume estimates. PRPs will also have the option to perform additional biological tests (including the amphipod bioassay, juvenile bivalve larvae test, benthic infaunal analyses and/or bioaccumulation). These additional biological tests will be used to confirm and refine sediment volume estimates based on chemical test results.

<u>Use of AET Values in Sediment Management Decisions</u>--Both approaches utilize chemical AET values in sediment management decisions. Under PSDDA, the ML was defined as the highest AET generated from either the oyster larvae, Microtox, amphipod, or benthic community tests. For sediments having chemical concentrations that exceed ML concentrations, site-specific biological testing is not required, because the material is generally considered unacceptable for disposal at an unconfined, open water disposal site. Dredging proponents, however, have the option of performing biological testing to rebut this presumption.

In order to identify sediments that have very low toxicity potential, and that are acceptable for disposal, the PSDDA screening levels were established. In most instances, SLs were set at 10 percent of the ML concentrations. If sediment contaminant levels are below all SL concentrations, then site-specific biological testing is not required and sediments are considered acceptable for disposal.

The Commencement Bay N/T FS cleanup goals have been established as the lowest AET for a range of three indicators (amphipod, oyster larvae, benthic infauna), and a measure of bioaccumulation potential. As described above and in PTI (1988a), PRPs have the option of performing additional biological testing during the Remedial Design phase. In general, cleanup goals fall in between the SL and ML concentrations.

Decision-Making Guidelines--

In developing disposal guidelines, PSDDA considered seven possible site conditions representing the relative severity of potential onsite effects at the disposal site. Of these seven alternatives, three were evaluated in detail: Site Condition I, representing "no adverse effects due to sediment chemicals of concern;" Site Condition II, defined as "minor adverse effects;" and Site Condition III, defined as "moderate adverse effects." In laboratory terms, Site Condition I would allow "no significant sublethal, chronic toxicity" of any kind within the site. Site Condition II would allow "no significant acute toxicity" onsite. Site Condition III would allow "no severe acute toxicity" onsite.

Site Condition II was chosen as the preferred management condition for unconfined, open-water disposal at the central Puget Sound sites. Selection of Site Condition II was based on several factors: the relatively low concentrations of chemicals of concern, the selection of nondispersive sites, consistency with state water quality standards, cost-effectiveness, and consistency with Clean Water Act Section 404(b)(1) guidelines.

In contrast to the PSDDA approach, the equivalent of the Site Condition I has been selected as the preferred condition for the Commencement Bay N/T area. This decision was based on several factors: consistency with the PSWQA Management Plan and the development of sound-wide sediment quality goals, the critical nature of the shallow marine habitat in the Commencement Bay area, and the fact that the PSDDA program was designed to address long- and short-term problems associated with disposal of material from maintenance dredging whereas sediment remediation in Commencement Bay is designed to achieve long-term protection of public health and the environment.

2.4.2 Relationship Between the PSWQA Management Plan Elements and the Commencement Bay Superfund Project

One of the PSWQA program goals is to ". . . reduce and ultimately eliminate adverse effects on biological resources and humans from sediment contamination throughout the Sound by reducing or eliminating discharges of toxic contaminants and by capping, treating, or removing contaminated sediments . . . ." In order to achieve this goal, the 1989 PSWQA management plan sets up a comprehensive sediment quality program. The following plan requirements are of particular importance or relevance to the Commencement Bay Nearshore/Tideflats FS:

- Ecology must develop standards for classifying sediments that cause observable biological effects

- Ecology and local governments must expand efforts to assure that ambient sediment standards will not be violated and that sources of contaminants will be controlled

- Ecology must develop rules and sites for disposal of dredged material

- Ecology must develop guidelines for determining when existing sediments should be capped, excavated, or otherwise treated

- Ecology and U.S. EPA must expand the urban bay program to provide for additional source control and consideration of remedial actions for existing areas of high sediment contamination.

Criteria for Classifying Sediments Having Adverse Effects (Plan Element P-2)--

Under Plan Element P-2, Ecology is required to develop and promulgate sediment standards to identify and designate sediments that have ". . . acute or chronic adverse effects on biological resources or pose a significant health risk to humans . . . ." These standards are intended to be sound-wide sediment quality goals and serve as the basis for preventing future contamination problems. Specifically, the standards will be used to limit discharges through the NPDES and other source control programs, and to identify sites with sediment contamination. In relation to goals established for other programs, PSWQA (1989) noted that the standards for unconfined, open-water disposal will probably be less stringent than those to be developed under Element P-2 because PSDDA sites will be selected for minimal impact, the sites will be monitored, and the effects of any contaminated sediments will be mitigated by cleaner material also being disposed of at the open-water sites. With respect to decisions on contaminated sediment cleanup, PSWQA also noted that Ecology may determine it is not cost-effective to cap, treat, or remove all sediments that do not meet the Element P-2 standards, and that higher trigger levels may need to be developed under the remedial action guidelines.

In developing sediment cleanup goals for the Commencement Bay N/T site, the sound-wide sediment goal was determined to be appropriate for regulating ongoing discharges, preventing future contamination problems, and defining cleanup areas and volumes. However, as envisioned by PSWQA, this sound-wide goal may not be achievable in all areas under certain site-specific conditions. If, for example, it can be shown that application of all known, available, and reasonable technologies will not result in achievement of the sound-wide goal at a particular site, then the remedial strategies may need to be modified for that area.

Expand Programs to Reduce Contaminant Discharges from Industrial and Municipal Point Sources (Plan Elements P-6, 7, 8, 14, and 20)--

A major goal of the PSWQA management program is to expand efforts to reduce the amount of toxic pollutants released into Puget Sound by industrial and municipal dischargers. The overall approach for achieving this goal is 1) to require that all waste discharge permits include appropriate limitations on toxicants and other pollutants of concern, and 2) to devote substantially increased resources to the inspection and enforcement of waste discharge permits and the discovery and control of unpermitted discharges. Preferred remedial alternatives for this FS were identified on the assumption that such source controls would be implemented.

Develop Stormwater Management Programs (Plan Elements SW-1 through SW-4)--

The PSWQA Management Plan includes new initiatives to deal with stormwater runoff. Similar measures are required under Section 405 of the Clean Water Act Amendments of 1987. The major responsibilities for complying with these new requirements rests with Ecology and local governments.

Ecology is required to prepare a series of technical manuals and guidelines for local stormwater programs. In addition, the agency is required to issue permits for industrial storm drains (by February 1991) and municipal storm drains (by February 1993 for the Tacoma area). Local governments, in turn, are required to begin stormwater program development by December 1989, demonstrate substantial progress toward implementation by June 1991, file an NPDES permit application by February 1992, and comply with the permits by February 1996. The dates specified above are target dates and are subject to change.

In the Commencement Bay N/T site, storm drains have been identified as a significant source of contaminants in several waterways. The City of Tacoma, the Tacoma-Pierce County Health Department, and Ecology have developed an approach (Ecology 1986) for identifying and controlling sources of contaminants to several storm drain systems. The continued implementation and expansion of this program to fulfill statutory requirements will be a critical ingredient in correcting sediment quality problems in the project area.

Develop Confined Disposal Standards for Sediments (Plan Element S-4)--

Under Plan Element S-4, Ecology is required to develop and adopt standards for reuse or disposal of dredged material containing concentrations of contaminants that exceed those that are acceptable for disposal at PSDDA sites. The standards will protect aquatic and terrestrial organisms, including humans, from potential harm caused by contact with contaminated sediments. The standards will be used by Ecology, shoreline jurisdictions, and local health departments to evaluate permits for the use or disposal of contaminated dredged material. The target date for adoption of the final standards is July 1990.

The standards developed under Plan Element S-4 were not available for use within the Commencement Bay N/T FS. However, the recommended remedial alternatives are consistent with CERCLA/SARA guidance by providing cleanup "which assures protection of human health and the environment." The approach also appears to be consistent with PSWQA's intent. Remedial alternatives for the disposal of contaminated sediments from each problem area were evaluated according to several criteria, including protectiveness. The recommended alternative for each area ensures a high level of protection for environmental and human health. Long-term monitoring programs are included within each remedial alternative to confirm the containment of disposed sediment.

Develop Remedial Action Guidelines (Plan Element S-7)--

Under Plan Element S-7, Ecology is required to develop and adopt guidelines for deciding when sediments that cause adverse effects should be capped, excavated, or otherwise treated. In developing these guidelines, PSWQA directed Ecology to consider natural recovery process, develop a priority system, and identify trigger levels for identifying sediments requiring expedited remedial action. PSWQA also provided some guidance on the relationship between the sediment remedial action guidelines and the sound-wide sediment criteria by noting that ". . . Ecology may determine that it is not cost-effective to cap, treat, or remove all sediments in urban bays that exceed the [sound-wide criteria] but may set higher (more contaminated) trigger levels that would result in remedial actions . . . ."

Although these guidelines are not scheduled for completion until 1991, the approach used in Commencement Bay N/T FS appears to be consistent with

PSWQA's intent. First, the failure to meet the long-term sediment cleanup goal in one or more areas has not automatically triggered proposals for sediment remedial action. Instead, areas within the Commencement Bay N/T project area were prioritized with respect to contaminant concentrations, spatial extent of contamination, and confidence of source identification. As discussed in Section 2.3.4, only the more highly contaminated areas were considered for sediment remedial action. Although specific numerical contamination levels were not established for defining which problem areas were to be evaluated for sediment cleanup, the approach taken in defining problem areas for remediation is consistent with the concept of a trigger level for remedial action. In other less contaminated areas, source control actions would be needed to ensure that these lower priority areas would recover via natural processes within an acceptable timeframe.

Second, in evaluating sediment cleanup alternatives, the impact of source control and natural sediment recovery processes were evaluated. As reflected in Chapters 5-13 no additional sediment remediation is recommended in those areas where source control and natural processes were sufficient to correct problems in a reasonable timeframe.

2.4.3 Relationship Between PSEP and the Commencement Bay Superfund Project

The U.S. EPA Region X and Ecology, in cooperation with many other agencies, have developed the Puget Sound Estuary Program. This is a coordinated program designed to develop management information for Puget Sound and to correct identified problems. PSEP tasks and studies that are of particular importance to the Commencement Bay project include development of sediment quality goals, and development of and support for the Urban Bay Action Team approach.

Development of Sediment Quality Goals--

The PSEP has an ongoing project to develop sediment quality values for use in Puget Sound. Phase I of the project was conducted in conjunction with PSDDA. The following were three major objectives of Phase I:

- Compile and review existing chemical and biological data from Puget Sound in order to identify statistical relationships between sediment contaminant concentrations and empirically determined biological effects

- Evaluate possible techniques for identifying numerical values of chemical concentrations in sediments that are correlated to biological effects

- Evaluate the appropriateness of using sediment quality values in various regulatory applications.

The final report, titled "Development of Sediment Quality Values for Puget Sound," (Tetra Tech 1986a) was completed in September 1986.

The work performed during the Commencement Bay N/T RI laid much of the foundation for the Phase I report. The expanded database, sediment quality values, and additional evaluations included in the Phase I report were then used in formulating long-term sediment cleanup goals for the FS.

Phase II of this effort was initiated in September 1987. Its primary objective is to further test the reliability of the AET values. A final study report was completed in September 1988 (PTI 1988c).

Urban Bays Toxics Control Program (Plan Element S-8)--

U.S. EPA and Ecology joined with other agencies and organizations in 1985 to develop and implement the Urban Bays Toxics Control Program. This program is designed to identify known and suspected pollutant sources, outline procedures to eliminate existing problems, and identify agencies responsible for implementing corrective actions. The Urban Bays Toxics Control Program was incorporated into the 1987 and 1989 PSWQA management plans.

The primary responsibility for initiating and enforcing corrective actions rests with the "action teams" led by Ecology. Other state and local agencies also play key roles. The action team for a particular urban bay area works to control or eliminate sources of toxic contaminants, utilizing permitting mechanisms, enforcement orders, consent orders or decrees, or court action. As sources of contaminants are controlled, attention is given to possible remedial alternatives for areas that have contaminated sediments.

The Commencement Bay Action Team was formed in the fall of 1985. Of the four members of the team, two work on contaminated sites and two work on storm drains and permitted industries. In addition, existing hazardous waste, solid waste, and water quality staff from Ecology and U.S. EPA are used on specific projects. As of September 1987, the team had conducted 134 site inspections; assessed 7 penalties amounting to $94,000; issued 6 administrative orders; negotiated 1 memorandum of agreement, 7 consent orders, and 2 consent decrees; and initiated permit actions at 9 sites (Ecology 1987).

Many of the sites handled by the action team were identified as high priority sites in the RI report (Tetra Tech 1985a), and regulatory actions have resulted in the collection of additional data that have been incorporated into the FS evaluations. Specific regulatory actions have been included in the Integrated Action Plan (PTI 1988a). The action team will have a major role in implementing the final Integrated Action Plan.

2.5 ROUTINE DREDGING WITHIN COMMENCEMENT BAY

The Port of Tacoma is an active shipping center that receives ships from all over the world. Total waterborne commerce through the Tacoma harbor area has increased from 7.9 million short tons in 1975 to 15.8 short tons in 1985. The Port of Tacoma projects that similar increases will occur in the next 10 to 15 yr.

Getting cargo on and off ships requires modern dock facilities with adequate water depth. Construction of docks and maintenance of navigational channels requires existing sediments to be excavated. Between 1970 and 1985, 2.95 million yd^3 of material were dredged from Commencement Bay and the immediate vicinity. PSDDA estimates that over 3.9 million yd^3 material will be dredged from the Commencement Bay area during the next 15 yr.

When properly performed, these routine dredging activities will also produce significant cleanup benefits by removing contaminated sediments. Routine dredging within Commencement Bay thus represents an integral part of the overall cleanup strategy.

During the last several years, the prospect of future Superfund cleanup activities has inhibited the planning and implementation of routine dredging projects. A major concern has been uncertainty regarding additional regulatory requirements that apply to routine dredging projects in Commencement Bay because it is a Superfund site.

The regulatory requirements and procedures for routine dredging projects in Commencement Bay are discussed below. This discussion is divided into three sections. First, the general regulatory requirements and procedures for projects in Puget Sound are described in Section 2.5.1. These procedures will be used for projects in the low priority Superfund areas of Commencement Bay. These areas include Blair Waterway, Milwaukee Waterway, the Puyallup River, and portions of the Ruston-Pt. Defiance Shoreline. In Section 2.5.2, the procedures for projects within the nine high priority areas are described. These involve the same basic procedures and requirements as those for the rest of Puget Sound, with several modifications to address Superfund program concerns regarding the dilution of highly contaminated sediments and the potential for increasing exposure to contaminated sediments. In Section 2.5.3, the relationship between routine dredging and sediment cleanup actions is summarized.

2.5.1 Regulatory Requirements for Routine Dredging Projects in Puget Sound

In Puget Sound, the excavation and disposal of sediments are regulated under a number of local, state, and federal laws and regulations. At the federal level, the Clean Water Act and the Rivers and Harbors Act of 1899 have several sections that control the dredging and disposal of sediments. Section 404(a) of the former requires a federal permit for the discharge of dredged or fill material into navigable waters. Guidelines for issuing permits for discharges of dredged or fill material are specified in Parts 320 to 330 of Title 33 of the Code of Federal Regulations. This requirement is administered by the U.S. Army Corps of Engineers. A permit is also required under the Rivers and Harbors Act of 1899 for the "construction of structures or the excavation or filling or other alteration or modification of the bed or channel of the navigable waters of the U.S." In practice, these two permit requirements are combined in the U.S. Army Corps of Engineers permit process.

Under Clean Water Act Section 404(c), U.S. EPA can prohibit or withdraw a permit upon determining that the discharge of dredged material will have an unacceptable adverse effect. In addition to U.S. EPA concurrence on the U.S. Army Corps permit, the state must issue a water quality certification for any project (e.g., dredging and dredged material disposal) that may cause the violation of a state water quality standard. This certification is granted or denied by Ecology. Details of the state's water quality standards are found in WAC 173-201.

In administering these programs in central Puget Sound (including the Commencement Bay area), the U.S. Army Corps of Engineers, U.S. EPA, and Ecology utilize the testing and decision-making guidelines developed by PSDDA. In 1988, PSDDA issued a Management Report and an Environmental Impact Statement specifying procedures and criteria for evaluation of dredged material and recommended locations and management procedures for unconfined, open-water dredged material disposal sites in central Puget Sound.

The PSDDA evaluation procedures include detailed guidelines for sediment sampling, analysis, and data interpretation. Under these guidelines, dredgers are required to collect sediment samples from the proposed dredging area and perform a series of chemical and biological analyses. Based on these data, the agencies determine whether the dredged material can be disposed of at an unconfined, open-water disposal site.

Under the proposed Commencement Bay N/T cleanup strategy, projects in the low priority Superfund areas would continue to be regulated under these existing procedures and those developed to implement the Element S-4 tasks of the PSWQA Management Plan. Key sampling and analysis requirements are described in Phillips et al. (1988). Under those guidelines, a dredger is required to estimate the volume of sediment for a project and the number of "dredged material management units." A "dredged material management unit" is defined as the smallest volume of dredged material for which a separate disposal decision can be made. The size of a dredge management unit is based on a consideration of dredge cut depth and potential for chemical contamination.

In Commencement Bay, there is a relatively high level of concern with respect to chemical contamination. Consequently, dredgers are usually required by PSDDA to collect one sediment sample for every 4,000 yd^3 of surface sediments (0-4 ft cut depth) and subsurface sediments (defined as deeper than 4 ft). Once the samples are collected, dredgers are required to analyze all of the surface sediments. Subsurface samples are composited to provide an analytical intensity of 1 sample analysis per 12,000 yd^3.

Based on these test results, a determination is made on 1) whether the dredged material can be disposed of at a PSDDA site and 2) the restrictions (if any) on various dredging and disposal activities. In general, sediments predicted to result in "no significant acute toxicity" or "minor adverse effects on biological resources due to sediment chemicals" at the disposal site are considered suitable for unconfined, open-water disposal. PSDDA defines this level as "Site Condition II." The test interpretation guidelines used to make project-specific disposal decisions are shown in Table 2-7.

TABLE 2-7. BIOLOGICAL DISPOSAL GUIDELINES FOR ALTERNATIVE SITE MANAGEMENT CONDITIONS[a]

Site Condition I	"No sublethal or acute toxicity" is defined as: no one acute sediment toxicity bioassay[b] exhibiting a statistically significant ($P<0.05$) response over reference conditions and exceeding 20 percent absolute mortality over control; water column larval response does not exceed 0.01 of the LC50 after 4 h of mixing; and no bioaccumulation levels exceeding a human health tissue guideline value.
Site Condition II	No "significant acute toxicity" is defined as: no two acute sediment toxicity bioassays exhibiting the above conditions; and no one acute sediment toxicity bioassay response greater than or equal to 30 percent[c] over reference conditions and statistically significant with respect to reference conditions; water column larval response does not exceed 0.01 of the LC50 after 4 h of mixing; and no bioaccumulation levels exceeding a human health tissue guideline value.
Site Condition III	No "severe acute toxicity" is defined as: no two acute sediment toxicity bioassay responses greater than or equal to 30 percent[c] over reference and statistically significant with respect to reference conditions; no more than one acute sediment toxicity bioassay response greater than or equal to 70 percent over reference and statistically significant with respect to reference conditions; water column larval response does not exceed 0.01 of the LC50 after 4 h of mixing; and no bioaccumulation levels exceeding human health tissue guideline value.

[a] From Phillips et al. (1988).

[b] Biological tests that are used in the disposal guidelines are discussed in Section II-6.

[c] Greater than 30 percent (absolute) over reference: e.g., if reference mortality is 12 percent, test mortality cannot exceed 42 percent.

2.5.2 Regulatory Requirements for Routine Dredging Projects in the High Priority Areas of Commencement Bay

Under the proposed Commencement Bay N/T cleanup strategy, routine dredging projects within the nine high priority Superfund areas would continue to be handled under the same regulatory process as projects in low priority areas. Under the proposal, dredgers will need to obtain all necessary permits and approvals from federal, state and local agencies. In order to obtain the necessary permits and approvals, dredgers will be required to satisfy the basic PSDDA testing and analysis requirements with two modifications. These proposed modifications, which will minimize inconsistencies between dredging projects and Superfund cleanup actions, are described below.

Sediment Sampling and Analysis Requirements--

When conducting routine dredging in the high priority Superfund areas, dredgers will be required to sample and analyze the top 1 ft and the next 3 ft of sediment. This modification will minimize the potential for diluting highly contaminated surface with less contaminated underlying sediments. Results for the top 1 ft would be evaluated separately from those for the next 3 ft, using the PSDDA decision-making guidelines.

This modification is necessitated by the fact that the PSDDA sediment sampling and analysis approach is based on the intentional presumption that sediments would be acceptable (thus the sampling requirements allow for use of routine dredging equipment, which has a vertical precision of ±2 ft). In contaminated areas such as parts of Commencement Bay, the PSDDA approach may obscure the Superfund cleanup effort by "diluting" or mixing the problem sediments with cleaner subsurface sediments. PSDDA acknowledged the potential for this to occur and noted that a 1-ft cut depth and the use of special dredging equipment may be more cost-effective (because a smaller volume of material would be subject to confined disposal requirements) and should be considered in cleanup areas.

Exposed Surface Guidelines--

When conducting routine dredging within a high priority Superfund area, the dredger will be required to sample and analyze the top 1 ft of the newly exposed surface. If the test results demonstrate that the exposed surface contaminant concentrations exceed those in the original surface material, the dredger will be required to undertake additional measures to assure that the exposed surface will have the same concentration as the original surface or the PSDDA Maximum Level concentration, whichever is lower.

2.5.3 Relationship Between Routine Dredging and Sediment Cleanup Actions

During the development of the FS, several interested parties expressed concerns over the relationship between routine dredging projects and sediment cleanup actions in high priority areas. Of particular concern was whether the Superfund program would require PRPs to remediate sediments that are acceptable for disposal at a PSDDA site. These concerns are based in part on the fact that the long-term sediment cleanup goal in Commencement Bay is more stringent than the PSDDA guidelines. Consequently, a portion of the sediments within the Commencement Bay areas of concern are predicted to be acceptable for disposal at a PSDDA site.

As a general policy, the Superfund program does not intend to require PRPs to remediate sediments that could be taken to a PSDDA site. However, because of the differences in exposure potential for Commencement Bay and the PSDDA sites, there may be situations where PRPs will be required to undertake sediment cleanup actions for sediments that pass the PSDDA guidelines. Examples of such situations include the following: elevated concentrations of PCBs or other contaminants that have a high potential for bioaccumulation in a nearshore area, but demonstrate relatively low toxicity in laboratory tests; elevated concentrations of contaminants that are highly toxic to benthic communities but exhibit relatively low toxicity in laboratory tests; highly contaminated surface sediments with relatively clean underlying sediments; and elevated contaminant concentrations with low sedimentation rates. Based on available sediment data, it does not appear that problem sediments requiring remediation will pass the PSDDA guidelines. If they do pass, dredged material removed as a result of a Superfund enforcement action will need to be taken to a non-PSDDA site.

2.5.4 Conclusions

Under the proposed approach, routine dredging projects will continue to be regulated under existing federal and state regulatory programs. The primary basis for decisions on the disposal of dredged material will be the PSDDA and Element S-4 procedures. However, for dredging projects within the nine Commencement Bay problem areas, the PSDDA procedures would be modified to incorporate a more precise sampling and analysis program. This modified approach would require dredgers to separately sample and analyze sediments from the top 1 ft and next 3 ft of sediment. These procedures will reduce the potential for diluting the higher contamination levels present in the surface sediments with underlying sediments containing low concentrations. In addition, the top 1 ft of the eventual exposed surface (below the overdepth) should be routinely analyzed. If the surface to be exposed exceeds the contamination of the original surface, the dredger should undertake additional measures to assure that the exposed surface will have the same concentration as the original surface or the PSDDA maximum level, which ever is lower.

Sediment cleanup actions will be handled under federal and state Superfund programs. Potentially responsible parties will be required to perform additional sediment testing to refine estimates of sediment volumes and then perform sediment cleanup. Specific actions will, at a minimum, comply with the PSDDA guidelines and Element S-4 requirements. In general, Superfund cleanup actions will not be required for sediments which are found to be acceptable for disposal at a PSDDA site. These cleanup actions will be coordinated with routine dredging projects to ensure cost-effective cleanup solutions.

3.0 REMEDIAL TECHNOLOGIES FOR DEVELOPMENT OF AREA-WIDE SEDIMENT REMEDIAL ALTERNATIVES

Technologies that are potentially applicable to the remediation of contaminated media in the Commencement Bay N/T study area are evaluated in this section. The results of this evaluation are used to select remedial alternatives which are composed of institutional controls and remedial technologies applicable to the cleanup of a contaminated site. Remedial technologies are described in detail in the beginning of this section. Sediment remedial alternatives are presented in the latter parts of the section.

During the evaluation of remedial technologies, both source control and sediment remedial technologies are evaluated, as control of contaminant sources is an essential element of the overall approach to cleanup of problem sediments. The purpose of the evaluation is to screen or eliminate from further consideration technologies that are inappropriate based on technical implementability, given the nature and extent of contamination and physical characteristics at the site. Approaches to remediation fall into six general categories: no action, institutional controls, containment, removal, treatment, and disposal.

Consideration of no action is required by the NCP and provides a baseline from which to evaluate the effects of responses that directly address the cleanup or isolation of contaminated materials. Under the no-action approach, potential contaminant sources would be subject only to the regulatory controls that would have been initiated in the absence of the RI/FS process (e.g., conventional NPDES permitting procedures). Institutional controls involve limiting the potential for public exposure to site contaminants by such means as educational programs and site access restrictions. Under the institutional controls approach, contaminant sources would be subject to regulatory controls addressing identified sediment contamination problems that, while allowable under existing effluent permitting and waste management programs, would not have been implemented in the absence of the RI/FS (e.g., prohibitions in new or modified NPDES permits against discharge of problem chemicals found in the sediments). In the case of the Commencement Bay N/T area, the institutional controls response action involves no cleanup of contaminated sediments.

The remaining approaches all involve aggressive contaminated sediment control as a key element. Containment response actions involve in situ sediment capping or lateral barriers to isolate contaminants from the environment or to preclude the introduction of additional contamination into sensitive areas. Removal response actions include dredging of contaminated sediments prior to disposal or treatment and disposal. Treatment of contaminated media is an element of response actions intended to significantly reduce contaminant concentrations, mobility, and toxicity, and may be applied either in situ or following removal operations. Disposal of sediments or treatment by-products is the final general category of response. The containment, removal, treatment, and disposal approaches also incorporate aggressive source control regulatory activities specifically oriented toward the sediment remediation and subsequent maintenance of long-term sediment quality in the Commencement Bay N/T study area.

Response actions may be used alone or in concert with one another. Each general response action may comprise one or more technology type. For example, treatment responses can involve physical, chemical, or biological technologies. In addition, each technology type may represent one or more specific process options.

Sediment remedial technologies are evaluated in Section 3.1 and potential source remedial technologies are evaluated in Section 3.2. Emphasis, however, is placed on the former. The goal of the evaluation is to select applicable technology types and representative process options suitable for the development of sediment remedial alternatives for the Commencement Bay N/T site.

Area-wide remedial alternatives are presented for Commencement Bay sediments that exceed target cleanup goal concentrations. The development of alternatives is conducted in two steps. The first step is creation of generic alternatives based on viable general response actions (Section 3.3). The second step is creation of specific alternatives from the technology types and process options that are most applicable to sediment remediation in the Commencement Bay N/T study area (Section 3.4). According to the intent of draft CERCLA/SARA guidance, the objective of a feasibility study is to obtain a set of remedial alternatives representing all technology types considered suitable for evaluation.

3.1 GENERAL RESPONSE ACTIONS FOR SEDIMENTS

Potential sediment remedial technologies and associated general response actions are presented in Figure 3-1. Capping is the only technology type considered for in situ containment of contaminated sediments. Although dredging is essentially the only technology for removal of sediments, several categories of dredging are discussed. The treatment response action is divided into two categories: in situ and post-removal treatment. Disposal technologies, implemented post-removal, are categorized as either confined or unconfined.

3.1.1 No Action

The no action alternative provides a baseline against which other sediment remedial alternatives can be compared. Under this alternative, the problem area remains unchanged, and nothing is done to mitigate public health and environmental risks. No source control measures are implemented under this alternative beyond those required under existing regulatory programs. Adverse biological and potential public health impacts continue at preremediation levels.

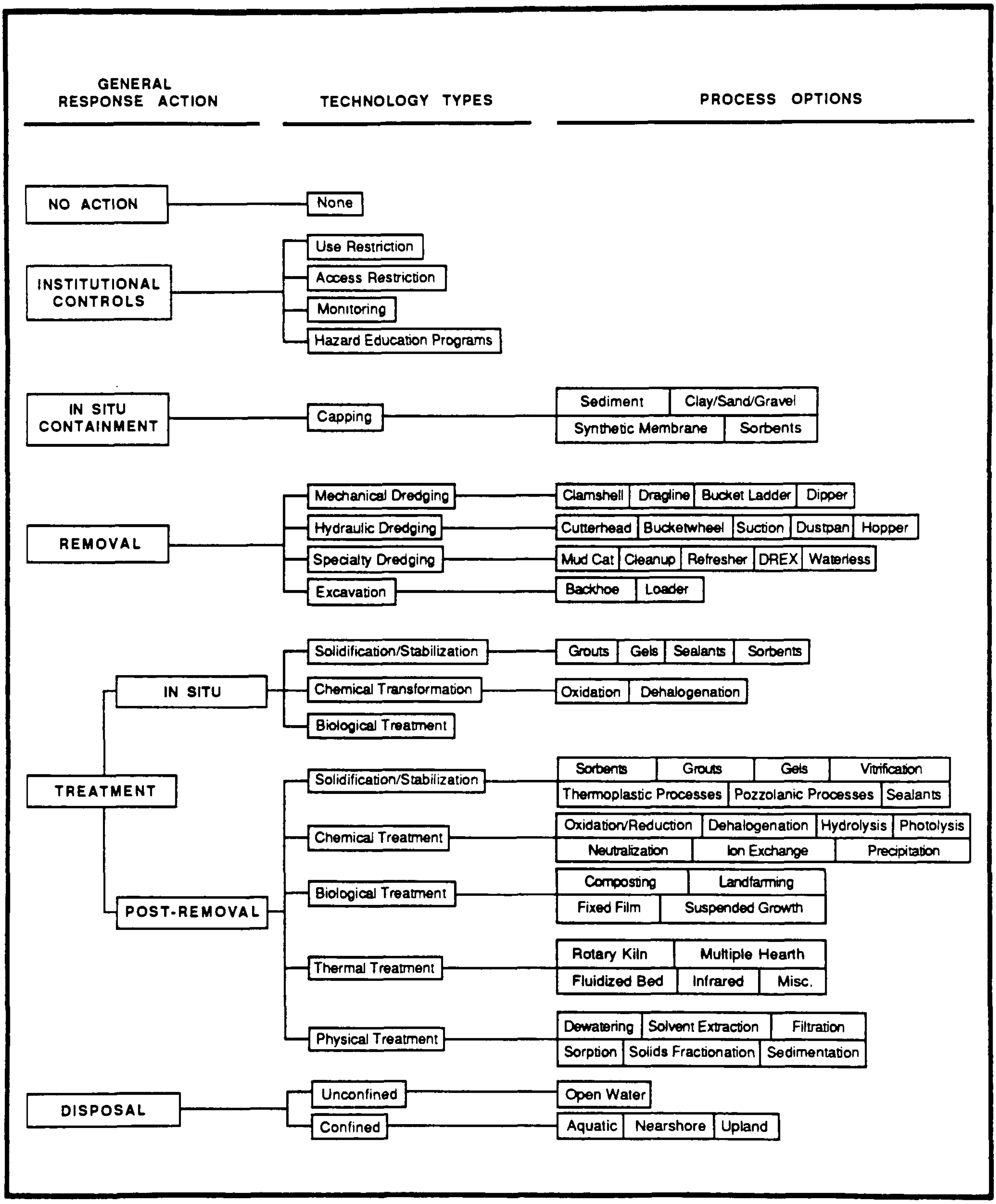


Figure 3-1. Response action, technology types, and process options for remediation of contaminated sediments.

3.1.2 Institutional Controls

Institutional controls involve nonstructural practices to reduce public contact and possible health effects associated with contact with contaminated materials. Institutional controls include use and access restrictions such as identification and posting of "no fishing" areas. Hazard education and public awareness programs can also be used as methods of institutional control. Programs of this type have been shown to be quite successful, as discussed in Section 3.2.2. Monitoring programs to identify trends of contamination and improve the general understanding of the problem can also be included in a broad definition of institutional controls.

3.1.3 In Situ Containment

In situ sediment containment strategies such as capping are designed to isolate contaminated sediments without removing them. Typically, clean fill material suitable for recolonization by benthic organisms is used to cover a contaminated sediment zone. The cap is thick enough to preclude significant contaminant migration by physical processes and bioturbation. Split-hulled barges and hydraulic conveyance systems for slurried dredged material have been used for in situ capping of sediments. This equipment was originally developed for dredging operations involving unconfined aquatic disposal of dredge spoils. Specialized equipment for placement of capping materials with minimum turbidity (e.g., diffusers) has been developed (U.S. Army Corps of Engineers 1986b). Descriptions of capping strategies, their effectiveness, implementation considerations, and examples of field applications are presented in Appendix B.

Capping is retained as an appropriate remedial measure for contaminated sediments in Commencement Bay, except where periodic dredging is required to maintain channel depths or where the geomorphic surface is unstable because of slumping or erosion. Potentially applicable capping options include the use of uncontaminated dredge spoils, the use of clean fill from terrestrial sources, and the use of low permeability additives in the capping material. Such additives either react with or hydraulically isolate the sediments of concern and further reduce the potential for contaminant migration.

3.1.4 Removal

A wide range of dredging technologies has been developed to address different aspects of sediment removal. The following discussion summarizes the findings of the U.S. Army Corps of Engineers report entitled Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments (Phillips et al. 1985), and integrates other pertinent literature.

Mechanical Dredges--

Mechanical dredges remove materials through the direct application of mechanical force to dislodge and excavate bottom sediments. Types of mechanical dredges include clamshell, dragline, bucket ladder, and dipper dredges. Descriptions of these dredges are presented in Appendix B. The clamshell dredge is considered the only mechanical dredge suitable for removal of contaminated sediments (Phillips et al. 1985); resuspension and loss of sediment due to mechanical disturbance is unacceptable with the others.

Clamshell dredges are usually mounted on a barge and are available in bucket capacities of 1 to 18 yd^3. Production rates exceeding 600 yd^3/h are possible with the large buckets. Dredged material is transferred to a separate barge for transport to a treatment area or disposal site. Depending on the production rate and the distance from the dredge site to the treatment or disposal site, the use of two barges could permit nearly continuous operations.

Clamshell dredges are capable of removing sediments at depths of greater than 100 ft, which makes it a feasible dredging technique for all problem areas in Commencement Bay. Depending on operator experience, depth accuracies of 1-2 ft can usually be achieved. The equipment is highly maneuverable and can operate effectively in confined areas or in debris-laden sediments. A significant advantage of clamshell equipment is its ability to maintain nearly in situ sediment densities. This feature results in fewer dredge water management problems compared to hydraulic dredging (see below) and, generally, less handling of material.

Conventional clamshell dredging resuspends approximately 2 percent of the total sediment mass dredged (Tavolaro 1984), which is cause for concern when the sediments are contaminated. The resuspended material is distributed throughout the water column. A watertight clamshell concentrates resuspended material near the sediment-water interface. However, watertight clamshells produce dredged material with a significantly higher percentage of water than conventional clamshells, which may increase the need for management of contaminated dredge water.

Because the percentage of sediment resuspended by clamshell dredging is only 2 percent or less, and since the majority of the contaminants in Commencement Bay sediments are particle-bound, solubilization of contaminants into the water column is not expected to be significant. Aside from the obvious visual impacts associated with sediment resuspension, actual environmental impacts must be evaluated on a case-by-case basis to determine the degree to which sediment contaminants are released into the water column. Operational steps that can be taken to reduce the extent of sediment resuspension include controlling the drop speed, hoist speed, and swing of the bucket; preventing the bucket from dragging along the bottom; and preventing barge overflow. Additional measures such as cofferdams and silt curtains may be necessary, however, to contain resuspended sediment around the dredging area.

Cofferdams are installed when hydraulic isolation of an area of contaminated sediment is desired. Typically, the use of cofferdams is limited to locations with shallow water depths (typically under 10 ft). For this reason, Wheeler-Osgood Waterway may be the only problem area where use of a cofferdam is feasible. This waterway is relatively inactive and much of it is intertidal. Conversely, most waterways in Commencement Bay are at least 25 ft deep with active shipping traffic.

Silt curtains installed around the dredging site will trap suspended solids and debris generated during dredging. Silt curtains are usually constructed of nylon-reinforced polyvinylchloride membranes in 90-ft sections. The sections are joined together at the site to provide the desired length. Silt curtains can be installed in several configurations, depending on site-specific needs. Circular configurations would most likely be necessary in Commencement Bay because the tidal influence reverses flow in the waterways. Silt curtains normally do not extend below the surface by more than 4-5 ft, but theoretically could be extended to greater depths. Silt curtain effectiveness is considered questionable (Malek, J., 17 December 1987, personal communication) but should be evaluated further as a turbidity control measure.

Both conventional and watertight bucket clamshell dredging are readily implementable technologies and are retained for further evaluation for the removal of contaminated Commencement Bay N/T sediments.

Hydraulic Dredges--

Hydraulic dredges are barge-mounted systems that employ diesel- or electric-powered centrifugal pumps to remove and transport sediments in a liquid slurry. The dredges may either be self-propelled or require towing between dredging sites. Hydraulic dredges evaluated include the bucket-wheel, suction, cutterhead, dustpan, and hopper models. Descriptions of these dredges are presented in Appendix B.

Hydraulically dredged sediments are removed by suction. In all but the most unconsolidated materials, suction must be preceded by some mechanical action to dislodge the sediments. A suction head is mounted on an adjustable ladder to facilitate depth control during the dredging operation. Hydraulic dredge capacities are generally classified according to the diameter of the discharge line: small dredges have 4- to 14-in diameter discharge lines, medium dredges have 16- to 22-in diameter discharge lines, and large dredges have 24- to 36-in diameter discharge lines. Production rates range from 70 to 1,875 yd^3/h. Single-pass excavation depths range from 18 to 36 in.

Sediment slurries are pumped into bins or hoppers on the dredges, into barges tethered alongside of the dredge, or through floating or pontoon-supported discharge lines (pipelines) to a disposal or treatment site (Phillips et al. 1985). For transport distances exceeding 2 mi, booster pumps may be required. Other conditions (e.g., coarse sediments, small dredges) may also necessitate the use of booster pumps.

Because sediment disturbance is confined to the bottom and because the dredged material travels through the water column within an enclosed pipeline, hydraulic dredging methods usually generate less turbidity at the dredging site than mechanical methods. The degree of resuspension varies with the type of hydraulic dredge, operational controls, and sediment characteristics. The pipeline cutterhead dredge is reported to resuspend approximately 1 percent of the dredged sediment mass (Hayes 1985). Specialized head adaptations are available to reduce resuspension of solids (see following discussion). Improved operational controls can be implemented to further reduce resuspension. Unlike mechanical dredges, hydraulic dredges cannot remove large objects and debris (e.g., drums and scrap metal) from waterways. Hydraulic dredges are typically more accurate than mechanical dredges, with accuracies on the order of ±0.5 ft.

Hydraulic dredges produce slurries of 10-20 percent solids by weight. Nearshore or upland disposal of this material will require removal of solids from the dredge water (e.g., by sedimentation) and possibly additional treatment of that water. The need to remove additional suspended solids or soluble contaminants must be assessed on a case-by-case basis.

The hydraulic dredges listed previously are not all appropriate for the Commencement Bay N/T project. Only the cutterhead is retained for further evaluation. The dustpan dredge is eliminated because it is most effective for the removal of free-flowing granular sediments such as sand and gravel in rivers, and tends to generate excess turbidity. Hopper dredges are eliminated from further consideration because they cannot dredge sediments from around piers, docks, or other structures--areas where some of the highest concentrations of problem chemicals were observed in Commencement Bay. Also, hopper dredges are not appropriate for the removal of contaminated sediments: the economically preferable mode of operation involves overflow of the hopper, which would generate excessive suspended solids. Likewise, the bucketwheel and suction dredges have been eliminated, as discussed in Appendix B.

Specialized Design Dredges--

Variations of conventional hydraulic dredges have been developed during the last few years in Japan, Europe, and the U.S. These variations have been driven by the need for special applications, improved performance, mitigation of negative environmental impacts, and economic advantages. There are many specialized dredges on the market, in various stages of development, that pump high solids, produce low turbidity, or both. Specialized dredges include portable dredges (e.g., mud cat, mini dredge, dragon) and specialized head adaptations (e.g., DREX, cleanup, refresher, and waterless). Some models, such as the mud cat, have the characteristics of being portable and using a special head adaption. Descriptions of the mud cat and the specialized dredging heads are presented in Appendix B.

The availability of a specialized dredge depends primarily on whether it is a foreign or domestic technology. If a specialized design is not marketed domestically, its use may require a specific international, government, or private agreement (Phillips et al. 1985). Production may be restricted to a small number of units because of the limited application of some designs. Availability of these specialized units is likely to be unfavorable if the demand exceeds the current supply. Additionally, new and emerging designs may be limited to a few test models. These factors influence the availability of a special design and dictate the initial and mobilization costs. However, technologies with limited availability should not be rejected on the basis of initial costs alone, since the overall economic feasibility is determined by analysis of all costs, including operation and maintenance of all equipment; transportation, treatment, and disposal of dredged material; labor; and other project-related expenses. Specialized dredges may prove to be economically competitive with conventional methods as the initial costs are amortized.

As an example of this type of dredge, the mud cat is retained for further evaluation of its specific application to shallow-water sites. The availability of the cleanup and refresher dredging heads (designed by Japanese firms) and the waterless dredge (designed by the American firm Waterless Dredge Company) should be reevaluated prior to scheduled dredging. Limited availability of these dredging heads may result in higher mobilization and initial costs. Limited availability must be weighed against the advantages in reduced sediment resuspension and maximized solids content of dredged material.

Excavation--

Operating principles of backhoes and loaders are summarized in Appendix B. Backhoes and loaders have limited application to the removal of submerged contaminated sediments primarily because they generate substantial amounts of suspended solids. This equipment may be useful for onshore dredged material management but is not retained for further consideration for sediment removal.

3.1.5 Treatment

In Situ Treatment--

Technologies potentially applicable to the in situ treatment of sediments may be grouped into the following categories:

- Stabilization/solidification
- Chemical
- Biological.

Thermal and physical treatment technologies are not applicable to the in situ treatment of contaminated sediments because they cannot be performed in place for submerged sediments.

Stabilization and solidification technologies, which are detailed below for possible application in the treatment of contaminated dredged material, are unproven for in situ remediation of contaminated sediments underwater. Sediments have been solidified to improve bearing capacity (Otsuki and Shima 1984), but the applicability of this technology to in situ contaminant immobilization is relatively unexplored (Francingues 1985). It is possible that an innovative solidification process could be developed for use in conjunction with capping to substantially cut off dispersive pathways of contaminant migration (e.g., via diffusion, bioturbation, or erosion processes). Therefore, solidification is retained as an innovative technology within the context of in situ containment via capping.

Successful in situ chemical treatment of contaminated sediments has not been documented. However, chemical treatment options have been studied for in situ treatment applications. During initial screening of remedial technologies for PCB-contaminated sediments in the upper Hudson River, ultraviolet ozonation and chemical treatment (e.g., dechlorination) were considered, but rejected as unproven (NUS 1983). Dechlorination involving reaction of potassium hydroxide and polyethylene glycols was fully evaluated both for remnant sediments exposed when the river level dropped and for dredged material. Reagents would need to be rototilled into the exposed sediments and several applications might be necessary. This procedure would have limited in situ application even with hydraulic isolation because of the possible length of time required to reduce PCB levels adequately.

For submerged sediments, implementation of a chemical treatment process is complicated by the presence of overlying water. In addition, sediments contaminated with a complex set of pollutants would probably require more than one treatment step, and the production of undesirable by-products would be a distinct possibility. This is particularly relevant for the Commencement Bay study area, where sediments are frequently contaminated with a variety of organic and inorganic constituents. From the standpoint of implementability, in situ chemical treatment of contaminated sediments is impractical and is not retained for further evaluation.

No reports of enhanced in situ biological treatment of contaminated sediments were found. For this reason, in situ bioreclamation is not retained for further evaluation.

Post-Removal Treatment--

Technologies potentially applicable to the treatment of dredged sediments are considered in this section. Post-removal treatment represents an intermediate step between removal and disposal, and is intended to reduce contaminant concentrations, mobility, or toxicity. Treatment technologies discussed in this section fall within the following categories:

- Solidification/stabilization
- Chemical
- Biological
- Thermal
- Physical.

Post-removal management of sediments prior to disposal may require treatment of the sediment slurry as a whole, treatment of dewatered sediment solids, or treatment of the water removed from the sediment slurry.

Solidification/Stabilization--Stabilization and solidification are designed to improved waste handling characteristics, reduce contaminant mobility, or alter the solubility or toxicity of waste constituents (U.S. EPA 1986a). Specifically, stabilization involves the addition of materials to reduce contaminant mobility in solid waste, primarily by removing free water through hydration reactions. Handling characteristics are generally improved by stabilization processes. Solidification processes result in the consolidation of a solid waste into much greater aggregate sizes, sometimes resulting in a monolithic block, which possess significantly greater structural integrity. Solidification and stabilization are effective in reducing the mobility or leaching potential of contaminants that have a strong tendency to migrate from the original media with which they are associated. As a result of insoluble hydroxide formation, metals are particularly well suited to immobilization in cement or pozzolanic (cement-like) systems. Particle-associated organic contaminants are restricted from leaching through physical encapsulation, but little evidence is available on the leaching potential of specific organic contaminants from solidified or stabilized wastes (U.S. Army Corps of Engineers 1986a).

Stabilization and solidification are not mutually exclusive treatment approaches, and several techniques utilize characteristics of both. The main categories of stabilization and solidification technologies are as follows:

- Sorption
- Lime-fly ash pozzolan processes
- Pozzolan-Portland cement processes
- Thermoplastic microencapsulation
- Vitrification.

Sorption--Sorption techniques can involve both absorptive and adsorptive processes. Absorptive processes are used primarily to reduce the moisture content of a waste material, thereby permitting the waste to be disposed of as a solid. In contrast, adsorption involves the molecular adhesion of contaminants to sorptive materials. The most common sorptive materials include relatively inexpensive industrial waste products such as bottom ash, fly ash, or kiln dust from the manufacture of cement and lime. Natural materials that may be considered include clay minerals (e.g., zeolites and bentonite). Activated carbon, alumina, and a host of synthetic materials may be considered as well. Ideally the sorbent selected for a particular use should be unreactive, nondegradable, and compatible with the waste constituents. For dredged sediment disposal in an upland site, stabilization by sorption, perhaps in conjunction with another process, might be considered. However, there are no reports of the use of sorption methods in conjunction with contaminated dredged material disposal.

Fly Ash Pozzolan Processes--Lime-fly ash pozzolan treatment of hazardous wastes involves mixing the waste with a pozzolanic fly ash (high silicic acid content) and hydrated lime. The resulting material is either packed in molds for curing or placed in a landfill. It is an inexpensive solidification process, but usually results in a material with greater leaching potential than occurs with cement-based systems. Hazardous wastes treated by this process often cannot be delisted. Applications of this technology for dredged sediments have not been reported.

Pozzolan-Portland Cement--Portland cement can be blended with a pozzolanic fly ash to yield a stronger concrete-like product. Actual solidifying formulations can vary from those containing no pozzolanic material to those containing additives such as solvents, surfactants, emulsifiers, and clay minerals. These additives improve binding strength or reduce the mobility of waste constituents in the porous product. The most suitable formulation depends on waste chemical characteristics and the reactivity of waste constituents with cementing agents. Cement-based solidification and stabilization systems have not been field-demonstrated for treatment of contaminated dredged material.

Thermoplastic Microencapsulation--Thermoplastic microencapsulation involves the mixing of heated and dried wastes with a thermoplastic material such as polyethylene, paraffin, or asphalt bitumen that cools to form a solid mass suitable for landfill disposal. The technology is very expensive to implement and has a considerable air pollution potential. The process is generally reserved for wastes that are difficult to treat by any other means. Thermoplastic microencapsulation has been successfully used for the disposal of nuclear wastes and has been proposed for use in disposing of certain industrial wastes such as arsenicals. There have been no attempts to apply this technology to treatment of contaminated dredged material.

Vitrification--Vitrification is an energy-intensive process whereby fusable components of a waste (silica, alumina) are melted under the influence of an electrical current. When cooled, the treated material becomes a solid glass-like mass, effectively immobilizing inorganic constituents. Organic constituents tend to be pyrolyzed within the molten mass, emerge above the surface as gas, and are oxidized during the high-temperature process. Therefore, the potential for air emissions must be addressed when considering vitrification. The technology was originally developed for the solidification and immobilization of low-level radioactive metals contamination in soils. No contaminated dredged material applications have been reported.

The use of stabilization and solidification technologies as a part of contaminated dredged material remediation projects has not been reported in the literature but has recently been explored in pilot studies. Prior to implementation of stabilization or solidification processes, bench-scale testing would be required to evaluate effectiveness in meeting remediation objectives. Conceptually, however, either stabilization to reduce moisture content or solidification to both reduce moisture content and immobilize contaminants would be appropriate for consideration in conjunction with post-removal sediment disposal operations. Formulations most appropriate for consideration for the treatment of contaminated dredged material are sorption, lime-fly ash pozzolan, and Portland cement-pozzolan systems. In addition, proprietary formulations could also be suitable.

The U.S. Army Corps of Engineers (1986a) tested sediments from Everett Harbor, using cement, fly ash, lime/fly ash, and a proprietary additive, Firmix. Arsenic and zinc were completely immobilized (U.S. Army Corps of Engineers 1986a). Certain process formulations reduced the leaching of cadmium, chromium, and lead by 93 percent. No information was obtained on the leachability of specific organic contaminants following treatment. Pilot-scale solidification tests are underway as part of the New Bedford Harbor feasibility study (Cullinane, J., 8 January 1988, personal communication).

Various approaches have been considered for the implementation of solidification/stabilization technologies in the treatment of contaminated dredged material (Ludwig et al. 1985; Francingues 1985). All scenarios involve a confined nearshore or upland disposal facility. Disposal of solidified contaminated dredged material in a confined aquatic disposal site has not been considered. Disposal of solidified coal ash and scrubber sludge (by-products of coal combustion) in water has been conducted (New York State Energy Research and Development Authority 1985). This waste has a high metals content. In a study on treatment and disposal of this material in water following solidification, the physical integrity of the solidified mass remained intact and leaching rates were negligible to low over the 3-yr study period. However, the high salt content (e.g., chloride, magnesium) of marine sediments would be expected to extend the curing time required for effective solidification/stabilization. The need to stage sediments while curing takes place may preclude implementation of this option for in-water disposal of solidified sediments when large volumes of sediment are involved. Although it has not been attempted before, solidification or stabilization agents could also be added to contaminated dredged material on a barge, using specially designed portable mixing equipment (Willet, J., 6 April 1988, personal communication). The slurry mixture would be returned to the aquatic environment with a hydraulic pump following the addition of solidification agents. The sediment return mechanism would need to be carefully engineered to minimize disturbance and dissociation of solidification agent and sediment. The stabilization/ solidification process for marine sediments would require field testing before implementation. Therefore the treatment of contaminated dredged material using stabilization/solidification technologies is considered here as an innovative technology.

Chemical Treatment--

Chemical treatment options are considered here for potential application in the remediation of contaminated dredged material. In general, chemical treatment technologies are appropriate for aqueous and liquid chemical wastes that are reasonably uniform in composition. Solid wastes are rarely treated by chemical means. For complex wastes containing a variety of contaminants, chemical approaches are generally less favorable than other treatments in that incomplete reactions and the formation of by-products often require that multiple treatment steps be included. Applications of chemical treatment for contaminated soils are under development (U.S. EPA 1986c), but none have been reported for treatment of contaminated dredged material (U.S. Army Corps of Engineers 1986c). The most appropriate context in which to consider chemical treatment is during management of contaminated dredge water generated during dewatering operations.

Water generated as a result of sediment dredging or dewatering (i.e., as a part of post-removal sediment treatment) is likely to contain relatively dilute concentrations of both organic and inorganic contaminants, and may require treatment prior to discharge to a receiving water. The following technologies are reviewed for their applicability to the treatment of dredge water removed from contaminated dredged material:

- Hydrolysis
- Neutralization
- Photolysis
- Oxidation and reduction
- Precipitation
- Ion exchange.

Hydrolysis, neutralization, and photolysis are probably not applicable to the problem chemicals in Commencement Bay sediments. Hydrolysis has been used to destroy carbamate and organophosphorus pesticides, neither of which is a contaminant of concern in Commencement Bay sediments. Neutralization is used to adjust pH in highly acidic or alkaline waters, conditions not associated with contaminated marine sediments in Commencement Bay. Photolysis has been used to reduce concentrations of dioxins and other polychlorinated organic compounds. It is unlikely that concentrations of these compounds are high enough in the problem sediments to require treatment.

Chemical oxidation has been used to detoxify cyanide and to treat dilute aqueous wastes containing oxidizable organics. Organic compounds for which oxidative treatment has been reported include aldehydes, mercaptans, phenols, benzidine, unsaturated acids, and certain pesticides. Oxidation has been used to pretreat recalcitrant compounds prior to biological oxidation. The primary drawbacks of the technology are that incomplete oxidation and by-product formation may not result in adequate detoxification of the material. From an operational standpoint, the oxidants are very hazardous and require great care in handling. Oxidation methods are unlikely to be applicable to the treatment of contaminated dredge water.

Reduction techniques have been used to remove mercury and lead, and to reduce hexavalent chromium. They are used primarily in the electroplating and metal finishing industries. There have been no reported uses of reduction technology for organic compounds.

Chemical precipitation through the addition of a coagulating agent is a technology suitable for consideration in eliminating metals from solution. The technology is not applicable to the removal of organic compounds. Chemical precipitation has been used to treat aqueous wastes containing zinc, arsenic, copper, mercury, manganese, cadmium, trivalent chromium, lead, and nickel. It is a commercially available technology and its use is widespread. Precipitation methods are sensitive to changes in waste stream composition, and formation of organometallic complexes can limit removal efficiency. Chemical precipitation methods have usually been applied to contaminated fresh water.

Ion exchange involves the replacement (exchange) of ions electrostatically held to the surface of a solid with similarly charged ions in solution. The solid medium, usually referred to as a resin, can be made selective for ions of both positive and negative charge. Resins selective for heavy metals (e.g. copper, lead, mercury) are available. The technology is not applicable to the removal of neutral organic compounds from solution. If dredge water must be treated for both metals and organics, two process steps would be required.

Ion exchange is generally intended as a polishing step to reduce the concentrations of ions from 1-100 ppm to a few ppb. Water produced during the dredging of contaminated sediments from Commencement Bay is likely to contain metals within or below this range of treatable concentrations. Feed solutions for ion exchange systems must have low suspended solids concentrations (less than 5 Nephelometer Turbidity Units), which could necessitate a prefiltration step. The effects of high salinity on resin performance would need to be evaluated. The potential for resin biofouling resulting from biodegradable organic compounds in the feed must also be considered. Chelating agents, both organic and inorganic, could severely reduce exchange efficiency. An acidic solution requiring further treatment would be produced as a result of resin regeneration. One possible regenerant treatment strategy would include precipitation and filtration, with return of the filtrate to the exchange system and disposal of the sludge. However, because the high salinity would be expected to hinder resin performance, ion exchange is not considered to be applicable for treatment of dredge water from Commencement Bay.

Biological Treatment--

Biological treatment technologies can be applied to both dredge water and dredged sediment. Biological wastewater treatment technologies are appropriate for the removal of biodegradable organic compounds from wastewater and are not intended for removal of metals. Even so, some metals are removed by adsorption or incorporation into the suspended or fixed biomass that eventually emerges in the sludge. Treatment for both categories of contaminants will generally require more than one process step. Many industrial wastes and the majority of municipal wastes are treated biologically. Methods used for the treatment of these wastewaters are applicable to many hazardous wastes and are finding acceptance as treatment alternatives. Biological treatment techniques for dilute aqueous solutions containing organic contaminants are reviewed in Section 3.2.1.

The single biological treatment option potentially applicable to contaminated sediments is land treatment. Land treatment is the controlled application of a waste into the biologically active upper zone of a soil and the maintenance of conditions optimal for microbiological activity. In addition, the amount of waste applied to the soil is controlled so that the cation exchange capacity of the soil (i.e., the capacity of the soil to immobilize metals) is not exceeded. Generally the natural microflora is expected to acclimate to the amended soil conditions, but microbiological seeding is sometimes considered. A fundamental objective of land treatment is to avoid permanent or long-term contamination of the treatment soil so that it may be considered for any potential use following the treatment period.

Land treatment of contaminated marine sediments has not been reported. Problems associated with salinity may require mitigation prior to or following application of the sediment. Land treatment is not suitable for wastes containing recalcitrant compounds such as PCBs, and must be limited to wastes for which degradation of hazardous constituents can be demonstrated. Runoff and leaching of contaminants to groundwater must be considered during facility design. The major drawback to land treatment as a sediment treatment alternative is the potentially excessive land areas that would be required to handle the large volumes of dredged sediments. However, because land treatment provides a viable biological treatment option, it is retained for further consideration.

Thermal Treatment--

Thermal treatment processes are designed to destroy combustible organic wastes. They are also used to eliminate hazardous organic contaminants in low concentrations from incombustible materials such as soils. The elimination of hazardous organic constituents from marine sediments by incineration has not been reported but, in theory, is feasible. Thermal processes are not suitable or economical for the treatment of water containing low concentrations of organic constituents and are only discussed in conjunction with treatment of dewatered sediments.

Incineration is the most common thermal treatment technology. The conventional process options include liquid injection, multiple hearth, fluidized bed, rotary kiln, and infrared incineration systems. Large, permanent systems are capable of handling approximately 500 tons/day (Breuger, J., 19 January 1988, personal communication). This process rate is approximately equivalent to between 270 and 420 yd^3/day, depending on total solids content of the sediment. Emerging technologies include the following:

- Molten salt
- Wet air oxidation
- Plasma arc torch
- Pyrolysis

- High temperature fluid wall
- Supercritical water
- Advanced electric reactor
- Vertical tube reactor.

In general, these emerging technologies are not suitable for consideration as treatment options for contaminated marine sediments. Molten salt incineration is intended primarily for the treatment of small quantities of liquid and solid organic wastes with a low ash content, and has been demonstrated to be highly effective for the destruction of chlorinated hydrocarbons and some pesticides. Wet air oxidation is designed for the treatment of concentrated aqueous organic wastes. Plasma arc systems are still largely under development and are intended to treat small quantities of liquid wastes at extremely high temperatures (>10,000^{o} C). Pyrolysis involves the heating of wastes in an oxygen-deficient atmosphere to degrade wastes to a fixed carbon ash residue and a gas component. The objective of the process is to convert waste material from a disposal problem to a gaseous fuel source. Pyrolysis systems cannot handle wastes that have a high sodium content. The high temperature fluid wall is well suited for the treatment of contaminated soil, but the material must first be ground, dried, and reduced to a free-flowing solid with a particle size of approximately 100 mesh. The technology is therefore impractical for the treatment of large quantities of contaminated sediments. Supercritical water, advanced electric reactors, and vertical tube reactors are also in the development stage.

Liquid injection incineration is designed for the combustion of liquid organic wastes such as PCBs, solvents, still and reactor bottoms, polymer wastes, and pesticides. Wastes high in metals and moisture content are not suitable for treatment using this process. The multiple hearth incinerator is widely used to incinerate sewage sludge but is also capable of handling all forms of combustible waste materials, including sludges, tars, solids, liquids, and gases. It is not suitable, however, for the incineration of materials with a high ash content such as soils and sediments.

Fluidized beds are typically used for the disposal of municipal wastewater treatment plant sludge, oil refinery waste, and pulp and paper mill waste. It is well suited for incineration of wastes with high ash and moisture contents, and may be considered for the remediation of contaminated dredged material.

The rotary kiln is an applicable incineration technology for the treatment of sediments contaminated with organic materials. It is the most versatile of the incineration technologies because it can handle wastes in any physical form. Rotary kiln incineration is the method of choice for the thermal treatment of mixed hazardous solid residues, is the most frequently chosen system for commercial offsite operations, and has been used for the destruction of hazardous organic constituents in soils. Mobile incineration units are available for onsite destruction of hazardous materials.

Infrared incineration systems use electric heating elements instead of combustible fuels to bring waste material to combustion temperatures. Pilot experience using this approach has demonstrated the applicability of infrared systems to the remediation of sludge materials (Shirco Infared Systems, Inc. 1987). The following factors must be addressed in considering the selection of incineration technologies to treat dredged sediments from the Commencement Bay N/T study area:

- Effects of inorganic constituents on refraction material
- Sediment pretreatment requirements (e.g., dewatering)
- Temporary storage of dredged sediments prior to incineration
- Site selection (i.e., onsite or offsite) and associated transportation costs
- Particulate emission controls to reduce metals releases
- Characterization of ash and determination of disposal method.

Physical Treatment--

Physical approaches to treatment of contaminated dredged material and associated dredge water result in the isolation and in some cases the concentration of contaminants in a waste stream. The two primary categories of applicable physical treatment technologies are phase separation and partitioning processes. Phase separation approaches include filtration, sedimentation, and dewatering. Solids fractionation is also considered here as a volume reduction step. Partitioning processes include solvent extraction and sorption.

Filtration--Filtration is the process whereby relatively low concentrations of suspended solids are removed from an aqueous stream by forcing the liquid through a porous medium. Particulate matter is retained on the medium. Filtration is unlikely to be necessary for management of contaminated dredge water unless a treatment sensitive to suspended solids concentrations (e.g., ion exchange, carbon adsorption) is required. Removal of the majority of suspended material from dredge water is best accomplished by sedimentation followed by chemical coagulation.

Sedimentation--Sedimentation is the removal of suspended particulate matter from a slurry or aqueous suspension by gravity settling. In the context of contaminated dredged material management and disposal, especially following hydraulic dredging, sedimentation is likely to be an integral component of the overall remediation scheme. The U.S. Army Corps of Engineers has evaluated sedimentation followed by chemical coagulation, with the sedimentation basin also serving as the ultimate confinement area (Schroeder 1983). In this approach, removal of dredge water from contaminated dredged material deposited at a nearshore or upland site is followed by capping and closure procedures.

Solids Fractionation--Separation of granular material into particle size fractions has potential for reducing the volume of contaminated solids requiring treatment when the contaminants of concern are associated with a discrete and separable fraction of the solid medium. Equipment for industrial solids fractionation applications includes screens and sieves, hydraulic and spiral classifiers, cyclones, and settling basins.

In general, particle fractionation schemes for the treatment of contaminated dredged material are conceptual and site-specific in potential applicability. The efficiency with which the contaminated fraction can be separated from the relatively uncontaminated material is critical to the success of the process. A pilot-scale demonstration of particle fractionation has been attempted in the Netherlands (Cullinane, J., 18 November 1987, personal communication) to recover material suitable for construction work. The sediment was incidentally contaminated. Contaminants were concentrated in the fines but the coarse material still contained residual contamination.

Solids fractionation is unlikely to be an appropriate technology for reducing the large volume of contaminated material dredged from Commencement Bay problem areas. Sediments in the area are typically fine-grained, which limits the suitability of solids fractionation technology. Bench-scale treatability tests and pilot demonstrations would be required before implementation on a field scale could be considered.

Dewatering--Dewatering reduces the moisture content of contaminated dredged material beyond what can be accomplished by gravity settling in a sedimentation basin. Numerous mechanical dewatering devices have been developed for industrial applications but have not been widely applied to dewater dredged material (Yoshino et al. 1985). For the dewatering of contaminated dredged material intended for upland confinement, incorporation of an underdrainage system into the sedimentation basin disposal facility is probably the most suitable approach (U.S. Army Corps of Engineers 1986c). The underdrainage system would operate by gravity or be vacuum-assisted. Treatment of water obtained from the dewatering of contaminated dredged material must be considered in the event that contaminant concentrations exceed acceptable values.

Solvent Extraction--Solvent extraction to remove organic contaminants is under consideration at the New Bedford CERCLA site and a Hudson River project (Austin, D., 22 January 1988, personal communication). In both cases, PCBs are the primary contaminants of concern. In both instances, the levels of PCB contamination are several orders of magnitude higher than those observed in the Commencement Bay problem area. The specific technology being evaluated is the BEST™ process marketed by Resources Conservation Company.

The process involves using a solvent such as triethylamine (TEA), which has the unusual property of being completely miscible in water at approximately 50° F but immiscible at temperatures near 100° F. It has a low boiling point and heat of vaporization, which is favorable from an energy standpoint. The solvent is mixed with solid waste at the lower temperature to extract organic contaminants and water into the liquid phase. The liquid is warmed to effect the phase transition whereupon aqueous and organic phases are separated. Residual TEA is recovered from the treated solids in a drying step. The aqueous phase has low contaminant concentrations and, because TEA is not a regulated hazardous constituent, can generally be discharged without further treatment. Evaporative concentration of the TEA solution and recovery of the solvent completes the process. Alkaline conditions in the process can lead to precipitation of metals as hydroxides, which remain in the treated solids. If the metals concentrations are not of concern, it is plausible to consider returning the treated solids to the marine environment. System capacities of over 500 ton/day are believed to be feasible (Austin, D., 22 January 1988, personal communication).

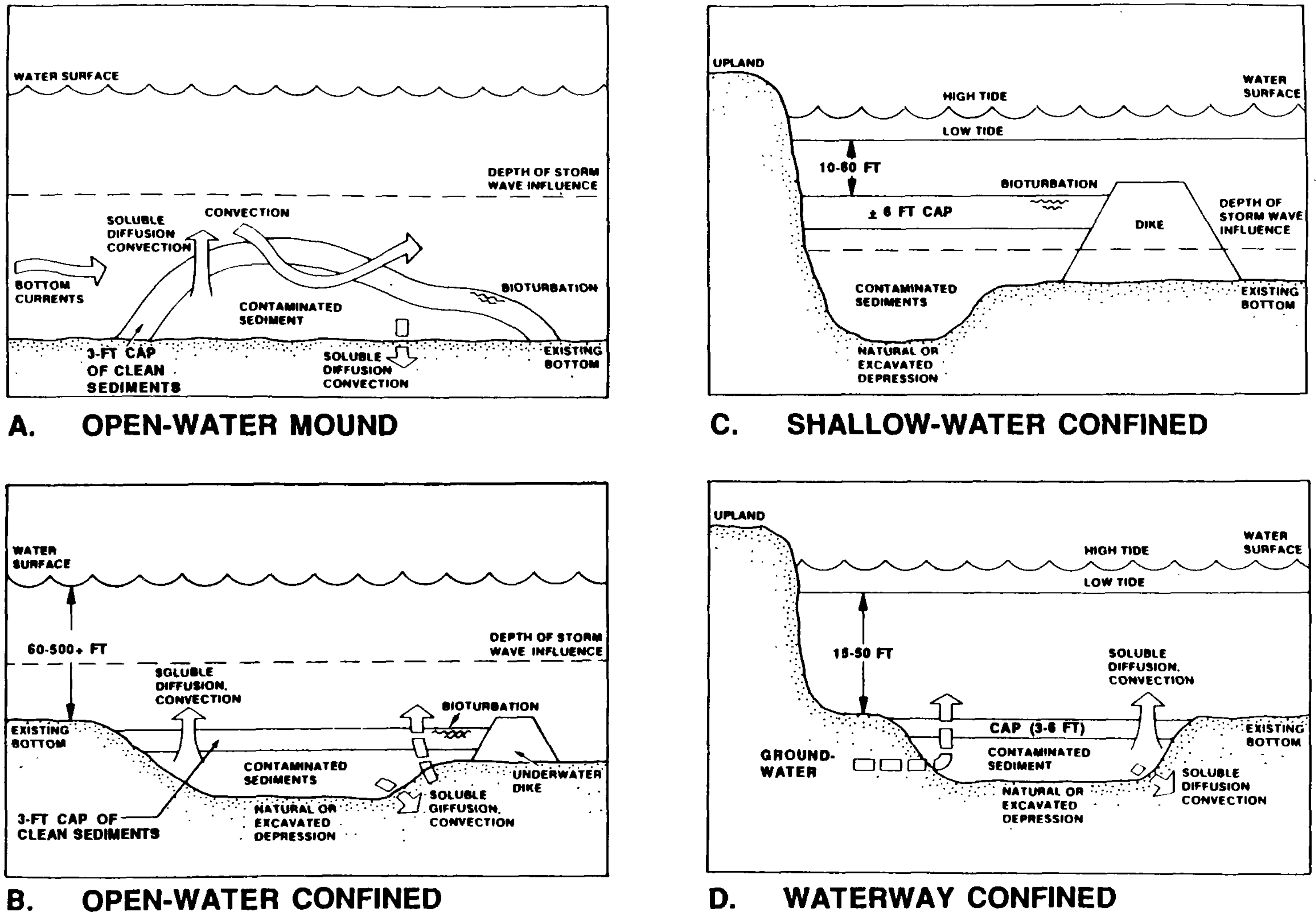
Sorption--Removal of organic contaminants from aqueous wastes by granular activated carbon adsorption is a proven and effective technology. For contaminated dredged material management and disposal, carbon adsorption may be appropriate for the treatment of contaminated dredge water. Although the technology is best suited to the removal of organic contaminants, metals such as arsenic, antimony, and mercury can also be removed to some extent. To prevent clogging, the suspended solids concentration needs to be reduced to less than 50 mg/L by treatment such as filtration or sedimentation. A carbon treatment system will be used to remove PCBs from contaminated dredge water during pilot dredging studies scheduled for the New Bedford CERCLA site (Cullinane, J., 8 January 1988, personal communication).

3.1.6 Disposal Options

Remedial alternatives that involve a dredging component necessarily include disposal in an aquatic, nearshore, or upland environment. In all three cases, the deposited material can be confined or unconfined. Unconfined disposal is generally inappropriate for Commencement Bay sediments requiring remediation because of environmental and human health concerns. Unconfined disposal is conceivable, however, for treated dredged material. The various confined disposal options that are potentially applicable to the Commencement Bay study area are reviewed below. Details are described in Phillips et al. (1985).

Confined Aquatic Disposal--

The variations of the confined aquatic disposal option are depicted in Figure 3-2. The open-water mound involves no lateral confinement structures, and is the least protective confined aquatic disposal alternative. Dredged material is transported to a location above the disposal site and discharged by a split-hulled barge or through a vertical pipeline diffuser. Clean cap material is then placed on the mound, using either discharge method in order to achieve an appropriate cap thickness. The U.S. Army Corps of Engineers (1986b) has identified a thickness of approximately 3 ft as appropriate for most contaminated dredged material. Lack of precision in obtaining an adequate cap thickness may require significantly more material than theoretically required. Contaminant loss is limited to diffusion through



Reference: Phillips et al. (1985).

Figure 3-2. Confined aquatic disposal of contaminated dredged material.

the cap as long as the cap thickness is sufficient to mitigate the effects of bioturbation or mechanical disturbances.

The open-water confined option depicted in Figure 3-2 is more protective than the mound in that an artificial or natural depression in conjunction with diking provides lateral confinement. Disposal of contaminated dredged material in an open-water confined aquatic facility is proposed for the Everett Harbor Carrier Battle Group Homeport program. For that project, it is proposed that contaminated sediment will be dredged using a clamshell, transported to the disposal site in a split-hulled barge, and dumped. Precision positioning equipment will be used to ensure that contaminated dredged material is placed within the target disposal zone. The disposal site is sloped and will have a containment dike constructed along the lower boundary. Depth to the disposal site is approximately 250-350 ft. The cap material will be hydraulically placed using a diffuser positioned at a depth of 60 ft below the water surface.

Confined aquatic disposal of contaminated dredged material has been implemented at several sites, including Long Island Sound, the New York Bight, and Rotterdam Harbor (the Netherlands). The contaminants associated with those sediments included primarily inorganics, petroleum hydrocarbons, and PCBs. Although limited data on disposal site conditions and capping material were collected prior to disposal, subsequent performance monitoring indicates that confined aquatic disposal has been effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988).

Shallow-water disposal sites as depicted in Figure 3-2 are within the influence of storm waves but are below intertidal depths (-10 to -60 ft MLLW). Structural considerations are the same as for open-water confinement, except the cap is thicker to accommodate the energetics associated with the shallower depths. The level of control over placement of dredged material, berm, and cap materials is greater than for the open-water alternative.

Waterway confinement as presented in Figure 3-2 is a variation in which a pit, excavated in a relatively shallow (15-50 ft) navigable waterway, receives both contaminated dredged material and cap materials. The hydraulic energy associated with the quiescent waterways in the Commencement Bay problem area is lower than that in other shallow-water environments exposed to more direct wave action. However, propeller wash and ship scour would be expected to increase subsurface energy significantly in the shallow waterway environment. The volumetric requirements for disposal must account for placement of the entire volume of contaminated dredged material, with an appropriate bulking factor applied. Depending on dredging and placement techniques, bulking factors of up to 100 percent must be applied. The development of a single, open excavation of that size is not practical within a waterway primarily because of logistics, such as temporary storage of a large quantity of contaminated dredged material following the initial excavation. Instead, the confined aquatic disposal site would be configured to contain the required volume in a series of smaller cells or possibly parallel trenches. If possible, the disposal site should be located in an area that will not be dredged. In waterways requiring periodic dredging, the contaminated dredged material and cap would need to be placed deep enough to preclude damage from the dredging. This approach to confined aquatic disposal has not been field-tested although it is being considered for the New Bedford Harbor Project.

Confined Nearshore Disposal--

Design features specific to confined nearshore disposal sites are illustrated in Figure 3-3. Nearshore disposal locations are within areas subject to tidal fluctuations (U.S. Army Corps of Engineers 1986c). Dredged material is added to the diked area until the final elevation is above the high tide elevation, and a cap 3-6 ft thick is installed. Nearshore disposal sites are normally used in conjunction with hydraulic dredges. However, at the Pier 90/91 nearshore fill in Elliott Bay (Seattle, WA), mechanically dredged sediment was deposited at the disposal site, using a split-hulled barge.

Disposal of contaminated marine sediments has occurred in several nearshore facilities throughout the country. Approximately 90,000 yd^3 of sediments contaminated with heavy metals, PAH compounds, and PCBs was disposed of at the Elliott Bay Pier 90/91 site in 1986. Monitoring conducted following disposal has revealed that the contaminated material has been effectively confined. Although there appears to have been some mobilization of inorganic contaminants, it is unclear if the material originated from within the confinement structure or from the material used to construct the dike and cover (Hotchkiss, D., 20 April 1988, personal communication). Approximately 20 nearshore disposal sites have been constructed in the Great Lakes to confine dredged materials deemed unsuitable for open-water disposal (U.S. Army Corps of Engineers 1987). However, limited analyses of contaminated sediments were conducted prior to disposal in these facilities, which compromises the assessment of facility performance.

Depending on placement, physicochemical conditions in nearshore facilities can be similar to those observed in both confined aquatic and confined upland disposal sites. Subtidal portions of the fill remain saturated and anoxic, which can aid in maintaining constant physicochemical conditions to reduce contaminant migration potential. This condition minimizes the potential for migration of metal contaminants. The fill zone above tidal influences eventually drains and becomes upland in nature. Within the tidal zone, tidal pumping may increase the likelihood of contaminant migration by contributing oxygen and providing a convective component for dispersion. Depending on the site-specific geohydrologic features, groundwater may influence the hydraulics within a nearshore fill unless barriers and liners are incorporated. Contaminant releases are less amenable to control than is possible with upland confinement. However, dredging, transport, and disposal technologies use well-established equipment and methods to aid in effective implementation with minimal public health or environmental hazards.

Confined Upland Disposal--

Design features and environmental exposure pathways specific to confined upland disposal are illustrated in Figure 3-4. Upland disposal involves the

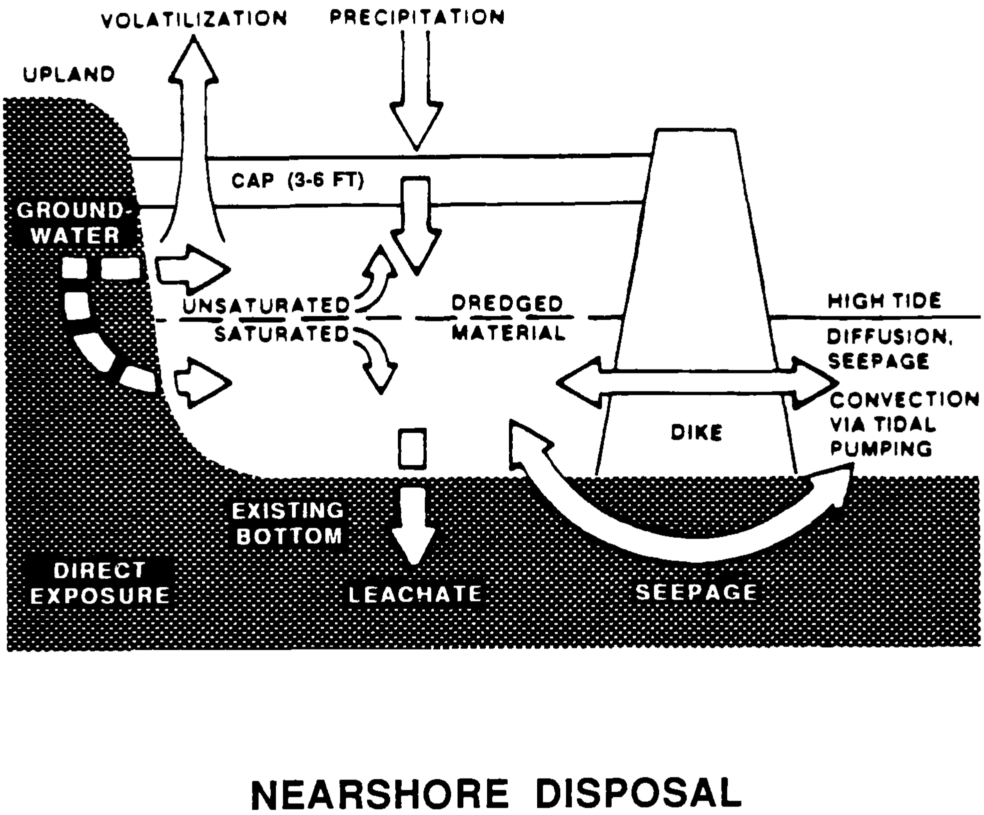
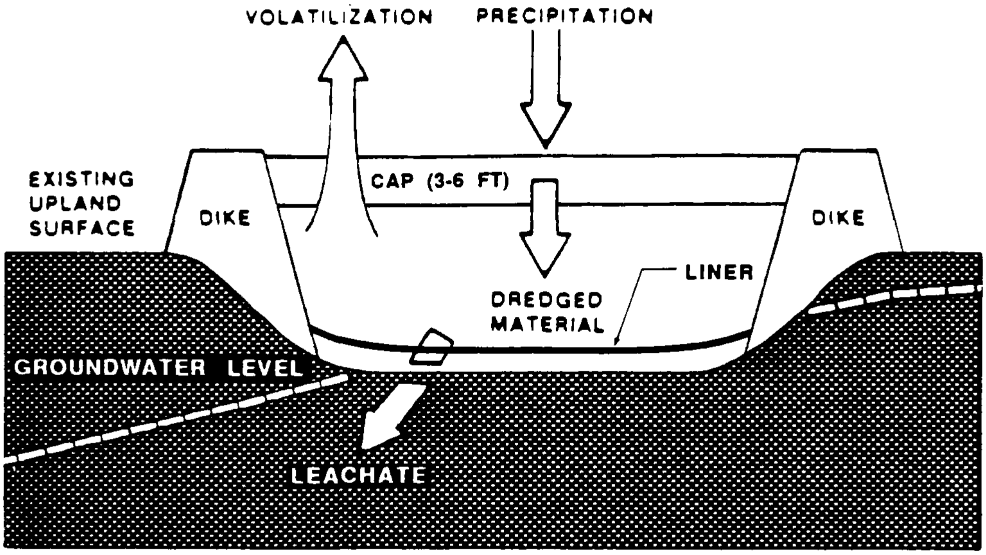


Figure 3-3. Confined nearshore disposal of contaminated dredged material.

a UPLAND DISPOSAL



b CROSS SECTION

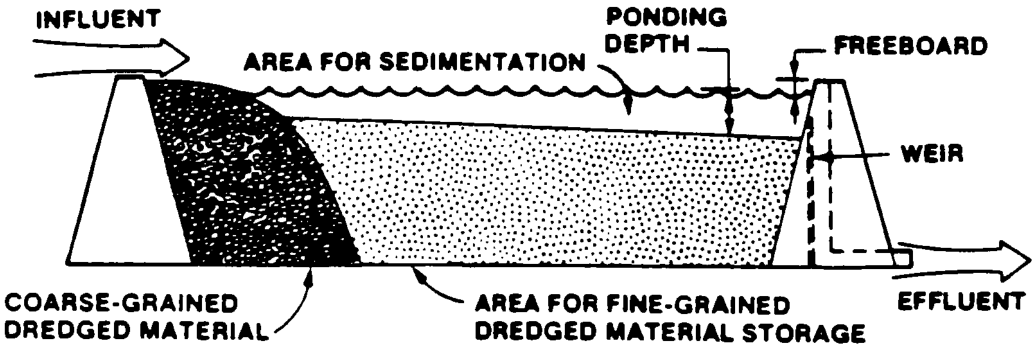


Figure 3-4. Confined upland disposal (a) and components of a typical diked upland disposal site (b).

placement of dredged material in environments that are not inundated by tidal waters. Upland disposal sites are normally diked and capped to confine the dredged solids while allowing the dredge water to be released. Upland disposal sites are most often associated with hydraulically dredged sediments pumped to the upland site via pipeline. The transport of contaminated dredged material following dewatering to upland disposal sites by truck is possible for relatively short distances. Transportation of large quantities of contaminated dredged material over a longer distance or through congested traffic areas could pose a potential environmental hazard and is not economical.

Relative to other listed options, upland disposal poses the greatest potential risk to groundwater supplies, but also allows for greater control of contaminated wastes through design features, improved monitoring capabilities, backup contaminant interception, and treatment facilities.

Prior to placement in a landfill, it is likely that both dewatering and stabilization of contaminated sediment would be required. If the dredged sediment were classified as a hazardous waste, which is unlikely, disposal of untreated contaminated dredged material in a RCRA-approved landfill would be necessary. Compliance with all applicable hazardous waste handling and transport regulations would be required for sediment classified as hazardous waste. Problem sediments that do not violate established standards and criteria for hazardous waste classification would require handling in accordance with other appropriate environmental statutes. Relatively more flexibility and options are available for handling problem sediments not classified as hazardous waste. Intermixing of hazardous with nonhazardous sediments should be avoided to reduce the volume requiring special treatment and the associated transportation costs.

Both new and existing landfill facilities could receive dredged, dewatered, and stabilized sediments. The design of the facility would depend on the characteristics and final classification of the fill material. Appropriate technical considerations would have to include options for control and possibly treatment of effluent from dewatering process.

New RCRA landfills are subject to especially stringent criteria regarding design, management, and the nature of wastes that may be handled. Important design requirements include the following:

- A liner system to prevent leachate migration beyond the waste containment zone
- A leachate removal and collection system
- A stormwater run-on management system
- A stormwater runoff management system
- A groundwater monitoring system.

Disposal Site Availability--

Potential sites identified by Phillips et al. (1985) for the disposal of contaminated Commencement Bay sediments are shown in Figure 3-5. The sites were identified in a preliminary effort to locate potential disposal facilities. This effort was not directed toward compiling the definitive list of all possible disposal sites in the area. Potential capacities, and land ownership information for each site identified is listed in Table 3-1. The following discussion is a review of each site, with emphasis on availability for contaminated dredged material disposal.

Open-Water Sites--Three open-water disposal sites are shown in Figure 3-5. The Washington Department of Natural Resources (WDNR) site has been designated for unconfined disposal of dredged material since 1972 and has regularly received material since that time. Closure of the WDNR site is expected in June 1988.

The Puyallup River delta site, owned by the State of Washington until 1972, was designated for unconfined open-water disposal. The site is characterized by sloping topography, which has led to slides of sediment mass into deeper waters (Phillips et al. 1985). Capping would therefore be inappropriate under these circumstances. It may be possible to conduct confined aquatic disposal operations in the deeper waters near the edge of the slide zone, where any further sliding activity would increase cap thickness. However, disposal operations would occur in the path of salmonid migration to and from the Puyallup River system. Additional studies need to be conducted to clarify the technical and institutional feasibility of using this site for disposal. Currently, the Puyallup River delta site must be considered unavailable.

The Hylebos/Brown's Point location has no history of disposal activities. It is characterized as a natural horseshoe-shaped depression which could be closed off on the fourth side by creating a dike. Estimated capacity of the depression is 2.5 million yd^3. The depth of the site ranges between 100 and 200 ft (Phillips et al. 1985). Because the site has previously not been used for disposal purposes, the existing benthic community is largely undisturbed. However, the water surface in the area has been used extensively for log booming which may have impacted the benthic community. Because this site contains sufficient capacity for a large volume of material and appears to be topographically suited to capping operations, this site is considered for confined aquatic disposal of Commencement Bay problem area sediments. Hydrological, geotechnical, and environmental investigations of the site would be required prior to use.

Although there are no sites that are considered immediately available, the potential exists for designating an area in Commencement Bay as an open-water confined aquatic disposal site. The waterway confined aquatic disposal option is generally implementable and sites should be available in the Commencement Bay waterways. Confined aquatic disposal out of the waterways may be preferable to the in-waterway option because of the possibility that the waterways will be deepened in the future to accommodate large shipping vessels.

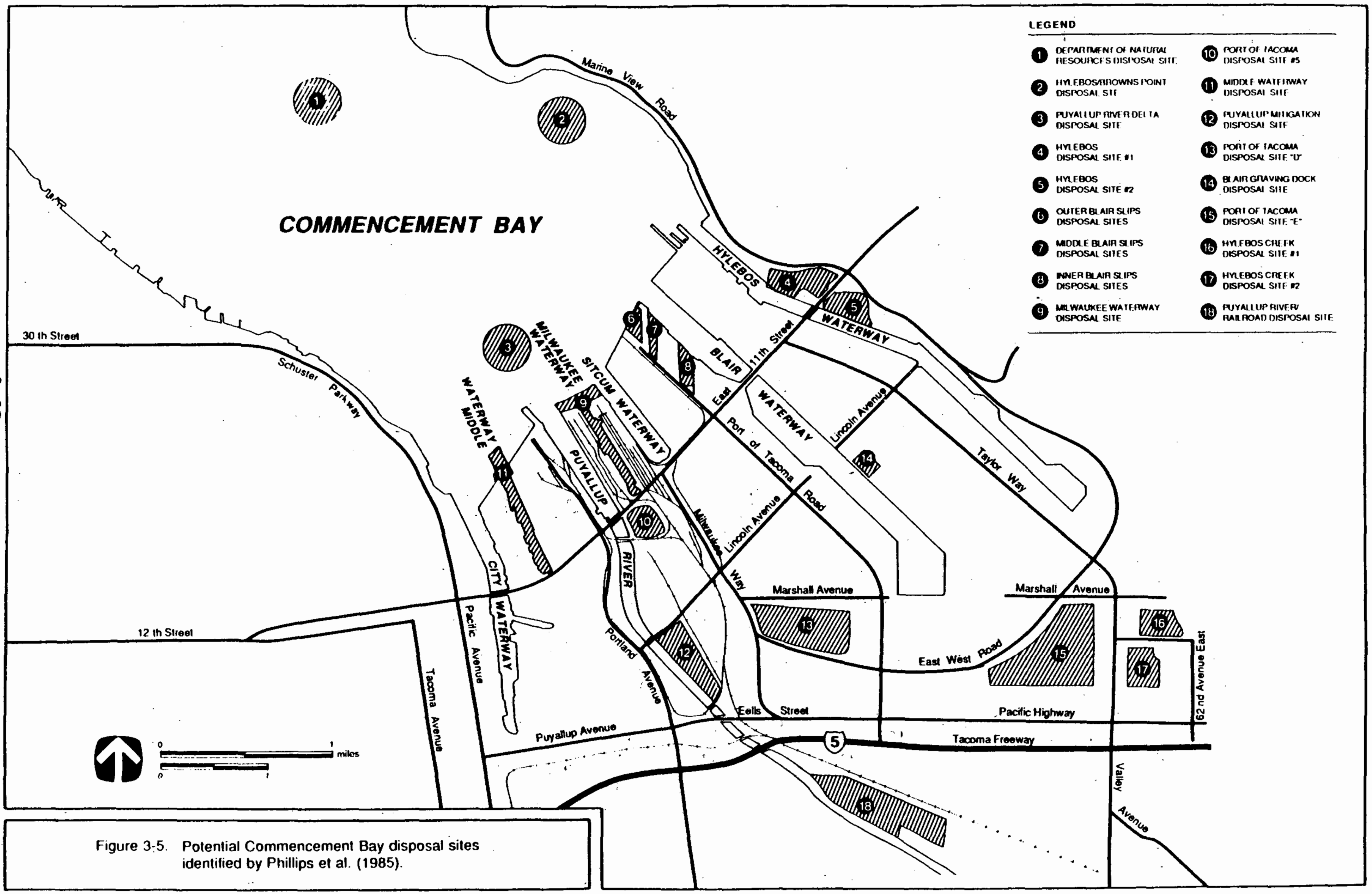


Figure 3-5. Potential Commencement Bay disposal sites identified by Phillips et al. (1985).

TABLE 3-1. POTENTIAL SITES FOR CONTAMINATED DREDGED MATERIAL DISPOSAL[a]

Site	Capacity	Ownership
OPEN-WATER DISPOSAL SITES		
Puyallup River Delta Site	Approximately 900 ft in diameter with up to 170 ft in depth	State of Washington
WDNR Disposal Site	Approximately 900 ft in diameter down to 500 ft in depth	State of Washington
Hylebos/Brown's Point Site	2.5M yd^3	State of Washington
UPLAND SITES		
Puyallup Mitigation Site	40 ac 1.0M yd^3	Port of Tacoma
Port of Tacoma Site "D"	60 ac 1.55M yd^3	Port of Tacoma
Puyallup River/Railroad site	80 ac 3.3M yd^3	Union Pacific Railroad
Port of Tacoma Site "E"	71 ac 1.7M yd^3	Port of Tacoma City of Tacoma
Hylebos Creek Site No. 1	25 ac 0.45M yd^3	Multiple ownership
Hylebos Creek Site No. 2	20 ac 0.325M yd^3	Multiple ownership
NEARSHORE SITE		
Middle Waterway Site	27 ac 0.65M yd^3 (0.39M yd^3 wet, 0.26M yd^3 dry)	Land users/owners include: Foss Towing Paxport Mills Union Pacific R.R. St. Regis Paper Co. and others Waterway owned by State of Washington
Milwaukee Waterway Site	30 ac 2.16M yd^3 (0.29M yd^3 wet, 1.87M yd^3 dry)	Port of Tacoma

TABLE 3-1 (Continued)

	Capacity	Ownership
Blair Waterway Slips	Outer slip: 0.892M yd^3 (0.825M yd^3 wet, 0.067M yd^3 dry)	State of Washington
	Middle slip: 8 ac 0.945M yd^3 (0.868M yd^3 wet, 0.077M yd^3 dry)	Port of Tacoma
	Inner slip: 12 ac 0.60M yd^3 (0.484M yd^3 wet, 0.116M yd^3 dry)	Port of Tacoma
Blair Creek Dock Site	700 ft x 500 ft 0.2M yd^3 (0.136M yd^3 wet, 0.064M yd^3 dry)	Port of Tacoma
Hylebos Waterway No. 1	74 ac 1.274M yd^3 (0.550M yd^3 wet, 0.724M yd^3 dry)	Port of Tacoma
Hylebos Waterway No. 2	24 ac 0.30M yd^3 (0.07M yd^3 wet, 0.23M yd^3 dry)	Sound Refining Co. (owned by Chrysen Corp.)

Reference: Phillips et al. (1985).

Nearshore Sites--Hylebos sites #1 and #2 are subtidal and intertidal areas. Both are environmentally sensitive and would therefore be difficult to develop in terms of both technical and regulatory considerations. Extensive mitigation measures would be required to develop these sites. Chrysen Corp., owner of Sound Refining which borders the Hylebos #2 site, has expressed interest in filling the area to expand operations but has been opposed by tribal groups and Ecology (Mori, R., 13 January 1988, personal communication).

Two of the three slips in Blair Waterway initially identified as potential disposal sites are no longer under consideration. The outer slip has been used as a fish habitat mitigation site, and the inner slip has been filled as part of a Terminal 3 expansion project (Carter, S., 11 January 1988, personal communication). The middle slip (Slip 1) originally designated as a potential nearshore facility remains as a potential disposal site. This slip covers an area of approximately 8 ac and has an average elevation of approximately -37 ft MLLW (Phillips et al. 1985). The total capacity of this facility as a disposal site has been estimated at approximately 900,000 yd^3.

The Port of Tacoma plans to fill Milwaukee Waterway with essentially uncontaminated sediments from Blair Waterway in order to expand port-related operations (Sacha, L., 16 November 1987, personal communication). It is possible that Commencement Bay problem sediments would be acceptable for disposal in Milwaukee Waterway if proposed future uses of the site were not compromised.

Although Middle Waterway is not maintained for channel depth by the U.S. Army Corps of Engineers, shoreline businesses use medium draft vessels in the waterway. It is shallow along its entire length, with an average elevation of -7 MLLW. Little information is available on the suitability of any part of this waterway for disposal of contaminated dredged material.

The Port of Tacoma is assessing the suitability of the Blair graving dock site as a disposal site for sediments dredged from Sitcum Waterway as part of a pier extension project. The graving dock site is estimated to have a volume of 100,000 yd^3 (Sacha, L., 9 May 1988, personal communication). This site is considered potentially available for disposal of dredged materials.

The only potentially available nearshore disposal sites within the Commencement Bay waterway system that can receive contaminated dredged materials are Blair Waterway Slip 1, Milwaukee Waterway, and the Blair graving dock. The Port of Tacoma is reluctant to accept contaminated dredged material in Milwaukee Waterway. Additional evaluation is needed to explore the feasibility of Middle Waterway as a nearshore site. Hylebos sites #1 and #2 appear to be unacceptable for use as disposal sites because of wetland habitat considerations.

Upland Sites--The Puyallup mitigation site is a wetland area that is protected from development. Port of Tacoma Site D has been developed into a foreign trade zone and is therefore no longer eligible for consideration as a disposal site. The only municipal landfill identified for disposal of treated dredged material is the Coal Creek landfill in King County. However, disposal at Coal Creek is not considered feasible because of the required transport distance (approximately 50 mi), and traffic impacts associated with hauling large volumes of material).

RCRA Facilities--Two RCRA landfills operate in U.S. EPA Region X. Chem-Security Systems, Inc. (CSSI) operates a minimum technical standards landfill under interim permit status at its Arlington, OR facility. Envirosafe Services of Idaho operates a facility near Grandview, ID, which is also under interim status. Neither firm currently has a stabilization capability. Because the Commencement Bay problem area is subject to the CERCLA regulatory framework, onsite stabilization could be performed prior to shipment to either of these facilities. Offsite RCRA landfilling should be considered as a reserve option only, in keeping with Section 121(b) of CERCLA, which discourages the offsite transport and disposal of untreated hazardous substances or contaminated materials.

Transportation--

Several methods are available in Puget Sound to transport sediments from the Commencement Bay study area. The most practical method will be dictated by the dredging method and access to the disposal site. Sediments removed by hydraulic dredge can most efficiently be transported by pipeline to a nearshore, upland, or aquatic disposal site if distances between the dredge and disposal sites are only a few miles. Sediments removed by clamshell dredge will have nearly in situ densities. Such sediments can be transported by split-hulled barge to nearshore and aquatic disposal sites and by truck to upland disposal sites.

3.1.7 Summary of Preliminary Screening of Sediment Remedial Technologies

General response actions, technology types, and process options that passed preliminary screening are illustrated in Figure 3-6. All six general response actions identified initially remain applicable to sediment remediation in Commencement Bay. In situ solidification/stabilization processes are considered to be at a conceptual level of development for the treatment of contaminated sediments, and are therefore not explicitly represented during the development of remedial alternatives. They are instead retained as a possible process option to be used in conjunction with in situ containment.

3.2 SOURCE CONTROLS

Contamination in Commencement Bay sediments is the result of industrial activities, waste disposal practices, and surface water management practices. Efforts to reduce or eliminate further introduction of contaminants from the various sources is essential to the overall sediment remedial effort. Remedial technologies potentially applicable to source control are presented in this section. This discussion of source control technologies is not comprehensive and is intended to provided guidance for future studies

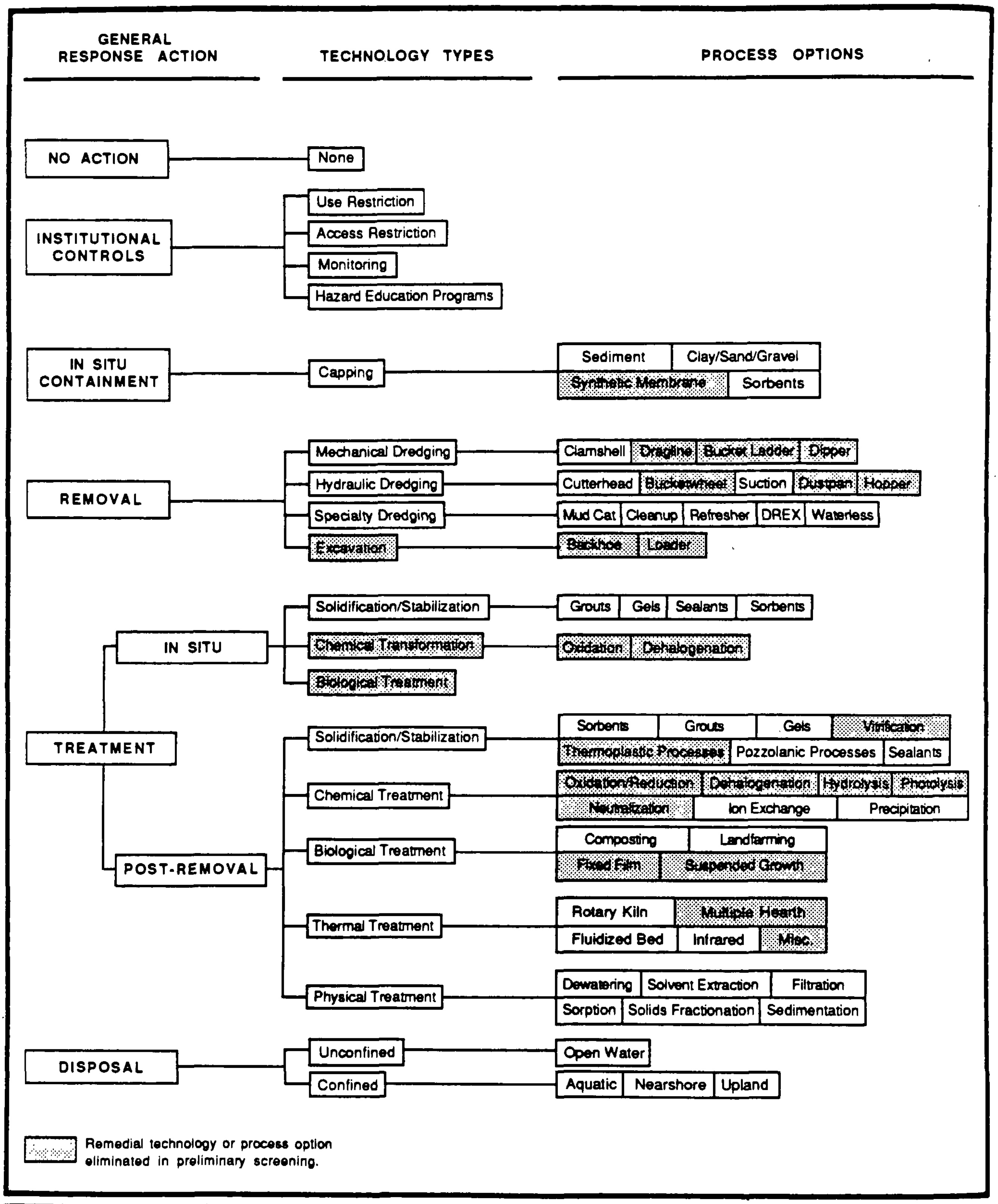


Figure 3-6. Potential sediment remedial technologies and process options that are retained for further evaluation.

focusing on specific sources. Information for the technology discussions was drawn from U.S. EPA (1984, 1985a,b, 1986a,b, 1987), Wilson et al. (1986), Rich and Cherry (1987), and Schueler (1987). The four general sources discussed here are groundwater, surface water, soil, and air.

3.2.1 Groundwater

Past hydrogeologic investigations in the Commencement Bay N/T study area indicate that three distinct aquifers underlie the vicinity (AWARE 1981). Groundwater reportedly occurs under water table conditions in the surficial aquifer, and under confined conditions in two deeper aquifers. Previous studies suggest that the prevailing hydraulic head differential tends to concentrate contaminants from surficial sources in the 25- to 50-ft depth horizon. Downward migration of pollutants is prevented below this elevation by upward pressures in the deeper zones (Walker Wells 1980b). Upward and downward groundwater pressure-gradient effects have also been attributed to the controlling influence of tidal fluctuations in Commencement Bay. During low tides, Commencement Bay seawater exerts minimal back pressure on the aquifer system, and water table gradients steepen toward the bay and adjacent waterways. During high tides, the maximum back pressure is exerted and the water table rises, forcing groundwater flow landward. The surficial aquifer in the vicinity of the study area is regarded as brackish with specific conductivity values ranging up to 19,400 umhos/cm.

Although the hydrogeologic characteristics of the area have not been thoroughly characterized, some hydraulic variables of the shallow groundwater in the study area have been measured. Flow velocities have been found to range from 4.9 ft/day at low tide to 0.4 ft/day at high tide (Hart-Crowser & Associates 1983). Hydraulic gradients have been measured in the range of 0.001 to 0.011 ft/ft, with a general average of approximately 0.005 ft/ft (Hart-Crowser & Associates 1983). The specific yield of the surficial aquifer has been calculated at 0.2, with a coefficient of permeability of approximately 50 gal/day/ft^2 (Walker Wells 1980b).

Institutional Controls--

Institutional controls are nonstructural measures to mitigate the public health and environmental impacts associated with contaminated groundwater in the Commencement Bay study area. Restrictions on access or use of contaminated groundwater would be considered as institutional controls. Institutional controls are also available for preventing the contamination of surface water which would (see Section 3.2.2) affect the potential for groundwater contamination.

Containment--

Containment technologies prevent uncontaminated groundwater and infiltrating surface water from contacting contaminated areas (for a discussion of surface water diversions see Section 3.2.2). Lateral and downgradient movement of a contaminated plume can also be restricted by these technologies, which include caps, vertical barriers, horizontal barriers, and gradient controls.

Capping--Surface sealing or capping is intended to prevent infiltration of surface water. Infiltrating surface water may transport contaminants into groundwater by mobilizing them from soil, buried sludges, slag, or landfills. Paving is the most common surface sealing or capping method currently used in the Commencement Bay area. Cement, clay, native soil, a synthetic membrane, or a combination of these materials may be used. Flexible synthetic liner materials currently in use consist of polyvinyl chloride (PVC), chlorinated polyethylene, ethylene propylene rubber, butyl rubber, neoprene, and elasticized polyolefin (U.S. EPA 1985d). The effectiveness of a cap in reducing permeability varies, depending on cap material and construction methods selected. Because the Commencement Bay area is characterized by a relatively shallow water table, some type of barrier may be required in combination with a cap to prevent contact of groundwater with contaminated soils.

Surface caps are usually designed to conform to performance standards of RCRA landfill closure requirements. These standards include minimum liquid migration through the wastes, low cover-maintenance requirements, effective site drainage, resistance to loss of structural integrity (e.g., from subsidence), chemical stability, and a permeability lower than or equal to the underlying liner system or natural soils (U.S. EPA 1985d). Multi-layered caps are often required to meet the above standards for performance. Prior to capping, soils may also be treated with lime or nonhazardous ash to provide cementing properties, optimize grain size distribution, and reduce shrink/swell behavior.

Vertical Barriers--Vertical barriers are subsurface cutoff walls or diversions that contain, capture, or redirect lateral groundwater flow in the vicinity of a contaminated site (U.S. EPA 1985d). Slurry walls are the most commonly used barriers, followed by sheet piling, and grout curtains.

Slurry walls provide a relatively inexpensive means of reducing or redirecting groundwater flow in unconsolidated materials. The wall extends vertically from the ground surface to an impervious zone below the contaminated aquifer. The most common slurry is a mixture of soil, bentonite, and water. Slurry walls offer low installation costs, a wide range of chemical compatibilities, and low permeabilities (U.S. EPA 1985d). Soil/bentonite slurries may be incompatible with strong acids and bases, strong salt solutions, and some organic chemicals, which may restrict its use in the Commencement Bay area. This mixture also exhibits the highest compressibility, and hence the least strength, and is restricted to sites that can be graded to nearly level because of its relatively low viscosity compared with other slurries. A cement/bentonite mixture, made up of Portland cement, bentonite, and water, can also be used. This slurry sets up into a semirigid solid and can accommodate variations in topography. The cement/bentonite slurry is less elastic (stiffer) but more susceptible to fracture and more permeable than the soil/bentonite mix. Cement/bentonite mixtures are susceptible to attack by sulfates, strong acids and bases, and highly ionic substances (U.S. EPA 1985d).

Sheet piling can also be used to form a groundwater barrier. Because of cost and unpredictable integrity, sheet piling is used primarily for temporary dewatering or erosion protection. Sheet piles can be made of wood, precast concrete, or steel. Steel is generally considered to be the most effective in terms of efficiency and cost (U.S. EPA 1985d).

Grout curtains are formed around a zone of contamination by injecting a grouting mixture into well borings. These borings are usually arranged in a pattern of two or three adjacent rows in order to extend the curtain width. The fluid is injected under pressure, filling voids within the subsurface material, and reducing the hydraulic permeability of the material as it hardens. Grout curtains should be extended to an impermeable layer for maximum effectiveness. Compatibility of grouting material with the waste is essential. Grout curtain technology is not applicable for very fine-grained or permeable soil conditions, or for situations where heterogeneous geologic conditions exist.

Horizontal Barriers--Horizontal barriers are constructed beneath zones of contamination and are intended to control the vertical flow of contaminated groundwater, redirect uncontaminated groundwater, or lower the water table within an isolated area. Two approaches to formation of horizontal barriers are grout injection and block displacement. Both methods are in the development stage (U.S. EPA 1987). Grout injection consists of drilling a series of holes across a site and injecting grout at the base of the borings to form a horizontal or curved barrier.

Block displacement is an extension of grout injection technology and involves complete isolation of a large earthen mass or block of earth by means of a subsurface physical barrier (U.S. EPA 1983a). The barrier system comprises a vertical perimeter and a horizontal bottom barrier. The vertical component is constructed using one of the conventional techniques described above. The bottom barrier is initiated by creating horizontal notches at the base of two or more injection borings followed by the pumping of a slurry mixture into the injection zone. Injection of the slurry continues under pressure, with propagation of the notches eventually resulting in a single separation zone. As water drains from the perimeter and bottom barriers, a low permeability cake or grout is formed, which effectively isolates the block of earth from surrounding strata. Block displacement technology is not fully developed.

Neither grout injection nor block displacement is suitable for heterogeneous or unconsolidated conditions. For waste site remediation, grouting technologies are most appropriate for sealing voids or fractures in rock formations (U.S. EPA 1985d). No documented applications of bottom sealing or bottom barrier techniques to hazardous waste sites have been reported (U.S. EPA 1985d).

Gradient Control--Groundwater levels may be manipulated to redirect subsurface flow by using various drain or well systems. In shallow aquifers, subsurface collection trenches and drains immediately downgradient of the contaminated groundwater can be used to route the contaminated flow towards a predetermined collection point for subsequent remediation.

Upgradient interception trenches can be used to capture and redirect unaffected groundwater, thus reducing the volume of contaminated groundwater requiring collection or treatment. Gravel drains, perforated pipe drains, or dual media drains may be used, depending on site-specific conditions and requirements.

Extraction wells, in combination with injection wells where hydraulic conductivities are moderate, can also be used to alter gradients. Extraction and injection wells are often used in combination with subsurface barriers to control groundwater movement by reducing or increasing flow. Local hydrogeology should be thoroughly characterized before designing and implementing controls involving extraction and injection wells. Special design considerations are required for semiconfined aquifers, such as the secondary aquifer in the Commencement Bay study area in which contamination has been documented.

Collection--

Contaminated groundwater may be actively collected for subsequent treatment by pumping, or passively collected in subsurface drains.

Groundwater Pumping--Groundwater pumping techniques described above for gradient control may be used to collect groundwater for treatment and disposal. Clean water injected under pressure may help flush contaminants from the subsurface materials into the groundwater, in addition to directing flow towards the extraction wells. This technology is limited by the chemical and physical properties of the contaminants and the aquifer. The types of wells used in groundwater monitoring and pumping systems include well points, suction wells, injector wells, and deep wells. Caution must be exercised to avoid saltwater intrusion into nonsaline groundwater systems in the Commencement Bay vicinity.

Subsurface Drains--Subsurface drains can also be used to collect groundwater. Contaminated groundwater can be collected downgradient for treatment, or clean groundwater can be collected upgradient. Upgradient drains and flow barriers can be used to divert flow away from the contaminated zone and the downgradient collection system to reduce treatment volumes. Typically these drains are not feasible for collecting groundwater at depths greater than 50 ft because of construction difficulties. In the project area, drains are potentially applicable to problems at log sorting yards (if shallow groundwater is determined to be contaminated) and waste burial locations (if underlying groundwater is protected by an impermeable layer). Subsurface drains are generally more cost-effective than other groundwater collection methods (e.g., pumping) if contamination is confined to the upper aquifer.

In Situ Treatment--

In situ treatment techniques are receiving increased attention for the remediation of water table aquifer systems contaminated with organics (Wilson et al. 1986). Biological treatment approaches are based on the stimulation of indigenous microbial populations that are physiologically capable of degrading a variety of organic contaminants. Augmentation of natural populations with genetically altered organisms or with bacteria that selectively degrade target compounds remains unproven technologically. Physical/chemical methods of in situ groundwater treatment have not been demonstrated for remediation of contaminated aquifers. Approaches to biological in situ treatment typically include groundwater pumping, above-surface treatment, nutrient and oxygen enrichment of treated water, and reinjection to the contaminated aquifer.

Pumping in conjunction with physical barrier systems serve to control and contain the contaminant plume. Above-surface treatment may include a sequence of process steps to remove metals and volatile organics. Possible process options are similar to those discussed for contaminated dredge water in Section 3.1.5. Nutrients such as nitrogen and phosphorus may be added to the treated water as needed. If air stripping is one of the treatment steps, further oxygen enrichment is generally not needed. Otherwise, a separate oxygenation step may be considered. This step can be accomplished using either air or elemental oxygen, or through the addition of a dilute stream of hydrogen peroxide. The prepared water is then channeled to an infiltration zone for recharge of the contaminated aquifer. Direct injection of air or oxygen into the aquifer may be considered as an alternative or additional aeration measure.

Post-Removal Treatment--

Treatment is generally required for groundwater extracted by a collection program. Numerous physical, biological, and chemical treatment processes are available to remove contaminants from aqueous wastes. Many of the methods are widely used in municipal and industrial waste treatment, and their effectiveness and limitations are well known. Treatment methods applicable to a surficial aquifer in the project area must include the impacts of brackish water that may be present. Saline groundwater has been successfully treated in the past. However, a complete chemical characterization must be conducted to provide a thorough understanding of the chemical matrix subject to treatment.

<u>Biological Treatment</u>--Technologies for the treatment of contaminated groundwater using above-surface biological systems have been demonstrated (Nyers, E., 11 November 1987, personal communication). However, most conventional approaches using trickling filter, activated sludge, and rotating biological contactor technology are not suitable for the special requirements of groundwater treatment systems. These systems must be designed to operate under variable feed conditions and at much lower substrate concentrations than conventional systems are capable of handling. Compounds that are readily biodegraded include alcohols, phenols, carbonyl compounds, and a variety of petroleum hydrocarbons. Chlorinated compounds are generally not suitable for biological treatment. High metals concentrations can adversely affect biological systems. At least one operational system is treating contaminated groundwater with a total dissolved solids concentration of 15,000 ppm, and seawater salinities of around 30,000 ppm are not believed to present a problem for biological treatment (Nyers, E., 11 November 1987, personal communication).

Physical Treatment--Physical treatment involves the following methods to remove contaminants: phase separation, sedimentation, coagulation and flocculation, filtration, air or gas stripping, distillation, ultrafiltration, reverse osmosis, carbon adsorption, and resin adsorption. Phase separation takes place in a settling tank where liquids of different densities separate into discrete layers. Oil and other floating products are collected by a skimmer for subsequent handling. Chemical additives may be used to enhance separation.

Sedimentation and settling processes involve the sinking of suspended particulates, which may have adsorbed contaminants. For certain contaminants, addition of a chemical flocculating agent to the liquid enhances the aggregation of suspended particles, which can then settle by gravity. This method is used to separate suspended colloidal particles from a liquid. In liquids below pH 7.5, arsenic, cadmium, and chromium can be removed by precipitation processes (U.S. EPA 1986a). For organic compounds, which form organometallic complexes (U.S. EPA 1985d), cyanide, and other ions interfere with precipitation.

Filtration separates particles suspended in groundwater by forcing the liquid through a porous filter medium. Trapped particles form a cake which can be periodically removed as necessary, and the filter can be regenerated by backwashing.

Ultrafiltration removes solutes with high molecular weights by using a semipermeable membrane under a low pressure gradient. Reverse osmosis involves filtering contaminated water through a semipermeable membrane at a pressure greater than the osmotic pressure caused by the dissolved materials in the water. Because membrane surfaces are susceptible to clogging, influent suspended solids concentrations must be fairly low. Both are emerging technologies (U.S. EPA 1987). Ultrafiltration will be adversely affected by the salinity of the dredge water from Commencement Bay.

Air and gas stripping may also be effective in remediating groundwater contaminated with volatile organic contaminants. Air stripping is frequently accomplished in a packed tower system with an air blower. Generally, components with Henry's Law constants of greater than 0.003 can be effectively removed by air stripping. Stripping is often only partially effective and may be followed by another treatment process such as carbon adsorption (U.S. EPA 1985d). Carbon adsorption may also be used to remove organics in the air stream prior to discharge.

Carbon adsorption methods can be used to remove many organic contaminants (e.g., chlorinated hydrocarbons, phenols, aromatics). Per unit volume, activated carbon has a large surface area onto which contaminants can be adsorbed. Compounds with low water solubility, high molecular weight, low polarity, and low degree of ionization are most effectively removed by carbon adsorption. Some heavy metals (e.g., arsenic and chromium) and some inorganic species have shown good to excellent adsorption potential (U.S. EPA 1985d). Although saline solutions have little effect on the system, high concentrations of inorganic salts and certain pH ranges cause scaling. Suspended solids concentrations greater than 50 mg/kg and oil and grease concentrations greater than 10 mg/kg cause clogging and should be removed by other means prior to carbon treatment (U.S. EPA 1987). Spent carbon can be regenerated thermally. To minimize the expense and volume of carbon, this treatment method is often used as one of the last steps in a treatment scheme.

Solvent extraction allows recovery of certain dissolved contaminants from groundwater by utilizing an immiscible liquid for which the components have a high affinity. Solvent extraction in most cases requires the use of other treatment processes (e.g., distillation or air stripping) to effectively remove residual impurities before discharge. Several stages of solvent extraction would be necessary for treating organic contaminants at the Commencement Bay site. Application of solvent extraction to treat groundwater is costly and would require pilot studies.

Chemical Treatment--Potential chemical treatment technologies appropriate for post-removal groundwater remedial action are identical to those discussed in conjunction with treatment of contaminated dredge water (Section 3.1.5).

Preliminary Screening of Groundwater Remedial Technologies--

The following technologies appear to have the greatest applicability to contaminated groundwater in the study area:

- Capping
- Certain vertical barriers
- Gradient controls (e.g., pumping, subsurface drains) both to contain and to collect groundwater
- Post-removal treatment, particularly by carbon adsorption and ion exchange.

In all cases, the local hydrogeology and the chemical and physical characteristics of the contaminated groundwater must be thoroughly understood.

3.2.2 Surface Water

Surface water in the Commencement Bay watershed can be contaminated from specific point sources such as facility operations and from areawide sources such as urban runoff. Although the strategy for implementation will differ between the two kinds of sources, the same remedial technologies will apply.

Methods of controlling contaminants in urban runoff are often called best management practices (BMPs). These BMPs include measures of institutional control, containment and diversion technologies, and collection techniques. The effectiveness of various technologies is highly variable and depends on a number of factors, including the nature and extent of contamination in runoff, the sources of contamination, local topographic features, and design considerations. Schueler (1987) compared the effectiveness of various urban BMP designs and developed the results presented in Figure 3-7. As shown in the figure, the different designs range in effectiveness from 0 to 100 percent. Some BMPs believed to be appropriate for the Commencement Bay study area are discussed in the following sections. Treatment technologies are also discussed.

Institutional Controls--

Institutional controls involve nonstructural practices to reduce the level of contamination in surface water runoff that reaches the waterways of Commencement Bay. Both quantity and quality may be controlled by the following kinds of management practices:

- Maintenance of existing drainage systems (e.g., regular cleaning of oil/water separators)
- Street sweeping
- Soil management (e.g., revegetation)
- Public education
- Land use regulations.

Maintenance of Drain System--Proper maintenance of existing drainage systems features designed to reduce runoff quantity and control quality is a requirement for continued system efficiency. For example, oil/water separators are typically placed in storm drain systems in areas with high vehicle use (e.g., parking lots, maintenance areas, car wash facilities) to remove floating oil and grease from the runoff prior to discharge. These systems must be cleaned regularly to prevent oil and grease from being resuspended and discharged during subsequent runoff events. Oil/water separators would be applicable to many of the industrial sites in the study area. The City of Tacoma is currently requiring the installation of oil/water separators in drainage systems for automobile dealers, car washes, and automobile detailers. Discharge from the separators will be routed to the sanitary sewer system.

Street Sweeping--Street sweeping is a common method of removing dirt and debris from city streets. Street sweeping reduces the amount of sediments washed off street surfaces by storm water and, in theory, decreases suspended solids and associated contaminant loadings in stormwater runoff. However, investigations have found that street sweeping is not an effective means of controlling contaminant loading because sweepers preferentially remove the large-grained particles rather than the smaller particles, which adsorb most of the contaminants (U.S. EPA 1983b). Modified street cleaners have also been tested in an effort to reduce respirable fugitive dust emissions. Modified street cleaners showed substantially better performance than regular mechanical street cleaners in removing small particle sizes. However, for the smallest particle size measured (<125 um), inconsistent

BMP/design	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	TOTAL NITROGEN	OXYGEN DEMAND	TRACE METALS	BACTERIA	OVERALL REMOVAL CAPABILITY
EXTENDED DETENTION POND							
DESIGN 1	◕	◔	◔	◔	◑	⊗	MODERATE
DESIGN 2	●	◑	◔	◑	◕	⊗	MODERATE
DESIGN 3	●	◕	◑	◑	◕	⊗	HIGH
WET POND							
DESIGN 4	◕	◑	◔	◔	◔	⊗	MODERATE
DESIGN 5	◕	◑	◔	◔	◕	⊗	MODERATE
DESIGN 6	●	◕	◑	◑	◕	⊗	HIGH
INFILTRATION TRENCH							
DESIGN 7	◕	◑	◑	◕	◕	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
INFILTRATION BASIN							
DESIGN 7	◕	◑	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
POROUS PAVEMENT							
DESIGN 7	◑	◕	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◕	◕	◕	●	●	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
WATER QUALITY INLET							
DESIGN 10	○	⊗	⊗	⊗	⊗	⊗	LOW
FILTER STRIP							
DESIGN 11	◔	○	○	○	◔	⊗	LOW
DESIGN 12	●	◑	◑	◕	●	⊗	MODERATE
GRASSED SWALE							
DESIGN 13	○	○	○	○	○	⊗	LOW
DESIGN 14	◔	◔	◔	◔	○	⊗	LOW

KEY:

- ○ 0 TO 20% REMOVAL
- ◔ 20 TO 40% REMOVAL
- ◑ 40 TO 60% REMOVAL
- ◕ 60 TO 80% REMOVAL
- ● 80 TO 100% REMOVAL
- ⊗ INSUFFICIENT KNOWLEDGE

Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 1.0 inch, detained 24 hours.
Design 3: As in Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 0.5 inch storage per impervious acre.
Design 5: Permanent pool equal to 2.5 (Vr); where Vr=mean storm runoff.
Design 6: Permanent pool equal to 4.0 (Vr); approx. 2 weeks retention.
Design 7: Facility exfiltrates first-flush; 0.5 inch runoff/imper. acre.
Design 8: Facility exfiltrates one inch runoff volume per imper. acre.
Design 9: Facility exfiltrates all runoff, up to the 2 year design storm.
Design 10: 400 cubic feet wet storage per impervious acre.
Design 11: 20 foot wide turf strip.
Design 12: 100 foot wide forested strip, with level spreader.
Design 13: High slope swales, with no check dams.
Design 14: Low gradient swales with check dams.

Figure 3-7. Comparative pollutant removal of urban best management practice (BMP) designs, as determined by Schueler (1987).

results were obtained for all street cleaners. Therefore, the effectiveness of the technology is questionable (Pitt and Bissonnette 1984). The City of Tacoma operates a street cleaning program, but its effectiveness in controlling contaminants in surface runoff has not been evaluated.

Soil Management--Proper management of surface soils is required to prevent excessive dispersion of sediment and associated contaminants in runoff. Establishment of vegetative cover on barren areas helps to reduce soil erosion. Revegetation is also used to stabilize the surface of hazardous waste disposal sites and commonly functions as the upper layer in multilayer capping systems. Revegetation may not be feasible at sites exhibiting high concentrations of phytotoxic chemicals or poor moisture and soil conditions. Therefore, in many cases, revegetation is preceded by other remedial activities such as waste removal, grading, terracing, and fertilization.

The basic elements in designing a revegetation program for soil management include the following points:

- Selection of a suitable plant species
- Preparation of soil to maintain growing conditions (e.g., stabilization, grading, mulching, neutralization, fertilization)
- Determination of optimum time for planting
- Maintenance (i.e., irrigation, fertilization).

Public Education Programs--Public education programs can be effective in reducing the contaminant loading resulting from the improper disposal of waste oils, solvents, and other household hazardous materials. Public inattention to safe disposal practices can be addressed through well-timed press releases, public service announcements, utility bill inserts, informational pamphlets distributed at the point of purchase of household chemicals, and programs within the local communities and public school system. The City of Bellevue reported that increased public awareness significantly reduced the dumping of wastes in catch basins and improved neighborhood control of pet wastes and litter (Finnemore 1982). State- and city-sponsored programs to collect hazardous wastes from the public may also be effective in reducing the source of contaminants to the city storm drain system.

The City of Tacoma has instituted a public awareness and education program as part of an agreement with Ecology. The program has been developed by the Tacoma-Pierce County Health Department and is targeted specifically towards the Commencement Bay area of Tacoma. The major elements of the program are as follows:

- Informational meetings with chamber of commerce and civic groups

- Distribution of informational pamphlets on household hazardous wastes as inserts to utility bills

- Provision of information and guidance to business as part of the inspection program initiated by the city sewer utility

- Cartoon coloring books for children.

The program is currently budgeted for the duration of the city storm drain program (summer 1988). In addition Tacoma-Pierce County Health Department is sponsoring a city- and county-wide household hazardous waste collection day. The first collection day occurred on 26 September 1987 and is expected to continue as an annual event (Pierce, D., 14 August 1987, personal communication).

Land Use Regulation--Implementation and enforcement of the following examples of land use regulations can reduce inputs to the storm drainage system:

- Onsite collection and treatment of stormwater runoff at new residential, commercial, and industrial developments

- Erosion and sedimentation controls at construction sites.

Containment--

Containment technologies for surface water are designed to prevent generation of contaminated runoff by diverting clean water away from contaminated areas, controlling erosion of exposed waste piles, or both. Run-on can be prevented by structurally routing drainage away from the waste source (i.e., via surface diversions). Erosion of contaminated waste piles can be controlled by revegetating, capping, or reshaping the land surface in question.

Surface Diversion--Surface diversion process options include dikes, berms, diversion channels, floodwalls, terraces, and grading.

Dikes and berms are well-compacted earth embankments constructed around the perimeter or immediately upslope of waste disposal areas to prevent surface runoff from contacting contaminated soil zones. In addition, these structures are widely used to provide temporary isolation of wastes and surface runoff during removal or treatment operations. Flood control dikes are designed to prevent surface water inundation of contaminated soil zones during flooding events and therefore tend to be much larger structures than dikes intended for stormwater management. U.S. Soil Conservation Service standards describe three classifications of flood control dikes, based on the level of protection required (Ehrenfeld and Bass 1983).

Open channels are conventional drainage structures which can be used at hazardous waste sites for the collection and eventual containment of contaminated surface water or for transfer of diverted clean water away from zones of contamination. Channel stabilization may be required, depending on bed slope and whether use as a waterway is intended. Channels with parabolic cross sections are preferred for use at hazardous waste sites because they cause less erosion than alternative configurations.

Land surfaces can be reshaped through grading, terracing, and bench construction to control surface runoff and reduce erosion. Grading is relatively inexpensive and can be used to either promote or reduce surface runoff, depending on site conditions. Regrading to cause an increase in surface runoff is typically used to prevent infiltration and thereby control groundwater contamination at landfills and waste disposal sites, and is used in conjunction with surface sealing and capping techniques. Landfill and waste disposal site surfaces are graded to increase the slope so that most of the rainfall runs off the surface rather than infiltrating through the waste materials.

Reduction of surface runoff by regrading the land surface is an effective means of controlling soil loss in areas where there are steep slopes that accelerate erosion. However, because there is little surface relief in most of the tideflat areas, grading is probably unnecessary. Terraces and benches generally serve the same function by reducing slope length.

The primary application of grading in the Commencement Bay study area is recontouring the land surface to route surface runoff away from contaminated areas and to direct runoff to collection and treatment systems. For example, one facility has combined surface grading with berm and curb construction to collect runoff from the property and route it to the facility's wastewater treatment plant (Parametrix 1987).

Revegetation--This technology is discussed above.

Surface Capping and Sealing--Surface capping and sealing isolate buried waste materials to prevent surface water runoff and rainfall from contacting them. Although capping is typically considered a groundwater control technology, it also provides surface water control. Other surface water controls such as ditches, dikes, and grading are commonly used in conjunction with capping to collect rainwater drainage from the capped area.

Collection--

Surface water may be collected for treatment or disposal by using the same routing mechanisms described for containment (e.g., dikes, berms, diversions channels, grading).

Treatment--

Discussions presented above for the physical, chemical, and biological treatment of contaminated dredge water and groundwater are applicable to the treatment of contaminated surface water. A special consideration in the case of surface water is that the volumes of contaminated water collected are likely to be very small in comparison to the volumes that would be generated during groundwater and dredge water remedial efforts. This suggests that batch treatment systems would be appropriate for consideration.

Data from a number of studies conducted on the effectiveness of detention and retention basins for treatment of stormwater runoff indicate that removals of up to 75 percent total suspended solids, 99 percent lead, 98 percent zinc, 60 percent copper, 55 percent cadmium, and 50 percent nickel are achievable (McCuen 1980; Whipple and Hunter 1981; and Horner and Wonacott 1985). Studies on the effectiveness of grassy swales for removal of particulates and metal contaminants in storm water have revealed that removals of over 90 percent for iron and lead, 75 percent for copper, and 84 percent for zinc (Miller 1987). Removal efficiencies varied with nature and duration of storm event, basin design, antecedent weather conditions, and other factors.

Preliminary Screening of Surface Water Remedial Technologies--

The following technologies appear to have the greatest applicability for controlling contamination carried in surface water runoff:

- Institutional controls (e.g., drain maintenance, revegetation, erosion control), primarily applicable to reduce contamination from ongoing inputs not related to contaminant reservoirs onsite

- Capping

- Surface diversion to prevent or collect runoff

- Treatment of collected runoff.

3.2.3 Soil

Soil acts as a sink for immobile contaminants and as a reservoir or conduit for more mobile contaminants. Groundwater quality may be affected by surface water percolating through contaminated soil in the unsaturated zone. Surface water may also become contaminated via direct contact with contaminated soil. For this reason, soil control technologies include many of those described for groundwater and surface water. Removal options (e.g., excavating contaminated soil), which were not generally discussed as source control technologies for other media, are relevant for contaminated soil. In situ treatment is also more applicable to soil than to other media.

Institutional Controls--

Restricting access to contaminated areas may reduce public health risks caused by inhalation, ingestion, or dermal contact with soil particulates. Access restriction alone, however, does not reduce the potential for migration of contaminants into groundwater and eventually offsite via surface water or groundwater. Remediation of contaminated soils can be conducted under federal, state, and local regulatory statutes.

Containment--

Containment technologies applicable to soil include caps, vertical barriers, horizontal barriers, revegetation, and surface diversion techniques. These technologies are described in Sections 3.2.1, and 3.2.2.

Removal--

The removal of contaminated soils from hazardous waste sites is accomplished using conventional earth moving equipment such as backhoes, front end loaders, and bulldozers. Excavation plans generally include provisions to minimize the amount of soil removed. After cleanup levels are established, removal operations are conducted in several steps, each of which is followed by sampling and analysis to determine the levels of remaining contamination and the need for further excavation.

In Situ Treatment--

In situ treatment methods are most suitable for spills and plume-type contamination where the contaminants are homogeneous and evenly distributed. Some of the techniques may be limited to shallow areas (e.g., less than 2 ft deep) or those lying above the water table (U.S. EPA 1984). More than one technique may be needed if there is a diverse mixture of contaminants.

Stabilization/Solidification--Stabilization reduces the solubility or chemical reactivity of waste by changing its chemical state or by physical entrapment (microencapsulation). Solidification converts the waste into an easily handled solid with reduced hazards from volatilization, leaching, or spillage. Both stabilization and solidification improve the containment of contaminants in treated wastes. Combined processes are often referred to as encapsulation or fixation. Stabilization and solidification are discussed in Section 3.1.5 for treating contaminated dredged material. Among various technologies, lime-fly ash processes and pozzolan-Portland cement systems are probably most feasible and relatively inexpensive for large volumes of contaminated soil. Pozzolan solidified wastes are less stable and less durable than pozzolan-Portland cement composites. Leaching losses from the pozzolan-waste materials have been considered to be relatively high compared with those for pozzolan-Portland cement waste materials. A number of materials such as sodium borate, calcium sulfate, potassium bichromate, chlorides, and carbohydrates will interfere with the binding reaction and prevent bonding of materials. Oil and grease can also physically interfere with bonding by coating waste particles. Both processes are considered potentially viable for soil treatment.

Physical Treatment--Physical treatment techniques include heating, attenuation, and reduction of volatilization. In situ heating methods use steam injection or radio frequency heating to destroy or remove organic contaminants. Because of their early stage of development, use of these technologies in the Commencement Bay study area is currently not feasible.

Attenuation techniques involve mixing clean soil or other material with the contaminated soil to reduce contaminant concentrations. The level of volatile emissions can be reduced in situ by reducing pore volume or by cooling the soil. These same in situ techniques can be used to retain the volatile contaminants for subsequent treatment.

Chemical Treatment--In situ chemical treatment methods for contaminated soils are developmental or conceptual and have not been fully demonstrated for hazardous waste site remediation (U.S. EPA 1985d). The single in situ method that shows promise is solution mining, also referred to as soil flushing. This technique has been used extensively by the chemical processing and mining industries but has had limited application in the treatment of hazardous wastes (U.S. EPA 1987). Solution mining involves the injection of a solvent or aqueous solution, containing complexing agents, into the soil. Following passage through the zone of contamination, this solution is then collected at wells. Pilot tests for the decontamination of soils containing PCBs and dioxins using chemical treatment have been conducted by the U.S. EPA.

Biological Treatment--In situ treatment of organic contaminants by biological organisms may be enhanced in several ways (see also Section 3.2.1). Activity of naturally occurring organisms can be enhanced by adjusting soil moisture, oxygen content, pH, or nutrient content. Addition of organic amendments (e.g., supplemental carbon or other energy sources) may stimulate treatment of some xenobiotic compounds (U.S. EPA 1984). Artificial enrichment analogs (compounds chemically similar to the hazardous compounds of interest) can result in co-metabolism of the hazardous compound. For example, biphenyl has been successfully used to stimulate co-metabolism of PCBs (U.S. EPA 1984). Addition of exogenous organisms that have acclimated to the contaminated soil (e.g., via mutation or genetic engineering) can result in improved treatment, if their growing conditions are optimized (U.S. EPA 1984). The addition of enzymes obtained from organisms able to degrade hazardous wastes theoretically should accelerate degradation.

Post-Removal Soil Treatment--

Technologies discussed in Section 3.1.5 for sediments are also applicable to the treatment of soils. In particular, thermal treatment for the removal of organics and solidification to immobilize metals are proven soil remediation technologies. For soils containing biodegradable organic compounds and low concentrations of metals, land treatment is a viable alternative. Solvent extraction using the BEST™ process is also potentially viable for treatment of contaminated soil.

Preliminary Screening of Soil Remedial Technologies--

The following technologies appear to have the greatest applicability to contaminated soils in the study area:

- Capping
- Certain vertical barriers
- Surface diversion of run-on and runoff

- In situ treatment for well-characterized shallow contamination
- Removal
- Certain post-removal treatments.

Many of the technologies are used only for specific waste types (e.g., inorganic compounds, metals), whereas other technologies are nonspecific in their action. The nonspecific technologies can alter the soil matrix detrimentally for other uses.

3.2.4 Air

Air pollution resulting from contaminated sites in the study area is not considered a major problem relative to the other media, particularly since the ASARCO smelter has ceased operation. Air pollutants reach surface water and sediments of Commencement Bay in two ways: by settling directly on the water, and by settling on the land and then washing into the waterways. Stack emissions in the problem area are regulated by federal, state, and local regulations in conjunction with PSAPCA.

Contamination of the air can result from gaseous emissions and fugitive emissions. Gaseous emissions result from the vaporization of liquids, venting of entrained gases (e.g., from tanks), and biological and chemical reactions with solid and liquid waste material. Fugitive emissions include windblown dusts from waste piles or surface soil, reentrained particulates distributed by vehicles, and dusts generated during waste excavation. Technologies for controlling airborne contaminants are described below for gaseous and fugitive emissions. Containment, collection, removal, and treatment technologies are integrated, as applicable, in the following descriptions.

Gaseous Emissions--

Two primary methods of reducing gaseous emissions include covering the evaporative surface to minimize exposure to the air, and installing an active gas collection system. Covers can be used for both liquid and solid wastes. Synthetic material, such as plastics, can be used. For liquid wastes in lagoons or other detention basis, covers can be made by floating spheres or immiscible liquids on the surface.

Active interior gas collection and recovery systems change pressure gradients and gas migration paths within the waste mass by mechanical methods (e.g., pumps, compressors, blowers) and collect the gases in extraction wells or headers. The gas must be treated after recovery. Example treatment methods include adsorption, afterburning, and condensation.

The following technologies are particularly applicable to reduce gaseous emissions from impoundments:

- Increasing freeboard depth in holding tank and storage ponds
- Minimizing the surface area (e.g., by using deeper impoundments with smaller surface dimensions)
- Locating the inflow and outflow pipes to minimize turbulence
- Reducing influent temperature to the ambient temperature in the impoundment
- Installing wind fences around the impoundment
- Minimizing disturbance from operations such as dredging
- Adding bulking agents to tie up the liquids and thereby reduce emissions.

Fugitive Emissions--

Methods to reduce fugitive emissions include spraying dust suppressant chemicals or water, erecting wind fences, and modifying the waste pile. Particulate materials can also be removed physically, by sweeping and vacuuming. Dust suppressants include resins, bituminous materials, polymers, and water. If water is used, spraying must be performed often, on the order of every 2 h (U.S. EPA 1985c). Vegetation can be used as a dust suppressant. Porous wind screens can be erected to deflect or slow wind to speeds below the threshold velocity for migration of the material. Vegetation can also serve the same function.

Waste piles may be modified in several ways to reduce fugitive emissions:

- Aggregate of larger diameter (e.g., large gravel) can be spread on the surface to armor it against wind action
- The surface can be compacted mechanically
- The surface can be covered with a sheet of impervious or porous material
- The slope angle and orientation to the wind can be modified mechanically to reduce wind effects.

In operations that move contaminated materials, techniques that minimize dust generation should be used. For example, an auger feed system can be used instead of a clamshell bucket hauling system.

Preliminary Screening of Air Remediation Technologies--

Approximately 6,000 tons of toxic air contaminants were released in 1986 from Pierce County (Puget Sound Air Pollution Control Agency 1987). Roughly 75 percent of this was generated by nonpoint sources. The degree to which these pollutants are returned to the terrestrial environment by either wet or dry deposition processes is uncertain, but is believed to be negligible in comparison with other sources of contamination. A determination of the significance of public health problems related to these releases is not within the scope of this document.

3.3 DEVELOPMENT OF SEDIMENT REMEDIAL ALTERNATIVES

As discussed previously, sediment remedial technologies may be grouped into one of six viable general response actions: no action, institutional controls, containment, removal, treatment, and disposal. Each general response action consists of one or more technology types and associated process options. Sediment remedial alternatives are developed to define the possible approaches to sediment remediation based on those general response actions. The simplest sediment remedial alternative is no action; the most complex alternative involves removal, treatment, and disposal technologies. Costs and the level of permanency generally increase in progressing from no action to alternatives involving sediment dredging and treatment.

A primary drawback of all operations requiring removal of contaminated sediments or capping with clean fill material is the temporary destruction of existing benthic communities and associated impacts on fish rearing habitats. Past habitat management has frequently focused on replacing lost intertidal or shoreline areas through the use of single, large, offsite habitat projects. Recent efforts in urban embayment projects stress the importance of improving habitats in existing intertidal and shoreline areas (Demming, T., 18 April 1988, personal communication). Mitigation projects in such areas should provide substrates that facilitate rapid recolonization of benthic communities (e.g., incorporating large-grained, rocky material at moderate slopes to maximize productive surface area). In this report, remedial alternatives involving dredging of shoreline and intertidal habitats include replacement of intertidal sediments to preremediation elevations.

A list of the general response actions and representative technology types that passed screening relative to sediment remediation is presented below. These technologies are considered to have the greatest potential for timely and effective remediation of contaminated Commencement Bay sediments.

- No Action
  - Accept current status
- Institutional Controls
  - Use/access restriction

  - Monitoring
  - Education
- In Situ Containment
  - Capping
- Removal
  - Mechanical dredge
  - Hydraulic dredge
  - Specialty dredge
- Treatment
  - Solidification/stabilization
  - Chemical treatment
  - Physical treatment
  - Thermal treatment
  - Biological treatment
- Disposal
  - Unconfined
  - Confined.

3.3.1 No Action

There are no activities or technologies associated with implementing a no-action approach to sediment contamination. This general response action involves only the continuation of ongoing non-CERCLA/SARA permitting and regulatory efforts for the potential contaminant sources within the project area.

3.3.2 Institutional Controls

The viable technology types associated with this general category of response are access restrictions, monitoring, and education. The first type of technology involves actions that restrict access to contaminated sediments as a method of preventing direct exposure (e.g., swimming, diving) or indirect exposure (e.g., consumption of contaminated seafood). Monitoring technologies are incorporated to ensure that restrictions are adequate and appropriate. Education programs are included to provide a forum for dissemination of public information regarding potential hazards and updates on restricted areas. Aggressive regulatory source control measures specifically designed to address the remediation of contaminated Commencement Bay N/T sediments are an integral component of the institutional controls response action.

3.3.3 Containment

For in situ containment of sediments, capping is the only viable technology. For implementation of capping, use of uncontaminated dredged material for the cap was assumed, although the use of a different medium could be considered in a more detailed analysis. In situ solidification coupled with capping may be effective but was not evaluated because subaquatic solidification of sediments is not a developed technology (see Section 3.1.3). Aggressive pursuit of source control measures to facilitate the sediment remediation process is also inherent in this response action.

3.3.4 Removal

Hydraulic and mechanical dredging represent the two fundamental approaches to sediment removal. The pipeline cutterhead dredge is the most commonly used hydraulic dredge in the U.S. and the Pacific Northwest (U.S. Army Corps of Engineers 1985). Several modifications for the removal of contaminated sediments with hydraulic dredges have been developed to improve production capabilities and reduce dredging sediment resuspension (Phillips et al. 1985). Although the pipeline cutterhead dredge was selected to represent hydraulic dredging, specialty hydraulic dredges identified in the preliminary screening of dredging technologies may warrant consideration during final design and equipment selection, especially for dredging in confined spaces or around existing structures. Aggressive pursuit of source controls (i.e., as in institutional controls) is inherent in the removal response action.

The clamshell dredge is the only mechanical dredge retained from the preliminary screening. Although use of a watertight bucket modification was assumed for development of alternatives involving mechanical dredging, a conventional clamshell should also be considered when selecting equipment.

3.3.5 Treatment

Several sediment treatment technologies were selected for further evaluation. Of the possible stabilization/solidification process options, only sorbent stabilization, pozzolan/cement systems, and proprietary stabilizing materials passed the preliminary screening. Pozzolan/cement systems were identified as the representative process option because they are the most protective from the standpoint of contaminant immobilization, particularly when the sediments contain particle-associated organic constituents. In some cases, however, stabilization rather than solidification may be adequate for the reduction of contaminant mobility, and will generally be less expensive. Proprietary stabilizing formulations should also be evaluated during treatability studies to select the most suitable stabilizing material. Aggressive pursuit of source controls (i.e., as in institutional controls) in inherent in the treatment response action.

Within the category of physical treatment, three process options were selected for further evaluation as components of one or more sediment remedial alternatives: solvent extraction using the BEST™ process, sedimentation to remove suspended solids from dredge water, and dewatering to further reduce the moisture content of dredged material. The BEST™ solvent extraction process is potentially applicable to the removal of hazardous organic contaminants (e.g., PCBs, PAH, chlorinated hydrocarbons, phenols). The process essentially concentrates the organics in liquid form, which may then be incinerated or disposed of at much less expense than the dredged material itself.

Sedimentation is essential for nearshore and upland disposal of hydraulically dredged sediments. Chemical flocculation to remove solids remaining in suspension following primary solids removal was assumed to be included in the sedimentation process option. In this case, chemical flocculation would involve the addition of a liquid polymeric flocculent to the effluent from the primary containment and sedimentation area at the weir structure. This process is shown schematically in Figure 3-8.

Dewatering methods, both passive and mechanical, are an essential feature of upland disposal options when landfill requirements must be met. Mechanical dewatering is not evaluated further here, but should be considered in a more detailed evaluation of alternatives involving upland disposal, especially for small volumes of dredged material. In the development of sediment remedial alternatives, passive dewatering in the form of underdrains provided in upland confinement systems was assumed.

Three thermal treatment systems were retained for further evaluation an explicit following preliminary screening: rotary kiln, fluidized bed, and infrared incineration systems. Infrared incineration was selected as the most representative thermal treatment. Mobile systems with high capacities are available, and they have been demonstrated to be effective in treating contaminated soils and sludge-like materials.

No chemical treatment process options were selected for evaluation as an explicit part of sediment remedial alternatives, because none were identified as feasible for the treatment of dredged material solids. Nonetheless, treatment of dredge water by sedimentation followed by flocculation may be necessary to meet water quality criteria. Management of dredge water produced during hydraulic dredging was assumed to involve chemically assisted sedimentation. Mechanical dredging was assumed to result in minimal production of dredge water and negligible treatment costs. The severity of dredge water contamination is determined by the physical and chemical properties of the contaminants and the degree to which they are partitioned among particulate, aqueous, and gaseous phases. Many of the problem contaminants in Commencement Bay sediments have strong particle affinities and may be substantially removed by the sedimentation process alone. Elutriate testing of Commencement Bay dredged material will be necessary during the design phase to determine the need for dredge water treatment.

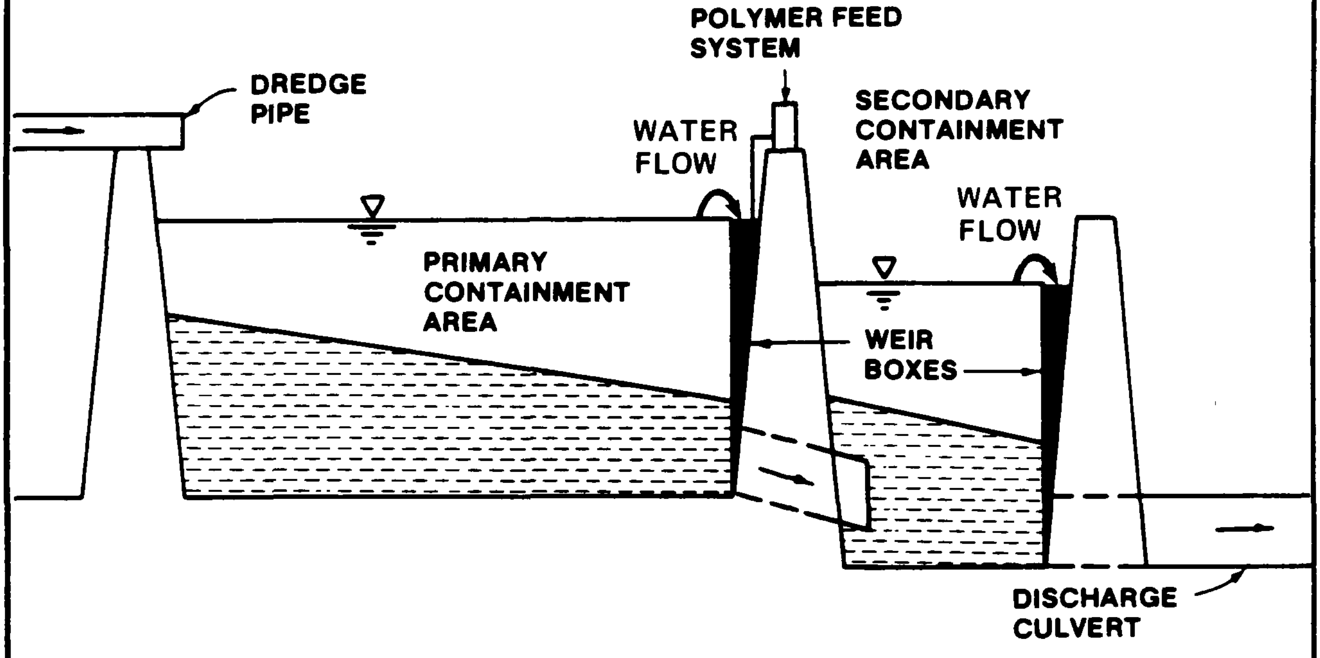


Figure 3-8. Dredge water chemical clarification facility.

3.3.6 Disposal

Disposal technologies include both unconfined and confined process options. Confined aquatic, nearshore, and upland disposal are confined process options. These three confined disposal process options passed preliminary screening. Confined aquatic disposal options include waterway, shallow-water, and open-water techniques using dikes and caps to isolate contaminants. Nearshore disposal options involve dike and cap construction methods for contaminant containment within an intertidal environment. Upland disposal options incorporate underdrains, liners, dikes, and caps to isolate contaminants and control contaminant migration.

For the Commencement Bay N/T FS, long-term cleanup goals were set based on the lowest AET value of the three biological indicators (see Section 1.3.5). PSDDA guidelines for unconfined, open-water disposal use two levels of chemical concentrations for dredged material evaluation. The screening level defines the concentrations below which no adverse effects would be expected at the disposal site. Conversely, the maximum level is used to identify material that would be unacceptable for unconfined, open-water disposal. Sediments exhibiting concentrations between the screening and maximum levels are subjected to biological evaluation to determine disposal status, similar to the process for refinement of volumes for Commencement Bay N/T sediment remediation. Generally the FS target cleanup goals fall between the PSDDA screening and maximum levels. A portion of the Commencement Bay problem sediments may meet PSDDA open-water disposal guidelines. However, because of the impracticality of separating sediments within a problem area that meet open-water guidelines from those that do not, and because of the institutional considerations regarding liability of Commencement Bay problem sediments, unconfined open-water disposal is not considered as part of any remedial alternative. Unconfined open-water disposal may be a feasible option for treated sediments when the level of contamination has been reduced to below target cleanup goals or it has been demonstrated that the potential for adverse biological effects has been eliminated.

3.4 IDENTIFICATION OF CANDIDATE REMEDIAL ALTERNATIVES

The six general response actions and sediment remedial technology types identified above were combined to form the set of ten candidate sediment remedial alternatives presented below:

- No action
- Institutional controls
- In situ capping
- Removal/confined aquatic disposal
- Removal/nearshore disposal
- Removal/upland disposal

- Removal/solidification/upland disposal
- Removal/incineration/upland disposal
- Removal/solvent extraction/upland disposal
- Removal/land treatment.

Each alternative represents a plausible combination of remedial actions for the Commencement Bay sediment remediation effort. As a whole, the set encompasses the range of general response actions and represents all viable sediment remedial action technologies and process options. Implicit in each of the identified sediment remedial alternatives, except no-action, is the aggressive pursuit of source control measures under all existing environmental authorities to reduce contaminant inputs to sediments to the maximum extent possible, using all known, available, and reasonable technologies. The level of achievable contaminant source control must be considered in evaluating alternatives to assess long-term remediation effectiveness and the potential for recreating adverse biological effects. This aspect of the sediment remediation effort is addressed for each specific problem area in Chapters 5-13. Each alternative is defined in more detail below.

3.4.1 No Action

The no-action alternative supplies a baseline against which other sediment remedial alternatives can be compared. Under the no-action alternative, the site would be left unchanged, with no remediation of sediment contamination. This alternative does nothing to mitigate the public health and environmental risks associated with the site, but its evaluation is required by the National Contingency Plan. Absence of any additional source control under the provisions of CERCLA/SARA regulations is an implicit element of this alternative. Potential impacts of the no-action alternative include the following:

- Continued potential for human health effects associated with consumption of contaminated fish and shellfish
- Continued high incidence of fish disease (e.g., liver lesions)
- Continued bioaccumulation of problem chemicals in the aquatic food chain
- Continued depressions of the benthic communities (reducing the value of contaminated areas as habitat for fishery resources)
- Continued acute and chronic toxicity associated with sediments.

3.4.2 Institutional Controls

Institutional controls include access restrictions, limitations on recreational use of nearshore areas, issuance of public health advisories, monitoring, and most importantly, aggressive regulatory control of contaminant sources specifically oriented toward remediation of sediment contamination. Limitations on access and recreation (e.g., fishing, diving) reduce human exposure and risk to public health, but do nothing to mitigate the existing environmental impacts mentioned under the no-action alternative. Some degree of long-term mitigation is expected as a result of reductions in source loadings. The effects of source control on contaminant loadings and on natural recovery of sediments is discussed for each problem area in Chapters 5-13. Monitoring is included in this alternative to permit identification of contaminant migration patterns and assess sediment recovery associated with source control. Monitoring would be designed to allow assessment of changes in risks to public health and the environment before impacts are realized.

3.4.3 In Situ Capping

In situ capping involves containment and isolation of contaminated sediments through placement of clean material on top of existing substrates. Implementation of the in situ capping alternative can only be initiated following implementation of adequate source control measures to ensure that sediment recontamination does not occur. The capping material may be clean dredged material or fill (e.g., sand). In addition, it may be feasible to include additives (e.g., bentonite) to reduce hydraulic permeability of the cap or sorbents to inhibit contaminant migration. In situ capping can substantially reduce the risks of environmental exposure to sediment contaminants.

Both mechanical and hydraulic dredging equipment can be used for in situ capping operations. Cohesive, mechanically dredged material would be placed by using a split-hulled barge. Hydraulically dredged material would be placed by using a downpipe and diffuser. Depending on site topography, diking may be necessary along a margin of the capped sediments to provide lateral cap support.

In situ capping as a sediment remedial alternative has the advantage of preserving the original physicochemical conditions of the problem sediments. This limits the potential for metals mobilization, which can result from bringing predominantly anaerobic sediments into an aerobic environment during dredge and disposal operations. Furthermore, contaminant redistribution from resuspension of sediments during dredging is avoided. Therefore, in situ capping provides a highly protective alternative for isolation of contaminated sediments. The in situ capping alternative can be readily implemented, with no obstacles associated with disposal facility siting. Performance monitoring of capping operations in the shallow environments typical of the Commencement Bay N/T problems areas uses well-established sampling and analytical methods. In addition, construction and engineering controls for in situ capping and diking operations can be easily implemented in the shallow-water environment.

Capping is inappropriate for environments with a high potential for ship scour, currents, or wave action because these disturbances can lead to cap erosion. Currents in the contaminated Commencement Bay waterways are primarily tidal in origin and result in generally quiescent flow conditions. The region along the Ruston-Pt. Defiance Shoreline has currents of sufficient strength to be considered nondepositional in nature (i.e., subject to erosion). Maintenance dredging precludes the use of capping in areas maintained for shipping (e.g., Hylebos, City, and Sitcum Waterways).

For the purposes of evaluating the capping alternative and estimating costs, it was assumed that clean dredged material from the Puyallup River would be used to construct the cap. Although in situ capping has been successfully conducted with hydraulic dredging equipment, for costing purposes it was assumed that the capping material would be dredged using a clamshell to maintain cohesiveness, transported to the problem areas and deposited hydraulically to create a cap with a minimum thickness of 3 ft. Evaluation during design may dictate placement of additional capping material to prevent failure due to erosion or diffusion of mobile contaminants. Additional cap thickness or barrier layers may also need to be included to mitigate the effects of deep burrowing species on cap integrity.

3.4.4 Removal/Confined Aquatic Disposal

As with in situ capping, implementation of the confined aquatic disposal alternative requires that aggressive source control measures be enacted to prevent recontamination of remediated areas. Confined aquatic disposal can also substantially reduce environmental exposure to sediment contaminants. In this alternative, contaminated sediment would be dredged from one location, confined at a different aquatic location, and capped. The several confined aquatic disposal options described in Section 2.0 differ from one another based largely on depth and physical characteristics of the disposal site. Hydraulic or mechanical dredging followed by hydraulic or split-hulled barge placement techniques can be used to implement this alternative.

Four confined aquatic disposal approaches were described in Section 3.1.6. Of these, the open-water and waterway approaches appear to be the most suitable for sediment remediation in Commencement Bay. Shallow-water disposal sites have not been identified. Such sites are considered to be less protective because of the proximity to the water surface and potential for wave-induced erosion of the containment structure. Open-water disposal siting is also somewhat uncertain, but potential sites have been identified in Commencement Bay (Phillips et al. 1985). As compared to the in situ capping alternative, additional time would be required prior to implementation to allow for siting and development of an open-water facility. Placement of contaminated dredged material in an open-water disposal facility followed by capping would effectively minimize the potential for contaminant migration in that nearly in situ physicochemical conditions would be maintained. In addition, the low energy environment of the facility would help ensure cap stability and effectiveness and further aid in reducing the potential for leaching of contaminants to adjacent substrates as compared to nearshore and upland disposal options. Implementation of the confined aquatic disposal alternative in an open-water site would be complicated by the difficulties associated with accurate placement of dredged material at depths exceeding 75 ft. Monitoring and general maintenance activities at an open-water disposal site are also complex and generally more costly than for more accessible sites (e.g., nearshore or upland).

The waterway confined aquatic disposal option is feasible and has the advantage of retaining the contaminated sediments within CERCLA site boundaries. As envisioned for a contaminated Commencement Bay waterway, the waterway alternative would involve minimum transport of sediments with confinement of the dredged material within the waterway itself. This approach would entail dredging an area well below the zone of contamination, depositing contaminated dredged material in the excavated pit, and capping it with clean dredged material. (See discussion in Appendix B.) This approach has the disadvantage of requiring placement of a significant amount of dredged material (some possibly contaminated) out of the waterway because of bulking. The process also entails placement of a thick cap in areas where post-remediation maintenance dredging is likely to occur. This form of confined aquatic disposal was not considered because of uncertainty regarding required maintenance depths for larger vessels. To accommodate the potential for future dredging to -50 ft MLLW in the Commencement Bay N/T area, excavation of excessive amounts of sediment would be required to ensure isolation of contaminated material. The waterway confinement option would also require interruption of waterway traffic for implementation of the cellular approach to dredged material excavation and placement.

Use of an open-water disposal site was assumed for this feasibility study. A clamshell dredge would be used to maintain nearly in situ densities. Also, by minimizing water entrainment, a clamshell dredge would result in easier transport and fewer or less severe water quality impacts. Dredged materials would be transported to the disposal site and placed directly with a split-hulled barge to limit bulking and water column impacts. Cap materials would subsequently be placed in the disposal site using a submerged diffuser system to minimize water column turbidity and facilitate more accurate placement of materials. Use of the diffuser system would eliminate upper water column impacts by radially dispersing the material parallel to and just above the bottom at low velocity (Phillips et al. 1985).

3.4.5 Removal/Nearshore Disposal

Dredging followed by confined disposal in the nearshore environment is another possible alternative for sediment remediation at the Commencement Bay N/T site. As with the previous alternatives, an effective remediation program incorporating nearshore disposal can only be conducted following successful control of ongoing contaminant sources to the sediments. Generally, nearshore sites need to be diked before they can receive dredged material. There are essentially no limitations in the selection of dredging and transport equipment, although hydraulic dredging followed by pipeline transport to the disposal facility is considered optimal (Phillips et al. 1985). All variations considered for the removal/nearshore disposal option utilize industry standard equipment and methods that are generally available.

Implementation of the alternative can also proceed rapidly as a result of the availability of the Blair Waterway site. Hydraulic dredging confines dredged material to a pipeline during transport, thereby minimizing exposure potential and handling requirements. Systems for management and treatment of dredge water can be readily incorporated into the facility design. The distances between several of the problem areas and the proposed Blair Waterway nearshore disposal site are extensive. Mechanical dredging with a clamshell system would be used for implementing this alternative in problem areas greater than 2 mi distant from the disposal site. For problem areas within 2 mi, a hydraulic dredging system would be possible. Logistical problems may be encountered, however, in areas with heavy marine traffic.

Compared to confined aquatic disposal, confined nearshore disposal permits a greater degree of control in both the design, construction, and maintenance of the confinement system. In addition, it is easier to monitor for contaminant migration through the perimeter dike of a nearshore facility than a large subaquatic cap. Because of the relatively gentle surface water conditions typical of the Commencement Bay area, appropriate dike construction would be expected to control wave erosion of the confining materials.

The primary environmental impact associated with implementation of this alternative is loss of existing benthic habitat at both the dredge and disposal sites. Because of the intertidal location of the disposal site and the high value placed on intertidal habitat, this alternative would require a habitat mitigation component. Also, the influence of tides and groundwater on contaminant transport would be much greater for nearshore confinement than for confined aquatic or upland disposal. In addition, altered redox conditions may increase the mobility of metals, depending upon the level of placement within the disposal site. To the maximum extent practical, sediments containing predominantly inorganic contaminants would be placed below the water table level in the confinement facility to minimize contaminant mobility.

For the purpose of evaluating this alternative, it was assumed that the nearshore disposal facility in Blair Waterway would be utilized. A cutterhead hydraulic dredge and pipeline transport system would be used for problem areas close to the nearshore facility (e.g., Sitcum Waterway). Because of the low solids content of hydraulically dredged sediments (15-25 percent solids by volume), management of dredge water would be required. In this case, dredge water would be clarified to remove suspended solids prior to discharge to the marine environment. A chemical coagulant addition system and secondary settling basin similar to that described by Schroeder (1983) would be included as an element of this remedial alternative where hydraulic dredging is proposed. For those problem areas greater than 2 mi distant from the disposal site or where use of a pipeline system is logistically infeasible, a clamshell dredge would be used to excavate and place dredged material in the nearshore facility. This is a conservative costing approach. It may also be feasible to leave an access point in the outer containment dike at the disposal site to facilitate placement of dredged material using a split-hulled barge. This approach would require placement of a barrier across the dike to contain suspended sediments during the remediation process. It would also require that placement of dredged material be done sequentially within a reasonable timeframe from waterways where nearshore disposal is to be used.

A schematic depicting general features of a nearshore disposal facility is presented in Figure 3-3. To accommodate a dredge water control system using chemical flocculation, the secondary settling basin would resemble that illustrated in Figure 3-8. Other assumed design features include fill depth of 30 ft and a minimum cap thickness of 3 ft. Additional capping material may be required to facilitate subsequent construction over the confinement facility. The facility was assumed to be unlined.

3.4.6 Removal/Upland Disposal

Dredging followed by upland disposal would involve the transfer of dredged material to a confinement facility that is not under tidal influence. Sediment could be dredged either mechanically or hydraulically and transferred to the disposal site by truck, rail, or pipeline. As in the case of nearshore disposal, the alternative can be implemented using standard dredging and transport equipment that is generally used for similar operations. Provisions would be required for the management of dredge water and leachate generated during the dewatering process. Implementation of sediment remedial efforts would be contingent upon the successful control and regulation of contaminant sources to the problem area in question.

Upland disposal would provide for the greatest level of contaminant control in the absence of treatment. Design features would include a liner and cap. The liner system would include an underdrainage for dewatering the fill material and for controlling leachate over the long term. The underdrainage would be designed to operate as either a passive collection system or a vacuum-assisted dewatering system.

The primary environmental impact of this remedial alternative would be destruction of existing benthic life at the dredging site. As with all alternatives that involve dredging, resuspension of contaminated sediment would also be a concern. Destruction of habitat at the upland disposal site is likely to be less significant than at a nearshore site. Implementation of this alternative would also involve risks to area groundwater resources in the event of contaminant migration from the confinement facility. Transport of contaminated dredged material to the upland facility would also pose additional worker and public exposure hazards in the event of a system failure or spill. Disposal in an upland facility would result in significant physicochemical changes in dredged material which could increase mobility of the metal contaminants.

For the purpose of evaluating this alternative, it was assumed that an upland disposal site would be developed within 3 mi of the problem area. Compared to the in situ capping and nearshore disposal alternatives, additional time would be required prior to implementation to allow for siting and development of an upland disposal facility. Dredging would be conducted using a pipeline cutterhead dredge and material would be hydraulically transported to the disposal site. Clamshell dredging could also be conducted with upland disposal as the ultimate destination, but the requirement for double handling of the contaminated material (i.e., removal to barge and then transfer to truck or railcar) would be a distinct disadvantage. A schematic of an upland confinement facility is presented in Figure 3-3. Dredge water clarification (e.g., using the secondary settling basin and chemical clarification design shown in Figure 3-8) would be an essential feature of the facility. It was assumed that the disposal facility would be constructed to contain contaminated dredged material to a depth of 15 ft. A dual synthetic liner and passive underdrainage system would be included to permit removal of percolating dredge water and allow for long-term leachate collection. Dredged material would settle and ponded dredge water would be removed. Passive collection of percolating water would continue until the fill had consolidated to an extent that allowed capping operations to commence. The upland landfill would be lined with 4 ft of clay and have an underdrain system. The cap would be 2 ft thick and composed of clay.

3.4.7 Removal/Solidification/Upland Disposal

Solidification, as an option for treatment of contaminated dredged material following implementation of source control measures, is considered below in conjunction with clamshell dredging and upland disposal. Solidification can significantly reduce the mobility of problem chemicals by chemically immobilizing metals and encapsulating the particle-associated organic compounds. A significant increase in volume may result from this treatment option.

Treatment by solidification could be conducted at either nearshore or upland disposal sites. Either hydraulic or mechanical dredging equipment could be used to remove the contaminated sediment. In the former case, sedimentation to remove most of the dredge water would be required prior to blending in the solidification agents. However, some moisture (approximately 50 percent) is required for the hydration reaction required as part of some solidification processes (Long, D., 12 April 1988, personal communication). As discussed in Section 3.1.5, several solidification agents and implementation scenarios are feasible for this treatment option, although none have been field-tested with marine sediments.

For the evaluation of this alternative, contaminated sediments were assumed to be mechanically dredged and transported to the upland site. Clamshell dredging has the disadvantage of requiring double handling of the contaminated dredged material. However, solidification of material with a relatively high solids content can result in a 10-15 percent treatment cost reduction because of reduced reagent requirements. Dredged material would be staged in hoppers and fed by a screw conveyor system for solidification. Mixing would be completed in a treatment facility with in-line mixing of solidification agents. Discharge would be either directly to the confinement facility or to a truck for transport to the facility. Curing times for the process may be extended as a result of the salt (e.g., chloride, magnesium) content of the dredged material.

Design features for the disposal facility would depend on the hazard level of the solidified sediment. In developing this alternative, it was assumed that the treated material would not be a RCRA hazardous waste and that the confinement facility could be designed to satisfy minimum functional standards for landfills in accordance with state regulations (WAC 173-304). The liner would be 4 ft thick and composed of clay to meet a maximum permeability standard of 1×10^{-7} cm/sec. An underdrainage system atop the clay liner would remove dredge water. The facility would accommodate a 15-ft fill depth and be capped with 2 ft of clay to meet a permeability standard of 1×10^{-6} cm/sec. Although it may be possible to return solidified sediments to the problem area of origin, this option has not been field-tested for marine sediment. Extended curing times based on the salt content of dredged material would be expected to complicate the process for large volumes of sediments.

3.4.8 Removal/Incineration/Upland Disposal

Incineration permanently eliminates organic contamination in sediments. This alternative has limited application in the Commencement Bay N/T because most problem areas are characterized by significant metals contamination, and because marine sediments are characterized by very low Btu content, making incineration extremely energy-intensive and less cost-effective. As for the other alternatives, aggressive pursuit of source control measures was assumed.

For this alternative, sediments were assumed to be mechanically dredged, using a watertight clamshell bucket to minimize water content of the dredged material, minimize water column partitioning of contaminants, and maintain in situ sediment densities. Wastes low in moisture content are preferred for incineration because costs increase significantly as the amount of water that must be driven off increases. If hydraulic dredging were selected, an additional process step to settle and recover the solids from the dredge slurry would be necessary. Even with clamshell dredging, some dewatering may prove to be cost-effective.

The dredged material would be transported to shore by barge and then to an upland site for incineration. It is possible that an incinerator could be located adjacent to the problem area and transport by truck could be avoided. Analysis of the incinerated residue may reveal that the material no longer requires special handling and confinement. Open-water disposal may be a feasible option for disposal of incinerated contaminated dredged material, but in this alternative, disposal in a minimum security landfill was assumed for evaluation.

3.4.9 Removal/Solvent Extraction/Upland Disposal

For sediments containing primarily organic contaminants, solvent extraction followed by incineration of the organic concentrate would be a feasible alternative. Depending on the concentration of metals in the problem sediments, all disposal options may be considered. This approach to sediment remediation would result in permanent removal and destruction of organic compounds. Source control would be necessary to prevent recontamination.

For the purpose of evaluating this alternative, use of the BEST™ technology marketed by Resources Conservation Company (Bellevue, WA) was assumed. This process takes advantage of the inverse immiscibility properties of aliphatic amines to separate organics from aqueous slurries of contaminated material and from organic sludges. Effluents from the process would include wastewater, treated solids, and a concentrated waste organic mixture. Depending on the quality of the wastewater, additional treatment may be required. Solids retain a low residual concentration of extracting solvent and, depending on metals content, may be returned to the removal site for unconfined disposal, placed in a PSDDA open-water disposal site, or landfilled in a secure facility. The extracting solvent, typically triethylamine, is not a listed hazardous waste constituent, which simplifies waste solids and wastewater disposal.

It was assumed that contaminated sediments would be dredged using a clamshell, transported via barge, and offloaded using a clamshell to an onshore treatment facility. The contaminated dredged material would be treated, dried, and transported to an upland disposal facility. Because the process effectively dewaters the solids, stabilization was considered unnecessary.

3.4.10 Removal/Land Treatment

For sediments contaminated with biodegradable organic compounds, a land treatment option may be considered. Land treatment involves the incorporation of waste into the surface zone of soil, followed by management of the treatment area to optimize degradation by natural soil microorganisms. Chemical and physical characteristics of the waste need to be evaluated to determine the amount that can safely be loaded onto the soil without adversely impacting groundwater. Soils possess substantial cation exchange capacity, which can effectively immobilize metals. Therefore, wastes containing metals can be land-treated, but careful consideration of the assimilative capacity of the soil for metals is essential.

For evaluating this alternative, it was assumed that sources would be controlled and that sediments would be removed using a clamshell to minimize water content of the dredged material. After transport by barge and truck to the land treatment facility, the sediment material would be distributed and tilled into the upper 15-30 cm of soil. The land treatment facility design would prevent stormwater run-on and allow collection and management of runoff. Lysimeters and monitoring wells would be installed and periodically sampled to aid in the detection of subsurface contaminant migration.

4.0 DEVELOPMENT OF SEDIMENT REMEDIAL ACTION EVALUATION CRITERIA

A detailed analysis of the 10 candidate sediment remedial alternatives and recommendation of the preferred alternative for each problem area is the final stage of the feasibility study process. This section presents the criteria used to analyze the alternatives. A narrative evaluation matrix has been included in the problem area-specific sections to provide a summary of the key considerations for each candidate alternative relative to each criterion.

Evaluation criteria for the detailed analysis can be grouped into three general categories: effectiveness, implementability, and cost. For the Commencement Bay Nearshore/Tideflats (N/T) Feasibility Study (FS), there are four effectiveness criteria: short-term protectiveness; timeliness; long-term protectiveness; and reduction in contaminant toxicity, mobility, or volume. The three implementability criteria comprise technical feasibility, institutional feasibility, and availability of both equipment and disposal facilities. (Other types of implementability criteria, such as coordination among agencies and public acceptance, are more appropriately evaluated during the development of a Record of Decision and are not discussed in this document.) Cost elements include design and specification preparation, capital construction, intertidal habitat replacement, operation and maintenance (O&M), and monitoring.

The criteria specified in this section are consistent with the requirements of CERCLA/SARA and NCP. Final guidance has not been provided by U.S. EPA on the procedures for evaluating remedial alternatives at Superfund sites. However, categories of criteria specified in CERCLA guidance documents (e.g., U.S. EPA 1985e) were modified on an interim basis by U.S. EPA (1986d) and Porter (1987) to include new requirements under SARA [e.g., compliance with all applicable or relevant and appropriate requirements (ARARs) and preference for permanent solutions or treatments]. In addition, the draft guidance document for conducting feasibility studies in accordance with CERCLA/SARA, including the preferred alternative selection process (U.S. EPA 1988a), has been incorporated into this report.

Effectiveness, implementability, and cost criteria are defined in Sections 4.1, 4.2, and 4.3, respectively. Section 4.2 is substantially longer than the other sections, primarily because the set of ARARs discussed under institutional feasibility is large and complex. Section 4.4 presents the framework for identifying the preferred sediment remedial alternative. By definition, this alternative must effectively meet the objectives of the Commencement Bay N/T sediment remediation effort and the intent of recent guidance to provide solutions that are consistent with ARARs. The selection process is complicated by technical and institutional uncertainties and by tradeoffs among alternatives. The evaluations presented are based on the best available information. The relative significance of these uncertainties affects the final standing of the various alternatives; this factor is considered in the evaluations. The tradeoffs that emerge in comparing the alternatives are also considered in the selection process. The final selection and implementation of the preferred alternative for each problem area may be modified to reflect refinements of the existing technological or chemical database.

4.1 EFFECTIVENESS CRITERIA

The purpose of this section is to identify and define four effectiveness criteria: short-term protectiveness; timeliness; long-term protectiveness; and reduction in contaminant toxicity, mobility, or volume.

4.1.1 Short-Term Protectiveness

Short-term protectiveness is the predicted ability of the candidate sediment remedial alternative to minimize public health and environmental risks caused by exposure to contaminants during the implementation phase. The analysis identifies potential hazards associated with implementation and corresponding control measures. The evaluation of candidate sediment remedial alternatives based on short-term protectiveness includes the following considerations:

- Community protection during implementation - Potential public health risks due to implementing the alternative, including additional hazards due to the action itself. This evaluation includes a general assessment of potential hazards to public health associated with excavation, transfer/transport, treatment, and disposal of the contaminated sediments. Potential routes of exposure and targets are also considered.

- Worker protection during implementation - Potential occupational hazards due to implementing the alternative, including hazards associated with exposure of sediments during excavation, transfer/transport, treatment, and disposal. This evaluation includes both physical and chemical hazards associated with each process option, the degree of specialized safety training required for implementation, and an informal assessment of the potential hazards posed by a major worker exposure incident.

- Environmental protection during implementation - Nature and magnitude of potential environmental impacts associated with implementing the alternative. This evaluation includes identification of the environment at risk and review of the potential impacts associated with system failures during implementation.

4.1.2 Timeliness

Timeliness refers to the estimated time required for the candidate alternative to meet remedial objectives (i.e., to effect mitigation and achieve results based on observed biological effects). This evaluation includes an assessment of the time required for the following activities:

- Implement source controls integral to success of the alternative
- Demonstrate feasibility of unproven technologies
- Modify existing technologies to site-specific conditions
- Develop treatment or disposal facilities not currently in existence
- Implement sediment remediation, including treatment and disposal as necessary.

4.1.3 Long-Term Protectiveness

Long-term protectiveness is the predicted ability of the candidate sediment remedial alternative to minimize potential hazards in both the problem areas and the ultimate disposal sites after the objectives of the alternative have been met. Effectiveness of the engineering and institutional controls available to manage risk (U.S. EPA 1988a) are especially important. This analysis includes an assessment of hazards associated with disposal of untreated waste, disposal of residuals resulting from treatment options, and potential failure of the technical components (e.g., containment structures, treatment systems). The evaluation of candidate sediment remedial alternatives based on evaluation of long-term protectiveness includes the following considerations:

- Long-term reliability of containment facilities - Success in remediating the observed adverse environmental effects and in providing a final solution for the isolation, treatment, and disposal of contaminated sediments. The analysis estimates the magnitude and nature of the hazards due to potential failure of the protective components of the system, identifies the components most susceptible to failure, and assesses the engineering and institutional controls required to ensure system reliability. Population and environment at risk are identified.
- Protection of public health - Long-term ability to reduce public health hazards associated with the contaminated sediments. This evaluation includes an assessment of how the subject alternative achieves protection over time, how site hazards are reduced, and how treatment or disposal processes impact long-term health hazards. This evaluation requires estimates of the feasibility of source control.

- Protection of the environment - Potential long-term environmental impacts associated with implementation, based on system reliability and associated long-term hazards. This evaluation includes identification of the environment and media at risk and the potential sensitivity of the environment to system failures (including failure to perform to prescribed specifications). This evaluation also requires an assessment of the effectiveness of system performance monitoring.

4.1.4 Reduction in Toxicity, Mobility, or Volume

This criterion addresses the statutory preference (U.S. EPA 1988b) for treatment vs. isolation (i.e., prevention of exposure). This analysis requires that volume be addressed separately from toxicity or mobility because some of the treatment or removal process options can increase volumes (e.g., solidification, hydraulic dredging). For problem areas containing mixed wastes (e.g., organic and inorganic contaminants), the portion of the waste subject to treatment is delineated. The reduction in the threat posed by the contaminants may be achieved through destruction of toxic contaminants (e.g., incineration), reduction of the total mass of toxic contaminants (e.g., chemical oxidation), irreversible reduction in contaminant mobility (e.g., solidification), or reduction of total volume of contaminants (e.g., solvent extraction). The degree to which treatment processes are irreversible, the type and quantity of residuals remaining following treatment, and the methods for managing residuals are considered.

The evaluation under this criterion focuses on the treatment processes used and the contaminants they have been developed to address. The estimated efficiency of the treatment process is considered based on the problem chemicals present. The percentage reduction in toxicity, mobility, or volume can only be quantified following the completion of bench-scale testing of problem sediments. SARA revisions to CERCLA and recent U.S. EPA guidance further suggest development of alternatives that use permanent solutions, and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Based on the nature and concentration of the contaminants in the sediments of the nine problem areas, recovery of reusable resources is not expected to be practical.

4.2 IMPLEMENTABILITY CRITERIA

The purpose of this section is to identify and define three general implementability criteria: technical feasibility, institutional feasibility, and availability.

4.2.1 Technical Feasibility

Technical feasibility is the ability of the candidate sediment remedial alternative to be fully implemented based on site-specific chemical and physical features as well as general construction and engineering constraints. The evaluation of technical feasibility focuses on implementation, maintenance, and monitoring, and includes the following considerations:

- Feasibility and reliability of process options - Feasibility of constructing the necessary components of the remedial alternatives, and reliability of the corresponding process options. This evaluation includes a qualitative estimate of hazards due to system failure at any point in the remediation process, and may include an evaluation of the effectiveness of contingency plans. The ability of a technology to meet specified process efficiencies or performance goals is also considered.

- Implementation of monitoring programs - Ability to track performance in meeting the remedial objectives. This evaluation involves estimating confidence in early detection of problems and identifying potential exposures (public health and environment) caused by inability to detect system failures. This evaluation also requires a determination of whether migration pathways are sufficiently well defined to be monitored adequately.

- Implementation of O&M programs - Feasibility and time required to implement an O&M program to ensure the maximum reliability and performance of the system.

4.2.2 Institutional Feasibility

Institutional feasibility is the ability of the candidate sediment remedial alternative to meet the intent of all applicable criteria, regulations, and permitting requirements. The evaluation of the candidate sediment remedial alternatives based on institutional feasibility includes the following considerations:

- Approval of relevant agencies - Feasibility of obtaining necessary agency approvals, including time and activities required. Although CERCLA actions are exempt from permit requirements under SARA, this evaluation addresses the need for, and feasibility of, obtaining concurrence from appropriate agencies on whether the candidate alternative will meet the substantive aspects of the permit requirements. The compliance of the subject alternative with advisories and guidance for similar projects in similar environmental settings is also considered.

- Compliance with applicable or relevant and appropriate requirements (ARARs) - Compliance of the subject alternative with the regulatory framework governing activities related to the problem area-specific environmental setting, protection of public health, and implementation of the remedial action and associated process options.

The following detailed discussion is provided to identify ARARs that must be considered in evaluating the alternatives. Additional details on ARARs are presented in Appendix C.

Compliance with ARARs--

The purpose of this section is to identify ARARs in terms of their importance in assessing candidate alternatives. ARARs are critical in the selection of appropriate remedies and will influence the implementation of remedial alternatives in individual problem areas. Because several actions such as dredging, dredge water management, and dredged material disposal are common to more than one candidate alternative, the discussion is organized by functional activity rather than remedial alternative, as follows:

- No action
- Institutional controls
- Dredging
- Treatment of contaminated sediments
- Disposal of sediments and treatment residues.

Section 121 (d)(2)(A) of CERCLA as amended by SARA incorporates the CERCLA compliance policy. According to this policy, remedial actions must meet promulgated requirements, criteria, or limitations that are legally applicable or relevant and appropriate. The policy further states that other standards, criteria, advisories, and guidance that may be useful in developing remedies are to be considered, but not according to the formal evaluation process required for ARARs. ARARs of federal and state government and Indian tribes must be considered during CERCLA remedial action. Although local ordinances are not specified as ARARs, they are considered in the selection of alternatives.

Porter (1987) differentiates between requirements that are legally applicable, and requirements that are relevant and appropriate:

- Legally applicable requirements consist of substantive environmental protection requirements (e.g., standards for cleanup or control) promulgated under federal, state, or tribal law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site (e.g., drinking water standards, air emissions criteria, or state hazardous waste regulations that would be applicable at the site even if it were not being addressed under CERCLA)

- Relevant and appropriate requirements consist of substantive requirements promulgated under federal, tribal, or state law that, while not applicable, are sufficiently similar to applicable requirements that their use is well suited to a particular site (e.g., design requirements for RCRA landfills may be considered relevant and appropriate for a disposal operation at the site even though it is under CERCLA, not RCRA, jurisdiction).

For remedial actions within the CERCLA site boundary, ARARs must be met unless the requirements are waived pursuant to Sections 121 (d)(4)(a-f) of CERCLA for one of the following reasons:

- The remedial action selected is only part of a total remedial action that will attain compliance with ARARs

- Compliance with ARARs will result in greater risk to human health or the environment than other alternative actions

- Compliance with ARARs is technically impractical

- The action will attain the equivalent of an ARAR through an analogous process

- For state requirements, the state has not consistently applied the ARAR in similar circumstances

- For CERCLA Section 104 actions, compliance with ARARs will jeopardize the availability of fund money for other sites (i.e., fund balancing).

If components of a candidate remedial alternative fall under the jurisdiction of a given ARAR, that ARAR is deemed applicable. Jurisdictional requirements include the following:

- Substances covered

- Time period covered

- Types of facilities covered

- Persons covered

- Actions covered

- Areas covered.

A requirement may be relevant and appropriate even if it is not legally applicable. In general, a requirement can be considered relevant and appropriate if the situation at the CERCLA site is sufficiently similar to a problem that the requirement is designed to address. This determination relies heavily on professional judgment. The following factors are used to compare the site conditions to the requirement in question:

- Similarity of goals and objectives of the requirement and the remedial alternative
- Environmental media and substances regulated and targeted for remediation
- Action or activity regulated and considered for remediation
- Type of physical location, structure, and facility regulated and considered for remediation
- Resource use or potential use.

Given the complexities of the general response actions under consideration for the Commencement Bay N/T site, classification of a specific environmental statute as applicable or relevant and appropriate will be established in the Record of Decision and further refined in the remedial design phase. However, the following discussion provides a format for evaluating legislation likely to be most important in selecting a preferred remedial action for the site.

Federal, state, and local permits are not required for the portion of any removal or remedial action conducted entirely onsite, or for work performed under CERCLA Sections 104 and 106. However, substantive (but not procedural or administrative) requirements of permit applications may be legally applicable or relevant and appropriate for onsite actions. Offsite actions do not require an analysis of ARAR compliance. However, the transfer of hazardous or contaminated material offsite is allowed only if there is a facility operating in compliance with RCRA, TSCA, or other applicable state and federal requirements. The purpose of this offsite policy (U.S. EPA 1988b) is to ensure that disposal facilities are technically sound so that CERCLA wastes do not contribute to present or future environmental problems.

ARARs can be classified as chemical-specific, location-specific, or action-specific.

<u>Chemical-specific ARARs</u> are health-based or risk-based concentrations or ranges of concentrations in environmental media for specific chemicals. Examples of chemical-specific ARARs are federal water quality criteria, air quality standards (federal and state), and maximum contaminant levels [MCLs, or MCL goals (MCLG)] set by the Safe Drinking Water Act (SDWA). If a chemical has more than one ARAR, the most stringent value should be used.

<u>Location-specific ARARs</u> may set restrictions on remedial activities based on the characteristics of the environment in the vicinity of the site. Examples of location-specific ARARs include the Coastal Zone Management Act (CZMA), Executive Orders for floodplain and wetland protection, state land

use laws and regulations, and regulations to protect sites of archaeological and historical value.

Action-specific ARARs may set restrictions based directly on the nature of a remedial alternative. Examples of action-specific ARARs are RCRA design and monitoring requirements for closure and post-closure of disposal sites, and Clean Water Act requirements for dredging and dredged material disposal.

Factors To Be Considered --

The CERCLA compliance policy specifies that other nonpromulgated or interim standards, advisories, and guidance that may be useful in developing remedial action alternatives are to be considered (TBC). TBC factors for the Commencement Bay N/T remedial effort may include federal and state policies, guidelines, and advisories; local ordinances such as City of Tacoma shoreline and land use plans; PSDDA guidelines for the handling and disposal of dredged material; and carcinogenic potency factors and reference doses established by U.S. EPA for use in developing criteria such as MCLs. TBCs can also be classified as chemical-specific, action-specific, or location-specific.

Classification of ARARs and TBCs--

The remainder of this section is organized by type of ARAR or TBC (i.e., chemical-, location-, or action-specific). For each ARAR or TBC type, a selected list of potential ARARs or TBCs is developed; and for each ARAR, a preliminary classification (i.e., applicable, or relevant and appropriate) is assigned. This classification refers specifically to response actions undertaken as part of sediment remedial actions at the site. An ARAR analysis is not required for response actions undertaken as part of a source control event because the state will continue to regulate those activities under non-CERCLA environmental laws and regulations. Compliance with ARARs will be required for upland activities only if they are specifically related to sediment remediation (e.g., treatment, transportation, dewatering, and disposal of dredged material).

Potential Chemical-Specific ARARs--For dredging and dredged material disposal, chemical-specific ARARs issued at the federal level that must be evaluated include MCLs and MCLGs under SDWA, and ambient water quality criteria under Section 303 or 304 of the Clean Water Act. MCLs are enforceable drinking water standards developed for public drinking water supplies. MCLs are based primarily on health considerations, with some allowance for cost and feasibility. MCLGs are developed under SDWA as chemical-specific health goals and are used to set MCLs. MCLGs are set at levels where there are no known or anticipated health effects, and include a safety margin. Federal ambient water quality criteria are based on laboratory bioassays and are designed for the protection of aquatic life.

In addition, RCRA incinerator regulations include a process for establishing chemical-specific emission limitations for principal organic hazardous constituents (POHCs). U.S. EPA has also proposed regulations to limit emissions from boilers utilizing contaminated materials as feedstock. Under Section 121 (d) of CERCLA, remedial actions require a level or standard of control for hazardous substances, pollutants, or contaminants which at least attains MCLGs or water quality criteria where such goals are deemed to be relevant and appropriate.

Other potential federal ARARs include ambient air quality standards specified by the Clean Air Act and standards specified by the federal Occupational Safety and Health Act (OSHA). The federal Clean Air Act specifies standards for suspended particulates and a limited number of chemicals. Under OSHA, the National Institute for Occupational Safety and Health (NIOSH) develops permissible exposure limits (PELs) and other enforceable worker exposure guidelines for selected hazardous chemicals.

At the state level, potential chemical-specific ARARs include requirements for new sources including Ecology's Toxic Air Guidelines. Requirements have also been promulgated by the Washington Industrial Safety and Health Act (WISHA) for workers exposed to hazardous chemicals. In addition, Ecology, under a mandate from the Puget Sound Water Quality Authority (PSWQA), has been tasked with establishing sediment quality criteria for Puget Sound (element P-2 of PSQWA management plan). Draft interim sediment standards addressing long-term goals for Puget Sound were issued in June 1988, with final standards expected in June 1989. Development of sediment standards to be applied in various sediment-related programs (e.g., discharge permits, dredging and disposal operations, sediment remedial activities) will be promulgated in a phased sequence according to the PSQWA management plan. As these standards are promulgated, they will satisfy the definition of ARARs. Other potential state ARARs include state water quality standards promulgated under Chapters 90 and 173 of the Washington Administrative Code (WAC). These regulations establish water quality criteria as well as discharge requirements. In addition, WAC Chapter 173-303 implements Chapter 70.105 of the Revised Code of Washington (RCW), the Hazardous Waste Management Act of 1976, and Subtitle C of Public Law 94-580 (RCRA) establishing Washington State Dangerous Waste Regulations. These regulations designate wastes that are dangerous or extremely hazardous to the public health and the environment and the requirements for handling, transfer, and disposal of dangerous and extremely hazardous waste.

At the regional level, potential chemical-specific ARARs include emissions standards of the Puget Sound Air Pollution Control Agency (PSAPCA). PSAPCA has generally adopted and enforces federal clean air standards (although in some cases, regional standards are more restrictive). However, PSAPCA can and has developed chemical-specific standards on a case-by-case basis.

<u>Chemical-specific TBCs</u>--Chemical-specific TBCs that are issued at the federal level include carcinogenic potency factors (for carcinogens) and reference doses (for noncarcinogens). Carcinogenic potency factors and reference doses relate to site activities through the development of human health risks based on various exposure pathways (e.g., consumption of seafood or ingestion of groundwater). Chemical-specific limits derived from exposure estimates may be considered. The U.S. Food and Drug Administration

(FDA) has developed limited criteria for maximum concentrations of hazardous compounds in fish tissue destined for interstate transportation and sale. These criteria exist for PCBs (2.0 mg/kg) and mercury (1.0 mg/kg). Although those criteria are promulgated, they are included under the TBC category because they are based on assumptions that are not specifically relevant and appropriate to the site. More accurate public health risk assessment information has been developed for the site (Versar, Inc. 1985). PSDDA interim guidelines for the disposal of dredged material in Puget Sound are also based on defining potential problem sediments as determined by biological effects associated with observed chemical contamination (i.e, the AET method). PSDDA interim disposal guidelines are not codified but have been applied and are presently being considered for adoption for standard use by regulatory agencies in Puget Sound.

Chemical Specific Legal Applicability or Relevance and Appropriateness--Federal ambient water quality criteria are directly applicable to alternatives involving dredging or the placement of dredged material or other material in marine waters. Federal water quality criteria and state sediment quality criteria apply (when promulgated) to the substances in question (dredged material), persons covered (any person), and actions covered (dredging). State sediment quality criteria and procedures have not been codified but will satisfy the definition of ARARs upon promulgation. Applicability of these ARARs does not depend on the time period covered or the types of facilities involved. Federal water quality criteria are also applicable to confinement alternatives because these alternatives involve the disposal of uncontaminated material. Federal water quality criteria are applicable to nearshore disposal alternatives insofar as there is a potential for contaminants from the dredged material to reach the adjacent water (e.g., water quality criteria are appropriate for use during a post-remediation monitoring plan).

OSHA and WISHA requirements are applicable insofar as workers may be exposed to hazardous substances during the course of remediation. Federal clean air standards and PSAPCA standards are applicable to the extent that materials may be released to the atmosphere during remediation (e.g., volatilization of contaminants during nearshore and upland placement, or release of contaminants during incineration). SDWA MCL and MCLGs may be legally applicable to the alternatives involving onsite disposal either upland or nearshore if it is determined that there is an aquifer for public drinking water sources on the site.

SDWA MCL and MCLGs, and Clean Water Act federal water quality criteria for drinking water are relevant and appropriate to remedial alternatives involving the onsite placement of contaminated sediment nearshore or upland. These ARARs are relevant and appropriate primarily because they regulate groundwater concentrations of contaminants - a factor that will have to be considered (e.g., via post-remediation monitoring) at upland and nearshore dredged material disposal sites. MCL, MCLGs, and water quality criteria for drinking water are relevant and appropriate for situations where groundwater is or may be used for drinking water. Where a groundwater aquifer is not used as a drinking water supply and is discharging to one of the waterways, acute and chronic marine water quality criteria are relevant and appropriate.

Major chemical-specific ARARs for contaminated sediment remedial alternatives are listed in Table 4-1. Chemicals listed in Table 4-1 are priority chemicals found in one or more problem areas.

Major chemical-specific TBCs for contaminated sediment remedial alternatives are listed in Table 4-2. These TBCs are expected to be promulgated in the near future and will be applicable to sediment remedial activities at that time. Included in the table are the PSDDA screening level concentrations (below which no unacceptable adverse effects would be expected following disposal) and the PSDDA maximum level concentrations (above which material would be expected to be unacceptable for unconfined, open-water disposal) (U.S. Army Corps of Engineers 1988).

Potential Location-Specific ARARs--Location-specific ARARs at the federal level that must be evaluated include the Coastal Zone Management Act; Clean Water Act; Marine Protection, Research, and Sanctuaries Act (MPRSA); and the Rivers and Harbors Appropriations Act. The CZMA established a program whereby coastal states can receive assistance in developing their own coastal zone management program. The State of Washington developed such a program under the CZMA and the Shoreline Management Act (described below) effectively superceding the CZMA. The most important provisions of the Clean Water Act with respect to the site are Section 401 (state water quality certification for federally permitted activities), Section 402 (establishes the NPDES program), and Section 404 (establishes a permitting and permit review process for dredging and dredged material disposal). The most important component of the MPRSA is its provisions, requirements, and guidelines for ocean disposal of dredged materials. The Rivers and Harbors Appropriation Act provides the U.S. Army Corps of Engineers authority to regulate any activities that may interfere with navigation (e.g., dredging and dredged material disposal).

At the state level, potential location-specific ARARs include the Shoreline Management Act, Washington Department of Natural Resources (WDNR) guidelines and procedures for leasing submerged lands, the Toxics Control Act, the Department of Fisheries hydraulics permit requirements, and Department of Game hydraulics permit requirements. Under the state Shoreline Management Act, the City of Tacoma has prepared a Shoreline Master Program to regulate land use and construction within the coastal zone. As trustee over the submerged lands of the state, WDNR manages all dredged material disposal sites via a submerged lands leasing program. The Puget Sound Water Quality Authority is planning to develop sediment criteria to identify potential problem areas in Puget Sound based on no-observable-adverse-effects levels. When developed, those criteria would be applicable.

Location-Specific TBCs--At the regional and local levels, potential location-specific TBCs are limited to 1) the requirements, procedures, and guidelines for open-water disposal specified by PSDDA; and 2) land use requirements specified by the City of Tacoma in its shoreline plan and land use plan (for areas outside the coastal zone). PSDDA has developed procedures for evaluating the suitability of dredged material for unconfined, open-water disposal, and procedures, guidelines, and criteria for establish-

TABLE 4-1. SELECTED POTENTIAL CHEMICAL-SPECIFIC ARARs FOR PROBLEM AREA CHEMICALS

Chemical	SDWA MCL (mg/L)	Marine WQC Acute/Chronic (mg/L)	SDWA MCLG (mg/L)	NIOSH[a] PEL (mg/m^3)	ACGIH[a] TLV (mg/m^3)
Antimony	--	--	--	0.5	0.5[b]
Arsenic	0.05	0.013	--	0.01	0.002[c]
Cadmium	0.01	0.0093	0.005	0.1	0.05[d]
Copper	--	0.0029	1.3	1.0	--
Lead	0.05	0.0056	0.02	0.05	<0.1[b]
Mercury	0.002	2.5E-05	0.003	0.05[b]	0.05
Nickel	--	0.0071	--	1	1
Zinc	--	0.058	--	--	--
Trichloroethene	--	--	--	--	--
Tetrachloroethene	--	--	--	35	7
Hexachlorobenzene	--	--	--	--	--
1,2-Dichlorobenzene	--	--	0.62	300[d]	--
1,3-Dichlorobenzene	--	--	--	--	--
1,4-Dichlorobenzene	0.75	--	0.75	75	--
Hexachlorobutadiene	--	0.032[e]	--	--	--
Pentachlorocyclopentane isomer	--	--	--	--	--
HPAH	--	--	--	--	--
LPAH	--	--	--	--	--
Methylpyrenes	--	--	--	--	--
Methylphenanthrene	--	--	--	--	--
Dibenzothiophene	--	--	--	--	--
2-Methoxyphenol	--	--	--	--	--
Dibenzofuran	--	--	--	--	--
4-Methylphenol	--	--	--	--	--
Phenol	--	5.8	--	19	20[b]
2-Methylphenol	--	--	--	--	--
1-Methyl, 2-(methylethyl) benzene	--	--	--	--	--
Naphthalene	--	--	--	50	--
2-Methylnaphthalene	--	--	--	--	--
Biphenyl	--	--	--	1	--
Pentachlorophenol	--	3.4E-04	0.221	0.5	--
Dibenzothiophene	--	--	--	--	--
Ethylbenzenes	--	0.43	0.681	--	--
Xylenes	--	--	--	435	100[b]
Bis(2-ethylhexyl)phthalate	--	--	--	--	--
Alkylated benzene isomer	--	--	--	--	--
Benzyl alcohol	--	--	--	--	--
N-nitrosodiphenylamine	--	--	--	--	--
Diterpenoid hydrocarbon	--	--	--	--	--
Retene	--	--	--	--	--
Butyl benzyl phthalate	--	--	--	--	--
Aniline	--	--	--	19	10

TABLE 4-1. (Continued)

Chemical	SDWA MCL (mg/L)	Marine WQC Acute/Chronic (mg/L)	SDWA MCLG (mg/L)	NIOSH[a] PEL (mg/m^3)	ACGIH[a] TLV (mg/m^3)
Phthalate esters	--	0.034	--	--	--
PCBs	--	3.0E-05	--	--	--
Total organic carbon	--	--	--	--	--
Total volatile solids	--	--	--	--	--
Oil and grease	--	--	--	--	--

[a] 8-h time-weighted average unless otherwise indicated - units in mg/m^3 of air.

[b] 10-h time-weighted average.

[c] 15-min ceiling.

[d] Ceiling value.

[e] Lowest observed effect level.

TABLE 4-2. SELECTED POTENTIAL CHEMICAL-SPECIFIC TBCs

Chemical	PSDDA Screening Level (mg/kg)	PSDDA Maximum Level (mg/kg)
Antimony	2.6	26
Arsenic	70	700
Cadmium	0.96	9.6
Copper	80	800
Lead	70	700
Mercury	0.21	2.1
Nickel	28	49
Zinc	160	1,600
Lindane	0.005	---
Total DDTs	0.007	0.069
Total PCBs	0.130	2.50
Dimethyl phthalate	0.160	---
Diethyl phthalate	0.097	---
Di-n-butyl phthalate	1.40	---
Butyl benzyl phthalate	0.470	---
Bis(2 ethylhexyl)phthalate	1.90	---
Di-n-octyl phthalate	68.0	---
Phenol	0.120	1.20
2-Methylphenol	0.006	0.063
4-Methylphenol	0.120	1.20
2,4-Dimethylphenol	0.01	0.029
Pentachlorophenol	0.140	---
Benzoic acid	0.216	0.650
Benzyl alcohol	0.010	0.073
Hexachlorobutadiene	0.029	0.290
Dibenzofuran	0.054	0.540
N-nitrosodiphenylamine	0.022	0.22
Hexachloroethane	1.40	14.00
Total xylene	0.012	0.120
Ethylbenzene	0.004	0.037
Tetrachloroethene	0.014	0.140
Trichloroethene	0.160	1.60
LPAH[a]	0.610	6.10
HPAH[a]	1.80	18.0
1,3-Dichlorobenzene	0.170	---
1,4-Dichlorobenzene	0.026	0.26
1,2-Dichlorobenzene	0.005	0.05
1,2,4-Trichlorobenzene	0.006	0.064
Hexachlorobenzene	0.023	0.230

[a] Regulated for individual constituents only by state regulations.

ing unconfined, open-water disposal sites. PSDDA guidelines for chemical and biological evaluations of dredged material are given in Appendix C. PSDDA is in the process of developing similar guidance for other disposal options, including conventional land disposal, nearshore disposal, and confined disposal.

Under the Shoreline Management Act, the City of Tacoma may issue a shoreline substantial development permit for any project with a value in excess of $2,500, including the designation of a dredged material disposal site. Application of Tacoma land use regulations will vary with specific land use designations in problem areas.

The offshore, nearshore, and upland (within 200 ft of ordinary high water) disposal of dredged material, and any other remedial alternative involving shoreline development (e.g., construction of dredged material treatment facilities) is subject to the specifications and guidelines set forth in the Tacoma shoreline and land use plans. Any such development occurring offsite but still within the coastal zone and exceeding $2,500 in value would be required to meet the substantive requirements of a Tacoma shoreline substantial development permit. Activities occurring offsite are subject to the substantive and administrative requirements of Tacoma land use regulations.

Location-Specific Legal Applicability or Relevance and Appropriateness--Based on the determining factors listed above, Sections 404 and 401 of the Clean Water Act and Section 10 of the Rivers and Harbors Appropriations Act (guidance provided in 40 CFR Part 230.10 and 33 CFR Parts 320-330) are applicable to all remedial alternatives involving dredging and disposal of dredged material in navigable waters. The CZMA is applicable to alternatives involving the disposal of material or construction of treatment facilities in the coastal zone.

MPRSA requirements for ocean disposal are relevant and appropriate to remedial alternatives involving the open-water disposal of dredged or capping material. The MPRSA establishes guidelines and requirements for determining the suitability of materials for ocean disposal, siting ocean disposal sites, and monitoring dumping activities therein.

Major location-specific ARARs for contaminated sediment remedial alternatives are listed in Table 4-3.

Potential Action-Specific ARARs--Action-specific ARARs deal with restrictions based directly on the nature of remedial alternatives. Section 121 of CERCLA specifies that actions incorporating treatment technologies to permanently and significantly reduce volume, toxicity, or mobility are to be preferred. Offsite transport and disposal of contaminated substances is also discouraged (Public Law 99-499, 17 October 1986 Section 121(b) of CERCLA).

The alternatives developed for the Commencement Bay N/T FS encompass a wide range of response actions providing varying degrees of public health and environmental protection. The no-action and institutional controls

TABLE 4-3. SELECTED POTENTIAL LOCATION-SPECIFIC ARARs FOR CANDIDATE REMEDIAL ALTERNATIVES

Location	Requirement[a]	Prerequisites	Citation
Within 100-year floodplain	Facility must be constructed, maintained, and operated to prevent washout	RCRA hazardous waste treatment, storage, and disposal	40 CFR 264.18(b)
Within floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values	Action will occur in lowlands and flat areas adjoining inland and coastal waters	Executive Order 11988; 40 CFR 6 Appendix A
Within coastal zone	Conduct activity in manner consistent with Washington Shoreline Management Act	Activities affecting coastal zone, including shorelands, tidelands, and submerged lands	Coastal Zone Management Act (16 USC Section 1451)
			Washington Shoreline Management Act
			Tacoma Shoreline Management Plan
Oceans or waters of the United States	Action to dispose of dredged and fill material requires a permit	Oceans and waters of the United States	Clean Water Act Section 404, 401, 40 CFR 125
			Marine Protection Resources and Sanctuaries Act Section 103
	Disposal of dredged material under permit authority of the U.S. Army Corps of Engineers		Rivers and Harbors Appropriations Act Section 10
Washington State waters	Action affecting the natural flow of water requires		Department of Fisheries and Game Hydraulics Permit RCW 75-20.100, WAC 220-110

[a] Permits are not required under SARA.

alternatives are included to provide a baseline for evaluation and to examine an option for meeting the objectives of the remediation effort without implementing sediment mitigation measures. The alternatives involving in situ capping and removal/disposal without treatment were developed to provide effective measures for long-term contaminant isolation. The treatment alternatives were developed to examine innovative, permanent solutions for contaminated sediment mitigation.

CERCLA requires that the following factors be considered in reviewing alternative remedial actions:

- Long-term uncertainties associated with land disposal
- Goals, objectives, and requirements of the Solid Waste Disposal Act
- Contaminant persistence, toxicity, mobility, and propensity to bioaccumulate
- Potential for adverse effects from human exposure
- Long-term maintenance costs
- Potential for future remedial actions if the identified action were to fail, and associated human and environmental health threats.

For the Commencement Bay N/T remedial actions, these factors must be reviewed in view of the high volume and relatively low concentrations of contaminated sediments. U.S. EPA guidance suggests that for sites involving these special circumstances, treatment technologies may not be practical and that containment options may be more appropriate (U.S. EPA 1988a). For the most part, contaminants in the study area have demonstrated high particle affinity, relatively low solubility, and therefore, low mobility potential. These factors aid in minimizing the uncertainty associated with confinement of untreated sediments. The capping and removal/disposal alternatives do not result in the degree of permanence provided by treatment or destruction of contaminants. However, the protectiveness associated with effective isolation of contaminated sediments can provide a long-term solution to observed adverse biological and potential public health impacts.

Contaminant toxicity, mobility, persistence, and propensity to bioaccumulate were considered in the selection of indicator chemicals. All action-oriented remedial alternatives were selected for evaluation on the basis of their ability to minimize or eliminate the potential for adverse effects on the environment and human health from exposure to contaminated sediments. The alternatives are also evaluated, in part, based on the resources at risk in the event of system failures and the difficulty involved in implementing corrective actions.

This section is organized according to the following categories of actions involving contaminated sediments: no action; institutional controls;

dredging; treatment of dredged material; and placement, disposal, or discharge of treated dredged material and water (e.g., from dewatering, settling, and treatment), untreated dredged material, capping material, and treatment residues (e.g., filter cakes from water treatment operations).

No Action--The "implementation" of this alternative would result in the nonattainment of many ARARs, including the intent of CERCLA/SARA and the National Contingency Plan. For example, the NCP requires that selected remedies cost-effectively mitigate and minimize threats to and provide adequate protection of public health and welfare and the environment [40 CFR Part 300.68(i)]. Based on evidence presented in the RI and other documents, the no-action alternative does not accomplish this goal. Other ARARs that would not be satisfied by this alternative include criteria for groundwater protection (e.g., MCLs) and possibly U.S. EPA ambient water quality criteria.

Institutional Controls--Institutional controls minimize human health risks from hazardous substances primarily via mechanisms that prevent access to the substances. There are many types of possible institutional controls, including site fencing, posting of health advisories, land use restrictions, and bans for the consumption of contaminated biota or groundwater. Site fencing may require boundary survey work and consideration of Tacoma land use and permitting requirements. Posting of health advisories may require close coordination with the Tacoma-Pierce County Health Department and consideration of their regulations and guidelines. Because of the limited effectiveness of institutional controls alone, this alternative will fail to satisfy major ARARs, including the intent of CERCLA/SARA. However, it is feasible and advisable to use selected institutional controls in conjunction with other remedial alternatives.

Dredging Activities--Dredging technologies under consideration include hydraulic cutterhead, specialized hydraulic dredge, watertight bucket clamshell, and mud cat. Federal action-specific ARARs relating to dredging include the Clean Water Act (Sections 404 and 401), Rivers and Harbors Appropriations Act (Section 10), and MPRSA. There are no state ARARs that specifically regulate dredging at this time. However, state water quality requirements (under Section 401 of the Clean Water Act) may be considered during dredging activity and may be considered an action-specific ARAR as well as a location-specific ARAR. Water quality considerations may involve the Washington Departments of Ecology, Natural Resources, Fisheries, and Game. The Departments of Fisheries and Game must consider the substantive requirements for a hydraulics permit for any project that may interfere with the natural flow of surface water. ARARs that specifically regulate dredging in the Commencement Bay N/T area are addressed in the City of Tacoma Shoreline Management Plan.

The substantive requirements of the Clean Water Act (including state water quality certification), and the Rivers and Harbors Appropriations Act are legally applicable to dredging actions on an action-specific basis because remedial dredging satisfies their jurisdictional requirements. Limitations on times of the year when dredging may occur are further specified by the Puyallup Indian Tribe and the Department of Fisheries as the designated trustees for commercial fisheries resources. In general, dredging is not allowed between mid-March and June, or during the fall.

It is possible that the legal applicability, or relevance and appropriateness of specific requirements of dredging ARARs may vary by problem area and by dredging technology. For example, compliance with the substantive provisions of Sections 404 and 401 of the Clean Water Act and state water quality requirements will be necessary for all dredging activities. However, specific restrictions may be imposed by some agencies under certain conditions (e.g., required use of a silt curtain by the Department of Fisheries or Game to avoid impacts to migrating anadromous fish).

The MPRSA does not provide requirements or guidelines for the testing of dredged material per se and is thus not a legally applicable ARAR. However, general guidelines for the testing of material for ocean disposal may be relevant and appropriate for remedial alternatives involving dredging.

Treatment Activities--Categories of treatment technologies under consideration include solids separation, incineration, solidification, and land treatment. There are a variety of alternative treatment methods within each of these categories. The discussion of ARARs in this section focuses only on the above four categories.

Most ARARs for contaminated sediment treatment relate to the release or disposal of materials resulting from the treatment process. In addition, there may be releases to the atmosphere (e.g., from incineration), groundwater (e.g., from infiltration of effluent or leachate), and surface water (discharge of effluent). There may also be the need to dispose of materials such as filters contaminated during the treatment process (see next subheading).

Potential federal ARARs for waste treatment are currently limited to onsite incineration and land treatment. There are proposed standards for thermal treatment other than incinerators; for chemical, physical, and biological treatment other than tanks, surface impoundments, or land treatment units; and for the control of volatile organic emissions from air stripping operations. There are no potential state ARARs for specific candidate treatment technologies.

Disposal--Action-specific ARARs that pertain to the disposal of materials overlap somewhat with chemical-specific and location-specific ARARs. ARARs for the open-water or nearshore disposal of dredged material (treated or untreated) or capping material are analogous to location-specific (and to some extent, chemical-specific) ARARs discussed above. ARARs for the disposal of treated and untreated dredged material and capping material depend to a significant degree on contaminant concentrations. For example, some materials may not meet the PSDDA chemical-specific guidelines for open-water disposal, requiring either treatment or confined disposal. Element S-4 of the PSWQA will establish standards for disposal of sediments classified as having adverse effects in confined disposal facilities. These standards will meet the definition of ARARs when promulgated.

Current U.S. EPA policy requires that any untreated, contaminated dredged materials taken offsite be disposed of at a facility that is in compliance with RCRA or TSCA (PCB disposal) or other appropriate federal or state requirements, depending on the contaminants of concern and their concentrations. The requirements for handling and disposal of treated dredged material will depend on chemical analyses conducted following remediation.

Action-specific ARARs may also be invoked for the disposal of effluent from treatment processes. It is very unlikely that an effluent will be classified as a RCRA hazardous waste or a State of Washington dangerous or extremely hazardous waste. However in such a case, the potential ARARs discussed above would have to be evaluated. Depending on the results of bench-scale treatability studies, treatment wastewater may be discharged to surface water or a publicly owned treatment works (POTW) if applicable effluent guidelines can be achieved. Potential federal ARARs for such actions include requirements for testing and monitoring of Section 402 of the Clean Water Act and requirements for the discharge of effluent to a POTW. Potential state ARARs for the discharge of treatment wastewater include the following (see Appendix C for regulatory citations):

- Water pollution control and discharge standards that require treatment with known, available, and reasonable methods

- Regulations for the protection of upper aquifer zones that require protection of water quality to the extent practical

- The state waste discharge program that regulates discharges of wastewater to groundwater

- Water pollution control regulations that provide for the use of water quality regulations at hazardous waste sites.

All of the action-specific ARARs discussed must be evaluated because their jurisdictional requirements are met by the candidate remedial alternatives.

Action-Specific TBCs--Action-specific TBCs relating to the Commencement Bay N/T remedial actions would include current PSDDA guidelines for the testing of dredged material prior to removal and disposal. TBCs for the disposal of treated and untreated dredged material and capping material depend to a significant degree on contaminant concentrations. In addition, construction of treatment facilities may require consideration of the City of Tacoma's land use plan, building codes, and grading and drainage ordinances. It is unlikely that disposal of untreated sediment will be allowed at a local municipal solid waste landfill within Pierce County or a PSDDA unconfined, open-water site because of liability issues associated with CERCLA wastes. The action level triggering sediment remediation in Commencement Bay is expected to be very close to the level of sediment toxicity at which unconfined, open-water disposal of dredged material is prohibited under PSDDA guidelines.

Major action-specific ARARs and TBCs for contaminated sediment remedial alternatives are listed in Table 4-4.

Large portions of the Commencement Bay N/T site are within the boundaries of the Puyallup Indian Reservation. Environmental regulations promulgated by the Puyallup Tribal Government will therefore need to be evaluated as potential ARARs. Although the tribe has not adopted any specific environmental legislation to date, it is actively pursuing the development of laws and programs to address the control of hazardous substances and pollution sources within its jurisdiction. The degree of tribal involvement and the tribe's authority to promulgate environmental regulations will vary according to the provisions of those federal environmental statutes which the tribe desires to administer, and the U.S. EPA policies and programs providing for such authority. For example:

- The Clean Water Act provides that Indian tribes may qualify to administer programs regulating point and nonpoint sources of pollution, dredge and fill, and other programs. Formal delegation of these programs follows a process of review and approval by U.S. EPA defined in Section 319 of Clean Water Act.

- Under the Safe Drinking Water Act, the tribe may qualify for primary enforcement status pursuant to regulatory requirements promulgated by U.S. EPA.

- Under CERCLA, the tribe may enter into a cooperative agreement with U.S. EPA to undertake Superfund cleanup of any NPL sites on the reservation.

- Although U.S. EPA has confirmed its regulatory jurisdiction regarding RCRA-regulated facilities, it may work with the tribe in the development and implementation of RCRA programs.

4.2.3 Availability

This evaluation criterion refers to the availability of the equipment and specialized expertise required to perform the candidate alternative as well as the availability of the necessary treatment, storage, or disposal capacity. Current stage of development (i.e., of the various technologies) and potential vs. current availability are also considered.

At present, the availability of upland disposal facilities within the Commencement Bay N/T site is uncertain. As discussed in the preliminary screening of alternatives (Chapter 2), several potential disposal sites within the project boundaries have been identified. However, no upland disposal sites have been established and approved for disposal of contaminated dredged material in the Commencement Bay N/T project area. It was assumed for the evaluation, however, that an upland disposal facility could be made available within the project area. It was also assumed that agency approval, tribal acceptance, and public acceptance could be attained. This assumption was made based on recent guidance for remediation of Superfund

TABLE 4-4. SELECTED POTENTIAL ACTION-SPECIFIC ARARs FOR CANDIDATE REMEDIAL ALTERNATIVES

Action	Requirement[a]	Prerequisites	Citation
Upland disposal (closure) of RCRA hazardous waste	Removal of all contaminated material	RCRA hazardous waste placed at site, or movement of waste from one area to another	40 CFR 264.11, 40 CFR 264.228, and 264.258, 40 CFR 264.228(a)(2), and 264.258(6), 40 CFR 264.310 52 FR 8712
Upland disposal (containment) of RCRA hazardous waste	Construction of new landfill onsite Design, maintenance, and operation requirements	RCRA hazardous waste placed in new landfill	40 CFR 264.301, 264.303, 264.304, 264.310, 264.314, 268 Subpart D, 264.220, 264.221
Upland disposal (post closure)	Monitoring requirements	RCRA hazardous waste	40 CFR 264.1
Upland disposal (groundwater protection)	Groundwater monitoring at RCRA disposal facilities	RCRA hazardous waste	40 CFR 264.90-264.101, 265.90-265.94
	General protection requirements		
Upland disposal of extremely hazardous waste	Disposal in state-approved facility	State designates as extremely hazardous waste (EHW)	WAC 173-303-081, WAC 173-303-140
Upland disposal of solid waste or dangerous waste	Disposal in an approved surface impoundment	Material must not be classified as EHW	WAC 173-303-081, WAC 173-303-650

TABLE 4-4. (Continued)

Action	Requirement[a]	Prerequisites	Citation
Dredging and open-water or nearshore disposal of dredged material	Dredging in waters of the United States requires a permit	Waters of the United States	Clean Water Act Section 404, 40 CFR 125
	Disposal of dredged material requires a permit		
	Dredging or aquatic disposal of dredged material requires state water quality certification		Clean Water Act Section 401, 40 CFR 125
	Hydraulics permit	Interference with natural water flow of Washington state waters	RCW 75-20.100 WAC 220-110
	Requirement for a shoreline substantial development permit	Disposal site within Tacoma city limits	Tacoma Shoreline Master Program
	Guidelines and criteria for testing dredged material and establishing disposal sites	Oceans of the United States	Marine Protection Resources and Sanctuaries Act
		Puget Sound	Puget Sound Dredged Disposal Analysis
	Confined disposal standards (S-4)	Puget Sound	(under development)
Sediment quality and sediment discharge (proposed) standards	Limitations on sediment discharges	Marine and fresh waters of the State of Washington	RCW 90.48 and 90.70 WAC 173-204 (pending)
Incineration of dredged material	Requirements for incineration of RCRA hazardous waste	RCRA hazardous waste	40 CFR 264.340-264.999, 265.270-265.299
	Requirements for incinerators to achieve local standards, new source requirements		PSAPCA permit issuance

TABLE 4-4. (Continued)

Location	Requirement[a]	Prerequisites	Citation
Direct discharge of treatment system effluent	Requirements and criteria including compliance with federal WQC and BAT; NPDES permit requirements	Direct discharge to waters of the United States	40 CFR 125.123(b), 125.122, 125.123(d)(1), 125.124
Discharge to a POTW	Requirements for discharges to POTWs	Discharge to Tacoma POTWs	40 CFR 403.5, 40 CFR 264.71, 264.72
	Tacoma Pretreatment Program		Tacoma POTW Pretreatment Program
Land treatment	Design, monitoring, and treatment requirements	RCRA hazardous waste	40 CFR 264.271, 264.273, 264.276, 264.278, 264.281, 264.282, 264.283
Treatment	Proposed standards for treatment other than incineration and land treatment	RCRA hazardous waste	50 FR 40726, 40 CFR 264, 40 CFR 268.10-268.13, 42 U.S.C. 3004(d)(3), 3004(e)(3), 6924(d)(3), 6924(e)(3)

[a] Permits are not required under SARA.

sites, which emphasizes the need to identify solutions that minimize offsite transport of contaminants (Porter 1987).

The availability of a nearshore disposal facility within the Commencement Bay N/T site has been enhanced by the recent emergence of Slip 1 in Blair Waterway as a potential site. This facility has been designated for filling by the Port of Tacoma, and has a capacity of approximately 900,000 yd^3. Once again, it was assumed that agency approval, tribal acceptance, and public acceptance could be attained.

The potential for offsite disposal of untreated contaminated dredged material has largely been dismissed because of inherent difficulties associated with dewatering and transport of marine sediment, and the associated costs of both transport and disposal. However, if treated sediment is determined to meet state and federal criteria for designation as nonhazardous waste, the material could feasibly be placed in a sanitary or demolition landfill. Concentrated residues that may be generated by implementation of one or more treatment alternatives will be dealt with in strict accordance with state and federal regulations, including disposal at a RCRA-approved facility, as appropriate.

4.3 COST CRITERIA

Order-of-magnitude costs were estimated for each combination of remedial alternative and problem area. Costs were grouped into the following categories:

- Construction and implementation - Costs for engineering design, development of specifications, dredging, transportation, treatment, intertidal habitat replacement, and disposal.

- Operation and maintenance - O&M costs associated with all post-disposal onsite activities, including monitoring. Engineering site inspections of containment structures, erosion control, drainage, repairs, and landscape upkeep are all aspects of O&M. The latter category includes refertilization, mowing, and general maintenance of site vegetation.

Monitoring activities are designed for both short- and long-term surveillance of containment structure or cap performance. In practice, activities should begin just prior to the disposal operation and remain intense for the first year, tapering off over the course of an assumed 30-yr program. In this manner, failure to initially contain sediment contaminants can be detected immediately. In addition, frequent monitoring after completion of the remedial action allows an assessment of the rate and extent of contaminant migration that can be expected to occur over the long term. Assuming that initial monitoring efforts confirm predicted rates of contaminant migration based on pre-implementation bench-scale tests and modeling studies, it is reasonable to assume that the sampling frequency can be reduced over time. The lack of contaminant releases within approximately 1 yr of sediment disposal indicates that the level of monitoring can be reduced.

Cost estimates for specific items within each category were normalized to 1988, using an annual inflation rate of 6 percent. For yearly costs associated with monitoring, operation, and maintenance, the present worth was calculated using a 10 percent interest rate. A discussion of the estimation method, assumptions, and information sources used is presented in Appendix D (along with summary tables for each remedial alternative).

4.4 IDENTIFICATION OF PREFERRED ALTERNATIVES

Guidance for identifying a preferred remedial alternative for each of the nine high priority problem areas in the Commencement Bay N/T study area is provided in Section 121 of SARA, the NCP, and U.S. EPA guidance (Porter 1987; U.S. EPA 1988a). The SARA revisions to CERCLA mandate that the remedial actions selected have the following characteristics:

- Are protective of human health and the environment
- Attain federal, tribal and state public health and environment requirements
- Are cost-effective
- Use permanent solutions and alternative treatment or recovery technologies to the maximum extent practicable.

Treatment is defined as those activities that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. Selection of permanent remedies that have not yet been implemented under similar circumstances are authorized under the law. However, the preference for selection of an alternative that eliminates the need for long-term management (i.e., a permanent treatment) may not be practical in some circumstances. Recent draft RI/FS guidance (U.S. EPA 1988a) indicates that permanent treatment may not be reasonable in circumstances where site conditions, limitations in technologies, and extreme costs may be controlling factors. For example, sites with very large volumes of potentially low concentration wastes, such as municipal landfills and mining sites, fall into this category. Contaminated dredged materials from the Commencement Bay N/T area may also fall into this category. It is further stated in SARA that remedies requiring offsite transport of untreated contaminant materials should be the least favored action where practicable treatment technologies are available.

The following process was used to identify the preferred alternative in each problem area. First, effectiveness and implementability of candidate alternatives were summarized. Results are shown in Chapters 5-13 as oversized narrative tables. Next, the candidate alternatives were compared with one another. Results are shown as "evaluation summary" tables, with ratings of high, moderate or low in the major evaluation criteria. The rationale and method followed when assigning ratings are described below in Sections 4.4.1-4.4.8. The preferred alternatives were identified from these summary tables. This approach was developed to identify one preferred remedial alternative with the broadest applicability for each of the nine Commencement Bay N/T problem areas, but the process is complicated by the variable nature of both the contaminants and the environmental and operational features within the problem areas. For this reason, a brief review and analysis was conducted to identify other alternatives that may be suitable for sediments contaminated by a particular class of compounds (e.g., inorganic contaminants) or located within a specific environmental setting (e.g., intertidal areas). A discussion of this analysis is presented for each problem area, following description of the preferred alternative.

4.4.1 Short-Term Protectiveness

Community, worker, and environmental protection during implementation of the candidate alternative are evaluated under the short-term protectiveness criterion.

A candidate alternative rates high for short-term protectiveness if implementation is expected to pose only minimal risks to workers and the community. Community exposure risks are expected to be low, as site controls can be readily implemented for all alternatives to minimize potential contact with contaminated dredged material. Worker exposure potential is lowest for alternatives in which contaminated sediments are left in place. Alternatives involving dredging increase worker exposure risks, but process controls, available personal protective equipment, and the relatively low level of hazard associated with contaminated dredged material contact could preserve a high rating for this aspect of an alternative. Environmental protection during implementation is highest when sensitive resource areas are not damaged or destroyed by the alternative. Environmental controls exist for most alternatives (e.g., silt curtains for dredging, emission controls for incineration). However, short-term impacts are expected for loss of habitat due to dredging, capping, or disposal operations.

Moderate ratings were assigned to candidate alternatives involving effective remediation technologies with an increased potential for some adverse impacts, but where engineering and safety controls are feasible. In this case, a moderate to high risk of exposure to workers may be anticipated, but safety controls are adequate to significantly reduce the exposure potential. Process-related risks associated with treatment alternatives prolong exposure potential, and therefore generally reduce the short-term protectiveness rating. A moderate rating was also given to an effective technology that poses moderate risk to a low sensitivity environment and that involves risk control methods which are difficult or costly to implement.

Candidate sediment remedial alternatives received low ratings if they offer only minor overall benefits, with high probability of producing or allowing significant environmental impacts, and where engineering and safety controls are not feasible. This rating was also assigned to candidate alternatives that pose a high risk to sensitive environments or populations, with inadequate mitigative controls or monitoring capabilities.

4.4.2 Timeliness

The comparison of the candidate alternatives for timeliness is based on their ability to mitigate observed biological impacts rapidly without compromising the integrity of the various process options. The time required to obtain concurrence from the various state and federal agencies on all components of the remediation system, including treatment, storage, and disposal facilities was considered. In all cases, source control measures were assumed to be implemented rapidly and effectively to facilitate subsequent implementation of sediment remediation.

A high rating was assigned to alternatives that can be completed within 1-2 yr of implementation of adequate source controls. These alternatives would have to rely on currently available equipment and facilities, with minimal bench-scale or pilot testing required. Alternatives that produce immediate environmental benefits were also rated high.

Moderate ratings were assigned to candidate alternatives that can be implemented within 2-5 yr following implementation of adequate source control. These alternatives would generally require some testing and development of technologies because there has been little or no field application to date. Alternatives that must be modified because the sediments are of marine origin or that require lengthy review times for any aspect of the technology were also rated moderate.

Low ratings for timeliness were assigned to candidate alternatives that require greater than 5 yr to implement and complete. Included in this category are alternatives that require substantial treatability testing, that have low production rates, or where significant delays in development may be expected (e.g., determination of treatment feasibility, siting of a land treatment facility).

4.4.3 Long-Term Protectiveness

The comparison of candidate alternatives in terms of long-term protectiveness is based on their effectiveness in permanently mitigating the observed adverse biological impacts of sediment contaminants in the Commencement Bay N/T project area. Reliability, long-term risks and benefits, uncertainties remaining after implementation of the alternative, environments or populations at risk, and the effectiveness of monitoring following remediation were all considered. Included in the comparison of long-term protectiveness are the criteria for reviewing future exposure potentials, reliability, and public health and environmental protection.

The candidate alternatives that rate high afford a high degree of post-remediation reliability and security and allow monitoring to be readily implemented. System failures are detectable long before public health or environmental impacts occur. High ratings were also assigned to facilities that would cause minimal adverse impacts if any critical component failed, and to alternatives that permanently reduce public health and environmental risks.

Moderate ratings were given to alternatives that present a higher potential for future exposure, yet are readily monitored or amenable to engineering controls. This rating also applies to alternatives that are less reliable, yet present minimal risk of adverse impacts from system failures. Moderate ratings were assigned to alternatives that remove or isolate contaminants with minimal on- or offsite risks.

Low ratings for long-term protectiveness were assigned to alternatives involving significant risks after remediation. For alternatives with a high degree of uncertainty and where significant adverse public health or environmental impacts would be expected from system failures, low ratings were applied. Alternatives involving a high potential for future exposure, great uncertainty concerning monitoring, or uncertainty concerning contaminant fate and transport also received a low rating.

4.4.4 Reduction in Contaminant Toxicity, Mobility, or Volume

The comparison of candidate sediment remedial alternatives in terms of reduction in toxicity, mobility, or volume focuses on the extent to which an alternative results in the permanent destruction or detoxification of sediment contaminants. The permanent treatment of waste contaminants affords a higher level of overall effectiveness than does isolation (Porter 1987).

High ratings for reduction in contaminant toxicity, mobility, or volume were assigned to alternatives that result in significant and irreversible reductions with minimal residual material. High ratings were also assigned to alternatives that may be less effective in reducing overall residual mass yet generate residual materials that can be classified as nonhazardous waste.

Moderate ratings are applicable to alternatives that provide some degree of reduction in toxicity, mobility, or volume. This rating was applied to alternatives incorporating treatment technologies that generate a large volume of less mobile and toxic waste.

Low ratings apply to alternatives that lack a treatment element. All capping and dredge/disposal alternatives rank low because they isolate contaminated sediments without substantially affecting the contaminants themselves, although mobility is physically limited.

4.4.5 Technical Feasibility

Technical feasibility is based on implementability and the reliability of the process options that make up each alternative, as judged by past performance in similar applications, the importance of long-term O&M to success of the system, and the effectiveness of monitoring systems in tracking performance.

High ratings for technical feasibility were applied to alternatives that can be implemented with little bench- or pilot-scale testing and that incorporate highly reliable, proven procedures. High ratings are also applicable to alternatives that require minimal O&M or where O&M procedures are well established, effective, and easily implemented as part of the ongoing performance of the treatment or isolation process. For those alternatives where performance monitoring is focused and allows early detection of system failures, high ratings were also given.

Moderate ratings for technical feasibility are applicable to alternatives that appear to be technically feasible, yet require extensive testing or development prior to implementation. Moderate ratings were also applied to alternatives that require more extensive, routine maintenance using proven procedures. Where monitoring requirements are more extensive but the systems are estimated to be effective in detecting performance problems, moderate ratings are also appropriate.

Low ratings for technical feasibility apply to alternatives that are complex and difficult to implement or that involve technologies that are significantly constrained by site conditions. Low ratings were given to alternatives that require extensive O&M following remediation, and where intensive O&M is critical to system success.

4.4.6 Institutional Feasibility

Institutional feasibility is based on the ability of alternatives to adequately address all applicable or relevant and appropriate regulations and other nonpromulgated agency guidelines, advisories, and policy that require consideration. The comparison of alternatives includes an assessment of the likelihood that ARARs can be met and that TBCs can be favorably addressed.

High ratings for institutional feasibility were applied to alternatives that comply with all ARARs as well as all relevant guidance and policy. Alternatives that are flexible in terms of timing and that incorporate components likely to be approved by the regulatory agencies were also rated high.

Moderate ratings apply to alternatives that meet ARARs and meet the intent of most relevant guidance. Moderate ratings also apply to alternatives likely to receive agency acceptance, albeit through negotiations.

Low ratings apply to alternatives that do not comply with ARARs and present problems with respect to agency policy and guidance that are probably unresolvable.

4.4.7 Availability

Availability is based on the accessibility of necessary equipment, specialized expertise, and disposal facilities. The highest ratings for availability were assigned to alternatives that use existing and readily accessible materials, facilities, and personnel. A high rating was also applied to alternatives that can use existing facilities to accommodate treated or altered contaminated sediments.

Moderate ratings were applied to alternatives involving technologies that are regarded as feasible but require adaptation to the site-specific conditions. This rating applies to alternatives incorporating technologies that require bench-scale or treatability testing to define design parameters. This rating also applies to alternatives that rely on disposal facilities that have been identified as part of previous studies in the Commencement Bay area, but have not been formally approved or developed for use.

Low ratings were applied to alternatives that rely totally on unproven technologies; on technologies that require personnel and equipment not currently available in the project area; or on the use of disposal or treatment facilities not currently available or planned, or that appear to entail a high degree of uncertainty in their development.

4.4.8 Cost

The comparative evaluation of cost-effectiveness among alternatives can only be conducted following the evaluation of the effectiveness and implementability factors. This process allows the overall effectiveness of each alternative to be assessed, based on the objectives for the Commencement Bay N/T remediation program. These objectives include mitigation of observed biological impacts and long-term protection of the environment and public health. Cost comparisons are most appropriate after identification of candidate alternatives that offer the best balance of predicted results. In conducting a cost comparison of final candidates, consideration must be given to the statutory goal of permanently and significantly reducing contaminant toxicity, mobility, or volume, because alternatives that involve feasible permanent solutions generally require additional capital funds for implementation.

5.0 HEAD OF HYLEBOS WATERWAY

Potential remedial actions are defined and evaluated in this section for the head of Hylebos Waterway problem area. The waterway is described in Section 5.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 5.2 provides an overview of contaminant sources including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contaminant concentrations are discussed in Section 5.3. Areas and volumes of sediments requiring remediation are discussed in Section 5.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 5.5. The preferred alternative is identified in Section 5.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 5.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

5.1 WATERWAY DESCRIPTION

Hylebos Waterway is designated as a navigational waterway with a required maintenance depth of 30 ft below MLLW. The problem area designated as the head of Hylebos Waterway extends roughly 1 mi from the head of the waterway (which is approximately 16,500 ft from the mouth), to a point approximately 11,000 ft from the mouth of the waterway. Both turning basins in the waterway are located in this problem area. At their widest points, the lower turning basin measures approximately 750 ft and the upper turning basin measures approximately 1,000 ft. Subbottom profiling of Hylebos Waterway showed that midchannel depths in the area average approximately 33 ft below MLLW, with depths varying across the channel bottom between 30 and 40 ft below MLLW (Raven Systems and Research 1984). Depths in the northwestern reaches of the head of Hylebos Waterway problem area were fairly constant at 40 ft below MLLW. Sediments within the waterway are typically silty sands with an average composition of 65 percent fine-grained material (with a range of 44-78 percent) and an average clay content of 20 percent (Tetra Tech 1985b). The waterway has been characterized as showing a reduction in sedimentation rates from the mouth to the head (Tetra Tech 1987b).

Hylebos Waterway was formed by dredging the Puyallup River delta in the early 1920s. Since that time, the southern shoreline of the waterway has become heavily industrialized. Industrial development along the north shore has not been as extensive as along the south shore, due principally to the limited land area available between the waterway and the steep bluffs. An illustration of the waterway and the locations of nearby industries are shown in Figure 5-1.

Dredging by the Port of Tacoma and the U.S. Army Corps of Engineers has changed the shape and size of Hylebos Waterway. When it was created in the 1920s, it extended only to the point of what is now the lower turning basin, near the northwestern end of the problem area. In the mid-1950s, the Port of Tacoma extended the waterway approximately 3,800 ft (Tetra Tech 1986c). Subsequent dredging by the U.S. Army Corps of Engineers widened the upper reaches of the waterway and created the upper turning basin at the head of the waterway (Dames & Moore 1982).

5.1.1 Nature and Extent of Contamination

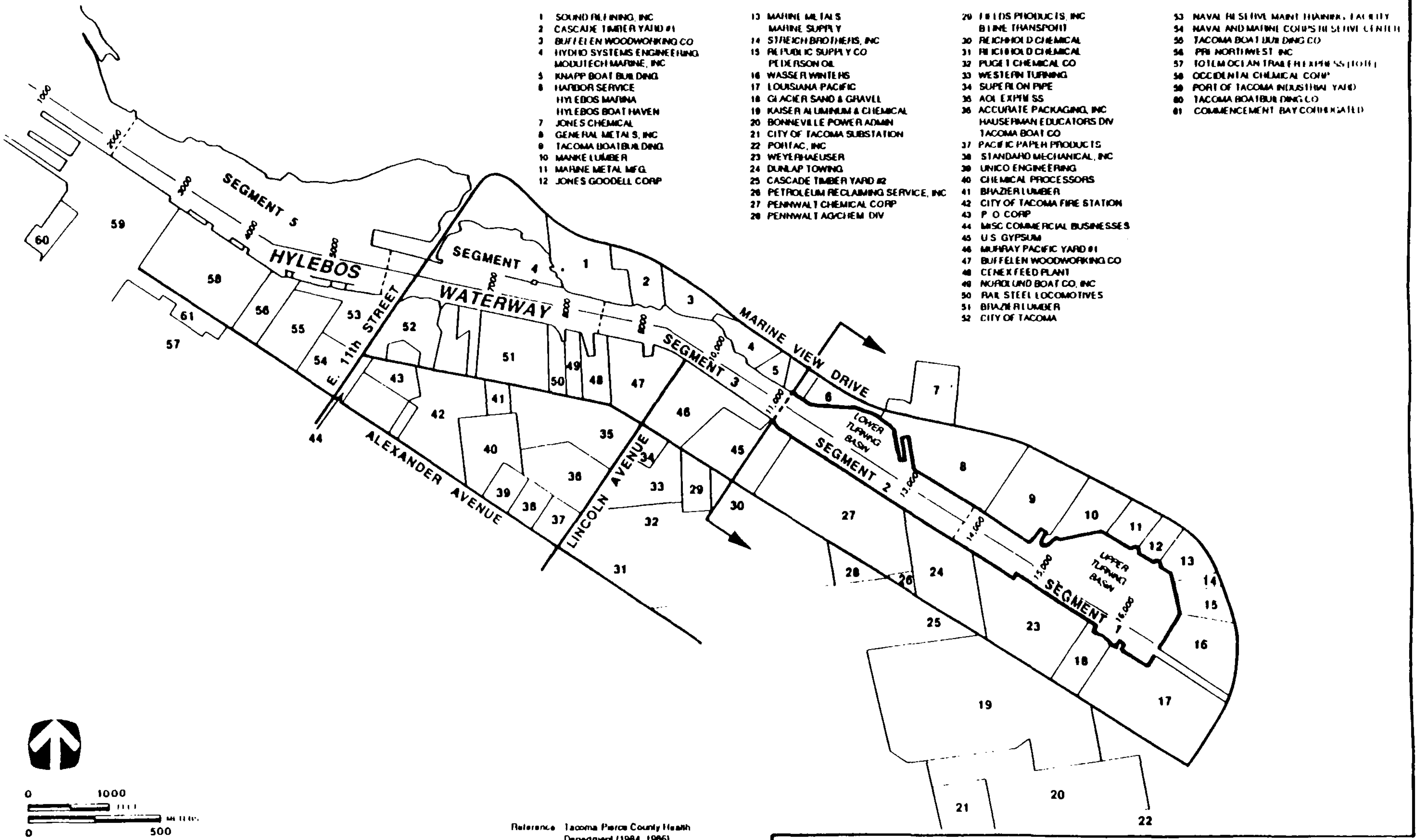
An examination of sediment contamination data obtained during RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical surveys has revealed that sediments in the head of Hylebos Waterway contain elevated concentrations of both organic and inorganic materials. PCBs, HPAH, arsenic, and zinc were identified as Priority 1 contaminants in the waterway. Priority 2 contaminants that have been detected in the waterway include copper, antimony, lead, nickel, mercury, tetrachloroethene, and phenol. The following compounds exceeded their AET value at only one station and are therefore considered Priority 3 contaminants: methylpyrene, methylphenanthrene, dibenzothiophene, ethylbenzene, xylene, chlorinated benzenes, chlorinated butadienes, bis(2-ethylhexyl) phthalate, benzyl alcohol, and an alkylated benzene isomer. Available data suggest that these contaminants in the head of Hylebos Waterway have relatively high particle affinity with a low volatility or solubility potential (Tetra Tech 1987c).

Fish in Hylebos Waterway had significant accumulations of PCBs, mercury, and phthalates in muscle tissues and significantly elevated prevalences of liver lesions (Tetra Tech 1985b).

Arsenic, HPAH, and PCBs were selected as indicator chemicals for the head of Hylebos Waterway. Surface sediment enrichment ratios (i.e., ratio of observed concentration to long-term cleanup goal) for these three contaminants were higher over a greater area than for other identified problem chemicals. These contaminants were also selected as indicators on the basis that they represent contaminant loading to the waterway from potential sources of contamination including Kaiser Ditch, Pennwalt, log sorting yards, Hylebos Creek, Kaiser Aluminum, Tacoma Boatbuilding Company, General Metals, and storm drains (see Section 5.2).

Concentrations of arsenic exceeding the long-term cleanup goal of 57 mg/kg were observed in the southeastern-most reaches of the problem area within the upper turning basin, between the two turning basins, and in the northwestern-most areas in the vicinity of the lower turning basin. The available data indicate that a major source of arsenic exists near the head.

Concentrations of HPAH exceeding the long-term cleanup goal of 17,000 ug/kg cover the entire central portion of the problem area, primarily in the area between the two turning basins. Concentrations peaked in the



Reference Tacoma Pierce County Health Department (1984 1986)

Notes Property boundaries are approximate based on aerial photographs and drive by inspections

Figure 5-1. Head of Hylebos Waterway - Existing industries and businesses center of the problem area and decreased towards both the head and mouth. The high HPAH concentrations appear to be associated with an accumulation of HPAH-contaminated organic material in the sediment (Tetra Tech 1985a).

Concentrations of PCBs exceeding the long-term cleanup goal of 150 ug/kg cover a large percentage of the problem area with high levels noted in the two turning basins and the south shoreline. PCB concentrations were highly variable in Hylebos Waterway sediments. A relatively patchy distribution remained after concentrations were normalized to sediment organic carbon content, suggesting that this contaminant does not come from the major carbon sources in the waterway (e.g., Kaiser Ditch, silt from the Puyallup River) but from multiple local, and possibly historic, sources (Tetra Tech 1985a). PCB concentrations peaked approximately 12,000 ft from the mouth of the waterway, in the vicinity of the Pennwalt Chemical Corporation facility. Dredging in that vicinity by Pennwalt is believed to have influenced the observed surficial sediment distribution of PCBs (Tetra Tech 1985b). Concentrations observed in sediments following dredging were similar to those found in deeper layers of undisturbed portions of the waterway.

Areal and depth distributions of arsenic, HPAH, and PCBs are shown in Figures 5-2, 5-3, and 5-4, respectively. Concentrations in the figures are normalized to long-term cleanup goals, such that values above 1.0 define problem sediments. The cleanup goal for arsenic was set by the AET for benthic infaunal abundance depression. The cleanup goal for HPAH was determined by the AET for the oyster larvae bioassay. The cleanup goal for PCBs is based on data for bioaccumulation of the contaminant in English sole muscle tissue.

Included in Figures 5-2, 5-3, and 5-4 are contaminant depth profiles based on core samples from the head of Hylebos Waterway. Arsenic concentrations were either variable with depth or displayed surface minima, suggesting that metals loading is recent but may be decreasing (Tetra Tech 1985a, 1987c). The possibility that there is a significant groundwater source of arsenic to the waterway complicates the interpretation of sediment profile data. Depth profiles suggest that arsenic contamination exceeds the cleanup goal to a depth of approximately 1.0 yd.

Although the sediment profiles indicate that HPAH concentrations vary somewhat with depth, for the waterway as a whole greater concentrations of HPAH were observed in subsurface horizons (Tetra Tech 1985a). A conservative estimate based on depth profiles suggest that HPAH contamination exceeding the cleanup goal can be expected to a depth of approximately 0.5 yd.

Deep cores collected during the RI indicate that historical discharges of PCBs were greater than current discharges. Resolution of the depth profiles obtained during the FS sampling was constrained by analytical limitations (e.g., chlorinated interferences). Although the results were somewhat inconclusive, surface minima were observed for the station at the head of the waterway, suggesting that loading has decreased. The profile collected adjacent to the Pennwalt Chemical Corporation (near the 1982 dredging operation site) showed variable concentrations of PCBs with depth.

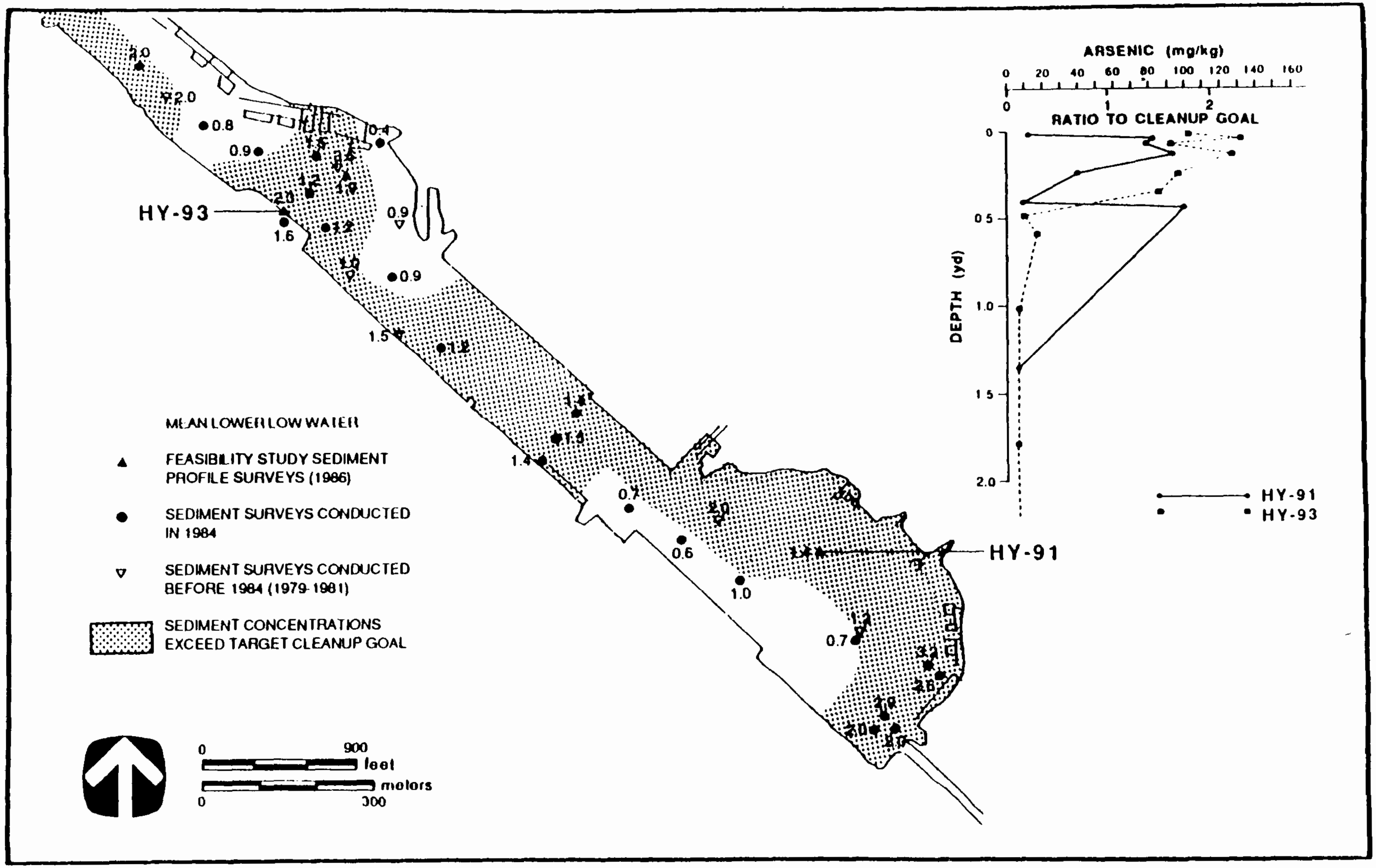


Figure 5-2. Areal and depth distributions of arsenic in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal.

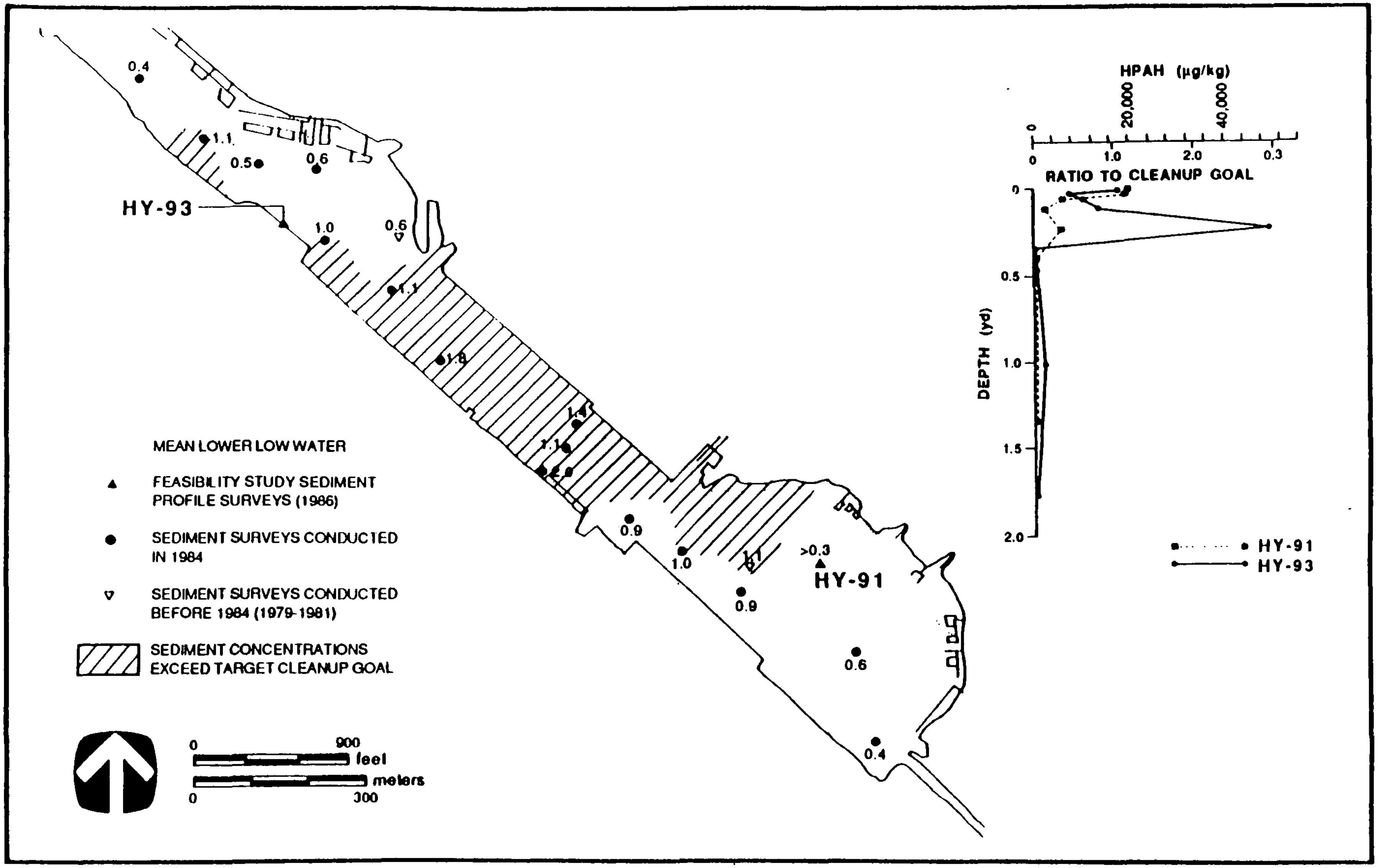


Figure 5-3. Areal and depth distributions of HPAH in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal.

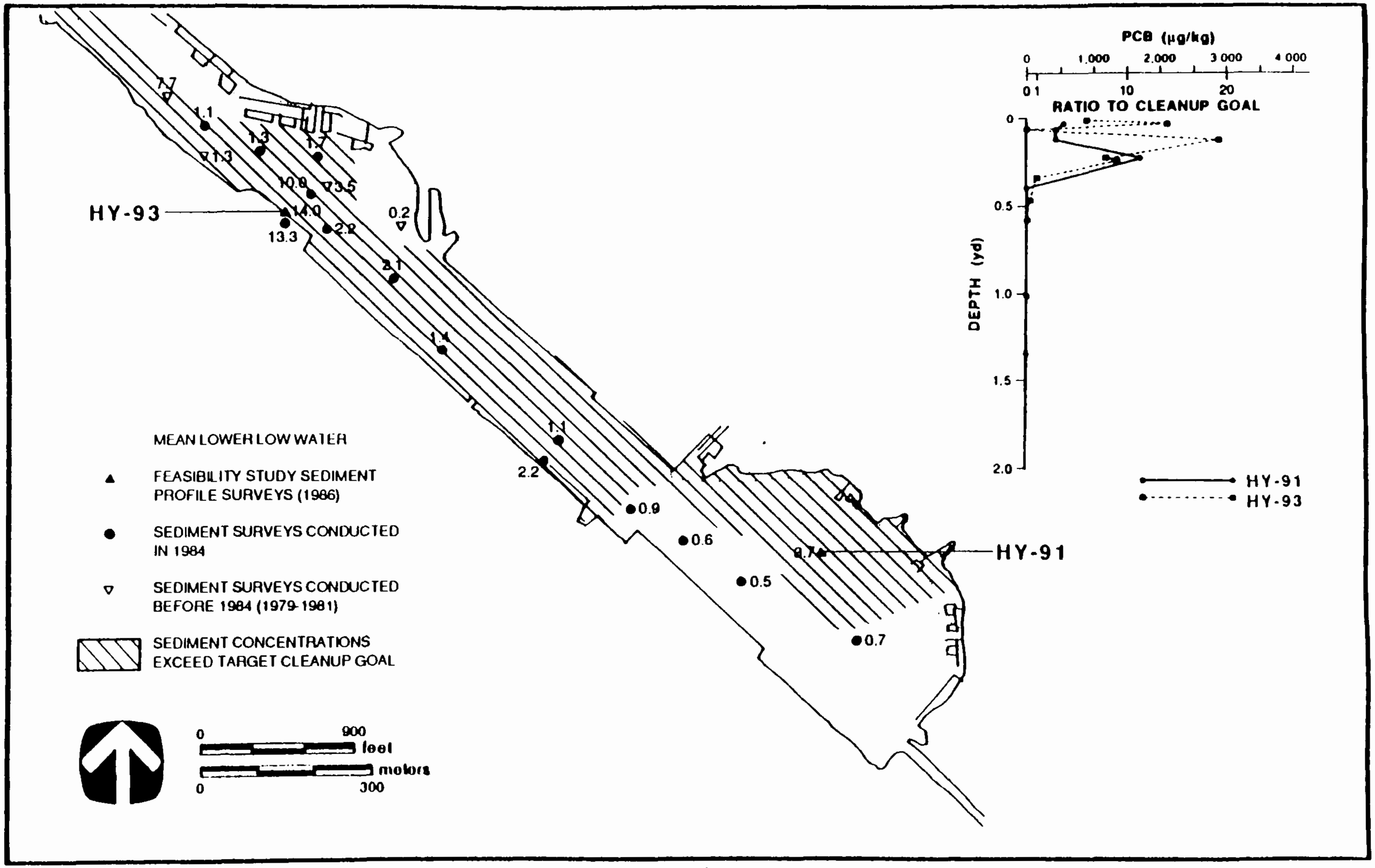


Figure 5-4. Areal and depth distributions of PCBs in sediments at the head of Hylebos Waterway, normalized to long-term cleanup goal.

Depth profiles suggest that PCB contamination exceeding the long-term cleanup goal can be expected to a depth of approximately 0.5 yd.

5.1.2 Recent and Planned Dredging Projects

General Metals dredged 2,000 yd^3 of sediment from the head of Hylebos Waterway in October 1988 (Vail, R., 9 November 1988, personal communication). The sediment was deposited on General Metals property. The company has a 10-12 yr permit to dredge in the head of Hylebos Waterway every other year. The volume of material to be dredged is unspecified in the permit.

Weyerhaeuser and Pennwalt have requested dredging permits from the U.S. Army Corps of Engineers. Weyerhaeuser intends to begin work in 1988 or early 1989 (Sinclair, J., 9 November 1987, personal communication). Pennwalt wants to install bulkheads and fill (U.S. Army Corps of Engineers, 27 October 1987, personal communication).

Businesses and industries that responded when queried about future dredging plans are itemized below.

- Weyerhaeuser has not planned any major dredging projects. In 1988 or early 1989, the company needs to repair the ramp for removing logs. Approximately 40 yd^3 of material will need to be removed before the concrete can be poured (McLain, D., 22 October 1987, personal communication). Disposal of this material is currently planned for a local landfill.

- Glacier Sand and Gravel knew of no planned dredging projects in the head of Hylebos Waterway, but expected that dredging would be necessary sometime within 10 yr (Johnson, J., 22 October 1987, personal communication).

- Streich Brothers, Inc., U.S. Gypsum, Murray Pacific Yard #1, McFarland Cascade, Hylebos Boat Haven, and Manke Lumber have not planned any dredging projects (Rain, T., 22 October 1987, personal communication; Anonymous, 22 October 1987a, personal communication; Miller, L., 22 October 1987, personal communication; Snap, C., 22 October 1987, personal communication; Norlund, Mrs., 22 October 1987, personal communication; Goeoze, D., 22 October 1987, personal communication).

The Port of Tacoma has not identified any areas within the head of Hylebos Waterway that require dredging (White, M., 28 August 1987, personal communication). However, the Port of Tacoma and the U.S. Army Corps of Engineers have suggested that navigational channels in the Commencement Bay area may be deepened in the future to accommodate vessels with deeper drafts.

5.2 POTENTIAL SOURCES OF CONTAMINATION

This section provides an overview of the sources of contamination to the sediments in the head of Hylebos Waterway (Table 5-1) and a summary of

TABLE 5-1. HEAD OF HYLEBOS WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b] Segment 1	Segment 2	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
PCBs	--	1	Unknown	No	No	Historical	Surface minimum
			General Metals	Yes	No	Ongoing	
Arsenic	1	2	Kaiser Ditch	Yes	Yes	Ongoing	Surface minimum, or variable
Zinc	1	2	Pennwalt outfall	Yes	Yes	Ongoing	
Copper	--	2	Storm drains	Yes	Yes	Ongoing	
Lead	--	2	Log sort yards	Yes	Yes	Ongoing	
Antimony	2	--	Hylebos Creek	Yes	Yes	Ongoing	
Nickel	--	2					
Mercury		2					
HPAH	1	2	Kaiser Aluminum, Kaiser Ditch	Yes	Insufficient data	Historical, runoff from disposal onsite	Variable
Methylpyrenes	3 (HY-15, HY16, HY17)	3 (HY-22)					
Methylphenanthrene	--	3 (HY-22)	Ubiquitous oil spills	Potential	No	Ongoing, sporadic	
Dibenzothiophene	--	3 (HY-22)					
Tetrachloroethene	3 (HY-17)	2	Pennwalt outfall	Yes	Yes	Ongoing, past disposal practices	Undetected at all depth horizons
Ethylbenzene	3 (HY-17)	--					
Xylenes	3 (HY-17)	--	Pennwalt groundwater infiltration	Potential	No	Ongoing, past disposal practices	
Chlorinated benzenes	--	3 (HY-22)					
Chlorinated butadienes	--	3 (HY-22)					
Phenol	2	3 (HY-22, HY-01)	Kaiser Ditch	Yes	Insufficient data	Ongoing	Surface minimum
			East Channel Ditch	Yes	Insufficient data	Ongoing	
Bis(2-ethylhexyl)phthalate	--	3 (HY-22)	Unknown	No	No	Historical	c
Alkylated benzene isomer	3 (HY-16, HY-17)		c	c	No	c	c
Benzyl alcohol	--	3 (HY-22)	Unknown	No	c	c	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

available loading information for the contaminants of concern. Log sorting yards [Wasser/Winters, Louisiana Pacific, Weyerhaeuser, Cascade Timber Yard #2, and 3009 Taylor Way (sometimes called Dunlap Towing)] occupy nearly all of the southern and eastern shorelines in the upper portion of the waterway (see Figure 5-1). Pennwalt Chemical Corporation is located on the south shore of the waterway east of Lincoln Avenue, and was one of the first industries established in the area producing chlorine and inorganic compounds for local pulp and paper industries.

Two smelting industries were established along the upper part of the waterway in the early 1940s. Ohio Ferro Alloys, located on the south side of Taylor Avenue about 13,500 ft from the mouth of the waterway, was built in 1942. Ohio Ferro Alloys produced chrome, silica, and ferrosilicate. After the plant closed in 1972, the Port of Tacoma bought the property, which has recently been used as a log sorting yard. The second smelting company, Kalumite Inc./Olive Company, opened in 1941-42 on the site now owned by Kaiser Aluminum and Chemical Company. Kaiser took over operation of the plant in 1949.

Other facilities located adjacent to the problem area include Tacoma Boatbuilding Company, Glacier Sand and Gravel, Jones Chemical, Petroleum Reclaiming, and General Metals (see Figure 5-1). Permitted discharges to the problem area include General Metals (State permit No. 5006), Pennwalt Chemical Corporation (NPDES permit No. WA0003115), Glacier Sand and Gravel (NPDES permit No. WA003402), and Tacoma Boatbuilding Company (State permit No. WA003710-9) (Figure 5-5). Nonpermitted discharges to the problem area include an 8-in concrete pipe, Hylebos Creek, Kaiser Ditch, Morningside Ditch, East Channel Ditch, Pennwalt East Seep, Pennwalt West Seep, the Pennwalt east stormwater drain, a 6-in concrete pipe, a Pennwalt discharge pipe, and groundwater seeps along the south bank. There are approximately 20 additional surface water discharges to the head of Hylebos Waterway.

As indicated in Table 5-1, the inorganic contaminants present represent a group of chemicals with numerous ongoing sources including Kaiser Ditch, Pennwalt, several log sorting yards, Hylebos Creek, and storm drains. Tacoma Boatbuilding Company has also been indicated as a source of inorganic contaminants to the problem area based on a recent site inspection (Ecology and Environment 1987). Much of the metals contamination at the head of Hylebos Waterway may ultimately be derived from ASARCO waste material. ASARCO slag is a constituent of the ballast used at the log sorting yards. In addition, Hylebos Creek has been identified as a source of metals that may originate from upstream landfills that received baghouse dust from the smelter. Wet scrubber sludges from Kaiser Aluminum have been identified as a source of HPAH. Oil spills are also a potential source of PAH and associated organic chemicals (i.e., methylpyrenes, methylphenanthrene, and dibenzothiophene). No major sources of PCBs were identified in the problem area during the RI sampling effort. However, high concentrations of PCBs were subsequently observed in several catch basins at General Metals (Stinson et al. 1987).

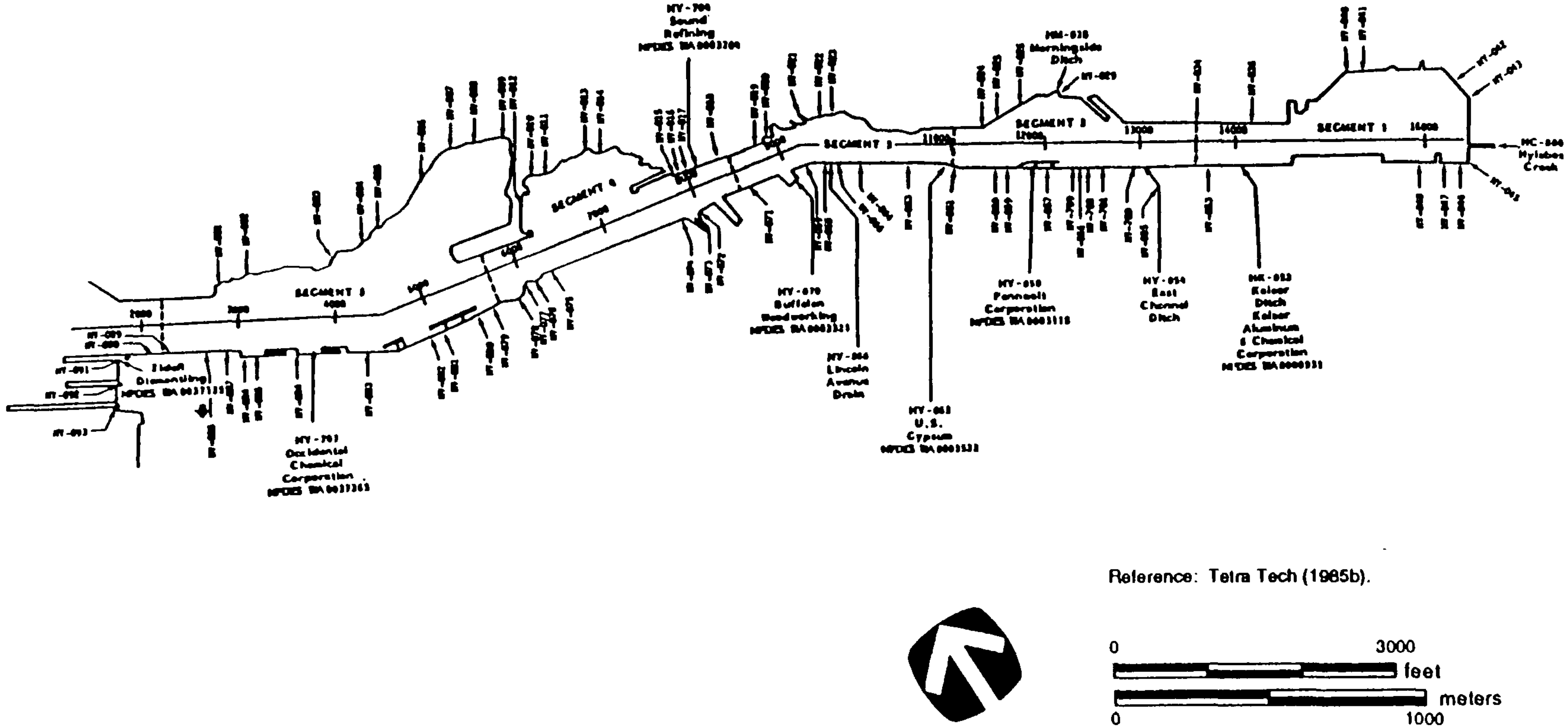


Figure 5-5. NPDES-permitted and nonpermitted discharges to Hylebos Waterway.

5.2.1 Kaiser Aluminum

Site Background--

Kaiser Aluminum and Chemical Corporation operates an aluminum production plant on a 96-ac site near the head of Hylebos Waterway. Production capacity is approximately 80,000 ton/yr, roughly half of which is fabricated into aluminum rod at the plant. The facility was built in 1942 by the Defense Plant Department, and operated by Olin Inc. until 1946. Kaiser Aluminum acquired the property in 1946 and continued operations until 1958, when economic conditions led to cessation of production. Production resumed in 1964 and has continued to the present day.

In the early 1950s, Kaiser Aluminum installed a wet scrubber system to reduce air emissions. The system generated a wastewater containing aluminum, reduction cell bath materials, carbon, and condensed pitch volatiles (Hanneman 1984). Wastewater was discharged to a series of settling (sludge) ponds for removal of suspended solids. Clarified water was recycled or discharged. Generation of wet scrubber sludge ceased in 1974, when a dry scrubber system was installed. In 1983, analysis of wet scrubber sludge revealed HPAH concentrations of up to 5 percent (Stanley, R., 27 June 1983, personal communication; Landau Associates 1984). On the basis of HPAH content and results of bioassay tests, Ecology characterized the sludges as "extremely hazardous wastes in accordance with WAC 173-303." High concentrations of HPAH were also found in Kaiser Ditch (discharge 52 in Figure 5-6), which drained the sludge ponds. These results, in conjunction with the finding that waterway sediments near the Kaiser Ditch outfall contained elevated concentrations of HPAH, led to identification of Kaiser as a potential source of HPAH contamination to Hylebos Waterway (Tetra Tech 1985a).

Atmospheric emissions of PAH from Kaiser Aluminum were also identified as a possible source of contamination to Hylebos Waterway. These PAH could enter the waterway as direct deposition, or as runoff via Kaiser Ditch from areas receiving direct deposition (Tetra Tech 1985a). HPAH emissions from production pot rooms have been quantified and found to be significant (Nord, T.L., 1 November 1983, personal communication; Fenske, F., 25 April 1985, personal communication). However, a link between atmospheric HPAH emissions and increased concentrations of HPAH in Hylebos Waterway has not been established.

Contaminant Source Identification--

Approximately 65,000 yd^3 (88,000 tons wet weight) of wet scrubber sludge deposits rest on the western side of the property. The sludge management area consists of three contiguous unlined surface impoundments covering approximately 11 ac. This area is the primary source of available HPAH on Kaiser Aluminum property. The potential for wet or dry deposition of HPAH from atmospheric emissions has not been evaluated.

In late 1986, a 3,000-gal spill of PCB-contaminated transformer oil occurred at the Kaiser Aluminum facility. PCBs in the oil were measured at

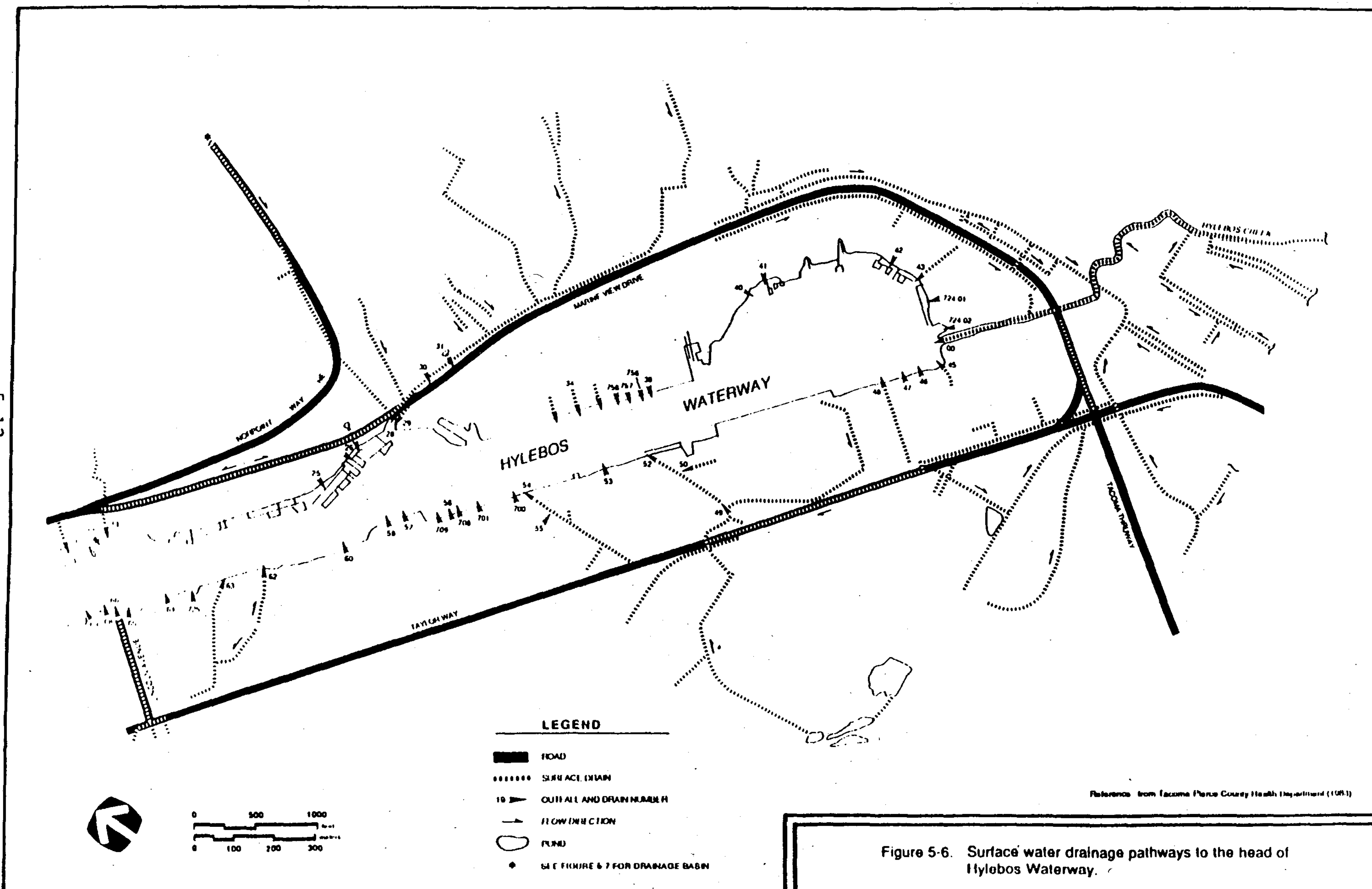


Figure 5-6. Surface water drainage pathways to the head of Hylebos Waterway.

17 mg/kg. After the spill, contaminated soil was removed and disposed of at the Arlington, OR hazardous waste disposal facility. Groundwater in the vicinity of the spill was collected with the aid of trenches, and treated using an oil/water separator. This water was discharged to the City of Tacoma wastewater treatment plant under a temporary permit.

Recent and Planned Remedial Activities--

In April 1983, Ecology issued Kaiser Aluminum an order to determine the nature and extent of sludge deposits on plant property, and the nature and extent of sludge contamination in surface and groundwater. In 1984, Kaiser Aluminum installed silt curtains adjacent to the Kaiser Ditch to keep sludges out of the ditch. Also in 1984, 1,400 yd^3 of soil contaminated with HPAH was removed from adjacent properties and consolidated on the Kaiser Aluminum site (Davies, D., 15 May 1988, personal communication). In June 1985, following completion of the characterization study, Ecology issued a new order requiring Kaiser Aluminum to undertake a groundwater monitoring and testing program, and establish a sludge management plan. The groundwater monitoring program (Landau Associates 1987) was completed and a plan for onsite management of the sludge was proposed. Conducted by Landau Associates (1987), the groundwater monitoring program included a hydrogeological characterization of the site and 2 yr of monitoring (eight quarterly sampling events between August 1985 and May 1987). Water samples collected from wells placed around the sludge deposits contained very low (<10 ug/kg) concentrations of total HPAH, indicating that subsurface migration of HPAH is negligible. However, the thin-layer chromatography analytical method used is considered to be only semi-quantitative. The proposed sludge management plan involves consolidating sludge from the three impoundments into one enclosure, capping it and monitoring the groundwater. The sludge management closure plan was submitted to Ecology in September 1987. Negotiation of a consent decree (under Chapter 70.105B RCW or the Model Toxics Control Act) between Ecology and Kaiser Aluminum for remediation of the wet scrubber sludge disposal area is scheduled to resume in early 1989.

Kaiser Aluminum has also installed a tide gate at the mouth of Kaiser Ditch and re-routed its NPDES-permitted discharge of process wastewater. The tide gate prevents the waterway from backing up into Kaiser Ditch and carrying away additional sediments. Process water, which had been channeled through the sludge ponds, is now routed to Blair Waterway. The NPDES permit requires monitoring for pH, fluoride, total suspended solids, oil and grease, and benzo(a)pyrene as an indicator of HPAH. No benzo(a)pyrene has been detected in the effluent (Fenske, F., 4 May 1988, personal communication).

Air emission monitoring for HPAH has been ongoing at the plant and Ecology is in the process of determining whether additional controls need to be implemented (Fenske, F., 28 September 1987, personal communication).

5.2.2 U.S. Gypsum

Site Background--

A landfill site formerly owned by U.S. Gypsum was identified during the RI as a potential source of arsenic in Hylebos Waterway. The landfill was situated on 2.6 ac between Route 99 and Interstate 5 west of Milton. Hylebos Creek (see Figure 5-6) runs along the southeastern edge of the site for 250 ft and discharges into Hylebos Waterway less than 2 mi downstream.

The landfill was used intensively between 1971 and 1973, and became inactive in 1979. Approximately 17,000 yd^3 of waste was placed in the landfill, including paper, asphalt-coated paper, shot, and off-specification mineral fiber. Approximately 10 percent of the waste was in the form of baghouse dust produced during the manufacture of mineral fiber and was rich in arsenic (21.7 percent by weight). Other metals of concern in the baghouse dust are lead (6.4 percent), zinc (2.8 percent), and copper (1.0 percent). The shot and off-specification mineral fiber contained much less arsenic than the baghouse dust (Dames & Moore 1983).

Contaminant Source Identification--

The U.S. Gypsum landfill was unlined and depths of waste fill ranged from 1 to 13 ft. The fill was generally sloped towards Hylebos Creek at the southeastern portion of the site. No barriers existed on the slope between the creek and the landfill area, suggesting that surface water runoff could have traveled directly to the creek. A drainage ditch between Interstate 5 and the east boundary of the landfill collected runoff from the highway and the north end of the landfill. Sampled waste from the southern portion of the site, which contained most of the baghouse dust, was analyzed for EP toxicity. Only arsenic concentrations exceeded the EP maximum contaminant level of 5.0 mg/L. A single sampling of Hylebos Creek water above and below the landfill site indicated that there was very little contamination of the creek water from the site (Dames & Moore 1983). Concentrations of arsenic, lead, zinc, and copper remained below the primary drinking water standards. A similar effort by Johnson and Norton (1985b) during both low water and high water stream conditions indicated that the site was not a major contributor of arsenic to the creek, and that the arsenic loading potential from the east side drainage ditch was low. However, arsenic concentrations in stream sediment samples obtained by Johnson and Norton (1985b) were higher downstream of the landfill than upstream of the landfill during both wet and dry seasons. This pattern was not observed for other metals.

Groundwater beneath the site appears to have been contaminated by landfill leachate. Between August 1982 and June 1983, groundwater was sampled from wells positioned on or near the site and samples were analyzed for metals (Dames & Moore 1983). Arsenic concentrations exceeded the primary drinking water standard of 0.05 mg/L in eight of the nine monitoring wells at the site. In the two wells that continued to be monitored for 10 mo after site cleanup (see below), arsenic concentrations ranged from 3.0 to 9.4 mg/L. Zinc and copper concentrations consistently remained below the primary standards of 5 and 1 mg/L, respectively. Lead concentrations generally remained below the primary drinking water standard of 0.05 mg/L but in a few instances were higher, in one case by almost a factor of 10.

Recent and Planned Remedial Activities--

Fill and underlying contaminated soil were removed from the U.S. Gypsum landfill site in the fall of 1984. Excavation was discontinued once the EP toxicity concentration of arsenic in soil dropped below the target level of 0.5 mg/kg established by Ecology (U.S. Gypsum Company, no date; Reale, D., 14 September 1987, personal communication). Groundwater monitoring has continued since that time in two wells located near the southeastern boundary of the site along Hylebos Creek. Between 6 March and 6 July 1986, arsenic concentrations in groundwater from groundwater wells at the landfill consistently remained below 0.5 mg/L, which is Ecology's preliminary target cleanup criterion (Reale, D., 14 September 1987, personal communication). No post-cleanup data are available on arsenic concentrations in Hylebos Creek downstream of the site. The landfill site has recently been developed into a parking lot. As a result of the remedial action it is unlikely that the U.S. Gypsum landfill site poses a long-term threat of continuing arsenic input to Hylebos Creek.

5.2.3 B&L Landfill

Site Background--

A landfill owned by B&L Trucking is located near the Surprise Lake Drain west of Milton. The fill covers approximately 17.3 ac and consists primarily of soil and wood wastes scraped from the surface of log sorting yards on the Tacoma tideflats (Johnson and Norton 1985b). Fill operations at the site began in 1978 and continued through 1980, at which time the Tacoma-Pierce County Health Department prohibited further placement of fill (Pierce, D., 18 March 1986, personal communication). The department approved placement of fill in low uncontoured areas at the site, but apparently there was very little disposal activity during 1981-1982 (Pierce, D., 18 March 1986, personal communication). By the middle of 1984, B&L had installed screening equipment at the site, and expected to recycle the bark wastes into a usable product (Carr, J., 11 July 1984, personal communication). In 1985, studies implicating the landfill as a source of metals contamination prompted the owner to cap a substantial portion of the landfill with clean fill material in an attempt to reduce leachate production (Burdorff 1985). More than half of the fill area was capped (Carr, J., 6 January 1987, personal communication). By approximately the middle of 1985, a court order resulted in the cessation of all fill activities (Olczak 1987).

Contaminated leachate from the B&L landfill could reach Hylebos Waterway by entering the Surprise Lake drainage, which empties into Hylebos Creek.

Contaminant Source Identification--

The B&L landfill consists primarily of soil and wood wastes from log sorting yards in the Tacoma tideflats. Metal-laden ASARCO slag used as ballast at the log sorting yards was also collected with the solid and wood waste for disposal at the landfill. It also contains some shredded automobile wastes. More than half of the landfill is capped with an unknown amount of clean fill.

Recent and Planned Remedial Activities--

The only remedial actions at the site to date are cessation of disposal activities and capping. Ecology believes that this cap is inadequate and plans additional action. A unilateral order from Ecology in April 1987 instructed the owner to implement a remedial investigation and Feasibility Study (FS) (Reale, D., 17 September 1987, personal communication). The Ecology order was subsequently appealed to the Pollution Control Hearing Board. Ecology cancelled the order due to the inability of the owner to comply and the intent of Ecology to notify an expanded list of potentially liable persons to request immediate site stabilization, full investigation, and remediation under Chapter 70.105B RCW. Following a site inspection in September 1987, Ecology oversaw preparation of a site stabilization plan (focused FS) to control contaminated leachate. Ecology is currently negotiating with several PRPs to perform a RI/FS. It is anticipated that a RI/FS will begin in late 1988.

5.2.4 Pennwalt

Site Background--

Pennwalt Corporation's Tacoma plant, which began operations in 1929, is located at 2901 Taylor Way and borders the southern shore of Hylebos Waterway. Chemicals currently produced at the facility are chlorine, sodium hydroxide, sodium chlorate, chlor (a bleaching agent), and hydrochloric acid. Chlorine and sodium hydroxide are produced via the electrolysis of salt brine. During the Commencement Bay Nearshore/Tideflats (N/T) RI and subsequent source evaluation refinement (Tetra Tech 1985a, 1986c), the Tacoma plant was identified as a potential source of chlorinated ethenes, arsenic, lead, copper, zinc, and nickel.

Chlorinated ethenes and other chlorinated hydrocarbons historically were generated as by-products of chlorine production, primarily as a consequence of using linseed oil-impregnated graphite anodes (AWARE 1981). Passage of product gas through cooling towers resulted in the condensation of water and chlorinated hydrocarbon by-products. This condensate was deposited in onsite evaporation ponds known as the Taylor Lake Waste Treatment and Disposal Area. In 1975, titanium anodes replaced the graphite anodes, resulting in significantly reduced production of chlorinated hydrocarbon by-products (High, O., no date, personal communication). In 1981, the discharge of cooling tower condensate into the Taylor Lake evaporation ponds was discontinued. The waste stream is now passed through a chlorine stripper and discharged to Hylebos Waterway through the NPDES-permitted main outfall. Measurable concentrations of chlorinated ethenes were not detected in the single analysis of that effluent after the cooling tower condensate had been routed to the main outfall (Yake, B., 9 March 1982, personal communication).

Intertidal sediments along the Pennwalt waterfront contained the highest levels of arsenic measured in Hylebos Waterway during the RI (Tetra Tech 1985a). Arsenic discharges from the Pennwalt site stem from past production of the pesticide sodium arsenite (tradename Penite) and disposal of corresponding waste sludges. The pesticide was produced between 1939 and 1974 at the Tacoma plant. Waste sludges were landfilled onsite between the chlorine production facility and the Taylor Lake evaporation ponds. Before 1981, three outfalls discharging surface water runoff to Hylebos Waterway were contributing a substantial portion of total arsenic input (Tetra Tech 1985a). After completion of a site hydrogeology study by AWARE (1981), Pennwalt disconnected these outfalls and rerouted the surface runoff to the main outfall. From 1981 to early 1986, arsenic loading from the main outfall was estimated to be between 3 and 5 lb/day (Hart-Crowser & Associates 1986). Pennwalt's NPDES permit was revised in 1986 to require reduction of arsenic discharges in the main outfall. Since that time, Hart-Crowser & Associates (1986) have reported that arsenic discharges from the permitted outfall have been virtually eliminated. However, arsenic is not included as a monitoring variable under the NPDES permit for the outfall, and measured arsenic concentrations in the discharge have not been provided for Ecology to substantiate.

Elevated concentrations of copper, lead, zinc, nickel, and mercury in sediments adjacent to Pennwalt coupled with loading data associated with the main outfall implicated Pennwalt as an important source of these metals (Tetra Tech 1985a, 1986c).

Contaminant Source Identification--

Contaminant reservoirs onsite consist of various ponds, moats, and pits. Site descriptions presented below are based primarily on information from an AWARE (1981) report, and information from Ecology personnel, except where indicated.

The Chlorate Pond has been inactive since 1979. It contains approximately 780 yd^3 of sludge. The constituent of primary concern is hexavalent chromium, which is included as dichromate in the sodium chlorate product as a corrosion inhibitor.

Taylor Lake intermittently received sludges from brine settling tanks. The sludges consist primarily of calcium carbonate and magnesium hydroxide. There was no standing water in Taylor Lake during the AWARE (1981) study. The lake is currently inactive.

The West Taylor Lake extension is contiguous with the larger Taylor Lake. The extension received wastewater containing chlorinated organics during 1974 and 1975. In December 1975, the extension became inactive, although it continues to contain brine muds deposited in Taylor Lake. The remaining waste deposits in the extension consist of 760 yd^3 of sludge. This area is currently inactive.

Until 1985, the 0.3-ac Asbestos Pond received wash water containing particulate asbestos. The two cells of the pond contain a total of approximately 900 yd^3 of sludge. One of the cells contained approximately 70,000 gal of supernatant at the time of the AWARE (1981) study.

In 1975, the Cell Room Pond, a 0.8-ac disposal site, began receiving chlorine-rich wastewater from chlor-caustic production. The pond is an active holding area to permit dissipation of residual chlorine. It has also received some brine muds from Taylor Lake. Samples of both supernatant and sludges from the Cell Room Pond were reported as being nonhazardous (AWARE 1981). However, the sampling procedure used may have resulted in an inaccurate waste designation (Michelena, T., 4 May 1988, personal communication).

The Taylor Lake Moat, also known as the Taylor Lake Waste Treatment and Disposal Area, encircled most of the above areas, and was closed by Pennwalt in 1981. Sludge from the moat was moved to the southern corner of Taylor Lake (Hart-Crowser & Associates 1987a). While active, the moat collected leachate from the pond system. Collected leachate was recycled back to the ponds. Liquid and solid samples collected from the moat before it closed were reported as nonhazardous (AWARE 1981). However, questionable sampling procedures may have resulted in an inaccurate waste designation (Michelena, T., 4 May 1988, personal communication).

EP toxicity arsenic concentrations in all samples from the Taylor Lake area obtained during the AWARE (1981) study were below 0.05 mg/L, indicating that this area was probably not an existing source of arsenic contamination to Hylebos Waterway.

The Wypenn Pond, located near the southwest corner of the Pennwalt site, is less than 0.1 ac in surface area and was constructed in 1970. It received discharge from a nearby oil skimmer and basement water from the Ag Chem Building. In addition, the pond received discharge from laboratory sinks, presumably from the Ag Chem Building. The site is now closed and apparently has been graded and landscaped. Supernatant and sludge samples collected before closure were reported as being nonhazardous (AWARE 1981). EP toxicity arsenic concentrations in the sludge and supernatant were 1.7 and 2.5 mg/L, respectively.

Waggoner's Wallow is a 0.36-ac moat system in the salt storage area. It was constructed in 1969 as a holding area for absorber liquid. Waste streams from the sodium hypochlorite production facility are currently discharged to Waggoner's Wallow (Hart-Crowser & Associates 1987b). The moat generally consists of sludges, with little standing water. Sludge sampled from the moat was nonhazardous (AWARE 1981).

The Ag Chem waste pits are inactive. The Ag Chem waste pits received drums and bottles of various chemicals and solvents used during pesticide research. The pits were covered with soil and planted with grass. Soil samples collected from the Ag Chem waste pits were nonhazardous, but resulted in EP toxicity arsenic concentrations of up to 1.2 mg/L (AWARE 1981). However the procedure used for sample collection from the Ag Chem waste pits may also have resulted in an inaccurate waste designation (Michelena, T., 4 May 1988, personal communication).

The Penite waste disposal area consisted of three ponds and one burial pit. Waste deposited at the site included sodium arsenite (i.e., Penite) sludges, pipes containing Penite sludge, drums of various plant wastes, and drums of Ag Chem wastes. Two soil samples collected from the Penite waste disposal site exceeded EP toxicity arsenic concentration limits (52 and 300 mg/L) and were therefore considered hazardous (AWARE 1981).

The Pennwalt Tacoma facility's 1985 NPDES permit contains maximum daily average discharge limits for copper, lead, nickel, total chlorine, total suspended solids, pH, and flow. The facility has repeatedly violated pH and copper limits specified in this permit (White, M., 9 May 1988, personal communication). The NPDES permit does not require Pennwalt to monitor for arsenic. However, the permit does require Pennwalt to determine the source of arsenic in the wastewater discharge, and to implement measures for mitigating or eliminating the source. Hart-Crowser & Associates (1986) reported that measures taken to reduce arsenic contamination in the wastewater were successful. As indicated, Ecology has not received data to support this assertion (White, M., 9 May 1988, personal communication).

Additional elements of the NPDES permit are as follows:

- Only noncontact cooling water may be discharged from the sodium chlorate facility. Cooling water must periodically be monitored for chromium content to verify the integrity of the cooling system.

- No discharge is permitted to Hylebos Waterway from the Asbestos Pond, Taylor Lake, Waggoner's Wallow, Cell Room Pond, or Wypenn Pond.

- No discharge of asbestos to the waterway is permitted.

- Process wastewaters from hydrochloric acid production may be discharged through the outfall, but must not cause an exceedance of the NPDES effluent limits.

According to Hart-Crowser & Associates (1986), the dominant input of arsenic to Hylebos Waterway from the Pennwalt Tacoma plant is via groundwater. Groundwater data generated by Kennedy/Jenks/Chilton (1987a) to evaluate arsenic mitigation alternatives indicate that the source of arsenic to the contaminated uppermost aquifer beneath the site is the former Penite waste disposal area. Maximum arsenic concentrations in groundwater (greater than 1,000 mg/L) were observed in the vicinity of the former Penite disposal area and emanating in a northeasterly direction. A groundwater concentration gradient between 100 and 1,000 mg/L was observed surrounding the plume maximum (Kennedy/Jenks/Chilton 1987a). The outer bound of the groundwater plume was defined by an arsenic concentration of 1.0 mg/L and intersected the bank of Hylebos Waterway along approximately an 800-ft distance. Samples from wells installed near the plant boundary had arsenic concentrations typical of background levels (0.017-0.3 mg/L). Data collected in 1986 from the intermediate aquifer directly beneath the center of the plume revealed arsenic concentrations ranging from less than 0.2 to 1.2 mg/L (Hart-Crowser & Associates 1986), suggesting that the aquitard below the uppermost aquifer confines arsenic migration (Kennedy/Jenks/Chilton 1987a). The site characterization report and final engineering evaluation work plan for the groundwater arsenic mitigation program are currently under review by Ecology (Reale, D., 18 May 1988, personal communication).

The arsenic soil sampling program in the former Penite waste disposal area was completed in 1987 (Kennedy/Jenks/Chilton 1987b). This project was conducted concurrently with the uppermost aquifer arsenic characterization in an effort to provide a comprehensive assessment of site conditions. Arsenic concentrations greater than 10,000 mg/kg and as high as 190,000 mg/kg were found within a layer 2-7 ft below the ground surface. Leachate testing conducted on the highly contaminated soils produced high levels of arsenic in leachate. These data suggest that arsenic in soil at the facility can be dissolved in the groundwater (Kennedy/Jenks/Chilton 1987b).

Groundwater is probably the only existing source of chlorinated hydrocarbons from the Pennwalt site, since wastes containing these contaminants are no longer produced in significant quantity. In April 1984, bank seepage samples collected by Johnson (23 July 1984, personal communication) along Pennwalt property contained 110 ug/L hexachloroethane, 120 ug/L chloroform, and 340 ug/L tetrachloroethene.

Recent and Planned Remedial Activities--

Pennwalt is currently under a consent decree issued by Ecology in July 1987. Terms of the decree require Pennwalt to implement a comprehensive site characterization by late 1988. The essential elements of the study involve sampling, with organic and inorganic analysis of groundwater, surface impoundments, surface water runoff, Wypenn Pond area soils, and Penite areas. A consent decree issued in August 1986 in response to a sulfuric acid spill at the facility requires that an operations and maintenance plan be developed for all pipes carrying fluids.

The groundwater and Penite area soil sampling portion of the site characterization completed in 1987 was designed to evaluate and recommend actions to mitigate the impact of arsenic contamination in the uppermost aquifer. Pennwalt recommended placement of a slurry wall to contain groundwater arsenic contamination in conjunction with placement of a low permeability cap. To provide an inward hydraulic gradient within the confinement system, approximately 94,000 gal of groundwater will be extracted and transported for offsite disposal at a RCRA compliant facility (Kennedy/Jenks/Chilton 1987a).

Under the surface impoundment program, samples will be collected from the Chlorate Pond, Asbestos Pond, Taylor Lake, Cell Room Pond, Taylor Lake Moat, and Waggoner's Wallow. Except for dissolved metals, the same analyses conducted on groundwater samples will also be conducted on surface impoundment samples. Surface water runoff will be sampled and analyzed during the surface water quality program. All samples will be analyzed for pH, volatile organics, and total metals. In the Wypenn Pond area study, impoundment usage history will be further characterized, and soils in the area will be analyzed for PAH.

5.2.5 General Metals, Inc.

Site Background--

General Metals of Tacoma, Inc. is an active scrap metal recycling firm located along Hylebos Waterway at 1902 Marine View Drive. The facility prepares scrap ferrous metals from automobiles, railroad cars, and locomotives for shipment overseas. Clear evidence linking contamination of Hylebos Waterway to General Metals was not presented during the RI (Tetra Tech 1985a). Nevertheless, the high concentrations of metals in the waterway coupled with the nature of past and current operations at the site led to General Metals being considered a possible source of metals. General Metals is also considered a potential source of PCBs to the waterway based on the presence of the contaminant in several catch basins onsite (Stinson et al. 1987).

Contaminant Source Identification--

Contaminant sources at General Metals include buried brine sludges, fill material covering them, PCB-contaminated soil, and possibly hydrocarbon-contaminated soil.

Between 1972 and 1977, when a portion of the property was owned by Occidental Chemical Corporation, a portion of the site was used for disposal of approximately 13,000 tons of process sludge. The brine sludges making up this waste resulted from the sodium chloride purification process and contained small amounts of chlorinated hydrocarbons, heavy metals, and asbestos (Feller and Monahan 1981). When General Metals assumed ownership of the property, ASARCO slag, ground car interiors, dredge spoils from Hylebos Waterway, and pit run material were deposited over the area used by Occidental for waste disposal. This cover is believed to be at least 4 ft thick.

For an undetermined period of time, transformers containing PCBs were stored on the grounds at General Metals. Limited testing initiated by Ecology demonstrated the presence of PCBs in soil and surface water runoff from the site. PCB levels of 21 ppm and above have been detected in sediments collected from four catch basins (Stinson et al. 1987). Groundwater quality at the site has not been characterized.

Oils and lubricants generated during the metals reclamation process are handled and stored at General Metals. Petroleum products are generated from the scraping of locomotives and automobiles, and from maintenance of the machine shop and equipment. Improper handling of these waste petroleum products has led to various incidences of contamination. The extent of the problem and potential for contamination of the waterway remains uncharacterized.

Recent and Planned Remedial Activities--

In 1987 and 1988, Ecology conducted three site inspections at General Metals: an inspection to determine the nature of the PCB problem, a Class II hazardous waste and water quality inspection, and a TSCA hazardous materials inspection related to the PCB problem. The firm is under an administrative order and penalty, issued by Ecology in August 1987, to remove the inactive PCB-containing transformers from the site and to submit a work plan for complete site characterization. The liquid contents of the transformers have since been removed and the cases decontaminated (Morrison, S., 29 September 1987, personal communication). The work plan for the RI/FS was submitted in March 1988. The administrative order also requires that the firm initiate site stabilization activities. These actions will focus on monitoring and modifying the site drainage system (Morrison, S., 4 May 1988, personal communication).

5.2.6 Log Sorting Yards

Site Background--

More than half of the log sorting yards in the Commencement Bay N/T area (i.e., 7 of 12) discharge to Hylebos Waterway. Log sorting yards occupy nearly all of the southern shoreline of upper Hylebos Waterway and several areas throughout the middle portion of the waterway. Of the seven yards discharging to Hylebos Waterway, Cascade Timber Yard #2, 3009 Taylor Way (Dunlap Towing), and Wasser/Winters are currently inactive. The Wasser/Winters site has been inactive for nearly 2 yr (Stefan, F., 18 June 1987, personal communication). It is likely that some of the sites will no longer be used as log sorting yards.

The log sorting yards were identified as sources of arsenic, copper, lead, and zinc (Tetra Tech 1985a, 1986c; Sweet-Edwards & Associates et al. 1987). In addition, antimony, cadmium, and nickel have been found in surface runoff from the yards (Norton and Johnson 1985a). The log sorting yards were initially implicated as sources on the basis of the relationship between metals in the ASARCO slag used as ballast in the yards and sediment concentrations of those metals in the waterway. Subsequent analyses of samples of surface runoff from the sites confirmed the presence of the contaminants in runoff (Norton and Johnson 1985a).

Contaminant Source Identification--

The primary reservoir of contaminants at the log sorting yards is the ASARCO slag used as ballast. Analyses of ASARCO slag revealed the following ranges of concentrations (Tetra Tech 1985a, 1986c): 7,300-9,000 mg/kg arsenic, 5,000 mg/kg copper, 5,000 mg/kg lead, and 18,000 mg/kg zinc. Slag was used primarily between 1975 and 1980.

The pathways for contaminants to reach the waterway are direct surface runoff; surface water runoff to creeks or ditches that drain into the waterway; and groundwater discharges to the waterway, creeks, or ditches. Wood chips and sawdust scraped from the surfaces of the yards are also contaminated with scraped and pulverized slag.

Recent and Planned Remedial Activities--

No remedial activities at the log sorting yards have occurred to date (Morrison, S., 4 May 1988, personal communication). Investigative activities are currently being conducted at the following four sites:

- Wasser/Winters - The Wasser/Winters log sorting yard is the subject of a consent order between the Port of Tacoma and Ecology. A work plan and a preliminary site characterization/interim remediation FS (Sweet-Edwards & Associates et al. 1987) has been completed. The U.S. EPA Field Investigation Team has installed several groundwater wells and collected groundwater data. A proposal submitted by the Port of Tacoma in August 1987 to mitigate contamination problems associated with soils, slag, and wood waste was rejected by Ecology. In January 1988, the Port of Tacoma agreed to prepare an amended proposal for an alternative form of site remediation for mitigation of both surface and groundwater contamination (Stefan, F., 21 January 1988, personal communication). Investigations expected to begin in May 1988 include groundwater and surface water monitoring.

- 3009 Taylor Way (Dunlap Towing) - A consent decree between Pennwalt and Ecology was formalized, and the first quarterly report completed in October 1987. Wet-weather sampling was scheduled for completion between November 1987 and January 1988, and a focused FS submitted in March 1988 is under Ecology review. The site RI work plan was approved with revisions by Ecology in December 1987. Initiation of RI activities has begun (Reale, D., 4 May 1988, personal communication).

- Cascade Timber Yard #2 - A consent order was issued in spring 1987, but Cascade Timber refused further negotiation. A site inspection was completed by the U.S. EPA Field Investigation Team in March 1987.

- Louisiana Pacific - Surface water drainage field studies were completed in 1987 under an administrative order issued by Ecology. A groundwater investigation work plan was submitted in November 1987. In March 1988, the administrative order was amended to include this groundwater investigation. A FS work plan was received by Ecology in January 1988. Ecology plans to negotiate with Louisiana Pacific to amend the administrative order again to include the FS (Reale, D., 4 May 1988, personal communication).

5.2.7 Tacoma Boatbuilding Company

Site Background--

Tacoma Boatbuilding Company has operated a general ship construction facility on Hylebos Waterway since 1969. Fill material was used in developing the property for its current use. However, no ASARCO slag was reportedly used (Ecology and Environment 1987).

Tacoma Boatbuilding Company is involved in new ship construction although approximately 5 percent of the work has included refurbishing older craft. Waste-producing operations include sandblasting, painting, and metal cleaning. A metal slag (believed to be a copper smelting by-product) is used for sandblasting. Sandblasting is currently performed in an enclosed building. Historically, sandblasting was performed near the covered bulkhead area (Ecology and Environment 1987).

Contaminant Source Identification--

A site inspection was conducted by Ecology and Environment in January 1987. Sandblast grit, soil, and sediment from a drainage ditch and storm drain were sampled and analyzed for the variables included on U.S. EPA's Target Compound List. However, data for pesticides, PCBs, and acid/base/neutrals were rejected during a quality assurance review. Therefore, only volatile organic compounds and metals values were reported.

Sandblast grit from two locations had elevated concentrations of arsenic (particularly older grit), copper, and zinc. Neither sample exhibited concentrations that exceeded the EP toxicity regulatory limits specified in WAC Chapter 173-303.

Two composite sediment samples were collected from a drainage ditch on the west side of the property adjacent to the General Metals facility. This ditch receives runoff from a limited portion of the Tacoma Boatbuilding Company property as well as an undetermined amount from General Metals. In both cases, arsenic, copper, and zinc concentrations were elevated over the long-term cleanup goals of 57, 390, and 410 mg/kg, respectively. For a given metal, concentrations in the two samples were quite different, indicating spatial variability of metals concentrations in the ditch. In general, metals concentrations in composite soil samples collected at several locations across the site were similar to background samples collected (Ecology and Environment 1987).

Metals concentrations in sediment from a storm drain (HY-36) that discharges from the Tacoma Boatbuilding Company to Hylebos Waterway were greater than corresponding long-term cleanup goals. Enrichment ratios were 1.6 (estimated) for arsenic, 7 for copper, and 23 for zinc. Concentrations of copper, lead, and zinc in a surface water sample from HY-36 did not meet marine chronic ambient water quality criteria. Concentrations of copper and zinc also exceeded marine acute ambient water quality criteria. Arsenic was also detected in this discharge.

Recent and Planned Remedial Action--

Ecology is currently involved in a shipyard pollution prevention education program. The program includes workshops to inform shipyard owners of best management practices and NPDES application procedures. Although shipyards in the Commencement Bay area are not currently permitted under the NPDES program, Ecology plans to write permits for all shipyard facilities. These activities are tentatively scheduled for 1989. Permit requirements will include provisions to prevent sandblast grit and other materials from entering the waterways, as well as monitoring requirements for oil and grease, turbidity, and metals.

5.2.8 Storm Drains

The major storm drains discharging into the head of Hylebos Waterway (see Figure 5-6) are the Pennwalt Chemical storm drains (HY-708, HY-056), Kaiser Ditch (HK-052), East Channel Ditch (HY-054), and Morningside Ditch (HY-028). Runoff from the Pennwalt site is discussed in Section 5.2.4. The Kaiser, East Channel and Morningside Ditches are discussed below.

Kaiser Ditch--

Process wastewater from Kaiser Aluminum was historically discharged indirectly to Kaiser Ditch until about 1985. Stormwater runoff is the only source of flow to the ditch now. Kaiser Ditch receives runoff from the Kaiser Aluminum facility, Cascade Timber Yard #2, Weyerhaeuser log sorting yard (paved), and 3009 Taylor Way (Dunlap Towing) log sorting yard (Tetra Tech 1985b). Kaiser Aluminum appears to be the largest single source of HPAH to the Hylebos Waterway via the Kaiser Ditch (Tetra Tech 1985a).

East Channel Ditch--

The East Channel Ditch was originally installed on an easement through the Pennwalt property to provide surface drainage for the Ohio Ferro Alloys property (now Port of Tacoma property - Murray Pacific log sorting yard) located on the south side of Taylor Way. This area (approximately 30 ac) currently drains to Kaiser Ditch (HK-052).

The East Channel Ditch (HY-054) currently drains approximately 15 ac comprising the portion of the Pennwalt property located east of the Taylor Lake and Cell Room Pond areas, and the western boundary of the 3009 Taylor Way log sorting yard area (Figure 5-6). The 3009 Taylor Way log sorting yard, is presently inactive. It is likely that Pennwalt Chemical will fill in the East Channel Ditch in the near future (High, O., 17 August 1987, personal communication).

The City of Tacoma has widened Taylor Avenue and installed curbs, gutters, and storm drains to collect road surface runoff. Runoff from the section of Taylor Avenue opposite the Pennwalt property has been rerouted from the East Channel to the Kaiser Ditch system (Baughman, P., 17 May 1988, personal communication). There was some concern that excavation of a ditch for the storm drain system would intercept the groundwater contaminant plume from beneath the Pennwalt property and cause disposal problems. The city investigated groundwater conditions along the proposed storm drain route to determine if contaminated groundwater in the area would be a problem. Prior to initiating construction activities, a waste containment site was constructed as a contingency if construction monitoring revealed subsurface contamination. Slightly elevated organic vapor readings were noted in the Pennwalt vicinity on one occasion and some excavation materials were temporarily held in the containment facility. In addition to the temporary containment site, several interception trenches and dams were constructed to prevent groundwater intrusion into the construction area.

In the past, the East Channel Ditch also received leachate from the Taylor Lake drainage moat on the Pennwalt property via an 8-in PVC pipe (HY-055). (See Section 5.2.4 for description of wastes contained within the area surrounded by the moat.) The moat was closed and covered in 1981 by Pennwalt (AWARE 1981). Little data are available to characterize contaminant loadings from the leachate in the storm runoff ditch. A single sediment sample collected from the runoff ditch leading to the East Channel Ditch exhibited a pH of 9.5 and arsenic concentration (EP toxicity) of 4.0 mg/L (AWARE 1981). Discharge of leachate from Pennwalt to the East Channel Ditch was stopped in 1981 when the moat was closed and the PVC pipe was plugged.

Runoff from the Petroleum Reclaiming property may also have discharged to the East Channel Ditch in the past. Petroleum Reclaiming recycles waste oils for use as industrial burner fuel through dehydration and solids removal. The site was regraded about 5.5 yr ago to direct surface water runoff to a pit onsite, from which it is recycled through the plant (Richland, D., 17 August 1987, personal communication). Trucks are unloaded directly over the pit to reduce spill hazards.

Morningside Ditch--

The Morningside Ditch (HM-028) serves approximately 600 ac located on the north side of Marine View Drive. The drainage basin includes part of East Tacoma, extending north from Marine View Drive to about SW 347th Street (Figure 5-7). Discharge from the ditch is composed of surface water runoff and discharges from the Woodworth gravel washing operations (Young, R., 19 August 1987, personal communication). There are no NPDES-permitted industrial discharges in the basin. Annual runoff in the drainage basin is estimated at about 400 ac-ft/yr (0.6 ft^3/sec) based on average rainfall of 37 in and a runoff coefficient of 0.2 (Viessmann et al. 1977). Land use distribution is approximately 50 percent residential use, 40 percent undeveloped (tree covered), and 10 percent industrial use. The Woodworth gravel pit and associated facilities constitutes the majority of the industrial land in the basin.

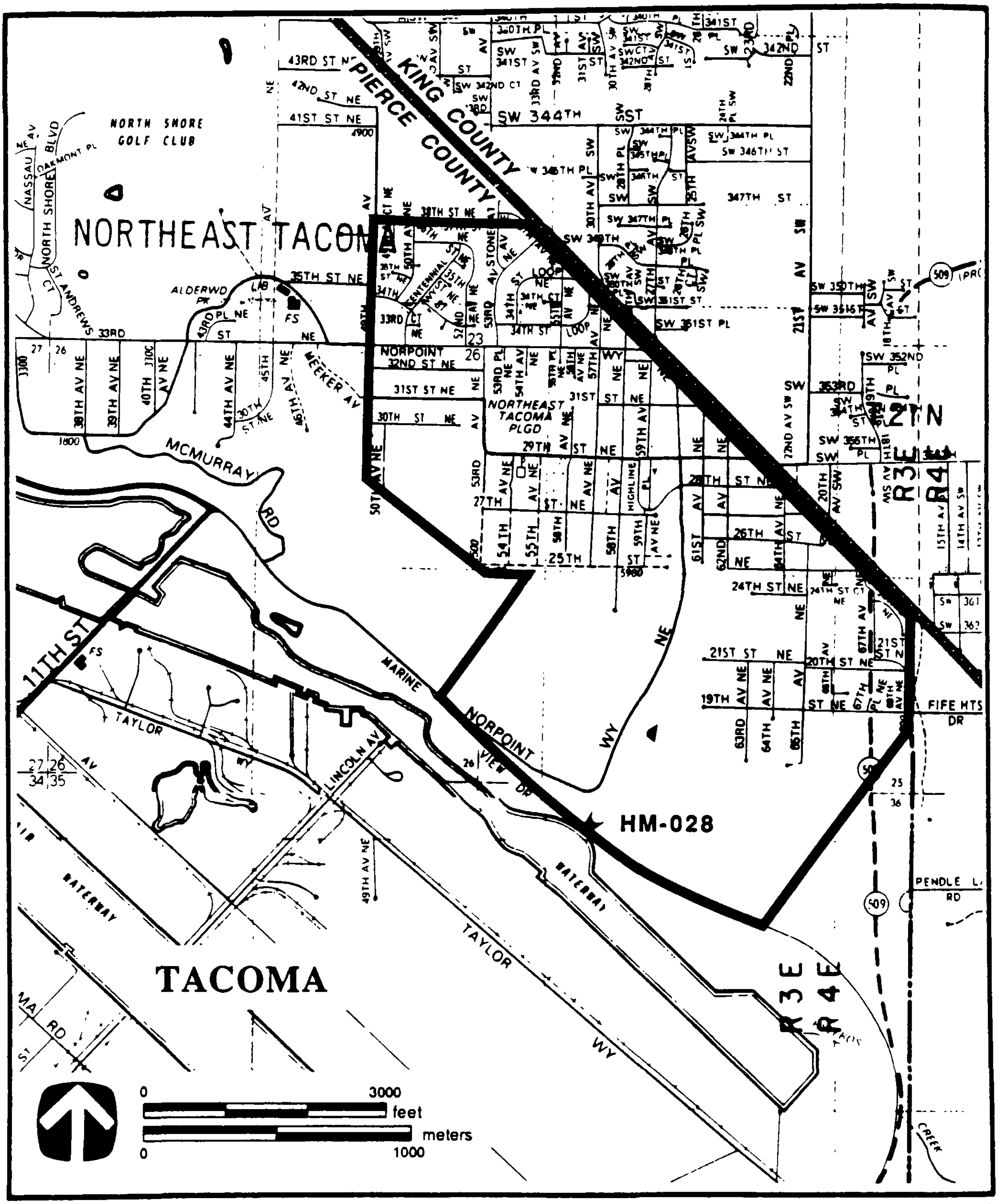


Figure 5-7. Drainage basin for Morningside Ditch.

5.2.9 Loading Summary

Summary loading tables for the Priority 1 and 2 contaminants of concern for the head of Hylebos Waterway (i.e., arsenic, copper, lead, mercury, nickel, zinc, tetrachloroethane, PCBs, and phenol) are provided in Appendix E. Post-RI loading data for the following discharges are included in Appendix E:

- Wasser/Winters log sorting yard drainage ditches HY-724-01, HY-724-02, and HY-043 (Sweet-Edwards & Associates et al. 1987)
- Pennwalt groundwater loading (Hart-Crowser & Associates 1986).

Recent groundwater loading information regarding the Pennwalt Chemical Corporation (Kennedy/Jenks/Chilton 1987a) and data from recent investigations at several of the log sorting yards (Ecology and Environment 1987; CH2M HILL 1987; and ERT 1987) have not been included in Appendix E. The following is a summary of available loading information for the contaminants of concern by contaminant source.

Pennwalt Chemical Corporation--Pennwalt's NPDES permit contains maximum daily average discharge limits for copper, lead, and nickel of 1.5, 0.45, and 0.86 kg/day, respectively. As mentioned previously, the copper limitation has been violated on several occasions. Kennedy/Jenks/Chilton (1987a) reported a groundwater loading of arsenic to the waterway of 52 lb/day. This is considerably higher than the loading presented in Hart-Crowser & Associates (1986), since the aquifer parameters used to calculate the discharge have been refined.

For the Wasser/Winters log sorting yard, Ecology (Norton, D., 10 November 1987, personal communication) estimated that loading of total arsenic from groundwater is approximately 1-12 percent as great as the annual average surface water loading (Norton and Johnson 1985a; see also Appendix E). Groundwater input was estimated from contaminant concentrations reported by Ecology and Environment (1987) and a flow rate calculated from the aquifer parameters reported by Ecology and Environment (1987). Surface water loading reported by Sweet-Edwards & Associates et al. (1987) for the same site is 6.4 lb total arsenic (5.1 lb dissolved), based on a 25-h storm in which 1.4 in of precipitation was recorded. That value is similar to the surface water loading of 4.4 lb/day total arsenic reported by Norton and Johnson (1985a) for storm conditions.

For the Louisiana Pacific site, a surface water loading of 0.17 lb/day total arsenic (with 81 percent soluble) was reported in CH2M HILL (1987). This estimate was based on data obtained from six sampling events and represents a weighted average of storm and non-storm flow. Arsenic loadings measured during two storm events by Norton and Johnson (1985a) averaged 0.74 lb/day.

A dry-weather surface water loading of 0.016 lb/day total arsenic was reported for the 3009 Taylor Way site based on one sampling event (ERT

1987). This value is much lower than that presented in Norton and Johnson (1985a) where an average daily surface water loading of 0.49 lb/day total arsenic was reported. However, this value represents a weighted average of storm and nonstorm loadings.

Kaiser Ditch--The average concentration of arsenic in effluent from the Kaiser Ditch based on 10 measurements is 41 ug/L (see Appendix E) which is well above average urban runoff concentration (residential and highway) for arsenic reported by Metro (Stuart et al. 1988). The calculated average surface water loading of arsenic to the head of Hylebos Waterway reported in Appendix E is 0.65 lb/day based on eight observations. No information is available for loadings of PCBs or HPAH from Kaiser Ditch to the head of Hylebos Waterway.

Ecology collected sediment from the Kaiser Ditch June 1987. Results from this study (Norton, D., 15 April 1988, personal communication) indicate that arsenic in the sediment is elevated somewhat (1.8 times) over the cleanup goal of 57 mg/kg. HPAH and PCBs were measured at concentrations of 6 and 3.3 times the long-term cleanup goals of 17,000 ug/kg and 150 ug/kg, respectively. The comparison of drainage ditch sediment with cleanup goals assumes no mixing of sediment with cleaner material from other sources. Such comparisons provide a worst-case analysis of the impact of drainage ditch discharge on waterway sediment quality.

East Channel Ditch--The concentrations of metals in effluent from the East Channel Ditch reported in Appendix E are among the highest measured in sources to the head of Hylebos Waterway. The average concentration of arsenic in effluent from the East Channel Ditch is 14,740 ug/L (see Appendix E) which is well above average urban runoff concentration (residential and highway) for arsenic reported by Metro (Stuart et al. 1988). The average calculated loading to the head of Hylebos Waterway reported in Appendix E is 0.68 lb/day based on six measurements.

Morningside Ditch--Average concentrations of metals in effluent from Morningside Ditch are similar to those reported for urban runoff (residential and highway) by Metro (Stuart et al. 1988). The average calculated arsenic loading reported in Appendix E is 0.0045 lb/day (seven measurements).

Ecology collected sediment from Morningside Ditch in June 1987. Results from this study (Norton, D., 15 April 1988, personal communication) indicate that sediment arsenic concentrations are 5.5 times as great as the long-term cleanup goal of 57 mg/kg. Measured HPAH concentrations were well below the corresponding long-term cleanup goal, indicating that Morningside Ditch is not a significant source of this class of compounds. Measured PCB concentrations were 6.3 times as great as the 150 ug/kg long-term cleanup goal. By ignoring mixing with cleaner sediment from other sources, such comparisons provide a worst-case analysis of the impact of drainage ditch sediment or waterway sediment quality.

5.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated based on contaminant concentrations in the sediment and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to maintain acceptable sediment quality over the long term.

5.3.1 Feasibility of Source Control

In this section, sources of contamination are summarized; available control technologies are identified; and contaminant reductions technically achievable through the use of all known, available, and reasonable technologies are estimated.

Seven major potential problem sources have been identified at the head of Hylebos Waterway: Kaiser Aluminum and Chemical Corporation's plant (PAH); Pennwalt Chemical Corporation's plant (various chemicals); General Metals of Tacoma, Inc.'s scrap metal recycling operation (metals and potentially PCBs); seven log sorting yards (metals); the East Channel, Morningside, and Kaiser ditches (various chemicals); the landfill operated by B&L Trucking (metals); and Tacoma Boatbuilding Company (metals). Three of the log sorting yards and B&L landfill have ceased operations (no additional controls are recommended for the U.S. Gypsum facility). Source controls have been implemented or may be required for the following mechanisms of contaminant discharge:

- Process effluents (Pennwalt)
- Storm drains and ditches (Kaiser, East Channel, and Morningside Ditches)
- Surface water runoff (Kaiser sludge deposits, Pennwalt, log sorting yards, General Metals, Tacoma Boatbuilding Company)
- Groundwater seeps and infiltration (Kaiser sludge deposits, Pennwalt, log sorting yards, General Metals, B&L landfill leachate)
- Air emissions (Kaiser facility; the need for air emission controls has not been established and is not considered here).

The level of source control assumed to be feasible for the major sources is noted in Table 5-2.

TABLE 5-2. EFFECTIVENESS OF SOURCE CONTROL FOR HEAD OF HYLEBOS WATERWAY

Problem Area	Frequency of Detection[a] (%) As	HPAH	PCB	Estimated Average Annual Discharge (10^6 gal/yr)	Average Load[a] (lb/day)	Estimated Source Control (%)	Rationale for Percent Source Control
Kaiser Aluminum							
Process water		+[b]		212-361[c]	Unknown	HPAH-90	Wet scubber sludges identified as main HPAH source.
Surface water (HK-052)	90	33		30	0.65 As <0.15 HPAH	As-90	Surface runoff from plant area has been relocated around sludge areas to minimize contact. Sludge management plan involves consolidating sludge into one impoundment with an impermeable layer, and monitoring groundwater Tide gate installed at mouth of Kaiser Ditch. NPDES-permitted discharge routed through settling basin prior to discharge to Kaiser Ditch. Surface water controls assumed to be implemented at log sorting yards in HK-052 basin to reduce As loading.
U.S. Gypsum Landfill	+[b]			0.2	Unknown	90	Landfill inactive since 1979. Fill and underlying contaminated soils excavated to level where EP toxicity concentration for As dropped below target level of 0.5 mg/kg. Site paved and is now a parking lot.
B&L Landfill							
Surface water	100			10	4.6-5.4 mg/L[d]	90	Landfill inactive since 1985, partial capping of fill completed (1985-1987). Ecology is pursuing site cleanup under the State Superfund Law (70:105B). Eleven-month RI/FS will begin in December 1988.
Groundwater	100			Unknown	0.15-38 mg/L[e]	90	Ecology is hiring a contractor to prepare a site stabilization plan to control contaminated leachate. Plan to control groundwater contamination assumed to be implemented.
Pennwalt							
Process water (HY-058)	100			4,700	3.9	95	Source of As discharge for plant outfall was identified and mitigated by Pennwalt in 1986.[f]
Groundwater	96			33[g]	0.6-11 52[g]	95	Pennwalt predicts reduction in As loading from 52 lb/day to 0.1 lb/day as a result of recommended As mitigation plan, which involves construction of a groundwater containment barrier, surface capping, and groundwater monitoring.[f]
Storm drains (HY-056, HY-708, HY-709)	100	HY-709: 50		70	8.6 As	As-80	Surface runoff from plant area routed through plant treatment system (pH neutralization) in 1981. As loading to waterway decreased by 75-95 percent.

TABLE 5-2. (Continued)

Problem Area	Frequency of Detection[a] (%) As	HPAH	PCB	Estimated Average Annual Discharge (10^6 gal/yr)	Average Load[a] (lb/day)	Estimated Source Control (%)	Rationale for Percent Source Control
General metals			+[b]	Unknown	HY-34 drain sediments (ug/kg)[h]: #1-31,000 #2-21,000 #3-23,000 #4-21,000	70	Inactive PCB transformers removed in September 1987 under administrative order. Work plan for RI/FS study expected to be completed by February 1988. Remediation of site assumed.
Log sorting yards							
Surface water	100			90	5.9	90	Four of five log sorting yards in basin are currently inactive. remaining yard (Weyerhaeuser) is paved. Implementation of surface water controls was assumed.
Groundwater	78			Unknown	Cascade #2; Wasser/Winter: 0.018-0.22 mg/L[d]	80	Same as above. Implementation of groundwater controls was assumed.
Storm drains HY-054, HM-028	100			140	0.7	90	Loading is primarily from HY-054 which drains portion of Dunlap Towing log sorting yard (currently inactive). Consent Decree has been formalized. Focused FS is under Ecology review. Implementation of surface water controls was assumed.
Hylebos Creek (HC-000)	67			5,900	2.4	60	Available data indicate that elevated As concentrations caused by leachate from B&L landfill, U.S. Gypsum landfill in upper basin, and log sorting yards in lower basin.[d] Remediation of these three sources was assumed. Removal of contaminated streambed sediments found downstream of landfills was assumed.[c]
Other storm drains	100			120	HY-043+HY-055: 1.0	60	Drains HY-043 and HY-055 serve portions of log sorting yards. Construction of surface water controls at log sort yards was assumed. Control of other As sources (slag-related) in basin was not assumed.

[a] Tetra Tech (1987c).
[b] +=Documented historical contamination. Not quantifiable.
[c] Davies, D., 10 June 1988, personal communication.
[d] Johnson and Norton (1985b).
[e] Ecology & Environment (1987).
[f] Hart-Crowser & Associates (1986).
[g] Kennedy/Jenks/Chilton (1987a).
[h] Stinson et al. (1987).

Technologies for reducing contaminants in process effluents include primary and secondary wastewater treatment, outfall relocation, and in-plant contaminant reduction through process changes or product substitution.

Available technologies for controlling migration of contaminants via groundwater are summarized in Section 3.2.1. General categories include removal or treatment of the contaminant source, containment (e.g., slurry walls), collection, in situ treatment, and post-removal treatment.

Available technologies for controlling surface water runoff are summarized in Section 3.2.2. These technologies include methods for retaining runoff onsite (e.g., berms, channels, grading, sumps), revegetation or capping to reduce erosion of waste materials, and removal or treatment of contaminated material.

Methods for treating storm water after collection in a drainage system also exist. Sedimentation basins and vegetation channels (or grassy swales) have been shown to effectively remove contamination associated with particulate matter. Removals of up to 75 percent and 99 percent for total suspended solids and lead, respectively have been reported for detention basins (Horner and Wonacott 1985; Finnemore and Lynard 1982). Removals of 90 percent for lead, copper, and zinc and 80 percent for total suspended solids have been achieved using grassy swales (Horner and Wonacott 1985; Miller 1987). Water containing both particle-bound and soluble metals can be treated by conventional coagulation. Effectiveness varies depending on water characteristics (speciation is particularly important for arsenic). However, removals of 80-95 percent are attainable for arsenic (James M. Montgomery, Consulting Engineers, Inc. 1985).

Conclusion--

Implementation of appropriate measures to control contaminant inputs to the head of Hylebos Waterway via process wastewater, surface water, and groundwater should result in significant reductions in contaminant discharges. Given the contaminant types, multiplicity of sources, and available control technologies, it is estimated that implementation of all known, available, and reasonable control technologies will reduce contaminant loadings by up to 70, 80, and 90 percent for the indicator chemicals PCBs, arsenic, and HPAH, respectively. The relatively higher percentage of source control assumed feasible for HPAH results from the presence of fewer HPAH sources. Sources of PCBs have not been fully identified, and a lower degree of source control (70 percent) is assumed feasible.

5.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals PCBs, arsenic, and HPAH. Results are reported in full in (Tetra Tech 1987a). A summary of those results is presented in this section.

The depositional environment at the head of Hylebos Waterway can be reasonably well-characterized by a sedimentation rate of 990 $mg/cm^2/yr$ (0.77 cm/yr) and a mixing depth of 10 cm. Losses due to biodegradation and diffusion for the indicator chemicals were determined to be negligible. Two timeframes for sediment recovery were considered: a reasonable timeframe (defined as 10 yr) and the long term.

Source loadings for all three indicator chemicals in the head of Hylebos Waterway are assumed to be in steady-state with sediment accumulation for the purpose of establishing the relationship between source control and sediment recovery. This assumption is environmentally protective in that sediment profiles suggest a trend toward decreasing contaminant loading. Results of the sediment recovery evaluation are summarized in Table 5-3.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted to be 35 yr for PCBs, 19 yr for arsenic, and 10 yr for HPAH. These predictions are based on the highest concentrations of the indicator chemicals measured in the problem area. Sediment recovery in the 10-yr timeframe is predicted to be possible only for HPAH under conditions of complete source elimination. Sediment recovery is not predicted to be possible in the 10-yr timeframe for PCBs or arsenic. Minimal reductions in sediment concentrations are predicted unless sources are controlled.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source control is expected to reduce source inputs by 70 percent for PCBs, 80 percent for arsenic, and 90 percent for HPAH. With this level of source control as an input value, the model predicts that sediments with enrichment ratios of 1.6 for PCBs (i.e., PCB concentrations of 240 ug/kg dry weight), 1.7 for arsenic (i.e., arsenic concentrations of 97 mg/kg dry weight), and 1.9 for HPAH (i.e., HPAH concentrations of 32,130 ug/kg dry weight) will recover to the long-term cleanup goal within 10 yr (Table 5-3). These estimates are based on the average of the three highest concentrations measured in the problem area for each indicator chemical. The surface area of sediments not expected to recover to long-term cleanup goals is shown in Figure 5-8. For comparison, sediments currently exceeding long-term cleanup goals for indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that 89 percent of the PCBs, 70 percent of the arsenic, and 47 percent of the HPAH inputs must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (Table 5-3). These estimates are based on the average of the three highest sediment concentrations measured for each indicator chemical in the problem area.

TABLE 5-3. HEAD OF HYLEBOS WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals		
	PCBs	Arsenic	HPAH
Station with Highest Concentration			
Station identification	HY-22	H1	HY-16
Concentration[a]	2,000	203	34,280
Enrichment ratio[b]	13.3	3.6	2.0
Recovery time if sources are eliminated (yr)	35	19	10
Percent source control required to achieve 10-yr recovery	NP[c]	NP[c]	100
Percent source control required to achieve long-term recovery	93	72	50
Average of Three Highest Stations			
Concentration[a]	1,340	190	31,855
Enrichment ratio[b]	8.9	3.3	1.9
Percent source control required to achieve long-term recovery	89	70	47
10-Yr Recovery			
Percent source control assumed feasible	70	80	90
Highest concentration recovering in 10 yr[a]	240	97	32,130
Highest enrichment ratio of sediment recovering in 10 yr	1.6	1.7	1.9

a Concentrations in ug/kg dry weight for organics, mg/kg dry weight for metals.

b Enrichment ratio is the ratio of observed concentration to cleanup goal.

c NP = Not possible.

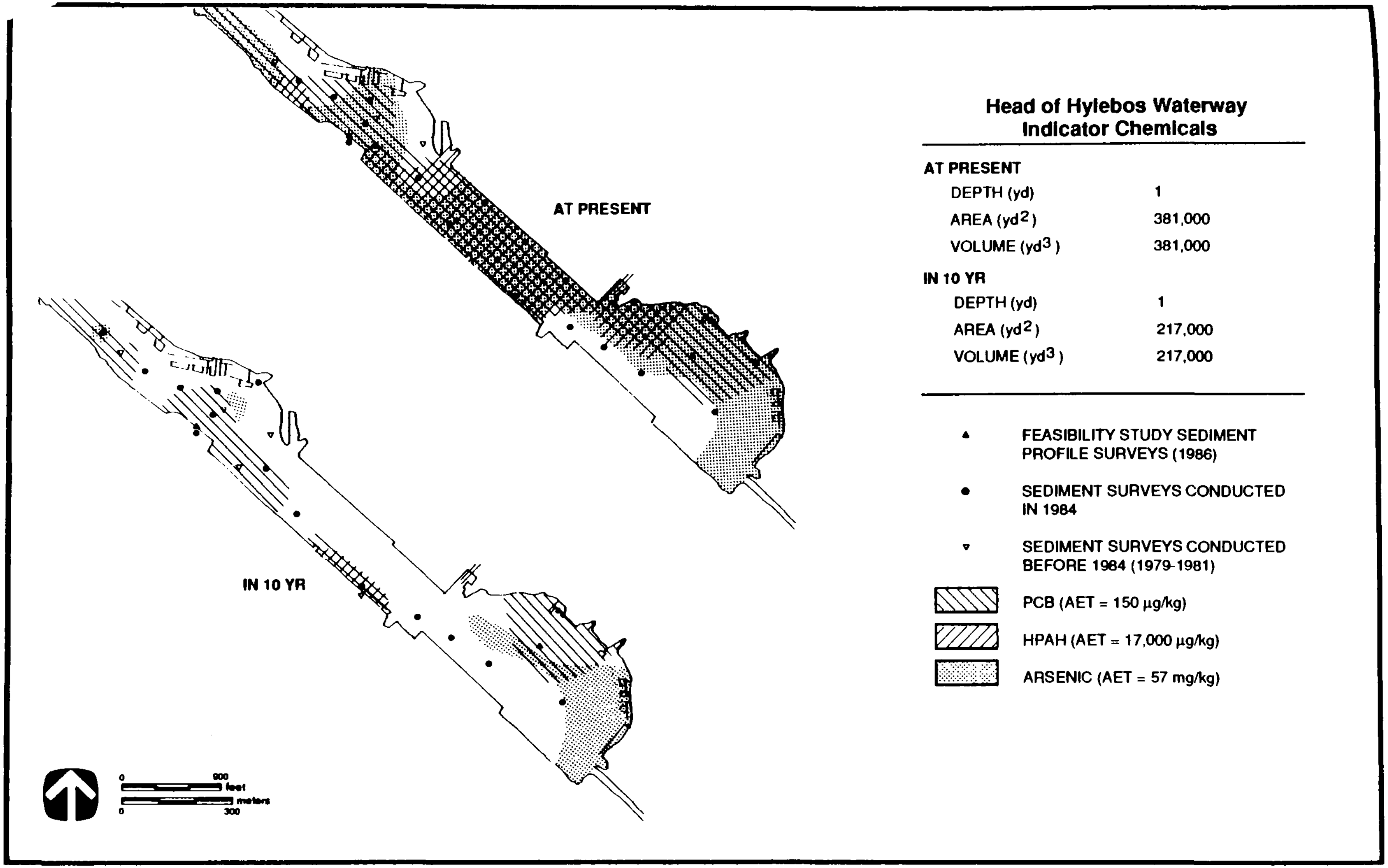


Figure 5-8. Sediments at the head of Hylebos Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

These values are presented for comparative purposes; the actual percent reduction in source loading is subject to the uncertainty inherent in the predictive model. These ranges may represent upper limit estimates of source control requirements, since the assumptions incorporated into the model are considered to be environmentally protective. This may be particularly true for PCBs since the sources appear to be largely historic.

For comparison with source control estimates derived using the mathematical model, the required percent reductions of indicator chemicals in sediment from the Kaiser and Morningside Ditches were calculated. Kaiser Ditch sediment data indicate that reduction of 84, 16, and 72 percent would be required for PCBs, arsenic, and HPAH, respectively to maintain adequate sediment quality. For sediment from Morningside Ditch, reductions of 75, 85, and 0 percent would be required. This comparison is conservative and assumes no mixing of incoming sediments with cleaner material from other sediment sources.

5.3.3 Source Control Summary

The major identified known or potential sources of problem chemicals to the head of Hylebos Waterway include Pennwalt Chemical Corporation, General Metals, Inc., log sorting yards, storm drains/ditches, Kaiser Aluminum, and Tacoma Boatbuilding Company. If these sources are completely eliminated, then it is predicted that sediment concentrations of the indicator chemicals in the surface mixed layer will decline to the long-term cleanup goal of 150 ug/kg for PCBs in approximately 35 yr, to 57 mg/kg for arsenic in 19 yr, and to 17,000 ug/kg for HPAH in approximately 10 yr. Sediment remedial action will therefore be required to mitigate the observed and potential adverse biological effects associated with sediment contamination within a reasonable timeframe.

Prior to initiating sediment remedial actions, additional source control measures will be needed to ensure that acceptable sediment quality is maintained. The estimated percent reduction required for long-term maintenance is 89 percent for PCBs, 70 percent for arsenic, and 47 percent for HPAH, based on the average of the three highest observed concentrations for the three indicator chemicals. Implementation of all known, available, and reasonable control technologies are expected to provide approximately 70, 80, and 90 percent reductions in PCBs, arsenic, and HPAH, respectively. Comparison of required reductions to maintain acceptable sediment quality with estimated feasible levels of source control suggests that acceptable sediment quality can be maintained for arsenic and HPAH (see Table 5-3). However, the percent source control required to maintain acceptable levels of PCBs in sediments is approximately 20 percent greater than that estimated to be feasible. The former estimate was based on the three stations exhibiting the highest levels of contamination in the waterway, specifically in the vicinity of the Pennwalt facility. Using an average of all PCB concentrations exceeding the long-term cleanup goal of 150 ug/kg in the problem area, the required source reduction would be reduced to approximately 70 percent. This provides an illustration of the uncertainty related to the estimates of required source control based on measured sediment concentrations and confirms that the approach taken is environmentally protective.

5.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with PCBs, arsenic, and HPAH concentrations exceeding long-term cleanup goals is approximately 381,000 yd^3 (see Figure 5-8). This volume was estimated by multiplying the areal extent of sediment exceeding the long-term cleanup goal (381,000 yd^2) by 1.0 yd, the estimated depth of contamination (see contaminant sediment profiles in Figures 5-2, 5-3, and 5-4). The estimated thickness of contamination is only an approximation; few sediment profiles were taken and the vertical resolution of those profiles was poor at the depth of the contaminated horizon. For the volume calculations, depths were slightly overestimated. This conservative approach was taken to reflect the fact that depth to the contaminated horizon cannot be accurately dredged, to account for dredge techniques tolerances, and to account for uncertainties in sediment quality at locations between sediment profile sampling stations.

The total volume of sediments with PCBs, arsenic, and HPAH chemical concentrations that are expected to exceed long-term cleanup goals 10 yr following implementation of all known, available, and reasonable control technologies is approximately 217,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratios greater than 1.6 for PCBs, 1.7 for arsenic, and 1.9 for HPAH (see Table 5-3) by the estimated 1.0 yd depth of contamination. Remedial alternatives were evaluated using 217,000 yd^3 as the volume of sediment requiring remediation.

5.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

5.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, this set of alternatives is evaluated to determine the suitability of each alternative for the remediation of contaminated sediments in the head of Hylebos Waterway. Remedial measures address contaminated sediments that are predicted to exceed cleanup goals 10 yr after implementing feasible source controls and allowing natural recovery processes to occur. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost using available data.

The first step in this process is to assess the applicability of each alternative to remediation of contaminated sediments in the head of Hylebos Waterway. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; and site physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

Selection of remedial alternatives for this problem area is complicated by the presence of a complex contaminant matrix comprised of both organic and inorganic contaminants. The Pennwalt facility has been identified as a source of inorganic contaminants (primarily arsenic) and HPAH to the waterway. Kaiser Aluminum has been identified as a major source of HPAH to the problem area. The General Metals facility has been associated with possible PCBs and metals inputs. The log sorting yards have been identified as another source of inorganic contaminants to the sediments. The storm drains and ditches that discharge to the waterway have been identified as sources of HPAH, metals, and PCBs (see Section 5.2). Areal distributions for all three indicators are presented in Figure 5-8 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery.

The relatively high organic content of sediments in the head of Hylebos Waterway, in conjunction with extensive PCBs and HPAH contamination, suggests that treatment processes for organics might be technically feasible. The solvent extraction process is expected to be highly effective in removing PCBs and HPAH from problem area sediments. In addition, this process has been shown to be effective in precipitating inorganic contaminants from wastes in a nonleachable form (Austin, D., 22 January 1988, personal communication). Incineration of the organic contaminants should also provide an effective treatment system for the organic problem chemicals present. The presence of metals at concentrations ranging as high as 3,500 mg/kg (a zinc value derived from a station near the head of the waterway) may require that additional engineering controls for particulate emissions be incorporated as part of the incineration process.

The land treatment alternative has been eliminated from consideration based on the large volume of sediment requiring remediation and uncertainties regarding the effectiveness of the process for materials containing PCBs in a complex organic matrix. Solidification alone is also unlikely to be successful because of the high concentrations of total organic carbon (greater than 10 percent throughout the central portions of the problem area) and other organic contaminants, and is therefore not evaluated.

The need for periodic dredging to maintain channel depth precludes the use of in situ capping within the channel boundaries. The potential that future dredging, will be needed to deepen the waterway for deeper draft vessels would also compromise the effectiveness of a cap in the adjacent shoreline areas.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from exposure to contaminated sediments without implementing sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives are applicable to remediation of contaminated sediments in the head of Hylebos Waterway. The following seven sediment remedial alternatives are evaluated in this section for the cleanup of the head of Hylebos Waterway:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solvent extraction/upland disposal
- Clamshell dredging/incineration/upland disposal.

5.5.2 Evaluation of Candidate Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 5-4. A comparative evaluation of alternatives based on ratings of high, moderate, and low in the seven subcategories of evaluation criteria is presented in Table 5-5. As discussed in Chapter 4, for effectiveness these subcategories are short-term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. The implementability subcategories are technical feasibility, institutional feasibility, and availability. Capital and O&M costs are also presented in Table 5-5. Remedial costs are shown for two sediment cleanup scenarios. The "long-term cleanup goal cost" presented refers to the costs associated with remediation of all sediments with concentrations currently exceeding the long-term cleanup goal. The "long-term cleanup goal 10-yr recovery cost" refers to the costs associated with remediation of sediments that are expected to exceed the cleanup goal 10 yr after implementing source controls and allowing natural recovery to occur (i.e., the volume requiring remediation described at the end of Section 5.4).

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts would continue with the contaminated sediments remaining in place. Source control measures initiated ɿs part of the institutional controls would tend to reduce sediment ɔntamination with time, but adverse impacts would persist in the interim.

The clamshell dredging/nearshore disposal alternative is rated moderate short-term protectiveness primarily because nearshore intertidal habitat d be lost in siting the disposal facility. While the loss of habitat to nearshore site development in Commencement Bay may be mitigated by ing habitat enhancement in a nearby area, the availability of sites

TABLE 5-4. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE HEAD OF HYLEBOS WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during dredging and disposal. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treating dredged material increases worker risk significantly over dredge/disposal options. Workers wear protective gear.	Incineration of CDM is accomplished over an extended period of time requiring temporary storage thereby increasing exposure risks. Additional treatment process increases hazards. Workers wear protective gear.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Short-term benthic habitat impacts at the disposal site.	Existing contaminated habitat is destroyed. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations.	Existing contaminated habitat is destroyed by dredging. Sediment is resuspended during dredging operations. Process controls are required to reduce potential air emissions.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked seventh overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. Natural recovery ranges from 10 to 36 years. This alternative is ranked sixth overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Waterway shipping needs delay project completion. This alternative is ranked second overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment and methods are available. Disposal siting issues should not cause any delays. This alternative is ranked first for timeliness.	Approvals and construction are estimated to require a minimum of 1 to 2 years. Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Bench and pilot scale testing are required for the solvent extraction process. Full scale equipment is available. Remediation could be accomplished within 2 to 3 years. This alternative is ranked fourth overall for timeliness.	Substantial CDM testing and incinerator installation time are required before a thermal treatment can be implemented. Remediation could be accomplished within 2 to 3 years. This alternative is ranked fifth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in the absence of physical disruption is good.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Treated CDM may be used as inert construction material or disposed of at a municipal or demolition solid waste landfill. Testing required to determine disposition of treatment residuals. Treatment effectively destroys or contains contaminants.	Treated CDM may be used as inert construction material or disposed of at a municipal solid waste landfill. Testing required to determine disposition of treatment residuals. Treatment effectively destroys or contains contaminants.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Harmful organic contaminants are removed from CDM. Permanent treatment for organic contaminants is effected and inorganic contaminants are isolated by incineration of concentrated organic residue and inorganic solidification.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals is effectively treated by encapsulation.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system reduces the potential for environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Physicochemical changes could be minimized by placing sediments below low tide elevation.	Upland disposal is secure, with minimal potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Residual inorganic contaminants are solidified.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Harmful contaminants are removed from CDM. Concentrated organic contaminants are disposed of by RCRA- approved treatment or disposal. Toxicity and mobility considerations are eliminated by extraction followed by incineration or solidification.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous.

TABLE 5-4. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, although feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Upland confinement technologies are well developed.	Although still in the development stages, sludges, soils, and sediments have successfully been treated using this technology.	Incineration systems capable of handling CDM have been developed, but no applications involving CDM have been reported. Effects of salt and moisture content must be evaluated.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring is required only to evaluate the reestablishment of benthic communities. Monitoring programs can be readily implemented.	Disposal site monitoring is not required if treated CDM is determined to be nonhazardous. Air quality monitoring is intensive during implementation.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.
	INSTITUTIONAL FEASIBILTY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting is uncertain but is assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals depend largely on results of pilot testing for extraction and solidification and the nature of treatment residuals.	Approvals for incinerator operation depend on pilot testing and ability to meet air quality standards.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Section 404 permit is required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. Requires RCRA permit for disposal of concentrated organic waste.	WISHA/OSHA worker protection required. Section 404 permit is required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant toxicity and mobility. Requires compliance with PSAPCA standards.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Waterway CAD site is considered available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Process equipment is available in developmental stages. Disposal site availability is not a primary concern because of reduction in hazardous nature of material.	Incineration equipment can be installed onsite for CDM remediation efforts. Applicable incinerators exist. Disposal site availability is not a concern because of reduction in hazardous nature of material.

TABLE 5-5. EVALUATION SUMMARY FOR HEAD OF HYLEBOS WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Extraction/ Upland Disposal	Clamshell/ Incinerate/ Upland Disposal
Short-Term Protectiveness	Low	Low	High	Moderate	High	Moderate	Moderate
Timeliness	Low	Low	Moderate	High	Moderate	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High	High
Technical Feasibility	High	High	Moderate	High	High	Moderate	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	High	Moderate	Moderate	Moderate
Long-Term Cleanup Goal Cost[a]							
Capital	---	6	3,016	9,350	16,685	80,533	183,060
O&M	---	2,325	481	558	823	787	787
Total	---	2,331	3,497	9,908	17,508	81,320	183,847
Long-Term Cleanup Goal with 10-yr Recovery Cost[a]							
Capital	---	6	1,731	5,338	9,503	45,880	104,275
O&M	---	2,325	376	421	572	551	551
Total	---	2,331	2,107	5,759	10,075	46,431	104,826

[a] All costs are in $1,000.

with potential for habitat enhancement is limited. The confinement of contaminated dredged material to a barge offshore during dredging and disposal and the availability of means for adequately protecting both the public and workers during implementation aids in minimizing human health hazards. Alternatives involving treatment also received moderate ratings for short-term protectiveness because all involve additional dredged material handling, longer implementation periods, and increased air emissions, which potentially increase worker and public exposure.

The clamshell dredging/confined aquatic disposal and hydraulic dredging/upland disposal alternatives are rated high for short-term protectiveness because worker and public exposure potentials are minimized, and because the habitats that are compromised for disposal are of relatively low sensitivity. The confinement of contaminated dredged material in the subaquatic environment at a designated disposal site outside the waterway, using a mechanical dredge for removal and a downpipe and diffuser for disposal, minimizes handling requirements. Hydraulic dredging with upland disposal confines contaminated dredged material to a pipeline system throughout implementation, thereby reducing exposure potentials. If contaminated dredged material is determined to be unacceptable for disposal at an existing solid waste landfill, use of a previously unaffected site may be required. Although this would result in short-term impacts in the upland environment, the tradeoff of improved waterway habitat and marine productivity may offset them.

Timeliness--

Because an extensive amount of time is necessary for sediments to recover naturally, both the no-action and institutional controls alternatives are rated low. Source control measures instituted as part of the institutional controls would tend to reduce contamination with time but adverse impacts would persist in the interim. Natural recovery times for the three indicator compounds range from 10 to 35 yr (see Section 5.3.2) if sources are completely eliminated.

Moderate ratings have been applied to the clamshell dredging/confined aquatic disposal, hydraulic dredging/upland disposal, clamshell dredging/solvent extraction/upland disposal, and clamshell dredging/incineration/upland disposal options. For dredging options that involve siting of unused and undeveloped upland or confined aquatic disposal facilities, approvals and construction are estimated to require a minimum of 1-2 yr. The equipment and methods used require no development period, and pre-implementation testing is not expected to be extensive. Treatment processes may require additional time for bench-scale testing, pilot burns, and equipment development or modification. Facility siting and technology development could be conducted concurrently, however. Once approval is obtained, treatment of contaminated sediments in the head of Hylebos Waterway will require a period of approximately 2-3 yr, assuming maximum treatment rates of 500 yd^3/day.

The clamshell dredging/nearshore disposal option is rated high for timeliness because this alternative can be implemented rapidly with available technologies and expertise. Major site development would be required (e.g., diking) but can be completed in a relatively short timeframe. Necessary equipment and methods are readily available, and disposal siting issues are not likely to delay implementation.

Long-Term Protectiveness--

The comparative evaluations for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for natural recovery is long. For the institutional controls alternative, the potential for exposure to contaminated sediments would remain, albeit at declining levels following implementation of source reductions, and the observed adverse biological impacts would continue.

Moderate ratings are assigned for clamshell dredging/nearshore disposal and hydraulic dredging/upland disposal alternatives because of potential physicochemical changes due to placing metal-contaminated dredged material in these disposal facilities. These changes, primarily from new redox conditions, would tend to increase the migration potential of the metal contaminants. Leachate testing on dredged sediments indicates that leachability of organic compounds is enhanced under aerobic vs. anaerobic conditions (U.S. Army Corps of Engineers 1986c). Contaminated dredged material testing should provide the necessary data on the magnitude of these impacts. In a nearshore site, physicochemical changes could be minimized by placing sediments below the low tide water elevation. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature as a result of wave action and tidal influences. In addition, the fish mitigation area in the outer Blair Waterway slip adjacent to the proposed disposal facility would be regarded as a sensitive area. The upland disposal facility would be generally regarded as a more secure option because of improved engineering controls during construction, but there is potential for impacts on groundwater resources.

The clamshell dredging/confined aquatic disposal, clamshell dredging/solvent extraction/upland disposal, and clamshell dredging/incineration/upland disposal alternatives are rated high for long-term protectiveness. Placement of material in a confined, quiescent, subaquatic environment would provide a high degree of isolation, with little potential for exposure to an environment sensitive to the contaminated dredged material. In addition, confinement under these circumstances would maintain physicochemical conditions comparable to in situ conditions, further reducing contaminant migration potential. The effectiveness of contaminant removal by solvent extraction and contaminant destruction by incineration substantially increases the long-term protectiveness of these alternatives over nontreatment dredge and disposal alternatives.

Reduction in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except those involving treatment, which were rated high. Although the confined aquatic, upland, and nearshore disposal alternatives would isolate contaminated dredged material from the surrounding environment, the chemistry of the material would remain unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated contaminated dredged material may actually increase with changes in redox potentials. Without treatment, the toxicity of contaminated sediments would remain at preremediation levels. Contaminated sediment volumes would not be reduced, and may actually increase with the hydraulic dredging option because the material would be suspended in an aqueous slurry.

Solvent extraction of contaminated dredged material prior to disposal would effectively remove organic contaminants, thereby reducing mobilization potential permanently and significantly for the bulk of the sediments. Through isolation of contaminants in the extraction residue, this process would also reduce the volume of contaminants substantially, as compared with nontreatment alternatives. Because the available data suggest that the inorganic contaminants are not present at high concentration, the process may also be relatively effective in extracting these compounds. Performance tests during bench-scale testing of the extraction process would be expected to provide sufficient data to substantiate or invalidate these conclusions. The fate of the residual material and particulates collected during the incineration process would be contingent upon the results of characterization analyses. The inorganic contaminant content of the material will largely determine disposal requirements.

Technical Feasibility--

Clamshell dredging/confined aquatic disposal, clamshell dredging/solvent extraction/upland disposal, and clamshell dredging/incineration/upland disposal alternatives have been assigned a moderate rating for technical feasibility. This rating was applied to the treatment alternatives because of the need to conduct bench-scale testing and pilot burns prior to implementation. Technologies for the large-scale treatment of contaminated dredged material are conceptual at this point, although the methods appear to be feasible. A moderate rating was also applied to the clamshell dredging/confined aquatic disposal option. Placement of dredge and capping materials at depths of approximately 100 ft would be difficult, although feasible. Considerable effort and resources may be required to monitor the effectiveness and accuracy of dredging, disposal, and capping operations.

High ratings have been assigned to all other alternatives because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective elsewhere for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods (e.g., sediment cores, monitoring wells) are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives have been assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be not achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings have been assigned to the remaining five alternatives because of potential difficulty in obtaining agency approvals for disposal sites or implementation of treatment technologies. Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. It was assumed that the Blair Waterway nearshore facility would be available for use. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of the effectiveness of each alternative in meeting established performance goals (e.g., treatability of dredge water, removal of contaminants through extraction).

Availability--

Candidate sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities are rated high for availability. Because the no-action and institutional controls alternatives can be implemented immediately, they received a high rating. A nearshore disposal site was assumed to be available, allowing rapid implementation of the clamshell dredging/nearshore disposal alternative. Thus, this alternative also received a high rating for availability.

Remedial alternatives involving dredging with confined aquatic or upland disposal are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that confined aquatic and upland sites will be available. However, no sites for contaminated sediments are currently approved for use and no sites are currently under construction. Depending on the final characterization of sediments, upland disposal in an existing municipal or demolition landfill may also be feasible. For costing purposes, development of a RCRA-equivalent upland site was assumed. A moderate rating has also been assigned to the alternatives involving treatment because of the same uncertainties regarding disposal site availability. However, testing conducted as a part of the bench-scale treatability and performance evaluation for the treatment processes should confirm that the resulting product is nonhazardous and appropriate for a standard solid waste management facility. For costing purposes, disposal in a standard solid waste management facility was assumed.

Cost--

Capital costs increase with increasing complexity (i.e., from no action to the treatment options). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are approximately 75 percent higher than those for clamshell dredging/nearshore disposal, primarily because of underdrain and bottom liner installation, dredge water clarification, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting the treatment alternatives increases as a result of material costs for the processes, and associated labor costs for material handling and transport. Incineration costs are high because of the low Btu content of the sediment and resulting increase in fuel consumption. Dredge water clarification management costs are also incurred for these options.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls) or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Costs for monitoring of the confined aquatic disposal facility are significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution to monitor migration. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single groundwater sample from each well to assess contaminant migration.

It was also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding long-term cleanup goals) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the solidification alternative are significantly lower because the process results in lower contaminant migration potential.

5.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the seven candidate sediment remedial alternatives proposed for the head of Hylebos Waterway, clamshell dredging with nearshore disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, nearshore disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. The nearshore disposal alternative is currently preferred for the following reasons:

- The alternative protects public health and the environment by effectively isolating contaminated sediments in an engineered disposal facility

- The alternative is consistent with existing plans to fill the Blair Waterway Slip 1 proposed nearshore fill site

- The nature of the organic contaminants (high molecular weight, low solubility, and low partitioning potential) is such that placement below the saturated zone should minimize migration potential

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental requirements

- Performance monitoring can be accomplished effectively and implemented readily

- The estimated 217,000-yd^3 volume of contaminated sediments is compatible with the capacity of the proposed nearshore facility

- Although the cost of this alternative is approximately $4.3 million less than that of the upland disposal alternative, it is expected to provide an equivalent degree of public health and environmental protection

- Although this option is approximately $4 million more than the confined aquatic disposal option, largely due to the cost of acquiring nearshore property in the project area, the additional expenditure is justified since the action can be implemented more quickly in an available facility that offers appropriate confinement conditions for the contaminants of concern.

This alternative is rated high for timeliness, technical feasibility, and availability because available equipment, resources, and disposal facilities would be used. The alternative can be implemented quickly with reliable equipment that has proven effective in past similar operations.

The alternative is rated moderate for short-term protectiveness because of the loss of intertidal habitat at the disposal site and during dredging operations in the waterway. This disadvantage can be offset through incorporation of a habitat replacement project in the remedial process and replacement of intertidal sediments in the waterway on a one-to-one basis. The goal of habitat replacement is addressed in part by removal of contaminated sediments from the waterway itself and subsequent reestablishment of that marine habitat. The alternative is also rated moderate for long-term protectiveness because contaminated sediments would be placed in an environment subject to wave and tidal influences. In addition, there is potential for long-term impacts to the adjacent fish mitigation area in the outer slip of Blair Waterway. Contaminants in the head of Hylebos Waterway have demonstrated relatively high particle affinities (Tetra Tech 1987c), which would serve to improve long-term containment reliability. Hart-Crowser & Associates (1985) concluded that monitoring of contaminant mobility from nearshore disposal sites could be effectively accomplished with monitoring wells in containment berms for early detection of contaminant movement. Long-term protectiveness could also be improved with the placement of slurry walls within the berm (Phillips et al. 1985); however, this measure has not been included in the cost estimate for this alternative. As indicated in Table 5-4, this alternative provides a cost-effective means of sediment mitigation.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with redistribution of contaminated dredged material. The effect of dredging on water quality can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Because this alternative can be implemented over a relatively short timeframe, seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

During the remedial design phase, additional sampling will be required to refine the area requiring remediation. If as a result of this additional sampling it is determined that total levels of contamination exceed the minimum levels established to define dangerous waste, then additional remedial alternatives that are applicable to the disposal of dangerous waste will have to be considered for those sediments that qualify as dangerous waste.

The confined aquatic disposal alternative was not selected because the volume of material is compatible with the available nearshore disposal site. The nearshore alternative can be implemented more quickly, while providing a degree of protection that is appropriate for the contaminants of concern.

Solvent extraction/upland disposal and incineration/upland disposal were not selected as preferred alternatives since the timeframe for remedial action would be lengthened. Implementation would require bench-scale and possibly pilot-scale testing and pilot burns. In addition, treatment itself would take a considerable period of time, given available equipment and the large volume of contaminated sediment. Removal (extraction) or destruction (incineration) of contaminants due to the treatment processes is expected to increase long-term protectiveness compared with nearshore disposal. However, performance monitoring associated with the nearshore disposal facility would allow early detection of movement to the surrounding environment. The approximately $41 and $99 million greater cost for the extraction and incineration options, respectively, also favor the nearshore disposal alternative for the large volume of contaminated sediments at moderate levels of contamination.

Hydraulic dredging with upland disposal was not selected because of uncertain disposal site availability and the high cost of siting and developing a facility to appropriate technical standards for disposal of untreated contaminated dredged material in an upland environment. This alternative is feasible from both a technical and institutional standpoint. The risk of system failures for disposal in the upland environment (e.g., groundwater risks) along with the high costs and disposal siting uncertainties compromises its desirability.

No-action and institutional controls alternatives are ranked high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public health impacts far outweighs these advantages.

5.7 CONCLUSIONS

The head of Hylebos Waterway was identified as a problem area because of the elevated concentrations of both inorganic and organic contaminants in the sediment. PCBs, arsenic, and HPAH were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 381,000 yd^2, and a volume of 381,000 yd^3. Some of the sediment is predicted to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 164,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 217,000 yd^3.

The primary identified and potential sources of problem chemicals to the head of Hylebos Waterway include the following:

- Process effluents from Pennwalt Chemical
- Drainage ditches including Kaiser Ditch, East Channel Ditch, and Morningside Ditch
- Surface water runoff from Pennwalt Chemical (potential), log sorting yards, General Metals, Kaiser Aluminum, and Tacoma Boatbuilding Company
- Groundwater seeps and infiltration from Pennwalt Chemical, log sorting yards, General Metals (potential), B&L Landfill, and Kaiser (potential).

Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Reduce the amount of metals in process effluent from Pennwalt Chemical

- Reduce contaminant concentrations of metals, hydrocarbons, and PCBs in the discharge from the ditches

- Reduce contamination in surface water discharging to the waterway

- Reduce groundwater contamination discharges to the waterway

- Implement best management practices at the Tacoma Boatbuilding Company facility

- Confirm that all sources of problem chemicals have been identified and controlled

- Monitor sediments regularly to confirm sediment recovery predictions and assess the adequacy of source control measures.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. The level of source control required for PCBs was estimated to be approximately 89 percent compared to a technically feasible level of approximately 70 percent. Additional evaluations to further delineate PCB sources and refine these estimates will be required as part of the source control measures described above. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals PCBs, arsenic, and HPAH. The assumptions used in determining source control requirements were environmentally protective. It is anticipated that more detailed loading data will demonstrate that sources can be controlled to the extent necessary to maintain acceptable sediment quality. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then area requiring sediment remediation may be re-evaluated.

For sediment areas not predicted to recover within 10 yr of implementation of source controls, clamshell dredging/nearshore disposal was recommended as the preferred alternative. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments in an engineered disposal facility where performance monitoring can be readily implemented. Disposal sites for nearshore confinement are available at this time. Use of material from the head of Hylebos Waterway in a nearshore disposal facility is compatible with the Port of Tacoma's industrial development plans, minimizing the impacts of using another facility. Concerns regarding potential contaminant migration to an adjacent fish mitigation area will be addressed through the ongoing monitoring program to detect potential problems in sufficient time to implement corrective measures, if necessary. Nearshore disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 5-5, clamshell dredging/nearshore disposal provides a cost-effective means of sediment mitigation. The estimated capital cost to implement this alternative is $5,338,000. The present worth of 30 yr of environmental monitoring and other O&M at the disposal site is estimated to be $421,000. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total estimated present worth of the preferred alternative is $5,759,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions practicable, and are cost-effective.

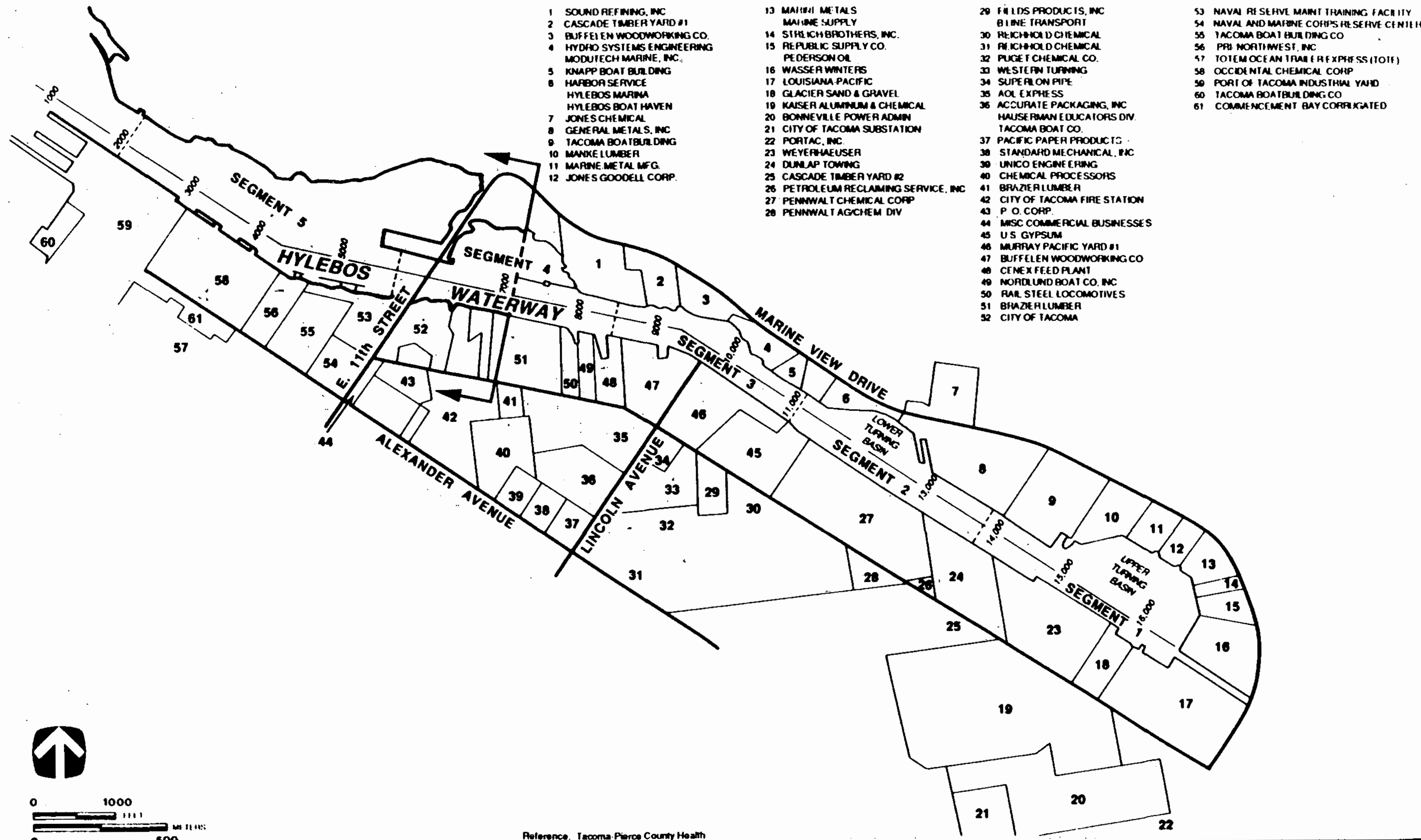
6.0 MOUTH OF HYLEBOS WATERWAY

Potential remedial actions are defined and evaluated in this section for the mouth of Hylebos Waterway problem area. The waterway is described in Section 6.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 6.2 provides an overview of contaminant sources, including site background, identification of apparent contaminant sources, remedial activities, and current site status. The effects of source control measures on sediment contamination levels are discussed in Section 6.3. Areas and volumes of sediment requiring remediation are provided in Section 6.4. The detailed evaluation of the sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 6.5. The preferred alternative is identified in Section 6.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 6.7 summarizes the findings of the selection process and integrates the required source control with the selected remedial alternative.

6.1 WATERWAY DESCRIPTION

Hylebos Waterway is designated as a navigational waterway with a required maintenance depth of 30 ft below MLLW. An illustration of the waterway and the locations of nearby industries and businesses is presented in Figure 6-1. The problem area designated as the mouth of Hylebos Waterway extends from the mouth of the waterway to approximately 7,200 ft from the mouth. The width of the main channel measures between 600 and 1,000 ft in this problem area, with a large intertidal area west of East 11th Street extending another 800 ft to the north. Recent subbottom profiling of Hylebos Waterway in this area showed that mid-channel depths average between approximately 37 and 44 ft below MLLW, with depths across the channel bottom varying between 28 ft below MLLW at the south bank to 36 ft below MLLW at mid-channel (Raven Systems and Research 1984). Total sediment accumulation was estimated to be between 1 and 4 ft, with a pronounced 4-ft accumulation along the south side of the waterway, adjacent to Occidental Chemical Corporation. Sediments within Hylebos Waterway are typically silty sand with an average composition of 64 percent fine-grained material (range of 44-78 percent) and 20 percent clay (Tetra Tech 1985b). Sedimentation rates diminish from the mouth to the head (Tetra Tech 1987b).

Hylebos Waterway was formed by dredging the Puyallup River delta in the early 1920s. Since that time, the southern shoreline of the waterway has become heavily industrialized. Industrial development along the north



Reference: Tacoma-Pierce County Health Department (1984, 1986).

Notes: Property boundaries are approximate based on aerial photographs and drive by inspections.

Figure 6-1. Mouth of Hylebos Waterway - Existing industries and businesses.

shore has not been as extensive as that along the south shore, due principally to the limited land area available between the waterway and the steep bluffs.

Dredging by the Port of Tacoma and the U.S. Army Corps of Engineers has changed the shape and size of Hylebos Waterway. When created in the 1920s, the waterway extended only to the point of what is now the lower turning basin. In the mid-1950s, the Port of Tacoma extended the waterway approximately 3,800 ft (Tetra Tech 1986c). Subsequent dredging by the U.S. Army Corps of Engineers widened the upper reaches of the waterway and created the upper turning basin at the head of the waterway (Dames & Moore 1982).

6.1.1 Nature and Extent of Contamination

An examination of sediment contamination data obtained during both the RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical surveys has revealed that the mouth of Hylebos Waterway contains elevated concentrations of organic materials. PCBs were identified as a Priority 1 contaminant in the waterway. Priority 2 contaminants that have been identified in the mouth of Hylebos Waterway include hexachlorobenzene, trichloroethene, tetrachloroethene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, hexachlorobutadiene, a pentachlorocyclopentane isomer, and lead. The following organic and inorganic compounds exceeded their corresponding AET values at only one station sampled, and are therefore considered Priority 3 contaminants: HPAH, LPAH, methylphenanthrene, methylpyrene, biphenyl, phenol, benzyl alcohol, copper, and zinc.

The area of concern in the mouth of Hylebos Waterway has been defined as the entire deep water portion of the problem area (Tetra Tech 1985b). Although cross-channel sampling was limited, existing data showed sediments from the southern side of the waterway to be more contaminated than those from the middle or north side. Selected chlorinated compounds from sediments along the south shore were present in the highest concentrations observed throughout Commencement Bay.

PCBs and hexachlorobenzene were selected as indicator chemicals for the mouth of Hylebos Waterway. Surface sediment enrichment ratios (i.e., ratio of observed concentration to long-term cleanup goal) for these two contaminants were higher over a greater area than for other identified problem chemicals. These contaminants were also selected because they represent surface runoff and contaminant loading to the waterway from Occidental Chemical Corporation (see Section 6.2.1).

The highest concentrations of PCBs in the mouth of Hylebos Waterway were restricted to the southern shore of the waterway. PCB concentrations dropped abruptly with increasing distance from the south shoreline (Tetra Tech 1985a), suggesting that the source of PCB contamination is or was along the southern shore of the waterway.

Concentrations of chlorinated benzene compounds were highest approximately 4,000 ft from the mouth of the waterway. Decreasing concentrations with distance from this area suggest the presence of a source in that immediate vicinity (Tetra Tech 1985a). There was no apparent cross-waterway contamination gradient in the problem area. Review of data collected during the RI for the spatial distributions of chlorinated hydrocarbons led to the conclusion that the chlorinated benzenes and chlorinated butadienes were derived from a common source.

Areal and depth distributions of PCBs and hexachlorobenzene in the mouth of Hylebos Waterway are shown in Figures 6-2 and 6-3, respectively. Concentrations are normalized to cleanup goals, which are 150 ug/kg for PCBs and 22 ug/kg for hexachlorobenzene. Values above 1.0 define problem sediments. The cleanup goal for PCBs was set by data for bioaccumulation of the contaminant in English sole muscle tissue. The cleanup goal for hexachlorobenzene was set by the benthic infauna AET.

Included in Figures 6-2 and 6-3 are contaminant depth profiles for core samples collected as part of the FS. Although surface minima were noted for PCBs in the problem area, recent investigations (Stinson et al. 1987) suggest that there are ongoing sources of this contaminant. Of the four core samples collected during the RI, three showed an increase of chlorinated hydrocarbons with depth. Subsurface infiltration of contaminated groundwater at permeable horizons has been suggested for the increases (Tetra Tech 1985a). Remediation to a depth of 2 yd was assumed based on available core data.

6.1.2 Recent and Planned Dredging Projects

The most recent dredging in the mouth of Hylebos Waterway was confined to three small areas in the vicinity of the 11th Street Bridge. Since 1972, the only dredging in the waterway has been performed by specific industries along the waterfront (Tetra Tech 1985a).

The Puyallup Indians have applied for a permit to excavate an upland area adjacent to a highly productive and heavily used intertidal fish rearing habitat at the mouth of Hylebos Waterway. The excavated material will be relocated to an existing spit to the west, thereby increasing the intertidal area behind the spit. The new spit elevation will be 14 ft above MLLW, and the existing intertidal area will increase by 35-40 percent. A total of 10,800 yd^3 of sediment will be placed in the new spit (U.S. Army Corps of Engineers, 10 November 1988, personal communication). Businesses and industries that responded when queried about future dredging plans are itemized below:

- Occidental Chemical Corporation does not plan to dredge at the mouth of Hylebos site in the near future, but will probably apply for a dredging permit within 3-5 yr (Hartman, R., 22 October 1987, personal communication).

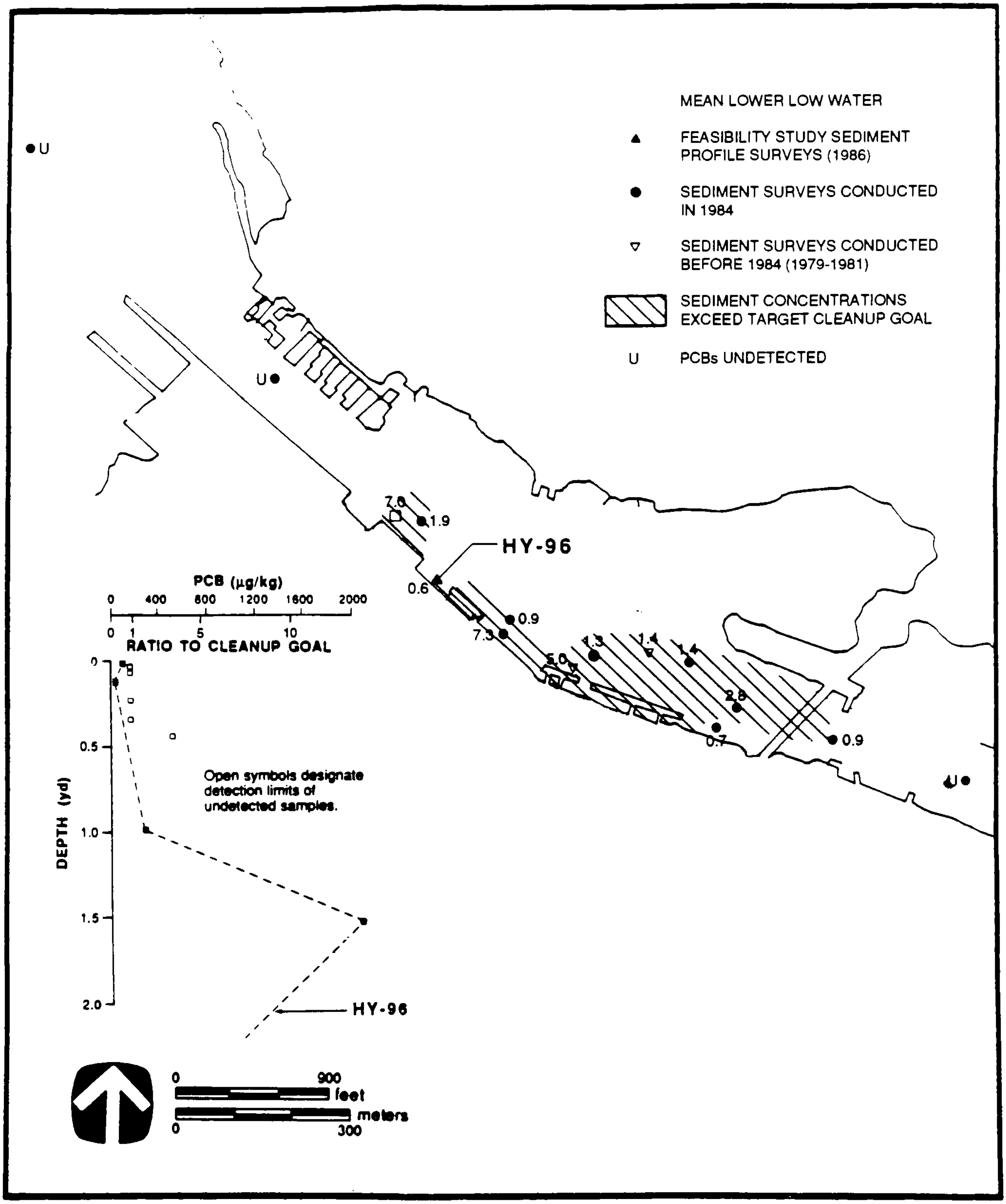


Figure 6-2. Areal and depth distributions of PCBs in sediments at the mouth of Hylebos Waterway, normalized to long-term cleanup goal.

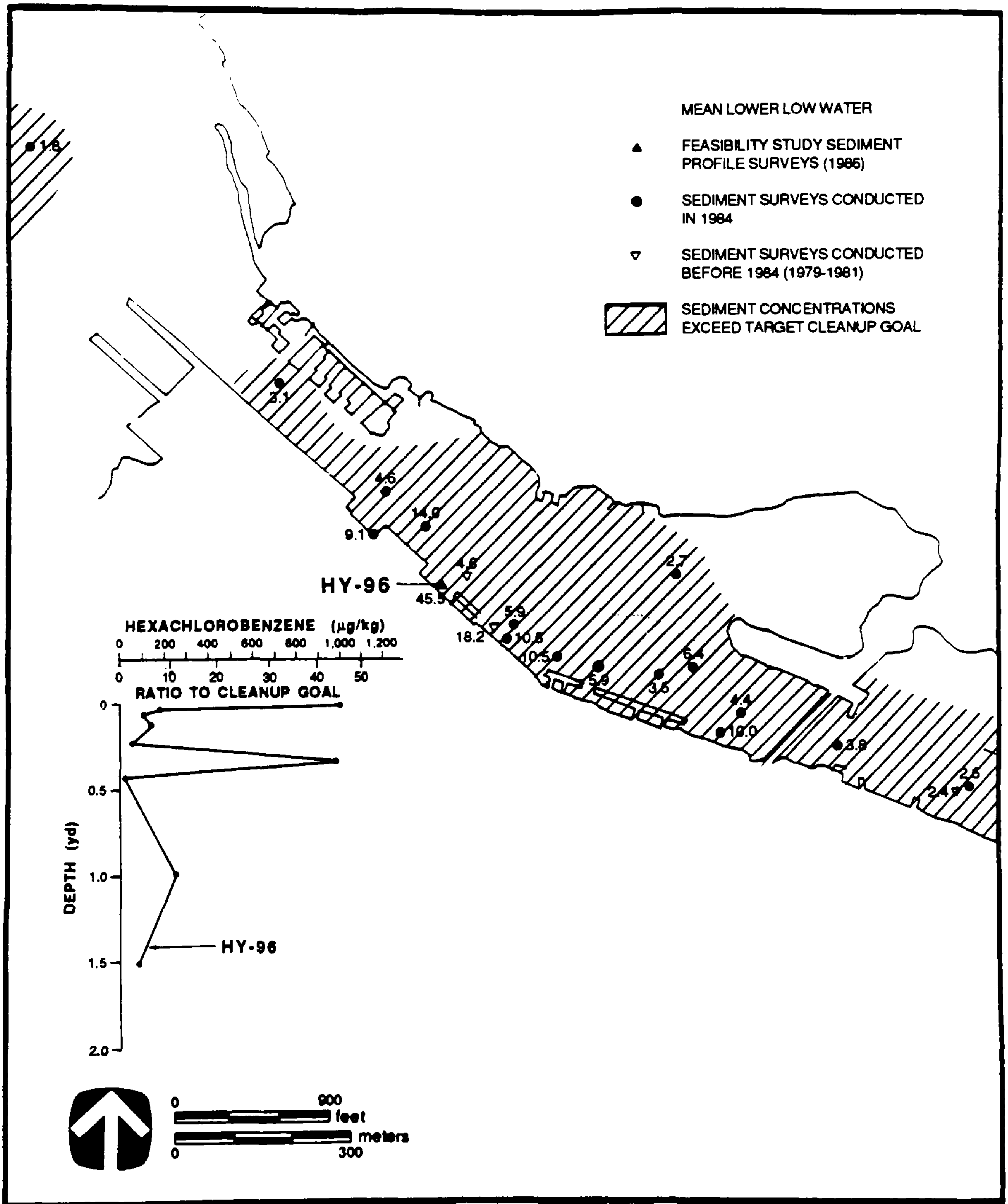


Figure 6-3. Areal and depth distributions of hexachlorobenzene in sediments at the mouth of Hylebos Waterway, normalized to long-term cleanup goal.

- Tacoma Boatbuilding Company does not foresee any need to dredge because silt buildup (which is periodically checked) is slow in their channel. The company last dredged approximately 10 yr ago. The company plans to build a dock at its leased Port of Tacoma site. Although this construction will require dredging, a permit has not yet been requested (Brady, B., 22 October 1987, personal communication).

- Totem Ocean Trailer Express, and the Naval and Marine Corps Reserve Center do not plan any dredging projects in the foreseeable future (Bimick, B., 22 October 1987, personal communication; Kuzek, Lt., 22 October 1987, personal communication).

The U.S. Army Corps of Engineers has not received any recent requests for dredging permits. However, the Port of Tacoma and the U.S. Army Corps of Engineers have suggested that navigational channels in the Commencement Bay area may be deepened in the future to accommodate large vessels with deeper drafts.

6.2 POTENTIAL SOURCES OF CONTAMINATION

This section provides an overview of the sources of contamination to the sediments in the mouth of Hylebos Waterway and a summary of available loading information for the contaminants of concern. Because the north shore of Hylebos Waterway is primarily steep bluffs, industrial development has not been as extensive as that along the south shore (see Figure 6-1). In this area of the waterway, there are no industries along the north shore. Much of the intertidal area is used for log storage and marina facilities (Tetra Tech 1986c).

Occidental Chemical Corporation (formerly Hooker Chemical and Plastics Corporation) was among the first industries established along Hylebos Waterway. The facility began operations in the 1920s to provide chlorine for pulp and paper industries. Occidental also operated an organic solvents plant between 1947 and 1973. Occidental Chemical is one of the five NPDES-permitted facilities located along Hylebos Waterway (Figure 6-4), and the only permitted discharge to this problem area. The facility's main outfall (HY-707) is classified as a major industrial discharge under the NPDES program (Permit #WA0037265). Nonpermitted discharges associated with Occidental include seven steel pipes (HY-085), two groundwater seeps (HY-083), and the groundwater beneath the facility. There are numerous other nonpermitted surface water discharges to the problem area (Figure 6-4). Other industrial facilities located along the banks of the mouth of Hylebos Waterway include Tacoma Boatbuilding Company, PRI Northwest, Inc., and the Port of Tacoma industrial yard.

Table 6-1 provides a summary of problem chemicals and source status information for the area. The high concentrations of chlorinated hydrocarbons in the sediments of the mouth of Hylebos Waterway have been attributed to the Occidental Chemical Corporation, based on their proximity to the problem area, known use of problem chemicals, and presence of soil

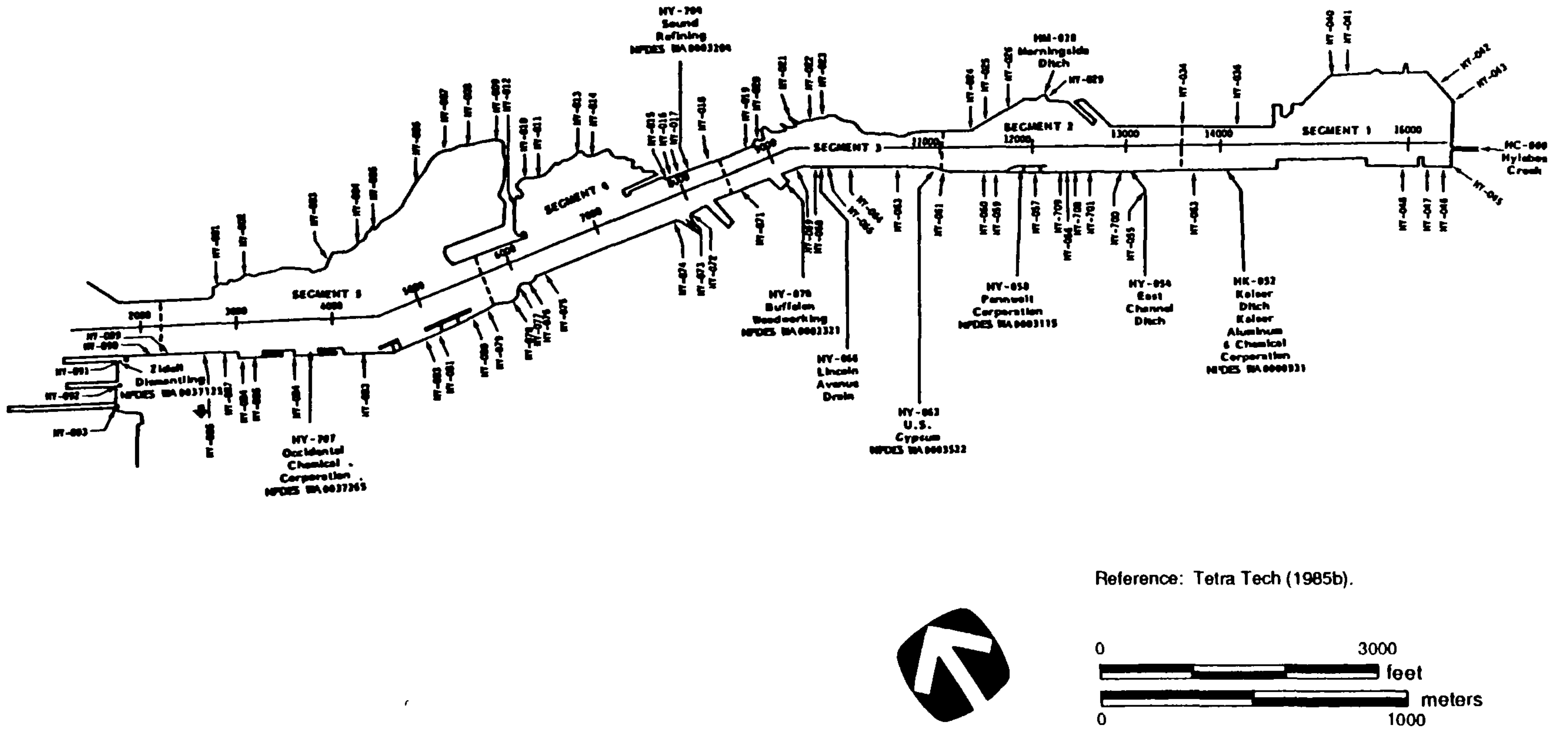


Figure 6-4. NPDES-permitted and nonpermitted discharges to Hylebos Waterway.

TABLE 6-1. MOUTH OF HYLEBOS WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
PCBs	1	Occidental Seep #1	Yes	Insufficient data	**Unknown**	Variable; data limitations
		Locomotive yards	Yes	No	Ongoing	
Trichloroethene	2	Occidental surface water runoff	Yes	Source loading calculations for Cl-ethenes, Cl-benzenes, Cl-butadienes	Solvent plant operations terminated in 1973; surface runoff and ground water are ongoing sources	Surface and subsurface maxima
Tetrachloroethene	2					
Hexachlorobenzene	2					
1,2 Dichlorobenzene	2					
1,3 Dichlorobenzene	2					
Hexachlorobutadiene	2					
Pentachlorocyclopentane isomer	2	Occidental ground-water infiltration	Yes	No	Direct discharge of chlorinated hydrocarbons associated with chlorine prediction has decreased	
HPAH	3 (HY-02)	Ubiquitous oil spills	Potential	No	Sporadic, ongoing	Variable
LPAH	3 (HY-02)					
Methylphenanthrene	3 (HY-36)					
Methylpyrene	3 (HY-36)					
Biphenyl	3 (HY-36)					
Lead	2	Occidental	Yes	Yes	Ongoing	Variable; lead has surface minimum
Copper	3					
Zinc	3	Storm drains	Yes	Yes	Ongoing	
Phenol	3 (HY-36)	Historical	No	No	NA	c
Benzyl alcohol	3 (HY-41)	Unknown	No	No	NA	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

and groundwater contamination at the facility (Tetra Tech 1985b). This facility has also been identified as a potential source of PCBs based on sediment samples collected adjacent to one of the groundwater seeps below the former Occidental solvents plant (Stinson et al. 1987). Although the locomotive yards have been identified as a potential source of PCBs to Hylebos Waterway, this facility is located well outside of the problem area. In addition, the sample exhibiting significant PCB concentrations was collected from a waste oil channel with no apparent route by which the material could enter Hylebos Waterway (Stinson et al. 1987).

6.2.1 Occidental Chemical Corporation

The Occidental Chemical Corporation chemical production facility is situated on Hylebos Waterway between East 11th Street and Commencement Bay. The 33-ac site is bordered by Alexander Avenue on the southwest and by Hylebos Waterway on the northwest. The facility operated as the Hooker Chemicals and Plastics Corporation from the initiation of operations in 1929 until the 1980s, when the name of the operation was changed to the current title.

Chlorine and sodium hydroxide have been manufactured by electrolysis ever since the plant opened. Production continues today. The facility also contains an ammonia plant and a muriatic acid plant. Industrial solvents were manufactured at the site from 1947 to 1973. In 1973, the solvent production equipment was dismantled and removed from the property (Walker Wells 1980a). Wastes generated during the active period of solvent production (1947-1973) were reportedly either discharged to Hylebos Waterway, disposed of at a deep-water disposal site within Commencement Bay, or buried onsite in unlined lagoons or pits (Boys, P. and J. Sceva, 3 July 1979, personal communication). From approximately mid-1972 until the solvents plant closed in 1973, solid wastes were removed for offsite disposal at several upland sites in the Commencement Bay vicinity. From 1929 to 1969 or 1970, effluents from the chlorine production operations were discharged directly to Hylebos Waterway through the main plant effluent (Boys, P. and J. Sceva, 3 July 1979, personal communication). Since that time, chlorinated organic compounds generated by the chlorine purification unit have been disposed of by offsite incineration. The effluent from the chlorine stripper continues to be discharged to Hylebos Waterway along with the total plant effluent.

As indicated previously, Occidental Chemical Corporation has also been identified as a potential source of PCB contamination to the waterway, based on sediment data in the vicinity of the groundwater seeps adjacent to the facility. However, soil testing conducted on the site has not produced any significant positive results (Robb, S., 9 May 1988, personal communication). In addition, groundwater beneath the site did not exhibit PCB contamination. A sample from an offsite well adjacent to the Occidental facility had a low, but measurable PCB concentration (Massimino, C., 13 May 1988, personal communication). The company does have electrical transformers on the site.

Occidental Chemical was identified as a source of problem chemicals found in the sediments of Hylebos Waterway based on its proximity to the problem area, its documented use of problem chemicals, and measurements of pollutant concentrations in groundwater and effluent. Occidental Chemical is the only confirmed source of chlorinated hydrocarbons (chlorinated ethenes, butadienes, and benzenes) and mercury to the mouth of Hylebos Waterway.

Identification of Contaminant Sources Onsite--

Current discharges associated with Occidental Chemical Corporation include the main plant outfall (HY-707), surface drain (HY-085), groundwater seeps (HY-083), and the groundwater beneath the plant site. Of these four confirmed sources of contaminants to Hylebos Waterway, it has been estimated that groundwater currently contributes the majority of the loadings, followed by the main plant outfall (Appendix E, Table E-10). In addition, subsurface soils in the vicinity of past onsite disposal areas contain significant quantities of chlorinated organic compounds, largely beneath areas of the site that have been excavated and then paved.

Groundwater contamination at the site has resulted primarily from the past onsite disposal of solvent plant wastes containing 3,000-4,000 mg/L of chlorinated organic compounds (Tetra Tech 1986c). These compounds included, but were not limited to, methylene chloride, chloroform, trichloroethylene, perchloroethylene, tetrachloroethane, hexachlorobutadiene, and various chlorinated ethenes. Chlorinated organic concentrations approaching 700 mg/L have been detected in groundwater at the site. The groundwater plume at the Occidental Chemical site is currently estimated to cover the western half of the site, with the major zone of contamination in the 25- to 50-ft depth zone. However, contamination was observed to a depth of 115 ft in the vicinity of the former solvents plant. Walker Wells (1980a) estimated that 19,000-35,000 lb of chlorinated organic contaminants were contained in the saturated zone beneath the facility. Total chlorinated organics loading to the waterway as a result of groundwater discharge has been estimated to range from approximately 5.5 to 12 lb/day (Walker Wells 1980a). Recent monitoring data indicates that the chlorinated organic content of groundwater beneath the facility has not declined appreciably since the monitoring effort began (Stoner, M., 26 April 1988, personal communication).

Chlorinated organic contaminants have also been identified in the unsaturated zone beneath the Occidental Chemical site. In 1980, 10,725 lb of chlorinated organics were estimated to be present in this zone (Walker Wells 1980a). Although subsurface soil containing greater than 150 mg/kg chlorinated organic contaminants has since been removed, residual contaminants in the unsaturated zone could percolate to the surficial aquifer beneath the site and eventually migrate to Hylebos Waterway (Ecology 1986).

Surface water runoff represents an additional potential source of contamination to the adjacent waterway. The documented releases of contaminated surface water from the Occidental Chemical Corporation (HY-085, see Appendix E) have been associated with relatively small flows (700 gal/day). However, there is potential for shallow contaminated groundwater to infiltrate storm sewer lines and subsequently enter Hylebos Waterway. Because the most highly contaminated soil has been removed and most of the site paved, surface water runoff does not appear to be a significant contaminant transport mechanism to Hylebos Waterway (Robb, S., 7 October 1987, personal communication). However, additional investigation is necessary to confirm this conclusion.

Recent and Planned Remedial Activities--

A number of remedial measures have already been undertaken by Occidental Chemical and a number of others are planned. These measures included soil excavation, groundwater remediation, process controls, and runoff controls. These measures are being undertaken pursuant to the stipulations of the RCRA Part B permit application and the Continuing Releases portion of the application for the site (Stoner, M., 26 April 1988, personal communication). It is anticipated that the approved RCRA Part B permit will be issued in the fall of 1988 (PTI 1988a).

As indicated previously, contamination of Hylebos Waterway via groundwater occurs largely from onsite disposal of solvent plant wastes in unlined lagoons and pits. In response to an Ecology order, Occidental Chemical Corporation removed 1,585 yd^3 of soil exceeding 150 mg/kg chlorinated organics and paved remaining subsurface areas containing at least 15 mg/kg (Ecology 1986). Approximately 87 percent (9,368 lb) of the estimated 10,725-lb reservoir of chlorinated hydrocarbons was removed by this action. Based on data submitted to U.S. EPA by Occidental Chemical (Stoner, M., 26 April 1988, personal communication), significant improvement in groundwater quality has not been observed since contaminated soils were removed. Runoff from the paved areas has been routed to the facility's main outfall.

Occidental Chemical Corporation has recently proposed a groundwater pumping, collection, and treatment program. Proposed treatment technologies include air stripping, carbon adsorption, steam stripping, and air stripping backed by carbon (Hartman, R., 1 May 1987, personal communication). Initial groundwater analyses have indicated that air stripping is not a viable option because of air quality emission limitations. Steam stripping has been tentatively identified by Occidental Chemical as the technology of choice (Hartman, R., 1 May 1987, personal communication). Additional design data are required for final selection of the groundwater treatment technology.

In-plant modifications have also been undertaken to minimize the discharge of chlorinated organics to Hylebos Waterway through the main plant outfall. The chlorine steam stripper is the only in-plant wastestream discharged through the main outfall that contacts toxic chlorinated compounds. A taller chlorine stripping tower has been installed and steam temperatures are now regulated at the top of the tower instead of the bottom. Chlorinated hydrocarbon concentrations in the stripper effluent have been reduced by approximately 95 percent (0.2 vs. 5.2 lb/day). These changes represent the best control available for graphite anode diaphragm cell technology, and hence the lowest achievable level of residual chlorinated hydrocarbon content (Scholes, D., 9 October 1985, personal communication). Other upgrades to in-plant operations and waste handling practices have also significantly reduced direct discharges to the waterway.

Occidental Chemical Corporation has been developing plans to dredge Hylebos Waterway in the vicinity of their dock. Sampling plans for the dredging were reviewed and approved by Ecology on 5 December 1984, and sediments were sampled by a contractor to Occidental Chemical on 10 December 1984 under Ecology supervision. Additional sampling is planned. However, as of this writing, no additional sampling or dredging has been accomplished (Hartman, R., 8 July 1988, personal communication). Previous sediment samples analyzed in 1983 showed high concentrations of chlorinated organic compounds.

6.2.2 Loading Summary

Where possible, source contaminant loading calculations have been updated to include data collected since the completion of the Remedial Investigation (Tetra Tech 1985a, 1986c). Summary loading tables for the Priority 1 and 2 contaminants of concern for the mouth of Hylebos Waterway (i.e., lead, PCBs, chlorinated ethenes, chlorinated benzenes, chlorinated butadienes, and pentachlorocyclopentane isomer) are provided in Appendix E. The only discharge to the mouth of Hylebos Waterway for which post-RI loading data are available is Occidental Chemical's main outfall HY-707 (Hartman R., 30 June 1987, personal communication).

Data from Occidental Chemical's main outfall (HY-707) have been collected primarily for two sampling periods, one in 1979 and the second in 1986. Data for seven inorganic compounds and the chlorinated hydrocarbons reveal a significant decrease in loadings to the waterway over that period. Loading rates dropped between 40 percent (zinc) and 99 percent (arsenic and nickel). From the limited data available for the chlorinated organic compounds, similar loading reductions have been realized (80 percent for chlorinated butadienes and 95 percent for chlorinated benzene). Available flow data indicate that the main outfall accounts for greater than 95 percent of the measured inputs to the problem area.

The seven steel pipes that constitute HY-085 were found to discharge less than 0.003 lb/day of the six inorganic and three organic variables measured at various times between 1980 and 1984 (one or two sampling events for each variable measured). The two groundwater seeps present in the vicinity of Occidental Chemical (HY-083) also revealed detectable levels of four inorganic compounds and chlorinated ethenes during sampling in 1984. Loading rates ranged from less than 0.0002 lb/day for the chlorinated ethenes to 0.012 lb/day for zinc.

6.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated. This evaluation was based on contaminant concentrations in the sediments, and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to maintain acceptable sediment quality over the long term.

6.3.1 Feasibility of Source Control

In this section, known sources of contamination are summarized, available control technologies are identified, and contaminant reductions technically achievable through the use of all known, available, and reasonable technologies are estimated. The identified source of several problem chemicals in the mouth of Hylebos Waterway (e.g., chlorinated ethenes, chlorinated butadienes, chlorinated benzenes, and metals) is the Occidental Chemical site.

The Occidental Chemical facility has been associated with elevated concentrations of problem chemicals in adjacent sediments. Process effluents, runoff, and groundwater seepage are suspected as three of the primary ongoing or historical sources of contaminants to the waterway.

Some remedial actions and best management practices have already been implemented at the facility: soil highly contaminated with chlorinated organic compounds has been excavated and disposed of offsite, soil in areas with lower concentrations of chlorinated organic compounds has been paved to minimize infiltration and leaching, and process modifications have substantially reduced contaminant discharges via the main plant effluent. Groundwater beneath the facility remains as the major potential contaminant source to the waterway. Additional groundwater quality and hydrogeological data being collected under the RCRA Continuing Releases Program will aid in defining the preferred technologies for the collection and treatment of contaminated groundwater.

Available technologies for mitigating groundwater contamination include various means of collecting and treating contaminants, gradient controls to contain or divert groundwater flow, and in situ biological treatment methods. As indicated previously, Occidental Chemical has proposed a pump and treat program that may include steam stripping as the method of choice for removal of chlorinated organic contaminants.

Available technologies for controlling surface water runoff include removal of contaminant sources within the drainage basin, methods for retaining runoff onsite (e.g., berms, channels, grading sumps), and revegetation or paving to reduce erosion of waste materials (see Section 3.2.2). Identification of control technologies for further reducing effluent concentrations of problem chemicals through operation or in-plant modification are beyond the scope of this document.

Based on the nature of the contaminants, the source pathways that have been identified, and available control technologies, it is estimated that implementation of all known, available, and reasonable (i.e., feasible) technologies will reduce source inputs of chlorinated hydrocarbon contaminants by approximately 95 percent. The sources and pathways of PCB contamination to the waterway are less clearly defined. Although Ecology has determined that sediments adjacent to the groundwater seeps were contaminated with PCBs (Stinson et al. 1987), they have not been detected in groundwater beneath the facility (Stoner, M., 28 April 1988, personal communication). They have been detected, however, at concentrations less than 2 ug/L in a well on adjacent Port of Tacoma property. For the purposes of evaluating the effects of source controls, it is estimated that implementation of all known, available, and reasonable technologies will reduce source inputs of PCBs by approximately 60 percent. This estimate is based on the lack of available information regarding specific PCB contaminant sources and pathways of migration.

Conclusion--

For the mouth of Hylebos Waterway problem area, the estimated maximum feasible level of source control for the two indicator chemicals is assumed to be 95 percent for hexachlorobenzene and 60 percent for PCBs. These estimates reflect both the assumed effectiveness of planned remedial measures (including best management practices) for the control of chlorinated hydrocarbons as well as uncertainty regarding PCB sources and migration pathways to the waterway. More precise source control estimates require improved definition of the sources of PCBs, which is beyond the scope of this document.

6.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals PCBs and hexachlorobenzene. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment at the mouth of Hylebos Waterway can be reasonably well characterized by a sedimentation rate of 2,500 $mg/cm^2/yr$ (1.77 cm/yr) and a mixing depth of 10 cm. Two indicator chemicals (hexachlorobenzene and PCBs) were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Losses due to biodegradation and diffusion were determined to be negligible for these chemicals. Two timeframes for sediment recovery were considered: a reasonable timeframe (defined as 10 yr) and the long term. Source loadings of both indicator chemicals at the mouth of Hylebos Waterway were assumed to be in steady-state with sediment accumulation. Results of the sediment recovery evaluation are summarized in Table 6-2.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted to be 11 yr for PCBs and 24 yr for hexachlorobenzene. These predictions are based on the highest concentrations of the indicator chemicals measured in the problem area. Therefore, sediment recovery in the 10-yr timeframe is not

TABLE 6-2. MOUTH OF HYLEBOS WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals	
	PCBs	Hexachlorobenzene
Station with Highest Concentration		
Station identification	HY-42	HY-96
Concentration (ug/kg dry weight)	1,100	1,000
Enrichment ratio[a]	7.3	45.4
Recovery time if sources are eliminated (yr)	11	24
Percent source control required to achieve 10-yr recovery	NP[b]	NP[b]
Percent source control required to achieve long-term recovery	86	98
Average of Three Highest Stations		
Concentration (ug/kg dry weight)	1,050	590
Enrichment ratio[a]	7.0	26.8
Percent source control required to achieve long-term recovery	86	96
10-Yr Recovery		
Percent source control assumed feasible	60	95
Highest concentration recovering in 10 yr (ug/kg dry weight)	300	101
Highest enrichment ratio of sediment recovering in 10 yr	2.0	4.6

[a] Enrichment ratio is the ratio of observed concentration to cleanup goal.

[b] NP = Not possible.

predicted to be possible. Minimal reductions in sediment concentrations are predicted unless sources are controlled.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source controls is expected to reduce source inputs by 60 percent for PCBs and and by 95 percent for hexachlorobenzene. With this level of source control as an input value, the model predicts that sediments with an enrichment ratio of 2.0 for PCBs (i.e., PCB concentrations of 300 ug/kg dry weight) and 4.6 for hexachlorobenzene (i.e., hexachlorobenzene concentrations of 101 ug/kg dry weight) will recover to the long-term cleanup goal within 10 yr (Table 6-2). The surface area of sediments not recovering to the long-term cleanup goal within 10 yr is shown in Figure 6-5. For comparison, sediments currently exceeding cleanup goals for indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

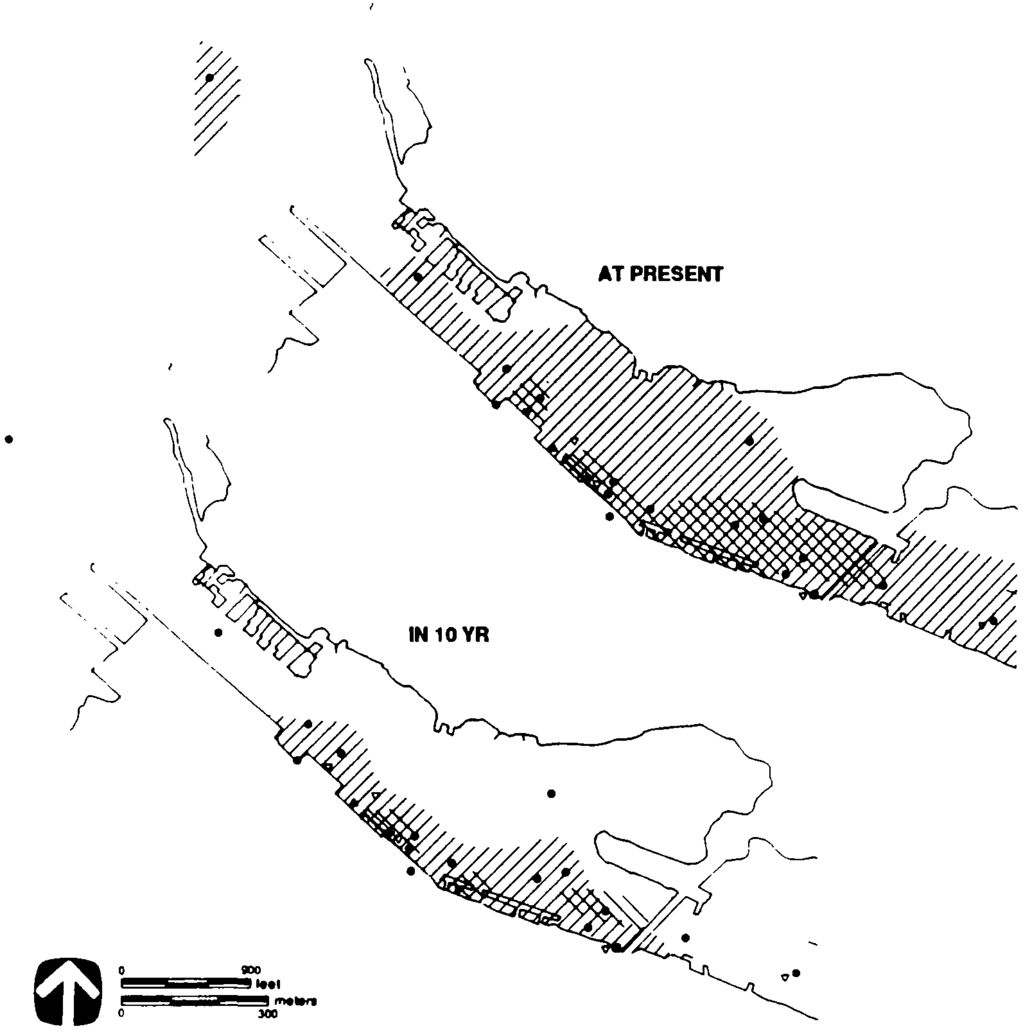
The model predicts that 86 percent of the PCBs and 96 percent of the hexachlorobenzene inputs must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (Table 6-2). These estimates are based on the average of the three highest enrichment ratios measured for the indicator chemicals in the problem area.

These values are presented for comparative purposes; the actual percent reduction required in source loading is subject to the uncertainty inherent in the assumptions required to apply the predictive model. These ranges may represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

6.3.3 Source Control Summary

The major identified source of hexachlorobenzene to the mouth of Hylebos Waterway is the Occidental Chemical Corporation. The source of PCBs to the mouth of Hylebos Waterway is currently undefined and is potentially historic. If the sources of PCBs and hexachlorobenzene are completely eliminated, then it is predicted that sediment concentrations in the surface mixed layer of the indicator chemical PCBs will decline to the long-term cleanup goal of 150 ug/kg in approximately 11 yr, while those of hexachlorobenzene (with a long-term cleanup goal of 22 ug/kg) will require 24 yr. Sediment remedial action will therefore be required to mitigate the observed and potential adverse biological effects associated with sediment contamination within a reasonable timeframe.

Substantial levels of source control will also be required to maintain acceptable sediment concentrations of hexachlorobenzene and PCBs even with sediment cleanup. The estimated percent reduction required for long-term maintenance is 86 percent for PCBs and 96 percent for hexachlorobenzene, based on the average of the three highest observed sediment concentrations for both indicator chemicals.



Mouth of Hylebos Waterway Indicator Chemicals

AT PRESENT	
DEPTH (yd)	2
AREA (yd^2)	393,000
VOLUME (yd^3)	786,000
IN 10 YR	
DEPTH (yd)	2
AREA (yd^2)	115,000
VOLUME (yd^3)	230,000

- ▲ FEASIBILITY STUDY SEDIMENT PROFILE SURVEYS (1986)
- ● SEDIMENT SURVEYS CONDUCTED IN 1984
- ▼ SEDIMENT SURVEYS CONDUCTED BEFORE 1984 (1979-1981)
- PCBs (AET = 150 µg/kg)
- HEXACHLOROBENZENE (AET = 22 µg/kg)

Figure 6-5. Sediments at the mouth of Hylebos Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

With 95 percent source control assumed to be feasible (i.e., known, available, and reasonable) for hexachlorobenzene, it should be possible to maintain acceptable sediment quality for chlorinated hydrocarbon inputs following sediment remediation. Whether or not maintaining sediment quality is possible will be a function of the accuracy of the estimated percent reduction of hexachlorobenzene required for long-term maintenance. Furthermore, any groundwater infiltration to the sediments that may be occurring must be effectively controlled through the groundwater pumping and treatment program. Because the sources of PCB in the problem area are undefined, only 60 percent source control was assumed feasible. Data from the RI (Tetra Tech 1985a) and this study suggest a historical source, because surface minima were present in the core samples. The estimated percent reduction required to maintain acceptable sediment quality for PCBs has been estimated to be approximately 86 percent, well above the 60 percent feasible level used to evaluate sediment recovery with the model. If implementation of all known, available, and reasonable control technologies fails to achieve the necessary level of source control required to maintain sediment quality, then re-evaluation of the area requiring remediation based on PCB contamination may be required. However, if further testing determines that the sources of PCBs to this problem area are historic, then maintenance of the cleanup goal (150 ug/kg) in sediments would be feasible.

6.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with PCB or hexachlorobenzene concentrations exceeding long-term cleanup goals is approximately 786,000 yd^3 (see Figure 6-5). This volume was estimated by multiplying the areal extent of sediment exceeding the long-term cleanup goal (393,000 yd^2) by the estimated 2-yd depth of contamination (see contaminant sediment profiles in Figures 6-2 and 6-3). The estimated thickness of contamination is only an approximation because few sediment profiles were collected and the vertical resolution of these profiles was poor at the depth of the contaminated horizon. For the volume calculations, depths were slightly overestimated. This conservative approach was taken to reflect the fact that depth to the contaminated horizon cannot be accurately dredged, to account for dredge technique tolerances, and to account for uncertainties in sediment quality at locations between the sediment profile sampling stations. This approach also accounts for the possibility that the depth of the contaminated horizon may vary significantly throughout the problem area, either as a result of past disposal practices or groundwater inputs to the sediments.

The total estimated volume of sediments with PCB or hexachlorobenzene concentrations that are expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 230,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratio greater than 2.0 for PCBs and 4.6 for hexachlorobenzene (see Table 6-2), an area of 115,000 yd^2, by the estimated 2-yd depth of contamination. These volumes are also approximations, accounting for uncertainties in sediment profile resolution and dredging tolerances. The quantity of sediment used in evaluating the remedial alternatives (i.e., to identify the preferred alternative) was 230,000 yd^3.

This volume of sediment will require remediation at the mouth of Hylebos Waterway.

6.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

6.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, this set of alternatives is evaluated to determine the suitability of each alternative for the remediation of contaminated sediments in the mouth of Hylebos Waterway. Remedial measures address contaminated sediments that are predicted to exceed cleanup goals 10 yr after implementing feasible source controls and allowing natural recovery processes to occur. Remedial efforts in this problem area are complicated by the uncertainties regarding the extent of contamination with depth for the chlorinated organic compounds. In the event that the depth of contamination is determined to be excessive (e.g., greater than 2 times current estimates), criteria regarding disposal site availability and appropriate dredging technologies may warrant re-evaluation. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost, using available data.

The first step in this process is to assess the applicability of each alternative to remediation of contaminated sediments in the mouth of Hylebos Waterway. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental settings; and site physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

To aid in evaluating contamination in the mouth of Hylebos Waterway, the organic indicator chemicals PCB and hexachlorobenzene were selected to represent sediment contamination in this problem area. Occidental Chemical has been identified as the primary source of hexachlorobenzene contamination to the waterway (see Table 6-1). The source of PCB contamination is currently undefined and may be historic. Areal distributions for both indicators are presented in Figure 6-5 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery.

The extensive PCB and hexachlorobenzene contamination in the mouth of Hylebos Waterway suggests that a treatment process for organics is an appropriate component of remedial action. Data from the RI studies (Tetra Tech 1985a) indicated a trend of decreasing inorganic contamination levels from the head to the mouth of the waterway. Concentrations of copper and zinc decreased by approximately 75 percent from the head to the mouth of the waterway, with a similar though less dramatic pattern for lead. The presence of relatively low concentrations of inorganic contaminants in the mouth of Hylebos Waterway is not expected to limit the effectiveness of the organic treatment processes. The solvent extraction process is expected to be highly effective in removing the PCBs and chlorinated hydrocarbons predominant in the problem area. Incineration of the organic contaminants should also be effective.

The land treatment alternative has been eliminated from consideration based on the low particle affinities exhibited by the contaminants and the enhanced potential for leaching and migration from the treatment facility. Similarly, the solidification process is unlikely to be effective in encapsulating the relatively mobile, leachable chlorinated hydrocarbons, and is therefore not evaluated.

The need for periodic dredging to maintain channel depth precludes the use of in situ capping within the channel boundaries. The potential for subsequent deepening of the channel to facilitate deeper draft vessels in the future could also compromise the integrity of a cap in the adjacent shoreline areas. Therefore, the in situ capping alternative is dropped from further consideration.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from exposure to contaminated sediments without implementing sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives are applicable to remediation of contaminated sediments in the mouth of Hylebos Waterway.

The following seven sediment remedial alternatives are evaluated in this section for the cleanup of the mouth of Hylebos Waterway:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solvent extraction/upland disposal
- Clamshell dredging/incineration/upland disposal

6.5.2 Evaluation of Candidate Alternatives

The three primary categories of evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 6-3. A comparative evaluation of alternatives is presented in Table 6-4 based on ratings of high, moderate, and low in seven subcategories of evaluation criteria. As discussed in Chapter 4, for effectiveness these

TABLE 6-3. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE MOUTH OF HYLEBOS WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during dredging and disposal. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Much longer implementation period. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Incineration of CDM is accomplished over an extended period of time requiring temporary storage thereby increasing exposure risks. Workers wear protective gear.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Impacts associated with disposal of the moderately soluble chlorinated compounds are minimized by use of the clamshell dredge.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations.	Existing contaminated habitat is destroyed but recovers rapidly. Sediment is resuspended during dredging operations. Process controls are required to reduce potential air emissions.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked seventh overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. Sediment recovery is improbable within 10 years. This alternative is ranked sixth overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Disposal siting and facility construction may delay project completion. This alternative is ranked second overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment and methods are available. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Bench and pilot scale testing are required. Full scale equipment is available. Remediation could be accomplished within 2 to 3 years. This alternative is ranked fourth overall for timeliness.	Substantial CDM testing and incinerator installation time are required before a thermal treatment scheme can be implemented. Remediation could be accomplished within 2 to 3 years. This alternative is ranked fifth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in a quiescent, subaquatic environment is considered good.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Migration of chlorinated hydrocarbons could significantly impact groundwater resources.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Permanent treatment for organic contaminants is effected	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area. Nearshore site is dynamic in nature.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Residual contamination is reduced below harmful levels.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobilty are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant moblity is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Effectively destroys or isolates the predominant organic contaminants. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Toxicity and mobility considerations are eliminated. Volume of contaminated material is substantially reduced.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Incineration is expected to destroy the organic contaminants. Treated CDM containing residual metals may have leaching potential. Volume of contaminated material is substantially reduced.

TABLE 6-3. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, although feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Although still in the developmental stages, sludges, soils, and sediments have successfully been treated using this technology.	Incineration systems capable of handling CDM have been developed, but no applications involving CDM have been reported. Effects of salt and moisture content must be evaluated.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Monitoring implementability is enhanced compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring is required only to evaluate the reestablishment of benthic communities. Monitoring programs can be readily implemented.	Disposal site monitoring is not required if treated CDM is determined to be nonhazardous. Air quality monitoring is intensive during implementation.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.
	INSTITUTIONAL FEASIBILITY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals depend largely on results of pilot testing and the nature of treatment residuals.	Approvals for incinerator operation depend on pilot testing and ability to meet air quality standards.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant mobility. Requires RCRA permit for disposal of concentrated organic waste.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant toxicity and mobility. Requires compliance with PSAPCA standards.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Process equipment available. Disposal site availability is not a primary concern because of reduction in hazardous nature of material.	Incineration equipment can be installed onsite for CDM remediation efforts. Applicable incinerators exist. Disposal site availability is not a concern because of reduction in hazardous nature of material.

TABLE 6-4. EVALUATION SUMMARY FOR MOUTH OF HYLEBOS WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Extraction/ Upland Disposal	Clamshell/ Incinerate/ Upland Disposal
Short-Term Protectiveness	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate
Timeliness	Low	Low	Moderate	High	Moderate	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High	High
Technical Feasibility	High	High	Moderate	High	High	Moderate	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	High	Moderate	Moderate	Moderate
Long-Term Cleanup Goal Cost[a]							
Capital	--	6	6,457	19,524	34,688	166,372	377,885
O&M	--	1,986	738	898	1,410	1,334	1,334
Total	--	1,992	7,195	20,422	36,098	167,706	379,219
Long-Term Cleanup Goal with 10-yr Recovery Cost[a]							
Capital	--	6	1,773	5,597	10,013	48,568	110,461
O&M	--	1,223	289	336	475	453	453
Total	--	1,229	2,062	5,933	10,488	49,021	110,914

[a] All costs are in $1,000.

subcategories are short-term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. For implementability the subcategories are technical feasibility, institutional feasibility, and availability. Capital and O&M costs are also presented in Table 6-4. Remedial costs are shown for two sediment cleanup scenarios. The long-term cleanup goal and cost presented refers to the costs associated with remediation of all sediments currently exceeding the long-term cleanup goal. The long-term cleanup goal 10-yr recovery cost shown refers to the costs associated with remediation of sediments that would be expected to exceed the cleanup goal 10 yr after implementing source controls and allowing natural recovery to occur.

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts would continue with the contaminated sediments remaining in place. Source control measures initiated as part of the institutional controls would tend to reduce sediment contamination with time, but adverse impacts would persist in the interim.

All other alternatives received a moderate rating. The clamshell dredging/nearshore disposal alternative is rated moderate for short-term protectiveness primarily because nearshore intertidal habitat would be lost in siting the disposal facility. While the loss of habitat due to nearshore site development in Commencement Bay may be mitigated by requiring habitat enhancement in a nearby area, the availability of sites with potential for habitat enhancement is limited. The confinement of contaminated dredged material to a barge offshore during dredging and disposal, and the availability of means for adequately protecting workers during implementation assures a low level of human health hazards. The confined aquatic disposal option is also rated moderate for this criterion because of potential water quality impacts associated with disposal of the moderately soluble chlorinated hydrocarbons compounds present. Use of the clamshell dredge to maintain in situ densities followed by deposition of a cohesive mass of sediment with the split-hulled barge should aid in minimizing this potential. The hydraulic dredge/upland disposal alternative is also rated as moderate in this subcategory because of the potential for solubilizing the chlorinated hydrocarbons in the dredge slurry. Alternatives involving treatment received moderate ratings for short-term protectiveness because all involve additional dredged material handling, longer implementation periods, and increased air emissions, which potentially increase worker and public exposure.

Timeliness--

The no-action and institutional controls alternatives received low ratings for timeliness. With no action, sediments would remain unacceptably contaminated, source inputs would continue, and natural sediment recovery would be unlikely. Source inputs would be controlled under the institutional controls alternative but, as discussed in Section 6.3.2, sediment recovery based on the indicator contaminants PCBs and hexachlorobenzene is improbable within 10 yr.

Moderate ratings were assigned to all other alternatives except clamshell dredging/nearshore disposal. Approvals and construction of upland or open water confined aquatic disposal sites are estimated to require a minimum of 1-2 yr. Equipment and methods used require no development period, and pre-implementation testing is not expected to be extensive. These factors indicate that the upland and confined aquatic disposal alternatives can be accomplished in a shorter period of time than if treatment is involved. The solvent extraction and incineration alternatives are likely to require a period of extensive testing before being accepted for implementation. Once approval is obtained, treatment of the contaminated sediments in the mouth of Hylebos Waterway to long-term goals will require a period of approximately 2-3 yr, assuming maximum treatment rates of 420 yd^3/day (see Section 3.1.5).

The clamshell dredging/nearshore disposal alternative is rated high for timeliness. Pre-implementation testing and modeling may be necessary to evaluate potential partitioning to the water column of the contaminants associated with these sediments. However, such testing is not expected to require an extensive period of time. Equipment and methods are readily available, and disposal siting issues are not likely to delay implementation.

Long-Term Protectiveness--

The evaluation for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for sediment recovery is extensive. For the latter alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source controls. The observed adverse biological impacts would continue.

Moderate ratings were assigned to the clamshell dredging/nearshore and hydraulic dredging/upland disposal alternatives because of the relatively high potential for migration of the chlorinated hydrocarbon compounds. In addition, the impacts of the chlorinated organics on groundwater resources in the upland environment would be significant if the contaminants migrated from the confinement facility. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature (i.e., from wave action and tidal influences). Release of the soluble organic contaminants from the disposal site could result in significant environmental damage, given the proximity of a fish habitat mitigation area (located in the outer slip of Blair Waterway) to the potential disposal area.

Both alternatives involving treatment received high ratings primarily because the treatment processes would result in the effective removal or destruction of organic contaminants. For both alternatives, the treated solids could be confined in a minimum standards municipal landfill, assuming that the material is determined to be nonhazardous. The small volume of concentrated hazardous residue resulting from the solvent extraction process would be incinerated and the material collected from particulate collection systems during incineration would require disposal in an RCRA-approved facility. The confined aquatic disposal alternative is also rated high for long-term protectiveness. Isolation of contaminated material in the quiescent, subaquatic environment would provide a high degree of protection, with little potential for exposure of sensitive environments to contaminated sediments. Confinement under nearly in situ conditions would maintain the physicochemical conditions of contaminated sediments, thereby minimizing potential contaminant migration.

Reduction in Toxicity, Mobility, or Volume--

Low ratings were assigned to all alternatives under this criterion, except those involving treatment. Although confined aquatic disposal, upland, and nearshore disposal alternatives isolate contaminated sediments from the surrounding environment, the chemistry and toxicity of the material itself would remain largely unaltered. Without treatment, the toxicity of contaminated sediments would remain at preremediation levels. Contaminated sediment volumes would not be reduced, and may actually increase with the hydraulic dredging option because the material would be suspended in an aqueous slurry.

Alternatives involving the solvent extraction and incineration treatment processes would effectively destroy or isolate the predominant organic contaminants, and therefore received high ratings. The solvent extraction process would change the chemical status of the metals by providing the alkaline conditions necessary for insoluble hydroxide formation. Incineration is expected to destroy the organic contaminants.

Technical Feasibility--

The two alternatives involving treatment received moderate ratings for technical feasibility because the treatment processes have never been applied to sediment remediation. All processes are believed to be suitable for application to the organic contaminants, but lack of experience and demonstrated performance in the use of these processes for treatment of contaminated dredged material warrants caution. Extensive bench-scale testing is likely to be required before treatment via solvent extraction or incineration could be implemented. The difficulty inherent in placing dredge and capping materials at depths of 100 ft or greater requires that a moderate rating be assigned to the confined aquatic disposal alternative, as well.

High ratings are warranted for the remaining alternatives because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective in the past for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives were assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings were assigned to the remaining alternatives because of potential difficulty in obtaining agency approvals for siting and development of disposal sites or for implementation of treatment technologies. Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of effectiveness.

Availability--

Sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities received high ratings for availability. The no-action and institutional controls alternatives can be implemented using available equipment and expertise, and received a high rating for this criterion. It was assumed that the Blair Waterway Slip 1 would be available as a nearshore disposal site, making the clamshell dredge/nearshore disposal alternative readily implementable.

Remedial alternatives that involve confined aquatic disposal or upland disposal of untreated sediments are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that confined aquatic and upland sites would be available. However, no sites for contaminated sediments are currently approved for use and no sites are currently under construction. For costing purposes, development of a RCRA-equivalent upland site within the project boundaries was assumed. Depending on the final characterization of sediments, upland disposal in an existing municipal or demolition landfill may also be feasible. A moderate rating has also been assigned to the two dredging/treatment/upland disposal alternatives, in part because of the same uncertainties regarding disposal site availability and because of uncertainties regarding equipment availability. However, testing conducted as a part of the bench-scale treatability and performance evaluation for the treatment processes should confirm that the products are nonhazardous and suitable for a standard solid waste management facility. For costing purposes, it was assumed that all but the small volume of extraction residue and incineration fly ash would be disposed of in a standard solid waste management facility in the project area.

Cost--

Capital costs increase with increasing complexity (i.e., from no action to the treatment options). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for clamshell dredging/nearshore disposal, primarily because of underdrain and bottom liner installation, dredge water clarification, and use of two pipeline boosters to facilitate dredged material transport to the upland site. The cost of conducting the extraction and incineration treatment alternatives increases as a result of material costs for the process, siting and construction of treatment facilities, and labor costs for material handling and transport. Dewatering and dredge water management costs are also incurred for the incineration option.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls) or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Estimated costs for monitoring of the confined aquatic disposal facility are also significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single groundwater sample from each well to assess containment migration.

It was also assumed that the monitoring program will include analyses for all problem chemicals (i.e., those exceeding long-term cleanup goals) identified in the mouth of the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the treatment alternatives are significantly lower because the processes result in lower contaminant migration potential. All unit costs and assumptions are presented in Appendix D.

6.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the seven candidate sediment remedial alternatives for the mouth of Hylebos Waterway, clamshell dredging with confined aquatic disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, confined aquatic disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. The confined aquatic disposal alternative is currently preferred for the following reasons:

- The alternative protects human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment

- Confined aquatic disposal is technically feasible and has been demonstrated to be effective in isolating contaminated sediments

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental requirements

- Performance monitoring can be accomplished effectively and implemented readily

- The volume of contaminated sediment requiring remediation (approximately 230,000 yd^3) is compatible with the available capacity of the tentatively identified confined aquatic disposal facilities within the Commencement Bay area

- The potential mobility of the relatively soluble organic contaminants can be minimized with mechanical dredging and split-hulled barge disposal techniques and capping in the subaquatic environment

- Potentially mobile chlorinated hydrocarbons, if placed in the nearshore environment, could be subject to leaching, which in turn could affect the sensitive fish habitat mitigation area adjacent to the proposed nearshore fill area in Blair Waterway

- The costs of developing an upland facility that is protective of groundwater resources are not warranted considering the levels of contamination and high bulk of sediments in the mouth of Hylebos Waterway

- Costs are $3.9 million less than those of the nearshore disposal alternative and over $8 million less than the hydraulic dredge/upland disposal alternative.

Clamshell dredging with confined aquatic disposal is rated high for long-term protectiveness and moderate for all other criteria, except reduction in toxicity, mobility, or volume, for which it is rated low. Implementation can be coordinated with similar sediment remediation activities in City Waterway, Wheeler-Osgood Waterway, and the Ruston-Pt. Defiance Shoreline. This alternative can be implemented within approximately 1-2 yr with available equipment that has proven effective in past similar operations. Implementation of the confined aquatic disposal alternative is contingent upon the siting and development of an open-water disposal site. This alternative is also cost-effective (see Table 6-4).

Leachate tests conducted on PCB-contaminated sediments in Indiana Harbor (U.S. Army Corps of Engineers 1987) revealed that contaminant release from compression settling was considerably lower than that from elutriate testing. Those findings suggest that mechanical dredging and bulk placement of contaminated sediments into the confinement facility would minimize release at the disposal site. The investigators also cited the need to modify the clamshell dredge by enclosing the clamshell bucket to minimize sediment resuspension.

Performance monitoring associated with the development of the confined aquatic disposal facility would be expected to provide sufficient warning of contaminant migration. Corrective actions (e.g., cap and berm repairs) could be implemented before adverse effects occur.

Although some sediment resuspension is inherent in dredging operations, silt curtains, clamshell bucket modifications, and other available engineering controls would be expected to minimize adverse impacts associated with redistribution. The impacts of dredging on water quality criteria can be predicted by using data from bench-scale tests to estimate chlorinated hydrocarbon contaminant partitioning to the water column. Some interstitial water loss during lift through the water column and in potential dewatering during transport would be expected. However, compared to hydraulic dredging, reduced disturbance and the absence of a slurry should result in less opportunity for contaminants to go into solution (Phillips et al. 1985). (PCB contaminants are expected to exhibit a higher particle affinity.) Production rates of clamshell dredges vary significantly depending on the nature of sediments and size of the bucket. However, based on the estimated 230,000 yd^3 of sediment requiring remediation, this alternative can be implemented in a reasonable timeframe. Seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

The nearshore disposal alternative was not selected because the volume of material is more compatible with confined aquatic disposal. The Blair Waterway Slip 1 nearshore fill area is not large enough to accommodate all contaminated sediments in the Commencement Bay Nearshore/Tideflats (N/T) area, nor is it appropriate for the contaminants in all sediments. Although confined aquatic disposal cannot be implemented as quickly as nearshore disposal at an available site, it offers a similar degree of protection at a lower cost.

The two alternatives for treatment of organic contaminants in the mouth of Hylebos Waterway are also feasible. Implementation of the solvent extraction alternative would require bench-scale and possibly pilot-scale testing of contaminated sediments. Implementation of the thermal treatment alternative would require test burns to establish destruction efficiency. In addition, potential air quality impacts would need to be addressed. The low Btu value of the sediments should necessitate use of an energy-intensive process. This factor is largely responsible for the extremely high cost associated with implementing the thermal treatment alternative (greater than $110 million).

Although the treatment options would result in destruction of organics, confined aquatic disposal of sediments should offer sufficient long-term protection, given the concentrations in the problem area. The cost associated with the two treatment options evaluated are approximately 24 (solvent extraction) and 54 (incineration) times as great as that of the confined aquatic disposal alternative. The additional expense associated with the performance achieved by implementing the treatment options does not appear warranted.

The hydraulic dredging/upland disposal option was not chosen as the preferred alternative because of uncertain disposal site availability and the policy bias against landfilling untreated contaminated materials. Although this alternative is feasible from both a technical and institutional standpoint, the risks of system failures for a disposal site in the upland environment (e.g., groundwater risks) compromise the desirability of this alternative.

The no-action and institutional controls alternatives were not selected since their implementation would not meet long-term cleanup goals.

6.7 CONCLUSIONS

The mouth of Hylebos Waterway was identified as a problem area because of the elevated concentrations of organic and inorganic contaminants in sediments. PCBs and hexachlorobenzene were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 393,000 yd^2, with a volume of 786,000 yd^3. Some of this sediment is expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 556,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 230,000 yd^3.

The primary identified source of problem chemicals to the mouth of Hylebos Waterway is the Occidental Chemical Corporation facility. Source control measures required to correct the identified problems at the facility and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Reduce the amount of chlorinated hydrocarbons that are present in the groundwater and that discharge to the waterway

- Continue monitoring the outfall at the Occidental Chemical main plant, and implement additional control technologies, if necessary

- Conduct additional source investigations to identify any ongoing sources of PCB contaminants in the area, and initiate additional source control measures as necessary

- Confirm that all significant sources of problem chemicals have been identified and controlled

- Implement regular sediment monitoring to confirm sediment recovery predictions, and address the adequacy of source control measures.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. However, the level of source control required for PCBs was estimated to be approximately 86 percent compared to the technically feasible level of approximately 60 percent. The estimated source control required for hexachlorobenzene was similar to levels considered to be technically achievable. Additional evaluations to refine these estimates will be required as part of the source control measures described above. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals PCBs and hexachlorobenzene. The assumptions used in determining source control requirements were environmentally protective. It is anticipated that more detailed loading data will demonstrate that sources can be controlled to the extent necessary to maintain acceptable sediment quality. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be reevaluated.

Clamshell dredging/confined aquatic disposal was recommended as the preferred alternative for remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment. Confined aquatic disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 6-4, clamshell dredging/confined aquatic disposal provides a cost-effective means of sediment mitigation. The estimated cost to implement this alternative for sediment that exceeds long-term goals following 10 yr of recovery is $1,773,000. The present worth of 30 yr of environmental monitoring and other O&M at the disposal site is estimated to be $289,000. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total estimated present worth of preferred alternative is $2,062,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures

- Final selection of a disposal site.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions practicable, and are cost-effective.

7.0 SITCUM WATERWAY

Potential remedial actions are defined and evaluated in this section for the Sitcum Waterway problem area. The waterway is described in Section 7.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 7.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contaminant concentrations are discussed in Section 7.3. Area and volume of sediments requiring remediation are discussed in Section 7.4. The detailed evaluation of candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 7.5. The preferred alternative is identified in Section 7.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 7.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

7.1 WATERWAY DESCRIPTION

Sitcum Waterway is a deep navigational waterway with a required maintenance depth of 35-40 ft below MLLW. An illustration of the waterway and the locations of storm drain outfalls and nearby industries is presented in Figure 7-1. It is not known when Sitcum Waterway was first created from the tideflats of the Puyallup River. Photographs dating back to 1923 show the waterway to be approximately twice its current width. A series of dredge and fill projects conducted since 1946 have shaped Sitcum Waterway into its present configuration (Tetra Tech 1986c). Material dredged from the waterway for maintenance was used to fill the north shore of the original channel, on which the Port of Tacoma Terminal 7 is presently located. The Port of Tacoma owns all of the property surrounding Sitcum Waterway, which is currently used for storage, shipping, and receiving facilities (Tetra Tech 1986c). Additional detail on land use activities is presented in Section 7.2.

7.1.1 Nature and Extent of Contamination

An examination of sediment contaminant data obtained during RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical surveys has revealed that the waterway contains elevated concentrations of both organic and inorganic chemicals. No Priority 1 contaminants were identified for the waterway. However, arsenic, copper, lead, and zinc were identified as Priority 2 contaminants. The following organic compounds exceeded their corresponding AET value at only one station sampled and are therefore considered Priority 3 contaminants: low molecular weight polynuclear

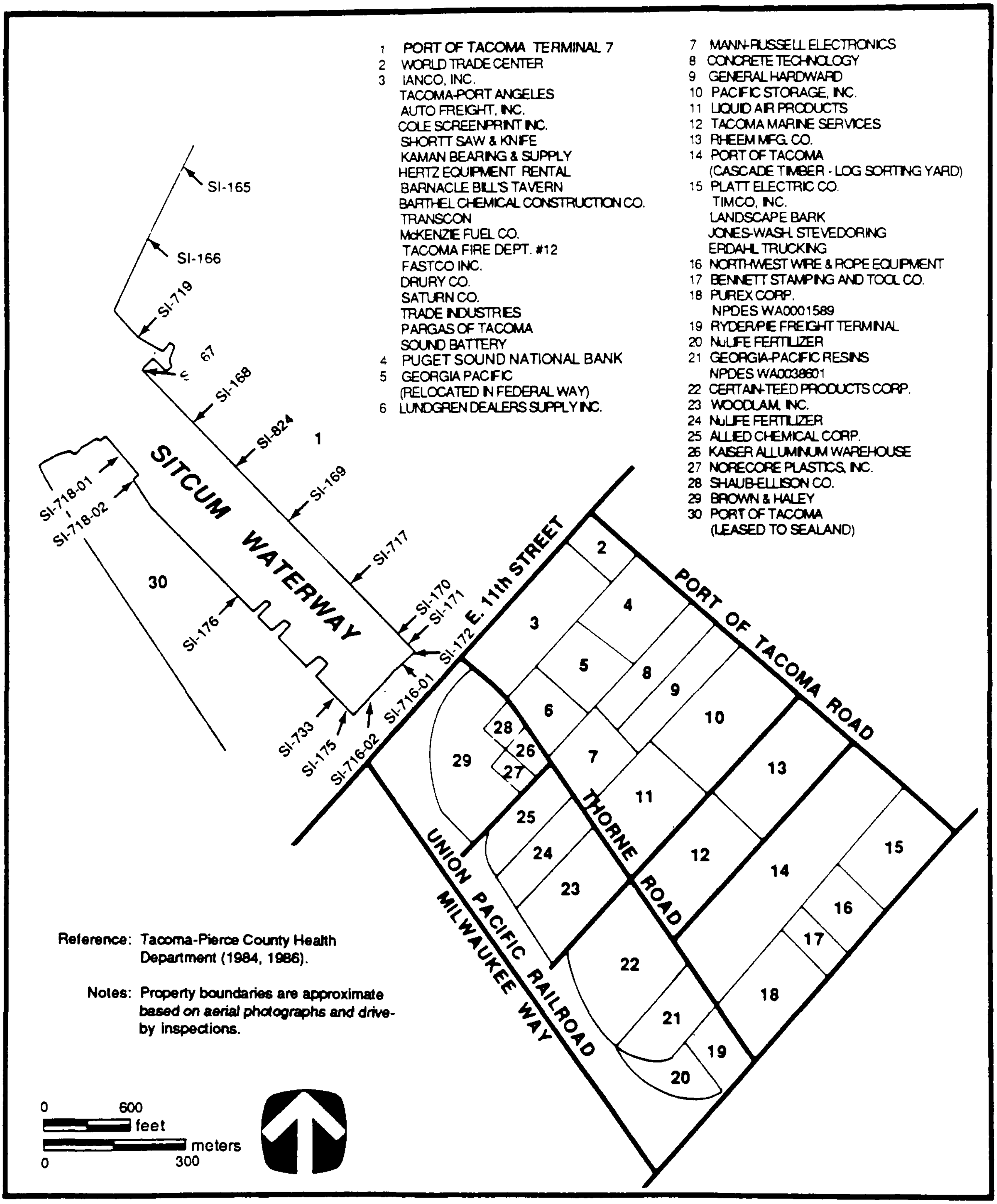


Figure 7-1. Sitcum Waterway - Existing industries, businesses, and discharges.

aromatic hydrocarbons (LPAH), high molecular weight polynuclear aromatic hydrocarbons (HPAH), an alkylated benzene isomer, a diterpenoid hydrocarbon, and N-nitrosodiphenylamine.

Concentrations of copper, zinc, lead, and arsenic were found to be elevated along the entire length of the waterway with especially high concentrations of the first three metals near the head (northeast corner, Tetra Tech 1985a) and along the northeast embankment. No clear trends in the spatial distribution of metal contaminants were observed and past dredging activity did not appear to account for the erratic distribution.

Copper and arsenic were selected as indicator chemicals for Sitcum Waterway. Surface sediment enrichment ratios (i.e., ratio of observed concentration to long-term cleanup goal) for these two contaminants were higher over a greater area than those for either of the other two metals. These contaminants were also selected as indicators on the basis that they represent contaminant loading to the waterway from ore spillage and storm drains (see Section 7.2.1).

Areal and depth distributions of copper and arsenic in Sitcum Waterway are presented in Figures 7-2 and 7-3, respectively. Levels of contamination indicated in the figures are normalized to cleanup goals (i.e., presented as enrichment ratios), which are 390 mg/kg for copper and 57 mg/kg for arsenic. Problem sediments are defined by values greater than 1.0. The cleanup goal for copper was set by the AET value derived for oyster larva bioassay, and the cleanup goal for arsenic was set by the AET value derived for benthic infaunal abundance depression. In addition, exceedances of amphipod and benthic AET for two Priority 3 organic compounds were noted at Station SI-12 (see Appendix F for location).

Included in Figures 7-2 and 7-3 are contaminant depth profiles obtained from two core samples. Subsurface maxima were observed for both copper and arsenic, indicating that inputs were historically greater than are observed currently. Data from core SI-91, which was obtained from the heavily contaminated northeast corner of the waterway, illustrate that contamination with depth is extensive. For the purpose of estimating the volume of sediment exceeding copper and arsenic cleanup goals, remediation to a depth of 1 yd was assumed (see SI-91 profile).

7.1.2 Recent and Planned Dredging Projects

The Port of Tacoma has requested a dredging permit for removal of approximately 2,000 yd^3 of material (U.S. Army Corps of Engineers, 27 October 1987, personal communication). The majority of this material lies along the southern side of the channel approximately midway up the waterway. These dredging plans were initially developed based on complaints from pilots. However, the complaints have ceased recently and the proposed shoal dredging plans have been put on hold (White, M., 15 April 1988, personal communication).

The Port of Tacoma has also formulated plans for conducting two pier extension projects in Sitcum Waterway. One of those projects is slated for

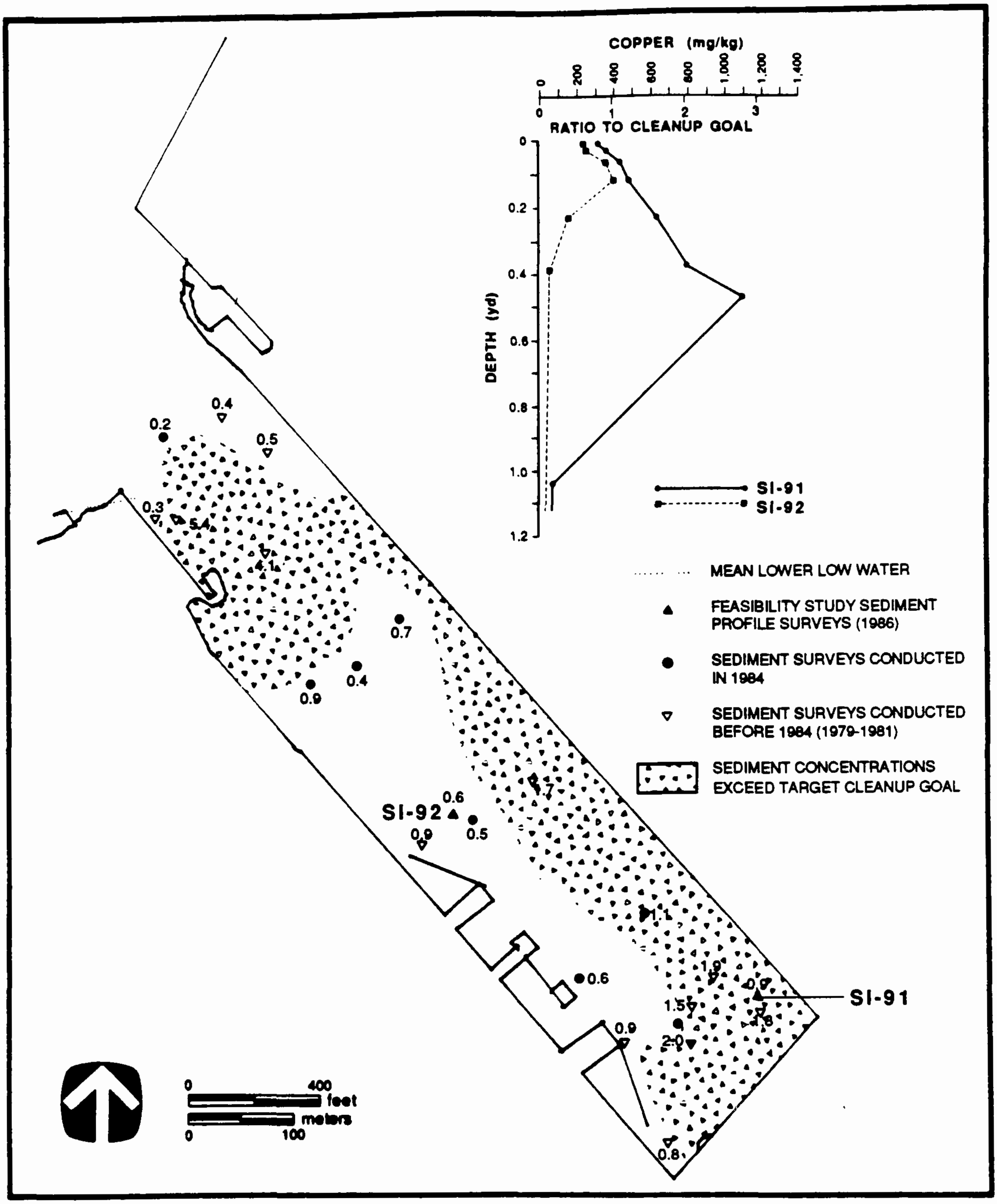


Figure 7-2. Areal and depth distributions of copper in sediments of Sitcum Waterway, normalized to long-term cleanup goal.

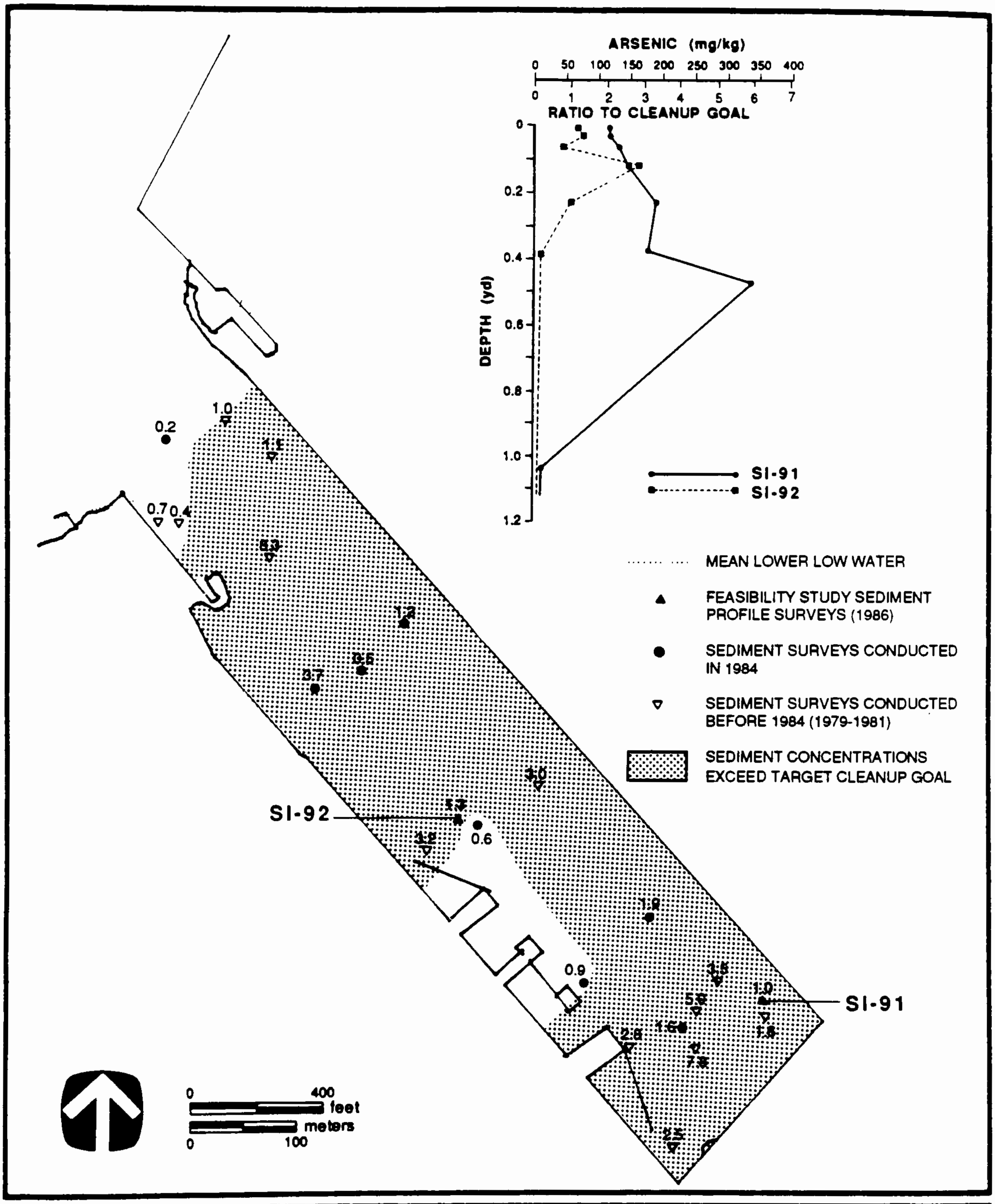


Figure 7-3. Areal and depth distributions of arsenic in sediments of Sitcum Waterway, normalized to long-term cleanup goal.

Pier 7d at the port's ore unloading facility on the north side of the waterway. The volume of material to be dredged is unclear at this time, but is estimated to be from 40,000 to 100,000 yd^3 (Sacha, L., 16 November 1988, personal communication). This project entails extending the existing pier at the mouth of the waterway (north shore) approximately 250 ft toward the bay, parallel to the existing shoreline (White, M., 15 April 1988, personal communication). This project is tentatively scheduled for 1989, and no permits had been applied for the work as of November 1988. Based on available information, the project does not appear to impact the sediment problem area defined for the waterway.

The second pier extension project involves a 400-ft pier extension along the south side near the mouth of the waterway. This project will require dredging of approximately 40,000 yd^3 of sediment. The project is scheduled for 1989 and all permit approvals except those from the U.S. Army Corps of Engineers have been received. The south side pier extension project also includes a habitat replacement component, in which the southwest corner at the head of the waterway will be filled with clean sediment to create new intertidal habitat. The surface area of this new habitat will be approximately 50 percent of that removed for the pier extension. Two storm drain outfalls discharging in the location of the proposed new habitat will be extended underneath the mitigation area. Both the pier and the habitat replacement components of the pier extension project will disturb sediments defined as contaminated in this report.

7.2 POTENTIAL SOURCES OF CONTAMINATION

All land surrounding Sitcum Waterway is owned by the Port of Tacoma. The south shore is leased to Sea-Land for storage, shipping, and receiving facilities. An office building at the head of the waterway has housed the Port of Tacoma executive offices since 1982. The Port of Tacoma's Terminal 7 occupies the north waterfront, with facilities for container handling and bulk unloading of alumina, lead, copper, and zinc. Ore unloading facilities are leased to Kaiser Aluminum (Carter, S., 22 September 1987, personal communication). Former occupants of the waterfront property include lumber and wood products industries, railroad yards, and oil storage facilities.

As shown in Figure 7-1, a large, high-density industrial/commercial area lies southeast of the waterway. Stormwater runoff from this area discharges to Sitcum Waterway via storm drain SI-172. Several other storm drains service the waterway [e.g., SI-717 (Terminal 7), SI-176 (Sea-Land)]. Emergency overflow from a sanitary sewer pump station also discharges via SI-176.

Table 7-1 provides a summary of problem chemical and source status information for the area. The high concentrations of metals at the head of the waterway have been attributed primarily to storm drains, particularly storm drain SI-172. The Port of Tacoma ore unloading facility has also been identified as a major contaminant source associated with the inorganic contaminants in the sediments of Sitcum Waterway. When input of metals as estimated from source loading data is compared to that as estimated from sediment concentrations, the values are within 1 order of magnitude,

TABLE 7-1. SITCUM WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
Copper Lead Zinc Arsenic	2 2 2 2	Port of Tacoma ore docks	Yes	No	Ongoing	Slight surface minima
		Storm drains	Yes	Yes SI-172 and SI-176 accounted for approximately 65% of copper, lead, and zinc and approximately 95% of arsenic	Ongoing	
LPAH HPAH Dibenzofuran	3 (EPA Sta. 3) 3 (EPA Sta. 3) 3 (SI-14)	Past oil spills	Potential	No	Historical	Variable
		Fire at Tacoma Boat (1970s)	Potential	No	Historical	
N-nitrosodiphenylamine	3 (SI-12)	Unknown	No	Inadequate data	Historical	Surface minimum
Diterpenoid hydrocarbon	3 (SI-12)	Unknown	No	No	Historical	c
Alkylated benzene isomer	3 (SI-11)	Storm drains	Potential	No	Unknown	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

indicating that no important data gaps exist in accounting for the major sources of metals to the waterway (Tetra Tech 1985b). The elevated concentrations of LPAH, HPAH, and dibenzofuran that were observed have tentatively been attributed to historical sources (i.e., past oil spills and a fire at Tacoma Boat in the 1970s) (Tetra Tech 1985a).

7.2.1 Port of Tacoma Terminal 7 Ore Unloading Facilities

The Port of Tacoma Terminal 7 ore unloading facilities are located along the entire north shore of Sitcum Waterway. Four berths are available for mooring freighters along a 2,700-ft pier.

Ore unloading is a small part of the Terminal 7 freight handling operations. Alumina shipments arrive approximately once per month and represent 65 percent of all the ore handled. Alumina itself contains zinc, copper, and lead at concentrations between 1 and 10 mg/kg (Norton and Johnson 1985b). Lead ore concentrate represents 20 percent and ores of copper and zinc combined represent the remaining 15 percent of the volume of ores handled at Terminal 7 (Carter, S., 25 September 1987, personal communication). Between 1973 and 1983, alumina passed through the Terminal 7 facilities at an average yearly rate of 520,000 mt/yr.

Alumina handled at Terminal 7 is transferred from shipboard to a closed hopper in a 25-yd^3 bucket sealed to minimize ore loss. A closed conveyor system carries the ore to two storage domes with a combined capacity of 136,000 mt. (The domes were built in 1966 and 1968.) Other ore types are loaded in 3- or 6.5-yd^3 buckets directly into open rail cars for shipment offsite. Ore spillage can occur during the unloading process but is more likely to be a problem with ores other than alumina because of the special sealed bucket used for unloading this material. In the past, spilled ore was recovered to the extent that was practical and the remaining material was washed into the waterway (Norton and Johnson 1985b).

Terminal 7 ore unloading facilities were identified as sources of metals based on the proximity of the facilities to the observed contamination and on the documented use and handling practices of the compounds of concern.

Identification of Contaminant Sources Onsite--

Contaminant sources onsite include the ore materials that are unloaded at the facility and surfaces where spilled ore may have accumulated. These sources have the potential to contaminate stormwater runoff which enters the waterway through storm drains. Storm drains serving the area are described in Section 7.2.2.

Loading Data--

Loading data for the drain under Terminal 7 (i.e., SI-717) are available for a single storm event (on 26 June 1984). Measured loadings for arsenic, copper, lead, and zinc are presented in Appendix E, Tables E-14 through E-17.

Recent and Planned Remedial Activities--

The practice of washing residual spilled ore into the waterway has been curtailed. Spilled ore is currently collected in a sweeper truck. The reclaimed material is transferred into drums for sale to smelters (Carter, S., 25 September 1987, personal communication). The use of a closed conveyor and a transfer bucket equipped with a special seal was also instituted recently. The seal apparently reduces alumina spillage significantly. The Terminal 7 facility has also instituted an ongoing monitoring program to ensure that spilled ore is cleaned from the dock area (Morrison, S., 22 January 1988, personal communication).

7.2.2 Storm Drains

Sixteen storm drains discharge directly into Sitcum Waterway (Figure 7-4). Eight serve the Port of Tacoma's Terminal 7 property (SI-167, SI-168, SI-169, SI-170, SI-171, SI-717, SI-719, and SI-824), two serve the office area at the head of the waterway (SI-716-01 and SI-716-02), and three serve the Sea-Land container terminal (SI-176, SI-718-01, and SI-718-02). Three other storm drains entering the head of Sitcum Waterway (SI-733, SI-175, and SI-172) drain the commercial and industrial areas on the south side of 11th Street. SI-172 is the largest storm drain in Sitcum Waterway, serving approximately 170 ac (40 percent of the total area draining to the waterway).

Drainage areas and estimated annual stormwater discharges from the drains in Sitcum Waterway are summarized in Table 7-2. Runoff estimates are based on an average annual precipitation of 37 in (Norton and Johnson 1985a) and on runoff coefficients determined for each drainage basin. The Sea-Land and Port of Tacoma properties located north of 11th Street are almost entirely covered with impermeable surfaces (e.g., pavement and buildings). A runoff coefficient of 0.95 was used to calculate the annual stormwater discharges from drains serving these areas (Viessman et al. 1977). The area south of 11th Street is a combination of paved industrial properties and unpaved, undeveloped areas. Runoff coefficients used for the three storm drains serving this area, SI-733, SI-175, and SI-172, were 0.4, 0.4, and 0.6, respectively.

Several industries also discharge noncontact cooling or process wastewater to the Sitcum Waterway storm sewer system. NPDES permit-holders for such discharges include Georgia Pacific Resins (No. 21 in Figure 7-1), Pabco Roofing Products (formerly Certain-Teed Products Corporation, No. 22 in Figure 7-1), Purex Corporation (No. 18 in Figure 7-1), and Allied Chemical Corporation (No. 25 in Figure 7-1).

Storm Drain SI-172--

Data collected during a single storm event indicate that SI-172 is the largest source of storm drain metals loading to Sitcum Waterway. Norton and Johnson (1985b) found that discharge from SI-172 accounted for about 80 percent of the flow (8 ft^3/sec) into the waterway on the day of the storm and sampling event (26 June 1984). Extrapolating these data to a daily

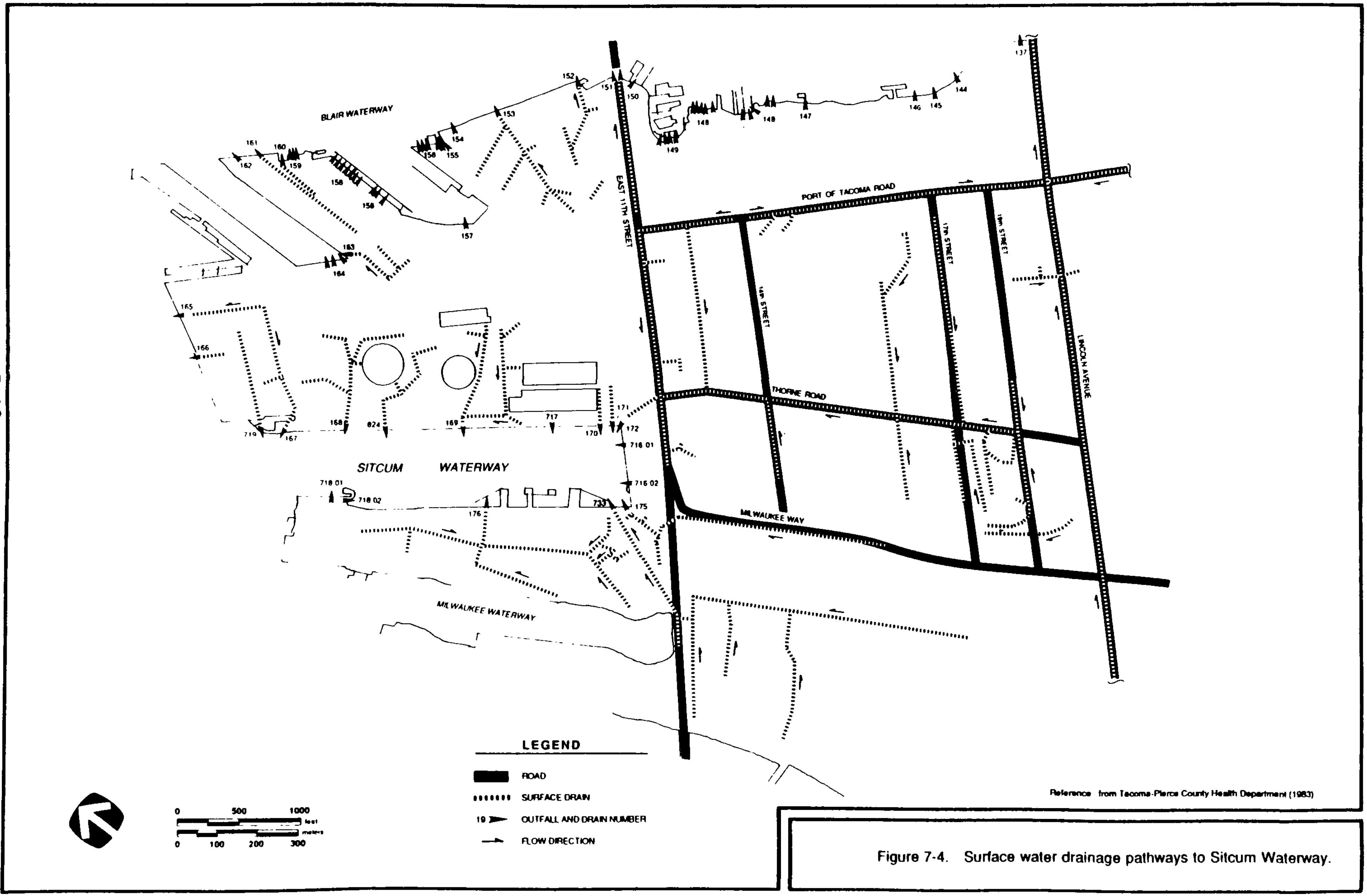


Figure 7-4. Surface water drainage pathways to Sitcum Waterway.

TABLE 7-2. STORM DRAINS DISCHARGING INTO SITCUM WATERWAY

Drain	Basin Area (ac)	Estimated Annual Stormwater Runoff (ac-ft/yr)
SI-719	5	15
SI-167	7	20
SI-168	30	90
SI-824	15	40
SI-169	30	90
SI-717	Unknown	--
SI-170	Unknown	--
SI-171	Unknown	--
SI-172	170	300
SI-716-01	Unknown	--
SI-716-02	Unknown	--
SI-175	30	40
SI-733	60	80
SI-176	40	120
SI-718-01	Unknown	--
SI-718-02	Unknown	--

loading rate during this event suggests that SI-172 accounted for 80-90 percent of the copper (7.6 lb/day), lead (8.6 lb/day), and zinc load (24 lb/day), and for 98 percent of the arsenic load (5.1 lb/day) to Sitcum Waterway. This finding is based on samples collected from 10 storm drains (SI-172, SI-716-02, SI-716-01, SI-175, SI-176, SI-718-02, SI-718-01, SI-719, SI-167, and SI-717) on 26 June 1984. Although metals concentrations in several of the other nine storm drains sampled on 26 June 1984 (e.g., SI-176, SI-719, SI-717, and SI-718-02) were similar to those measured in SI-172, the total loading was small because there was little flow in these drains. Class I inspections are scheduled for the spring of 1988 for most of the businesses contributing to SI-172 (Morrison, S., 22 January 1988, personal communication).

The City of Tacoma Sewer Utilities Department began an effluent testing program in October 1986. Storm drain SI-172, three drains in City Waterway, and one drain in Wheeler-Osgood Waterway are included in the program. Available data (Getchell, C., 12 October 1987, 18 December 1987, and 8 February 1988, personal communication) indicate that particulate matter in this storm drain is contaminated. Metals concentrations in particulate matter from drain SI-172 consistently exceeded sediment cleanup goals for copper, lead, and zinc. In two of the four sampling periods for which dry weather data are available, the arsenic cleanup goal was also exceeded. Comparison of storm drain sediment quality with remedial action cleanup goals provides a worst-case analysis: mixing with cleaner sediments from other sources is not considered.

Dames & Moore (1982) identified the following potential historical sources of contaminants in the SI-172 drainage basin:

- Rheen Manufacturing Company, located at 1702 Port of Tacoma Road, was reported as having possibly discharged paint wastes to the SI-172 drainage system for a period of approximately 10 yr prior to 1982

- Woodlam, Inc., manufacturer of laminated products located at 1476 Thorne Road, was reported to have discharged phenol glues out the back door of this facility.

Other Storm Drains--

Sediments collected recently by Ecology (Norton, D., 15 April 1988, personal communication) from storm drains SI-168, SI-169, and SI-733 were analyzed for priority pollutants. Arsenic, copper, lead, and zinc concentrations in sediments from drains SI-168 and SI-169 were greater than the long-term cleanup goals for these constituents. Lead and zinc concentrations in sediments from drain SI-733 also exceeded the cleanup goals.

The Milwaukee Railroad yards located in the SI-175 and SI-176 drainage basins are also potential historical contaminant sources. Milwaukee Railroad operated lines along Milwaukee Way on both the north and south sides of E. 11th Street. During the late 1950s, unspecified residual materials from railroad cars were dumped on the ground in the railroad yard on the south side of E. 11th Street and have accumulated on surficial soils (Dames & Moore 1982). Although Dames & Moore (1982) report that surface water runoff from the area entered Milwaukee Waterway, the Tacoma Pierce County Health Department (1983) drainage map indicates that surface water runoff from this area discharges into Sitcum Waterway via SI-175 or the newly installed (1984) SI-733. Numerous spills have also occurred in this area. Spills were generally not cleaned up and materials were allowed to seep into the ground (Dames & Moore 1982).

Numerous solid and liquid spills occurred at the Milwaukee Railroad yard located on the north side of E. 11th Street along the west bank of Sitcum Waterway (Dames & Moore 1982). Contaminants present in the spilled materials accumulated in the surficial soils and may have been transported to the waterway in stormwater runoff. This area is currently leased from the Port of Tacoma by Sea-Land for use as a container terminal. Because the area is completely paved, it is probably not an ongoing source of stormwater contamination. However, it may contribute contaminants to Sitcum Waterway via tidal flushing of contaminated groundwater. In addition, ASARCO slag was used as riprap along the west bank of Sitcum Waterway in the area.

Loading Summary--

Summary loading tables for the Priority 2 contaminants of concern for Sitcum Waterway (i.e., arsenic, copper, lead, and zinc) are provided in Appendix E exclusive of data from the City of Tacoma storm drain monitoring program. For the contaminants of concern, measured loadings (nine observations) range over 2 orders of magnitude. Additional data, not reported in the loading tables, from two dry-weather sampling events are also wide-ranging. Loading estimates based on these latter data sets are as follows: undetected and 0.2 lb/day for arsenic, 2.63 and 10.2 lb/day for copper, 0.2 and 4.9 lb/day for lead, and 4.7 and 33 lb/day for zinc (Odell, C., 20 April 1988, personal communication). With the possible exception of SI-176 for arsenic and SI-172 for arsenic, copper, and zinc, average inorganic contaminant concentrations derived from limited storm drain discharge data for the waterway are similar to those derived from the National Urban Runoff Program by Schueler (1987) and to those from Metro (Stuart et al. 1988).

7.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated. This evaluation was based on the levels of contamination in sediment and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to maintain acceptable levels of sediment contaminants over the long term.

7.3.1 Feasibility of Source Control

The two main sources of metals discharge are ore spillage (at the Port of Tacoma Terminal 7 ore unloading facility) and surface water runoff (from 16 storm drains that convey storm water directly into Sitcum Waterway).

Terminal 7 Ore Unloading Facilities--

The Port of Tacoma ore unloading facilities (including storm drains SI-168 and SI-169) have been associated with elevated concentrations of inorganic contaminants in adjacent sediments. Ore spillage and discharge of contaminants entrained in stormwater runoff are suspected as two of the primary ongoing or historical sources of metals to the waterway.

Three best management practices have already been implemented at the facility: collection of spilled ore via a sweeper truck, implementation of a monitoring program to ensure that spilled ore is removed from the dock area, and use of a bucket equipped with special seals and a closed conveyer. Given the types of contaminants, source pathways, and available control technologies, it is estimated that implementation of all known, available, and reasonable (i.e., feasible) technologies will reduce source inputs by 80 percent.

Storm Drains--

Storm drain SI-172 has been identified as the biggest contributor of metals to Sitcum Waterway via storm drains (Tetra Tech 1985a). The City of Tacoma is presently testing effluent from the drain under its storm drain monitoring program. Several of the storm drains discharging into Sitcum Waterway (particularly SI-168 and SI-169) have also been identified as sources of metals.

Available technologies for controlling surface water runoff to storm drains are summarized in Section 3.2.2. These technologies include methods for retaining runoff onsite (e.g., berms, channels, grading, sumps), revegetation or capping of waste materials, and waste removal or treatment.

Treatment methods for stormwater after collection in a drainage system also exist. Sedimentation basins and vegetation channels (or grassy swales) have been shown to remove contamination associated with particulate matter. Removals of up to 75 percent for total suspended solids and 99 percent for lead have been reported for detention basins (Finnemore and Lynard 1982; Horner and Wonacott 1985). Removals of 90 percent for lead, copper, and zinc and 80 percent for total suspended solids have been achieved using grassy swales (Horner and Wonacott 1985; Miller 1987).

Given the contaminant types, multiplicity of sources, and available control technologies, it is estimated that implementation of all known, available, and reasonable technologies will reduce contaminant inputs from storm water by up to 80 percent.

Conclusion--

For the waterway, the estimated maximum feasible level of source control for the two indicator chemicals is assumed to be 80 percent for copper and 80 percent for arsenic. These estimates reflect both the assumed effectiveness of implementing best management practices for the Terminal 7 ore handling operations as well as uncertainty regarding the relative importance of storm drain inputs and source control technologies. More precise source control estimates require improved definition of the sources of copper and arsenic, which is beyond the scope of this document.

7.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals copper and arsenic. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented here.

The depositional variables in Sitcum Waterway were estimated from measurements taken in adjacent waterways. A sedimentation rate of 2,400 $mg/cm^2/yr$ (1.65 cm/yr) and a mixing depth of 10 cm were selected for modeling sedimentation in Sitcum Waterway. Two indicator chemicals (copper and arsenic) were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Losses due to biodegradation and diffusion were determined to be negligible for these indicator chemicals. Source loadings of both indicator chemicals in Sitcum Waterway were assumed to be in steady-state with sediment accumulation. This assumption is environmentally protective in that sediment profiles suggest a recent decrease in inorganic contaminant loading (Tetra Tech 1987a). Two timeframes for sediment recovery were considered: a reasonable timeframe (defined as 10 yr) and the long term. Results of the sediment recovery evaluation are summarized in Table 7-3.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted to be 17 yr for copper and 13 yr for arsenic. Therefore, sediment recovery in the 10-yr timeframe is not predicted to be possible under conditions of complete source elimination for either copper or arsenic. These predictions are based on the highest concentrations of the indicator chemicals measured in the problem area. Minimal reductions in sediment concentrations are predicted unless sources are controlled.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source control is expected to reduce source inputs by 80 percent for both arsenic and copper. With this level of source control as an input value, the model predicts that sediments with an enrichment ratio of 2.9 (i.e., copper

TABLE 7-3. SITCUM WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals	
	Copper	Arsenic
Station with Highest Concentration		
Station identification	3[a]	SI-04
Concentration (mg/kg dry weight)	2,100	472
Enrichment ratio[b]	5.4	8.3
Recovery time if sources are eliminated (yr)	17	13
Percent source control required to achieve 10-yr recovery	NP[c]	NP[c]
Percent source control required to achieve long-term recovery	79	88
Average of Three Highest Stations		
Concentration (mg/kg dry weight)	1,490	400
Enrichment ratio[b]	3.8	7.0
Percent source control required to achieve long-term recovery	70	86
10-Yr Recovery		
Percent source control assumed feasible	80	80
Highest concentration recovering in 10 yr (mg/kg dry weight)	1,131	165
Highest enrichment ratio of sediment recovering in 10 yr	2.9	2.9

[a] On the basis of more recent information observed at nearby stations, the enrichment ratio of 23 observed at Station 1-9 in 1981 is not believed to be representative of current conditions.

[b] Enrichment ratio is the ratio of observed concentration to target cleanup goal.

[c] NP = Not possible.

concentrations of 1,131 mg/kg dry weight, arsenic concentration of 165 mg/kg dry weight) will recover to the long-term cleanup goal within 10 yr (see Table 7-3). The surface area of sediments not recovering to the cleanup goal within 10 yr is shown in Figure 7-5. For comparison, sediments currently exceeding long-term cleanup goals for the indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that 70 percent of the copper and 86 percent of the arsenic inputs must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (see Table 7-3). These estimates are based on the average of the three highest enrichment ratios.

These values are presented for comparative purposes; the actual percent reduction required in source loading is subject to the uncertainty inherent in the assumptions of the predictive model. These ranges probably represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

For comparison with source control estimates derived by using the mathematical model, the percent reductions necessary to meet long-term cleanup goals were calculated for particulate matter from SI-172. Based on six measurements by the City of Tacoma (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, and 19 August 1988, personal communications), average reductions of 67 percent for arsenic and 73 percent for copper would be needed to achieve sediment cleanup goals in particulate matter from storm drain SI-172 effluent. Based on one measurement of sediments (Norton, D., 15 April 1988, personal communication), reduction of 54 percent would be required to achieve the arsenic cleanup goal and reduction of 96 percent would be required to achieve the copper cleanup goal in both storm drains SI-168 and SI-169. As a measure of relative priority for source control, drain SI-172 supplies 38 percent of the estimated annual stormwater runoff flow to Sitcum Waterway, while SI-168 and SI-169 each supply approximately 11 percent (see Table 7-2).

7.3.3 Source Control Summary

The major sources of metals to Sitcum Waterway are the Port of Tacoma Terminal 7 ore unloading facilities and several area storm drains. If these sources are completely eliminated, it is predicted that sediment concentrations in the surface mixed layer of the indicator chemical copper will decline to the long-term cleanup goal of 390 mg/kg in 17 yr and that those of arsenic will decline to the long-term cleanup goal of 57 mg/kg in 13 yr. Sediment remedial action will therefore be required to mitigate the observed and potential adverse biological effects associated with sediment contamination.

Substantial levels of source control will also be required to maintain acceptable sediment concentrations of the indicator chemicals even with sediment cleanup. The estimated percent reduction required for long-term maintenance is 70 for copper and 86 for arsenic.

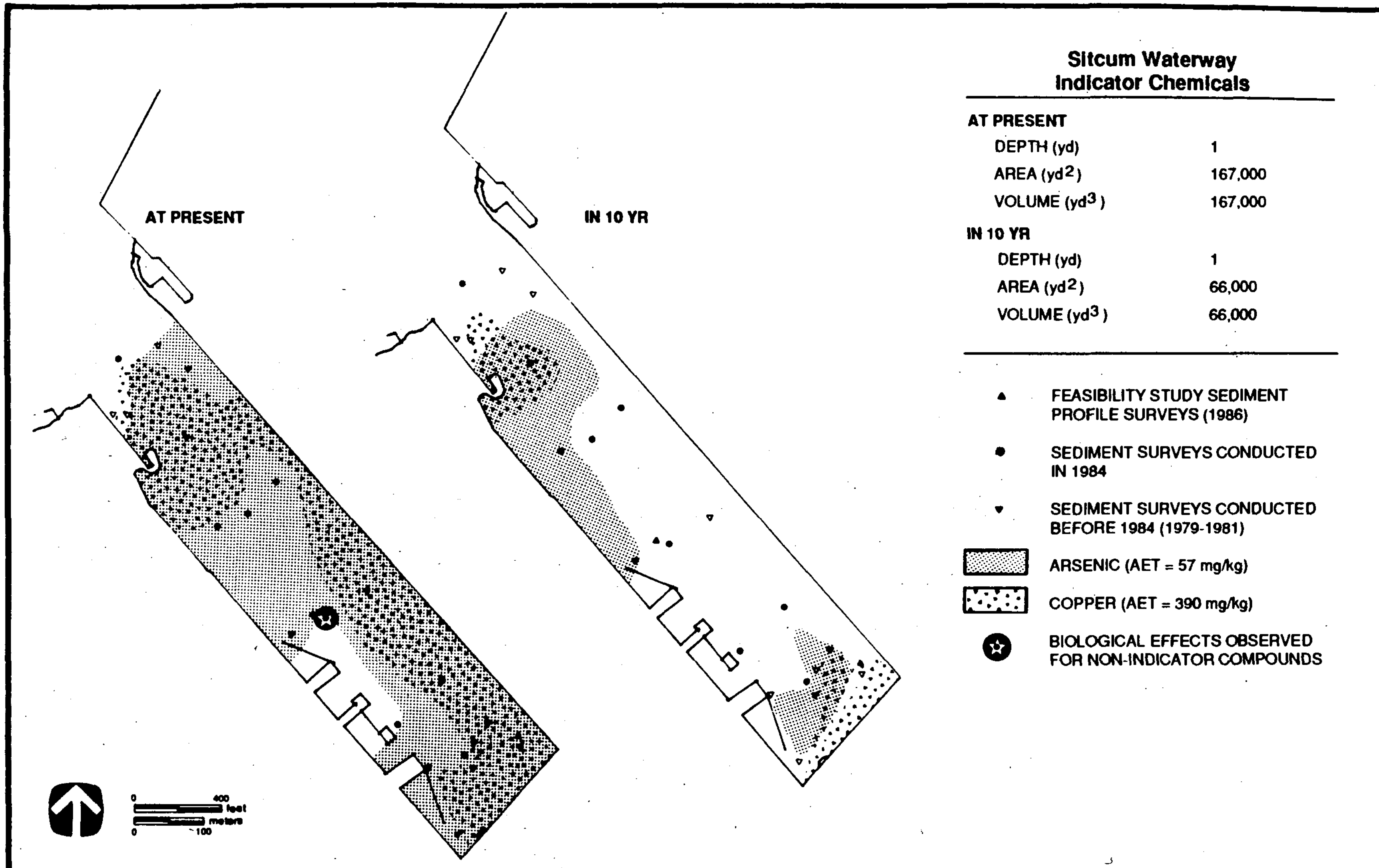


Figure 7-5. Sediments in Sitcum Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

The implementation of all known available and reasonable control technologies is expected to provide approximately a 80 percent reduction in contaminant loading to the waterway. This level of source control appears feasible for maintaining the cleanup goal for copper. The 6 percent difference between the percent source control assumed feasible for arsenic (80 percent), and the percent source control required to achieve long-term recovery for arsenic (86 percent) may be insignificant given the uncertainties in estimates of feasible source control and conservative assumptions built into the model. If implementation of all known, available, and reasonable control technologies fails to achieve the necessary level of source control required to maintain sediment quality, then re-evaluation of the area requiring remediation based on arsenic concentrations may be required.

7.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with copper or arsenic concentrations exceeding long-term cleanup goals is approximately 167,000 yd^3 (see Figure 7-5). This volume was estimated by multiplying the areal extent of sediment exceeding the cleanup goal (167,000 yd^2) by the estimated 1-yd depth of contamination (see contaminant sediment profiles in Figures 7-2 and 7-3. The estimated thickness of contamination is only an approximation; few sediment profiles were collected and the vertical resolution of these profiles was poor at the depth of the contaminated horizon. For the volume calculations, depths were slightly overestimated. This conservative approach was taken to account for dredge technique tolerances and to account for uncertainties in sediment quality at locations between the sediment profile sampling stations.

The total estimated volume of sediments with copper or arsenic concentrations that is still expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 66,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratios greater than 2.9 (see Table 7-3), an area of 66,000 yd^2, by the estimated 1-yd depth of contamination. These volumes are also approximations, accounting for uncertainties in sediment profile resolution and dredging tolerances.

In addition to chemical concentrations that exceed long-term cleanup goals for indicator chemicals, biological effects were observed at one station (SI-12; see Appendix F) as a result of elevated concentrations of the nonindicator compounds (see Figure 7-5). The volume of sediment exceeding long-term cleanup goals for these compounds is estimated as 10,000 yd^3. Sediment concentrations in these sediments are expected to recover to acceptable levels within approximately 10 yr.

The quantity of sediment used in evaluating the remedial alternatives (i.e., to identify the preferred alternative) was determined by adding the following values:

- The volume of all sediments currently exceeding the long-term cleanup goal within the waterway (i.e., 157,000 yd^3)

- The volume of sediment in the vicinity of the station where biological effects were observed for nonindicator compounds (approximately 10,000 yd^3).

For Sitcum Waterway, the volume of sediment requiring remediation is therefore 167,000 yd^3.

7.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

7.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, each alternative is evaluated to determine its suitability for the remediation of contaminated sediments in Sitcum Waterway. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess the applicability of each alternative in the waterway. Site-specific characteristics that must be considered include the nature and extent of contamination, the environmental setting, and site physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

The indicator chemicals arsenic and copper were selected to represent the two primary sources of contamination to the waterway: storm drains and the Terminal 7 ore unloading facilities (see Table 7-1). Areal distributions for both indicators are presented in Figure 7-5 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery. The U.S. Army Corps of Engineers is required to maintain water depths in Sitcum Waterway for shipping. For the first 1,000 ft of waterway extending from the head towards the mouth, the required channel depth is 35 ft below MLLW. For the remaining length of the waterway, the minimum channel depth is 40 ft below MLLW. The channel width along the entire length of the waterway is 300 ft.

Four alternatives are dropped from consideration for Sitcum Waterway. The need for periodic dredging to maintain channel depth precludes placement of a cap on existing sediments within channel boundaries. The bottom surfaces along sloping embankments outside the channel lines and adjacent to the channel where maintenance dredging will occur are also inappropriate for capping technologies where long-term isolation of sediments must be ensured. Therefore, the in situ capping alternative is dropped from further consideration in Sitcum Waterway. Alternatives involving treatment of organic contaminants are inappropriate because the sediments are contaminated with predominantly inorganic contaminants. Therefore, the solvent extraction, incineration, and land treatment alternatives are also dropped from further consideration.

The remaining six candidate sediment remedial alternatives for Sitcum Waterway are listed below:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Hydraulic dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solidification/upland disposal.

These candidate alternatives are described in detail in Chapter 3. Because of the close proximity of the problem area to the proposed nearshore disposal site in Blair Waterway, the dredging and nearshore disposal option has been defined to include a hydraulic dredging system for sediment removal, transport, and disposal.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from exposure to contaminated sediments without implementing sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives are applicable to remediation of sediment contamination in Sitcum Waterway. Solidification is retained as an appropriate treatment technology because it is primarily used to treat materials contaminated with inorganics. This treatment technology may also be effective in immobilizing the Priority 3 organic contaminants, which are assumed to have a high particle affinity.

7.5.2 Evaluation of Candidate Alternatives

The three primary categories of evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 7-4. A comparative evaluation of alternatives is presented in Table 7-5, based on ratings of high, moderate, and low in seven subcategories of evaluation criteria. As discussed in Chapter 4, the effectiveness subcategories are short-term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. The implementability subcategories are technical feasibility, institutional feasibility, and availability. Capital and O&M costs for each alternative are also presented in Table 7-5.

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse

TABLE 7-4. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE SITCUM WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	HYDRAULIC DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Hydraulic dredging confines CDM to a pipeline during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge treatment and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear. Increased potential for worker exposure due to direct handling of CDM.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Benthic habitat is impacted at the disposal site. Habitat has a lower sensitivity level than nearshore.	Existing contaminated habitat is destroyed. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants. Habitat has a lower sensitivity level than nearshore.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked sixth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. Natural recovery time ranges from 10 to 12 yrs. This alternative is ranked fifth overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Disposal siting and facility construction could delay implementation. This alternative is ranked second overall for timeliness.	Dredge and disposal operations could be accomplished quickly. This alternative can be implemented rapidly with available technologies and expertise. Disposal site identified. This alternative is ranked first for timeliness.	Dredge and disposal operations could be accomplished within approximately 1 to 2 years. Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Substantial CDM testing and equipment development are required before a solidification scheme can be implemented. This alternative is ranked fourth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant re-exposure in a quiescent, subaquatic environment is considered acceptable.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Long-term reliability of solidification treatment processes for CDM are believed to be adequate. However, data from which to confirm long-term reliability are limited. Upland disposal facilities are structurally reliable.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from hydraulic dredge operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Volume of contaminated sediments is not reduced and may increase with hydraulic dredge operations.	Contaminants are physically contained, thereby reducing toxicity and the potential for contaminant migration compared with non-treatment alternatives. Metals and organics are encapsulated.

TABLE 7-4. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	HYDRAULIC DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION, PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, although feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Hydraulic dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Solidification technologies for treating CDM on a large scale are conceptual. Implementation is considered feasible, but reliability is unknown. Bench-scale testing prior to implementation is necessary.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Installation of monitoring systems is routine aspect of facility siting.	Monitoring can be readily implemented to detect contaminant migration through dikes and liners. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring requirements for solidified material are low in comparison with dredge and disposal alternatives. Monitoring can be readily implemented.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment. System maintenance is intensive during implementation.
	INSTITUTIONAL FEASIBILTY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting is uncertain but is assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Disposal requirements are less stringent for treated dredge material, enhancing approval feasibility. However, bench scale testing is required to demonstrate effectiveness of solidification.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/ SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's onsite disposal policy. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's onsite disposal policy. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. May require that substantive aspects of CWA and shoreline management programs be addressed.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Waterway CAD site is considered available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Disposal site availability is uncertain but feasible. Solidification equipment and methods for large-scale CDM disposal are currently unavailable.

TABLE 7-5. EVALUATION SUMMARY FOR SITCUM WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Hydraulic/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Solidify/ Upland Disposal
Short-Term Protectiveness	Low	Low	High	Moderate	High	Moderate
Timeliness	Low	Low	Moderate	High	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High
Technical Feasibility	High	High	Moderate	High	High	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	High	Moderate	Moderate
Long-Term Cleanup Goal Cost[a]						
Capital	--	6	1,327	4,073	7,301	11,084
O & M	--	1,989	309	343	459	443
Total	--	1,995	1,636	4,416	7,760	11,527
Long-Term Cleanup Goal with 10-yr Recovery Cost[a,b]						
Capital	--	6	544	1,612	2,887	4,400
O & M	--	865	125	139	185	178
Total	--	871	669	1,751	3,072	4,578

[a] All costs are in $1,000.

[b] Includes sediment for which biological effects were obseved for non-indicator compounds.

biological and potential public health impacts would continue as the contaminated sediments remained in place. Source control measures initiated as part of the institutional controls would result in reduced sediment contamination with time, but adverse effects would persist in the interim.

The alternative requiring hydraulic dredging/nearshore disposal is rated moderate under this criterion because nearshore habitat would be lost in developing the disposal facility. The clamshell dredging/solidification/upland disposal alternative is also rated moderate because of the increased potential for worker exposures due to direct contact during solidification-related handling of contaminated dredged material. The potential hazard due to exposure during the treatment process is not expected to be major because of the nature and concentration of contaminants. In spite of the increased exposure potential, the moderate rating is appropriate because adequate worker health and safety controls are available.

The confined aquatic disposal and hydraulic dredging/upland disposal alternatives are rated high for short-term protectiveness because worker and public exposure potentials are minimized, and because the habitats that are compromised for disposal are of lower sensitivity than nearshore habitats. The confinement of contaminated dredged material in the subaquatic environment at a designated disposal site outside the waterway, using a mechanical dredge for removal and a split-hulled barge for disposal, minimizes handling requirements. Hydraulic dredging with upland disposal confines contaminated dredged material to a pipeline system throughout implementation, thereby reducing exposure potentials.

For the solidification alternative, if contaminated dredged material is determined to be unacceptable for disposal at an existing solid waste landfill, use of a previously unaffected site may be required. Although this would result in short-term impacts in the upland environment, the tradeoff of improved waterway habitat and marine productivity may offset the impacts of placing inorganic contaminants in an upland environment at concentrations that may not pose a significant environmental threat at the disposal site.

Timeliness--

Because an extensive amount of time is necessary for sediments to recover naturally, both the no-action and institutional controls alternatives are rated low. Natural recovery times for the two indicator compounds range from 13 to 17 yr (see Section 7.3).

Moderate ratings have been applied to the clamshell dredging/confined aquatic disposal, hydraulic dredging/upland disposal, and clamshell dredging/solidification/upland disposal options. For dredging options that involve siting of unused and undeveloped upland or confined aquatic disposal facilities, approvals and construction are estimated to require 1-2 yr. Solidification may require additional time for bench-scale testing, equipment development, or modification and actual treatment of sediments. However, facility siting and technology development could be conducted concurrently. Once approval is obtained, treatment of contaminated sediments using solidification to target goals would require a period of approximately 1-2 yr, assuming a maximum treatment rate of 1,000 yd^3/day.

The hydraulic dredging/nearshore disposal option is rated high for timeliness because this alternative can be implemented rapidly with available technologies and expertise. Major site development would be required (e.g., diking) but can be completed in a relatively short timeframe.

Long-Term Protectiveness--

The comparative evaluations for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for natural recovery is long. For the institutional controls alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source reductions, and the observed adverse biological impacts continue.

Moderate ratings are assigned for hydraulic dredging/nearshore disposal and hydraulic dredging/upland disposal alternatives because of potential physicochemical changes due to placing contaminated dredged material in these disposal facilities. These changes, primarily from new conditions affecting reduction and oxidation (redox) reactions, would tend to increase the migration potential of the contaminants. Contaminated dredged material testing should provide the necessary data on the magnitude of these impacts. In a nearshore site, physicochemical changes could be minimized by placing sediments below the low tide water elevation. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature as a result of wave action and tidal influences. In addition, the fish mitigation area in the outer Blair Waterway slip adjacent to the proposed disposal facility is regarded as a sensitive area. The upland disposal facility would be generally regarded as a more secure option because of improved engineering controls during construction, but the potential for impacts on area groundwater resources partially offsets the improvement in long-term security.

Both the clamshell dredging/confined aquatic disposal and the clamshell dredging/solidification/upland disposal alternatives are rated high for long-term protectiveness. Placement of material in a confined, quiescent, subaquatic environment provides a high degree of isolation, with little potential for exposure to an environment sensitive to the contaminated dredged material. In addition, confinement under these circumstances maintains physicochemical conditions comparable to in situ conditions, further reducing contaminant migration potential. The high degree of immobilization provided by solidification of primarily inorganic contaminants substantially increases the long-term protectiveness of this alternative over dredge and disposal alternatives.

Reductions in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except the clamshell dredging/solidification/upland disposal option which was rated high. None of the other five alternatives involves treatment of contaminated sediments. Although the confined aquatic, upland, and nearshore disposal alternatives isolate contaminated dredged material from the surrounding environment, the chemistry of the material remains unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated contaminated dredged material may actually increase with changes in redox potentials. Without treatment, the toxicity of contaminated sediments remains at preremediation levels. Contaminated sediment volumes are not reduced, and may actually increase with hydraulic dredging options because of suspension of the material in an aqueous slurry.

Solidification of contaminated dredged material prior to disposal effectively encapsulates inorganic contaminants, thereby reducing mobilization potential permanently and significantly. Through isolation in the solidified matrix, this process also reduces the effective toxicity of contaminants as compared with nontreatment alternatives. Because the available data suggest that the organic contaminants present have a high particle affinity, the process may also be relatively effective in encapsulating these compounds. Elutriate tests during bench-scale testing of solidified contaminated dredged material will provide sufficient data to substantiate or invalidate these conclusions.

Technical Feasibility--

Clamshell dredging/solidification/upland disposal has been assigned a moderate rating for technical feasibility because of the need to conduct bench-scale testing prior to implementation. Solidification technologies for the treatment of contaminated dredged material on a large scale are conceptual at this point, although the method appears to be feasible (Cullinane, J., 18 November 1987, personal communication). A moderate rating is also applied to the clamshell dredging/confined aquatic disposal option. Placement of dredge and capping materials at depths of approximately 100 ft is difficult, although feasible. Considerable effort and resources may be required to monitor the effectiveness and accuracy of dredging, disposal, and capping operations.

High ratings have been assigned to all other alternatives because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective elsewhere for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods (e.g., sediment cores, monitoring wells) are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives have been assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates will not be achieved. Requirements for long-term protection of public health and the environment are not met by either alternative.

Moderate ratings have been assigned to the remaining four alternatives because of potential difficulty in obtaining agency approvals for disposal sites or implementation of treatment technologies.

Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. It was assumed that the Blair Waterway nearshore facility would be available for use. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of the effectiveness of each alternative in meeting established performance goals (e.g., treatability of dredge water, immobilization of contaminants through solidification).

Availability--

Candidate sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities are rated high for availability. Because the no-action and institutional controls alternatives can be implemented immediately, they received a high rating. A nearshore disposal site was assumed to be available, allowing rapid implementation of the hydraulic dredging/nearshore disposal alternative. Thus, this alternative also received a high rating for availability.

Remedial alternatives involving dredging with confined aquatic or upland disposal are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that confined aquatic and upland sites will be available. However, no sites for contaminated sediments are currently approved for use and no sites are currently under construction. Depending on the final characterization of sediments, upland disposal in an existing municipal or demolition landfill may also be feasible. For costing purposes, development of a RCRA-equivalent upland site was assumed. A moderate rating has also been assigned to the clamshell dredging/solidification/upland disposal alternative because of the same uncertainties regarding disposal site availability. However, leachate tests conducted as a part of the bench-scale treatability and performance evaluation for the solidification process should confirm that the product is nonhazardous and suitable for a standard solid waste management facility. For costing purposes, disposal in a standard solid waste management facility was assumed.

Cost--

Capital costs increase with increasing complexity (i.e., from no action to the treatment option). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for hydraulic dredging/nearshore disposal, primarily due to underdrain and bottom liner installation, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting the solidification alternative increases as a result of material costs for the process, and associated labor costs for material handling and transport. Dredge water clarification management costs are also incurred for this option.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Costs for monitoring of the confined aquatic disposal facility are significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution to monitor migration. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single groundwater sample from each well to assess contaminant migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding AET values) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the solidification alternative are significantly lower because the process results in lower contaminant migration potential.

7.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the six candidate sediment remedial alternatives proposed for Sitcum Waterway, hydraulic dredging with nearshore disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., hydraulic dredging, nearshore disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. The nearshore disposal alternative is currently preferred for the following reasons:

- The alternative protects public health and the environment by effectively isolating contaminated sediments in an engineered disposal facility

- The alternative is consistent with existing plans to fill the Blair Waterway Slip 1 proposed nearshore fill site

- The nature of the contaminants is such that placement below the saturated zone should minimize migration potential

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental requirements

- Performance monitoring can be accomplished effectively and implemented readily

- The estimated 66,000-yd^3 volume of contaminated sediments is compatible with the capacity of the proposed nearshore facility

- The cost of this alternative is over $1 million less than that of the upland disposal alternative, and it is expected to provide an equivalent degree of public health and environmental protection

- Although this option is approximately $1 million more than the confined aquatic disposal option, largely due to the cost of acquiring nearshore property in the project area, the additional expenditure is justified since the action can be implemented more quickly in an available facility that offers appropriate confinement conditions for the contaminants of concern.

The nearshore disposal alternative is rated high for timeliness, technical feasibility, and availability because available equipment, resources, and disposal facilities are used. The alternative can be implemented quickly with reliable equipment that has proven effective in past similar operations.

The alternative is rated moderate for short-term protectiveness because of the loss of intertidal habitat. This disadvantage can be offset through incorporation of a habitat replacement project in the remedial process. This goal is addressed in part with the improvements realized by removing contaminated sediments from the waterway itself and subsequent reestablishment of that marine habitat. The alternative is rated moderate for long-term protectiveness because contaminated sediments are placed in an environment subject to wave and tidal influences. In addition, there is potential for long-term impacts to the adjacent fish mitigation area in the outer slip. However, contaminants in Sitcum Waterway have demonstrated relatively high particle affinities (Tetra Tech 1987c), which would serve to improve long-term containment reliability. Hart-Crowser & Associates (1985) concluded that monitoring of contaminant mobility from nearshore disposal sites could be effectively accomplished with monitoring wells in containment berms for early detection of contaminant movement. Long-term protectiveness could also be improved with the placement of slurry walls within the berm (Phillips et al. 1985); however, this measure has not been included in the cost estimate. As indicated in Table 7-5, this alternative also provides a cost-effective means of sediment mitigation.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with contaminated dredged material redistribution. The effect of dredging on water quality can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Because this alternative can be implemented over a relatively short timeframe, seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

The confined aquatic disposal alternative was not selected because the volume of material is compatible with the available nearshore disposal site. The nearshore alternative can be implemented more quickly, while providing a degree of protection that is appropriate for the contaminants of concern.

Solidification/upland disposal was not selected as the preferred alternative since the timeframe for remedial action would be lengthened. Implementation would require bench-scale and possibly pilot-scale testing. In addition, treatment itself would take a considerable period of time, given available equipment and the large volume of contaminated sediment. Decreased mobility of contaminants due to the stabilization is not expected to significantly increase long-term protectiveness compared with nearshore disposal, if the sediments are maintained in a reduced environment. Performance monitoring associated with the nearshore disposal facility would allow early detection of movement to the surrounding environment. The nearly $3 million greater cost for solidification/upland disposal also favors the nearshore disposal alternative.

Hydraulic dredging with upland disposal was not selected because of uncertain disposal site availability and the cost of siting and developing a facility to RCRA standards for disposal of untreated contaminated dredged material in an upland environment. The cost associated with this alternative is approximately $1 million more than that for the nearshore disposal alternative. Although this alternative is feasible from both a technical and institutional standpoint, the risk of system failures in the upland environment (e.g., groundwater risks) compromises its desirability.

No-action and institutional controls alternatives are ranked high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public health impacts far outweighs these advantages.

7.7 CONCLUSIONS

Sitcum Waterway was identified as a problem area because of the elevated concentrations of the inorganic contaminants in sediment. Copper and arsenic were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume of sediment to be remediated. In addition to these indicator chemicals, biological effects were also observed in Sitcum Waterway as a result of elevated concentrations of nonindicator compounds. The volume of sediment exceeding long-term cleanup goals for these compounds is estimated at 10,000 yd^3. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 167,000 yd^2, and a volume of 167,000 yd^3. Some of this sediment is predicted to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 101,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 66,000 yd^3.

The primary identified and potential sources of problem chemicals to Sitcum Waterway include the following:

- Terminal 7 ore unloading facilities
- Storm drains.

Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Reduce inputs of metal contaminants to the waterway from the Terminal 7 facility via stormwater runoff and ore spillage
- Reduce the amount of metals and other contaminants to the waterway from storm drain SI-172
- Investigate sources of contamination in other storm drains and initiate appropriate source control measures to reduce ongoing discharges
- Confirm that all significant sources of problem chemicals have been identified and controlled
- Perform ongoing monitoring to evaluate the effectiveness of best management practices at the ore unloading facilities.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals arsenic and copper. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be re-evaluated.

Hydraulic dredging with nearshore disposal was recommended as the preferred alternative for remediation of sediments that are not predicted to recover within 10 yr of implementation of source controls. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at near in situ conditions in an engineered disposal facility where performance monitoring can be readily implemented. Disposal sites for nearshore confinement are available at this time. Use of material from Sitcum Waterway in a nearshore facility is compatible with the Port of Tacoma's industrial development plans, minimizing the impacts of using another facility. Concerns regarding potential contaminant migration to an adjacent fish mitigation area will be addressed through the placement of contaminated material in a saturated environment and the ongoing monitoring program to detect potential problems in sufficient time to implement corrective measures. Nearshore disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 7-5, hydraulic dredging with nearshore disposal provides a cost-effective means of sediment mitigation. The estimated cost to implement this alternative is $1,612,000. Environmental monitoring and other O&M costs at the disposal site have a present worth of $139,000 for a period of 30 yr. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of the preferred alternative is $1,751,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions practicable, and are cost-effective.

8.0 ST. PAUL WATERWAY

Potential remedial actions are defined and evaluated in this section for the St. Paul Waterway problem area. The waterway is described in Section 8.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 8.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source controls on sediment remediation are discussed in Section 8.3. Areas and volumes of sediment requiring remediation are discussed in Section 8.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 8.5. The preferred alternative is identified in Section 8.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 8.7 summarizes the findings of the selection process and integrates source control recommendations with the preferred sediment remedial alternative.

8.1 WATERWAY DESCRIPTION

St. Paul Waterway is located between the Puyallup River to the north and Middle Waterway to the south (Figure 8-1). St. Paul Waterway was created in stages from 1920 to the early 1930s (Dames & Moore 1982). Early charts indicate that the inner portion at the waterway was used for log rafts and booms and was navigable to shallow draft boats. This part of the waterway remained intertidal and was apparently never dredged (Tetra Tech 1985a). In the early 1960s, the head of the waterway was filled to create the current configuration, which is about half its former size. Fill material is believed to have come from the U.S. Army Corps of Engineers dredging of the Puyallup River and may have included slash and sawdust from forest products industries in the area (Dames & Moore 1982).

St. Paul Waterway is approximately 2,000 ft long. Its width ranges from 400 ft at the head to 600 ft at the mouth (Tetra Tech 1985b). The depth of St. Paul Waterway increases from the head toward the mouth with fairly steep channel sides and mid-channel depths ranging from less than 10 ft below MLLW at the head to greater than 30 ft below MLLW at the mouth (Raven Systems and Research 1984).

St. Paul Waterway is not a designated navigation channel. Sediments within St. Paul Waterway are typically 50 percent fine-grained material, with a clay content of nearly 10 percent (Tetra Tech 1985a). Total organic carbon values for sediments in the waterway range from 1.5 to 16 percent. Contaminants identified in the waterway are primarily organic compounds that are relatively soluble and have low particle affinity (Tetra Tech 1987c).

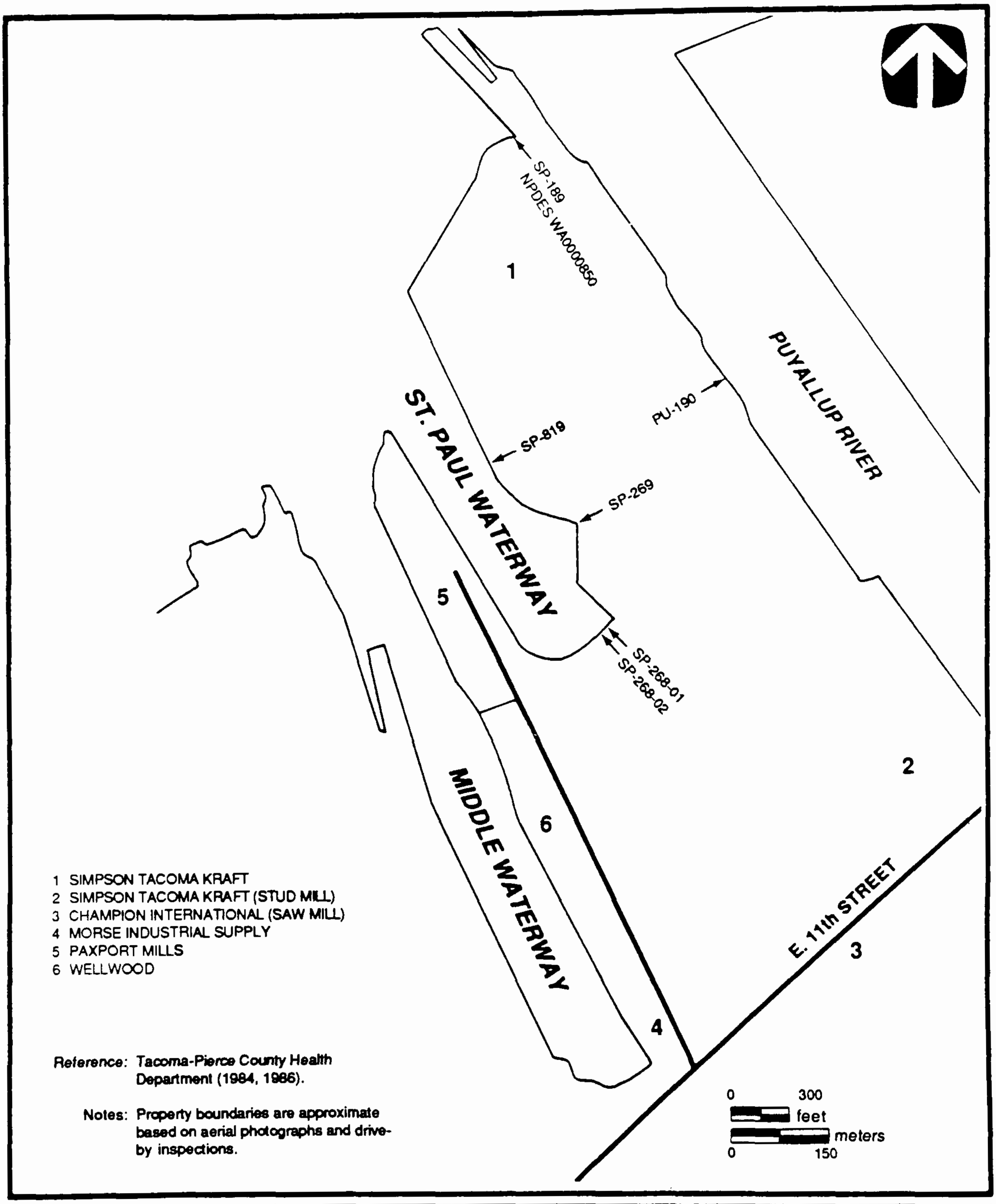


Figure 8-1. St. Paul Waterway - Existing industries, businesses, and discharges.

8.1.1 Nature and Extent of Contamination

Analysis of data collected during the RI and FS in conjunction with historical data has revealed that St. Paul Waterway contains elevated concentrations of organic contaminants (Tetra Tech 1985a, 1986c). 4-Methylphenol was identified as a Priority 1 contaminant in the waterway (see Section 1.3.5 for definitions of priority 1, 2, and 3 compounds). Priority 2 contaminants that have been detected in the waterway include phenol, 2-methoxyphenol, and 1-methyl-2-(methylethyl) benzene. The following compounds exceeded their corresponding AET values at only one station and are therefore considered Priority 3 contaminants: naphthalene, 2-methylnaphthalene, biphenyl, retene, diterpenoid hydrocarbons, nickel, total organic carbon, and total volatile solids.

The primary goal of sediment remediation in St. Paul Waterway is the isolation or removal of organic compounds observed at elevated concentrations near the mouth of the waterway. 4-Methylphenol was selected as the organic indicator compound. This compound is widespread in the problem area and is expected to persist in the sediments.

Estimated areal and depth distributions of 4-methylphenol are shown in Figure 8-2. Concentrations of 4-methylphenol exceeding the long-term cleanup goal of 670 ug/kg extend over the entire mouth of the waterway. This cleanup goal was set by the AET values derived for depressions in infaunal abundance and the oyster larvae bioassay. The values shown in Figure 8-2 that are below 1.0 represent clean sediments based on the concentration of 4-methylphenol at the station, while the above 1.0 define problem sediments. Depth profiles obtained from the two core stations suggest that 4-methylphenol contamination exceeds the cleanup goal to a depth of approximately 2 yd, with the highest concentrations occurring in the northeast corner of the mouth of the waterway and declining toward the head.

8.1.2 Recent and Planned Dredging Projects

The Simpson Tacoma Kraft Company recently dredged approximately 6,500 yd^3 of contaminated sediments in compliance with NPDES permit conditions requiring relocation of the plant's outfall (SP-189 on Figure 8-1; see Figure 8-3 for location of new outfall). The new outfall has been placed at a depth of 70 ft below MLLW, and the first 220 ft are buried beneath the sediment surface. Burial was required to provide stable support for the pipe, to protect the pipe from wave action, and to address regulatory concerns (Parametrix 1987). Contaminated dredged material, removed from the path of the outfall by using a watertight clamshell, was placed in a depression 16 ft below MLLW near the old outfall (see Figure 8-3). These measures were completed in December 1987.

A second dredging project was performed for the barge unloading pier near the northeast corner of the waterway. Approximately 1,000 yd^3 of sediment were dredged from the toe of the slope at the base of the pier in February 1988. This material was placed in a second depression at 16 ft below MLLW close to the first disposal site (see Figure 8-3). The depression

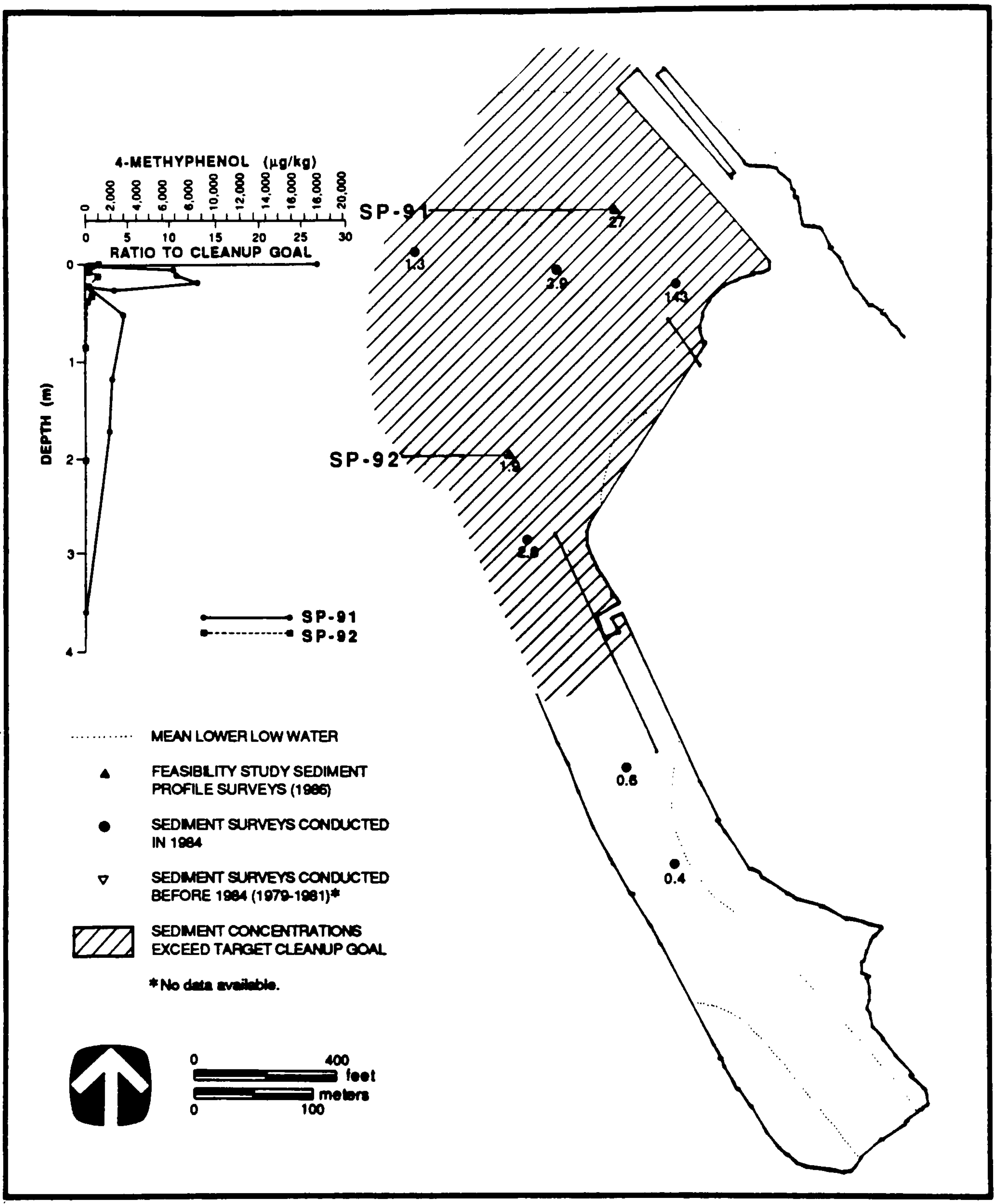


Figure 8-2. Areal and depth distributions of 4-methylphenol in sediments of St. Paul Waterway, normalized to long-term cleanup goal.

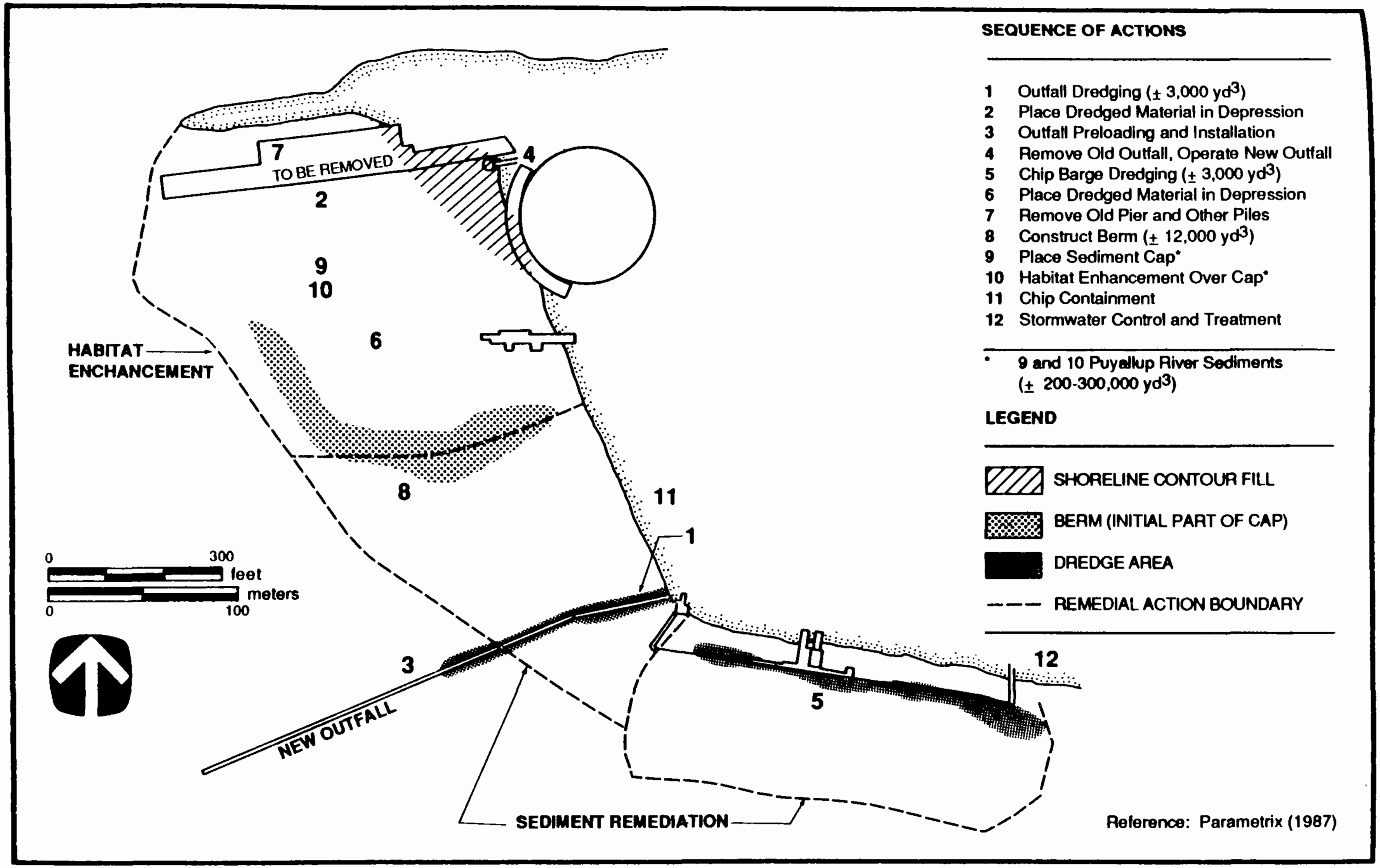


Figure 8-3. Remedial actions at the Simpson Tacoma Kraft Company facility.

was capped with clean fill from the Steilacoom Quarry. In the summer of 1988, the entire area was then capped 2-3 ft deep with approximately 238,000 yd^3 of clean fill from the Puyallup River (Ficklin, J., 9 November 1988, personal communication).

8.2 POTENTIAL SOURCES OF CONTAMINATION

This section provides an overview of the sources of contamination to the sediments in St. Paul Waterway and a summary of available loading information for 4-methylphenol. Table 8-1 provides a summary of problem chemicals and source status information for the problem area based on information derived from the RI studies (Tetra Tech 1985b, 1986c). The major source of contaminants that has been identified is the Simpson Tacoma Kraft pulp mill. Surface sediment concentrations of nearly all problem chemicals were greatest at Station SP-14, located immediately adjacent to the Simpson outfall (SP-189). Storm drains discharging to the waterway are also discussed in the section.

8.2.1 Simpson Tacoma Kraft Pulp Mill

Site Background--

The Simpson Tacoma Kraft Company occupies the peninsula between St. Paul Waterway and the Puyallup River. Activities at the site date from 1889, when the St. Paul and Tacoma Lumber Company began operations. The original mill was constructed south of 11th Street where a sawmill is currently located. In 1940, the St. Regis Company purchased waterfront land from the St. Paul and Tacoma Lumber Company and expanded its operation to the mouth of the waterway. In 1959, St. Regis acquired the St. Paul and Tacoma Lumber company. The pulp mill, located at the mouth of the waterway, and the facilities surrounding St. Paul Waterway were purchased from St. Regis Company by Champion International in 1984. The pulp mill was subsequently purchased by Simpson Tacoma Kraft Company in August 1985 (Parametrix 1987). To simplify discussion, contaminants from the area presently occupied by the Simpson Tacoma Kraft pulp mill are described as associated with Simpson operations, although Simpson only recently purchased the facility and some of the data or reports cited predate the change in ownership.

Simpson Tacoma Kraft Company, as its name suggests, operates a pulp and paper mill using the kraft process. Kraft pulping involves the use of sodium hydroxide and sodium sulfide to delignify wood chips so that the cellulose fibers can be separated. The mill produces unbleached Kraft linerboard, unbleached Kraft paper, bleached paper, and bleached market pulp.

Prior to 1970, untreated plant effluent was discharged to the Puyallup River. In late 1970, primary clarification was initiated and the outfall was moved to its current location (SP-189). The mill began secondary treatment of its wastewater in approximately 1975 (Fenske, F., 1 May 1987, personal communication), using a UNOX activated sludge process. Sludge is dewatered and burned in a hog fuel boiler at the mill. All sewers at the mill are routed to the treatment facility, although not all wastewater from the various mill processes pass through all stages of the treatment facility

TABLE 8-1. ST. PAUL WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
4-Methylphenol	1	Simpson Tacoma Kraft (SP-189)	Yes	Source loadings available for naphthalene only	Ongoing	Variable
Phenol	2					
2-Methoxyphenol	2					
1-Methyl-2-(methylethyl)-benzene	2					
Naphthalene	3					
2-Methylnaphthalene	3 (SP-14)					
Biphenyl	3 (SP-14)					
Total organic carbon	3 (SP-14)					
Total volatile solids	3 (SP-14)					
Nickel	3 (SP-14)					
Diterpenoid hydrocarbons	3 (SP-14)	Puyallup River	Potential	c	c	c
Retene	3 (SP-16)	Simpson Tacoma Kraft	Potential	c	c	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

(Fenske, F., 1 May 1987, personal communication). Wastewaters with low solids content (e.g., bleach plant wastewater, pump seal water) are routed directly to the secondary treatment process to reduce the hydraulic loading on the primary clarifiers. Limited information is available on the removal efficiencies for various contaminants through the mill's treatment system. Loading data for a 4-methylphenol are available from NPDES-permit monitoring data, but there are few data points (see Appendix E, Table E-18).

During the RI (Tetra Tech 1985a) and subsequent work (Tetra Tech 1985b, 1986c), contaminants of concern found in the sediments of St. Paul Waterway were determined to have originated from the mill. The mill is identified as a source based on proximity to the problem area in St. Paul Waterway, documented use of problem chemicals in mill processes, reduced concentrations of contaminants in sediments with distance from the mill outfall, and the presence of problem chemicals typically found in pulp mill effluents.

The mill has been identified as the major source of suspended organic matter (Tetra Tech 1985a) and is the only identified source of phenol to St. Paul Waterway (Tetra Tech 1986c). The mill is also an identified source of chloroform, copper, and naphthalene. The mill effluent was implicated as a source of 4-methylphenol based on the spatial distribution of 4-methylphenol in sediments adjacent to the outfall and on the possibility that 4-methylphenol is a degradation product of 2-methylphenol, a compound often found in pulp mill effluents (Tetra Tech 1985a). Subsequent analyses of the effluent verified the presence of 4-methylphenol, the only St. Paul Waterway sediment contaminant identified as Priority 1 in the RI (Tetra Tech 1985a). Parametrix (1986) verified the presence of chlorinated phenolic compounds, phthalate compounds, chloroform, copper, and zinc in the effluent.

Identification of Contaminant Reservoirs Onsite--

The primary source of contaminants to the St. Paul Waterway area sediments from the mill site appears to be effluent from the wastewater treatment facility (SP-189). Additional contaminant reservoirs or alternative pathways to the sediments have not been well characterized. There are two storm drains on the mill site and two storm drains at the head of St. Paul Waterway. Contaminant loadings from these drains have not been quantified. At the time of this study, insufficient information was available to characterize the relative importance of groundwater infiltration and surface runoff as potential sources of sediment contamination.

Recent and Planned Remedial Activities--

Simpson recently proposed a comprehensive remedial action and habitat restoration project in response to NPDES permitting requirements (Permit No. WA-000085-0). The following actions are included in that project:

- Relocate the secondary treatment outfall

- CAD contaminated sediments and restore nearshore habitat

- Control contaminant sources

- Monitor the effectiveness of implemented project measures.

The environmental studies and engineering plans for the proposed outfall relocation, remedial action, and habitat restoration have been reviewed and approved by Ecology.

Outfall Relocation--The Simpson permit requires relocation of the existing secondary treatment outfall (SP-189), which has been the primary source of sediment contamination in the area near the northeastern corner of the site (see Figure 8-3).

Installation of the new outfall system was completed in March 1988. The system is designed to provide a minimum design dilution ratio of 55:1 at a discharge depth of 70 ft below MLLW. However, with variations determined by tide stage, discharge rate, and other factors (Parametrix 1987) more common initial dilution ratios of 70:1 are expected. The new 48-in outfall pipe extends 920 ft offshore and terminates in a 180-ft long diffuser with 30 ports.

Sediment Remediation and Habitat Restoration--Simpson is planning to cap contaminated sediments in the vicinity of the old plant outfall (SP-189), eliminating exposure of biota and the water column to existing contamination. A submerged berm will be constructed to ensure containment of contaminated sediments, including dredged material from the outfall realignment and pier projects. Cap material (clean fill from the Puyallup River) will be placed over the contaminated sediments through a downpipe diffuser for controlled discharge. The depth of the cap will range from 4 to 12 ft. An additional 4-8 ft of sand and silt from the Puyallup River will be added to raise the sediment surface to intertidal or very shallow subtidal depths, thus providing intertidal habitat with sediment characteristics like those originally found in the area. The vicinity of the old outfall will be filled to above the highest tidal level (18 ft above MLLW) to provide maximum isolation and confinement of contaminated sediments (Parametrix 1987). This fill element will allow surface water control in the primary clarifier and hog fuel storage areas. The 0.6 ac of shallow-water shoreline to be converted to terrestrial land will be covered by an impervious surface, surrounded by a peripheral berm, and served by a runoff collection system. This phase of the project is scheduled for completion in August 1988.

Source Control (In-Plant)--Simpson has also initiated a contaminant source control effort to reduce contaminant concentrations in discharges to Commencement Bay to environmentally acceptable levels. The source control program consists of the following four elements:

- Reduce levels of harmful impurities in purchased chemicals or raw materials

- Treat runoff from plant processing areas

- Contain woody debris and wood chip feedstocks
- Make process modifications to reduce the ultimate discharge of harmful contaminants.

Although not named as priority chemicals for St. Paul Waterway during the RI, copper, chloroform, and chlorine had been identified by Simpson and Ecology as chemicals of potential concern.

Releases of chloroform, copper, and 4-methylphenol in plant discharge have declined since the program began (Parametrix 1987). Modifications to the mill's bleach plant are proposed over the next 2 yr to reduce chlorinated organics discharge in plant effluent. Copper loadings have been reduced as a result of Simpson placing more stringent specifications on the composition of Vanillin Black Liquor, a process material supplied by the Monsanto Company. In October 1985, Simpson established a maximum acceptable copper concentration of 60 mg/L for purchased Vanillin Black Liquor. In March 1986, Simpson lowered the maximum allowable concentration to 10 mg/L. According to Parametrix (1987), the annual input of copper from Vanillin Black Liquor to the effluent has been reduced by greater than 99 percent since 1985. Simpson has noted that additional minor contributions of copper to this region of Commencement Bay originate from City of Tacoma water, the Puyallup River, copper intrinsic in wood, and copper leached from process pipes.

Copper concentration in the effluent is currently measured daily (Fenske, F., 1 May 1987, personal communication). Average total and dissolved copper concentrations in secondary effluent samples are 51 ug/L (n=275) and 26 ug/L (n=144), respectively. The average background copper concentration in Commencement Bay is 8 ug/L. With the predicted dilution of 55:1, the copper concentration in the zone of initial dilution will be approximately 8.3 ug/L. Both the acute and chronic marine water quality criteria for copper are 2.9 ug/L. Simpson intends to conduct a rigorous monitoring program at the zone of initial dilution to evaluate actual dilution.

Discharge of 4-methylphenol from Simpson has reportedly decreased since 1986 (Parametrix 1987). Liquid salt cake (Na_2SO_4) from Northwest PetroChemical was apparently a major source of phenolic compounds in the effluent. Purchases of salt cake from Northwest PetroChemical were halted in the fall of 1986. Future purchases of salt cake will be contingent upon strict control of concentrations of phenols and other chemicals (e.g., cymenes). Parametrix (1987) estimated the annual contributions (ton/yr) of nine contaminants (including phenol) contained in the liquid salt cake, presumably to demonstrate that discontinuing use of this material would result in a large decrease in the discharge of the contaminants. However, neither the data from which the annual contributions were derived, nor the reasoning behind the assumptions used to calculate the annual contribution are provided in Parametrix (1987). In addition, contributions are attributed to "total phenolics", and the individual contributions of discrete compounds (e.g., 4-methylphenol) are not presented.

Acute and chronic bioassays of effluent were conducted in winter and spring of 1987. Results of the 96-h acute static bioassays on juvenile rainbow trout (Salmo gardneri) using 100 percent effluent showed 80-100 percent survival. In Ceriodaphnia chronic bioassays conducted on two samples of effluent, the lowest-observed-effect concentration varied from 10 to 100 percent.

Stormwater Runoff Controls--Stormwater controls (i.e., paving, grading, berms, and sumps) are being installed to collect and transport runoff from the plant site to the secondary treatment facility (Ficklin, J., 2 July 1987, personal communication). When the remedial program was initiated, runoff from the following areas discharged directly to the waterways (Figure 8-4):

- Primary clarifier and hog fuel storage area discharged directly to Commencement Bay
- Mill area adjacent to the Puyallup River discharged directly to Puyallup River
- Paper mill parking area and roof drains discharged to St. Paul Waterway (SP-269)
- Secondary treatment plant and parking area discharged to the Puyallup River via a sump.

During 1987, a portion of the site along the Puyallup River was paved and stormwater control facilities were installed. Under the remedial action plan (Parametrix 1987), this project will be extended to the remainder of the Simpson property along the Puyallup River (see Figure 8-3). In addition, areas around the primary clarifier and the hog fuel storage area will be filled and paved. Storm drains will be installed to collect and transport runoff to the treatment facility. Existing storm drains (SP-269 and SP-819) in the paper mill parking area will also be routed via a sump to the mill treatment system. Construction of stormwater control facilities is scheduled for completion in 1988.

Containment of Woody Materials--Construction of a new chip barge unloading facility to eliminate spillage during unloading from barges was completed during summer 1987. The chip storage piles were isolated from the bay by a paved, bermed, and fenced roadway. To contain the fine, readily suspended chip material, the area along the conveyor system adjacent to St. Paul Waterway was also paved, bermed, and fenced. In addition, water sprayers and conveyor belt brushes were added to minimize the resuspension potential of the fine material during conveyance.

8.2.2 Storm Drains

Three storm drains currently discharge to St. Paul Waterway: SP-269, SP-268-01, and SP-268-02 (Figure 8-5). Storm drain SP-269 collects surface runoff from the parking area and roof drains at the Simpson paper mill and was discussed in the previous section.

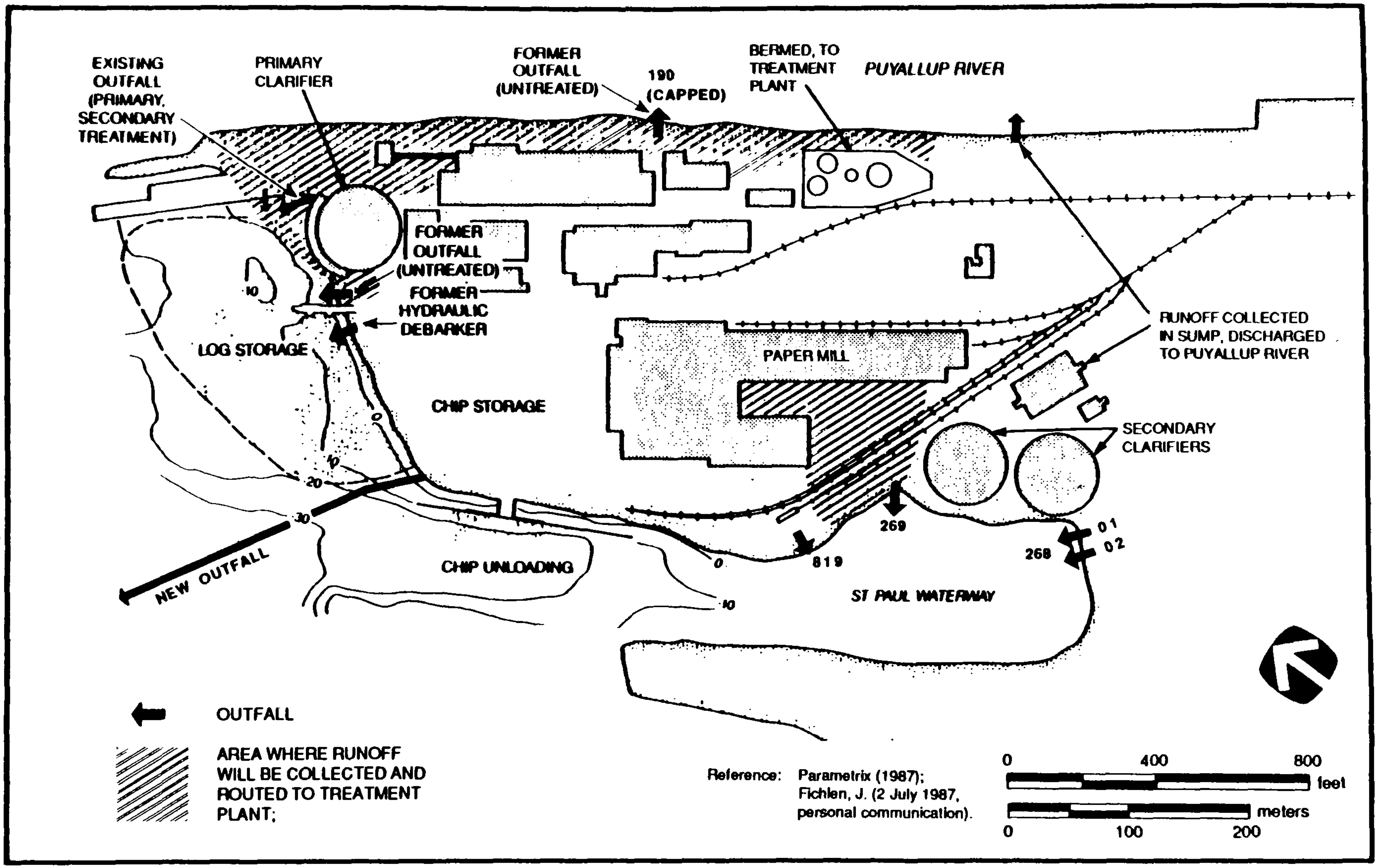
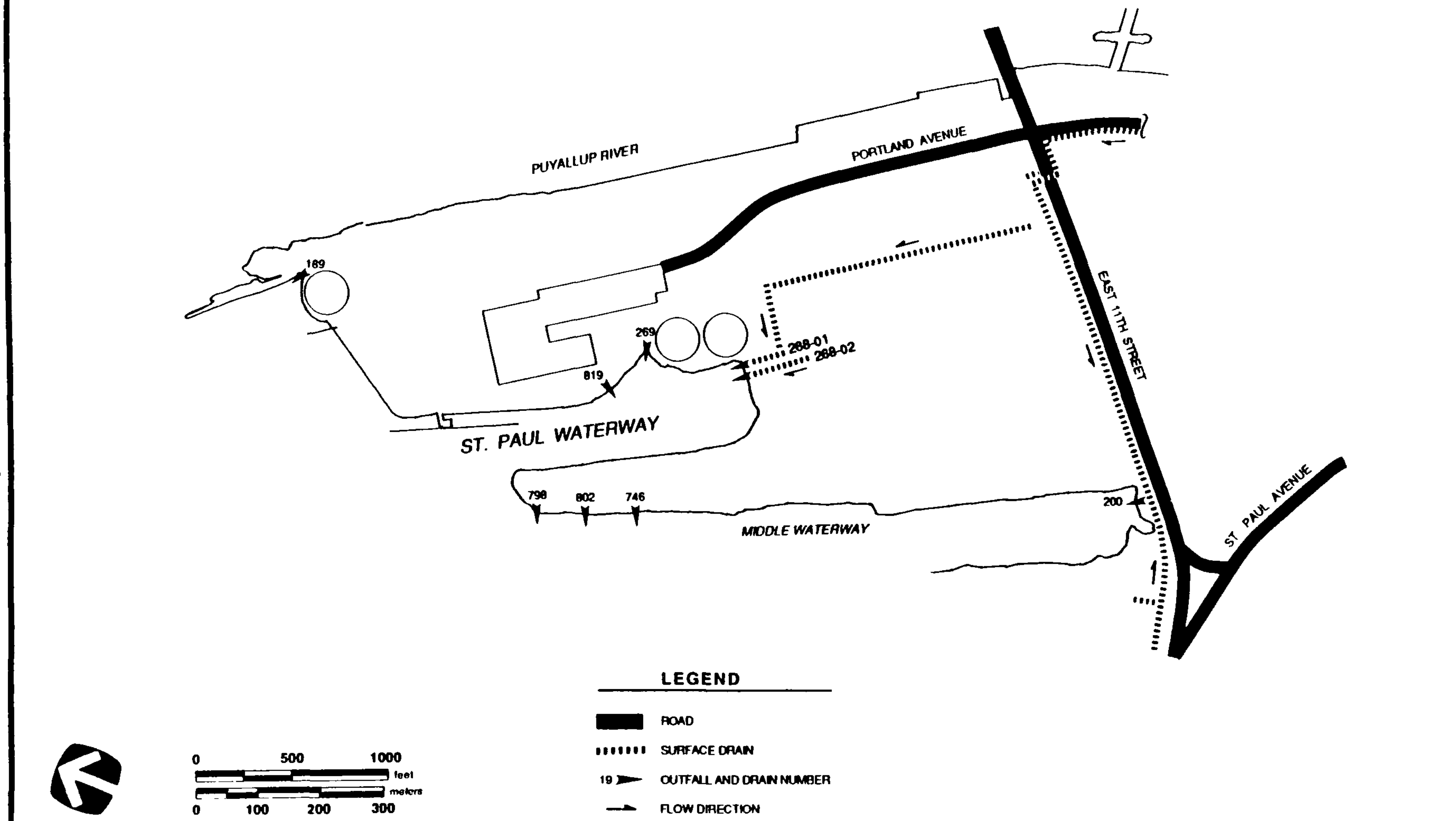


Figure 8-4. Proposed stormwater control areas at the Simpson Tacoma Kraft Company facility.



Reference: from Tacoma-Pierce County Health Department (1983).

Figure 8-5. Surface water drainage pathways to St. Paul Waterway.

The two remaining storm drains serve the area between the head of St. Paul Waterway and East 11th Street. Storm drain SP-268-01 serves approximately 35 ac comprising the Commencement Bay Company log storage facility and stud mill. In the past, SP-268-01 also drained a portion of the old St. Regis property (approximately 25 ac) located on the south side of 11th Street. This latter area currently drains to Middle Waterway via MD-200.

Discharge from SP-268-01 consists of stormwater runoff and noncontact cooling water. The Commencement Bay Company currently discharges between 90,000 and 100,000 gal/day (0.14-0.15 ft^3/sec) of cooling water to SP-268-01 (Corey, G., 6 August 1987, personal communication). The surface runoff component of the discharge is estimated at roughly 60 ac-ft/yr (0.08 ft^3/sec) based on an annual rainfall of 37 in (Norton and Johnson 1985a) and runoff coefficient of 0.5 (Viessman et al. 1977). The Commencement Bay Company plans to eliminate the discharge of cooling water to SP-268-01 by routing flows to the Simpson secondary treatment plant. When the rerouting is complete, the discharge from SP-268-01 will consist entirely of surface water runoff.

Storm drain SP-268-02 drains the area to the west of the SP-268-01 drainage basin. However, the basin boundaries and contributing area are not known.

Loading data for the contaminants of concern [i.e., phenol, 4-methylphenol, 2-methoxyphenol, and 1-methyl-2-(methylethyl)benzene] in St. Paul Waterway are not available for SP-268-01 and SP-268-02. However, estimates derived from available sediment data suggests that these drains are not currently contributing significant concentrations of problem chemicals to St. Paul Waterway sediments. Existing data indicate that both storm drains may be a source of solids loading to the waterway (Tetra Tech 1986c). Land use in the drainage basins of both drains has historically been associated with the forest products industry (i.e., sawmills and log storage yards). In addition to wood wastes, surface runoff from the basins may have been contaminated by glue because historically glue residues were commonly disposed of on sawdust piles.

8.2.3 Loading Summary

There are very few loading data for discharges into St. Paul Waterway. Source contaminant loading calculations presented in Appendix E, Table E-18, and where possible have been updated to include data collected since the completion of the Remedial Investigation (Tetra Tech 1985a, 1986c). Post-RI loading data are available for the Simpson main outfall SP-189 (Parametrix 1987) and have been incorporated into the appendix.

8.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated.

This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated. This evaluation was based on the sediment contaminant concentrations and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to correct existing sediment contamination problems over the long term.

8.3.1 Feasibility of Source Control

The main source associated with sediment contamination in St. Paul Waterway is process effluents from the Simpson Tacoma Kraft Company pulp mill.

The Simpson NPDES outfall (SP-189) was identified as a major source of 4-methylphenol and other chemicals (Tetra Tech 1985a). Available technologies for reducing process effluents (see Chapter 3) include primary and secondary wastewater treatment outfall relocation, and in-plant contaminant reduction through process changes and product substitution.

A number of these technologies have been implemented by Simpson Tacoma Kraft and its predecessors. Primary and secondary wastewater treatment systems were installed in 1963-64 and 1977, respectively. In March 1988, Simpson completed construction of an extended outfall and diffuser system. This system is expected to effectively eliminate the discharge of suspended solids from the plant. Discharge at the -70 ft MLLW elevation with the diffuser system and resultant minimum dilution of 55:1 are expected to prevent flocculation and settling of suspended solids and dissolved constituents in the plant effluent (Parametrix 1987). Moving the outfall to an offshore site is also expected to minimize effluent transport toward the shoreline (Parametrix 1987). Finally, the pulp mill has been effective in minimizing the production of process contaminants and removing contaminants from purchased chemicals (Parametrix 1987).

Continued operation of existing pollution measures and implementation of additional in-plant controls is expected to result in a significant reduction in contaminant discharges. Given the contaminant types, multiplicity of sources, and available control technologies, it is estimated that implementation of all known, available, and reasonable control technologies will reduce contaminant loading due to process effluent by up to 95 percent (the maximum assumed feasible).

Because major contaminant sources or pathways other than the effluent have not been positively identified or quantified and Simpson has implemented or has planned control measures for sources such as runoff, no other source controls are recommended at the pulp mill. Monitoring should be undertaken to assess the effectiveness of the implemented source control measures and to assess whether additional source control measures should be taken to prevent further contamination of Commencement Bay and St. Paul Waterway.

8.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemical 4-methylphenol. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional parameters in St. Paul Waterway were estimated from the overall depositional patterns observed for Commencement Bay. A sedimentation rate of 1,000 $mg/cm^2/yr$ (0.70 cm/yr) and a mixing depth of 10 cm were selected. This sedimentation rate is supported by the location of the problem area seaward of the main waterway channel and an estimated reduction in sediment loading with the relocation at the Simpson outfall. A single indicator chemical, 4-methylphenol, was used to evaluate the effect of source control and the degree of source control required for sediment recovery. Two timeframes for sediment recovery were considered: a reasonable timeframe (defined as 10 yr) and the long term. A decay constant of 0.693 (i.e., a half-life of 1 yr) was used to illustrate the effect of potential diffusive or biodegradative losses on sediment recovery (Tetra Tech 1987a). However, the possibility of in situ production of 4-methylphenol indicates that a more conservative assumption of no significant loss may be more appropriate. Source loading of 4-methylphenol is assumed to be in steady-state with sediment accumulation for the purposes of establishing the relationship between source control and sediment recovery. This assumption is conservative based on the extensive source control measures that have been implemented or planned. Results of the source control evaluation are summarized in Table 8-2.

Effects of Complete Source Elimination--

If sources are completely eliminated, a recovery time of 70 yr is predicted for sediments contaminated with 4-methylphenol. Sediment recovery is not possible in a reasonable timeframe (i.e., 10 yr), and sediment remedial actions will be required.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source control is expected to reduce source inputs of 4-methylphenol by 95 percent. At this level of source control, the model predicts that sediments with an enrichment ratio of 1.9 or less (i.e., 1,270 ug/kg or less of 4-methylphenol) will recover to the long-term cleanup goal within 10 yr (Table 8-2). The surface area of sediment not recovering to the cleanup goal within 10 yr is shown in Figure 8-6. For comparison, sediments currently exceeding long-term cleanup goals for indicator chemicals are also shown.

TABLE 8-2. ST. PAUL WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemical 4-Methylphenol
Station with Highest Concentration	
Station identification	SP-14
Concentration (ug/kg dry weight)	96,000
Enrichment ratio[a]	143
Recovery time if sources are eliminated (yr)	70
Percent source control required to achieve 10-yr recovery	NP[b]
Percent source control required to achieve long-term recovery	99
Average of Three Highest Stations	
Concentration (ug/kg dry weight)	38,900
Enrichment ratio[a]	58
Percent source control required to achieve long-term recovery	98
10-Yr Recovery	
Percent source control assumed feasible	95
Highest concentration recovering in 10 yr (ug/kg dry weight)	1,270
Highest enrichment ratio of sediment recovering in 10 yr	1.9

[a] Enrichment ratio is the ratio of observed concentration to cleanup goal.

[b] NP = Not possible.

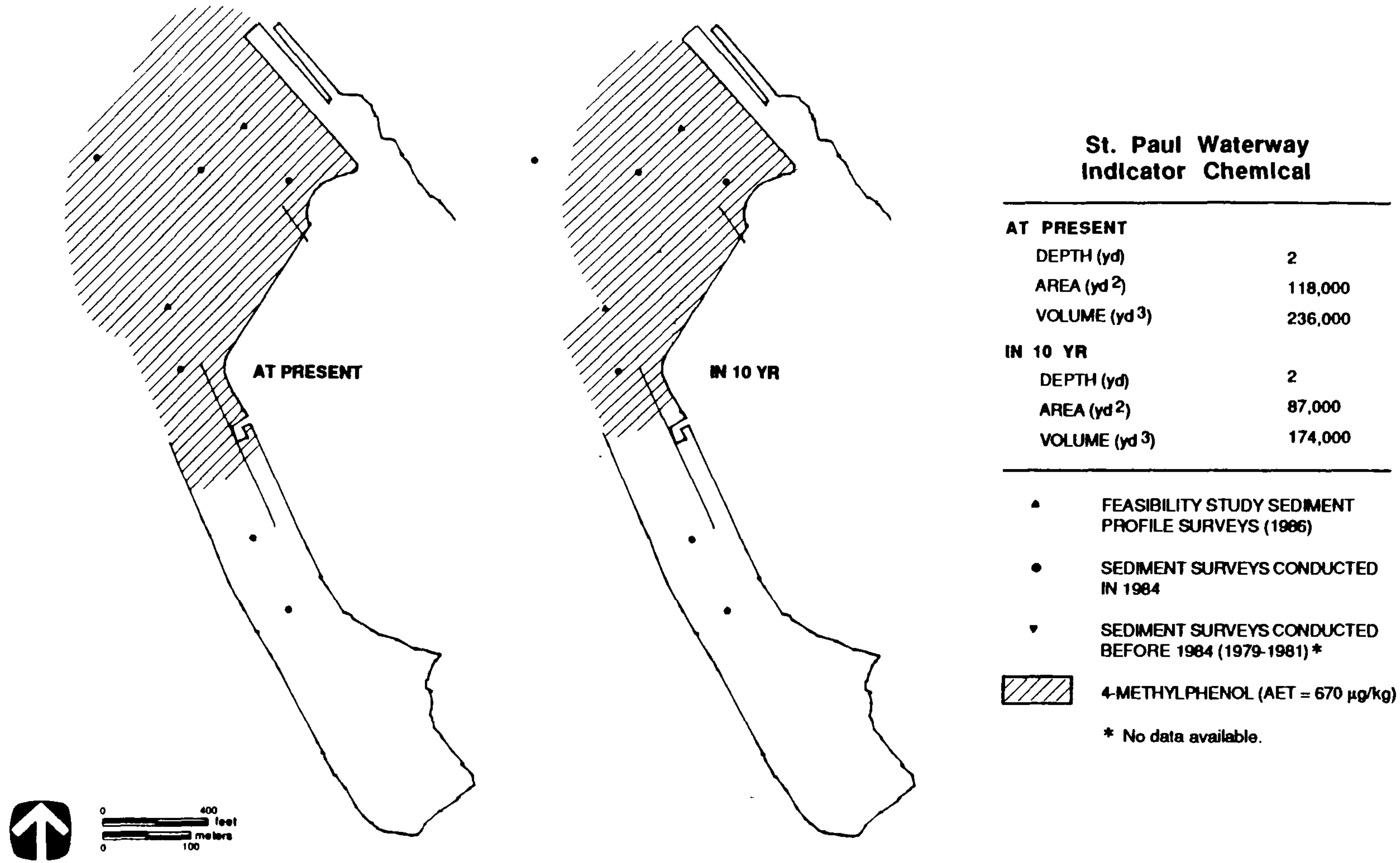


Figure 8-6. Sediments in St. Paul Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that virtually all of the 4-methylphenol input must be eliminated to maintain acceptable contaminant concentration in freshly deposited sediments. However, the actual percent reduction required in source loading is subject to the considerable uncertainty inherent in the assumptions of the predictive model.

8.3.3 Source Control Summary

The major source of 4-methylphenol to St. Paul Waterway is believed to be the Simpson Tacoma Kraft Mill effluent. If this source is completely eliminated it is predicted that sediment concentrations of the chemical will not decline to the long-term cleanup goal of 670 ug/kg until 70 yr have passed. Sediment remedial action will therefore be required to attain quality goals within a reasonable timeframe. The source control measures that have been, or will be, implemented are expected to be effective in maintaining adequate sediment quality following remediation. Ongoing monitoring following the implementation of remedial actions will provide the data necessary to confirm this assumption. The 3 percent difference between required and achievable levels of control (see Table 8-2) is not expected to be significant in light of the uncertainties inherent in the sediment recovery model.

8.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with 4-methylphenol concentrations exceeding the long-term cleanup goal is 236,000 yd^3 (see Figure 8-6). This volume was estimated by multiplying the areal extent of sediment exceeding the cleanup goal (118,000 yd^2) and the estimated 2-yd depth of contamination (see sediment contaminant profiles in Figure 8-2). The estimated thickness of contamination is only an approximation; few sediment profiles were collected and the vertical resolution of these profiles was poor at the depth of the contaminated horizon. For the volume calculations, depths were overestimated. This approach was taken to reflect the fact that depth to the contaminated horizon cannot be accurate dredged, to account for dredge technique tolerances, and to account for uncertainties in sediment quality at locations between the sediment profile sampling stations.

The estimated volume of sediment requiring remediation is 174,000 yd^3, based on the volume of sediment that is expected to exceed the 4-methylphenol long-term cleanup goal 10 yr after implementing feasible levels of source control. This value was calculated as the product of the area of sediment with an enrichment ratio greater than 1.9 (87,000 yd^2; see Table 8-2) and the depth of contamination (2 yd; see Figure 8-2).

8.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

8.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, this set of alternatives is evaluated to determine the suitability of each for the remediation of contaminated sediments in St. Paul Waterway. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess of the applicability of each alternative to remediation of contaminated sediments in St. Paul Waterway. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; the location of potential disposal areas; and the site's physical properties including waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

The indicator chemical 4-methylphenol was selected to represent inputs from the primary sources of contamination to the waterway: the Simpson Tacoma Kraft pulp mill and associated storm drains. Areal distribution of the indicator chemical is presented in Figure 8-6 based on long-term cleanup goals and estimated 10-yr sediment recovery. Sediment recovery estimates indicate that a reduction of approximately 25 percent could be achieved in 10-yr with 95 percent control of sources.

The predominance of organic contamination in St. Paul Waterway sediments indicate that a treatment process for organics is appropriate. The presence of metals at a total concentration of less than 500 mg/kg would not be expected to limit the applicability of solvent extraction, thermal treatment, or land treatment. Alternatives incorporating these treatment processes are evaluated for St. Paul Waterway. Solidification, however, is unlikely to be successful because of the high concentrations of total organic carbon and organic contaminants, and is therefore not evaluated.

It is assumed that the requirement to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

Nine of the 10 sediment remedial alternatives are evaluated below for the cleanup of St. Paul Waterway:

- No action
- Institutional controls
- In situ capping
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal

- Clamshell dredging/solvent extraction/upland disposal
- Clamshell dredging/incineration/upland disposal
- Clamshell dredging/land treatment.

8.5.2 Evaluation of Candidate Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix assessing each alternative based on effectiveness and implementability is presented in Table 8-3. A comparative evaluation of alternatives based on ratings of high, moderate, and low in the various subcategories of evaluation criteria is presented in Table 8-4. These subcategories are short-term protectiveness; timeliness; long-term protectiveness; reduction in toxicity, mobility, or volume; technical feasibility; institutional feasibility; availability; capital costs; and O&M costs. Remedial costs are shown for sediments currently exceeding long-term cleanup goal concentrations and for sediments that would still exceed the cleanup goal concentrations 10 yr after implementing feasible source controls (i.e., 10-yr recovery costs).

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts continue if the contaminated sediments remain in place unaltered. Source control measures initiated as part of the institutional controls would result in reduced sediment contamination with time, but adverse impacts would persist in the interim. The clamshell dredging/land treatment alternative is also rated low for this criterion; 4-methylphenol has a relatively high solubility [2.5 g/100 mL of water at 50^{o} C (Windholz et al. 1983)] which enhances its potential for migration from the treatment site.

The clamshell dredging/nearshore disposal alternative is rated moderate for short-term protectiveness primarily because nearshore intertidal habitat could be lost in siting the disposal facility. The clamshell dredging/confined aquatic disposal and hydraulic dredging/upland disposal options also are assigned a moderate rating. The potential for enhanced partitioning to the water column during hydraulic dredging or subaquatic disposal of sediments containing a relatively soluble compound with low particle affinity (Tetra Tech 1987c) may result in water column and environmental impacts and contaminant redistribution during dredging. Alternatives involving treatment (except land treatment) received moderate ratings for short-term protectiveness because all involve additional dredged material handling, longer implementation periods, and increased air emissions which increase potential worker exposure. The hazards inherent in the solvent extraction and incineration treatment processes themselves are also considerable. The use of a watertight clamshell dredge for excavation may enhance protectiveness during implementation. However, the potential material handling hazards would tend to moderate any improvement that may be

TABLE 8-3. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE ST. PAUL WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	IN SITU CAPPING	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ LAND TREATMENT
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is not a concern in the implementation of this alternative. CDM exposure and handling are minimal.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge and disposal sites is restricted. Clamshell dredging, land transport, and extended duration of treatment operations in open environment raise exposure risks.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Workers are not exposed to contaminated sediments.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear.	Incineration of CDM is accomplished over an extended period of time thereby increasing exposure risks. Workers wear protective gear.	Land treatment of CDM is accomplished over an extended period of time thereby increasing worker exposure. CDM is tilled into the treatment soil. Exposure potential decreases with time as degradation occurs.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Contaminant redistribution is minimized. Existing contaminated habitat is destroyed and replaced with clean material. Rapid recolonization is expected.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment with low particle affinity is resuspended during dredging operations. Benthic habitat is impacted at the disposal site.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment with low particle affinity is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations.	Existing contaminated habitat is destroyed by dredging but recovers rapidly. Sediment is resuspended during dredging operations. Process controls are required to reduce potential air emissions.	Existing contaminated habitat is destroyed by dredging but recovers rapidly. Sediment is resuspended during dredging operations. Contaminant has relatively high solubility which enhances its potential for migration from the treatment site.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked ninth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. This alternative is ranked eighth overall for timeliness.	In situ capping can be implemented quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available and disposal siting issues should not delay implementation. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available and disposal siting issues are not likely to delay implementation. This alternative is ranked second for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked fourth overall for timeliness.	Bench and pilot scale testing are required. Full scale equipment is available. Once approval is obtained, treatment should be possible within 2 years. This alternative is ranked fifth overall for timeliness.	Substantial CDM testing and incinerator installation time is required before a thermal treatment scheme can be implemented. Once approval is obtained, treatment should be possible within 2 years. This alternative is ranked sixth overall for timeliness.	Substantial testing would be required on the degradability of contaminants and to determine optimal operating conditions. Treatment would probably require a demonstration project, a long treatment period, and a closure phase. This alternative is ranked seventh overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant re-exposure in the absence of physical disruption is considered good.	The long-term reliability of the cap to prevent contaminant re-exposure in a quiescent, subaquatic environment is considered acceptable.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.	Liner, run-on, and runoff controls reliable. Potential system failure becomes less critical with time, as treatment progresses.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Permanent treatment for organic contaminants is effected.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.	There is potential for public health impacts as a result of contaminant migration from treatment facility. CDM is not confined.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area. Nearshore site is dynamic in nature.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Residual contamination is reduced below harmful levels.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.	Design features of land treatment system preclude contaminant migration to groundwater or surface water. Control of volatile emissions is limited.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Harmful contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Toxicity and mobility considerations are eliminated. Volume of contaminated material is substantially reduced.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential. Volume of contaminated material is substantially reduced.	Treatment of degradable organic compounds eliminates this component of CDM toxicity. Metals are not treated. Mobility of metals may be enhanced by aerobic soil conditions.

TABLE 8-3. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	IN SITU CAPPING	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ LAND TREATMENT
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredges and diffuser pipes are conventional and reliable equipment. In situ capping is a demonstrated technology.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, although feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Although still in the developmental stages, sludges, soils, and sediments have successfully been treated using this technology. Extensive bench- and pilot-scale testing are likely to be required.	Incineration systems capable of handling CDM have been developed, but no applications involving CDM have been reported. Effects of salt and moisture content must be evaluated. Extensive bench- and pilot-scale testing are likely to be required.	Land treatment is a demonstrated technology for materials contaminated with degradable organic compounds. Extensive bench- and pilot-scale testing are likely to be required.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Monitoring implementability is enhanced compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring is required only to evaluate the reestablishment of benthic communities. Monitoring programs can be readily implemented.	Disposal site monitoring is not required if treated CDM is determined to be nonhazardous. Air quality monitoring is intensive during implementation.	Monitoring programs can be readily implemented. Extensive monitoring is required during active treatment period, with less required during closure.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	O & M consists of maintaining monitoring equipment, optimal soil conditions, tilling equipment, and groundskeeping. Site inspections are required.
	INSTITUTIONAL FEASIBILTY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals depend largely on results of pilot testing and the nature of treatment residuals.	Approvals for incinerator operation depend on pilot testing and ability to meet air quality standards.	Treatment facility siting and operation require extensive agency review prior to approval.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/ SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed. This alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant mobility. Requires RCRA permit for disposal of concentrated organic waste.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant toxicity and mobility. Requires compliance with PSAPCA standards.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's policy for toxicity reduction and onsite disposal.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement this alternative are readily available.	Equipment and methods to implement alternative are readily available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Process equipment available. Disposal site availability is not a primary concern because of reduction in hazardous nature of material.	Incineration equipment can be installed onsite for CDM remediation efforts. Applicable incinerators exist. Disposal site availability is not a concern because of reduction in hazardous nature of material.	Availability of land treatment site is uncertain.

TABLE 8-4. EVALUATION SUMMARY FOR ST. PAUL WATERWAY

	No Action	Institutional Controls	In Situ Capping	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Extraction/ Upland Disposal	Clamshell/ Incinerate/ Upland Disposal	Clamshell/ Land Treatment
Short-Term Protectiveness	Low	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Timeliness	Low	Low	High	Moderate	High	Moderate	Moderate	Moderate	Low
Long-Term Protectiveness	Low	Low	High	High	Moderate	Moderate	High	High	Moderate
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	Low	High	High	Moderate
Technical Feasibility	High	High	High	Moderate	High	High	Moderate	Moderate	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Availability	High	High	High	Moderate	High	Moderate	Moderate	Moderate	Low
Long-Term Cleanup Goal Cost[a]									
Capital	--	6	909	1,825	5,749	10,281	49,841	113,348	8,295
O&M	--	1,142	1,317	293	311	475	453	453	294
Total	--	1,148	2,226	2,118	6,060	10,756	50,294	113,801	8,589
Long-Term Cleanup Goal with 10-yr Recovery Cost[a]									
Capital	--	6	672	1,341	4,234	7,568	36,742	83,566	6,154
O&M	--	876	1,282	218	231	352	335	335	222
Total	--	882	1,954	1,559	4,465	7,920	37,077	83,901	6,376

[a] All costs are in $1,000.

realized by reduced sediment resuspension. Studies conducted by Parametrix (1987) as part of the Simpson Tacoma Kraft remedial action effort have also suggested the possibility that hydrogen sulfide is present in the predominantly anaerobic sediments in the problem area. This factor may result in an air quality problem when staging materials for the treatment alternatives.

The in situ capping alternative rated high for short-term protectiveness. With in situ capping the contaminated sediments are left in place, which eliminates the potential for public or worker exposure. Contaminant redistribution is also minimized.

Timeliness--

The no-action, institutional controls, and land treatment alternatives received low ratings for timeliness. With no action, sediments remain unacceptably contaminated, source inputs continue, and natural sediment recovery is unlikely. Source inputs are controlled under the institutional controls alternative but as discussed in Section 8.3.2, sediment recovery based on the indicator contaminant 4-methylphenol is estimated to be improbable within 10 years. Land treatment would probably require a demonstration project, a relatively long treatment period, and a closure phase. Approval and siting considerations are likely to adversely affect the timeliness of this alternative.

Moderate ratings are assigned to all treatment alternatives, except land treatment, and to the dredge alternatives involving upland and confined aquatic disposal. Approval, siting, and development of upland or confined aquatic disposal sites is estimated to require a minimum of 1-2 yr to complete. However, equipment and methods used require no development period, and pre-implementation testing is not expected to be extensive. These conditions suggest that the upland and confined aquatic disposal alternatives can be accomplished in a much shorter period of time if treatment is not involved. The solvent extraction and incineration alternatives are likely to require a period of extensive testing before being accepted. However, once approval is obtained, treatment of the contaminated sediments in St. Paul Waterway should be possible within approximately 2 yr, assuming maximum treatment rates of 420 yd^3/day (see Section 3.1.5).

The capping and nearshore disposal alternatives are rated high for timeliness. Pre-implementation testing and modeling may be necessary to evaluate potential releases caused by dredging and contaminant migration through the cap, but such testing is not expected to require an extensive period of time. Equipment and methods are readily available, and disposal siting issues are less likely to delay implementation than for alternatives involving upland and confined aquatic disposal.

Long-Term Protectiveness--

The evaluation for long-term protectiveness results in low ratings for the no-action and institutional controls alternatives because the timeframe for sediment recovery is long. For the latter alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source reductions. The observed adverse biological impacts continue.

Moderate ratings are assigned to the clamshell dredging/nearshore and hydraulic dredging/upland disposal alternatives based on the relatively high solubility and migration potential of 4-methylphenol. Physicochemical changes may also affect the migration potential of 4-methylphenol. However, these effects would not be as significant as those for inorganic materials and can be minimized by placing contaminated dredged material below the MLLW level. Dredged material testing should provide the necessary data on the magnitude of these impacts. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature (i.e., from wave action and tidal influences). Even though the upland disposal facility is generally regarded as a more secure option because of improved engineering controls during construction, the potential for impacts on area groundwater resources offsets the improvement in long-term security. Although the alternative involving land treatment should be effective in degrading this organic contaminant, a moderate rating was assigned to reflect the potential for contaminant migration. In addition, the Oil and Hazardous Materials/Technical Assistance Data System (OHMTADS) indicates that 4-methylphenol exhibits significant toxicity potential in both freshwater and marine environments.

Because the solvent extraction and incineration alternatives are expected to be highly effective in treating 4-methylphenol contamination based on the physicochemical properties of the compound, a high rating for long-term protectiveness was assigned. The treated solids could be confined in a standard landfill, assuming that the material is considered non-hazardous. Both the in situ capping and confined aquatic disposal alternatives are also rated high for long-term protectiveness. Isolation of contaminated material in the subaquatic environment provides a high degree of protection, with little potential that sensitive environments will be exposed to sediment contaminants. Currents and wave energy are thought to be low in the problem area based on the presence of a sandbar from the Puyallup River delta in the vicinity of the contaminated sediments and the presence of high percentages of fine-grained material (Parametrix 1987). Relocation of the NPDES outfall is expected to result in increased deposition of Puyallup River sediments. In addition, confinement under in situ conditions aids in maintaining the physicochemical conditions of the contaminated sediments, thereby minimizing potential contaminant migration.

Reduction in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except those involving treatment. Although capping, confined aquatic disposal, upland, and nearshore disposal alternatives isolate contaminated sediments from the surrounding environment, the chemistry and toxicity of the material itself would remain largely unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated dredged material may actually be increased by physicochemical changes. Without treatment, the toxicity of contaminated sediments would remain at preremediation levels. Contaminated sediment volumes would not be reduced, and, with hydraulic dredging options, may actually increase because of suspension of the material in an aqueous slurry.

The land treatment alternative received a moderate rating for this criterion based on the potential for leaching or migration of contaminants from the treatment facility. Although run-on and runoff controls would be incorporated, 4-methylphenol is soluble and its potential toxicity would cause significant hazards if the compound migrated off-site.

Alternatives involving extraction and incineration would effectively remove or destroy organic contaminants and therefore received high ratings. These treatment systems should produce an effective reduction in the toxicity and mobility of sediments through the removal (solvent extraction) or destruction (incineration) processes. The solvent extraction process also concentrates contaminants into a small volume of residual material. Bench-scale testing of treatment residuals should provide data to substantiate or invalidate these conclusions.

Technical Feasibility--

Alternatives involving treatment received only moderate ratings for the criterion of technical feasibility because the treatment processes have never been applied to sediment remediation. All processes are believed to be suitable for this application, but lack of experience and demonstrated performance in the use of these processes for treatment of contaminated dredged material warrants caution. Extensive bench- and pilot-scale testing are likely to be required before the technical feasibility of treatment via solvent extraction, incineration, or land treatment could be assured. A moderate rating was also assigned to the option for dredging with confined aquatic disposal at an open-water site. Placement of dredge and capping materials at depths of approximately 100 ft is difficult, although feasible. Considerable effort and resources may be required to monitor the effectiveness and accuracy of dredging, disposal, and capping operations.

High ratings are warranted for the remaining alternatives because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective elsewhere for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives were assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings were assigned to the remaining alternatives because of potential difficulty obtaining agency approvals for disposal sites or implementation of treatment technologies. Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. In addition, excavation and disposal of untreated contaminated sediment is discouraged by recent RI/FS guidance documents (U.S. EPA 1988b). Agency approvals or granting of permits is assumed to be contingent upon a bench-scale demonstration of effectiveness in meeting established performance goals.

Availability--

Sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities are rated high for availability. Because of the nature of the no-action and institutional controls alternatives, equipment and siting availability are not obstacles to implementation. Disposal site availability is not an obstacle to implementation of the in situ capping alternative because the disposal site is the contaminated site. The nearshore disposal alternative received a high rating because it was assumed that the Blair Waterway site would be available.

Remedial alternatives with upland or confined aquatic disposal are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that sites identified in a U.S. Army Corps of Engineers survey (Phillips et al. 1985) will be available. However, no sites are currently approved for use and no sites are currently under construction. Equipment availability is not expected to preclude implementation of either the solvent extraction or incineration alternatives.

The availability of a land treatment site suitable for the remediation of contaminated dredged material is even less certain than that for conventional nearshore and upland disposal sites. Therefore, land treatment received a low rating for the availability criterion.

Costs--

Capital costs increase with increasing complexity (i.e., from no action to the treatment options). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for clamshell dredging/nearshore disposal, primarily due to underdrain and bottom liner installation, dredge water clarification, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of the extraction alternative increases because of materials for the process, and labor for material handling and transport. Clarification and dredge water management costs are also incurred for this option.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., in situ capping, confined aquatic disposal). Costs for monitoring of in situ capping and the confined aquatic disposal facility are significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide adequate depth resolution. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring the collection of only a single groundwater sample at each well to assess containment migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (exceeding AET values) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the treatment alternatives are significantly lower because the process results in lower contaminant migration potential.

8.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the preceding evaluation of nine candidate remedial alternatives for St. Paul Waterway, in situ capping has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., in situ capping) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. Because the waterway is shallow and is not designated for use in commercial shipping, in situ capping would provide a high degree of protectiveness and may also improve valuable nearshore habitat. By preserving the physicochemical conditions of the contaminated sediments and not disturbing material, this alternative would result in lowered potential for migration or redistribution of the relatively soluble contaminant 4-methylphenol, compared with alternatives involving dredging. The weak particle affinities exhibited by the organic contaminants may enhance migration potential during dredging as well. Bench-scale sediment column studies should be conducted to quantify contaminant mobilization potential and provide a basis for determining cap thickness. Capping contaminated sediments in St. Paul Waterway is expected to provide reliable long-term protection of both public health and the environment. The alternative may also serve to enhance the estuarine habitat in the area. The alternative can be readily implemented with available equipment, which has been used for in situ capping and as an element of confined aquatic disposal. Monitoring to evaluate long-term performance of the cap would not pose technical difficulties. With a total estimated cost of approximately $2.0 million (including initial costs and the present worth of a 30-yr monitoring and O&M program), in situ capping also appears to be cost-effective.

In situ capping rates high for all evaluation criteria except institutional feasibility (moderate) and reduction in toxicity, mobility, or volume (low). No other alternative received as many high ratings as in situ capping.

In comparison to confined aquatic, nearshore, and upland dredging and disposal alternatives, in situ capping eliminates exposure risks that accompany dredging of contaminated materials. From a contaminant mobility standpoint, the maintenance of in situ conditions is preferable to the physicochemical changes that can occur in nearshore and upland environments. In situ capping also eliminates the potential for excessive partitioning of contaminants to the water column as a result of sediment disturbance. The uncertainties associated with upland and confined aquatic disposal site availability and the bias against landfilling of untreated CERCLA/SARA waste lower the overall ratings of these dredge/disposal alternatives. The possibility of gaining nearshore habitat as a result of capping compares favorably with potential losses of nearshore habitat arising from implementation of a nearshore disposal alternative.

Treatment-based remedial alternatives were not considered preferable to capping because they would take longer to implement and cost $4.4 million to $82 million more to implement. If treatability testing revealed that incinerated or solvent-extracted solid residues were nonhazardous, these treatment alternatives would provide a better long-term protectiveness and greater reductions in toxicity and mobility. However, in situ capping can likely provide adequate protectiveness cost-effectively.

The no-action and institutional controls alternatives were not selected because their implementation would not meet long-term cleanup goals.

8.7 CONCLUSIONS

St. Paul Waterway was identified as a problem area because of the elevated concentrations of several organic contaminants in sediments. The compound 4-methylphenol was selected as the indicator chemical to assess source control requirements, evaluate sediment recovery, and estimate the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 118,000 yd^2, and a volume of 236,000 yd^3. Of the total sediment area currently exceeding cleanup goals, 31,000 yd^2 is expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 62,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 174,000 yd^3.

The primary identified source of problem chemicals to St. Paul Waterway is the Simpson Tacoma Kraft facility. Source control measures required to correct the identified problems, and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Control problem chemicals in process effluents (primarily phenolics)
- Confirm that all sources of problem chemicals have been identified and controlled
- Monitor sediments regularly to confirm sediment recovery predictions and assess the adequacy of source control measures.

Several source control measures have already been implemented, including relocation of the process effluent outfall.

The maximum achievable degree of source control assumed for this FS is 95 percent, yet the model predicts that 98 percent reduction of 4-methylphenol is required to maintain acceptable sediment quality over time. The difference between these two values is not expected to be significant, given the uncertainties and protective assumptions built into the model. Thus, it appears possible to control sources sufficiently to maintain acceptable long-term sediment quality following sediment remediation. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. Source control requirements were developed through application of the sediment recovery model for the indicator chemical 4-methylphenol.

In situ capping was recommended as the preferred alternative for remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at in situ conditions. In situ capping minimizes the potential for redistribution or solubilization of the organic contaminants. The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

The findings of a remedial action study (Parametrix et al. 1987) for St. Paul Waterway are in general agreement with those presented in this FS. The boundaries of the area for sediment remediation presented in the remedial action study are also similar to those identified in this FS. In addition, the remedial action proposed in the remedial action study (i.e., capping) is the same as the preferred alternative identified in this FS. Capping of sediments was accomplished through an Ecology Consent Decree in August 1988.

Monitoring in the sediment remedial area and at the Simpson Tacoma Kraft outfall will be required to verify the effectiveness of remedial measures. The area exceeding long-term cleanup goals is proposed for inclusion in the post-remediation confirmation study to confirm proper placement of the cap. This approach differs from the area generally designated for the post-remediation confirmation study (i.e., the area exceeding long-term goals with 10 yr recovery), but is considered environmentally protective. If monitoring demonstrates that remedial actions have not been effective, then additional source control or sediment remedial measures may be required. As indicated in Table 8-4, in situ capping provides a cost-effective means of sediment mitigation. The estimated cost to implement this alternative is $672,000. Environmental monitoring and other O&M costs at the disposal site have an estimated present worth of $1,282,000 for a period of 30 yr. These costs include long-term monitoring of the capping and sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of preferred alternative is $1,954,000.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations and remedial actions proposed by the potentially responsible parties, utilize the most protective solutions practicable, and are cost-effective.

9.0 MIDDLE WATERWAY

Potential remedial actions are defined and evaluated in this section for the Middle Waterway problem area. The waterway is described in Section 9.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 9.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source controls on sediment remediation are discussed in Section 9.3. Areas and volumes of sediments requiring remediation are defined in Section 9.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 9.5. The preferred alternative is identified in Section 9.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 9.7 summarizes the findings of the selection process and integrates source control recommendations with the proposed sediment remedial alternative.

9.1 WATERWAY DESCRIPTION

The mouth of Middle Waterway is used as a navigational waterway for commercial purposes. Water depths in Middle Waterway range from 0 ft below MLLW at the head to 25 ft below MLLW at the mouth. An illustration of the waterway and the locations of storm drain outfalls and nearby industries are presented in Figure 9-1. Middle Waterway was created from the tideflats of the Puyallup River prior to 1923 (Tetra Tech 1986c). Unlike the other waterways in the project area, much of Middle Waterway remains intertidal (approximately the upper half). With minor exceptions, the waterway remains unchanged from its original configuration at approximately 3,500 ft long and 350 ft wide. The waterway sediments contain organic carbon concentrations ranging from less than 1 to approximately 7 percent, with fine-grained sediments ranging from 24 to 73 percent. The waterway has also been characterized as having a low deposition rate and relatively shallow mixed layer (Tetra Tech 1987a). The intertidal areas at the head of the waterway exhibit increased erosion and transport associated with tidal and wave energy activities.

9.1.1 Nature and Extent of Contamination

An examination of sediment contaminant data obtained during RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical surveys has revealed that the waterway contains elevated concentrations of both inorganic and organic materials. No Priority 1 contaminants were identified for the waterway. However, copper and mercury were identified as Priority 2 contaminants. The following inorganic and organic compounds exceeded their

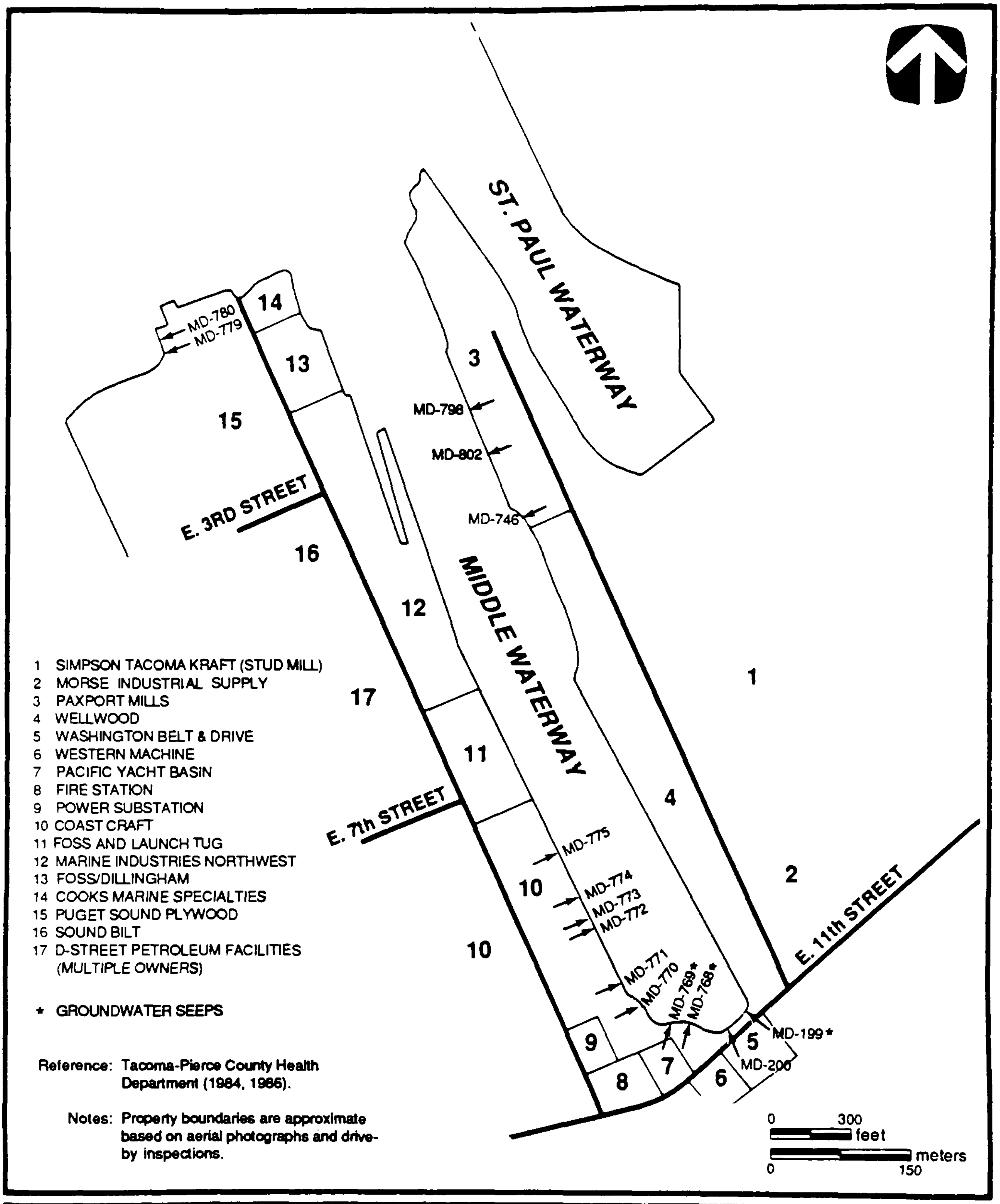


Figure 9-1. Middle Waterway - Existing industries, businesses, and discharges.

corresponding AET value at only one station sampled and are therefore considered Priority 3 contaminants: arsenic, zinc, lead, LPAH, HPAH, diterpenoid hydrocarbons, dibenzothiophene, 4-methylphenol, methylpyrene, dichlorobenzene, phenol, and pentachlorophenol.

The primary goal of sediment remediation in Middle Waterway is the isolation or removal of metal contaminants. Data on the spatial gradients of contaminants are limited as a result of sampling station distribution. However, inorganic contaminant concentrations were found to be greatest near the mouth of the waterway and decreased toward the head. No clear gradients existed for most organic compounds identified. Contaminants in the waterway demonstrate a high particle affinity. The Priority 3 contaminants arsenic, zinc, methylpyrene, and diterpenoid hydrocarbons exceeded AET values only when normalized to percent fine-grained sediments (Tetra Tech 1985a).

Copper and mercury were selected as indicator chemicals for Middle Waterway. Surface sediment enrichment ratios (i.e., ratio of observed concentration to target cleanup goal) for these two contaminants were higher over a greater area than for the Priority 3 contaminants. These contaminants were also selected as indicator chemicals because they are resistant to degradation. Copper and mercury contamination have been attributed to the same sources, primarily ship repair facilities (see Section 9.2.1). Areal and depth distributions of mercury and copper are shown in Figures 9-2 and 9-3, respectively. Levels of contamination indicated on the figures are normalized to cleanup goals, which are 390 mg/kg for copper and 0.59 mg/kg for mercury. The cleanup goal for copper was determined by the AET value for benthic infaunal abundance depression, and that for mercury was set by the AET for the oyster larvae bioassay. Problem sediments are defined as those with enrichment ratios greater than 1.0 (i.e., ratio of observed concentration to cleanup goal is greater than 1.0).

Included in Figures 9-2 and 9-3 are contaminant depth profiles obtained from two core samples. A subsurface maximum was observed for copper in core MD-92, indicating that inputs were historically greater than are currently observed. However, a surface maximum was observed for mercury indicating that input has increased recently. Cores MD-91 and MD-92 were obtained from the heavily contaminated mouth of the waterway and illustrate that contamination is extensive in the shallow sediments. Remediation to a depth of 0.5 yd was assumed based on data from these cores.

9.1.2 Recent and Planned Dredging Projects

The most recent dredging activity within the waterway occurred in 1982, when Paxport Mills (No. 3 in Figure 9-1) reset a seawall and filled an area on the east side of the waterway to provide additional storage for hogged fuel. Approval of the project by the U.S. Army Corps of Engineers and Ecology was contingent upon development of a salmon enhancement area near the mouth of the waterway and adjacent to Paxport Mills. The enhancement component was designed to replace intertidal area lost when the additional hogged fuel storage area was built. In 1972 and again in 1978, maintenance dredging was performed to deepen the channel near Puget Sound Plywood.

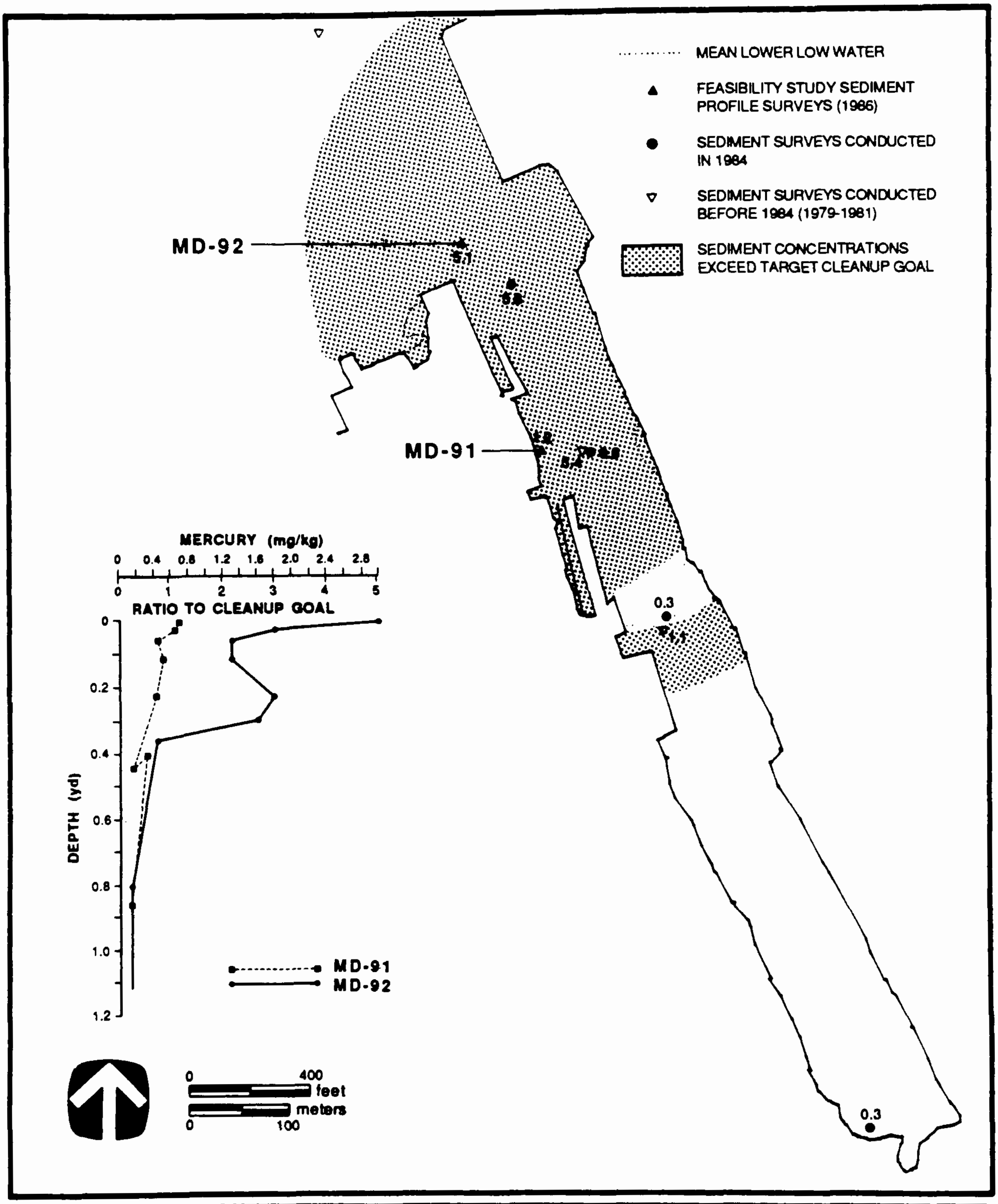


Figure 9-2. Areal and depth distributions of mercury in sediments of Middle Waterway, normalized to long-term cleanup goal.

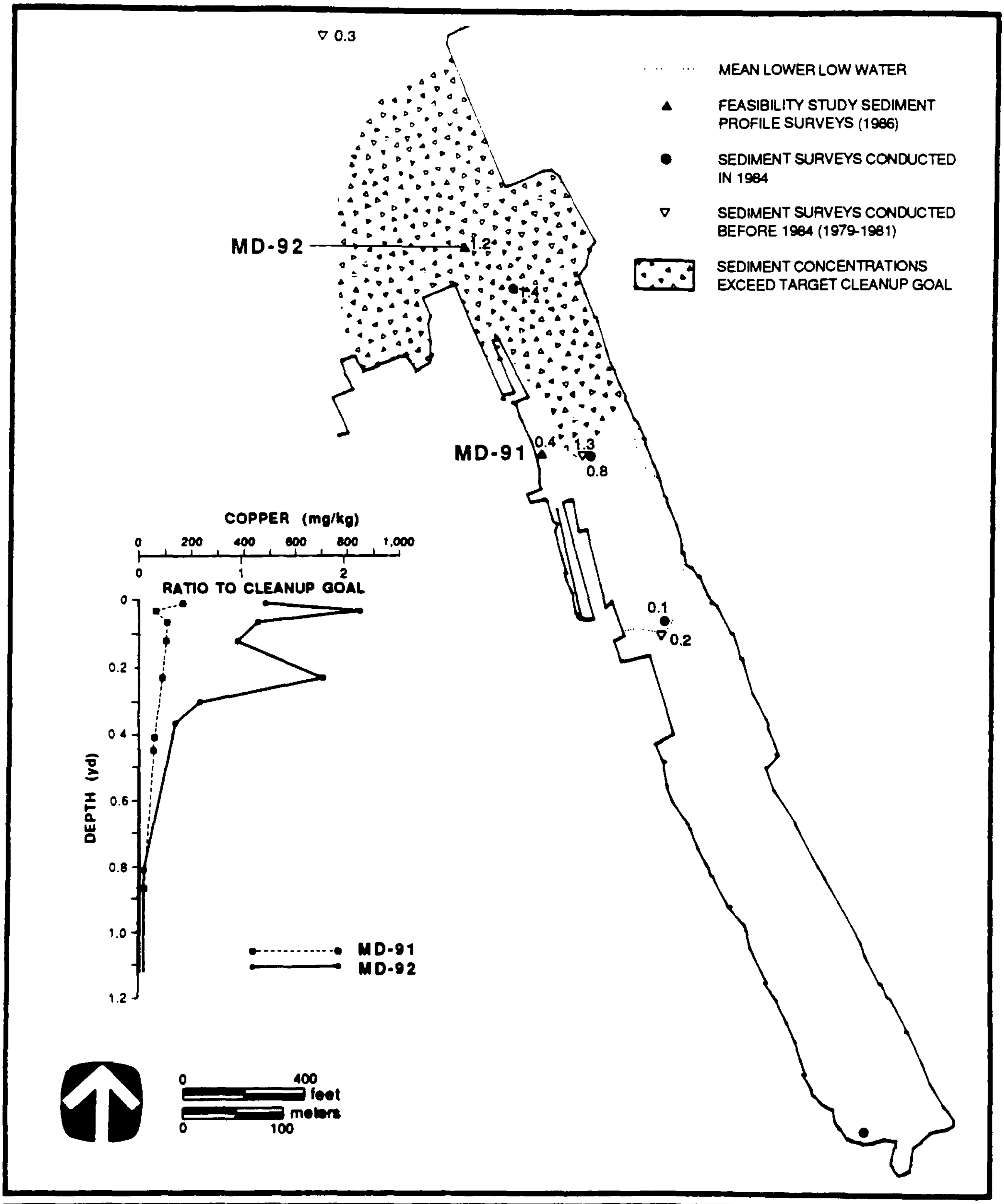


Figure 9-3. Areal and depth distributions of copper in sediments of Middle Waterway, normalized to long-term cleanup goal.

The U.S. Army Corps of Engineers has not recently received any applications for dredging permits in Middle Waterway. Neither the four major businesses that responded to telephone queries about future dredging plans (i.e., Paxport Mills, Foss Launch and Tug, Puget Sound Plywood, and Marine Industries Northwest), nor the Port of Tacoma have planned for future dredging operations in Middle Waterway (Griggs, Mr., 22 October 1987, personal communication; Hoke, D., 22 October 1987, personal communication; Chamblin, D., 22 October 1987, personal communication; Slater, D., 22 October 1987, personal communication).

9.2 POTENTIAL SOURCES OF CONTAMINATION

This section provides an overview of the sources of contamination to the sediments in Middle Waterway and a summary of available loading information for the contaminants of concern. Table 9-1 provides a summary of problem chemicals and source status, based on information from the RI and earlier FS studies (Tetra Tech 1985b, 1986c; Appendix G). Elevated metal concentrations at the mouth of the waterway with decreasing values toward the head suggest a major source near the mouth. Maritime industries located on the western shore are suspected, based on their proximity to the problem sediments and their use of metal-containing products. Storm drain inputs have also been suggested as a potential source of inorganic contaminants, based on a limited data set in which copper and mercury were detected from a single drain that was sampled on three occasions. As indicated previously, the spatial distribution of elevated concentrations of problem organic compounds was limited and no apparent gradients existed. In addition, data obtained during the RI/FS process suggests that it is unlikely that there are major ongoing sources of problem organic chemicals in the waterway (Tetra Tech 1985a). Tide and wave energy of the intertidal environment near the head enhance sediment erosion and transport from that area, and make the source identification process more difficult (Tetra Tech 1987a).

9.2.1 Ship Repair Facilities

Site Background--

Shipbuilding and ship repair have been the primary land uses along the western shoreline of Middle Waterway since the early 1900s. Although little site-specific information is available on past operations, sandblasting, painting, and metal-cleaning operations are the primary sources of metals contamination at most shipyards. Prior to about 1980, ASARCO slag was used exclusively by local ship repair facilities for sandblasting operations, and spent sandblasting grit was commonly disposed of directly in the nearest waterway. Typical metals concentrations in ASARCO slag have been reported as 9,000 mg/kg arsenic, 5,000 mg/kg copper, 5,000 mg/kg lead, and 18,000 mg/kg zinc (Norton and Johnson 1984; typical mercury concentrations in slag were not reported). After 1980, use of ASARCO slag was discontinued, replaced by other abrasives such as Tuf-Kut. The City of Tacoma analyzed clean samples of Tuf-Kut and reported concentrations of 20 mg/kg arsenic, 2,280 mg/kg copper, 3 mg/kg lead, and 753 mg/kg zinc (Getchell, C., 23 December 1986b, personal communication).

TABLE 9-1. MIDDLE WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
Mercury Copper Arsenic Zinc Lead	2 2 3 (MD-13) 3 (MD-19) 3 (MD-12)	Maritime industries (Cooks Marine Specialties, Foss Tug, Marine Industries NW)	Potential	No	Ongoing	Mercury has surface maxima. All other metals have surface minima
4-Methylphenol	3 (MD-13)	Spillover from Simpson (St. Paul)	Potential	No	Ongoing	
Phenol Pentachlorophenol	3 (MD-11) 3 (MD-11)	Wood products industries (Simpson Tacoma Kraft, Coast Kraft)	Potential	No	Ongoing	Surface minimum
Dibenzothiophene HPAH LPAH Methylpyrene	3 (MD-11) 3 (MD-11) 3 (MD-11) 3 (MD-12)	Ubiquitous oil spills	Potential	No	Sporadic, ongoing	Variable
Dichlorobenzene	3 (MD-11)	Unknown	No	No	c	c
Diterpenoid hydrocarbons	3 (MD-12)	c	c	c	c	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

Metals are used as antifoulant additives and constitute 2-60 percent by volume of commercial marine paints (Muehling 1987). Mercury compounds were often used prior to 1975, when cuprous oxide replaced mercury as the primary antifoulant (Muehling 1987). Organotins are generally used in conjunction with copper to increase the service life of the antifoulant paint and are used exclusively on aluminum hulled boats because of the corrosivity of cuprous oxide. The typical composition is 7-8 lb cuprous oxide and 1.5 lb organotin per gallon of paint.

Onsite Operations--

Maritime business along the western shore of the waterway include Foss Launch and Tug, Marine Industries Northwest, and Cooks Marine Specialties. Foss Launch and Tug operated a ship repair facility on Middle Waterway from about 1910 to the mid-1960s. Foss currently maintains only a customer service and tugboat dispatch office on its property at 225 East F Street. After ceasing ship repair activities in the mid-1960's, Foss leased most of its property along the western edge of Middle Waterway to Peterson Boat. Peterson Boat operated a shipbuilding and repair facility at this site until 1978. After Peterson shut down, Foss leased the property to Marine Industries Northwest and Cooks Marine Specialties. Marine Industries Northwest has operated a ship repair facility at 313 East F Street since 1981. Operations at Cooks Marine Specialties, located at 223 East F Street, include steel and aluminum work, and electrical and hydraulic repair on marine vessels. Some shipbuilding is also conducted at the site.

Little is known about Peterson Boat. However, Dames & Moore (1982) reported that the company had used ASARCO slag for sandblasting grit. Sandblasting at Marine Industries Northwest is conducted onsite by a subcontractor. After an inspection of the facility, Ecology reported that sandblast material was entering Middle Waterway from the Marine Industries Northwest property (Tracy 1983). There is no record of whether this problem has been corrected. Cooks Marine Specialties currently uses Tuf-Kut sandblasting grit, but reported that they originally used ASARCO slag (Cook, S., 16 October 1987, personal communication). After a December 1986 inspection of the Cooks facility, Ecology reported that sandblast grit was improperly disposed of along the shoreline adjacent to the boat ramp and in an open area in the dock. Ecology informed Cooks owners that spent sandblast material must be collected and disposed of at a permitted facility (Swigert, M., 23 December 1986, personal communication). Depending on the size of the vessel, sandblasting at Cooks is currently conducted either in a contained area or out over the water (Cook, S., 16 October 1987, personal communication). Smaller vessels that can be hauled out of the water are sandblasted on the marine railway where spent grit can be collected and removed. However, larger vessels must be sandblasted in the water. In those cases, Cooks reports that an apron is placed alongside the boat so that most spent grit can be captured and collected. Cooks currently stores spent sandblast grit in sacks onsite until shipment to a landfill for disposal.

Recent and Planned Remedial Activities--

Ecology is currently involved in a shipyard pollution prevention education program. The program includes workshops to inform shipyard owners of best management practices and NPDES application procedures. Although shipyards in the Commencement Bay area are not currently permitted under the NPDES program, Ecology plans to write permits for all shipyard facilities. These activities are tentatively scheduled for 1989. Permit requirements will include provisions to prevent sandblast grit and other materials from entering the waterways, as well as monitoring requirements for oil, grease, turbidity, and metals. Cooks Marine Specialties was inspected by Ecology in February 1988 and is currently going through the permitting process. Marine Industries Northwest has not yet been inspected as part of the NPDES program.

Loading Summary--

The primary routes of contamination from shipbuilding and ship repair activities include release of stored sandblasting material; deposition of spent grit; and spills, overspray, and drift of paint. Quantified loading data for these inputs from the maritime industries along Middle Waterway are not available.

9.2.2 Storm Drains

Approximately 15 storm drains discharge into Middle Waterway (Figure 9-4). The largest of these storm drains, MD-200, has been identified as a probable source of many of the problem organic chemicals in Middle Waterway (i.e., pentachlorophenol, dechlorinated benzenes, and PAH) (Tetra Tech 1985a). MD-200 drains an area of approximately 80 ac and discharges into the head of Middle Waterway. The drainage basin includes land on the north and south sides of East 11th Street between Portland Avenue and St. Paul Avenue. Annual stormwater runoff from the basin is estimated at 150 ac-ft/yr (0.2 ft^3/sec) based on average annual precipitation of 37 in (Norton and Johnson 1985a) and a runoff coefficient of 0.6 (Clark et al. 1977).

There are no NPDES-permitted discharges in the MD-200 drainage basin. Discharge from MD-200 consists primarily of stormwater runoff. The Tacoma-Pierce County Health Department discovered a sanitary connection to MD-200 from Nicholson Engineering and has notified the company to reroute sewage to the sanitary sewer system (Young, R., 19 August 1987, personal communication).

Land use in the MD-200 drainage basin is entirely commercial and industrial. Businesses currently operating in the basin include Simpson Tacoma Kraft, Morse Industrial Supply, Washington Belt and Drive Systems, Western Machinery, Ball Brass Company, Inc., Nicholson Engineering, and Pacific Yacht Basin (see Figure 9-1). However, the wood products industry was historically the primary industry in the basin. A lumber mill has operated in the basin south of East 11th Street since 1889. As recently as 1985, a sawmill, stud mill distributor, and log storage area were active in the southern portion of the basin. Champion International currently owns the

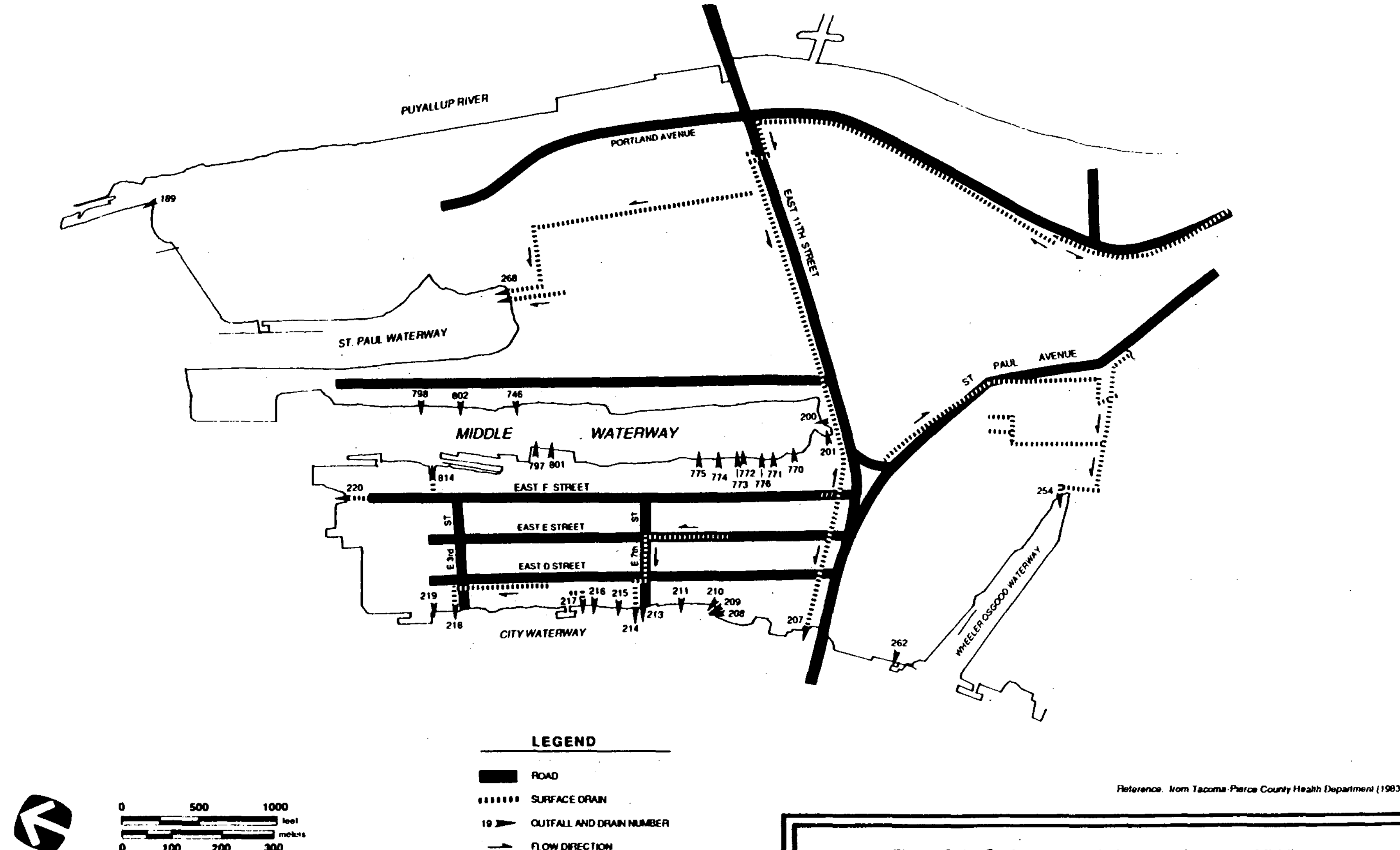


Figure 9-4. Surface water drainage pathways to Middle Waterway.

property around the mill, but the facility has been closed since about 1985 (Scott, E., 31 August 1987, personal communication).

Source contaminant loading calculations have been updated to include data collected since the completion of the RI (Tetra Tech 1985a, 1986c). Summary loading tables for the Priority 2 contaminants of concern for Middle Waterway (i.e., copper and mercury) are provided in Appendix E. No new data were available for any of the discharges in Middle Waterway. Storm drain MD-200 was sampled on three occasions between April and May 1984. Analyses for copper were conducted on two occasions, with detection once at a concentration of 30 ug/L. The average copper concentration of average urban runoff reported for National Urban Runoff Program study was 47 ug/L (Schueler 1987). Analyses for mercury were conducted on all three occasions. The compound was detected once at 0.21 ug/L. Ecology sampled sediments from MD-200 in June 1987. Of the priority pollutant metals analyzed, contaminant concentrations were less than cleanup goals with the exception of zinc. Zinc was detected at 410 mg/kg (enrichment ratio of 1.0) (Norton, D., 15 April 1988, personal communication). Other analytes included a variety of organic compounds.

9.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated. This evaluation was based on the levels of contamination in the sediment and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to correct existing sediment contamination problems over the long term.

9.3.1 Feasibility of Source Control

The main sources of metals to Middle Waterway are surface water runoff from shipbuilding and repair facilities, spillage or related disposal practices from the shipbuilding and repair facilities, and surface water runoff from storm drains.

Maritime Industries--

Marine Industries Northwest and Cooks Marine Specialties are two active shipyards currently associated with problem metals in the sediments of Middle Waterway. Improper handling of paints, feedstocks, and wastes related to sandblasting and painting operations are the primary sources or past sources of contaminant input to the waterway. Marine Industries Northwest and Cooks Marine Specialties are currently located on property that was previously occupied by Foss Launch and Tug, and Peterson Boat.

Marine Industries Northwest and Cooks Marine Specialties are currently involved in the shipyard pollution education program initiated by Ecology. The program is designed to inform the maritime industries of best management practices to minimize contaminant discharges. Following the education program, NPDES permits will be issued to the facilities to ensure that appropriate best management practices are implemented and that effectiveness is documented by monitoring. Among the practices to be considered for implementation at the facilities are routine cleaning of the operations areas, appropriate chemical storage, use of containment structures to minimize dispersion of dust and wastes generated during operations, constraints on bilge and ballast water discharge, and explicit limitations on oil or hazardous material discharges to the waterway. Implementation of best management practices is scheduled to take place over the next several months (PTI 1988a). Given the types of contaminants, source pathways, and available control technologies, it is estimated that implementation of all known, available, and reasonable (i.e., feasible) technologies will reduce source inputs by 70 percent.

Storm Drains--

Storm drain MD-200, the largest drain discharging to Middle Waterway, has been associated with problem organic chemicals in the waterway. However, sediment collected adjacent to MD-200 was not contaminated over cleanup goals. The relative importance of this drain and others in contributing to the Middle Waterway sediment problem is poorly understood at this time because of the lack of available data on storm drain discharge characteristics.

Available technologies for controlling surface water runoff quantity and quality include removal of contaminant sources within the drainage basin, onsite retention of runoff (e.g., berms, channels, grading, sumps), and revegetation or paving to reduce erosion of waste materials (see Section 3.2.2). In sedimentation basin or other studies, removals of over 99 percent have been achieved for lead. Removal efficiencies for other metals (e.g., copper and zinc) are lower.

Given the contaminant types, available data regarding sources, and available control technologies, it is estimated that implementation of all known, available, and reasonable technologies will reduce contaminant inputs from storm water by up to 70 percent.

Conclusion--

For the waterway, the estimated feasible level of source control is assumed to be 70 percent for both mercury and copper. These estimates reflect the uncertainty regarding the specific sources and pathways of contamination to the waterway, and the sediment transport mechanisms responsible for contaminant distribution. The relative importance of storm drain inputs is uncertain at this time. These values take into consideration the assumed effectiveness of implementing improved material and waste handling practices at the maritime facilities and implementation of best management practices for both industries and the storm drains. More precise source control estimates require improved definition of the sources of mercury and copper, which is beyond the scope of this document.

9.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals mercury and copper. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment in Middle Waterway was determined from excess 210-Pb profiles collected at two stations. A sedimentation rate of 430 $mg/cm^2/yr$ (0.27 cm/yr) and a mixing depth of 10 cm were considered representative of the mouth of the problem area where the majority of the contaminated sediments are located. The sedimentation rate represents the average of two values that deviate 47 percent from the mean. Two timeframes were considered for natural recovery of sediments: a reasonable timeframe (defined as 10 yr) and the long term. Losses due to biodegradation and diffusion were determined to be negligible for these chemicals. The source loading of copper is assumed to be in steady-state with sediment accumulation. Sediment profiles indicate that mercury loading may be increasing. For the purpose of this evaluation, it was assumed that the current concentration of mercury (in freshly deposited sediments) is 2 times that measured in the surface mixed layer. That is, if sources continue uncontrolled, the sediment concentration of mercury would eventually double before reaching steady-state with loading rates. Results of the sediment recovery evaluation are summarized in Table 9-2.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted as 71 yr for mercury and 9 yr for copper. These estimates are based on the highest concentrations of indicator chemicals measured in the waterways. Therefore, sediment recovery to the long-term cleanup goal for mercury in the 10-yr timeframe is not predicted to be possible, while sediment recovery for copper should be possible. Minimal reductions in sediment concentrations of copper are predicted unless sources are controlled. Sediment concentrations of mercury may increase if current inputs continue unabated.

Effect of Implementing Feasible Source Control--

As described in Section 9.3.1, implementation of all known, available, and reasonable source control is expected to reduce source inputs by 70 percent for both copper and mercury. With this level of source control as an input value, the model predicts that sediments with an enrichment of ratio of 1.2 (i.e., copper concentrations of 468 mg/kg dry weight, mercury concentrations of 0.70 mg/kg dry weight) will recover to the long-term cleanup goal within 10 yr (Table 9-2). The surface area of sediments not recovering to the cleanup goal within 10 yr is shown in Figure 9-5. For

TABLE 9-2. MIDDLE WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals	
	Copper	Mercury
Station with Highest Concentration		
Station identification	MD-13	MD-13
Concentration (mg/kg dry weight)	554	3.4
Enrichment ratio[a]	1.4	5.8
Recovery time if sources are eliminated (yr)	9	71
Percent source control required to achieve 10-yr recovery	NP[b]	NP[b]
Percent source control required to achieve long-term recovery	30	83
Average of Three Highest Stations		
Concentration (mg/kg dry weight)	507	2.8
Enrichment ratio[a]	1.3	4.8
Percent source control required to achieve long-term recovery	23	79
10-Yr Recovery		
Percent source control assumed feasible	70	70
Highest concentration recovering in 10 yr (mg/kg dry weight)	468	0.70
Highest enrichment ratio of sediment recovering in 10 yr	1.2	1.2

a Enrichment ratio is the ratio of observed concentration to cleanup goal.

b NP = Not possible.

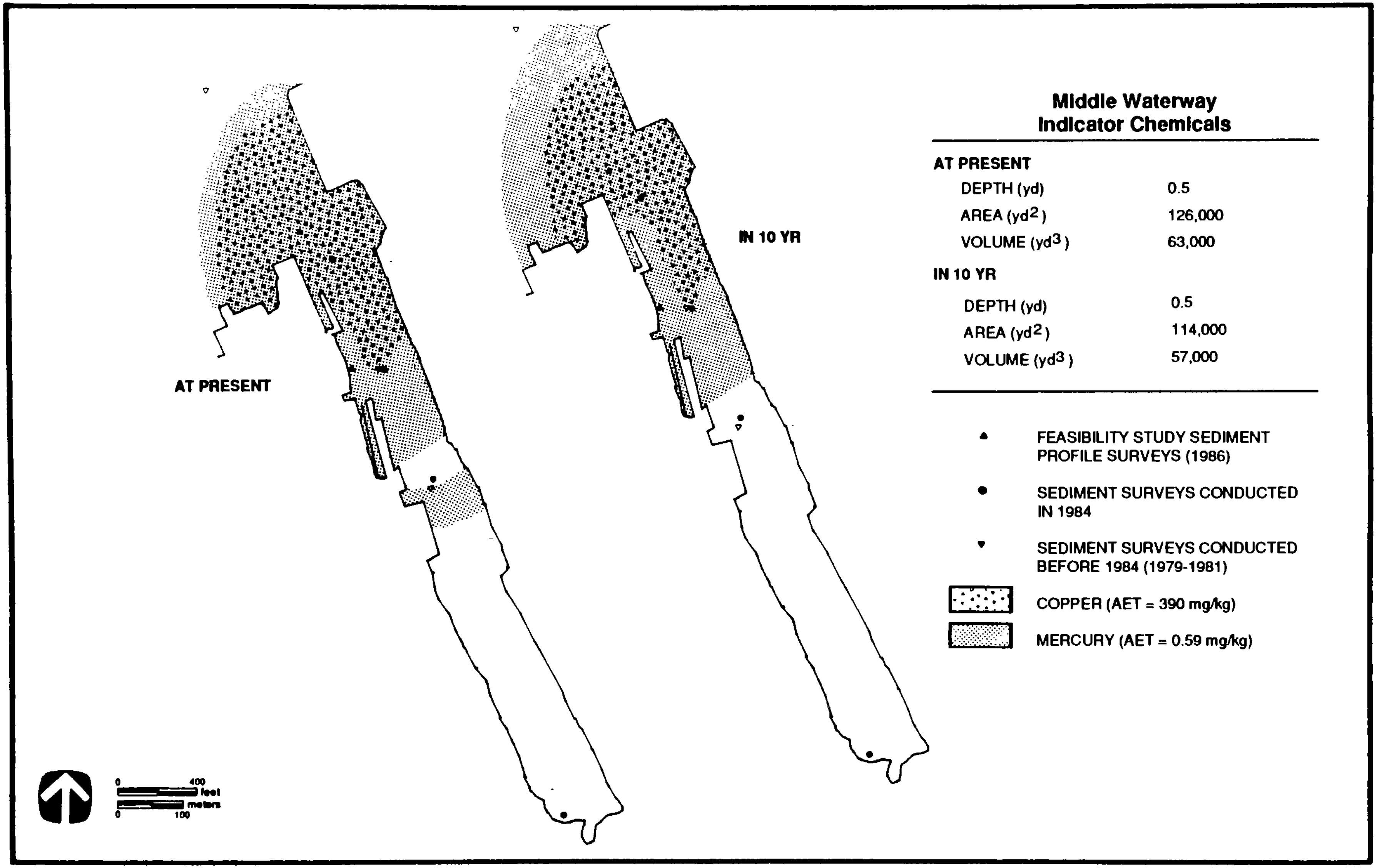


Figure 9-5. Sediments in Middle Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

comparison, sediments currently exceeding long-term cleanup goals for indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that 23 percent of copper and 79 percent of the mercury inputs to the waterway must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (see Table 9-2). These estimates are based on the average of the three highest enrichment ratios.

These values are presented for comparative purposes; the actual percent reduction required in source loading is subject to the uncertainty inherent in the assumptions of the predictive model. These ranges probably represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

9.3.3 Source Control Summary

Sediment recovery in a reasonable timeframe (10 yr) to long-term cleanup goals of 390 mg/kg for copper and 0.59 mg/kg for mercury is not possible, even with complete abatement of contaminant inputs. Consequently, sediment remedial action will be required to mitigate the contamination problems in the waterway.

Prior to initiating sediment remedial actions, source control measures will be required to ensure that acceptable sediment quality is maintained following remediation. Recommended source control measures include the following:

- Implementation of best management practices at Marine Industries Northwest and Cooks Marine Specialties to control surface water runoff and material or waste spillage
- Storm drain monitoring and implementation of control measures if unacceptable concentrations are found in storm drain sediments or runoff.

As part of these actions, a more complete characterization of each source will be required in order to determine the precise level of source control required to maintain adequate sediment quality and to determine the most feasible methods of achieving source control goals.

9.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with mercury and copper concentrations exceeding long-term cleanup goals is approximately 63,000 yd^3 (see Figure 9-5). This volume was estimated by multiplying the areal extent of sediment exceeding the cleanup goal (126,000 yd^2) by the estimated 0.5 yd depth of contamination (see sediment contaminant profiles Figures 9-2 and 9-3). The estimated thickness of contamination is only an approximation; few sediment profiles were collected and the vertical resolution of these profiles was poor at the depth of the contaminated horizon. For the volume calculations, depths were slightly overestimated. This conservative approach was taken to reflect the fact that depth to the contaminated horizon cannot be accurately dredged, to account for dredge technique tolerances, and to account for uncertainties in sediment quality at locations between the sediment profile sampling stations.

The total estimated volume of sediments with copper or mercury concentrations that is still expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 57,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratios greater than 1.2 (see Table 9-2), an area of 114,000 yd^2, by the estimated 0.5 yd depth of contamination. These volumes are also approximations accounting for uncertainties in sediment profile resolution and dredging tolerances. For Middle Waterway, this is the volume of sediment that would require remediation.

9.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

9.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion each alternative is evaluated to determine its suitability for the remediation of contaminated sediments in Middle Waterway. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess the applicability of each alternative to remediation of contaminated sediments in Middle Waterway. Site-specific characteristics that must be considered in the assessment include the nature and extent of contamination, the environmental setting, the location of potential disposal sites, and site physical properties including waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

Mercury and copper were selected as indicator chemicals to represent the two primary sources of contamination to the waterway: ship repair facilities and storm drains (see Table 9-1). Areal distributions for both indicators are presented in Figure 9-5 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals.

Four alternatives have been dropped from consideration for Middle Waterway. The need for periodic dredging to maintain channel depth at the mouth of the waterway precludes the use of a cap in that area. The intertidal areas of Middle Waterway have demonstrated the potential for increased erosion and sediment transport (Tetra Tech 1987b). Therefore, placement of a cap over this large intertidal area is not expected to be effective. Therefore, the in situ capping alternative is dropped from further consideration. Alternatives involving treatment of organic contaminants are inappropriate because the sediments are contaminated with inorganic materials. Therefore, the solvent extraction, incineration, and land treatment alternatives are not evaluated for this problem area.

It is assumed that the requirements to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

Six candidate sediment remedial alternatives are listed below for the cleanup of Middle Waterway:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solidification/upland disposal.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from direct or indirect exposure to contaminated sediments without implementation of sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives are all applicable to remediation of contaminated sediments in Middle Waterway. Solidification is primarily used to treat materials contaminated with inorganics. This treatment technology may also be effective in immobilizing the Priority 3 organic contaminants requiring remediation that have demonstrated a high particle affinity in this problem area.

9.5.2 Evaluation of Candidate Alternatives

The three primary categories of evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 9-3. A comparative evaluation of alternatives is presented in Table 9-4 based on ratings of high, moderate, and low in seven subcategories of evaluation criteria. As discussed in Chapter 4, these subcategories are short-term protectiveness; timeliness; long-term protectiveness; reduction in toxicity, mobility, or volume; technical feasibility; institutional feasibility; and availability. Capital and O&M costs for each alternative are also presented in Table 9-4. Remedial costs are shown for sediments currently exceeding long-term cleanup goal concentrations and for sediments

TABLE 9-3. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE MIDDLE WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge treatment and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear, as necessary.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear. Increased potential for worker exposure due to direct handling of CDM.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Benthic habitat is impacted at the disposal site.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked sixth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. This alternative is ranked fifth overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Disposal siting and facility construction could delay implementation. This alternative is ranked second overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available. Disposal site development should not delay implementation. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Equipment development will be required before a solidification scheme can be implemented. Remediation could be accomplished in approximately 2 years. Extensive bench- and pilot-scale testing are likely to be required. This alternative is ranked fourth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in a quiescent, subaquatic environment is considered acceptable.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Long term reliability of solidification treatment processes for CDM are believed to be adequate. However, data from which to confirm long-term reliability are limited. Upland disposal facilities are structurally reliable.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Solid fication is a more protective solution than dredge/disposa alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is reduced by maintaining CDM at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Solidification is a more protective solution than dredge/disposa alternatives. The potential for public exposure is significanty reduced as a result of contaminant immobilization.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobliy is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Contaminated sediment volumes may increase due to resuspension of sediment.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Volume of contaminated sediments is not reduced.	Contaminants are physically contained, thereby reducing toxicity and the potential for contaminant migration compared with non-treatment alternatives. Metals and organics are encapsulated.

TABLE 9-3. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, but feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Solidification technologies for treating CDM on a large scale are conceptual. Implementation is considered feasible, but reliability is unknown. Bench-scale testing prior to implementation is necessary.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Installation of monitoring systems is routine aspect of facility siting.	Monitoring can be readily implemented to detect contaminant migration through dikes and liners. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring requirements for solidified material are low in comparison with dredge and disposal alternatives. Monitoring can be readily implemented.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment. System maintenance is intensive during implementation.
	INSTITUTIONAL FEASIBILTY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. Approvals for facility siting are uncertain but assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Disposal requirements are less stringent for treated dredge material enhancing approval feasibility. However, bench scale testing is required to demonstrate effectiveness of solidification.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. May require that shoreline management aspects be addressed.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Disposal site availability is uncertain but feasible. Solidification equipment and methods for large scale CDM disposal are currently unavailable.

TABLE 9-4. EVALUATION SUMMARY FOR MIDDLE WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Solidify/ Upland Disposal
Short-Term Protectiveness	Low	Low	High	Moderate	High	Moderate
Timeliness	Low	Low	Moderate	High	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High
Technical Feasibility	High	High	Moderate	High	High	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	High	Moderate	Moderate
Long-Term Cleanup Goal Costs[a]						
Capital	--	6	519	1,566	2,754	4,199
O&M	--	1,274	195	180	224	218
Total	--	1,280	714	1,746	2,978	4,417
Long-Term Cleanup Goal with 10-yr Recovery Costs[a]						
Capital	--	6	461	1,409	2,481	3,791
O&M	--	1,183	179	165	205	199
Total	--	1,189	640	1,574	2,686	3,990

[a] All costs are in $1,000.

that would still exceed the cleanup goal concentrations 10 yr after implementing all known, available, and reasonable source controls and allowing natural sediment recovery to occur (i.e., 10-yr recover costs).

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts continue with the contaminated sediments remaining in place. Source control measures initiated as part of the institutional controls would tend to reduce sediment contamination with time but adverse impacts would persist in the interim. It is predicted that even with complete source elimination, reduction in sediment concentrations to acceptable levels could require over 70 yr for mercury (see Table 9-2).

The alternative requiring clamshell dredging and nearshore disposal is rated moderate under this criterion because nearshore habitat would be lost in siting the disposal facility. For example, use of the Blair Waterway Slip 1 site would result in the loss of up to 16 ac of nearshore marine habitat. While the loss of habitat due to nearshore site development in Commencement Bay may be mitigated by requiring habitat enhancement in a nearby area, the availability of sites with potential for habitat enhancement is limited. The clamshell dredging/solidification/upland disposal alternative is also rated moderate because of the increased potential for worker exposures due to solidification-related handling of contaminated dredged material. In spite of the increased exposure potential, the moderate rating is appropriate because adequate worker health and safety controls are available.

The clamshell dredging/confined aquatic disposal and hydraulic dredging/upland disposal alternatives are rated high for short-term protectiveness because worker and public exposure potentials are minimized. Hydraulic dredging confines contaminated dredged material to a pipeline system throughout implementation, thereby reducing exposure potentials. Although upland disposal requires use of an upland area, the tradeoff is considered to be acceptable because the habitats that are selected for disposal are generally of low sensitivity (U.S. Army Corps of Engineers 1988). Similarly, development of an open-water confined aquatic disposal site entails short-term impacts to the benthic community at the site. However, re-establishment of the area is expected to occur rapidly following capping. The placement of contaminated dredged material in the subaquatic environment with a split-hulled barge minimizes handling requirements. The potential also exists for adverse water quality impacts due to dredging of contaminated material. However, Middle Waterway sediments are characterized by predominantly inorganic materials with high particle affinity and little potential for partitioning to the water column.

Timeliness--

Because an extensive amount of time is necessary for sediments to recover naturally from mercury contamination, both the no-action and institutional controls alternatives are rated low. Recovery times for all sources of the indicator compounds would range from 9 yr to 71 yr (see Section 9.3.2).

Moderate ratings have been applied to the clamshell dredging/confined aquatic disposal, hydraulic dredging/upland disposal, and clamshell dredging/solidification/upland disposal options. For dredging options that involve siting of upland or open-water confined disposal facilities, approvals and construction are estimated to require a minimum of 1-2 yr. Solidification may require extra time for bench-scale testing and equipment development or modification, although facility siting and technology development could be conducted concurrently.

The clamshell dredging/nearshore disposal option is rated high for timeliness because this alternative can be implemented immediately with available technologies, expertise, and facilities.

Long-Term Protectiveness--

The comparative evaluation for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for natural recovery is long. For the institutional controls alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source reductions. The uncertainty associated with identifying the source of mercury contamination further compromises the protectiveness rating for institutional controls. The observed adverse biological impacts would also continue.

Moderate ratings were assigned for clamshell dredging/nearshore disposal and hydraulic dredging/upland disposal alternatives because of potential physicochemical changes resulting from the placement of contaminated dredged material in these disposal facilities. These changes, primarily from new redox conditions, would tend to increase the migration potential of the contaminants. However, contaminated dredged material testing should provide the necessary data on the magnitude of these impacts. For the nearshore disposal option, these impacts could be reduced by ensuring that Middle Waterway dredged materials are placed below the saturated zone in the confinement facility. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature as a result of wave action and tidal influences. The nearshore disposal alternative also introduces the potential for impacts to the adjacent fish mitigation area in the outer Blair Waterway slip. Proper site development and monitoring should minimize the potential for impacting this area. Even though an upland disposal facility is generally regarded as a more secure option because of improved engineering controls during construction, the potential for impacts on area groundwater resources partially offsets the improvement in long-term security.

The confined aquatic disposal option is rated high for this criterion because placement of material in a confined, quiescent, subaquatic environment provides a high degree of isolation, with little potential for exposure to sensitive environment. Once the cap is in place, maintaining its integrity against erosion and bioturbation will be sufficient to retain sediment-bound contaminants (Phillips et al. 1985). Maintaining the reduced conditions in the subaquatic environment also aids in minimizing the migration potential of inorganic contaminants.

The clamshell dredging/solidification/upland disposal alternative is also rated high for long-term protectiveness. The high degree of immobilization provided by solidification of primarily inorganic contaminants substantially increases the long-term protectiveness of this alternative over dredge and disposal alternatives. In addition, the lower priority organic contaminants that have been identified exhibit a high degree of particle affinity, enhancing immobilization due to particle encapsulation.

Reduction in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except the clamshell dredging/solidification/upland disposal option which was rated high. None of the other five alternatives involves treatment for contaminated sediments. Although the confined aquatic, upland, and nearshore disposal alternatives isolate contaminated dredged material from the surrounding environment, the chemistry of the material remains unaltered. For nearshore (depending on placement in the confinement facility) and upland disposal alternatives, the mobilization potential for untreated contaminated dredged material may actually increase with changes in redox potentials. Without treatment, the toxicity of contaminated sediments remains at preremediation levels. Contaminated sediment volumes are not reduced, and may actually increase in the short-term with hydraulic dredging options because material would be suspended in an aqueous slurry.

Solidification of contaminated dredged material prior to disposal effectively encapsulates inorganic contaminants, thereby reducing mobilization potential permanently and significantly. Through isolation in the solidified matrix, this process also reduces the effective toxicity of contaminants as compared with nontreatment alternatives. Because the available data suggest that the organic contaminants present have a high particle affinity, the process may also be relatively effective in encapsulating these materials. Elutriate tests during bench-scale testing of solidified contaminated dredged material will provide sufficient data to assess immobilization of contaminants.

Technical Feasibility--

The alternative involving solidification is assigned a moderate rating for technical feasibility because of the need for bench-scale testing prior to implementation. In addition, solidification technologies for the treatment of contaminated dredged material on a large scale are conceptual at this point, although the method appears to be feasible (Cullinane, J., 18 November 1987, personal communication). The difficulty inherent in placing dredge and capping materials at depths of over 100 ft requires that a moderate rating be assigned to the confined aquatic disposal alternative, as well.

High ratings are warranted for all other alternatives because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective elsewhere for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives have been assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings are assigned to the remaining four alternatives because of potential difficulty in obtaining agency approvals for disposal sites or implementation of treatment technologies.

Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. The Blair Waterway nearshore facility is considered to be available. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should satisfy the primary requirement for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of the effectiveness of each alternative in meeting established performance goals (e.g., treatability of dredge water and immobilization of contaminants through solidification).

Availability--

Candidate sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities are rated high for availability. The no-action and institutional controls alternatives can be implemented immediately, and equipment and siting availability are not obstacles to implementation. The clamshell dredging/nearshore disposal alternative is rated high because a disposal site is considered to be available at this time.

Remedial alternatives involving dredging with confined aquatic or upland disposal are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that open-water confined aquatic and upland sites will be available. However, no sites have been identified for use and no sites are currently under construction. Depending on the final characterization of sediments, upland disposal in an existing municipal or demolition landfill may also be feasible. However, no sites are currently available for use in the project area or adjacent vicinity. A moderate rating has also been assigned to the dredging/solidification/upland disposal alternative because of the same uncertainties regarding disposal site availability. However, leachate tests conducted as a part of the bench-scale treatability and performance evaluation for the solidification process should be adequate to determine whether the treated product is acceptable for placement in a standard solid waste management facility.

Cost--

The comparative evaluation of costs (see Table 9-4) reveals a trend of increasing capital cost with increasing complexity (i.e., from no action to the treatment option). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for clamshell dredging/nearshore disposal, primarily because of underdrain and bottom liner installation, additional dredge water clarification, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting the solidification alternative increases as a result of material costs for the process, and associated labor costs for material handling and transport. Clarification and dredge water management costs are also incurred for this option.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Costs for monitoring of the confined aquatic disposal facility are significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single groundwater sample from each well to assess contaminant migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding long-term cleanup goals) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the solidification alternative are significantly lower because the process results in lower contaminant migration potential.

9.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the six sediment remedial alternatives proposed for Middle Waterway, clamshell dredging with nearshore disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, nearshore disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. The nearshore disposal alternative is currently preferred for the following reasons:

- The alternative protects public health and the environment by effectively isolating contaminated sediments in an engineered disposal facility

- The alternative is consistent with existing plans to fill the Blair Waterway Slip 1 proposed nearshore fill site

- The nature of the contaminants is such that placement below the saturated zone should minimize migration potential

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental requirements

- Performance monitoring can be accomplished effectively and implemented readily

- The estimated 57,000-yd^3 volume of contaminated sediments is compatible with the capacity of the proposed nearshore facility

- Although the cost of this alternative is approximately $1 million less than that of the upland disposal alternative, it is expected to provide an equivalent degree of public health and environmental protection

- Although this option is approximately $1 million more than the confined aquatic disposal option, largely due to the cost of acquiring nearshore property in the project area, the additional expenditure is justified since the action can be implemented more quickly in an available facility that offers appropriate confinement conditions for the contaminants of concern.

The nearshore alternative is rated high for timeliness, technical feasibility, and availability because available equipment, resources, and disposal facilities are used. The alternative can be implemented quickly with reliable equipment that has proven effective in past similar operations. This alternative is also consistent with the Port of Tacoma's plans to fill Blair Waterway Slip 1 to create additional land space. The volume of contaminated dredged material requiring remediation is compatible with the capacity of the potential nearshore disposal facility.

The alternative is rated moderate for short-term protectiveness because of the loss of intertidal habitat. This disadvantage can be offset through incorporation of a habitat replacement project in the remedial process. The goal of habitat enhancement is addressed in part by removing contaminated sediments from the waterway. One-to-one replacement of excavated intertidal sediments with clean fill material has been incorporated into the cost calculations. The nature and placement of the clean intertidal materials can be designed to maximize habitat quality and recolonization potential.

The alternative is also rated moderate for long-term protectiveness because contaminated sediments are placed in an environment subject to wave and tidal influences, and because of the proximity of the adjacent fish mitigation area in the outer slip. Contaminants in Middle Waterway have demonstrated relatively high particle affinities (Tetra Tech 1987c), which would serve to improve long-term containment reliability. Hart-Crowser & Associates (1985) concluded that monitoring of contaminant mobility from nearshore disposal sites could be effectively accomplished with monitoring wells in containment berms for early detection of contaminant movement. Monitoring and corrective measures (in the event of system failures) would be more easily implemented in the nearshore facility than in a confined aquatic disposal site (which also received similar ratings). Long-term protectiveness could be enhanced with the placement of slurry walls within the berm (Phillips et al. 1985); however this measure has not been included in the cost estimate. As indicated in Table 9-4, the nearshore disposal alternative also provides a cost-effective means of sediment mitigation. This alternative is approximately $1 million less than the hydraulic dredging/upland disposal alternative, and less than 50 percent of the cost for the treatment option.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with contaminated dredged material redistribution. Potential impacts on water quality can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Because this alternative can be implemented over a relatively short timeframe, seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. For dredging contaminated sediments in the shallow and intertidal areas of the waterway, tidal stage will need to be accommodated. Dredging activities within this area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

Of the remaining alternatives, solidification of the inorganic contaminants prominent in Middle Waterway is also feasible. Solidification and upland disposal was not selected as the preferred alternative because of uncertainties regarding availability of a disposal site, the reliability and effectiveness of solidifying marine sediments, and high costs. These uncertainties and high costs are partially offset by the potential added degree of long-term protectiveness afforded by treating contaminated dredged material. The costs of implementing the treatment alternative are approximately $2.4 million more than the nearshore disposal alternative. With maximum enrichment ratios of 5.8 for mercury (mercury concentration of 3.4 mg/kg) and 2.2 for copper (subsurface concentration at MD-92 of 870 mg/kg), this additional expenditure does not appear to be warranted. If this option were considered, bench-scale testing of Middle Waterway contaminated dredged material would be warranted to more accurately define process effectiveness and treatment costs.

Hydraulic dredging with upland disposal was not selected because of uncertain disposal site availability and the bias against landfilling of untreated contaminated dredged material. Although this alternative is feasible from both a technical and institutional standpoint, the risk of system failures in the upland environment (e.g., groundwater risks) compromises its desirability.

The confined aquatic disposal alternative was not selected because the volume of material is compatible with the available nearshore disposal site. The nearshore alternative can be implemented more quickly, while providing a degree of protection that is appropriate for the contaminants of concern. Assuming that a confined aquatic disposal site becomes available, this option would also serve to effectively isolate dredged material. However, the close proximity of the Blair Waterway nearshore facility and availability of capacity below the water line where near in situ physicochemical conditions could be maintained for inorganic contaminants make nearshore disposal preferable. The close proximity of the Blair Waterway disposal site to the Middle Waterway problem area (approximately 1.5 mi) may also warrant review of the use of a hydraulic dredge for excavation and disposal during remedial design studies. Clamshell dredging and barge transport were selected in this case because of logistical uncertainties regarding the need to cross navigational waterways and the Puyallup River.

No-action and institutional controls alternatives are ranked high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public impacts far outweighs these advantages.

9.7 CONCLUSIONS

Middle Waterway was identified as a problem area because of the elevated concentrations of both inorganic and organic contaminants in sediments. Mercury and copper were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimated the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 126,000 yd^2, and a volume of 63,000 yd^3. Of the total sediment area currently exceeding cleanup goals, 12,000 yd^2 is predicted to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 6,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 57,000 yd^3.

The primary identified and potential sources of problem chemicals to Middle Waterway include the following:

- Marine Industries Northwest
- Cooks Marine Specialties.

Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Implement best management practices at Marine Industries Northwest and Cooks Marine Specialties
- Confirm that all significant sources of problem chemicals have been identified and controlled
- Routinely monitor sediment to confirm sediment recovery predictions and assess the adequacy of source control measures.

In general, it should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. However, the level of source control required for mercury was estimated to be approximately 79 percent, compared to a technically feasible level of approximately 70 percent. Additional evaluations to refine these estimates will be required as part of the source control measures described above. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals copper and mercury. The assumptions used in determining source control requirements were environmentally protective. It is anticipated that more detailed loading data will demonstrate that sources can be controlled to the extent necessary to maintain acceptable sediment quality. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be re-evaluated.

Clamshell dredging with nearshore disposal was recommended as the preferred alternative for the remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments in an engineered disposal facility where performance monitoring can be readily implemented. Disposal sites for nearshore confinement are available at this time. Use of material from Middle Waterway in a nearshore disposal facility is compatible with the Port of Tacoma's industrial development plans, minimizing the impacts of using another facility. Concerns regarding potential contaminant migration to an adjacent fish mitigation area will be addressed through the placement of contaminated material in a saturated environment and the ongoing monitoring program to detect potential problems in sufficient time to implement corrective measures. Nearshore disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 9-4, clamshell dredging with nearshore disposal provides a cost-effective means of sediment mitigation. The estimated cost to implement this alternative is $1,409,000. Environmental monitoring and other O&M costs at the disposal site have a present worth of $165,000 for a period of 30 yr. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of the preferred alternative is $1,574,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area.

The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions practicable, and are cost-effective.

10.0 HEAD OF CITY WATERWAY

Potential remedial actions are defined and evaluated in this section for the head of City Waterway problem area. The waterway is described in Section 10.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 10.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contaminant concentrations are discussed in Section 10.3. Areas and volumes of sediments requiring remediation are discussed in Section 10.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 10.5. The preferred alternative is identified in Section 10.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 10.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

10.1 WATERWAY DESCRIPTION

The problem area designated as the head of City Waterway extends from the head of the waterway to the 11th Street Bridge, approximately 3,500 ft from the mouth. An illustration of the waterway and nearby industries is presented in Figure 10-1. This portion of the waterway is approximately 4,500 ft in length and varies in width between 460 and 600 ft, with very irregular shorelines (Tetra Tech 1985a). City Waterway is a designated navigational channel. Subbottom profiling in the head of City Waterway indicated mid-channel depths ranging from less than 10 ft below MLLW in the southern end to approximately 30 ft below MLLW at the 11th Street Bridge (Raven Systems and Research 1984).

Significant sediment accumulation occurs in City Waterway primarily as a result of storm sewer discharges. Sediment accumulation is estimated to be greater than 10 ft deep at the head of the waterway and decreases to approximately 3 ft underneath the 11th Street Bridge. Sediments within City Waterway are typically 64 percent fine-grained material, with an average clay content of 18 percent. These sediments are described as anoxic with a very high organic content (nearly 9 percent). Between 1905 and 1948, the waterway was dredged every 3 to 12 yr. City Waterway has not been dredged by the U.S. Army Corps of Engineers since 1948.

10.1.1 Nature and Extent of Contamination

An examination of sediment contamination data obtained during both the RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical

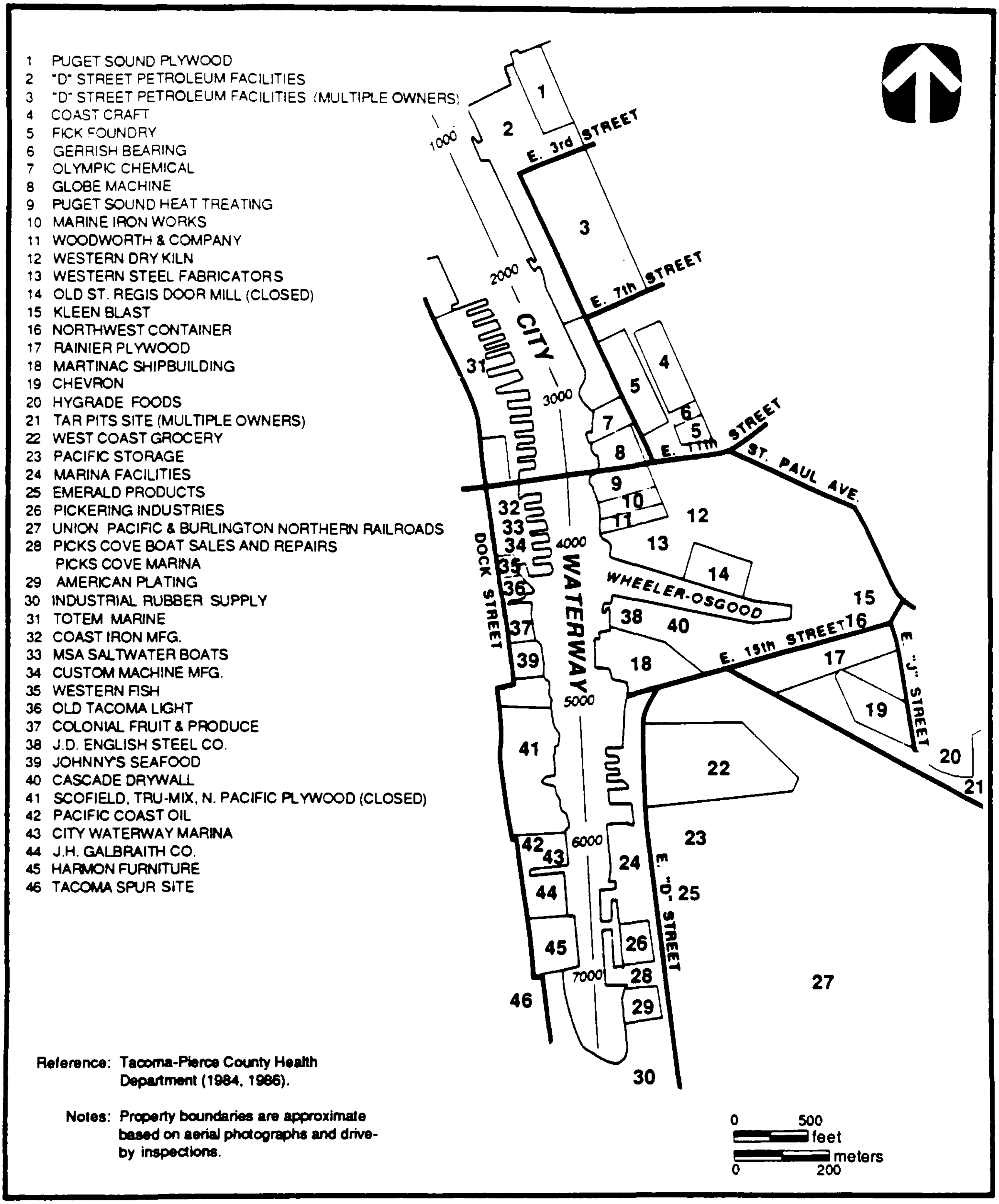


Figure 10-1. Head of City Waterway - Existing industries and businesses.

surveys revealed that the waterway contains concentrations of both organic and inorganic materials that are harmful to benthic organisms. The contaminants that were observed had a high particle affinity (Tetra Tech 1987c). Priority 1 contaminants include total organic carbon, zinc, lead, and mercury. Priority 2 contaminants include grease and oil, LPAH, HPAH, phenol, cadmium, nickel, 2-methylphenol, 4-methylphenol, bis(2-ethylhexyl)-phthalate, and butyl benzyl phthalate. The following organic contaminants exceeding their AET value at only one station sampled and are therefore considered Priority 3 contaminants: 1-4-dichlorobenzene, N-nitrosodiphenylamine, aniline, and benzyl alcohol.

Concentrations of total organic carbon and grease and oil were greater in the surface sediments of City Waterway than at any other location in the entire Commencement Bay N/T study area. Concentrations were highest at the head of the waterway, indicating that adjacent storm drains (CN-237 and CS-237) are a significant source. Untreated sewage and food waste products were historically discharged to the waterway from these storm drains, contributing major quantities of waste material to the sediments. The concentration profile of total organic carbon collected at the head of City Waterway displayed fairly constant levels to a depth of 200 cm, indicating that elimination of sewage discharges to the storm drain has not resulted in significant decreases in the surface sediment concentrations. Total organic carbon concentrations in surficial sediments decreased from the head of the waterway to the mouth (Tetra Tech 1985a).

HPAH was selected as an indicator chemical at the head of City Waterway to represent hydrocarbon contamination attributed to multiple potential sources (see Section 10.2). Areal and depth distributions of HPAH are illustrated in Figure 10-2. Concentrations of HPAH were below the long-term cleanup goal of 17,000 ug/kg at all stations except one. The sediment core profile shown in Figure 10-2 indicates that HPAH was present to depths of about 1 yd.

Zinc was identified as an indicator chemical for the head of City Waterway in the Commencement Bay RI. However, the AET used to determine enrichment ratios for zinc increased substantially (i.e., from 260 to 410 mg/kg) when the AET values were revised (PTI 1988). The increase in the AET value resulted in fewer stations exceeding long-term goals, hence the usefulness of zinc as an indicator of chemical contamination diminished. Cadmium is used as a replacement for zinc. The cadmium AET decreased (i.e., from 5.9 to 5.1 mg/kg) when the AET values were revised. Correspondingly, over 50 percent of the stations that have data for cadmium exceeded long-term goals. The distribution of cadmium in the head of City Waterway suggests that it is an appropriate indicator of chemical contamination.

Surface sediment concentrations of the metals zinc, copper, and lead were observed to increase toward the head of City Waterway suggesting a source near that area. The metals mercury, cadmium, and nickel did not exhibit a similar spatial distribution (Tetra Tech 1985a, 1986c). Lead was selected as an inorganic indicator contaminant to represent sources near the head of the waterway. Mercury and cadmium were selected to represent inorganic contaminants with more erratic distribution. Areal and depth

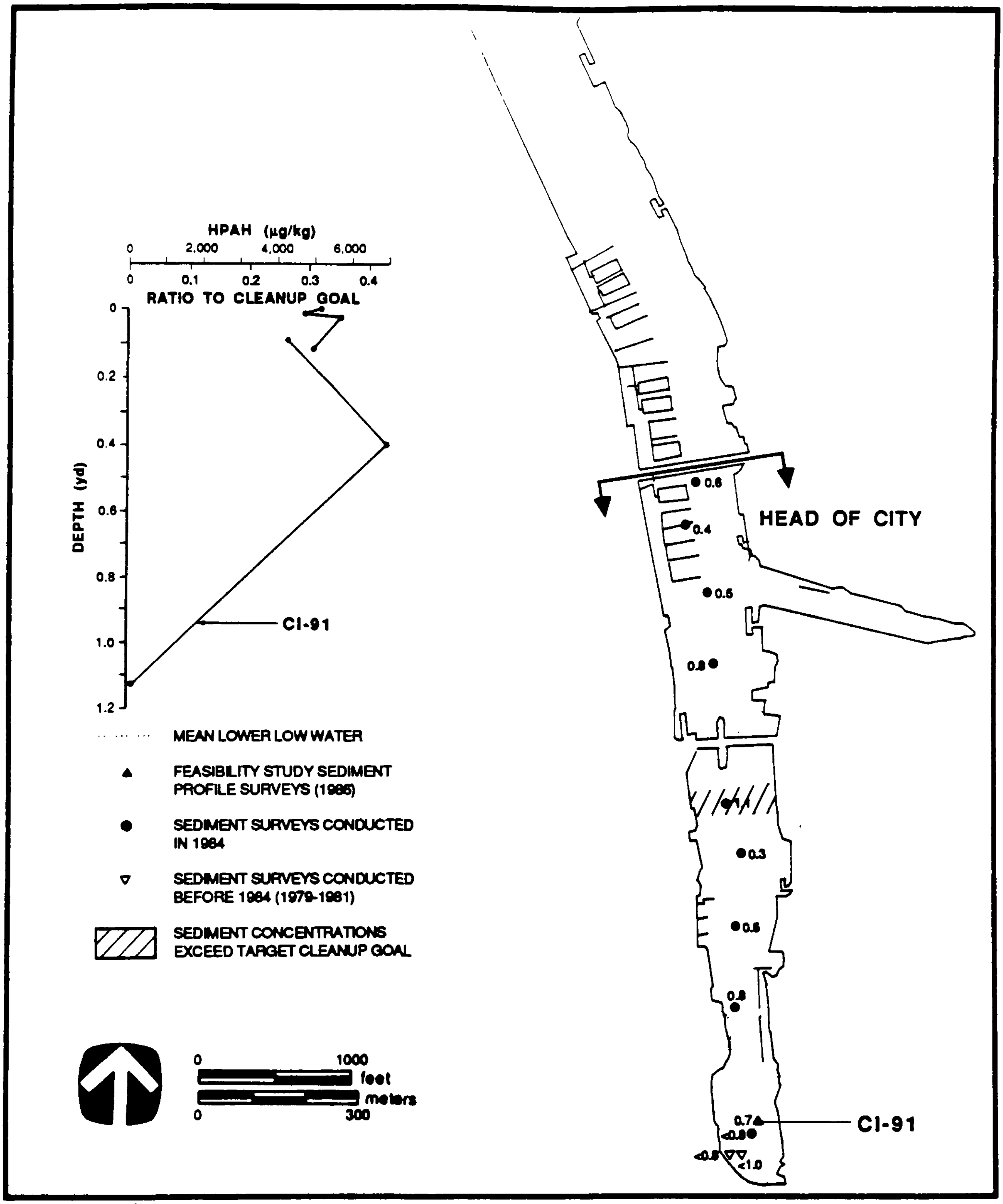


Figure10-2. Areal and depth distributions of HPAH in sediments at the head of City Waterway, normalized to long-term cleanup goal.

distributions of cadmium are illustrated in Figure 10-3. Cadmium concentrations in excess of the 5.1 mg/kg long-term cleanup goal were greatest in the lower and central portions of the problem area. The sediment core sample collected near the head of the waterway shows a subsurface maximum for cadmium, indicating that the accumulation of cadmium is due to historic sources. Cadmium concentrations exceeding long-term cleanup goals were observed at depths exceeding 2 yd. Areal and depth distributions of lead are illustrated in Figure 10-4. Elevated concentrations of lead were observed throughout the problem area, with surficial sediment concentrations exceeding the 450 mg/kg long-term cleanup goal. The sediment core profile collected near the head of the waterway revealed fairly constant concentrations of lead exceeding cleanup goals to a depth of 2 yd. Areal and depth distributions of mercury are shown in Figure 10-5. Surficial sediment concentrations of mercury were highest in the central portion of the problem area with patchy areas exceeding the long-term cleanup goal of 0.59 mg/kg observed both in the center of the problem area and near the 11th Street Bridge. The sediment core profile collected near the head of the waterway revealed a surface minimum, with elevated subsurface values to a depth of 2 yd.

Few sources have been identified for the numerous other high priority problem chemicals found in sediments at the head of City Waterway. The sediment profile of 2-methylphenol displayed a surface concentration maximum, indicating that inputs may be increasing. However, the sediment profile for 4-methylphenol displayed a surface concentration minimum, suggesting recent decreases in input. Other problem organic compounds exhibited limited spatial distribution, and elevations over AET were not excessive (Tetra Tech 1987c).

10.1.2 Recent and Planned Dredging Projects

Two enterprises at the head of City Waterway have requested dredging permits from the U.S. Army Corps of Engineers: the Port of Tacoma and City Marina, Inc. The Port of Tacoma recently constructed a pier and access ramp, and installed floats on property adjacent to the Dock Street businesses; however, no dredging was actually conducted as part of this work. City Marina plans to install floats, drive piles, and place riprap and backfill adjacent to their property at the head of the waterway.

Businesses and industries that responded when queried about future dredging plans are itemized below:

- City Waterway Marina dredged less than 40 yd^3 in summer 1987, (Norsen, 2 November 1987, personal communication). The company had a U.S. Army Corps of Engineers permit to build an over-water restaurant. Although this construction could involve some dredging, it is not likely that any significant dredging would be involved.

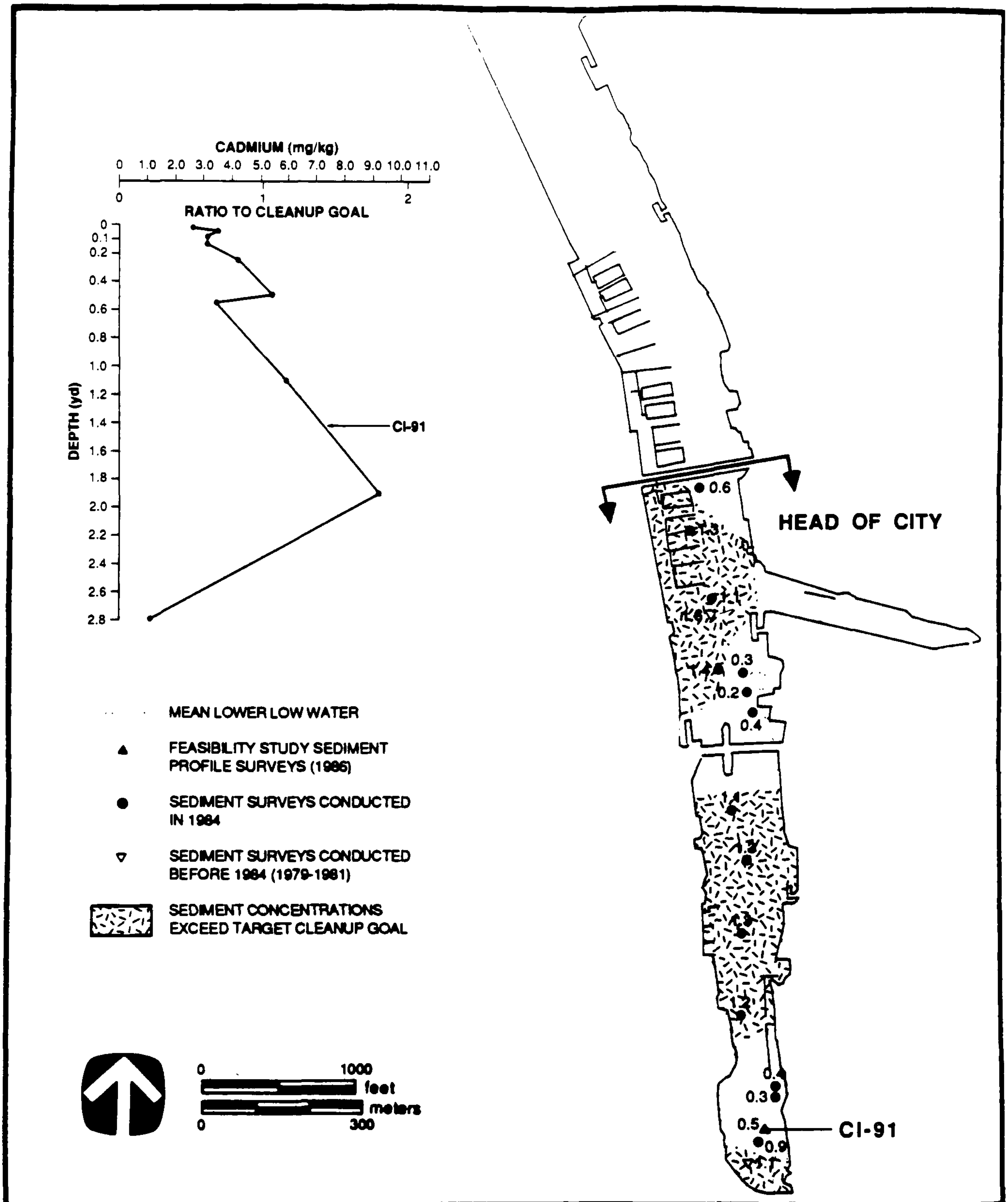


Figure 10-3. Areal and depth distributions of cadmium in sediments at the head of City Waterway, normalized to long-term cleanup goal.

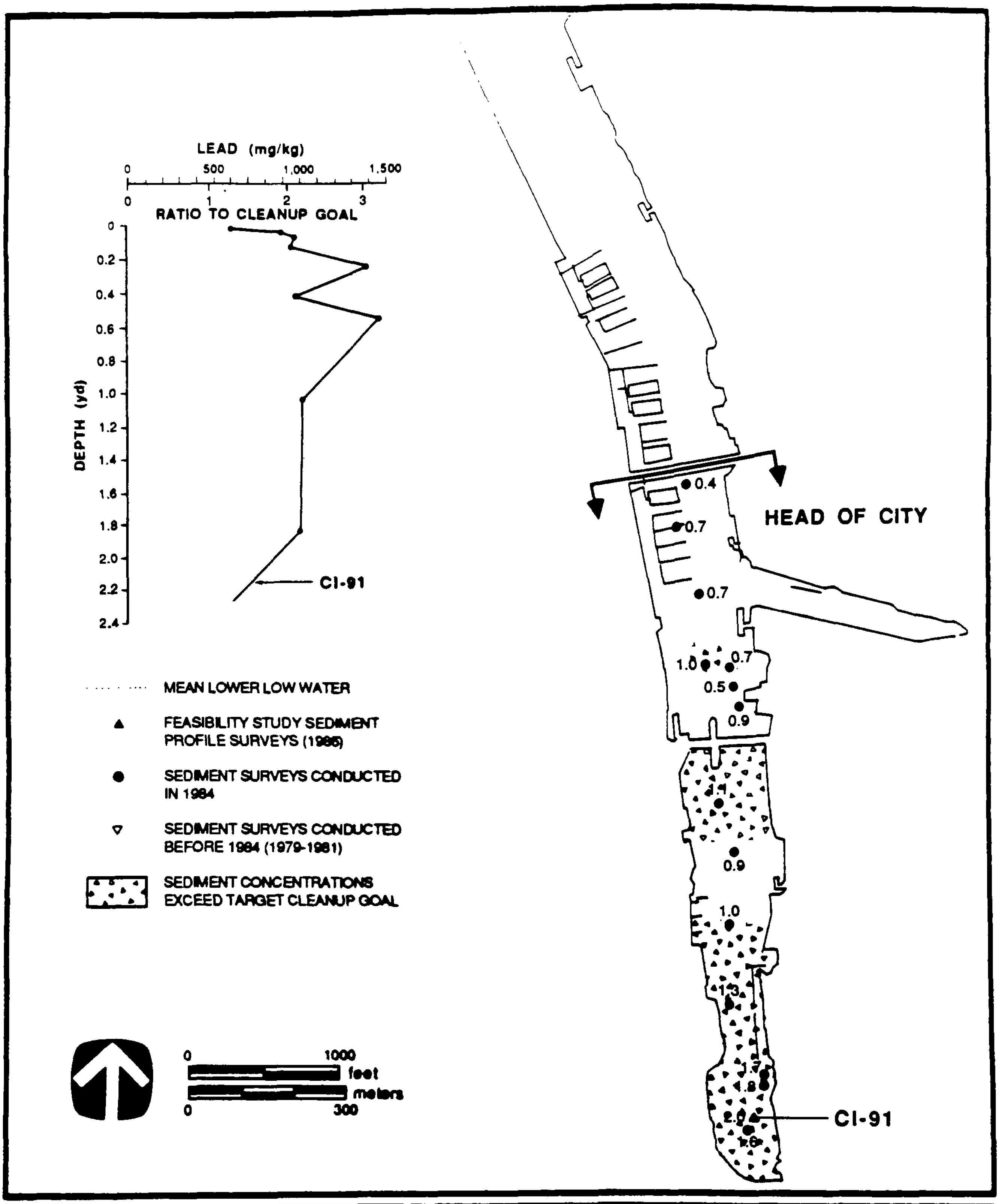


Figure 10-4. Areal and depth distributions of lead in sediments at the head of City Waterway, normalized to long-term cleanup goal.

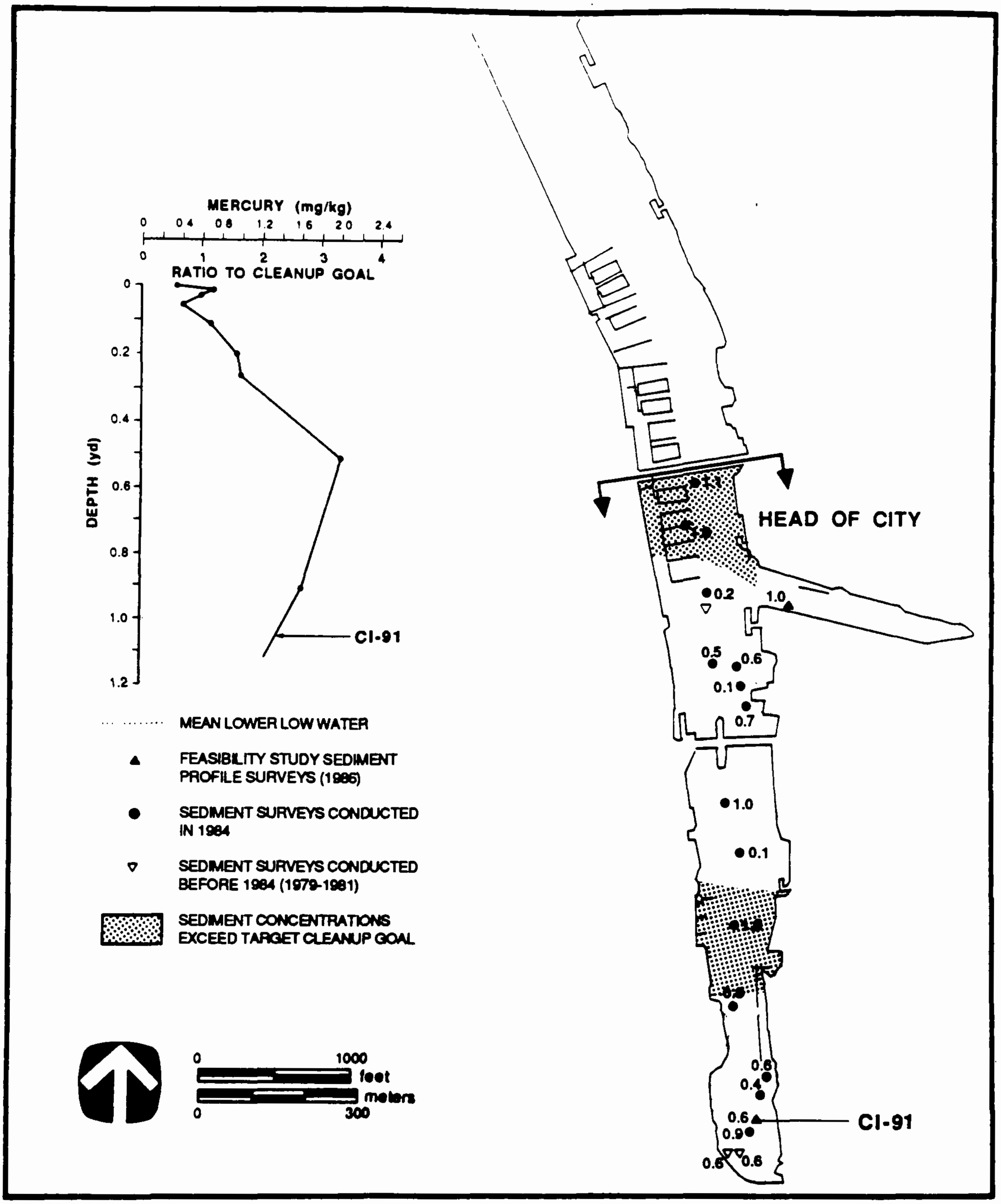


Figure 10-5. Areal and depth distributions of mercury in sediments at the head of City Waterway, normalized to long-term cleanup goal.

- Martinac Shipbuilding is considering a dredging project in City Waterway within the next year (Gerrard, K., 9 November 1988, personal communication). The project would involve dredging approximately 4-5 ft deep in an area approximately 50 ft x 300 ft (2,780 yd^3).

- City Marina, Inc. added some riprap in front of its building along the waterway in summer 1987, but no material was dredged (Anonymous, 28 October 1987, personal communication).

- Industrial Rubber Supply, Western Steel Fabricators, Harmon Furniture, J.D. English Steel Company, Puget Sound Plywood, and Totem Marina do not plan any dredging projects (Elmore, D., 22 October 1987, personal communication; Anonymous, 27 October 1987b, personal communication; Whitman, M., 27 October 1987, personal communication; Saylor, B., 27 October 1987, personal communication; Chamblin, D., 22 October 1987, personal communication; Anonymous, 27 October 1987a, personal communication).

10.2 POTENTIAL SOURCES OF CONTAMINATION

Sources of contamination at the head of City Waterway probably date back to the late nineteenth century. Industries along the waterfront in the 1890s and early 1900s included 10-15 warehouses and dock storage facilities, at least 7 lumber mills, 2 foundries, several food processing and storage companies, and 2 electric companies. Existing industries (see Figure 10-1) that were present prior to 1920 include Harmon Furniture, Fick Foundry, Northern Fish Products (now Ocean Fish), and Union Oil of California (Ruckelshaus 1985).

Much of the western shore of the waterway is currently occupied by marinas and storage facilities. North Pacific Plywood, located on the western shore since at least 1960, recently moved to Graham, Washington. Harmon Furniture, George Scofield Company, two seafood processors, and a wholesale produce distributor remain on the west side. Major reconstruction on the west side of the waterway is occurring with the building of a new 15th Street bridge across the waterway (Tetra Tech 1985a).

American Plating is located near the head of the waterway along its eastern shore. The firm has been present at this location (with other names and owners) since about 1955. Marinas front the eastern shoreline of the waterway as far north as 15th Street. Burlington Northern and Union Pacific Railroad yards and several large grocery warehousing facilities are on the east side of D Street near the head of the waterway. Martinac Shipbuilding, north of 15th Street, has been at this location since 1925 Tetra Tech 1985a).

Table 10-1 provides a summary of problem chemical and source status information for the area. Storm drains and the Martinac Shipbuilding operation are the largest potential sources of metals contamination in the head of City Waterway. Storm drains have also been shown to contribute

TABLE 10-1. HEAD OF CITY WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
Total organic carbon Grease and oil	1 2	Storm drains, mainly CN-237 and CS-237	Yes	Yes	Ongoing	Fairly constant over surface 200 cm
LPAH HPAH Phenol	2 2 2	Chevron Storm drains Ubiquitous oil spills Marina fires Tacoma Spur coal gasification	Potential Yes Potential Potential Potential	No Yes No No No	Ongoing Ongoing Ongoing, sporadic Historical Ongoing	HPAH fairly constant over surface 200 cm. LPAH has near-surface maximum
Zinc Copper Lead	1 2 1	Storm drains Martinac Shipbuilding American Plating Tacoma Spur coal gasification	Yes Potential Potential Potential	Yes No No No	Ongoing Ongoing Closed 1985 Ongoing	Fairly constant over surface 20 cm. Lead has surface minimum
Mercury Cadmium Nickel	1 2 2	Storm drains American Plating Unknown	Yes Potential	Yes No	Ongoing Closed 1985	Mercury and cadmium have surface minimum
1,4-Dichlorobenzene	3	Storm drains	Potential	Insufficient data	Unknown	
2-Methylphenol 4-Methylphenol	2 2	Union Pacific Railroad (glue wastes) N. Pacific Plywood Tacoma Spur Storm drains	Potential Potential Potential Potential	No No No No	Ongoing Closed 1985 Ongoing Ongoing	2-Methylphenol has surface maximum. 4-Methylphenol has surface minimum
Bis(2-ethylhexyl)phthalate Butyl benzyl phthalate	2 2	Storm drain Ship bilges	Potential Potential	Insufficient data No	Ongoing Ongoing, sporadic	c
N-nitrosodiphenylamine	3	Unknown	No	No	Ongoing	c
Aniline	3 (CI-01)	Storm drains, head of City Waterway	Potential	No	Ongoing	c
Benzyl alcohol	3 (CI-11)	Storm drains, head of City Waterway	Potential	No	Ongoing	c

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

significant quantities of HPAH. In addition, groundwater seepage is a source of HPAH, and the American Plating site is a potential source of cadmium and other metals.

10.2.1 Storm Drains

Approximately 45 storm drains discharge into the head of City Waterway (Figure 10-6). The drainage basin includes most of the downtown Tacoma business district, the Nalley Valley area, portions of south Tacoma, and portions of the tideflats between City Waterway and the Puyallup River. Six of the storm drains have been identified as significant contaminant sources: CN-237, CS-237, CI-225, CI-230, CI-243, CI-245. Storm drain CI-235 is also a known source of metals contamination.

Where data are available, storm drain loading calculations for the nearshore/tideflats area have been updated to include data collected since the completion of the Remedial Investigation (Tetra Tech 1985a, 1986c). However, City of Tacoma data collected as part of the storm drain monitoring program have not been included. Summary loading tables for the Priority 1 and 2 contaminants of concern for the head of City Waterway (i.e., cadmium, copper, lead, mercury, nickel, zinc, LPAH, HPAH, phenol, 2-methylphenol, 4-methylphenol, bis(2-ethylhexyl)phthalate, and butyl benzyl phthalate) are provided in Appendix E, Tables E-20 through E-34.

Storm Drains CN-237 and CS-237--

The Nalley Valley drain (CN-237) is the largest storm drain in the basin, serving approximately 2,800 ac south and east of the head of City Waterway (Figures 10-6 and 10-7). Commercial and industrial development is primarily concentrated around the Interstate-5 and South Tacoma Way corridors in the center of the drainage basin. The northern and southern portions of the basin are mainly residential. Nalleys and Atlas Foundry both have NPDES discharge permits to discharge to this storm drain.

The south Tacoma drain (CS-237) serves approximately 2,200 ac directly south of the head of City Waterway. The south Tacoma drainage basin is about 10 blocks wide, extending from the head of the waterway (South 23rd Street) south to about South 85th Street in south Tacoma. Land use in the basin is primarily residential. Most of the industrial and commercial activity is concentrated in the northern portion of the drainage basin near the Interstate-5 corridor. Together, storm drains CN-237 and CS-237 account for approximately 85 percent of the flow from the six major storm drain sources identified above.

The City of Tacoma sewer utility has been conducting inspections at businesses operating in the Nalley Valley and south Tacoma drainage basins to identify potential industrial or sanitary connections to the storm drain systems. Few problems have been found because most industries in the area discharge process wastewater to the sanitary sewer system, and because the storm and sanitary sewer systems were separated in the late 1960s. The most common storm drain problem found during the inspections involves the discharge of wash water from vehicle and engine wash operations (i.e.,

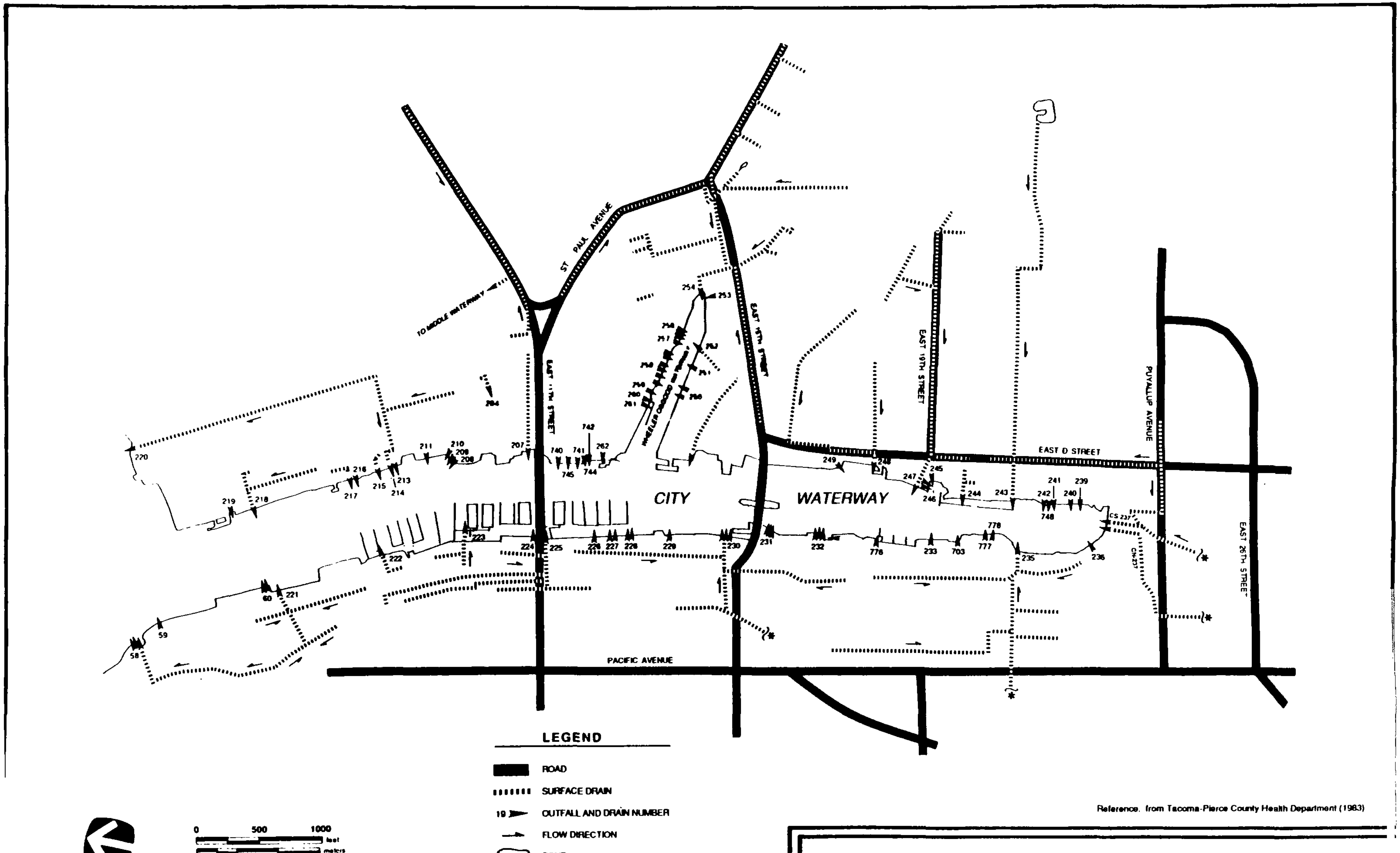


Figure 10-6. Surface water drainage pathways to the head of City Waterway.

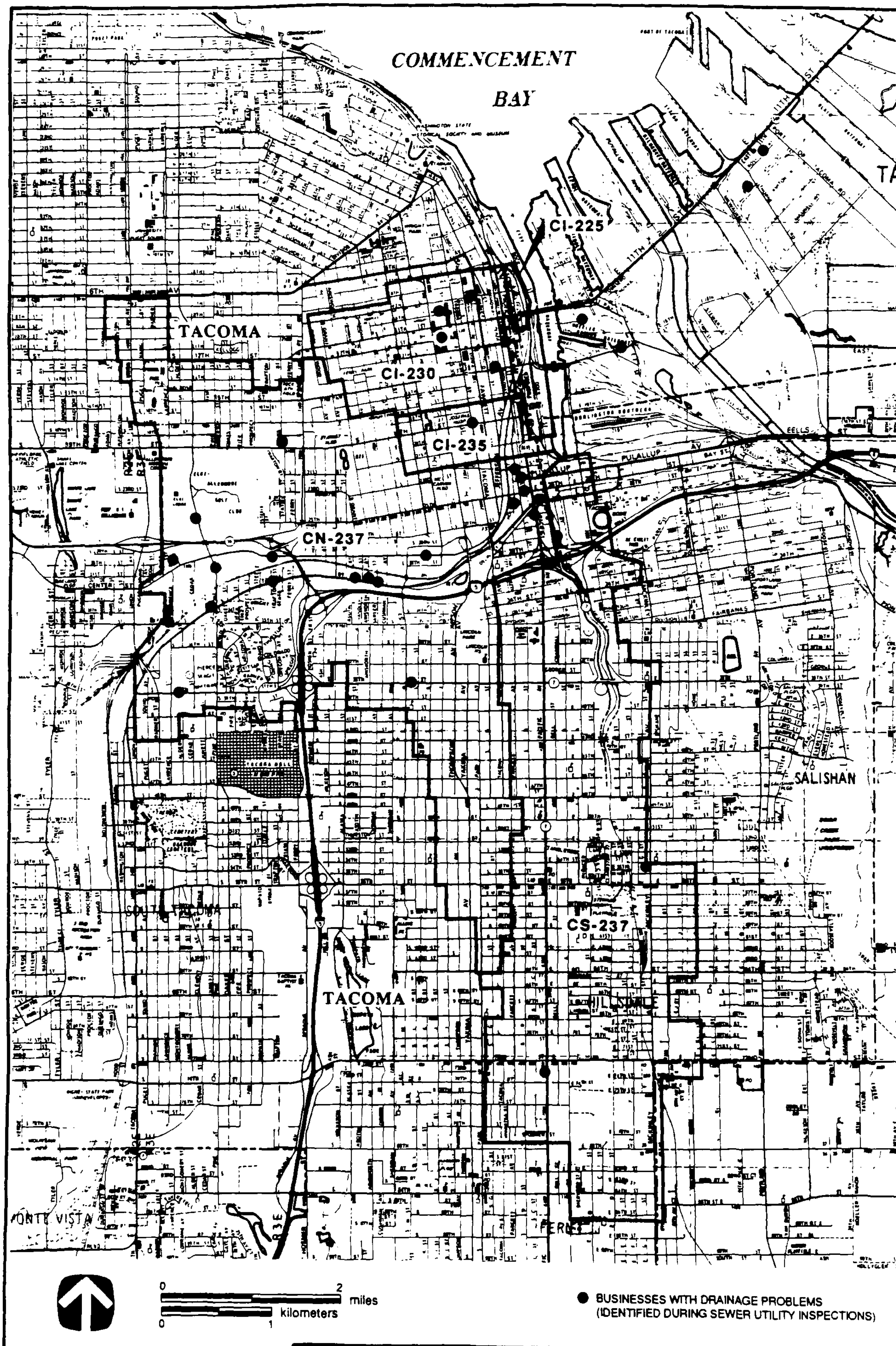


Figure 10-7. Drainage basins for City Waterway.

automobile dealers, car washes, and automobile detailers) to the city storm drains. A few sanitary connections were found in an unsewered section along South Tacoma Way. Discharges of industrial process water to storm drain catch basins were identified at two businesses (Robinson, R., 25 August 1987, personal communication). Specific problems identified during the business inspections are summarized in Table 10-2.

Tetra Tech (1985a) identified the Nalley Valley and south Tacoma storm drains as historical sources of contamination in City Waterway. Both drains functioned as sewer outfalls until the late 1960s, when the city rerouted sanitary and industrial wastes from City Waterway to the central wastewater treatment plant. Although not all cross-connections were corrected at the time, the Tacoma sewer utility believes that most were eliminated by 1979, when a new interceptor was installed.

As part of its storm drain monitoring program, the City of Tacoma has been monitoring effluent from CN-237 and CS-237 since October 1986. Data from four sampling periods are available (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, 19 August 1988, personal communications). Analyses of particulate matter in effluent from these storm drains have shown lead concentrations to exceed long-term goals (450 mg/kg) in approximately half of the samples. Cadmium did not exceed long-term goals (5.1 mg/kg) in any samples from CS-237, but did exceed long-term goals in four of seven samples from CN-237. Although not an indicator chemical, nickel was measured at concentrations over the long-term goal of 140 mg/kg in six of seven samples of particulate matter from both CN-237 and CS-237. HPAH concentrations in particulate matter were over the long-term goal of 17,000 ug/kg in one of seven samples collected from drain CS-237 and four of seven samples from CN-237. The comparison of storm drain particulate matter with long-term goals assumes no mixing of sediments with cleaner material from other sources. Such comparisons provide a worst-case analysis of the impact of storm drain discharge on the waterway.

Individual loading calculations in Appendix E for the problem chemicals vary over 2 orders of magnitude among sampling events. Recent data obtained from two dry-weather sampling events by the City of Tacoma confirm this variability (Getchell, C., 18 December 1987 and 8 February 1988, personal communications). Loading estimates for CS-237, based on these data for whole water samples, are 3.5 and 0.89 lb/day for lead, and 1.3 lb/day and not measurable for cadmium. Loading estimates for CN-237, based on the same data set, are 8.7 lb/day and not measurable for lead, and 0.2 lb/day and not measurable for cadmium (Odell, C., 20 April 1988, personal communication).

In general, loadings for indicator chemicals presented in Appendix E are similar to those expected due to typical urban runoff reported by Metro (Stuart et al. 1988). However, in samples collected by the City of Tacoma since Appendix E was prepared, cadmium concentrations were greater than those expected in typical urban runoff in three out of seven samples for CS-237 and five out of seven samples for CN-237.

TABLE 10-2. COMMERCIAL DISCHARGES TO STORM DRAINS CN-237 AND CS-237 IDENTIFIED DURING SEWER UTILITY BUSINESS INSPECTIONS

Industry Name	Type of Discharge to Storm Drain	Action Taken
CN-237:		
Top Auto	Inadequate sumps to control oil and grease in discharge from floor drains	Lease terminated.
Cammarano Brothers	Truck washing area	Letter sent to company.
Western Furnace	Vehicle wash area	Oil/water separator installed and connected to sanitary sewer.
Rollins Truck Leasing	Vehicle wash area	Plans for oil/water separator and connection to sanitary sewer approved. Installation by 10/1/87.
Star Rental, Inc.	Equipment wash area	Oil/water separator installed and connected to sanitary sewer.
Smitty's Fleet Service	Vehicle wash area	Installed wash pad, oil/water separator, connected to sanitary sewer.
City of Tacoma, Shops 2 and 3	- Caustic rinse water from parts cleaning operations - Floor drains from engine repair area	Facilities will not be used until controls installed.
Alpac Corp.	Vehicle wash area	Plans and specifications for oil/water separator approved. Construction scheduled for 9/87.
Big Toys	Overflow from wood-staining operations	Closed recycle system installed. Discharge to city storm drain eliminated.
Tacoma News Tribune	Vehicle maintenance and washing area	Connected to sanitary sewer.
TAM Engineering	Old oil/water separator inadequate to control discharge from yard area	TAM has hired consultant to design new control system.
38th Street Shell Station	Floor drains	Station closed. Property to be sold. Owner notified of illegal drain.

TABLE 10-2. (Continued)

Industry Name	Type of Discharge to Storm Drain	Action Taken
Star Ice & Fuel	Improper handling of oily products--oil has been entering storm drain	Oily wastes near drain have been cleaned up (5/11/87).
Personal Touch Car Detailing	Vehicle wash area	Wash water temporarily discharged onto ground away from storm drain.
Nalley's Fine Foods	Brine water overflow	Overflows will be routed to sanitary sewer, operational controls until piping installed. DOE writing NPDES permit for cooling water discharge; city writing pretreatment permit.
Solar Manufacturing	Lavatory	Building is empty and posted "No Occupancy" until illegal connection removed.
Peake, Inc.	Floor drain	Letter sent to company requiring correction.
CS-237:		
Tacoma Plastics	Oil in floor drain	Oily wastes near storm drain cleaned up (5/11/87).
Old-Fashioned Car Prep	Engine wash/degrease area	Owner is degreasing engines at another acceptable location until connection to sanitary sewer is completed.
Eagle Paper Box Co.	Storm drain catch basin near chemical storage area	Company's spill plan under review by sewer utility.

References: Robinson, R., 10 August 1987 and 31 August 1987, personal communications.

Storm Drains CI-225 and CI-230--

Storm drains CI-225 and CI-230 serve portions of the downtown Tacoma business and residential areas. CI-225 drains the 10-ac commercial area bounded by Dock Street, Pacific Street, 7th Street, and 12th Street (see Figures 10-6 and 10-7). Annual runoff from the basin is estimated at 20 ac-ft/yr (0.03 ft^3/sec) based on average rainfall of 37 in/yr and a runoff coefficient of 0.7. Discharge consists entirely of stormwater runoff. The Tacoma-Pierce County Health Department has reported flows of 3-15 gal/min (0.007-0.03 ft^3/sec) in CI-225 (Hanowell, R., 16 June 1987, personal communication). CI-225 currently receives runoff from part of the Tacoma Spur highway project. Ecology has received several reports of a white, milky-colored discharge from CI-225 that was caused by discharges of latex from the construction area (Morrison, S., 9 June 1987, personal communication). Discharges of latex, used as a whitener in the concrete mix for the road surface, from the construction project have occurred periodically during construction.

CI-230 serves about 530 ac consisting of a large part of the downtown Tacoma business district and a portion of the residential section of Tacoma west of the business district (see Figure 10-7). Annual discharge from CI-230 is estimated at 900 ac-ft/yr (1.2 ft^3/sec), using a runoff coefficient of 0.6.

During its inspections, the Tacoma sewer utility discovered only five businesses that discharged wastewater to CI-230. All discharges consisted of wash water from vehicle and engine washing operations (Table 10-3) and have since been rerouted to the sanitary sewer system. The downtown business district contributes cooling water discharges from office and computer air conditioning equipment, possibly containing algicides and corrosion control chemicals. It is not known how many facilities discharge to the city storm drains. However, the Tacoma sewer utility believes that most facilities discharge to the sanitary sewer system (Robinson, R., 25 August 1987, personal communication).

Dames & Moore (1982) report that Burlington Northern operated a railroad car washing facility in the CI-230 drainage basin. In the past, residues that were washed out of the cars, including grains, solvents, chemicals, and oils, were dumped onsite and were probably transported to City Waterway in stormwater runoff.

The City of Tacoma has been monitoring effluent from CI-230 since October 1986. Analyses of particulate matter from CI-230 have shown lead and mercury concentrations to be consistently over the long-term goals. Cadmium exceeded long-term goals in over 50 percent of the samples. Although not indicator chemicals, zinc, copper and nickel were also consistently measured over the cleanup goals of 410, 390 and >140 mg/kg, respectively. HPAH and LPAH concentrations in particulate matter were over the long-term cleanup goals in all seven samples collected (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, 19 August 1988, personal communications).

TABLE 10-3. COMMERCIAL DISCHARGES TO STORM DRAIN CI-230 IDENTIFIED DURING SEWER UTILITY BUSINESS INSPECTIONS

Industry Name	Type of Discharge to Storm Drain	Action Taken
Downtown Auto Detail	Auto- and engine-washing wastewater	Improvements to drainage sump and effluent has been rerouted to sanitary sewer system.
L.H. Bates Vocational School	Rinse tank for small engines	Training operation has moved to a new facility with state-of-the-art equipment.
Pierce County Fleet Service	Vehicle washing area	Discharge rerouted to sanitary system
Budget Rent-A-Car	Vehicle washing area	Discharge rerouted to sanitary system.
Rely On Automotive	Vehicle washing/repair area	Business is relocating.

Reference: Robinson, R., 10 August and 31 August 1987, personal communications.

Individual loading calculations (see Appendix E) for the problem chemicals vary greatly among sampling events. Recent data obtained from two dry-weather sampling events by the City of Tacoma for CI-230 confirm this variability (Getchell, C., 18 December 1987 and 8 February 1988, personal communications). Loading estimates for CI-230 based on these data are 1.5 and 65 lb/day for zinc, 0.8 and 4.7 lb/day for lead, and not measurable for mercury (Odell, C., 20 April 1988, personal communication). The lead loading of 4.7 lb/day is much higher than estimates reported in Appendix E based on four previously collected samples. The 65 lb/day zinc loading is also higher than previous estimates reported in Appendix E. The City of Tacoma loading estimates should be qualified since city staff experienced difficulty in obtaining flow measurements (Odell, C., 20 April 1988, personal communication).

Loading estimates for CI-225 and CI-230 presented in Appendix E are not, in general, elevated over average urban runoff (residential, commercial, and highway) reported by Metro (Stuart et al. 1988) for the indicator metals (cadmium, lead, and mercury).

Storm Drains CI-243 and CI-245--

Storm drains CI-243 and CI-245 serve drainage basins located in the southeast corner of City Waterway (Figure 10-6). CI-243 drains approximately 90 ac of the Union Pacific and Burlington Northern Railroad yards. Annual runoff from the basin is estimated at 110 ac-ft/yr (0.2 ft^3/sec) based on average rainfall of 37 in/yr and a runoff coefficient of 0.4. CI-245 drains an area of approximately 50 ac, which includes the railroad yards, the Emerald Products property, and part of the Pacific Cold Storage property. Runoff from the CI-245 basin is estimated at 110 ac-ft/yr (0.2 ft^3/sec) based on a runoff coefficient of 0.7.

Ecology collected sediment samples from both CI-243 and CI-245 in June 1987. Data from this study were reported by Norton (15 April 1988, personal communication). Of the indicator metals measured in sediments from CI-243, only mercury concentrations exceeded the long-term cleanup goal. Sediment from this storm drain also had a concentration of HPAH over the long-term cleanup goal. In sediment samples from CI-245, concentrations of all three metal indicator chemicals exceeded the long-term cleanup goals. No HPAH contaminants were measured in the sediment from this storm drain.

As indicated in Appendix E, very few loading estimates are available from drains CI-243 and CI-245 for the indicator chemicals cadmium and lead. No mercury data are available from either storm drain. No loading estimates are available for HPAH from CI-243 and only one estimate is available from CI-245.

Storm Drain CI-235--

Ecology also collected sediment samples CI-235. This drain was included because the drainage basin includes the area around the new Tacoma Spur freeway system (SR-705), which is the former location of a coal gasification facility. Waste products from the coal gasification process were removed as part of the freeway construction. Discharge to this storm drain consists entirely of stormwater runoff. Measured concentrations of all indicator metals and HPAH in storm drain sediment exceeded the long-term goals (Norton, D., 15 April 1988, personal communication).

10.2.2 Martinac Shipbuilding

Site Background--

Martinac Shipbuilding has operated a shipbuilding facility at 401 East 15th Street on City Waterway since 1924. Martinac is involved primarily in the design and construction of large commercial vessels, although some ship repair work is also conducted.

The Martinac facility is considered a potential source of arsenic, copper, and zinc because the concentrations of these metals in sediments offshore of the facility were 2-10 times as great as those elsewhere in City Waterway (Norton and Johnson 1984). The offshore sediment sample that exhibited the highest metals concentrations was composed of 95 percent sand and appeared to be sandblasting material.

Identification of Contaminant Reservoirs Onsite--

The operations associated with metals contamination at the Martinac facility include sandblasting and painting. Sandblasting is primarily used to clean welds (Martinac, Jr., 11 November 1987, personal communication). Sandblasting for ship repair and paint removal is a relatively minor part of the current operations because Martinac is involved primarily with new construction that utilizes preprimed steel requiring no sandblasting. Contamination associated with sandblasting may be more heavily related to past operations and waste disposal practices. Ecology inspected the Martinac facility in summer of 1986 and reported that spent sandblast grit had accumulated along the intertidal areas (Backous B., 22 October 1987, personal communication).

Martinac currently uses Tuf-Kut blasting sand. Waste blasting material found on the beach at the Martinac facility contained 213 mg/kg arsenic, 2,120 mg/kg copper, 125 mg/kg lead, and 1,690 mg/kg zinc (Getchell, C., 23 December 1986a, personal communication). However, in the past, many of the shipyards in the Commencement Bay area used ASARCO slag as sandblast grit. Typical metals content of ASARCO slag is 9,000 mg/kg arsenic, 5,000 mg/kg copper, 5,000 mg/kg lead, and 18,000 mg/kg zinc (Norton and Johnson 1984).

The primary routes of contamination from paint and painting activities include spills, overspray, drift, and removal during sandblasting operations. Metals are used as additives in many biofouling paints and constitute 2-60 percent by volume of commercial marine paints (Muehling 1987). Prior to 1975, various mercury compounds were often used as antifoulants. However, after 1975, cuprous oxide replaced mercury as the primary antifoulant (Muehling 1987). Organotins are generally used in conjunction with copper to increase the service life of the antifoulant paint and are used exclusively on aluminum hulled boats because of the corrosivity of cuprous oxide.

The typical composition is 7-8 lb cuprous oxide and 1.5 lb organotin per gallon of paint.

Recent and Planned Remedial Activities--

Ecology is currently involved in a shipyard pollution education program. The program includes workshops to inform shipyard owners of best management practices and NPDES permit application procedures. Although shipyards in the Commencement Bay area are not currently permitted under the NPDES program, Ecology plans to write permits for all shipyard facilities. Permit requirements will include best management practices to prevent sandblast grit and other materials from entering the waterways, as well as monitoring requirements for oil, grease, turbidity, and metals.

Martinac currently conducts most sandblasting activities onshore away from the water in a covered area protected from the wind to prevent sandblasting grit from entering City Waterway (Martinac Jr., 11 November 1987, personal communication). Spent sandblast material is collected, temporarily stored onsite, and periodically removed by a contractor. During their 1986 inspection, Ecology reported that Martinac had instituted suitable containment procedures for dockside sandblasting, including installation of a boom and visqueen curtain around the vessel to collect spent sandblast material (Backous B., 22 October 1987, personal communication).

Most painting operations are completed before the vessel is put in the water. Painting is conducted in an enclosed paint shop for smaller jobs and inside construction buildings for larger projects (Martinac Jr., 11 November 1987, personal communication). For large outside painting projects, nearby catch basins are covered with plastic to prevent spilled material from entering the waterway via the storm drain system. Dockside painting, when required, is applied with rollers rather than sprayers to eliminate overspray problems (Stoltenberg, S., 11 November 1987, personal communication).

10.2.3 Groundwater

Hart-Crowser & Associates (1984) reported that groundwater was contaminated in the vicinity of the Tacoma Spur highway project (SR-705) at the former location of a coal gasification plant. This facility was located between 21st and 24th Streets and A and Dock Streets. Groundwater adjacent to City Waterway near the head was contaminated with PAH and other one-ring compounds (e.g., benzene, toluene). Hart-Crowser & Associates (1984) indicated that other sources, in addition to waste from the coal gasification, were potentially contributing to this contamination. Other potential contributors include an abandoned gasoline station at Puyallup and A Streets, an equipment storage yard, a coal- and wood-powered electricity generating plant, and petroleum product and storage tanks.

As part of constructing SR-705, the Washington Department of Transportation removed 4,500 tons of PAH-contaminated soil to a hazardous waste disposal facility in Arlington, Oregon. In addition, approximately 13,000 tons of soil contaminated with PAH to a lesser degree were placed in three concrete vaults near Interstate-5. A groundwater monitoring program is being implemented in the area where waste was removed to assess impacts of the removal action on groundwater contamination levels.

10.2.4 American Plating

Site Background--

Between 1955 and January 1986 metal electroplating operations were conducted at 2110 East D Street near the head of City Waterway. Activities took place under the names Puget Sound Plating, Seymour Electroplating, and in 1975, American Plating. Metals used in American Plating's operations included cadmium, copper, nickel, and zinc, which are identified as contaminants of concern in City Waterway (Tetra Tech 1985a, 1986c). Chromium was also used.

Prior to 1978, American Plating had an NPDES permit to discharge process wastewaters directly into City Waterway. Information in Ecology files indicates that there were numerous permit violations (Tetra Tech 1985a). Permitted discharges were discontinued when, subsequent to 1978, American Plating was connected to the Tacoma sewer utility sanitary sewer lines. According to Ecology files, plating wastes have been spilled on the site at least 10 times since 1979. For example, on 6 October 1981 an unknown volume of waste containing 4 mg/L zinc was spilled on the property. On 6 December 1984 the company reported a spill of zinc-contaminated material into the waterway. The volume of this waste spill was not estimated.

Chemicals and other hazardous materials associated with the plating processes remained even though operations ceased in 1975. Under the direction of Ecology these hazardous materials have been removed. However, contaminated soils and groundwater may continue to contribute metals to the waterway.

Identification of Contaminant Reservoirs Onsite--

The primary known metals reservoir onsite is contaminated surface soil. (Groundwater quality has not been evaluated.) Contaminants in the soil may be transported to the waterway via overland runoff or, if infiltrating runoff leaches metals from the soil into groundwater, via groundwater.

Recent and Planned Remedial Activities--

The cleanup of process-related hazardous materials on the site and preliminary soil tests were conducted under the framework of a Consent Order from Ecology. A soil and groundwater investigation is being conducted at the site to define the magnitude and extent of contamination.

10.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the potential success of source control was evaluated. This evaluation was based on levels of contamination in sediments and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to maintain acceptable levels of sediment contaminants over the long term.

10.3.1 Feasibility of Source Control

Four major kinds of sources of contamination have been identified for the head of City Waterway: storm drains (metals, HPAH), the Martinac shipbuilding facility (metals), groundwater seepage (HPAH), and American Plating (metals). Of the roughly 45 storm drains that discharge to head of City Waterway, drains CS-237, CN-237, CI-230, CI-225, CI-243, and CI-245 appear to be the major sources of problem chemicals to the waterway. The RI also identified historical sources of HPAH (Tetra Tech 1985a). Source controls have been implemented or may be required for the following mechanisms of contaminant discharge:

- Improper drain connections (storm drains)
- Occasional direct spills (ship discharges)
- Groundwater transport of contaminants (movement through buried wastes)
- Surface runoff (including storm drains from Martinac Shipbuilding, American Plating).

The level of source control assumed to be feasible for each of the potential major sources is presented in Table 10-4.

Storm Drains--

Several storm drains discharging to head of City Waterway have been identified as ongoing sources of metal contaminants and PAH to the waterway. Storm drains CS-237, CN-237, CI-230, CI-225, CI-243, and CI-245 appear to be the major conduits through which problem chemicals enter the waterway.

Available technologies for controlling surface water runoff to storm drains are summarized in Section 3.2.2. The technologies include methods for retaining runoff onsite (e.g., berms, channels, grading, sumps), revegetation or capping to reduce erosion of waste materials, and waste removal or treatment.

Treatment methods for stormwater after collection in a drainage system also exist. Sedimentation basins and vegetation channels (or grassy swales) have been shown to remove contamination associated with particulate matter. Removals of up to 75 percent for total suspended solids and 99 percent for lead have been reported for detention basins (Finnemore and Lynard 1982; Horner and Wonacott 1985). Removals of 90 percent for lead, copper, and

TABLE 10-4. EFFECTIVENESS OF SOURCE CONTROL FOR HEAD OF CITY WATERWAY

Source	Frequency of Detection in Effluent[a] (%) HPAH	Cd	Pb	Hg	Estimated Average Annual Discharge (Mgal/yr)	Average Load (lb/day)	Feasible Source Control Assumed (%)	Rationale for Percent Source Control
<u>Storm Drains</u>								
CN-237, CS-237	--	86	75	14	2,250	Pb=2.2 Hg=0.0015 Cd=0.004	50	Business inspections conducted in basins by City of Tacoma did not identify any major discharges. Assumed nonpoint source pollution reduced by 50 percent as result of implementation of best management practices (BMPs) and public education program instituted by Tacoma-Pierce County Health Department (TPCHD).
CI-225, CI-230, CI-243, CI-245	40	44	70	43	1,140	Pb=0.38 Hg=0.008 Cd=0.0016 HPAH=<0.002	50	Same as above.
Other Storm Drains	--	45	100	(CI-248) 50	150	Pb=0.008 Hg=9.2×10^{-6} Cd=0.0017	50	Assumed nonpoint source pollution reduced by 50 percent as result of implementation of BMPs and public education program instituted by TPCHD.
Martinac Shipbuilding	--	N/A[b]	N/A[b]	N/A[b]	Unknown	(In offshore sediments) Pb=244-382 mg/kg Hg=0.035-0.4 mg/kg Cd=1.02-2.04 mg/kg	95	Contamination appears to be caused by historical sandblasting operations and waste handling practices. Current activities primarily involve new construction, with minimal sandblasting. Ongoing sandblasting and painting operations have been modified. Facility will be permitted under NPDES program.
Groundwater	N/A[b]	--	--	--	Unknown	Unknown	50	Groundwater seepage is probably a source of HPAH. Soil cleanup has been performed to reduce groundwater contamination.
American Plating	--	N/A[b]	N/A[b]	N/A[b]	Unknown	(In offshore sediments) Pb=737-817 mg/kg Hg=0.23-0.35 mg/kg Cd=1.53-5.61 mg/kg	90	No longer in operation, facility demolished, tank plating solutions removed. Site cleanup expected under Ecology Consent Order.

[a] Indicator chemicals for head of City of Waterway are high molecular weight polynuclear aromatic hydrocarbons (HPAH), cadmium (Cd), lead (Pb), and mercury (Hg). Data provided in Appendix E; does not include data from City of Tacoma monitoring program.

[b] N/A = Probable source, frequency data not available.

zinc and 80 percent for total suspended solids have been achieved using grassy swales (Horner and Wonacott 1985; Miller 1987).

Contaminant reductions of 50 percent in the storm drains surrounding head of City Waterway are assumed to be achievable through implementation of all known, available, and reasonable technologies.

Martinac Shipbuilding--

Martinac Shipbuilding has been associated with elevated concentrations of metal contaminants in adjacent sediments. Sandblasting grit and antifouling paints are the suspected sources of metals to the Waterway from operations at Martinac. However, much of the contamination in the vicinity of Martinac Shipbuilding appears to be associated with historical sandblasting activities. More recently, sandblasting has been curtailed and practices have been revised to limit contamination of the waterway. It is assumed that implementation of these practices will reduce contaminant loading from this source by 95 percent.

Groundwater--

Groundwater contamination in the area near the head of City Waterway on the west side has been shown to be contaminated with PAH among other organic compounds. Available technologies for controlling the migration of contaminants via groundwater are summarized in Section 3.2.1. General categories of technologies include removal of contaminant source, containment (e.g., slurry walls), collection, in situ treatment, and post-removal treatment. Approximately 17,500 tons of contaminated soil has already been removed by the Washington Department of Transportation. It is assumed that through implementation of measures such as this, contaminant reductions in groundwater seepage can be reduced by 50 percent.

American Plating--

American Plating has been identified as a potential source of metals to City Waterway (Tetra Tech 1985a). Ongoing contamination of the waterway from American Plating may occur via surface water runoff, groundwater flow, or both. Available technologies for controlling surface water runoff are summarized in Section 3.2.2. Technologies for control of contamination in surface water include methods for retaining runoff onsite (e.g., berms, channels, grading, sumps), revegetation or capping to reduce erosion of waste materials, and waste removal or treatment. General categories of technologies for contaminant control in groundwater include removal of contaminant source, (e.g., slurry walls), collection, in situ treatment, and post-removal treatment. Cleanup of process-related hazardous materials on the site under a Consent Order from Ecology is expected to result in a 90 percent reduction in contamination from this source.

Conclusions--

Implementation of these measures should result in a significant reduction in contaminant discharges. Given the contaminant types, multiplicity of sources, lack of defined sources in some cases (e.g., storm drains and groundwater contamination near the head of the waterway), and available control technologies, it is estimated that implementation of all known, available, and reasonable control technologies will reduce contaminant loadings by 60 percent for both the indicator metals (cadmium, lead, and mercury) and HPAH.

10.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment in the head of City Waterway varies throughout the problem area. A sedimentation rate of 600 $mg/cm^2/yr$ (0.43 cm/yr) and a mixing depth of 10 cm were selected to represent the depositional environment. Four indicator chemicals (HPAH, cadmium, lead, and mercury) were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Two timeframes were considered: a reasonable timeframe (defined as 10 yr) and the long term. Losses due to biodegradation and diffusion were determined to be negligible for these chemicals. Source loadings for all indicator chemicals were assumed to be in steady-state with sediment accumulation. Results of the sediment recovery evaluation are summarized in Table 10-5.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted to be 2 yr for HPAH, 13 yr for cadmium, 14 yr for lead, and 24 yr for mercury. Only for HPAH is sediment recovery predicted to be possible in a reasonable timeframe (i.e., 10 yr). These predictions are based on the highest concentrations of indicator chemicals measured in the problem area. Because the source loadings of all indicator chemicals at the head of City Waterway are assumed to be in steady-state with sediment accumulation, reductions in sediment concentrations are not predicted unless sources are controlled.

Effect of Implementing Feasible Source Controls--

Implementation of all known, available, and reasonable source control is expected to reduce source inputs by 60 percent for all indicator chemicals. With this level of source control, as an input value, the model predicts that sediments with an enrichment ratio (ratio of the observed concentration to the cleanup goal) of 1.3 (i.e., concentrations of 21,400 ug/kg for HPAH, 6.6 mg/kg for cadmium, 585 mg/kg for lead, and 0.74 mg/kg for mercury) will recover within 10 yr. The surface area of sediments not recovering to cleanup goals within 10 yr is shown in Figure 10-8. For comparison, sediments currently exceeding long-term goals for the indicator chemicals are also shown.

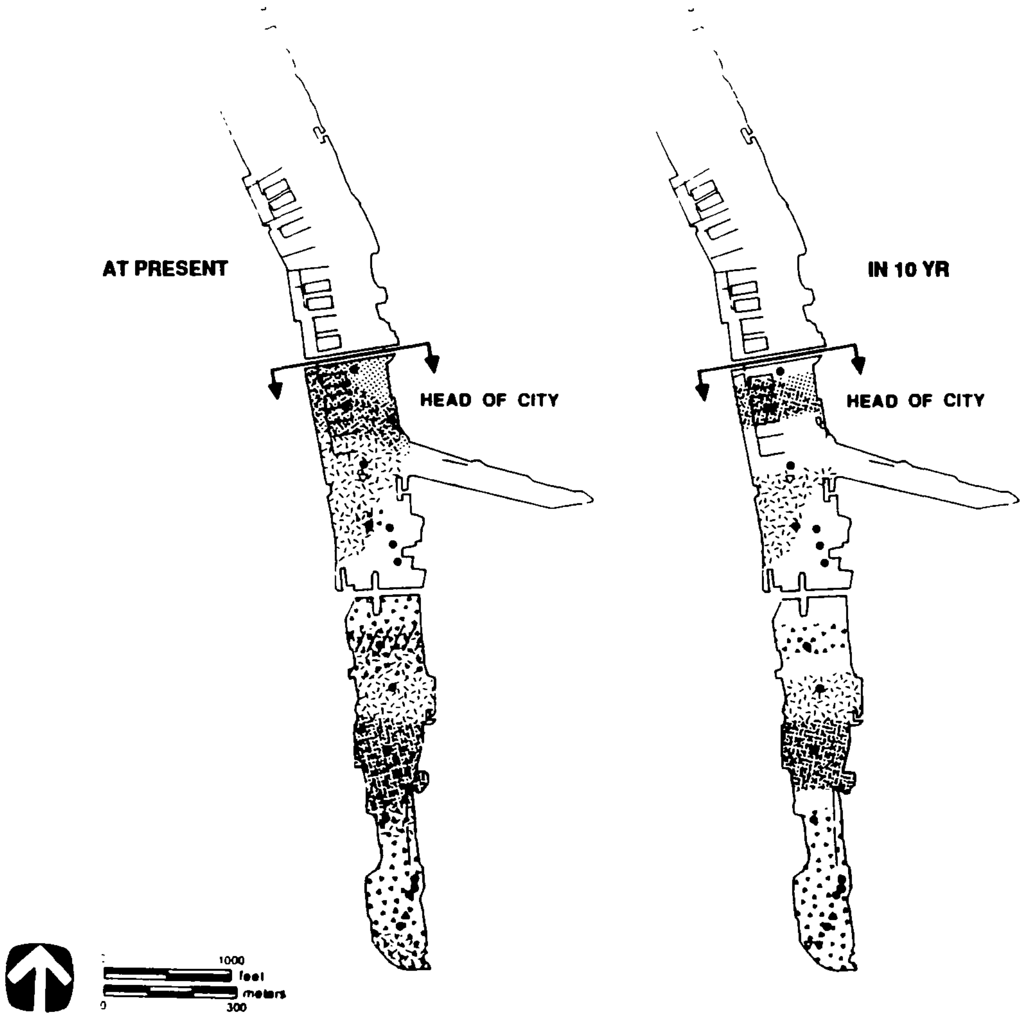
TABLE 10-5. HEAD OF CITY WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals			
	HPAH	Cadmium	Lead	Mercury
Station with Highest Concentration				
Station identification	CI-01	C11	CI-91	CI-13
Concentration[a]	18,660	8.2	820	1.5
Enrichment ratio[b]	1.1	1.6	1.8	2.5
Recovery time if sources are eliminated (yr)	2	13	14	24
Percent source control required to achieve 10-yr recovery	25	NP[c]	NP[c]	NP[c]
Percent source control required to achieve long-term recovery	9	38	45	61
Average of Three Highest Stations				
Concentration[a]	17,800	7.6	800	0.91
Enrichment ratio[b]	1.0	1.5	1.8	1.5
Percent source control required to achieve long-term recovery	4	33	44	35
10-Yr Recovery				
Percent source control assumed feasible	60	60	60	60
Highest concentration recovering in 10 yr[a]	21,400	6.6	585	0.74
Highest enrichment ratio of sediment recovering in 10 yr	1.3	1.3	1.3	1.3

a Concentrations in ug/kg dry weight for organics, mg/kg dry weight for metals.

b Enrichment ratio is the ratio of observed concentration to cleanup goal.

c NP = Not possible.



Head of City Waterway Indicator Chemicals

AT PRESENT	
DEPTH (yd)	2.5
AREA (yd^2)	230,000
VOLUME (yd^3)	575,000
IN 10 YR	
DEPTH (yd)	2.5
AREA (yd^2)	171,000
VOLUME (yd^3)	426,000

- ▲ FEASIBILITY STUDY SEDIMENT PROFILE SURVEYS (1986)
- ● SEDIMENT SURVEYS CONDUCTED IN 1984
- ▼ SEDIMENT SURVEYS CONDUCTED BEFORE 1984 (1979-1981)
- HPAH (AET = 17,000 µg/kg)
- MERCURY (AET = 0.59 mg/kg)
- CADMIUM (AET = 5.1 mg/kg)
- LEAD (AET = 450 mg/kg)

Figure 10-8. Sediments at the head of City Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

Source Control Required to Maintain Acceptable Contamination Levels--

As presented in Table 10-5, the percent source control needed to maintain acceptable contaminant concentrations in freshly deposited sediment is 4 for HPAH, 33 for cadmium, 44 for lead, and 35 for mercury. These estimates are based on an average of the three highest sediment concentrations for each indicator chemical measured in the head of City Waterway problem area. These values are presented for comparative purposes; the actual percent reduction required in source loading is subject to the uncertainty inherent in the assumptions of the predictive model. These values probably represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

Percent reductions needed to achieve cleanup goal concentrations of indicator chemicals in storm drain particulate matter are presented in Table 10-6. Average values reported for drains CS-237, CN-237, and CI-230 are based on seven samples each collected by the City of Tacoma (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, 19 August 1988, personal communications). The percent reductions needed to achieve long-term goal concentrations of indicator chemicals in sediments in storm drains CI-235, CI-243, and CI-245 are based on sediment data reported by Ecology (Norton, D., 15 April 1988, personal communication).

10.3.3 Source Control Summary

The four most important sources of problem chemicals to the head of City Waterway are as follows:

- Storm drains (HPAH, metals)
- Martinac Shipbuilding (metals)
- Groundwater seeps (HPAH)
- American Plating (metals).

If these sources are completely eliminated (100 percent source control), it is predicted that sediment contaminant concentrations in the surface mixed layer will decline to the HPAH long-term goal of 17,000 ug/kg in 2 yr, the cadmium long-term goal of 5.1 mg/kg in 13 yr, the lead long-term goal of 450 mg/kg in 14 yr, and the mercury long-term cleanup goal of 0.59 mg/kg in 24 yr. Consequently, sediment remedial action will be required to mitigate the observed and potential adverse biological effects within a reasonable timeframe.

Prior to initiating sediment remedial actions, additional source control measures will be needed to ensure that acceptable sediment quality is maintained. Estimates of the percent reductions required to maintain acceptable concentrations in freshly deposited sediment are 4 for HPAH, 33 for cadmium, 44 for lead, and 35 for mercury (see Table 10-5).

TABLE 10-6. AVERAGE PERCENT REDUCTIONS NEEDED TO ACHIEVE LONG-TERM CLEANUP GOAL CONCENTRATIONS OF INDICATOR CHEMICALS IN STORM DRAIN EFFLUENT PARTICULATE MATTER OR SEDIMENTS

	Indicator Chemical			
	HPAH (%)	Cadmium (%)	Lead (%)	Mercury (%)
CS-237[a]	32	0	0	0
CN-237[a]	83	44	5	56
CI-230[a]	90	31	58	50
CI-235[b]	51	0	0	65
CI-243[b]	32	0	0	51
CI-245[b]	0	58	43	73

[a] Effluent particulate matter; average of seven samples reported by City of Tacoma (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, 19 August 1988, personal communications).

[b] Sediments; data from Ecology (Norton, D., 15 April 1988, personal communication).

Implementation of all known, available, and reasonable control technologies is expected to provide an approximately 60 percent reduction of contaminant loadings to the waterway. Therefore, it appears that by implementing feasible levels of source control, long-term goals for all of the indicator chemicals can be maintained.

10.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with HPAH, cadmium, lead, or mercury concentrations currently exceeding long-term cleanup goals is approximately 575,000 yd^3 (see Figure 10-8). This volume was estimated by multiplying the areal extent of sediment exceeding the long-term cleanup goal (230,000 yd^2) by the estimated 2.5-yd depth of contamination (see contaminant sediment profiles in Figures 10-2 through 10-5). The estimated thickness of contamination is only an approximation since only one sediment profile was collected in this problem area.

The total estimated volume of sediments with HPAH, cadmium, lead, or mercury concentrations that is expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 426,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratios greater than 1.3 (see Table 10-5), an area of 171,000 yd^2, by the estimated 2.5-yd depth of contamination. These volumes are also approximations, accounting for uncertainties in sediment profile resolution and dredging tolerances.

The quantity of sediment used in evaluating the remedial alternatives (i.e., to identify the preferred alternative) was 426,000 yd^3. This is also the volume of sediment requiring remediation for the head of City Waterway.

10.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

10.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, this set of alternatives is evaluated to determine the suitability of each alternative for the remediation of contaminated sediments in the head of City Waterway. Remedial measures address 426,000 yd^3 of contaminated sediments. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess of the applicability of each alternative in the waterway. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; the location of potential disposal sites; and the site's physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives determined to be appropriate for the waterway can then be evaluated based on the criteria presented in Chapter 4.

The indicator chemicals HPAH, cadmium, lead, and mercury were selected to represent the primary potential sources of contamination to the waterway: storm drains, Martinac Shipbuilding, groundwater infiltration, and American Plating (see Table 10-1). Areal distributions for all four indicators are presented in Figure 10-8 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery.

It is assumed that the requirement to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

Four of the ten candidate alternatives have been eliminated for the head of City Waterway. Because total concentrations of metals are generally greater than 2,000 mg/kg, solvent extraction, thermal treatment, and land treatment are not applicable. In situ capping is eliminated because of the need to maintain a navigation channel in City Waterway. The following six candidate alternatives are evaluated for head of City Waterway:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solidification/upland disposal.

These candidate alternatives are described in detail in Chapter 3. Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from exposure to contaminated sediments without implementing sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives remain applicable to remediation of sediment contamination in the head of City Waterway. Solidification is retained as an appropriate treatment technology because it is primarily used to treat materials contaminated with inorganics.

10.5.2 Evaluation of Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 10-7. A comparative evaluation of alternatives based on ratings of high, moderate, and low in the various subcategories of evaluation criteria is presented in Table 10-8. For effectiveness, the subcategories are short-

TABLE 10-7. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE HEAD OF CITY WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge treatment and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim. However, an equivalent volume of clean sediment will be added to restore the habitat.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Benthic habitat is impacted at the disposal site.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked sixth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. Sediment recovery is improbable within 10 years. This alternative is ranked fifth overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Disposal siting and facility construction may delay project completion. This alternative is ranked second overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment and methods are available. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Disposal siting and facility construction delay implementation. This alternative is ranked third overall for timeliness.	Substantial CDM testing and equipment development are required before a solidification scheme can be implemented. Extensive bench- and pilot-scale testing are likely to be required. This alternative is ranked fourth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in a quiescent, subaquatic environment is considered acceptable.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Long-term reliability of solidification treatment processes for CDM are believed to be adequate. However, data from which to confirm long-term reliability are limited. Upland disposal facilities are structurally reliable
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Variable physicochemical conditions in the fill increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Contaminants are physically contained, thereby reducing toxicity and the potential for contaminant migration compared with non-treatment alternatives. Metals and organics are encapsulated.

TABLE 10-7. (CONTINUED)

		NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
IMPLEMENTABILITY – TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, although feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Solidification technologies for treating CDM on a large scale are conceptual. Implementation is considered feasible, but reliability is unknown.
IMPLEMENTABILITY – TECHNICAL FEASIBILITY	IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities are implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Monitoring implementability is enhanced compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring requirements for solidified material are low in comparison with dredge and disposal alternatives. Monitoring can be readily implemented.
IMPLEMENTABILITY – TECHNICAL FEASIBILITY	IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment. System maintenance is intensive during implementation.
IMPLEMENTABILITY – INSTITUTIONAL FEASIBILITY	APPROVAL OF RELEVANT AGENCIES	Approval is denied as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Disposal requirements are less stringent for treated dredge material, enhancing approval feasibility. However, bench scale testing is required to demonstrate effectiveness of solidification.
IMPLEMENTABILITY – INSTITUTIONAL FEASIBILITY	COMPLIANCE WITH CHEMICAL- AND LOCATION-SPECIFIC ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. May require that substantive aspects of CWA and shoreline management programs be addressed.
IMPLEMENTABILITY – AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Waterway CAD site is considered available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Disposal site availability is uncertain but feasible. Solidification equipment and methods for large scale CDM disposal are currently unavailable.

TABLE 10-8. EVALUATION SUMMARY FOR THE HEAD OF CITY WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Solidify/ Upland Disposal
Short-Term Protectiveness	Low	Low	High	Moderate	Moderate	Moderate
Timeliness	Low	Low	Moderate	Moderate	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High
Technical Feasibility	High	High	Moderate	High	High	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	Moderate	Moderate	Moderate
Long-Term Cleanup Goal Cost[a]						
Capital	--	6	4,526	14,086	25,171	38,121
O&M	--	2,325	604	721	1,121	1,066
Total	--	2,331	5,130	14,807	26,292	39,187
Long-Term Cleanup Goal with 10-yr Recovery Cost[a,b]						
Capital	--	6	3,372	10,454	18,658	28,260
O&M	--	2,101	485	572	869	828
Total	--	2,107	3,857	11,026	19,527	29,088

[a] All costs are in $1,000.

[b] Includes sediment for which biological effects were observed for non-indicator compounds.

term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. For implementability, the subcategories are technical feasibility, institutional feasibility, and availability. Costs include capital costs and O&M costs. Remedial costs are shown for sediments currently exceeding long-term cleanup goal concentrations.

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts continue with the contaminated sediments remaining in place. Source control measures initiated as part of the institutional controls would result in reduced sediment contamination with time but adverse impacts would persist in the interim. It is predicted that, even with complete source elimination, reduction in sediment concentrations to acceptable levels could require 14 yr for mercury (see Table 10-5).

Except for clamshell dredging/confined aquatic disposal, other alternatives involving dredging are rated moderate for short-term protectiveness. Removal of contaminated sediments is expected to create short-term disturbance to intertidal habitat along the shores of the waterway. However, an equivalent volume of clean sediment will be added to restore the habitat. The clamshell dredging/nearshore disposal alternative is rated moderate for short-term protectiveness primarily because some direct worker exposure is expected during dredging operations. However, worker exposure can be minimized through the use of protective clothing and other safety-related gear. The alternatives involving treatment received moderate ratings for short-term protectiveness because all involve dredged material handling and long implementation periods, which increase potential worker exposure.

Clamshell dredging/confined aquatic disposal is rated high for short-term protectiveness. Handling requirements are low, worker and public exposure can be minimized through the use of safety gears, and adverse effects to the benthic community at the disposal site are expected to be short-lived, with re-establishment occurring quickly once the site is capped.

Timeliness--

The no-action and institutional controls alternatives received low ratings for timeliness. With no action, sediments remain unacceptably contaminated, source inputs continue, and natural sediment recovery is unlikely. Source inputs are controlled under the institutional controls alternative but, as discussed in Section 10.3.2, sediment recovery based on the indicator contaminants cadmium, lead, and mercury is estimated to be improbable within 10 yr.

Moderate ratings were assigned to all other alternatives. The Blair Waterway Slip 1 nearshore disposal site would not be large enough to accommodate sediment from the head of City Waterway plus sediment from other problem areas. Therefore, an additional nearshore disposal site would need to be identified. Likewise, upland or confined aquatic disposal sites will also need to be identified. Approval and construction of nearshore, upland, or confined aquatic disposal sites is estimated to require 1-2 yr.

Long-Term Protectiveness--

The evaluation for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for sediment recovery is long. For the latter alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source reductions. The observed adverse biological impacts continue and the potential for impacts through the food chain remains.

Moderate ratings were assigned to the clamshell dredging/nearshore disposal and hydraulic dredging/upland disposal alternatives because of the physicochemical changes that would occur when dredged material is placed in these disposal facilities. These changes, primarily from new redox conditions, would tend to increase the migration potential of the inorganic contaminants. In nearshore facilities, these physicochemical changes can be minimized by placing sediments below the low tide elevation. Dredged material testing should provide the necessary data on the magnitude of these impacts. Although the structural reliability of nearshore facilities is regarded as good, the nearshore environment is dynamic in nature (i.e., from wave action and tidal influences). Even though the upland disposal facility is generally regarded as a more secure option because of improved engineering controls during construction, there is potential for impacts on groundwater.

The alternative involving solidification received a high rating primarily because the treatment processes would result in long-term isolation of the inorganic contaminants. Confined aquatic disposal was also rated high for long-term protection. Isolation of contaminated material in the subaquatic environment provides a high degree of protection, with little potential that sensitive environments will be exposed to sediment contaminants. In addition, confined aquatic disposal would maintain physicochemical conditions of the contaminated sediments, thereby minimizing potential contaminant migration.

Reduction in Toxicity, Mobility, or Volume--

Low ratings were assigned to all alternatives under this criterion, except for solidification. Although, the confined aquatic disposal, upland, and nearshore disposal alternatives isolate contaminated sediments from the surrounding environment, the chemistry and toxicity of the material itself would remain largely unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated dredged material may actually increase with changes in redox potential. Without treatment, the toxicity of contaminated sediments would remain at preremediation levels. Contaminated sediment volumes would not be reduced, and may actually increase with hydraulic dredging options because of suspension of the material in an aqueous slurry.

Clamshell dredging with solidification and upland disposal is rated high for reduction in toxicity, mobility, and volume because inorganic contaminants would be immobilized.

Technical Feasibility--

A moderate rating was applied to the option for dredging and confined aquatic disposal of contaminated sediments at an open-water disposal site, primarily because placement of dredged and capping materials at depths of approximately 100 ft would be difficult, although feasible. A moderate rating was also applied to the alternative involving solidification, primarily because of the need for bench-scale testing prior to implementation. Solidification technologies for the treatment of contaminated dredged material on a large scale are conceptual at this point, although the method appears to be feasible (Cullinane, J., 18 November 1987, personal communication).

High ratings were applied to the no-action and institutional controls alternatives because they can be implemented immediately. High ratings were also applied to the clamshell dredging/nearshore disposal and hydraulic dredging/upland disposal alternatives, which can be implemented with readily available equipment using well established methods.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives were assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings were assigned to the remaining alternatives because of potential difficulty in obtaining agency approvals for disposal sites or implementation of treatment technologies. Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. The Blair Waterway Slip 1 was assumed to be available as a nearshore facility, but remains undeveloped and in any case, would not be large enough to accommodate all sediments from this problem area and those from other areas. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. For the two upland disposal alternatives, agency approvals are assumed to be contingent upon bench-scale demonstrations of ability to meet established performance goals (e.g., treatability of dredge water and immobilization of contaminants through solidification).

Availability--

The no-action and institutional controls alternatives are rated high for availability. Because of the nature of the no-action and institutional controls alternatives, equipment and siting availability are not obstacles to implementation.

Remedial alternatives that include confined aquatic, nearshore, and upland disposal are rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that confined aquatic and upland sites will be available. However, no sites are currently approved for use and no sites are currently under construction. Although the Blair Waterway Slip 1 site is assumed to be available as a nearshore disposal facility, volumes from the head of City Waterway may exceed its capacity if sediments from other areas are to be accepted.

Cost--

Capital costs increase with increasing complexity (i.e., from the no-action to the treatment alternatives). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for clamshell dredging with either nearshore or confined aquatic disposal, primarily due to underdrain and bottom liner installation, dredge water clarification, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting solidification increases as a result of material costs for the processes, and associated labor costs for material handling and transport. Dredge water clarification management costs are also incurred for this alternative. The high cost of site acquisition makes the cost of nearshore disposal higher than the cost of confined aquatic disposal.

An important component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Monitoring costs for confined aquatic disposal are significantly higher than for other options because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a groundwater sample from each well to assess contaminant migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding AET values) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the treatment alternatives are significantly lower than for other alternatives because the treatment processes reduce the potential for contaminant migration.

10.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the six sediment remedial alternatives proposed for head of City Waterway, clamshell dredging with confined aquatic disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, confined aquatic disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. The confined aquatic disposal alternative is currently preferred for the following reasons:

- The alternative protects human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment

- Confined aquatic disposal is technically feasible and has been demonstrated to be effective in isolating contaminated sediments

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental requirements

- Performance monitoring can be accomplished effectively and implemented readily

- The volume of contaminated sediment requiring remediation (approximately 426,000 yd^3) is compatible with the available capacity of the tentatively identified confined aquatic disposal facilities within the Commencement Bay area

- The sediments in this problem area have high organic carbon concentrations; placement of these sediments in an oxidizing environment (present in areas of the nearshore facility above the water table) would tend to result in acidic conditions, which in turn could lead to mobilization of metals (U.S. Army Corps of Engineers 1985)

- Contaminant concentrations in the sediments are only moderately elevated over those acceptable for open-water disposal (PSDDA guidelines); severe water quality impacts due to dredging and disposal of sediments in water are not anticipated

- The costs of developing an upland facility that is protective of groundwater resources are not warranted considering the levels of contamination and high bulk of sediments in the mouth of Hylebos Waterway

- Costs are $7 million less than those of the nearshore disposal alternative and $16 million less than those of the upland disposal alternative.

Clamshell dredging with confined aquatic disposal is rated high for long-term protectiveness and moderate for all other criteria, except reduction in toxicity, mobility, or volume, for which it is rated low. Implementation of this alternative can be coordinated with similar sediment remediation activities in Wheeler-Osgood Waterway, and the mouth of Hylebos Waterway. The alternative is ranked as moderate for short-term protectiveness because of the potential worker safety hazards and disturbance of intertidal habitat along the shores of the waterway. This latter disadvantage can be offset in the long term through incorporation of a habitat replacement project in the remedial process. Habitat enhancement is addressed in part by removing contaminated sediments from the waterway itself and replacing them with clean sediment. As indicated in Table 10-8, this alternative also provides a cost-effective means of sediment remediation.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with contaminated dredged material redistribution. Potential impacts on water quality criteria can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Once a disposal site is selected, this alternative can be implemented over a relatively short timeframe, and seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

The nearshore disposal alternative was not selected because the volume of material is more compatible with confined aquatic disposal. The Blair Waterway Slip 1 disposal area is not large enough to accommodate all contaminated sediments in the Commencement Bay N/T area, nor is it appropriate for the contaminants in all sediments. Although confined aquatic disposal cannot be implemented as quickly as nearshore disposal at an available site, it offers a similar degree of protection at a lower cost.

The hydraulic dredging/upland disposal alternative is more costly than both the confined aquatic and nearshore disposal options, and does not provide any appreciable benefits over these options. Upland disposal is therefore not preferred. The solidification/upland disposal alternative was not selected since the timeframe required for remedial action would be lengthened. Implementation of this alternative would require bench-scale and possibly pilot scale testing prior to implementation. In addition, treatment itself would take a considerable amount of time, given available treatment equipment and the large volume of contaminated sediments. Decreased mobility of contaminants due to treatment by stabilization is not expected to significantly increase long-term protectiveness compared with confined aquatic disposal. Performance monitoring associated with confined aquatic disposal would allow early detection of contaminant movement to the surrounding environment, and corrective actions can be implemented before adverse effects occur. The solidification/upland disposal alternative has a cost of over 7 times as great than the confined aquatic disposal alternative. Expenditure of this additional money does not appear warranted based on the above discussion.

No-action and institutional controls alternatives are ranked high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public impacts far outweighs these advantages.

10.7 CONCLUSIONS

The head of City Waterway was identified as a problem area because of the elevated concentrations of several organic and inorganic contaminants. HPAH, cadmium, lead, and mercury were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume of sediment to be remediated. In this problem area, sediments with indicator chemical concentrations currently exceeding long-term cleanup goals cover an area of approximately 230,000 yd^2, with a volume of 575,000 yd^3. Of the total sediment area currently exceeding long-term cleanup goals, 59,000 yd^2 is predicted to recover within 10 yr following implementation of known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by 149,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 426,000 yd^3.

The primary current and historic sources of problem chemicals to the head of City Waterway include the following:

- Storm drains, particularly drains CN-237, CS-237, CI-225, CI-230, CI-243, and CI-245
- Martinac Shipbuilding
- Groundwater seepage
- American Plating.

Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include the following recent and proposed actions:

- Reduce the amount of metals and hydrocarbons in storm drain discharge
- Conduct additional source identification to identify sources of groundwater contamination, and implement control technologies if necessary
- Conduct additional investigation of the American Plating facility and implement control technologies if necessary
- Confirm that all significant sources of problem chemicals have been identified and controlled
- Implement regular sediment monitoring to confirm sediment recovery predictions and assess the adequacy of source control measures.

In general, it should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals HPAH, cadmium, lead, and mercury. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be re-evaluated.

Clamshell dredging with confined aquatic disposal was recommended as the preferred alternative for remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment. Confined aquatic disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 10-8, clamshell dredging with confined aquatic disposal provides a cost-effective means of sediment remediation. The estimated cost to implement this alternative is $3,372,000. Environmental monitoring and other O&M costs at the disposal site have a present worth of

$485,000 for a period of 30 yr. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of the preferred alternative is $3,857,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures

- Final selection of a disposal site.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize permanent solutions to the maximum extent practicable, and are cost-effective.

11.0 WHEELER-OSGOOD WATERWAY

Potential remedial actions are defined and evaluated in this section for the Wheeler-Osgood Waterway problem area. The waterway is described in Section 11.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 11.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contamination are discussed in Section 11.3. Areas and volumes of sediments requiring remediation are discussed in Section 11.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 11.5. The preferred alternative is identified in Section 11.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 11.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

11.1 WATERWAY DESCRIPTION

Wheeler-Osgood Waterway branches off of City Waterway approximately midway along its eastern side (Figure 11-1). Formed prior to 1894 from the old western channel of the Puyallup River (Tetra Tech 1986c), the waterway is ringed by abandoned buildings, warehouses, and several small industries. Wheeler-Osgood Waterway is privately owned and is not regarded as a navigable channel. Water depths in the waterway are generally less than 10 ft, and width ranges from approximately 65 ft at the head to approximately 100 ft at the mouth, where the channel intersects City Waterway.

11.1.1 Nature and Extent of Contamination

Analysis of data collected during the RI/FS in conjunction with historical data has revealed extensive organic and inorganic contamination in Wheeler-Osgood Waterway (Tetra Tech 1985a, 1986c). The highest levels of organic enrichment found within Commencement Bay Nearshore/Tideflats (N/S) area sediments were observed here. Total organic carbon concentrations of 10-18 percent were detected, and TOC was identified as a Priority 2 contaminant in the waterway (Tetra Tech 1986c). Other organic contaminants, all of which were classified as Priority 2, include LPAH, HPAH, biphenyl, phenol, 4-methylphenol, 1,2-dichlorobenzene, and N-nitrosodiphenylamine. HPAH was selected as an indicator of hydrocarbon contamination originating from several potential nonpoint sources (see Section 11.2). Estimated areal and depth distributions of HPAH are illustrated in Figure 11-2. Elevated concentrations of HPAH were observed throughout the central portion of the waterway, and surficial HPAH contamination exceeded the long-term cleanup

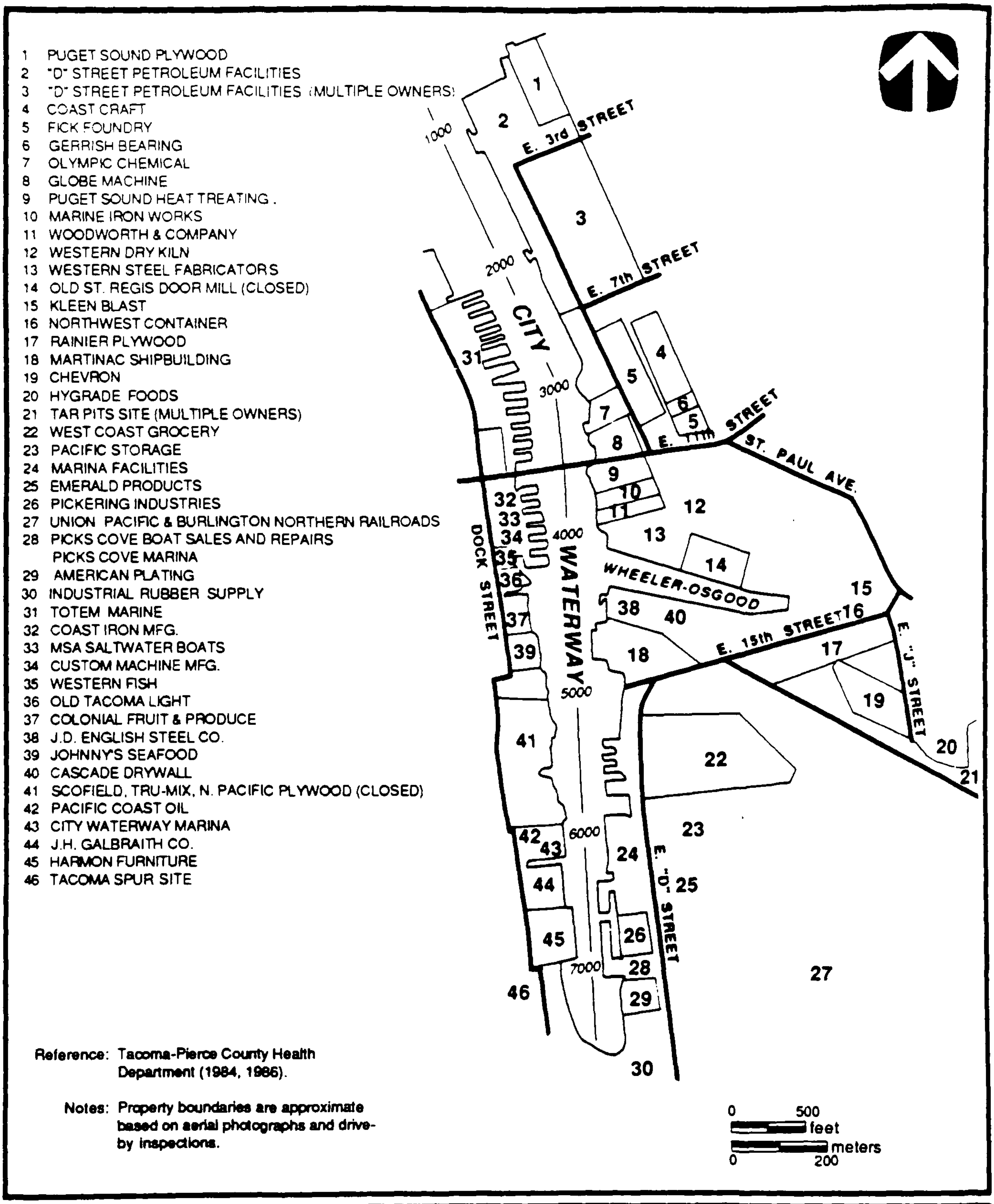


Figure 11-1. Wheeler-Osgood Waterway - Existing businesses and industries.

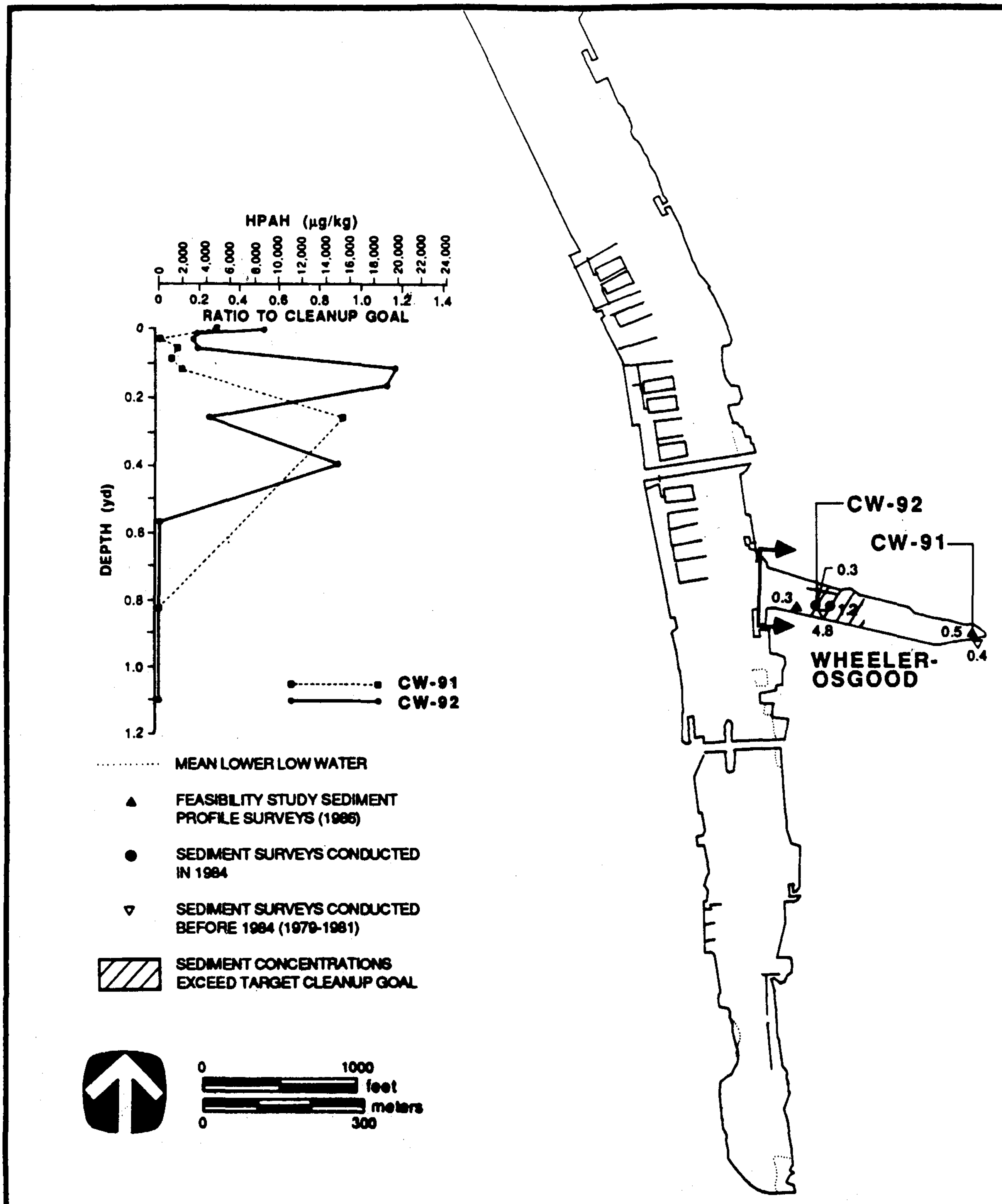


Figure 11-2. Areal and depth distributions of HPAH in sediments of Wheeler-Osgood Waterway, normalized to long-term cleanup goal.

goal of 17,000 ug/kg at two stations in the waterway. The sediment core profiles shown in Figure 11-2 indicate that high concentrations of HPAH were present to depths of approximately 0.5 yd. The fact that contamination was detected at depth in two cores separated by a considerable distance within the problem area suggests that the subsurface contamination is not localized.

Zinc, copper, lead, and cadmium were also observed at high concentrations in Wheeler-Osgood Waterway (Tetra Tech 1985a, 1986c). Metals evaluated during the RI were relatively uniformly distributed throughout the waterway (Tetra Tech 1985a) and all were identified as Priority 2 contaminants. Total metals concentrations based on the sum of maximum observed concentrations for lead, zinc, and copper were less than 2,000 mg/kg in the waterway. Zinc was selected as an indicator of metals contamination. Estimated areal and depth distributions of zinc are shown in Figure 11-3. Concentrations of zinc exceeding the cleanup goal of 410 mg/kg extend over the eastern two-thirds of the problem area. Depth profiles obtained from the two core sampling stations suggest that metals contamination exceeds the cleanup goal to depths of approximately 0.5 yd, with the highest concentrations occurring at the head of the waterway and declining towards the mouth.

11.1.2 Recent and Planned Dredging Projects

The U.S. Army Corps of Engineers has not recently received any applications for dredging permits in Wheeler-Osgood Waterway, nor does the Port of Tacoma have any existing dredging plans.

11.2 POTENTIAL SOURCES OF CONTAMINATION

This section provides an overview of the sources of contamination to the sediments of Wheeler-Osgood Waterway and a summary of available loading information for the contaminants of concern. The only potential source of contaminants that has been identified is storm drain runoff (Table 11-1).

The Wheeler-Osgood drain (CW-254) is the largest storm drain discharging into Wheeler-Osgood Waterway (Figure 11-4). It drains an area of approximately 80 ac adjacent to the head of Wheeler Osgood Waterway. Annual runoff from the CW-254 drainage basin is estimated at 160 ac-ft/yr (0.2 ft^3/sec), based on an average rainfall of 37 in (Norton and Johnson 1985a) and a runoff coefficient of 0.7. Industries currently active in the drainage basin include Hygrade Foods, Rainier Plywood, Kleen Blast, Northwest Container, and Chevron (see Nos. 20, 17, 15, 16, and 19, respectively in Figure 11-1). Discharge from CW-254 consists of stormwater runoff and noncontact cooling water from Hygrade Foods, the only NPDES-permitted industry in the basin.

Hygrade Foods is allowed to discharge a maximum of 190,000 gal/day (0.3 ft^3/sec) of noncontact cooling water to drain CW-254. The permit requires monitoring of total oil and grease and pH. During a site inspection of Hygrade Foods in October 1987, Ecology staff observed minor problems and found that the facility's drainage characterization was inadequate.

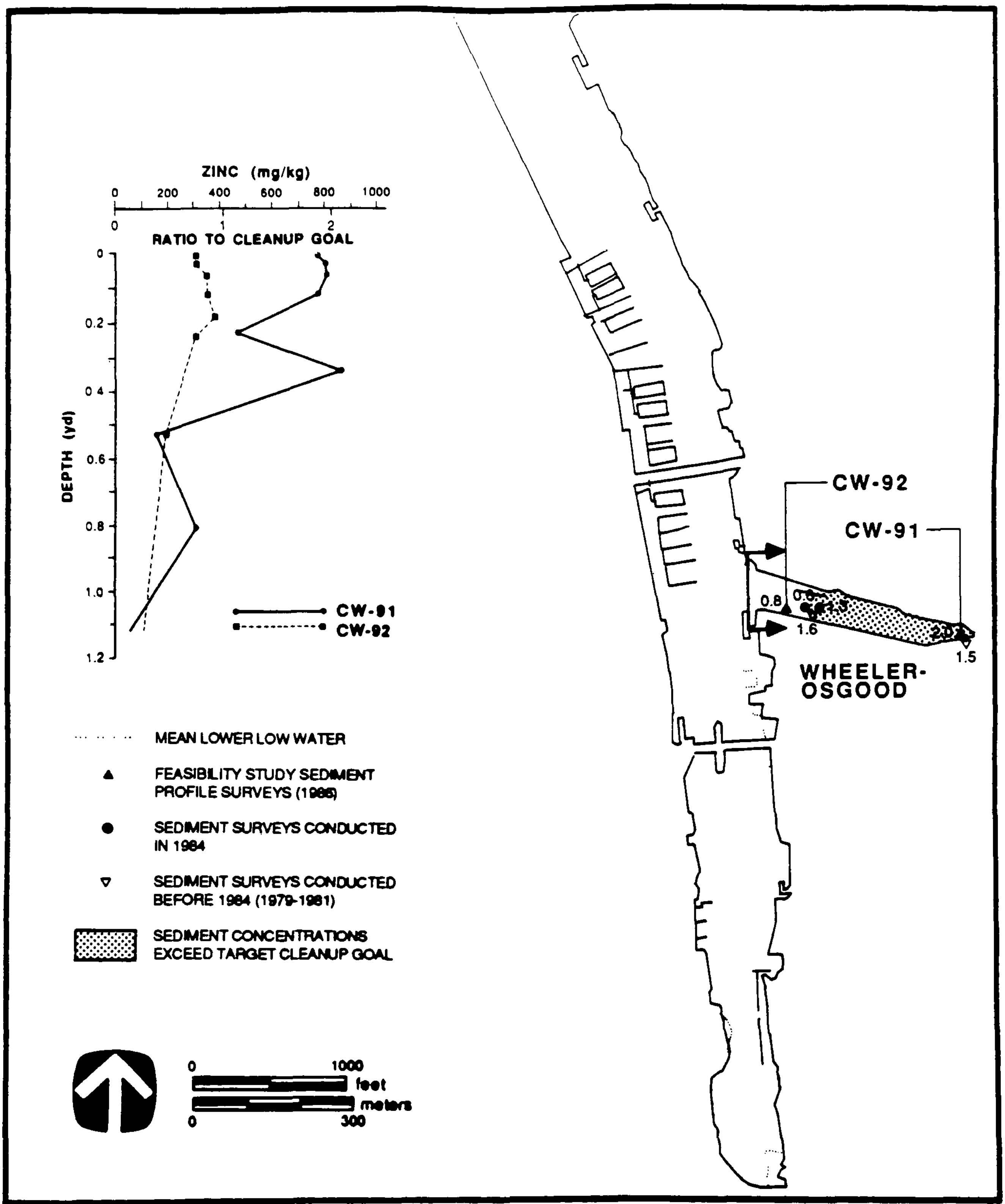


Figure 11-3. Areal and depth distributions of zinc in sediments of Wheeler-Osgood Waterway, normalized to long-term cleanup goal.

TABLE 11-1. WHEELER-OSGOOD WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
Total organic carbon	2	Storm drains, mainly at head of Wheeler-Osgood	Yes	Yes	Ongoing	No clear trend
Total volatile solids	2					
Grease and oil	2					
LPAH	2	Chevron	Potential	No	Ongoing	Variable; general surface minima
HPAH	2	Storm drains	Yes	Yes	Ongoing	
Biphenyl	2	Ubiquitous oil spills	Potential	No	Ongoing, sporadic	
Phenol	2	Marina fires	Potential	No	Historical	
Zinc	2	Storm drains	Yes	Yes	Ongoing	Fairly constant over surface 15 cm. Slight surface minima for lead at one station
Copper	2					
Lead	2	Unknown	No	No	Unknown	
Cadmium	2					
1,2-Dichlorobenzene	2	Carstens Packing House and Hygrade Food	Potential	No	Historical	Pronounced surface minimum
4-Methylphenol	2	Tacoma Tar Pits	Potential	No	Historical	Surface minimum
			Potential	No		
N-nitrosodiphenylamine	2	Unknown	No	No	Ongoing	Surface maxima

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

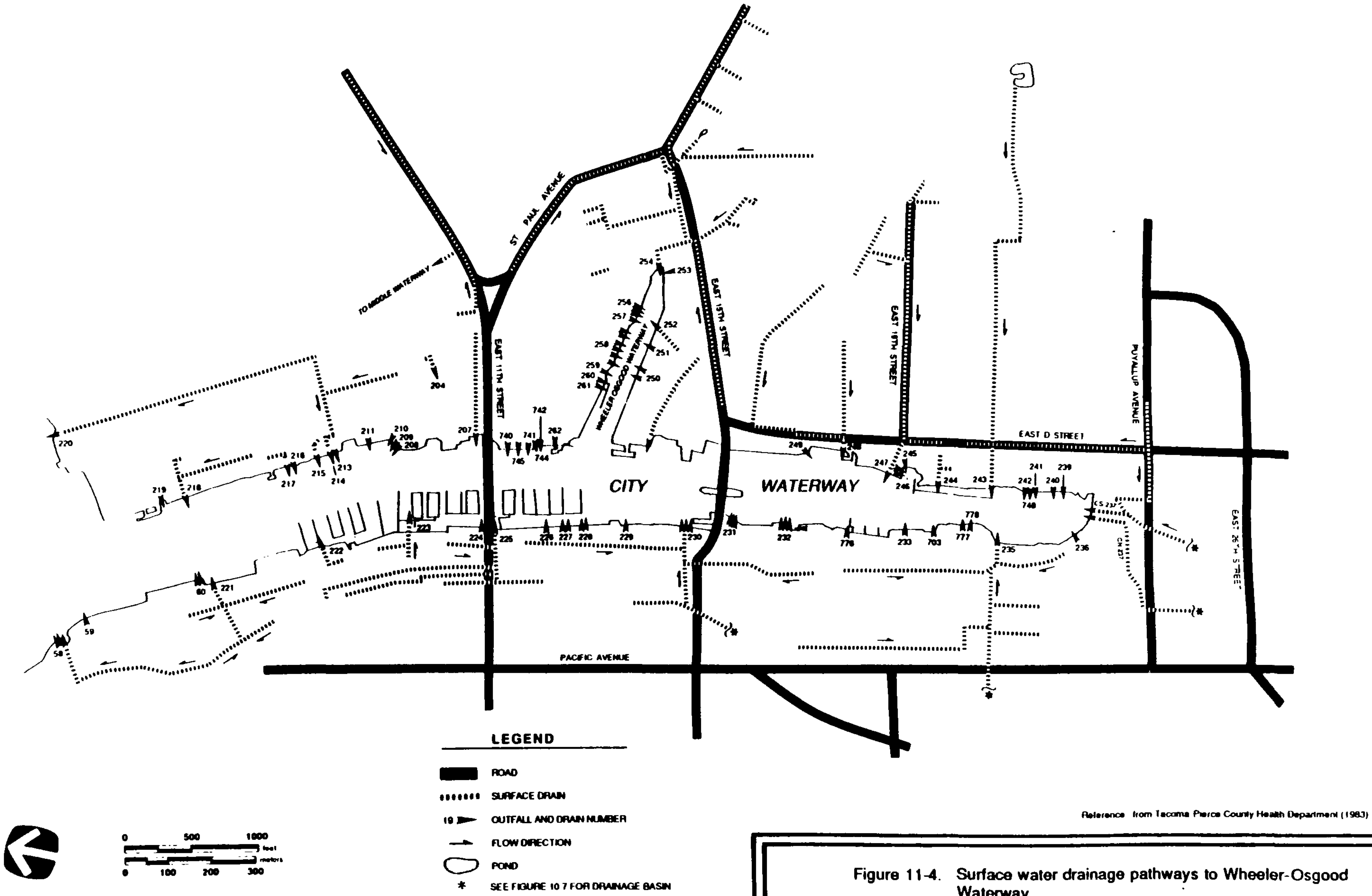


Figure 11-4. Surface water drainage pathways to Wheeler-Osgood Waterway.

Reissuance of the facility's permit was delayed until these deficiencies could be corrected (Morrison, S., 22 January 1988, personal communication).

In the past, storm drain CW-254 received untreated industrial wastes from Carsten's Packing Company. A slaughterhouse and meat packing plant, Carsten's was bought by Hygrade Foods in about 1960. The direct discharge of process wastes to CW-254 was discontinued around 1970, when Hygrade began discharging wastes to the city sanitary sewer system. However, because of unidentified cross-connections between the process effluent and the cooling water/storm drain system, some discharge of process waste to CW-254 continued until at least the mid-1970s (Tetra Tech 1985a).

Historical loading of contaminants into storm drain CW-254 may also have occurred from the Chevron property. Dames & Moore (1982) reported the occurrence of numerous spills onsite, noting that the historical method of dispersing oil was to dig holes in the sand and allow seepage into underlying soils. These waste materials were probably picked up in area drains and discharged to the waterway via CW-254.

Other storm drains discharging into Wheeler-Osgood Waterway are relatively minor, functioning primarily as roof and parking lot drains from adjacent property (Figure 11-4). Descriptions of these storm drains are provided in Table 11-2.

Ecology recently conducted a survey of storm drains in Wheeler-Osgood Waterway (Stinson and Norton 1987c). Grab samples were collected from 4 of the 11 drains in the waterway (i.e., CW-252, CW-254, CW-257, and CW-261) during a single rainfall event of 0.15 in. The remaining storm drains could not be sampled because of negligible flows. At 0.4 ft^3/sec, the Wheeler-Osgood drain (CW-254) accounted for more than 95 percent of the total storm drain flow measured during the sampling event. Flow in the other three drains ranged from 0.001 ft^3/sec to 0.006 ft^3/sec. Contaminants frequently detected in the storm drain discharges include metals (arsenic, copper, lead, and zinc), pentachlorophenol, PAH, and phthalates. Phenol, 2-methylphenol, and 4-methylphenol were detected only in drain CW-261.

In October 1986, the City of Tacoma began monitoring effluent quarterly from several drains in the tideflats area, including CW-254. Copper concentrations in particulate matter from CW-254 effluent have consistently been greater than the long-term sediment cleanup goals in the three data sets currently available. Cadmium, lead, nickel, mercury, zinc, LPAH and HPAH concentrations were greater than the long-term cleanup goals in most samples collected (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, and 19 August 1988, personal communications). The comparison of storm drain particulate matter with cleanup goals assumes no mixing of sediments with cleaner material from other sources, and provides a worst-case analysis of the impact of storm drain discharge on sediment quality in the waterway.

The available data indicate that CW-254 is the major source of metals loadings from surface runoff to Wheeler-Osgood Waterway. However, the relatively large loadings are primarily a function of flow. Metals concentrations observed in CW-254 discharges were consistently lower than

TABLE 11-2. STORM DRAINS DISCHARGING INTO WHEELER-OSGOOD WATERWAY

Drain Number	Description	Use
250	18-in open channel	Stormwater runoff from roof drain and paved area at JD English Steel
	18-in concrete pipe	Runoff from parking lot at JD English steel
251	24-in concrete pipe	Unknown
252	6-in PVC pipe	Runoff from parking lot at Cascade Drywall, Inc.
253	6-in concrete pipe	Runoff from parking lot at General Beer Distributors
254	30-in corrugated steel	Largest drain in waterway. Serves area between Portland Avenue and the head of Wheeler-Osgood Waterway. Also receives NPDES-permitted noncontact cooling water discharge from Hygrade Foods.
255	2-in iron pipe	No longer operational
256	6-in concrete pipe 4-in iron pipe 12-in concrete	Major drain for yard area
257	18-in concrete pipe	Unknown
258	Series of pipes	Roof drains for Waddles Company building
259	12-in concrete pipe	Unknown
260	8-in concrete pipe	Runoff from paved area at Western Steel Fabricators
261	12-in steel pipe	Unknown

Reference: Hanowell, R., 9 April 1986, personal communication.

the concentrations measured in other storm drain discharges to Wheeler-Osgood Waterway. Metals concentrations in all storm drains sampled were generally within the range typical of urban runoff, suggesting that metals may originate from nonpoint sources rather than a specific contaminant source.

Sources of HPAH to Wheeler-Osgood Waterway are not as well defined. HPAH concentrations in particulate matter from CW-254 was measured above the long-term cleanup goal of 17,000 ug/kg in five of six samples collected. under the City of Tacoma's storm drain sampling program (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, and 19 August 1988, personal communications). However, sediment samples from around this drain did not reveal concentrations above the cleanup goal. Data for HPAH from cores collected during the RI (Tetra Tech 1985a) and this study indicate that contaminant concentrations generally increased with depth. This depth distribution suggests that the major sources of HPAH are probably historic.

Summary loading tables for Priority 2 contaminants of concern for Wheeler-Osgood Waterway (i.e., cadmium, copper, lead, zinc, LPAH, HPAH, phenol, biphenyl, 1,2 dichlorobenzene, 4-methylphenol, and N-nitrosodiphenylamine) are provided in Appendix E. These tables reflect post-RI (Tetra Tech 1985a, 1986c) loading data for the following drains: CW-252, CW-254, CW-257, and CW-261 (Stinson and Norton 1987c). However, the information provided in Appendix E does not include recent data from the City of Tacoma storm drain monitoring program. (Flows were not measured for storm drain CW-254 in that study.)

11.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the potential success of source control was evaluated. This evaluation was based on contaminant concentrations and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to correct existing sediment contamination problems over the long term.

11.3.1 Feasibility of Source Control

Stormwater runoff from the Wheeler-Osgood drain (CW-254) and 10 smaller storm drains is the primary source of contamination in Wheeler-Osgood Waterway. Storm drain CW-254 has been identified as the major source of metals. It is one of five major storm drains included in the storm drain monitoring program being implemented by the City of Tacoma. The sources of HPAH appear to be largely historical, although HPAH is present in particulate matter from CW-254 effluent.

Available technologies for controlling surface water runoff are summarized in Section 3.2.2, including methods for retaining runoff onsite (e.g., berms, channels, grading, sumps) and revegetation or paving to reduce erosion. Contaminated storm water can also be treated during or after collection in a drainage system. For example, sedimentation basins, vegetation channels, and grassy swales can significantly reduce concentrations of particulate matter and their associated contaminants.

Implementation of these measures should result in a significant reduction in contaminant discharges. Given the contaminant types, nonpoint nature of sources, and available control technologies, it is estimated that implementation of all known, available, and reasonable control technologies will reduce contaminant loadings by up to 70 percent. This level of source control is assumed to be feasible for both indicator chemicals (zinc and HPAH). This estimate is based on the assumption that control of contaminants entering or discharging from Wheeler-Osgood drain (CW-254) could be implemented.

11.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals noted above. Complete results are reported in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment in Wheeler-Osgood Waterway has not been well characterized. A sedimentation rate of 375 $mg/cm^2/yr$ (0.31 cm/yr) and a mixing depth of 10 cm were considered representative of this problem area. The sedimentation rate was estimated from a 210-Pb profile collected from the waterway. Losses due to biodegradation and diffusion were determined to be negligible for these chemicals. Two indicator chemicals (i.e., HPAH and zinc) were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Two timeframes were considered: a reasonable timeframe (defined as 10 yr) and the long term. The source loadings of indicator chemicals in Wheeler-Osgood Waterway are assumed to be in steady-state with sediment accumulation. Results of the source control evaluation are summarized in Table 11-3.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times at the locations with the highest concentrations are predicted to be 51 yr for HPAH and 23 yr for zinc. These estimates are based on the highest zinc and HPAH concentrations measured in Wheeler-Osgood Waterway sediments. Sediment recovery is not predicted in a reasonable timeframe (i.e., 10 yr).

TABLE 11-3. WHEELER-OSGOOD WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals	
	Zinc	HPAH
Station with Highest Concentration		
Station identification	CW-91	CI
Concentration[a]	773	81,700
Enrichment ratio[b]	1.9	4.8
Recovery time if sources are eliminated (yr)	23	51
Percent source control required to achieve 10-yr recovery	NP[c]	NP[c]
Percent source control required to achieve long-term recovery	47	79
Average of Three Highest Stations		
Concentration[a]	677	36,850
Enrichment ratio[b]	1.7	2.2
Percent source control required to achieve long-term recovery	39	54
10-Yr Recovery		
Percent source control assumed feasible	70	70
Highest concentration recovering in 10 yr[a]	492	20,900
Highest enrichment ratio of sediment recovering in 10 yr	1.2	1.2

a Concentrations in ug/kg dry weight for organics, mg/kg dry weight for metals.

b Enrichment ratio is the ratio of observed concentration to cleanup goal.

c NP = Not possible.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source control is expected to reduce source input by 70 percent for HPAH and zinc. With this level of source control as an input value, the model predicts that sediments with an enrichment ratio of 1.2 or lower for both zinc and HPAH will recover within 10 yr (see Table 11-3). An enrichment ratio of 1.2 corresponds to a sediment concentration of 492 mg/kg for zinc and 20,900 ug/kg for HPAH. The surface area of sediments not recovering to the long-term cleanup goal within 10 yr is shown in Figure 11-5. For comparison, sediments currently exceeding long-term cleanup goals for the indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that 39 percent of the zinc and 54 percent of the HPAH inputs must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (see Table 11-3). These estimates are based on the average of the three highest enrichment ratios for the indicator chemicals. These values are presented for comparative purposes; the actual percent reduction required in source loading is subject to considerable uncertainty in the assumptions of the predictive model. These ranges probably represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

Based on four measurements by the City of Tacoma (Getchell, C., 12 October 1987, 18 December 1987, 8 February 1988, personal communications), average reductions of 67 percent for zinc and 79 percent for HPAH would be necessary to achieve the cleanup goals in particulate matter from storm drain CW-254. Data on particulate matter composition are not available for the other storm drains in Wheeler-Osgood Waterway. However, storm drain CW-254 appears to be the major source of contaminants to the waterway.

11.3.3 Source Control Summary

The major ongoing sources of metals and HPAH to Wheeler-Osgood Waterway are storm drains. From available data, it appears that, of the storm drains discharging to the waterway, CW-254 is the major source of contaminants. If contaminant loadings are completely eliminated (100 percent source control), then it is predicted that sediment concentrations of zinc in the surface mixed layer will decline to the long-term cleanup goal of 410 mg/kg in 23 yr and that concentrations of HPAH will decline to the long-term cleanup goal of 17,000 ug/kg in 51 yr. Sediment remedial action will therefore be required to mitigate the observed and potential adverse biological effects within a reasonable timeframe.

Substantial levels of source control will also be required to ensure that acceptable sediment quality is maintained after sediment cleanup. The estimated percent reduction in source loadings required for long-term maintenance is 39 percent for zinc and 54 percent for HPAH. Limited data obtained by the City of Tacoma indicate that for storm drain CW-254 average

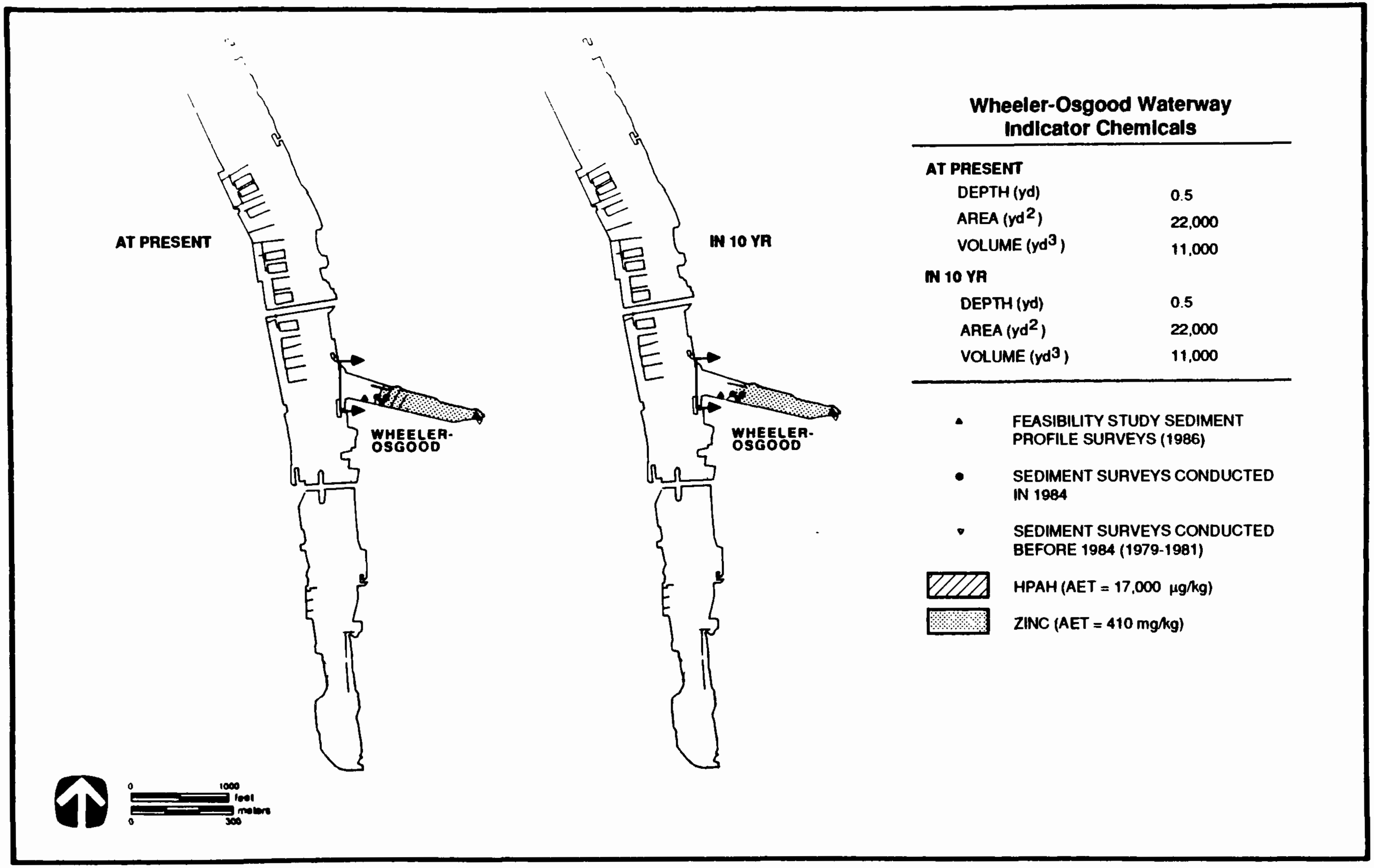


Figure 11-5. Sediments in Wheeler-Osgood Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

reductions of 67 percent for zinc and 79 percent for HPAH would be necessary to reduce particulate matter concentrations to sediment long-term cleanup goal levels.

Implementation of all known, available, and reasonable control technologies is expected to provide approximately a 70 percent reduction in contaminant loading to the waterway. Therefore, it appears that by implementing feasible levels of source control sediment cleanup goals can be maintained following sediment remedial action in Wheeler-Osgood Waterway.

11.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with zinc or HPAH concentrations exceeding long-term cleanup goals is approximately 11,000 yd^3 (see Figure 11-5). This volume was estimated by multiplying the areal extent of sediment exceeding the cleanup goal (22,000 yd^2) by the estimated 0.5-yd depth of contamination (see contaminant sediment profiles in Figures 11-2 and 11-3). The estimated thickness of contamination is only an approximation, since only two sediment profiles were collected.

The total estimated volume of sediments with zinc or HPAH concentrations that are still expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 11,000 yd^3. This volume was estimated by multiplying the areal extent (i.e., 22,000 yd^2) of sediment contamination with enrichment ratios greater than 1.2 (see Table 11-3) by the estimated 0.5-yd depth of contamination. This quantity of sediment (11,000 yd^3) was used to evaluate alternatives and to identify the preferred alternatives.

11.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

11.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, this set of alternatives is evaluated to determine the suitability of each alternative for the remediation of contaminated sediments in Wheeler-Osgood Waterway. Remedial measures address the 11,000 yd^3 of contaminated sediments that are expected to exceed long-term cleanup goals in 10 yr. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

An assessment of the applicability of each alternative to remediation of contaminated sediments in Wheeler-Osgood Waterway is required. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; the location of potential disposal sites; and site physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria presented in Chapter 4.

The indicator chemicals HPAH and zinc were selected to represent inputs from the storm drains, which are the primary source of contamination to the waterway (see Table 11-1). Areal distributions for both indicators are presented in Figure 11-5 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery. The high organic matter content of Wheeler-Osgood Waterway sediments in conjunction with the extensive HPAH contamination suggest that a treatment process for organics could be an appropriate component of remedial action. Total concentrations of metals in the waterway, which are generally less than 2,000 mg/kg, are not expected to limit the applicability of solvent extraction, thermal treatment, or land treatment. The alternatives incorporating these treatment processes are evaluated for Wheeler-Osgood Waterway. Solidification is less likely to be successful because of the high concentrations of total organic carbon and other organic contaminants, and is therefore not evaluated.

It is assumed that the requirements to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

Nine of the ten sediment remedial alternatives are evaluated below for the cleanup of Wheeler-Osgood Waterway:

- No action
- Institutional controls
- In situ capping
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solvent extraction/upland disposal
- Clamshell dredging/incineration/upland disposal
- Clamshell dredging/land treatment.

These candidate alternatives are described in detail in Chapter 3.

11.5.2 Evaluation of Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 11-4. A comparative evaluation of alternatives based on ratings of

TABLE 11-4. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE WHEELER-OSGOOD WATERWAY PROBLEM AREA

EFFECTIVENESS

		NO ACTION	INSTITUTIONAL CONTROLS	IN SITU CAPPING	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ LAND TREATMENT
SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is not a concern in the implementation of this alternative. CDM exposure and handling are minimal.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge and disposal sites is restricted. Clamshell dredging, land transport, and extended duration of treatment operations in open environment raise exposure risks.
SHORT-TERM PROTECTIVENESS	WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Workers are not exposed to contaminated sediments.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear.	Incineration of CDM is accomplished over an extended period of time thereby increasing exposure risks. Workers wear protective gear.	Land treatment of CDM is accomplished over an extended period of time. CDM is tilled into the treatment soil. Exposure potential decreases with time as degradation occurs.
SHORT-TERM PROTECTIVENESS	ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Contaminant redistribution is minimized. Existing contaminated habitat is destroyed and replaced with clean material. Rapid recolonization is expected.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment with low particle affinity is resuspended during dredging operations. Benthic habitat is impacted at the disposal site.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment with low particle affinity is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations.	Existing contaminated habitat is destroyed by dredging but recovers rapidly. Sediment is resuspended during dredging operations. Process controls are required to reduce potential air emissions.	Existing contaminated habitat is destroyed by dredging but recovers rapidly. Sediment is resuspended during dredging operations. Dredge water management needs are minimal. Contaminant has relatively high solubility which enhances its potential for migration from treatment site.
TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked ninth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. This alternative is ranked eighth overall for timeliness.	In situ capping can be implemented quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available. Disposal site development should not delay implementation. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked third overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available. Disposal site development should not delay implementation. This alternative is ranked second for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked fourth overall for timeliness.	Bench and pilot scale testing are required. Full scale equipment is available. Once approval is obtained, treatment should be possible within 2 years. This alternative is ranked fifth overall for timeliness.	Substantial CDM testing and incinerator installation time is required before a thermal treatment scheme can be implemented. Once approval is obtained, treatment should be possible within 2 years. This alternative is ranked sixth overall for timeliness.	Substantial testing would be required to insure that contaminants can be degraded and to determine optimal operating conditions. Treatment would probably require a demonstration project, a long treatment period, and a closure phase. This alternative is ranked seventh overall for timeliness.
LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in the absence of physical disruption is considered good.	The long-term reliability of the cap to prevent contaminant reexposure in a quiescent, subaquatic environment is considered acceptable.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.	Treated CDM low in metals can be used as inert construction material or disposed of at a standard solid waste landfill.	Liner, run-on, and runoff controls reliable. Potential system failure becomes less critical with time, as treatment progresses.
LONG-TERM PROTECTIVENESS	PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA approved treatment or disposal. Permanent treatment for organic contaminants is effected.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.	There is potential for public health impacts as a result of contaminant migration from treatment facility. CDM is not confined.
LONG-TERM PROTECTIVENESS	PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area. Nearshore site is dynamic in nature.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for shallow groundwater contamination exists.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA approved treatment or disposal. Residual contamination is reduced below harmful levels.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential.	Design features of land treatment system preclude contaminant migration to groundwater or surface water. Control of volatile emissions is limited.
CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Harmful contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA approved treatment or disposal. Toxicity and mobility considerations are eliminated. Volume of contaminated material is substantially reduced.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals may have leaching potential. Volume of contaminated material is substantially reduced.	Treatment of degradable organic compounds eliminates this component of CDM toxicity. Metals are not treated. Mobility of metals may be enhanced by aerobic soil conditions.

TABLE 11-4. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	IN SITU CAPPING	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ LAND TREATMENT
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredges and diffuser pipes are conventional and reliable equipment. In situ capping is a demonstrated technology.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, but feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Although still in the developmental stages, sludges, soils, and sediments have successfully been treated using this technology. Extensive bench- and pilot-scale testing are likely to be required.	Incineration systems capable of handling CDM have been developed, but no applications involving CDM have been reported. Effects of salt and moisture content must be evaluated. Extensive bench- and pilot-scale testing are likely to be required.	Land treatment is a demonstrated technology for materials contaminated with degradable organic compounds. Extensive bench- and pilot-scale testing are likely to be required.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Monitoring implementability is enhanced compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring is required only to evaluate the reestablishment of benthic communities. Monitoring programs can be readily implemented.	Disposal site monitoring is not required if treated CDM is determined to be nonhazardous. Air quality monitoring is intensive during implementation.	Monitoring programs can be readily implemented. Extensive monitoring is required during active treatment period, with less required during closure.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	O & M consists of maintaining monitoring equipment, optimal soil conditions, tilling equipment, and groundskeeping. Site inspections are required.
	INSTITUTIONAL FEASIBILTY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals depend largely on results of pilot testing and the nature of treatment residuals.	Approvals for incinerator operation depend on pilot testing and ability to meet air quality standards.	Treatment facility siting and operation require extensive agency review prior to approval.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed. This alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant mobility. Requires RCRA permit for disposal of concentrated organic waste.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Complies with policies for permanent reduction in contaminant toxicity and mobility. Requires compliance with PSAPCA standards.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's policy for toxicity reduction and onsite disposal.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement this alternative are readily available.	Equipment and methods to implement alternative are readily available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Process equipment available. Disposal site availability is not a primary concern because of reduction in hazardous nature of material.	Incineration equipment can be installed onsite for CDM remediation efforts. Applicable incinerators exist. Disposal site availability is not a concern because of reduction in hazardous nature of material.	Availability of land treatment site is uncertain.

high, moderate, and low in the various subcategories of evaluation criteria is presented in Table 11-5. For effectiveness, the subcategories are short-term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. For implementability, the subcategories are technical feasibility, institutional feasibility, availability, capital costs, and O&M costs. Remedial costs are shown for sediments currently exceeding long-term cleanup goal concentrations and also for sediments that would still exceed the cleanup goal concentrations 10 yr after implementing feasible source controls (i.e., 10-yr recovery costs).

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no action and institutional controls because the adverse biological and potential public health impacts continue with the contaminated sediments remaining in place. Source control measures initiated as part of the institutional controls would result in reduced sediment contamination with time but adverse impacts would persist in the interim. It is predicted that, even with complete source elimination, reduction in sediment concentrations to acceptable levels will require 23 yr for zinc and 51 yr for HPAH (see Table 11-3).

With the exception of clamshell dredging/confined aquatic disposal and hydraulic dredging/upland disposal, other alternatives involving sediment remediation are rated moderate. With in situ capping the contaminated sediments are left in place, which eliminates the potential for direct public or worker exposure; however, some intertidal habitat could be lost. The clamshell dredging/nearshore disposal alternative is rated moderate for short-term protectiveness primarily because some direct worker exposure is expected during dredging operations. Alternatives involving treatment received moderate ratings from short-term protectiveness because, as compared with nontreatment alternatives, all involve more dredged material handling, longer implementation periods and increased air emissions, which increase potential worker exposure. The risks inherent to the solvent extraction and incineration treatment processes themselves are also considered.

The clamshell dredging/confined aquatic disposal and hydraulic dredging/upland disposal alternatives are rated high for short-term protectiveness. For clamshell dredging/confined aquatic disposal, handling requirements are low, worker and public exposure can be minimized through the use of safety gear, and adverse effects to the benthic community at the disposal site are expected to be short-lived, with re-establishment occurring quickly once the site is capped. Upland disposal involves the use of land generally considered to be a less valuable resource than the intertidal areas which would be used for nearshore disposal.

Timeliness--

The no-action, institutional controls, and land treatment alternatives received low ratings for timeliness. With no action, sediments remain unacceptably contaminated, source inputs continue, and natural sediment

TABLE 11-5. EVALUATION SUMMARY FOR WHEELER-OSGOOD WATERWAY

	No Action	Institutional Controls	In Situ Capping	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Extraction/ Upland Disposal	Clamshell/ Incinerate/ Upland Disposal	Clamshell/ Land Treatment
Short-Term Protectiveness	Low	Low	Moderate	High	Moderate	High	Moderate	Moderate	Moderate
Timeliness	Low	Low	High	Moderate	High	Moderate	Moderate	Moderate	Low
Long-Term Protectiveness	Low	Low	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Moderate
Technical Feasibility	High	High	High	Moderate	High	High	Moderate	Moderate	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Availability	High	High	High	Moderate	High	Moderate	Moderate	Moderate	Low
Long-Term Cleanup Goal Cost[a]									
Capital	--	6	144	139	321	504	2,377	5,337	606
O&M	--	283	252	31	31	39	38	38	86
Total	--	289	396	170	352	543	2,415	5,375	692
Long-Term Cleanup Goal with 10-yr Recovery Cost[a]									
Capital	--	6	144	139	321	504	2,377	5,377	606
O&M	--	283	252	31	31	39	38	38	86
Total	--	289	396	170	352	543	2,415	5,375	692

[a] All costs are in $1,000.

recovery is unlikely. Source inputs are controlled under the institutional controls alternative but as discussed in Section 11.3.2, sediment recovery based on the indicator contaminants zinc and HPAH is estimated to be improbable within 10 yr. Land treatment would probably require a demonstration project, a relatively long treatment period, and a closure phase. Approval and siting considerations are likely to adversely affect the timeliness of this alternative.

Moderate ratings were assigned to the remaining treatment alternatives and to the dredge alternatives involving upland and confined aquatic disposal. Approvals and construction of upland or confined aquatic disposal sites is estimated to require 1-2 yr. Equipment and methods used require no development period, and pre-implementation testing is not expected to be extensive. These conditions suggest that the upland disposal alternatives can be accomplished in a much shorter period of time than if treatment is involved. The solvent extraction and incineration alternatives are likely to require a period of extensive testing before being accepted. However, once approval is obtained, treatment of the contaminated sediments in Wheeler-Osgood Waterway should be possible within less than 1 yr, assuming maximum treatment rates of 420 yd^3/day (see Section 3.1.5).

The in situ capping and nearshore disposal alternatives are rated high for timeliness. Pre-implementation testing and modeling may be necessary to evaluate the potential for contaminant releases resulting from dredging and from contaminant migration through the cap, but such testing is not expected to require an extensive period of time. Equipment and methods are readily available, and nearshore disposal siting issues are less likely to delay implementation than for alternatives involving upland and confined aquatic disposal.

Long-Term Protectiveness--

The evaluation for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for sediment recovery is long. For the latter alternative, the potential for exposure to contaminated sediments remains, albeit at declining levels following implementation of source reductions. The observed adverse biological impacts continue and the potential for impacts through the food chain remains.

In situ capping received a moderate rating for long-term protectiveness because it could result in a long-term reduction in intertidal habitat. Moderate ratings have been assigned to the clamshell dredging/nearshore and hydraulic dredging/upland disposal alternatives because of the physicochemical changes that would occur when dredged material is placed in these disposal facilities. These changes, primarily from new redox conditions, would tend to increase the migration potential of the inorganic contaminants. However, dredged material testing should provide the necessary data on the magnitude of these impacts. These physicochemical changes can be minimized in a nearshore facility by placement of sediments below the low tide elevation. Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature (i.e., from wave action and tidal influences). Even though the upland disposal facility is generally regarded as a more secure option because of improved engineering controls during construction, there is potential for impacts on groundwater resources.

Alternatives involving treatment all received moderate ratings primarily because the treatment processes would result in the destruction of organic but not inorganic contaminants. In the solvent extraction and incineration alternatives, the treated solids would be confined in a standard landfill, assuming that the material is considered nonhazardous. In the case of land treatment, metals would be immobilized in the soil.

Confined aquatic disposal is rated high for long-term protection. Isolation of contaminated material in the subaquatic environment provides a high degree of protection, with little potential for exposure of sensitive environments to sediment contaminants. In addition, confinement under in situ conditions maintains physicochemical conditions of the contaminated sediments, thereby minimizing potential migration of metal contaminants.

Reduction in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except the three involving treatment. Although capping, confined aquatic disposal, upland, and nearshore disposal alternatives isolate contaminated sediments from the surrounding environment, the chemistry and toxicity of the material itself would remain largely unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated dredged material may actually increase with changes in redox potential. Without treatment, the toxicity of contaminated sediments would remain at preremediation levels. Contaminated sediment volumes would not be reduced, and may actually increase with hydraulic dredging options because the material would be suspended in an aqueous slurry.

Alternatives involving treatment would destroy organic contaminants, but remain ineffective for the treatment of metal contaminants. Therefore, treatment alternatives received moderate ratings. The solvent extraction process would change the chemical status of the metals by providing the alkaline conditions necessary for formation of insoluble hydroxides. As long as the pH of the solid residue remained approximately neutral or alkaline, the mobility of the metals would remain reduced. Incineration may increase the mobility of metals in the treated solids. In land treatment, the cation exchange capacity of the soil would immobilize metals, but the potential for long-term leaching of the metals would remain.

Technical Feasibility--

Alternatives involving treatment received moderate ratings for the criterion of technical feasibility because the treatment processes have never been applied to sediment remediation. All processes are believed to be suitable for this application, but lack of experience and demonstrated performance in the use of these processes for treatment of contaminated dredged material warrants caution. Extensive bench- and pilot-scale testing are likely to be required before treatment via solvent extraction, incineration, or land treatment could be implemented. A moderate rating has also been applied to the clamshell dredging/confined aquatic disposal option. Placement of dredged and capping materials at depths of approximately 100 ft is difficult, although feasible. Considerable effort and resources may be required to monitor the effectiveness and accuracy of dredging, disposal, and capping operations.

High ratings are warranted for alternatives not involving treatment (except confined aquatic disposal) because the equipment, technologies, and expertise required for implementation have been developed and are readily accessible. The technologies constituting these alternatives have been demonstrated to be reliable and effective in the past for similar operations.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives were assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative. The land treatment alternative also received a low rating because of the difficulty associated with siting the facility and fulfilling permitting requirements.

Moderate ratings were assigned to the remaining alternatives because of potential difficulty in obtaining agency approvals for disposal sites or implementation of treatment technologies. Although several potential confined aquatic and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. It is assumed that Blair Waterway Slip 1 can be used as a nearshore facility, although the site remains undeveloped at this time. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of effectiveness of the alternative in meeting established performance goals (e.g., treatability of dredge water).

Availability--

Sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities were rated high for availability. The no-action, institutional controls, in situ capping, and nearshore disposal alternatives can be readily implemented. Because of the nature of the no-action and institutional controls alternatives, equipment and siting availability are not obstacles to implementation. Disposal site availability is not an obstacle to implementation of the capping alternative since capping would be performed on sediments in place. The nearshore disposal alternative was rated high because of the availability of Blair Waterway Slip 1 as a disposal site.

Remedial alternatives that include confined aquatic and upland disposal were rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that confined aquatic and upland sites will be available. However, no sites are currently approved for use and no sites are currently under construction. The sediment treatment alternatives, which include solvent extraction and incineration, were rated moderate for availability since some degree of difficulty in obtaining necessary equipment is expected. In addition, a location for disposal of treatment residuals will be needed.

The availability of a land treatment site suitable for the treatment of contaminated dredged material was considered as being more uncertain than for confined aquatic or upland disposal sites. This uncertainty is primarily due to the large land area requirements associated with land treatment. Therefore, land treatment received a low rating for the availability criterion.

Cost--

Capital costs increase with increasing complexity (i.e., from no action to the treatment alternatives). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for hydraulic dredging/upland disposal are significantly higher than those for clamshell dredging with either nearshore or confined aquatic disposal, primarily due to underdrain and bottom liner installation, dredge water clarification, and use of two pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting the treatment alternatives increases as a result of material costs for the processes, and associated labor costs for material handling and transport. Dredge water clarification management costs are also incurred for those alternatives. A major element in the land treatment cost is land acquisition.

An important component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Monitoring costs for confined aquatic disposal are significantly higher than for other options because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single groundwater sample from each well to assess contaminant migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding long-term cleanup goals) in the waterway. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the treatment alternatives are significantly lower than for other alternatives because the treatment processes reduce the potential for contaminant migration.

11.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the nine sediment remedial alternatives proposed for Wheeler-Osgood Waterway, clamshell dredging with confined aquatic disposal has been recommended as the preferred alternative for sediment remediation. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, confined aquatic disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. This currently preferred alternative offers a high degree of long-term protection of public health and the environment in that it isolates contaminated dredged material at a remote site well below tidal influence.

Implementation can be coordinated with similar sediment remediation activities in the head of City Waterway. The confined aquatic disposal alternative was recommended for these problem areas for the reasons provided in Section 10.6. The alternative is ranked as moderate for short-term protectiveness because intertidal habitat will be disturbed. This disadvantage can be offset in the long term by incorporating a habitat replacement project in the remedial process. This goal is addressed in part by removing contaminated sediments from the waterway and replacing them with clean sediment. As indicated in Table 11-5, this alternative provides a cost-effective means of sediment remediation. The total costs of the confined aquatic disposal alternative ($170,000) are approximately 50 percent of the nearshore disposal alternative, which has the next lowest cost.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with contaminated dredged material redistribution. Potential impacts on water quality can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Once a disposal site is selected, this alternative can be implemented over a relatively short timeframe. Seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this problem area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

Of the remaining alternatives, clamshell dredging with nearshore disposal in Blair Waterway Slip 1 is feasible, as are the treatment alternatives. However, nearshore disposal would not take advantage of the same procedures as those used for the preferred alternative in the head of City Waterway (i.e., dredging with confined aquatic disposal). The treatment options are considered too costly, given the limited amount of additional protection they would provide. In situ capping has been eliminated because of the shallow depths and potential destruction of nearshore habitat.

No-action and institutional controls alternatives are rated high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public impacts far outweighs these advantages.

11.7 CONCLUSIONS

Wheeler-Osgood Waterway was identified as a problem area because of the elevated concentrations of several inorganic and organic compounds. HPAH and zinc were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimated the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 22,000 yd^2, and a volume of 11,000 yd^3. Of the total sediment area currently exceeding cleanup goals, none is predicted to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The total volume of sediment requiring remediation is, therefore 11,000 yd^3.

The primary identified sources of problem chemicals to the Wheeler-Osgood Waterway are storm drains. Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Control problem chemicals (metals and hydrocarbons) discharging to the waterway through storm drains

- Confirm that all sources of problem chemicals have been identified and controlled

- Conduct routine sediment monitoring to confirm sediment recovery predictions and successful implementation of source control measures.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals HPAH and zinc. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be re-evaluated.

Clamshell dredging with confined aquatic disposal was recommended as the preferred alternative for remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment. Confined aquatic disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 11-5, clamshell dredging with confined aquatic disposal provides a cost-effective means of sediment mitigation. The estimated cost to implement this alternative is $139,000. Environmental monitoring and other O&M costs at the disposal site have a present worth of $31,000 for a period of 30 yr. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of preferred alternative is $170,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures

- Final selection of a disposal site.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions to the maximum extent practicable, and are cost-effective.

12.0 MOUTH OF CITY WATERWAY

Potential remedial actions are defined and evaluated in this section for the mouth of City Waterway problem area. The waterway is described in Section 12.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 12.2 provides an overview of contaminant sources including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contaminant concentrations are discussed in Section 12.3. Area and volume of sediments requiring remediation are discussed in Section 12.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 12.5. The preferred alternative is identified in Section 12.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 12.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

12.1 WATERWAY DESCRIPTION

The problem area designated as the mouth of City Waterway extends from the mouth at the confluence with Commencement Bay to the 11th Street Bridge, approximately 3,500 ft from the mouth. City Waterway is a designated navigational channel that was first bulwarked against erosion and dredged to accommodate ship traffic in approximately 1890 (Tetra Tech 1986c). The waterway was most recently dredged by the U.S. Army Corps of Engineers in 1948. An illustration of the waterway and the locations of nearby industries is presented in Figure 12-1. This portion of the waterway is approximately 3,500 ft long and 750 ft wide. Totem Marina extends nearly 300 ft into the waterway on the west side, which greatly reduces the actual navigable portion (Tetra Tech 1985b). The depth of this portion of the waterway increases from the 11th Street Bridge to the mouth. Subbottom profiling of this area showed mid-channel depths ranging from 30 ft below MLLW at the bridge to 35 ft below MLLW at the mouth (Raven Systems and Research 1984). Profiling revealed that sediment accumulation in the navigation channel ranges in depth from 1 to 4 ft, with a cross section near the bridge showing a fairly uniform soft sediment layer 2-3 ft thick (Tetra Tech 1985b). Sediments within the waterway are typically 64 percent fine-grained material (range of 28-83 percent) with an average clay content of 18 percent.

12.1.1 Nature and Extent of Contamination

An examination of sediment contamination data obtained during the RI/FS sampling efforts (Tetra Tech 1985a,b, 1986c) and historical data has revealed that sediments in the mouth of City Waterway contain concentrations

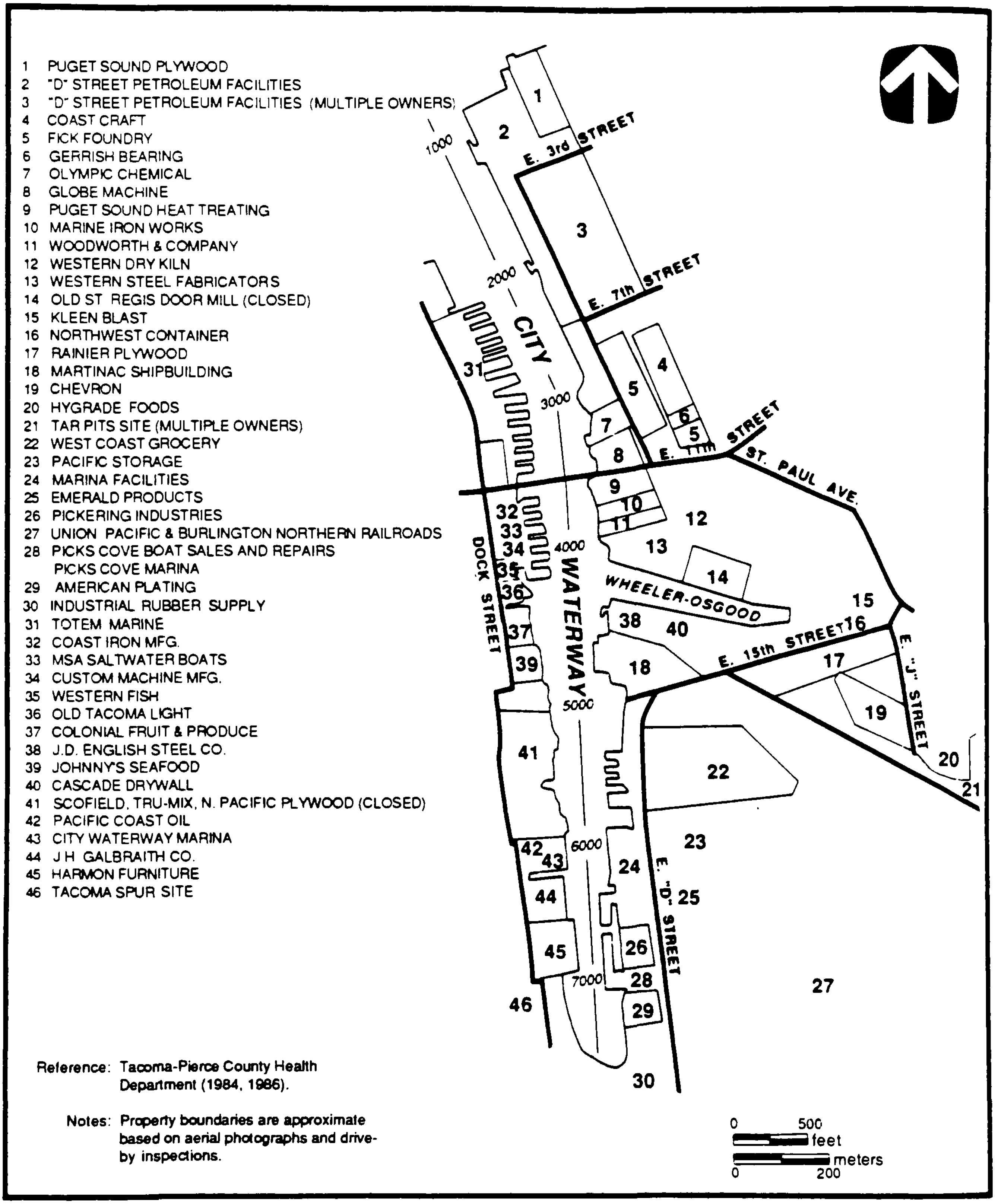


Figure 12-1. Mouth of City Waterway - Existing industries and businesses.

of organic contaminants that are harmful to benthic organisms. No Priority 1 contaminants were identified in the waterway. However, LPAH and HPAH were identified as Priority 2 contaminants. The following organic and inorganic compounds exceeded their corresponding AET value at only one station sampled and are therefore considered Priority 3 contaminants: dibenzothiophene, phenol, biphenyl, zinc, mercury, and PCBs.

HPAH has been selected as an indicator chemical at the mouth of City Waterway to represent numerous potential hydrocarbon contamination sources. The Priority 3 contaminant mercury was selected as an indicator representative of the erratically distributed inorganic compounds in the problem area.

The areal and depth distributions of HPAH are illustrated in Figure 12-2. HPAH concentrations exceeded the long-term cleanup goal of 17,000 ug/kg at only two stations. The sediment core profile for HPAH did not fall within the area determined to exceed cleanup goals, but was adjacent to a small problem area (Figure 12-2). A trend of erratic vertical distribution in the upper 0.8 yd was observed with a subsurface maximum apparent.

The areal and depth distributions of mercury are illustrated in Figure 12-3. The mercury concentration exceeded the cleanup goal of 0.59 mg/kg at only one surface sampling station, where a concentration of 0.60 mg/kg was observed. As shown in Figure 12-3, the concentration of mercury exceeded the cleanup goal at an adjacent station by a factor of more than 3 at a depth of 0.5 yd. Mercury concentrations appeared to fluctuate randomly in mid-channel stations (Tetra Tech 1986c). Data derived from the sediment core profile revealed a definite surface minimum suggesting that inputs have decreased over time. Based on the mercury core profile, contamination was assumed to extend to a depth of 1 yd.

12.1.2 Recent and Planned Dredging Projects

The U.S. Army Corps of Engineers has not recently received any application for dredging permits. The Port of Tacoma does not plan to dredge in the mouth of City Waterway.

12.2 POTENTIAL SOURCES OF CONTAMINATION

Several businesses and industries surround the mouth of City Waterway. Fick Foundry, present as early as 1920; Globe Machine; Olympic Chemical; and the D Street petroleum facilities are located along the east bank. Portions of the D Street tank farms have been present since the 1920s. Totem Marina occupies most of the west bank. The most significant potential sources of contamination to the head of City Waterway are the D Street petroleum storage facilities. Approximately 22 storm drains that discharge into the problem area are also potential sources of contamination (Figure 12-4). Contaminants may also enter the mouth of the waterway from sources in the head of the waterway and Wheeler-Osgood Waterway, which are discussed in Sections 10.2 and 11.2, respectively. Irregular spills from marinas along the west bank of the waterway are considered a less important

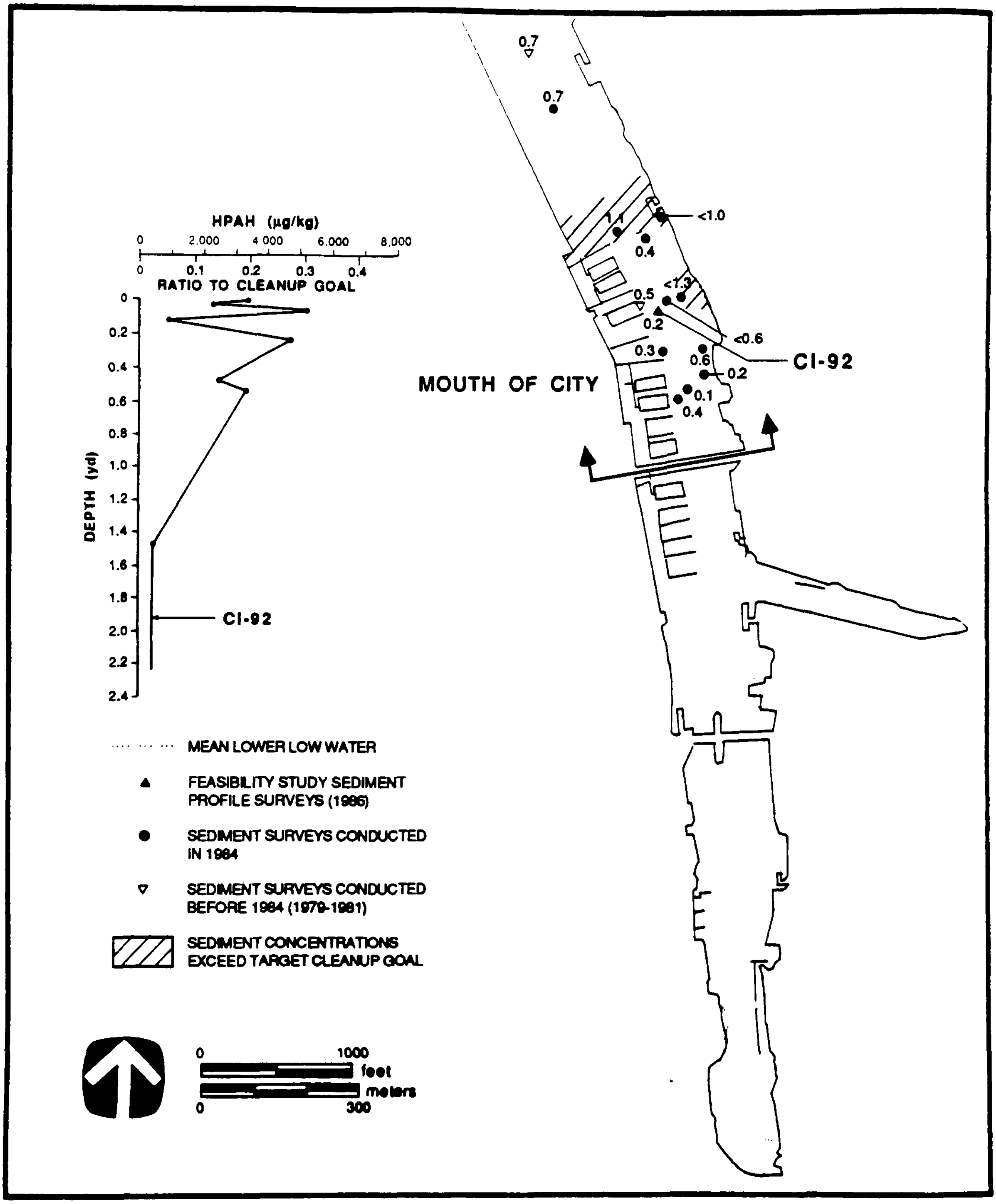


Figure 12-2. Areal and depth distributions of HPAH in sediments at the mouth of City Waterway, normalized to long-term cleanup goal.

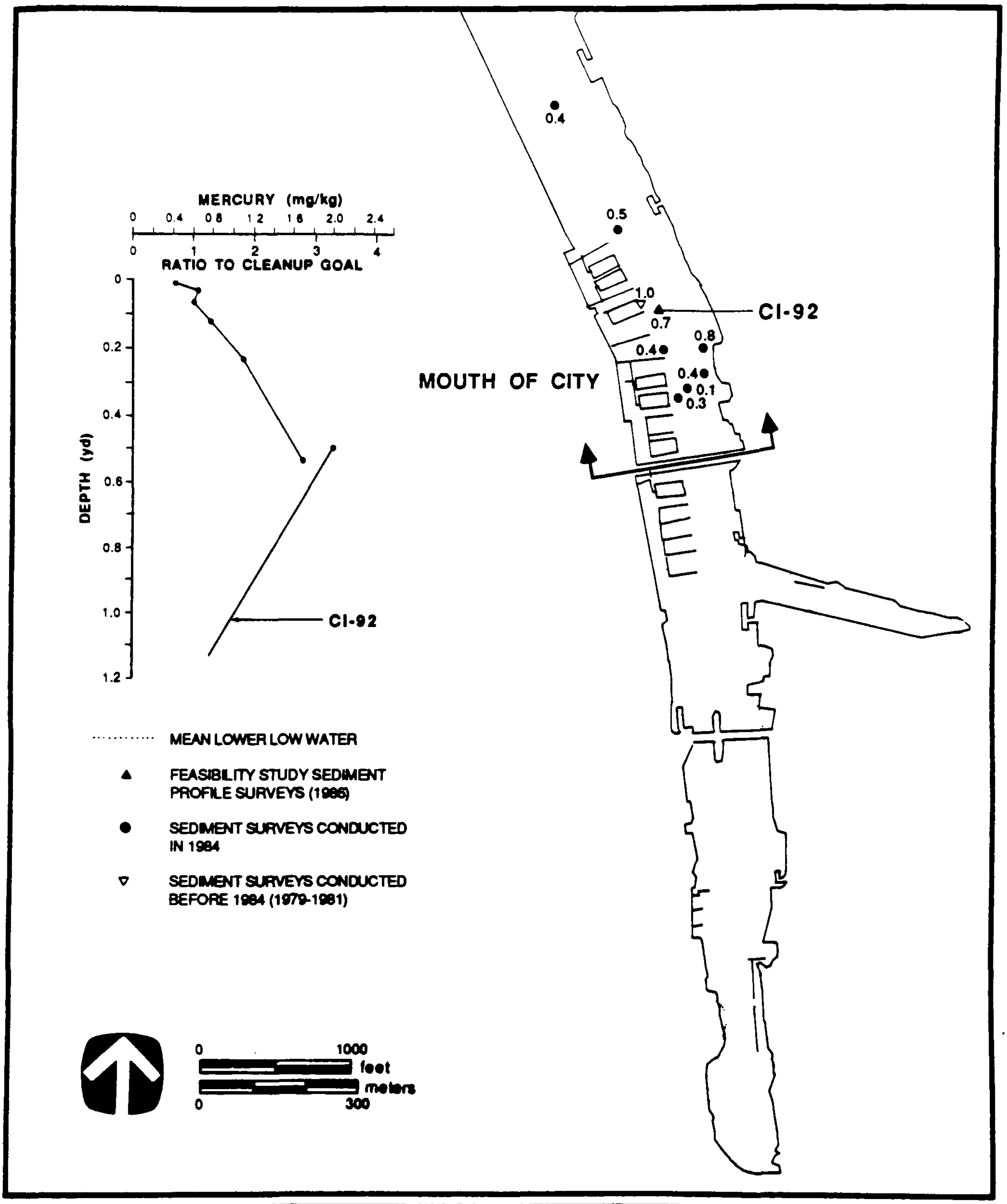


Figure 12-3. Areal and depth distributions of mercury in sediments at the mouth of City Waterway, normalized to long-term cleanup goal.

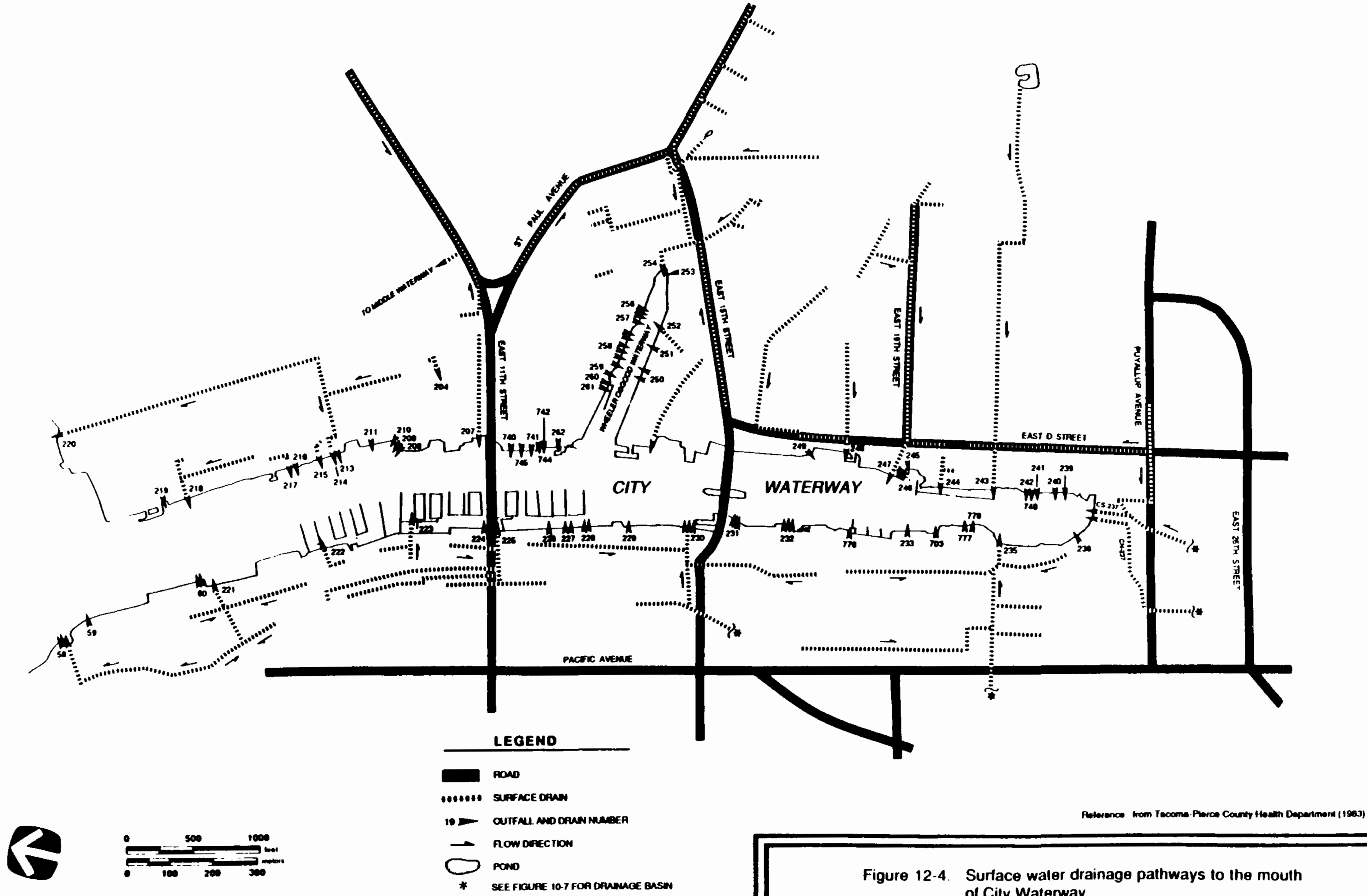


Figure 12-4. Surface water drainage pathways to the mouth of City Waterway.

source of contamination. Table 12-1 provides a summary of problem chemical and source status information for the head of City Waterway.

12.2.1 D Street Petroleum Storage Facilities

Site Background--

The D Street petroleum storage facilities are located along the northeastern shore of City Waterway. Bulk petroleum storage and distribution facilities are located in this area, including a subsurface pipeline owned by Olympic Pipeline Company. Currently, storage tanks used by Union Oil, Mobil Oil, and Shell Oil are located at the site. Globe Machine, located in the immediate vicinity, is not engaged in petroleum operations. Portions of the storage facilities have been present at the site since the 1920s.

The petroleum products managed at the D Street facilities include fuel oil, diesel fuel, leaded gasoline, and unleaded gasoline. Product leakage and spills have led to contamination of groundwater, and free product continues to be found in monitoring wells onsite (Johnson and Norton 1985a; Hart-Crowser & Associates 1987a). Intermittent seepage of petroleum product along the City Waterway embankment adjacent to the site has been observed for the past 17 yr. Product and contaminated groundwater removed from wells onsite contain one-, two-, and three-ring aromatic compounds, including alkylated derivatives. Low concentrations of phenol and cresols have also been detected (Johnson and Norton 1985a).

Identification of Contaminant Reservoirs Onsite--

Petroleum product from accidental spills and pipeline leakage percolates through the soil and accumulates on the water table (Hart-Crowser & Associates 1987a). The hydraulic gradient in the aquifer slopes toward the waterways on both sides of the peninsula on which the tank farms are situated. Thus free product and product constituents that have been partitioned into groundwater eventually migrate to the waterways. The groundwater flow rate in the contaminated aquifer has been estimated at 1-15 ft/yr (Hart-Crowser & Associates 1987a). Because surface soils at the site are contaminated with petroleum product, stormwater runoff is another potential pathway of contamination to the mouth of City Waterway.

Johnson and Norton (1985a) sampled water from two wells on the D Street site and determined that the major contaminants were the single-ring aromatics benzene, ethylbenzene, toluene, and total xylenes at concentrations ranging from 1 to 30 mg/L. Naphthalene, 2-methylnaphthalene, and phenanthrene were found in the well water but the higher molecular weight PAH were noticeably absent even with the low detection limits (1-5 ug/L) achieved in the analysis. Phenol and cresols were detected at concentrations below 1 mg/L. Overlying free product sampled from one of the wells contained appreciable quantities of the single-ring aromatics found in the underlying water. Phenanthrene was not detected in the free product at a detection limit of 200 mg/L.

TABLE 12-1. MOUTH OF CITY WATERWAY - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b]	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
LPAH	2	D St. petro. facility	Potential	No	Ongoing	Erratic; no clear trend
HPAH	2					
Dibenzothiophene	3 (CI-20)	Storm drains	Yes	Yes	Ongoing	
Phenol	3 (CI-20)					
Biphenyl	3 (CI-20)	Ubiquitous oil spills	Potential	No	Ongoing, sporadic	
		Marina fires	Potential	No	Historical	
Zinc	3 (CI-05)	Storm drains	Yes	Yes	Ongoing	Fairly constant over upper 50 cm. Mercury has surface minimum.
Mercury	3 (CI-20)					
PCBs	3 (historical)	Unknown	No	No	Historical	Surface minimum

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

In sediment samples removed from City Waterway adjacent to the site, the single-ring aromatics were not detected, but appreciable concentrations of unsubstituted high molecular weight PAH were found. Absence of the single-ring aromatics in the sediments is not surprising in view of their volatility and susceptibility to microbiological degradation. That the PAH in the sediments were generally unsubstituted suggests that the source of the PAH is not a fossil fuel but is derived from combustion. Thus despite unequivocal visual evidence that petroleum product from the D Street facilities is present along the City Waterway embankment, there is little evidence of a linkage between contaminants of concern at the mouth of the Waterway, namely PAH, and constituents of free product and contaminated groundwater underneath the site.

Recent and Planned Remedial Activities--

Efforts to recover lost product have been made by facility owners. Mobil Oil is reportedly still operating, at least intermittently, an interceptor drain installed in 1970-71 along its property next to City Waterway. In 1984, Shell Oil installed a recovery system on property now owned by Globe Machine and Manufacturing Company. Shell reportedly has also pumped free product from individual onsite wells. In 1985, Mobil Oil installed a recovery well and has successfully recovered product from it.

Despite these measures, Hart-Crowser & Associates (1987a) report that the extent and thickness of free product on the groundwater table has been increasing over the years. Without additional control measures or more effective use of existing recovery systems, the seepage of petroleum product into City Waterway may be expected to continue.

The following litigative considerations apply to the D Street petroleum storage operations:

- Globe Machine and Manufacturing, which purchased property from Shell Oil, initiated legal action against a group of oil companies for petroleum product contamination beneath its property (Reale, D., 17 September 1987, personal communication).

- A consent order has been initiated by Ecology to prepare a work plan for remedial action at the site. The plan should include additional subsurface product analyses and possibly some offshore sediment analyses. Most of the firms Ecology expects to participate in the consent order have expressed their willingness to do so (Reale, D., 17 September 1987, personal communication).

- A group of oil companies at the site engaged in a cooperative effort to install a trench recovery system affecting the subsurface region near the Globe Machine property. Product is currently being extracted from this trench system (Reale, D., 17 May 1988, personal communication).

12.2.2 Storm Drains

Of the storm drains that discharge into the mouth of the waterway, storm drain CI-214 is probably one of the most important sources of contamination. Storm drain CI-214 drains approximately 8 ac, and, based on seven observations, has an estimated average discharge of 3 gal/min (Comstock, A., 29 April 1988, personal communication). Runoff pathways to this storm drain are not well defined. However, it is known that Coast Craft discharges boiler blowdown to this drain. In addition, this drain receives runoff from portions of the Unocal and Mobil Oil facilities. Elevated pH levels have been measured in this discharge and oil sheens have been noted (Young, R., 17 May 1988, personal communication; Comstock 1988).

Ecology collected a sediment sample from this storm drain in June 1987 (Norton, D., 15 April 1988, personal communication). Measured concentrations of both indicator chemicals, HPAH and mercury, were greater than long-term cleanup goals. Measured lead, zinc, and LPAH concentrations were also greater than long-term cleanup goals.

No loading information is available for storm drain CI-214.

12.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of sources, the technologies available for source control, and source control measures that have been implemented to date. Second, the effects of source control and natural recovery processes were evaluated. This evaluation was based on contaminant concentrations and assumptions regarding the relationship between sources and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to correct existing sediment contamination problems over the long term.

12.3.1 Feasibility of Source Control

The D Street petroleum storage facilities, storm drains, and to a lesser extent, marinas are potential sources of hydrocarbons. Source controls have been implemented or may be required for the following mechanisms of contaminant discharge:

- Surface runoff (storm drains)
- Groundwater seeps and infiltration
- Irregular direct spills (marinas).

Available technologies for controlling surface water runoff are summarized in Section 3.2.2. These technologies incorporate methods of retaining runoff onsite (e.g., berms, channels, grading, sumps), revegetating or paving of waste materials to reduce erosion, and waste removal. Pump and treat methods, in combination with slurry walls or other diversion and barrier techniques, are assumed feasible for control of groundwater contamination. Site inspections and best management practices are feasible controls for discharge of contaminants from marinas.

Implementation of source control measures, including best management practices at the D Street oil facilities, is expected to result in a significant reduction in contaminant discharges. It is estimated that implementation of all known, available, and reasonable control technologies will reduce contaminant loadings by up to 70 percent. This level of source control is assumed to be feasible for both indicator chemicals (HPAH and mercury).

12.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for HPAH and mercury. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment near the mouth of City Waterway was characterized by a sedimentation rate of 950 mg/cm^2/yr (0.67 cm/yr) and a mixing depth of 10 cm. The sedimentation rate was determined from 210-Pb methods evaluated for the sediment core sample collected at Station CI-92. Two indicator chemicals, HPAH and mercury, were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Neither of these chemicals is expected to display losses due to biodegradation or diffusion. Two timeframes were considered: a reasonable timeframe (defined as 10 yr) and the long term. Results of the source control evaluation are summarized in Table 12-2.

Effect of Complete Source Elimination--

Contaminant concentrations in surface sediments are currently near long-term cleanup goals. If sources of contamination are not controlled, contamination in surface sediments is expected to remain at levels near long-term cleanup goals in the worst locations, and below long-term cleanup goals elsewhere. If sources are completely eliminated surface sediment concentrations throughout the area are expected to decline to less than cleanup goals within only a few years.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source control is expected to reduce source input by 70 percent for HPAH and mercury. With this level of source control as an input value, the model predicts that sediments with an enrichment ratio of 1.5 or lower for both HPAH and mercury will recover within 10 yr (see Table 12-2). An enrichment ratio of 1.5 corresponds to a sediment concentration of 25,800 ug/kg for HPAH and 0.90 mg/kg for mercury. As shown in Figure 12-5, all surface sediments are

TABLE 12-2. MOUTH OF THE CITY WATERWAY
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals	
	HPAH	Mercury
Station with Highest Concentration		
Station identification	CI-21	CI-05
Concentration[a]	19,180	0.60
Enrichment ratio[b]	1.1	1.0
Recovery time if sources are eliminated (yr)	2	0
Percent source control required to achieve 10-yr recovery	23	3
Percent source control required to achieve long-term recovery	12	2
10-Yr Recovery		
Percent source control assumed feasible	70	70
Highest concentration recovering in 10 yr[a]	25,800	0.90
Highest enrichment ratio of sediment recovering in 10 yr	1.5	1.5

a Concentrations in ug/kg dry weight for organics, mg/kg dry weight for metals.

b Enrichment ratio is the ratio of observed concentration to cleanup goal.

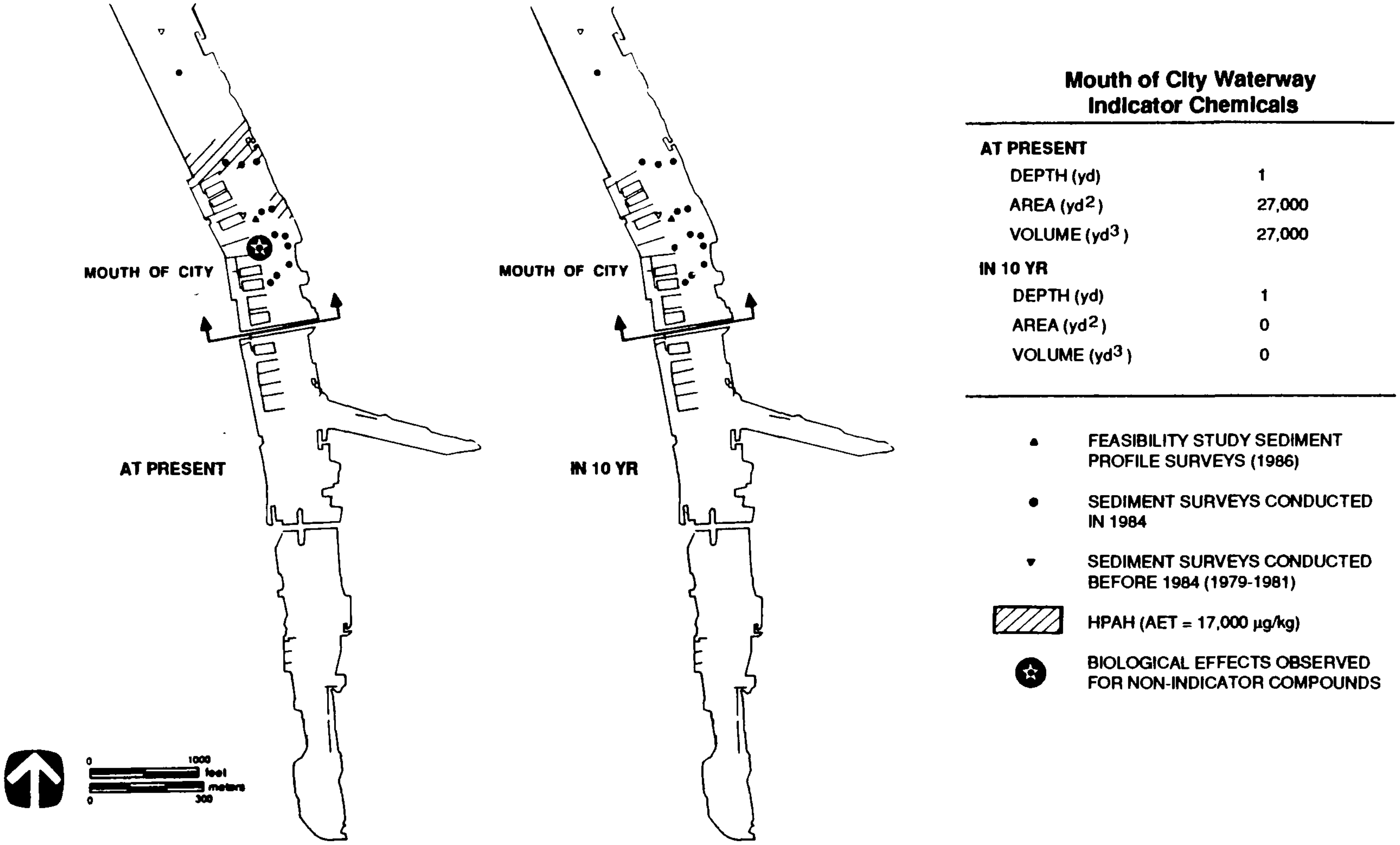


Figure 12-5. Sediments at the mouth of City Waterway not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

expected to recover in 10 yr. For comparison, sediments currently exceeding long-term cleanup goals for the indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that a 12 percent reduction in sources of HPAH is required to maintain acceptable contaminant concentrations in freshly deposited sediments (see Table 12-2). Only 2 percent source control is required to achieve long-term recovery of sediments contaminated with mercury. The actual percent reduction required in source loading is subject to the considerable uncertainty inherent in the assumptions of the predictive model.

As a comparison to source control requirements predicted using the model discussed above, the reductions required to achieve cleanup goals in storm drain sediment were calculated. On the basis of the sample collected in June 1987 in storm drain CI-214 (Norton, D., 15 April 1988, personal communication), sediment contaminant reductions of 55 percent would be required for HPAH and 70 percent for mercury to achieve long-term cleanup goals. Comparison of storm drain sediment with long-term cleanup goals assumes no mixing of sediments with cleaner material from other sources. Such comparisons provide a worst-case analysis of the impact of storm drain discharge on the waterway.

12.3.3 Source Control Summary

The major apparent sources of contamination to the mouth of City Waterway are the D Street petroleum facilities. If these sources are completely eliminated (100 percent source control), it is predicted that sediment concentrations of the indicator chemical HPAH in the surface mixed layer will decline to the long-term cleanup goal of 17,000 ug/kg in only 2 yr. Surface concentrations of mercury are already at or below the long-term cleanup goal of 0.59 mg/kg.

If sediment remedial actions are undertaken, only minimal levels of source control will be required to maintain acceptable concentrations of the indicator chemicals. The estimated percent reduction required for HPAH is 12 percent, and a 2 percent reduction is indicated for mercury. Additional source control may be required to maintain sediment quality immediately adjacent to the D Street petroleum facilities. However, very little sediment chemistry data are currently available in this area to confirm this statement. With 70 percent source control assumed feasible for both indicator chemicals for the problem area as a whole, it appears possible that acceptable sediment quality could be maintained following sediment remedial action in the mouth of City Waterway.

12.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with HPAH concentrations exceeding long-term cleanup goals is approximately 27,000 yd^3 (see Figure 12-5). This volume was estimated by multiplying the approximate areal extent of sediment exceeding the cleanup goal (27,000 yd^2) by the estimated

1-yd depth of contamination. The estimated thickness of contamination is only an approximation; only one sediment profile was collected and the vertical resolution of the profile was poor at the depth of the contaminated horizon.

In addition to chemical concentrations that exceed long-term cleanup goals for indicator chemicals, biological effects were observed at one station as where concentration of nonindicator compounds were very high (see Figure 12-5). The volume of sediment exceeding long-term cleanup goals for these compounds is estimated as 10,000 yd^3. With implementation of feasible source controls, sediment concentrations in these sediments are expected to recover to acceptable levels within 10 yr.

Ten years after implementation of feasible source controls, sediment concentrations of indicator chemicals are expected to be at or below long-term cleanup goals. Therefore, the volume of sediments requiring remediation is estimated to be zero.

12.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

12.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. Although no areas of sediment contamination in the mouth of City Waterway were identified for remediation, some areas do exceed long-term cleanup goals. Further refinement of areas of contamination may identify areas for remediation; therefore, an evaluation of alternatives was performed. Areas exceeding long-term goals serve as a basis for the evaluation. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess of the applicability of each alternative to remediation of contaminated sediments in the mouth of City Waterway. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; the location of potential disposal sites; and site physical properties such as waterway usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria presented in Chapter 4.

The indicator chemicals HPAH and mercury were selected to represent the primary sources of contamination to the waterway (see Table 12-1). Areal distributions for both indicators are presented in Figure 12-5. The HPAH contamination in the mouth of City Waterway suggests that a treatment process for organics could be an appropriate component of remedial action. Total concentrations of metals in the waterway, which are generally less than 2,000 mg/kg, are not expected to limit the applicability of solvent extraction or thermal treatment. The alternatives incorporating these treatment processes are therefore evaluated for the mouth of City Waterway.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, which is intended to protect the public from exposure to contaminated sediments without implementation of sediment mitigation, provides a second baseline for comparison. The three nontreatment dredging and disposal alternatives are applicable to remediation of sediment contamination in mouth of City Waterway.

Three alternatives were eliminated from consideration for this problem area: in situ capping, dredging with solidification and upland disposal, and dredging with land treatment. In situ capping is eliminated because of the need to maintain a navigation channel in the waterway. Solidification and upland disposal is not considered because the low levels of contamination do not warrant the additional expense over upland disposal without solidification. Land treatment is considered to be an appropriate remedial technology for sediments with high organic concentrations. However, land treatment is eliminated from consideration for this problem area because the sediments do not contain sufficient quantities of total organic carbon to warrant the use of this technology.

It is assumed that the requirements to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

The following seven sediment remedial alternatives are retained for evaluation for the cleanup in mouth of City Waterway:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solvent extraction/upland disposal
- Clamshell dredging/incineration/upland disposal.

12.5.2 Evaluation of Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 12-3. A comparative evaluation of alternatives based on ratings of high, moderate, and low in the various subcategories of evaluation criteria is presented in Table 12-4. For effectiveness, the subcategories are short-

TABLE 12-3. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE MOUTH OF CITY WATERWAY PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during dredging and disposal. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.	Public access to dredge, treatment, and disposal sites is restricted. Extended duration of treatment operations may result in moderate exposure potential.
		WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treating dredged material increases worker risk significantly over dredge/disposal options. Workers wear protective gear.	Incineration of CDM is accomplished over an extended period of time thereby increasing exposure risks. Additional treatment process increases hazards. Workers wear protective gear.
		ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination within a reasonable time frame. Minor adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Short-term benthic habitat impacts at the disposal site.	Existing contaminated habitat is destroyed. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed. Contaminated sediment is resuspended during dredging operations.	Existing contaminated habitat is destroyed by dredging. Sediment is resuspended during dredging operations. Process controls are required to reduce potential air emissions.
	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked seventh overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Complete sediment recovery is achieved naturally and contaminant levels decline to less than cleanup goals within a few years. This alternative is ranked first overall for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. Waterway shipping needs delay project completion. This alternative is ranked third overall for timeliness.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available and disposal siting issues should not delay implementation. This alternative is ranked second for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked fourth overall for timeliness.	Bench- and pilot-scale testing are required for the solvent extraction process. Full scale equipment is available. This alternative is ranked fifth overall for timeliness.	Substantial CDM testing and incinerator installation time is required before a thermal treatment and solidification scheme can be implemented. This alternative is ranked sixth overall for timeliness.
	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of the cap to prevent contaminant reexposure in the absence of physical disruption is considered good.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Treated CDM may be used as inert construction material or disposed of at a standard solid waste landfill. Treatment effectively destroys or contains contaminants.	Treated CDM may be used as inert construction material or disposed of at a standard solid waste landfill. Treatment effectively destroys or contains contaminants.
		PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains temporarily, but at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the overlying biota. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Permanent treatment for organic contaminants is effected and inorganic contaminants are isolated.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous. Treated CDM containing residual metals is effectively treated by encapsulation.
		PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline relatively quickly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Thickness of overlying cap prevents exposure of burrowing organisms. Potential for contaminant migration is low because CDM is maintained at in situ conditions.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Physicochemical changes could be minimized by placing sediments below the low tide elevation.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Harmful organic contaminants are removed from CDM. Concentrated contaminants are disposed of by RCRA- approved treatment or disposal. Residual inorganic contaminants are encapsulated.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous.
	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Harmful contaminants are removed from CDM. Concentrated organic contaminants are disposed of by RCRA- approved treatment or disposal. Toxicity and mobility considerations are eliminated by extraction or solidification.	CDM containing low levels of inorganic contaminants may be rendered nonhazardous.

TABLE 12-3. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLVENT EXTRACTION/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ INCINERATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, but feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Hydraulic dredging equipment is reliable. Secure upland confinement technology is well developed.	Sludges, soils, and sediments have successfully been treated using this technology. Solidification is effective treatment for inorganics after organics removal.	Incineration systems capable of handling CDM have been developed, but no applications involving CDM have been reported. Effects of salt and moisture content must be evaluated. Solidification after organics removal is effective.
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring compared with CAD.	Monitoring can be readily implemented to detect contaminant migration through dikes. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring is required only to evaluate the reestablishment of benthic communities. Monitoring programs can be readily implemented.	Disposal site monitoring is not required if treated CDM is determined to be nonhazardous. Air quality monitoring is intensive during implementation.
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements are minimal. Some O & M is associated with monitoring for contaminant migration and cap integrity.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.	No O & M costs are incurred at the conclusion of CDM treatment. System maintenance is intensive during implementation.
IMPLEMENTABILITY	INSTITUTIONAL FEASIBILITY	APPROVAL OF RELEVANT AGENCIES	Approval is denied as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are uncertain but are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Coordination is required for establishing discharge criteria for dredge water maintenance. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals depend largely on results of pilot testing for extraction and solidification and the nature of treatment residuals.	Approvals for incinerator operation depend on pilot testing and ability to meet air quality standards. Pilot testing for solidification is required.
IMPLEMENTABILITY	INSTITUTIONAL FEASIBILITY	COMPLIANCE WITH CHEMICAL- AND LOCATION-SPECIFIC ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	Sediments are expected to recover fully, thus meeting the intent of CERCLA/SARA and the NCP. Coordination with TPCHD for health advisories for seafood consumption is required during the recovery period.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy. Water quality criteria apply to dredge water.	WISHA/OSHA worker protection required. Section 404 permit is required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. Requires RCRA permit for disposal of concentrated organic waste.	WISHA/OSHA worker protection required. Section 404 permit is required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant toxicity and mobility. Requires compliance with PSAPCA standards.
IMPLEMENTABILITY	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Waterway CAD site is considered available. Availability of open water CAD sites is uncertain.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Process equipment available. Disposal site availability is not a primary concern because of reduction in hazardous nature of material.	Incineration equipment can be installed onsite for CDM remediation efforts. Applicable incinerators exist. Disposal site availability is not a concern because of reduction in hazardous nature of material.

TABLE 12-4. EVALUATION SUMMARY FOR MOUTH OF CITY WATERWAY

	No Action	Institutional Controls	Clamshell/ CAD	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Extraction/ Upland Disposal	Clamshell/ Incinerate/ Upland Disposal
Short-Term Protectiveness	Low	Moderate	High	Moderate	High	Moderate	Moderate
Timeliness	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate
Long-Term Protectiveness	Low	Moderate	High	Moderate	Moderate	High	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High	High
Technical Feasibility	High	High	Moderate	High	High	Moderate	Moderate
Institutional Feasibility	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	High	Moderate	Moderate	Moderate
Long-Term Cleanup Goal Costs[a]							
Capital	--	6	233	682	1,174	5,726	12,992
O&M	--	345	53	51	70	67	67
Total	--	351	286	733	1,244	5,793	13,059
Long-Term Cleanup Goal with 10-yr Recovery Costs[a]							
Capital[b]	--	6	NA	NA	NA	NA	NA
O&M[b]	--	345	NA	NA	NA	NA	NA
Total[b]	--	351	NA	NA	NA	NA	NA

[a] All costs are in $1,000.

[b] Implementing institutional controls will effectively eliminate the need for sediment remediation. Therefore, O&M costs were not evaluated for the other alternatives.

term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. For implementability, the subcategories are technical feasibility, institutional feasibility, availability, capital costs, and O&M costs. Remedial costs are shown only for sediments currently exceeding long-term cleanup goal concentrations, since no sediments would still exceed the cleanup goal concentrations 10 yr after implementing feasible source controls (i.e., 10-yr recovery costs).

The evaluation of alternatives is similar to that presented in Section 11.5.2 for Wheeler-Osgood Waterway, except that under institutional controls, the problem area recovers in 2 yr, so the effectiveness criteria and implementability receive a high ranking. In situ capping and land treatment alternatives were not deemed appropriate and therefore not considered for the mouth of City Waterway. The estimated volume of sediment exceeding long-term goals in the mouth of City Waterway (27,000 yd^3) is on the same order of magnitude as that for Wheeler-Osgood Waterway (11,000 yd^3). The indicator chemicals are also similar: HPAH and mercury for mouth of City Waterway, as compared with HPAH and zinc for Wheeler-Osgood Waterway. The reader is referred to Section 11.5.2 for a review of the considerations involved in the evaluation process. The evaluation summary table is explained in detail and each low, moderate, and high rating is discussed.

12.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Institutional controls are recommended as the preferred alternative for the mouth of City Waterway. Contaminant concentrations in the mouth of City Waterway are less than those concentrations predicted to recover to the long-term cleanup goals within 10 yr (in fact, the model indicates full recovery within 2 yr). Therefore, institutional controls provide a cost-effective and environmentally protective remedial alternative. Monitoring will determine the effectiveness of institutional controls. If monitoring results suggest that institutional controls are not effectively lowering contaminant concentrations, then clamshell dredging with confined aquatic disposal would be the currently preferred remedial alternative. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this latter alternative (i.e., clamshell dredging, confined aquatic disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. Clamshell dredging with confined aquatic disposal is rated high for short- and long-term protectiveness and moderate for all other criteria except reduction in toxicity, mobility, or volume, for which it is rated low. Implementation can be coordinated with similar sediment remediation activities in the head of City and Wheeler-Osgood Waterway. The confined aquatic disposal alternative was recommended for these problem areas for the reasons provided in Section 10.6. As indicated in Table 12-4, this alternative provides a cost-effective means of sediment remediation, based on remediation costs for sediments exceeding long-term goals.

Although some sediment resuspension is inherent in dredging operations, silt curtains and other available engineering controls would be expected to minimize adverse impacts associated with redistribution of contaminated dredged material. Potential impacts on water quality can be predicted by using data from bench-scale tests to estimate contaminant partitioning to the water column. Once a disposal site is selected, this alternative can be implemented over a relatively short timeframe. Seasonal restrictions on dredging operations to protect migrating anadromous fish are not expected to pose a problem. Dredging activities within this problem area are consistent with the Tacoma Shoreline Management Plan and Sections 404 and 401 of the Clean Water Act. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

Of the remaining alternatives, clamshell dredging with nearshore disposal in Blair Waterway Slip 1 is feasible, as are the treatment alternatives. However, nearshore disposal would be less protective than confined aquatic disposal and would fail to take advantage of the remedial activities that are expected to occur in the head of City Waterway (i.e., dredging with confined aquatic disposal). The treatment options are considered too costly, given the limited amount of additional protection they would provide. The upland disposal alternatives would add considerable costs to the sediment remediation effort with few additional benefits.

The no-action alternative is rated high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public impacts far outweighs these advantages.

12.7 CONCLUSIONS

The mouth of City Waterway was identified as a problem area because of the elevated concentrations of PAH and several other organic and inorganic chemicals. HPAH and mercury were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 27,000 yd^2, and a volume of 27,000 yd^3. This volume of material includes an estimated 10,000 yd^3 of sediment in the navigation channel which demonstrated biological effects for nonindicator compounds. The entire area exceeding long-term cleanup goals is predicted to recover within 10 yr following implementation of known, available, and reasonable source control measures. The total volume of sediment requiring remediation is therefore reduced to zero.

The primary identified sources of problem chemicals to this problem area are the D Street petroleum storage facilities and the storm drains that service these facilities. Source control measures required to correct these problems and ensure the long-term success of sediment cleanup in the problem area include capping and removal of contaminated materials, and other methods for controlling contamination in surface runoff. Best management practices for controlling spillage during handling of petroleum products are also appropriate.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals HPAH and mercury.

If monitoring confirms that sediment remediation is not required, then institutional controls (implementation) are proposed as the preferred alternative. If, however, additional refinement of the contaminated area identifies areas of sediment remediation, clamshell dredging with confined aquatic disposal would be the preferred remedial alternative. This alternative will take advantage of procedures and equipment being used to remediate sediment in the head of the waterway. The identification of these alternatives was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternatives meet the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments at near in situ conditions in a quiescent, subaquatic environment. Confined aquatic disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). Either alternative would be consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

The estimated cost (present worth) of implementing a monitoring program is $351,000. This program would be used to verify that source control and natural sediment recovery have corrected the contamination problems. Implementation of source control measures are not included in the cost analysis.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediments

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the implementation of source controls:

- Additional sediment monitoring to refine the area and depth of sediment contamination
- Further source investigations
- Monitoring of sources and sediments to verify the effectiveness of source control measures.

Implementation of institutional controls is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions to the maximum extent practicable, and are cost-effective.

13.0 RUSTON-PT. DEFIANCE SHORELINE

Potential remedial actions are defined and evaluated in this section for the Ruston-Pt. Defiance Shoreline Waterway problem area. The problem area is described in Section 13.1. This description includes a discussion of the physical features of the waterway, the nature and extent of contamination observed during the RI/FS field surveys, and a discussion of anticipated or proposed dredging activities. Section 13.2 provides an overview of contaminant sources, including site background, identification of known and potential contaminant reservoirs, remedial activities, and current site status. The effects of source control measures on sediment contamination levels are discussed in Section 13.3. Area and volume of sediments requiring remediation are discussed in Section 13.4. The detailed evaluation of the candidate sediment remedial alternatives chosen for the problem area and indicator problem chemicals is provided in Section 13.5. The preferred alternative is identified in Section 13.6. The rationale for its selection is presented, and the relative merits and deficiencies of the remaining alternatives are discussed. The discussion in Section 13.7 summarizes the findings of the selection process and integrates required source control with the preferred remedial alternative.

13.1 WATERWAY DESCRIPTION

The Ruston-Pt. Defiance Shoreline problem area extends along the southwest shore of Commencement Bay from the Pt. Defiance Zoo and Aquarium to the mouth of City Waterway. An illustration of the shoreline and the locations of storm drain outfalls and nearby industries are presented in Figure 13-1. The Tacoma Smelter, which began smelting lead in 1889, is also located along the shoreline. It was modified for copper smelting in about 1906, after it was purchased by ASARCO. The southwest shoreline is fairly steep and forested, with residential housing and small commercial establishments located along the shore and on the bluff. The waterfront of the Ruston-Pt. Defiance Shoreline has been modified as a result of dredge and fill operations. The peninsula enclosing the Tacoma Yacht Basin was formed by placement of copper smelting slag, issued under permits from 1917 to 1962. Slag was also used to build up the shoreline on which much of the ASARCO plant in now located. Between 55,000 and 90,000 yd^3 of slag near the Tacoma Yacht Basin was removed and replaced with riprap to stabilize shoreline embankments.

The subbottom profiling that was performed as part of the Commencement Bay Nearshore/Tideflats (N/T) RI did not extend through the problem area off Pt. Defiance (Raven Systems and Research 1984). Sediments along the Ruston-Pt. Defiance Shoreline are typically sands, averaging less than 20 percent fine-grained material and having a clay content of 5 percent (Tetra Tech 1985b). A large percentage of the gravel and coarse sand found off the ASARCO facility and slag fill areas appeared to be slag particles, based on

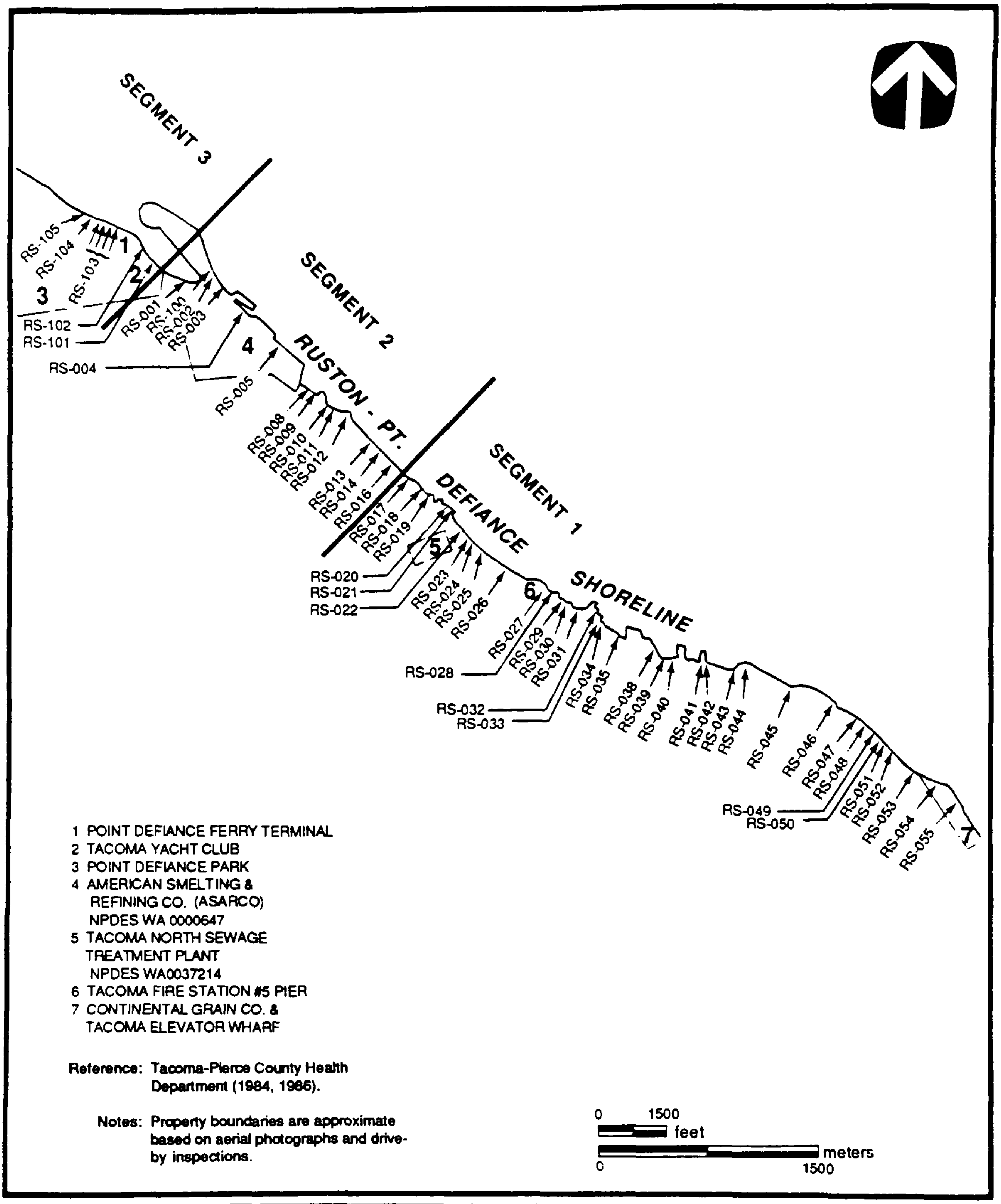


Figure13-1. Ruston-Pt. Defiance Shoreline - Existing industries, businesses, and discharges.

visual observations made during the development of the ASARCO interim RI report (Parametrix et al. 1988).

13.1.1 Nature and Extent of Contamination

An examination of sediment contaminant data obtained during both RI/FS sampling efforts (Tetra Tech 1985a, 1985b, 1986c) and historical surveys has revealed that the problem area contains concentrations of both organic and inorganic materials that are harmful to benthic organisms. Priority 1 contaminants that have been identified include arsenic, mercury, and LPAH. The following Priority 2 contaminants have also been identified: cadmium, nickel, copper, lead, zinc, antimony, HPAH, dibenzofuran, PCBs, and phthalate esters. The following organic compounds exceeded their corresponding AET values at only one station sampled and are therefore considered Priority 3 contaminants: biphenyl, dibenzothiophene, methylphenanthrene, methylpyrene, 4-methylphenol, 2-methylphenol, N-nitrosodiphenylamine, and an alkylated benzene isomer. Generally, these contaminants exhibit high particle affinity and low solubility (Tetra Tech 1987c).

Arsenic and mercury were selected as inorganic indicator chemicals for the Ruston-Pt Defiance Shoreline problem area. Estimated areal and depth distributions of arsenic are shown in Figure 13-2 and those for mercury are shown in Figure 13-3. Contaminated sediments located in water depths exceeding 200 ft were not included in the problem area because dredging cannot occur at greater depths. The highest concentrations of arsenic and mercury were found at sampling stations located near the main outfalls of ASARCO (Tetra Tech 1986c). Surficial arsenic concentrations equalled or exceeded the long-term cleanup goal of 57 mg/kg at all stations in the problem area. Surficial mercury concentrations reached or exceeded the long-term cleanup goal of 0.59 mg/kg at all but two sampling stations in the problem area. Levels of contamination in the figures are normalized to these cleanup goals. Problem sediments were defined by values of those indicator chemicals greater than 1.0 at stations in less than 200 ft of water. The cleanup goal for arsenic was set by the AET derived for benthic infaunal abundance depression and the cleanup goal for mercury was set by the oyster larvae bioassay.

Based on its presence in sediments at concentrations well above the long-term cleanup goal, LPAH was also selected as an indicator compound for the Ruston-Pt. Defiance Shoreline problem area. This cleanup goal was determined by the oyster larvae bioassay. Concentrations of LPAH exceeding the cleanup goal of 5,200 ug/kg were observed near the ASARCO docks and off several storm drains southeast of the facility (Figure 13-4). Levels of contamination in the figure are normalized to the long-term cleanup goal.

All sediment profiles of metals measured during the RI and FS displayed a concentration maximum at or very near the surface. Sediment profiles of LPAH concentrations demonstrate weak surface maxima. Remediation to a depth of 0.5 yd was assumed based on core profiles form stations RS-91, RS-92, RS-93, and RS-94.

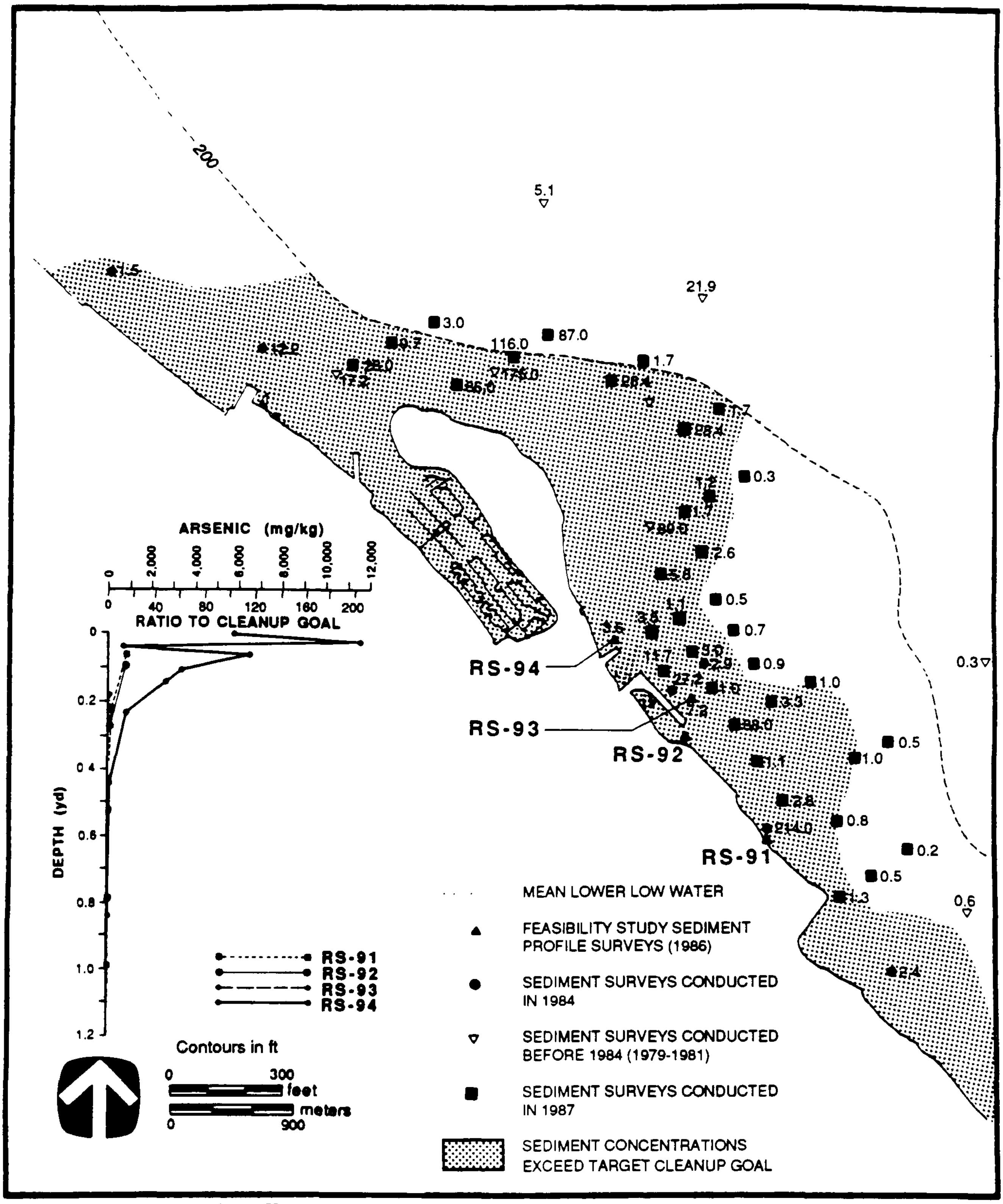


Figure 13-2. Areal and depth distributions of arsenic in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal.

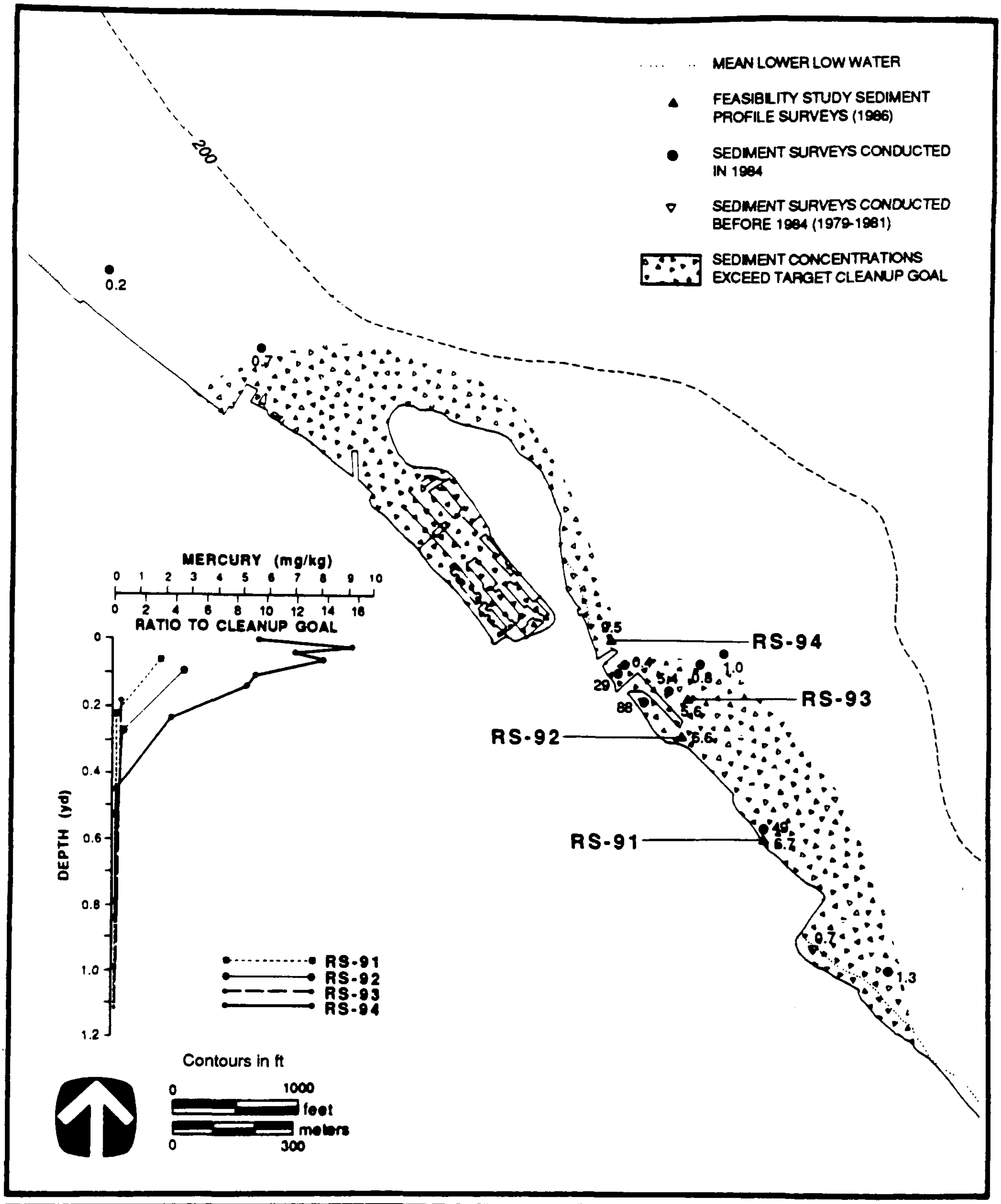


Figure 13-3. Areal and depth distributions of mercury in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal.

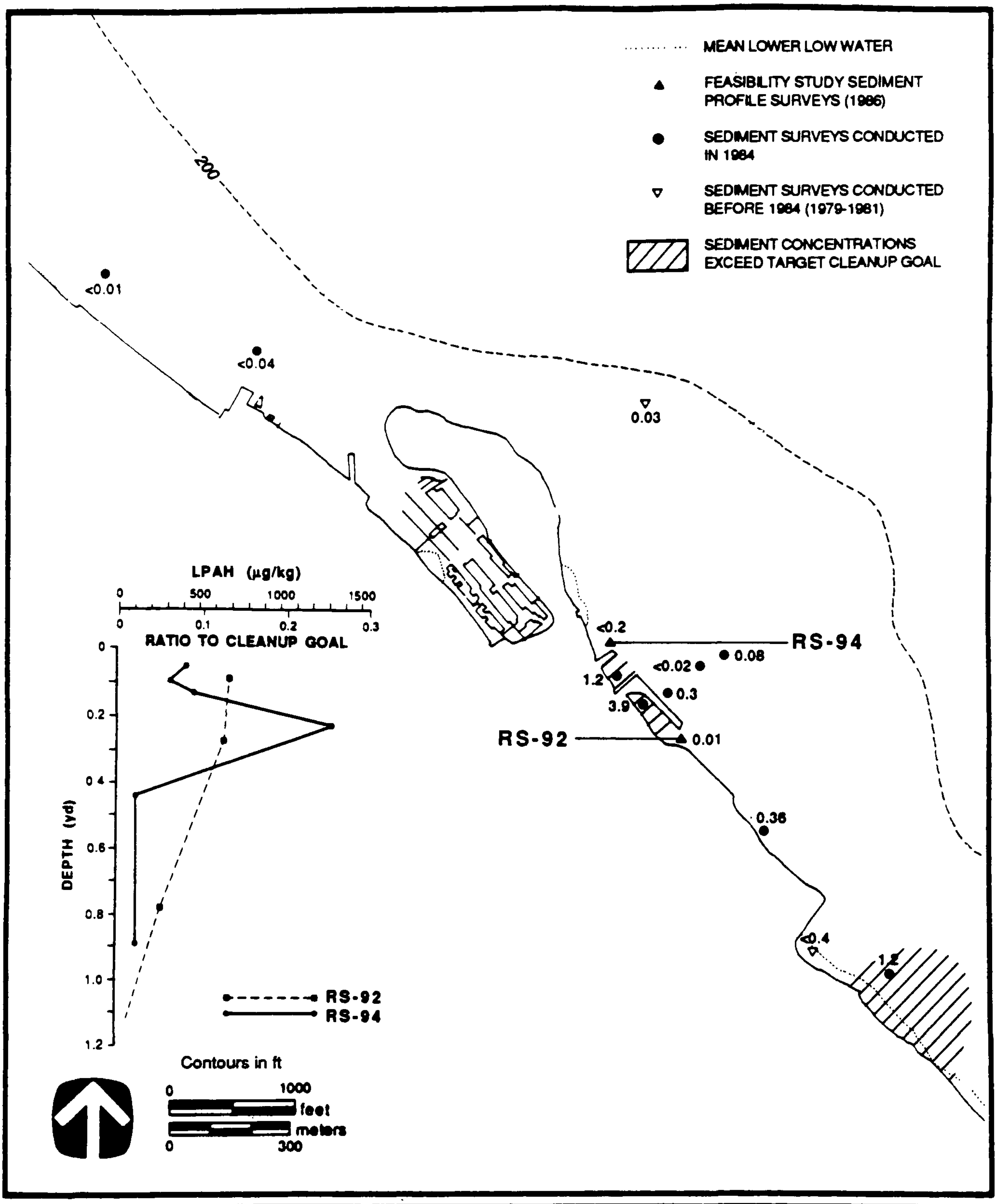


Figure 13-4. Areal and depth distributions of LPAH in sediments of Ruston-Pt. Defiance Shoreline, normalized to long-term cleanup goal.

13.1.2 Recent and Planned Dredging Projects

The Tacoma Metropolitan Park District is currently dredging 180 yd^3 of concrete, rubble, sand, and silt from the beach adjacent to Ruston Way, south of the ASARCO facility. Dredged material, to be disposed of on the nearby uplands, will be replaced with 196 yd^3 of sand along the Ruston-Pt. Defiance Shoreline (Heany, K., 27 October 1987, personal communication; U.S. Army Corps of Engineers, 27 October 1987, personal communication).

Of the establishments along the shoreline, the Tacoma Yacht Basin and the Continental Grain Company responded when queried about future dredging projects. Neither business plans any dredging operations in the foreseeable future (Anonymous, 22 October 1987b, personal communication; Aylor, M., 22 October 1987, personal communication).

13.2 POTENTIAL SOURCES OF CONTAMINATION

The ASARCO smelter began operations in the area in 1889 and continued metal refining until 1978. Copper smelting at the site ceased in 1985 and the arsenic trioxide plant was shut down in 1986. Other facilities currently operating in the area include the Pt. Defiance Ferry Terminal Slip, Tacoma Yacht Basin, City of Tacoma Fire Station No. 5 Pier, Continental Grain Company, Tacoma Elevator Wharf, and Tacoma North Sewage Treatment Plant (see Figure 13-1).

The Ruston-Pt. Defiance Shoreline study area was the location of the original Tacoma settlement in the late 1800s and the site of the Tacoma Mill, the first lumber mill on Commencement Bay, which began operation in 1869. Other industries that had been located on the Ruston-Pt. Defiance Shoreline include eight lumber companies, two grain elevators, a lime company, a boat building operation, a fuel company, a cold storage company, and railroad freight warehouses.

Table 13-1 provides a summary of problem chemical and source status information for the area. The high concentrations of metals have been attributed largely to the three main ASARCO outfalls and the historical use of slag as fill material and riprap. The elevated concentrations of LPAH have been tentatively attributed to fuel oil spills, fuel combustion, and stack emissions.

13.2.1 American Smelting and Refining Company

The ASARCO primary copper smelter is located along the Ruston-Pt. Defiance Shoreline along the southwestern shore of the Commencement Bay N/T study area. The site is owned by the American Smelting and Refining Company, Inc., a New Jersey corporation. ASARCO, Inc. owns approximately 97 ac within the adjacent municipalities of Ruston and Tacoma. Of this, approximately 67 ac are occupied by the smelter facility; the remainder comprises parking areas and adjacent undeveloped property. Land use in the vicinity of the site is primarily urban residential, with recreational and commercial land uses nearby (Parametrix et al. 1986).

TABLE 13-1. RUSTON-PT. DEFIANCE SHORELINE - SOURCE STATUS[a]

Chemical/Group	Chemical Priority[b] Segment 2	Chemical Priority[b] Segment 3	Sources	Source ID	Source Loading	Source Status	Sediment Profile Trends
Mercury	1		ASARCO Storm	Yes	>90% of metals	ASARCO closed in	Surface or near surface
Arsenic	1	2	Drains RS-003,		load from	1986	maxima
Cadmium	2	2	-004, -005		RS-004, RS-005	Ongoing source	
Nickel	2	2					
Copper	2	2	ASARCO slag	Potential	No	Historical source	
Lead	2	2					
Zinc	2	2	Groundwater from	Potential	No	Ongoing source	
Antimony	2	2	ASARCO				
LPAH	1	--	ASARCO fuel	Potential	No	c	Weak surface maxima
HPAH	2	--	storage tanks,				
Dibenzofuran	2	--	oil, oil spills				
Biphenyl	3 (RS-18)	--					
Dibenzothiophene	3 (RS-18)	--	Fuel combustion,	Potential	No	c	
Methylphenanthrene	3 (RS-18)	--	emissions				
Methylpyrene	3 (RS-18)	--					
			Storm drains	Potential	Yes	c	
4 Methylphenol	3 (RS-16)	--	Wood wastes	Potential	c	c	Variable, no significant
2 Methylphenol	3 (RS-18)	--					trend
PCBs	2	--	ASARCO facilities	Potential	No	c	Surface, subsurface maxima
Phthalate esters	2	--	No	No	No	c	
Alkylated benzene isomer	3 (RS-16)	--	c	c	c	c	
Retene	3 (none)	--	c	c	c	c	
N nitrosodiphenylamine	3 (RS-18)	2	c	c	c	c	

[a] Source information and sediment information blocks apply to all chemicals in the respective group, not to individual chemicals only.

[b] For Priority 3 chemicals, the station exceeding AET is noted in parentheses.

[c] Not evaluated for this study.

A lead smelting facility under the ownership of the Tacoma Smelter Company established operations at the site in 1889. Copper production commenced in 1902 and the smelter was purchased by the American Smelting and Refining Company in 1905. The facility continued lead and copper smelting operations until 1911, when lead smelting was discontinued in favor of copper smelting. The ASARCO facility continued to operate as a primary copper smelter until operations ceased permanently on 24 March 1985 (EPA Docket No. 1086-04-24-106). The facility continued to operate the arsenic production plant through January 1986 (Parametrix et al. 1986).

The ASARCO copper smelter generally operated around the clock, 7 days a week, from approximately 1912 until the facility ceased operations in 1985. Production averaged approximately 70,000 tons of anode copper per year. By-products of the copper smelting process have included sulfuric acid, liquid sulfur dioxide, arsenic trioxide, and arsenic metal (Parametrix et al. 1986). A molten slag was also created. Slag was deposited on the ground and at the edge of Commencement Bay as fill material or sold for use as sandblasting grit, riprap, fill material, road ballast, and ornamental rock (Parametrix et al. 1986). In addition, the dust collected by the electrostatic precipitators and the baghouse used in the emission control operations was used in the onsite production of marketable arsenic trioxide. Sulfur dioxide was also generated by the converter operations onsite in sufficient concentration and quantity to permit extraction in the onsite chemical plants.

Emission control programs and associated operational modifications were incorporated at the ASARCO site in 1970 (Parametrix et al. 1986). The emissions of primary concern from the facility have been sulfur dioxide and particulate matter containing inorganic arsenic. The principle sources of these contaminants have been the 562-ft main stack and a variety of low-level sources, principally the converter-reverberatory building. Closure of the copper smelting and arsenic production facilities have reportedly reduced emissions from approximately 59 ton/yr to fugitive dust emissions (U.S. EPA 1986d). Air quality enforcement proceedings date back to 1968, with the adoption of Regulation I by PSAPCA governing both ambient air and emissions standards for sulfur dioxide. Concern over arsenic emissions arose in 1972 when the Washington Department of Social and Health Services requested that PSAPCA adopt proposed arsenic standards. A series of environmental studies on emissions from the facility was initiated by U.S. EPA near ASARCO early the following year (Parametrix et al. 1986). These studies indicate that significant concentrations of heavy metals were present in local grazing areas, surrounding soil, house dust, and fugitive emissions from site equipment. In 1979, the Washington State Supreme Court ordered that an environmental impact statement was required before any variance from air emission standards could be granted to the facility. After completion of the studies, ASARCO was granted a variance from sulfur dioxide emission standards, but was subject to full compliance by 1987 and ordered to continuously monitor and report ambient arsenic concentrations (Parametrix et al. 1986).

Prior to plant shutdown, surface water had been sampled at the ASARCO site primarily in response to accidental spills of material. Three outfalls at the facility have been regularly monitored as part of their NPDES permits since 1975 (Parametrix et al. 1986). Loadings of arsenic, copper, cadmium, lead, and zinc were generally observed to decrease from 1979 to 1984 (the last full year of operation), with total metal loadings in 1984 estimated at 22,049 lb. Additional sampling since closure indicates that metals loadings to the bay have decreased by approximately 2 orders of magnitude (Norton and Stinson 1987). Discharges are currently limited to stormwater runoff and groundwater percolation through the site.

Parametrix et al. (1986, 1988) have compiled hydrogeologic information regarding conditions in the vicinity of the ASARCO facility. Many of the existing smelter facilities are located on reclaimed tideflats at the base of the Commencement Bay sea cliffs. These tidelands were reclaimed by placement of fill materials consisting of wood waste, debris, and smelter slag. Groundwater formations beneath the site have been divided into three units: the water-bearing materials within the fill beneath the site and two additional aquifers in the underlying formations. Groundwater flow beneath the site is primarily toward Commencement Bay (Parametrix et al. 1986, 1988). Recharge reportedly occurs via precipitation infiltration and upgradient flow from the various aquifer formations. Tides influence the shallow aquifer within the fill unit at the site.

During the RI (Tetra Tech 1985a) and subsequent studies (Tetra Tech 1985b, 1986c; Parametrix et al. 1988), the ASARCO site was identified as a major source of heavy metal contaminants found along the Ruston-Pt. Defiance Shoreline study area. Identification of the smelter site as a source of inorganic contaminants was based on its proximity to the problem area, measurement of identified contaminants in discharges from the site, and documented presence of heavy metal contaminants in the production process. Contamination of sediments with organic compounds near ASARCO is likely the result of historical activities including spills, leakage from storage tanks, and stack emissions (Tetra Tech 1986c). Oil was subsequently encountered at two locations within the slag fill at ASARCO during borehole drilling (Parametrix et al. 1988), supporting the theory that these organic contaminants have originated from the site.

Identification of Contaminant Reservoirs Onsite--

The three major discharges associated with the ASARCO facility are the NPDES-permitted plant outfalls to Commencement Bay (RS-003, RS-004, and RS-005). Other historical practices that may have contributed to the observed contamination in Commencement Bay cannot be definitely identified because of the age of the facility and the relatively short history of regulated emissions and discharges. Past Ecology inspections have consistently failed to trace drainage lines from various buildings to their ultimate discharge point, despite dye testing and consultations with plant personnel (Tetra Tech 1985b).

Although there are currently no smelting or refining activities at ASARCO, the three major outfalls continue to discharge water contaminated with metals, presumably storm water and shallow groundwater (Tetra Tech 1986c). Recent demolition activities contributed to surface water runoff from scrap steel washing operations and dust suppression efforts. These outfalls also carry runoff originating as groundwater seeps in the area of the plant stack (Hart-Crowser & Associates 1986).

Prior to 1976, when discharge of noncontact cooling water was discontinued, contact and noncontact cooling waters were mixed and discharged through the outfalls (Tetra Tech 1985b). Typically, the south outfall (RS-005) contained the highest metal concentrations. The flow from this discharge was composed of saltwater noncontact cooling water from the acid plant, springs, surface runoff from the property, and freshwater inputs from cooling water use. The middle outfall (RS-004) drained the primary smelting areas, the arsenic storage areas, and the copper anode pond where contact cooling waters were recirculated. This outfall also served as a surface stormwater runoff ditch. The north outfall (RS-003) drained the old refinery areas and the laboratory. It has been suggested that drainage from the arsenic kitchens was also discharged indirectly through this outfall (Tetra Tech 1985b). During plant operations, discharge rates ranged from a high of 3-4 MGD from RS-005 to an estimated 1 MGD from RS-003. A City of Ruston storm drain (RS-002) north of ASARCO discharges runoff from the oil tank storage areas and powerhouses.

The overall influence of surface soil contamination as a potential pollutant source may have increased because of site stabilization efforts underway at the site. Plant demolition activities are expected to greatly increase the surface area of exposed soils at the site, resulting in a proportionate increase in potential contaminant transport via surface water and air.

Contaminants may also be migrating from the site via groundwater discharge to Commencement Bay. Groundwater samples collected by Ecology in 1985 revealed arsenic, cadmium, and lead concentrations that exceeded primary drinking water standards (Tetra Tech 1985b).

Inorganic contaminants present in groundwater beneath the ASARCO site may have originated from slag deposited onsite during the years of active operation. During the early years of operation, molten slag was deposited directly into seawater. Dikes were subsequently constructed at the site and molten slag was dumped behind them. A number of the plant's current facilities now stand on land created by these activities. Slag depth has been estimated to extend to 10-12 m below sea level at the seaward edge of the property (Tetra Tech 1985b). Physical decomposition of slag by wave action may contribute to contamination of adjacent marine sediments.

Other major routes for release of contaminants were air emissions from the main stack and dust from process operations. In a permit granted by PSAPCA, limitations were established for total particulates, sulfur oxides, and arsenic emissions. The facility was also required to monitor and report lead and mercury emissions to PSAPCA on a monthly basis (Tetra Tech 1985b). U.S. EPA has estimated that about 34 lb/h of arsenic may have been released via fugitive arsenic process dust emissions, with most of the arsenic coming from process gases in the converter operation of the plant (Tetra Tech 1985b). Chemical analysis of emissions from the main ASARCO stack during operations indicate that particulate matter comprised 46 percent arsenic and 7 percent lead. The investigation also identified zinc, copper, cadmium, chromium, and mercury in the particulate matter emanating from the stack (Parametrix et al. 1986).

Although smelting operations are no longer being conducted on the site, fugitive dust emissions could result from current site stabilization and demolition activities and from resuspension of contaminated surface soils by wind. In addition, the facility has incinerated arsenic-contaminated wood waste generated by the demolition activities in one of the former converters.

Recent and Planned Remedial Activities--

The closure of the ASARCO primary copper smelting facility in 1985 and the shutdown of arsenic production operations in 1986 has reduced air emissions due to process operations and greatly reduced other discharges from the site. An Administrative Order on Consent signed by ASARCO, Inc. and the U.S. EPA in September 1986 provided the framework for completion of additional remedial activities (U.S. EPA 1986d).

On 10 September 1986, ASARCO and U.S EPA entered the order, in which ASARCO agreed to undertake a series of demolition efforts to reduce potential pollutant discharges and conduct an RI/FS at its Tacoma smelter. Phase I sampling for the RI included collection of samples from the following matrices: surface soil, subsurface soil, surface water, groundwater, and marine sediment samples. Phase II will include biological sampling. Preliminary results from groundwater, surface soil, subsurface soil, and marine sediment samples have been presented in an interim report (Parametrix et al. 1988). Data presented in the interim report had not been reviewed according to all of the quality assurance/quality control (QA/QC) protocols specified in the RI sampling and analysis plans. However, it is not anticipated that the final QA/QC review will result in altered conclusions from Phase I sampling (Parametrix et al. 1988).

Based on the results of the interim RI report, surface soils at the ASARCO site are a potential source of contamination for offsite migration. Arsenic concentrations of up to 262,250 mg/kg and mercury concentrations of up to 695 ug/kg were observed (Parametrix et al. 1988). Subsurface soil contained arsenic and mercury concentrations of up to 2,640 mg/kg and 1.9 ug/kg, respectively (Parametrix et al. 1988). Average contaminant concentrations for the various soil types present at the facility and for the various particle size distributions are not presented. Measured groundwater concentrations of arsenic, cadmium, chromium, and lead reported on a preliminary basis by Parametrix et al. (1988) (i.e., a full quality assurance evaluation had not been performed) were higher than maximum contaminant levels of the Safe Drinking Water Act. Of 14 measurements reported, the arsenic MCL of 0.05 mg/L was exceeded 10 times (highest measured arsenic concentration = 27.5 mg/L). The cadmium MCL of 0.01 mg/L was exceeded three times (highest measured concentration = 0.34 mg/L). The chromium MCL, assumed to be 0.05 mg/L, was exceeded twice (highest measured concentration = 0.24 mg/L), and the lead MCL of 0.05 mg/L was exceeded once (0.09 ug/L).

Results of surface water sampling and the assessment of surface soils covering slag deposits at the ASARCO facility were incomplete, and not included in the interim report (Parametrix et al. 1988).

The site stabilization effort was designed to remove many of the structural components that have been in contact either directly or indirectly with process materials. These process materials include flue dust, which may contain inorganic arsenic. Prior to the initiation of demolition activities, ASARCO agreed to perform the following actions:

- Remove dust from as many structures and areas as possible by standard process methods followed by power vacuum cleaning

- Remove all asbestos-containing materials from the structures slated for demolition

- Clean up portions of the brick flue leading to the main stack that had collapsed during earlier maintenance operations

- Remove reusable equipment and disconnect utilities (Parametrix et al. 1986).

Dust was suppressed during the demolition with high-pressure water-fogging nozzles. Ambient arsenic concentrations were monitored daily at six stations in the vicinity of the facility and one station on Vashon Island. On several occasions, the 2.0 ug/m^3 ambient arsenic concentration was exceeded at the south ore dock sampling station adjacent to Commencement Bay. In three cases, the elevated arsenic levels were attributed to preparation of arsenic-contaminated wood for incineration in the converter system. Dust suppression efforts were subsequently enhanced in the wood preparation area and no further exceedances were recorded. Arsenic levels in excess of the criterion were also noted during the early phases of the operation as a result of arsenic trioxide loading operations conducted by ASARCO concurrently with the demolition (White, R., 20 July 1987, personal communication).

The site stabilization effort resulted in removal of the two main brick flues and pneumatic conveyor system, the plate treaters, the pipe treater, and eight process and storage buildings. In addition, approximately 375 truckloads of scrap steel were sent for resmelting at a local metal production facility; approximately 750 truckloads of concrete, dirt, and brick debris were processed for disposal at a CERCLA-approved hazardous waste disposal facility; and approximately 1,000 tons of wood were incinerated in the site converter system following completion of acceptable emission testing.

Visually contaminated surface soils were removed. Where possible, soils overlying concrete foundations were also removed. Surface water management during the demolition and site stabilization made use of the existing collection and treatment facilities. Water from the operations flows by gravity to one of two collection points, from which it is pumped to the No. 1 refinery building and then through a heat exchanger to a series of lead-lined evaporation tanks. Solids are periodically removed from the tanks by rinsing and filtration. Following evaporation with electric heaters, the resulting wet residue is transported to ASARCO's East Helena (Montana) plant for recovery of metals.

Surface water runoff controls implemented subsequent to the stabilization effort include cleaning the existing drainage conduits and attempting to revegetate the stack area and adjacent hillside by standard hydroseeding techniques. The existing concrete pads are expected to aid in reducing groundwater recharge and leachate generation by precipitation. The integrity of several of the pads has been compromised, however, by the use of heavy equipment.

At present, all phases of the initial site stabilization have been completed in accordance with the Administrative Order on Consent. Additional structures may be removed, and negotiations for further activities are in progress. An amendment to the Consent Order has also been negotiated between ASARCO and U.S. EPA to disassemble the sulfur dioxide and acid plants on the south end of the facility and sell them to a prospective industrial buyer (Rose, K., 19 January 1988, personal communication).

The biological studies to be conducted as a part of the Phase II RI sampling will correlate the observed contaminant concentrations and sediment types to area-specific variations within the biological community. Particular attention will be paid to the effects on the biological indicators of sediments containing a high percentage of weathered slag. The ASARCO RI is currently scheduled for completion in January 1989, with completion of the FS and submittal of the document for public review in May 1989.

13.2.2 Loading Summary

Summary loading tables are provided in Appendix E for eight inorganic contaminants plus LPAH, HPAH, phthalates, and PCBs. Discharges along the Ruston-Pt. Defiance Shoreline problem area for which post-RI loading data are available include: ASARCO north outfall RS-003, ASARCO middle outfall RS-004, and ASARCO south outfall RS-005 (ASARCO 1987; Norton and Stinson 1987). The loading tables incorporate these 1987 data.

Data for the inorganic contaminants (except mercury) are presented for the three main ASARCO outfalls along with drains RS-022, the Tacoma North Wastewater Treatment Plant Outfall, and RS-040 (a 48-in concrete storm drain pipe). Mercury data and data on the organic contaminants of concern are provided for RS-022 and RS-040.

Average loading estimates for arsenic from the three main ASARCO outfalls for the active periods of operation at the facility range from 0.31 lb/day (RS-003) to 400 lb/day (RS-005). Average arsenic loadings decreased to approximately 0.2 lb/day at RS-005 following plant shutdown.

Average loading rates for copper followed a similar trend, with values during the active period of operation ranging from 1.2 lb/day (RS-003) to 120 lb/day (RS-005). Average copper loadings decreased to 0.14 lb/day at RS-005 following plant shutdown (no data were available for RS-003).

Average concentrations of antimony, cadmium, lead, and zinc in discharges from the ASARCO middle and south outfalls (RS-004 and RS-005) were greater than corresponding averages from the Nationwide Urban Runoff Program study (U.S. EPA 1983b), but were within 1 order of magnitude of those values. Inorganic contaminant concentrations measured in discharges RS-022 and RS-040 were well within the range of values noted in the study (U.S. EPA 1983b).

PCBs were not detected in discharges RS-022 and RS-040 during the two sampling events recorded. Phthalate loading rates from discharge RS-022 ranged from 0.04 to 1.8 lb/day [bis(2-ethylhexyl)phthalate and butyl benzyl phthalate, respectively]. The phthalate compounds were not detected in discharge RS-040. LPAH and HPAH loading rates from discharge RS-022 ranged from 0.52 to 1.16 lb/day.

13.3 EFFECT OF SOURCE CONTROL ON SEDIMENT REMEDIATION

A twofold evaluation of source control has been performed. First, the degree of source control technically achievable (or feasible) through the use of all known, available, and reasonable technologies was estimated. This estimate is based on the current knowledge of the source of contamination, the technologies available for source control, and source control measures that have been implemented to date. Second, the potential success of source control was evaluated. This evaluation was based on the levels of contamination in the sediment and assumptions regarding the relationship between the source and sediment contamination. Included within the evaluation was an estimate of the degree of source control needed to maintain acceptable sediment contaminant concentrations problems over the long term.

13.3.1 Feasibility of Source Control

The primary identified sources of contaminant discharge to the Ruston-Pt. Defiance Shoreline problem area are runoff and groundwater inputs from the ASARCO smelter facility. Outfall monitoring data along with the results of the ASARCO interim RI report (Parametrix et al. 1988) indicate that surface water runoff, surface soil, and groundwater beneath the facility are potential ongoing sources of contamination to the adjacent sediments. Additional data from the comprehensive surface water runoff monitoring program conducted as part of ASARCO RI process are pending.

Available technologies for controlling quantity and quality of surface water runoff from the ASARCO site include removal or hydraulic isolation of contaminant sources within the drainage basin (e.g., excavation, capping), methods for retaining runoff onsite (e.g., berms, channels, grading, sumps), and revegetation to reduce erosion of waste materials (see Section 3.2.2).

Treatment methods for stormwater after collection in a drainage system also exist. Sedimentation basins and vegetation channels (or grassy swales) have been shown to remove contamination associated with particulate matter. Removals of up to 75 percent for total suspended solids and 99 percent for lead have been reported for detention basins (Finnemore and Lynard 1982; Horner and Wonacott 1985). Removals of 90 percent for lead, copper, and zinc and 80 percent for total suspended solids have been achieved using grassy swales (Horner and Wonacott 1985; Miller 1987).

Recent efforts on the part of ASARCO to revegetate the areas of the site exposed by the site stabilization effort have met with limited success, possibly because of extremely dry conditions that prevailed during the incubation period following the hydroseeding effort. Continued revegetation efforts under more favorable conditions may be warranted to stabilize surface soils prior to initiating remedial actions.

Pump and treat methods are feasible for control of groundwater contamination. Several existing acceptable treatment technologies are available for the identified inorganic groundwater contaminants. However, placement of subsurface barriers to enhance groundwater isolation or diversion to minimize fluxes to the adjacent sediments would be complicated by the presence of slag throughout the area adjacent to the bay.

Given the contaminant types, confidence in the identification of the source of contamination, and available control technologies, it is estimated that implementation of all known, available, and reasonable technologies will reduce contaminant inputs to the problem area by 95 percent.

Conclusion--

For the problem area, the estimated maximum level of source control for the three indicator chemicals is 95 percent. This estimate is based on cessation of ASARCO operations and ongoing site stabilization efforts. The RI/FS process currently underway at the facility should adequately define contaminant sources, migration pathways, and mitigation technologies. LPAH contamination tentatively attributed to past fuel spills during off-loading and storage should be eliminated as a result of closure operations. More precise source control estimates require source-specific information regarding arsenic and mercury inputs, which is beyond the scope of this document.

13.3.2 Evaluation of the Potential Success of Source Control

The relationship between source loading and sediment concentration of problem chemicals was evaluated by using a mathematical model. (Details of the model are presented in Appendix A.) The physical and chemical processes of sedimentation, mixing, and decay were quantified and the model was applied for the indicator chemicals arsenic, mercury, and LPAH. Results are reported in full in Tetra Tech (1987a). A summary of those results is presented in this section.

The depositional environment along the Ruston-Pt. Defiance Shoreline was poorly characterized because of unacceptable excess 210-Pb data, lack of available dredging records, and lack of sediment core discontinuities. Sediment accumulation rates in this area are probably highly variable based on the observed grain size distribution. Accumulation rates appear to decrease along the shoreline toward Pt. Defiance because of strong longshore currents. This decrease is reflected in the presence of increasingly coarse sediments toward Pt. Defiance (Tetra Tech 1987a; Parametrix et al. 1988). The presence of silt in the surface sediments at Stations RS-91, RS-92, and RS-94, which are located along the shoreline adjacent to the ASARCO facility, suggest that particle deposition is enhanced by shoreline structures. It can be assumed that the deposition of naturally derived particulate material is quite low in the problem area. A sedimentation rate of <200 $mg/cm^2/yr$ (<0.12 cm/yr) and a mixing depth of 10 cm were selected as representative of this problem area. Three indicator chemicals (LPAH, arsenic, and mercury) were used to evaluate the effect of source control and the degree of source control required for sediment recovery. Losses due to biodegradation and diffusion were determined to be negligible for these chemicals. Two timeframes were considered: a reasonable timeframe (defined as 10 yr) and the long term. All three indicator chemicals along the Ruston-Pt. Defiance Shoreline were assumed to be in steady-state with sediment accumulation. This assumption is environmentally protective in that the recent shutdown of the ASARCO plant would be expected to result in a decrease in contaminant loading. However, termination of activities in 1986 would not be expected to be reflected in metal profiles collected the same year. Results of the sediment recovery evaluation are summarized in Table 13-2.

Effect of Complete Source Elimination--

If sources are completely eliminated, recovery times are predicted to be 379 yr for arsenic, 377 yr for mercury, and 112 yr for LPAH. Recovery in the 10-yr timeframe will thus require sediment remedial action.

Effect of Implementing Feasible Source Control--

Implementation of all known, available, and reasonable source controls is expected to reduce source inputs by 95 percent for the indicator contaminants arsenic, mercury, and LPAH. With this level of source control as an input value, the model predicts that sediments with an enrichment ratio of 1.1 (i.e., arsenic concentrations of 63 mg/kg dry weight, mercury concentrations of 0.66 mg/kg dry weight, and LPAH concentrations of 5,800 ug/kg dry weight) will recover to the long-term cleanup goal within 10 yr (see Table 13-2). The surface area of sediments not recovering to the cleanup goal within 10 yr is shown in Figure 13-5. For comparison, sediments currently exceeding long-term cleanup goals for the indicator chemicals are also shown.

Source Control Required to Maintain Acceptable Sediment Quality--

The model predicts that 99 percent of the arsenic, 97 percent of the mercury, and 52 percent of the LPAH inputs must be eliminated to maintain acceptable contaminant concentrations in freshly deposited sediments (see

TABLE 13-2. RUSTON - PT. DEFIANCE SHORELINE
SUMMARY OF SEDIMENT RECOVERY CALCULATIONS

	Indicator Chemicals		
	Arsenic	Mercury	LPAH
Station with Highest Concentration			
Station identification	RS-17	RS-18	RS-18
Concentration[a]	12,200	52	20,190
Enrichment ratio[b]	214	88	3.9
Recovery time if sources are eliminated (yr)	379	377	112
Percent source control required to achieve 10-yr recovery	NP[c]	NP[c]	NP[c]
Percent source control required to achieve long-term recovery	99	98	74
Average of Three Highest Stations			
Concentration[a]	10,300	32.7	10,900
Enrichment ratio[b]	181	33	2.1
Percent source control required to achieve long-term recovery	99	97	52
10-Yr Recovery			
Percent source control assumed feasible	95	95	95
Highest concentration recovering in 10 yr[a]	63	0.66	5,800
Highest enrichment ratio of sediment recovering in 10 yr	1.1	1.1	1.1

a Concentrations in ug/kg dry weight for organics, mg/kg dry weight for metals.

b Enrichment ratio is the ratio of observed concentration to cleanup goal.

c NP = Not possible.

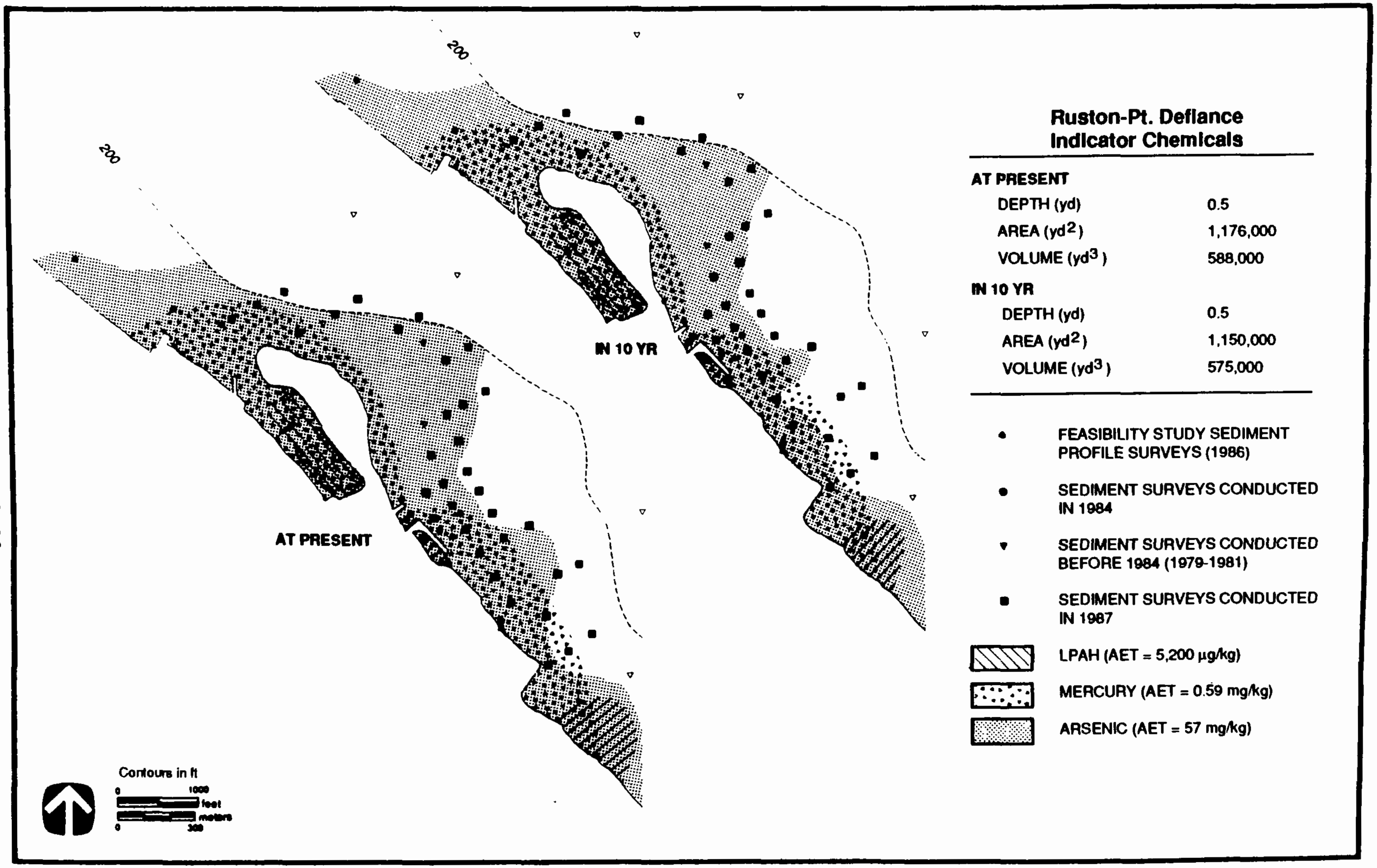


Figure 13-5. Sediments along the Ruston-Pt. Defiance Shoreline not meeting cleanup goals for indicator chemicals at present and 10 yr after implementing feasible source control.

Table 13-2). These estimates are based on the average of the three highest enrichment ratios measured for the indictor chemicals in the problem area.

These values are presented for comparative purposes; the actual percent reduction in source loading is subject to the uncertainty inherent in the assumptions of the predictive model. These ranges probably represent upper limit estimates of source control requirements since the assumptions incorporated into the model are considered to be environmentally protective.

13.3.3 Source Control Summary

The major identified source of arsenic and mercury to the Ruston-Pt. Defiance Shoreline is the ASARCO facility. The source of LPAH is not clearly defined and may be historic. If the sources of these indicator chemicals are completely eliminated, it is predicted that sediment concentrations in the surface mixed layer will not recover to long-term cleanup goals for over 100 yr for LPAH (long-term cleanup goal of 5,200 ug/kg). Recovery and would require approximately 380 yr each for arsenic and mercury (long-term cleanup goals of 57 mg/kg and 0.59 mg/kg, respectively). Sediment remedial action will therefore be required to mitigate the observed and potential adverse biological effects associated with sediment contamination within a reasonable timeframe.

Substantial levels of source control will also be required to maintain acceptable sediment concentrations of arsenic and mercury, even with sediment cleanup. The estimated percent reduction required for long-term maintenance is 99 percent for arsenic and 97 percent for mercury, based on the three highest observed concentrations for these two indicator chemicals. The estimated percent reduction required for long-term sediment maintenance for the indictor chemical LPAH is considerably lower at 52 percent. Based on September 1987 NPDES permit monitoring data collected by ASARCO, arsenic loading rates have been reduced by approximately 99 percent since the facility shut down. Average loading rates for the south outfall (RS-055) from November 1975 to September 1982 were 400 lb/day arsenic (range 7.4-2,300), while average loadings in September 1987 were 0.22 lb/day (range 0.02-0.89). A similar reduction was noted for RS-004, the ASARCO middle outfall, with loadings over the same time period dropping from 78 lb/day to 0.79 lb/day.

With 95 percent source control assumed to be feasible (i.e., known, available, and reasonable) for the three indicator chemicals in the Ruston-Pt. Defiance problem area, it appears that acceptable sediment quality can be readily maintained for LPAH. The level of source control required to maintain adequate sediment quality is very high for arsenic and mercury because enrichment ratios are great for those compounds, especially in the vicinity of the ASARCO outfalls. The assumed feasible level of source control (95 percent), the highest for this FS, reflects remaining uncertainties in identifying that all contaminant sources and uncertainties regarding implementation and effectiveness of mitigative actions. Thorough site characterization of the ASARCO facility to identify all contaminant sources and migration pathways along with selection and proper implementation of effective site remedial measures may, in fact, provide the necessary level of source control to maintain adequate sediment quality following sediment remediation.

13.4 AREAS AND VOLUMES OF SEDIMENT REQUIRING REMEDIATION

The total estimated volume of sediment with arsenic, mercury, and LPAH concentrations exceeding long-term cleanup goals is approximately 588,000 yd^3 (see Figure 13-5). This volume was estimated by multiplying the areal extent of sediment exceeding the cleanup goal (1,176,000 yd^2) by the estimated 0.5-yd depth of contamination (see contaminant sediment profiles in Figures 13-2, 13-3, and 13-4). Estimates of the areal extent of sediments exceeding long-term cleanup goals are subject to considerable uncertainty because the seaward extent of sampling stations during the RI/FS sampling was extremely limited. Outer limits of contamination were linearly interpolated from enrichment ratios for existing sampling stations. However, the contaminated areas presented agree well with the preliminary findings of the ASARCO RI for marine sediment surface sampling. In the interim RI report, Parametrix et al. (1988) reviewed data from over 100 surface sediment sampling stations. Their estimated surface area of arsenic concentrations exceeding the long-term cleanup goal was slightly greater and included an area northwest of the ASARCO facility (seaward from the peninsula formed northeast of the yacht basin) where the outer (seaward) limit of contamination could not be defined. The bottom off the Ruston-Pt. Defiance Shoreline in this area is very steep and even samples at depths greater than 200 ft were contaminated above the target cleanup goal area. These stations are not, however, included in the problem area because sediments deeper than 200 ft cannot be dredged. This area was also characterized as containing a relatively high percentage of slag particles.

For volume calculations, depths were slightly overestimated. This conservative approach was taken to reflect the fact that depth to the contaminated horizon cannot be accurately dredged, to account for dredge technique tolerances, and to account for uncertainties in sediment quality at locations between sediment profile sampling stations.

The total estimated volume of sediments with arsenic, mercury, or LPAH concentrations that are still expected to exceed long-term cleanup goals 10 yr following implementation of feasible levels of source control is 575,000 yd^3. This volume was estimated by multiplying the areal extent of sediment contamination with enrichment ratios greater than 1.1 (see Table 13-2), an area of 1,150,000 yd^2, by the estimated 0.5-yd depth of contamination. This volume includes sediments containing a high percentage of slag particles. In the event that the biological evaluation conducted as part of the facility's RI effort demonstrates that this material is biologically inert, further sediment volume refinement may be warranted. This volume is also an approximation, accounting for uncertainties in sediment profile resolution and dredging tolerances. For the Ruston-Pt. Defiance Shoreline problem area, this is the volume of sediment requiring remediation.

13.5 DETAILED EVALUATION OF SEDIMENT REMEDIAL ALTERNATIVES

13.5.1 Assembly of Alternatives for Analysis

The 10 sediment remedial alternatives identified in Chapter 3 broadly encompass the general approaches and technology types available for sediment remediation. In the following discussion, each alternative is evaluated to determine its suitability for the remediation of contaminated sediments in the Ruston-Pt. Defiance Shoreline problem area. The objective of this evaluation is to identify the alternative considered preferable to all others based on CERCLA/SARA criteria of effectiveness, implementability, and cost.

The first step in this process is to assess the applicability of each alternative in the problem area. Site-specific characteristics that must be considered in such an assessment include the nature and extent of contamination; the environmental setting; and site physical properties, including shoreline usage, bathymetry, and water flow conditions. Alternatives that are determined to be appropriate for the waterway can then be evaluated based on the criteria discussed in Chapter 4.

The indicator chemicals arsenic, mercury, and LPAH were selected to represent the primary source of contamination to the problem area: the ASARCO smelter. Areal distributions for all three indicators are presented in Figure 13-5 to indicate the degree to which contaminant groups overlap based on long-term cleanup goals and estimated 10-yr sediment recovery.

Sediment remedial alternatives selected for the Ruston-Pt. Defiance Shoreline have been selected based on the prevalence of inorganic contamination. Alternatives developed specifically to treat organic contaminants (i.e., solvent extraction, incineration, and land treatment) have been eliminated from consideration based on limited potential effectiveness. The solidification treatment alternative is a proven technology for the encapsulation and immobilization of inorganic contaminants and is retained for detailed evaluation.

Of the nontreatment alternatives, in situ capping has been eliminated from further consideration based on the steep bathymetric gradients present in the problem area. Gradients range from approximately 5 percent in the nearshore areas off the ASARCO facility to up to 30 percent off the slag fill area seaward of the yacht basin. The effectiveness of in situ capping could also be compromised by the uncertainty regarding the depositional environment of the Ruston-Pt. Defiance Shoreline area (see Section 13.3.2), and the depth of contamination observed (documented to depths of over 200 ft).

The nature of the contamination in the problem area also requires modification of the disposal options for the nontreatment dredging alternatives. Data obtained during both the Commencement Bay N/T RI/FS effort and the ASARCO RI indicate that extremely high levels of inorganic contamination are present off the ASARCO facility in the vicinity of the three main outfalls and off the slag fill area adjacent to the yacht basin (Tetra Tech

1985a; Parametrix et al. 1988). Commencement Bay N/T RI data revealed arsenic concentrations of up to 12,000 mg/kg (enrichment ratio of approximately 210) with several values over 8,500 mg/kg (enrichment ratio of approximately 150). The ASARCO interim RI report revealed a significant surface area near the facility and seaward of the yacht basin slag fill area for an undefined distance with arsenic values exceeding 3,000 mg/kg (enrichment ratios exceeding 50).

Based on dredged material leachate studies conducted as part of the Puget Sound Region Homeporting Project, U.S. Army Corps of Engineers (1986c) concluded that mobility of metals and organic contaminants is low under anaerobic conditions. Leachability of arsenic, however, was greater under anaerobic conditions than under aerobic conditions. Approximately 7 percent of the total sediment arsenic leached in sequential aerobic leaching tests. Although the presence of weathered slag in the sediments off the Ruston-Pt. Defiance Shoreline may reduce the percent arsenic available for leaching, based on past investigations (Crecelius 1986) an added measure of protectiveness is warranted at the highest observed concentrations.

Because of the high arsenic concentrations, the increased potential for water column impacts during dredged material placement, and the increased potential for migration of arsenic from a subaquatic (anaerobic) disposal site, the confined aquatic disposal option has been modified to include upland disposal for sediments containing greater than 3,000 mg/kg arsenic. Based on data in the ASARCO interim RI report (Parametrix et al. 1988), 20 percent of the total volume identified as requiring remediation (575,000 yd^3) is assumed to require upland disposal. It has further been assumed that an upland disposal facility for this material could be sited and developed within the ASARCO property to facilitate implementation of this alternative. The disposal facility may be developed in conjunction with other remedial actions for the ASARCO site.

The alternatives involving dredging with nearshore and upland disposal are also retained for further evaluation. Although some modifications to the dredging techniques may be required due to bathymetric and depth considerations (e.g., pneuma pump system for hydraulic dredging), these options are technically feasible for the problem area.

It is assumed that the requirements to maintain navigational access to the Puyallup River and Sitcum Waterway could preclude the use of a hydraulic pipeline for nearshore disposal at the Blair Waterway disposal site. Therefore, clamshell dredging has been chosen for evaluation in conjunction with the nearshore disposal alternative.

Evaluation of the no-action alternative is required by the NCP to provide a baseline against which other remedial alternatives can be compared. The institutional controls alternative, intended to protect the public from direct or indirect exposure to contaminated sediments without implementing sediment mitigation, provides a second baseline for comparison.

The following six sediment remedial alternatives are evaluated for the cleanup of the Ruston-Pt. Defiance Shoreline problem area:

- No action
- Institutional controls
- Clamshell dredging/confined aquatic and upland disposal
- Clamshell dredging/nearshore disposal
- Hydraulic dredging/upland disposal
- Clamshell dredging/solidification/upland disposal.

13.5.2 Evaluation of Alternatives

The three primary evaluation criteria are effectiveness, implementability, and cost. A narrative matrix summarizing the assessment of each alternative based on effectiveness and implementability is presented in Table 13-3. The alternatives for the confined aquatic and upland disposal options are evaluated separately in the narrative matrix. A comparative evaluation of alternatives based on ratings of high, moderate, and low in the various subcategories of evaluation criteria is presented in Table 13-4. For effectiveness, the subcategories are short-term protectiveness; timeliness; long-term protectiveness; and reduction in toxicity, mobility, or volume. For implementability, the subcategories are technical feasibility, institutional feasibility, availability, capital costs, and O&M costs. Remedial costs are shown for sediments currently exceeding long-term cleanup goal concentrations and also for sediments that would still exceed the cleanup goal concentrations 10 yr after implementing feasible source controls (ie., 10-yr recovery costs).

Short-Term Protectiveness--

The comparative evaluation for short-term protectiveness resulted in low ratings for no-action and institutional controls because the adverse biological and potential public health impacts continue with the contaminated sediments remaining in place. Source control measures initiated to date and additional measures initiated as part of the institutional controls would tend to reduce sediment contamination with time, but adverse impacts would persist for an extensive period during sediment recovery.

The alternative requiring clamshell dredging/nearshore disposal is rated moderate under this criterion because nearshore habitat would be lost in siting the disposal facility and because direct worker exposure would be expected during dredging operations. The clamshell dredging/confined aquatic/upland disposal alternative is rated moderate under this criterion. Although placement of the highly contaminated sediments in an upland disposal facility should help minimize water column impacts associated with subaquatic disposal, water column impacts may occur as a result of sediment removal. The confined aquatic/upland disposal alternative also involves the potential

TABLE 13-3. REMEDIAL ALTERNATIVES EVALUATION MATRIX FOR THE RUSTON - PT. DEFIANCE SHORELINE PROBLEM AREA

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC AND UPLAND DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	COMMUNITY PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Community exposure is negligible. CDM is retained offshore during dredge and disposal operations. Public access to area undergoing remediation is restricted.	Clamshell dredging confines CDM to a barge offshore during transport. Public access to dredge and disposal sites is restricted. Public exposure potential is low.	CDM is confined to a pipeline during transport. Public access to dredge and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.	Public access to dredge treatment and disposal sites is restricted. Exposure from CDM spills or mishandling is possible, but overall potential is low.
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	WORKER PROTECTION DURING IMPLEMENTATION	NA	There are no elements of institutional control measures that have the potential to cause harm during implementation.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Removal with dredge and disposal with downpipe and diffuser minimizes handling requirements. CDM handling during transport to upland site increases worker risk. Workers wear protective gear.	Clamshell dredging of CDM increases exposure potential moderately over hydraulic dredging. Workers wear protective gear.	Hydraulic dredging confines CDM to a pipeline during transport. Dredge water contamination may increase exposure potential. Workers wear protective gear.	Additional CDM handling associated with treatment increases worker risk over dredge/disposal options. Workers wear protective gear. Increased potential for worker exposure due to direct handling of CDM.
EFFECTIVENESS	SHORT-TERM PROTECTIVENESS	ENVIRONMENTAL PROTECTION DURING IMPLEMENTATION	Original contamination remains. Source inputs continue. Adverse biological impacts continue.	Source control is implemented and would reduce sediment contamination with time, but adverse impacts would persist in the interim.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Benthic habitat is impacted at the disposal site.	Existing contaminated habitat is destroyed but recovers rapidly. Nearshore intertidal habitat is lost. Contaminated sediment is resuspended.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations. Dredge water can be managed to prevent release of soluble contaminants.	Existing contaminated habitat is destroyed but recovers rapidly. Contaminated sediment is resuspended during dredging operations.
EFFECTIVENESS	TIMELINESS	TIMELINESS	Sediments are unlikely to recover in the absence of source control. This alternative is ranked sixth overall for timeliness.	Access restrictions and monitoring efforts can be implemented quickly. Partial sediment recovery is achieved naturally, but significant contaminant levels persist. This alternative is ranked fifth overall for timeliness.	Disposal siting and facility construction may delay project implementation. This alternative is ranked third overall for timeliness instead of second due to upland disposal requirements.	Dredge and disposal operations could be accomplished quickly. Pre-implementation testing and modeling may be necessary, but minimal time is required. Equipment is available. Disposal siting issues should not delay implementation. This alternative is ranked first for timeliness.	Equipment and methods used require no development period. Pre-implementation testing is not expected to be extensive. This alternative is ranked second overall for timeliness.	Substantial CDM testing and equipment development are required before a solidification scheme can be implemented. This alternative is ranked fourth overall for timeliness.
EFFECTIVENESS	LONG-TERM PROTECTIVENESS	LONG-TERM RELIABILITY OF CONTAINMENT FACILITY	CDM containment is not an aspect of this alternative.	CDM containment is not an aspect of this alternative.	The long-term reliability of cap to prevent contaminant reexposure in a quiescent, sub-aquatic environment is considered good. Upland confinement facilities were considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain and liner cannot be repaired.	Nearshore confinement facilities are structurally reliable. Dike and cap repairs can be readily accomplished.	Upland confinement facilities are considered structurally reliable. Dike and cap repairs can be readily accomplished. Underdrain or liner cannot be repaired.	Long-term reliability of solidification treatment processes for CDM are believed to be adequate. However, data from which to confirm long-term reliability are limited. Upland disposal facilities are structurally reliable.
EFFECTIVENESS	LONG-TERM PROTECTIVENESS	PROTECTION OF PUBLIC HEALTH	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains.	The potential for exposure to harmful sediment contaminants via ingestion of contaminated food species remains, albeit at a reduced level as a result of consumer warnings and source controls.	The confinement system precludes public exposure to contaminants by isolating contaminated sediments from the public and the biota adjacent to the CAD site. Protection is adequate.	The confinement system precludes public exposure to contaminants by isolating CDM. Varying physicochemical conditions in the fill may increase potential for contaminant migration over CAD.	The confinement system precludes public exposure to contaminants by isolating CDM. Although the potential for groundwater contamination exists, it is minimal. Upland disposal facilities are more secure than nearshore facilities.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
EFFECTIVENESS	LONG-TERM PROTECTIVENESS	PROTECTION OF ENVIRONMENT	Original contamination remains. Source inputs continue. Exposure potential remains at existing levels or increases.	Original contamination remains. Source inputs are controlled. Adverse biological effects continue but decline slowly as a result of sediment recovery and source control.	The confinement system precludes environmental exposure to contaminated sediment. Potential for contaminant migration is reduced by maintaining CDM at in situ conditions at CAD site. Potential for groundwater contamination exists at upland site.	The confinement system precludes environmental exposure to contaminated sediment. The potential for contaminant migration into marine environment may increase over CAD. Adjacent fish mitigation site is sensitive area.	Upland disposal is secure, with negligible potential for environmental impact if properly designed. Potential for groundwater contamination exists.	Solidification is a more protective solution than dredge/disposal alternatives. The potential for public exposure is significantly reduced as a result of contaminant immobilization.
EFFECTIVENESS	CONTAMINANT MIGRATION	REDUCTION IN TOXICITY, MOBILITY, AND VOLUME	Sediment toxicity and contaminant mobility are expected to remain at current levels or increase as a result of continued source inputs. Contaminated sediment volume increases as a result of continued source inputs.	Sediment toxicity is expected to decline slowly with time as a result of source input reductions and sediment recovery. Contaminant mobility is unaffected.	The toxicity of contaminated sediments in the confinement zone remains at preremediation levels.	The toxicity of CDM in the confinement zone remains at preremediation levels. Altered conditions resulting from dredge/disposal operations may increase mobility of metals. Volume of contaminated sediments is not reduced.	The toxicity of CDM in the confinement zone remains at preremediation levels. The potential for migration of metals is greater for upland disposal than for CAD or nearshore disposal. Contaminated sediment volumes may increase due to resuspension of sediment.	Contaminants are physically contained, thereby reducing toxicity and the potential for contaminant migration compared with non-treatment alternatives. Metals and organics are encapsulated.

TABLE 13-3. (CONTINUED)

			NO ACTION	INSTITUTIONAL CONTROLS	CLAMSHELL DREDGE/ CONFINED AQUATIC AND UPLAND DISPOSAL	CLAMSHELL DREDGE/ NEARSHORE DISPOSAL	HYDRAULIC DREDGE/ UPLAND DISPOSAL	CLAMSHELL DREDGE/ SOLIDIFICATION/ UPLAND DISPOSAL
IMPLEMENTABILITY	TECHNICAL FEASIBILITY	FEASIBILITY AND RELIABILITY OF REMEDIAL ACTION PROCESS OPTIONS	Implementation of this alternative is feasible and reliable.	Source control and institutional control measures are feasible and reliable. Source control reliability assumes all sources can be identified.	Clamshell dredging equipment is reliable. Placement of dredge and capping materials difficult, but feasible. Inherent difficulty in placing dredge and capping materials at depths of 100 ft or greater. Secure upland confinement technology is well developed.	Clamshell dredging equipment is reliable. Nearshore confinement of CDM has been successfully accomplished.	Clamshell dredging equipment is reliable. Secure upland confinement technology is well developed.	Solidification technologies for treating CDM on a large scale are conceptual. Implementation is considered feasible, but reliability is unknown. Bench-scale testing prior to implementation is necessary.
		IMPLEMENTATION OF MONITORING PROGRAMS	No monitoring over and above programs established under other authorities is implemented.	Sediment monitoring schemes can be readily implemented. Adequate coverage of problem area would require an extensive program.	Confinement reduces monitoring requirements in comparison to institutional controls. Sediment monitoring schemes can be readily implemented.	Monitoring can be readily implemented to detect contaminant migration through dikes. Installation of monitoring systems is routine aspect of facility siting.	Monitoring can be readily implemented to detect contaminant migration through dikes and liners. Improved confinement enhances monitoring over CAD. Installation of monitoring systems is routine aspect of facility siting.	Monitoring requirements for solidified material are low in comparison with dredge and disposal alternatives. Monitoring can be readily implemented.
		IMPLEMENTATION OF OPERATING AND MAINTENANCE PROGRAMS	There are no O & M requirements associated with the no action alternative.	O & M requirements are minimal. Some O & M is associated with monitoring, maintenance of warning signs, and issuance of ongoing health advisories.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment at the upland facility. Some O & M is associated with monitoring for contaminant migration and cap integrity at the CAD site.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment.	O & M requirements consist of inspections, groundskeeping, and maintenance of monitoring equipment. System maintenance is intensive during implementation.
	INSTITUTIONAL FEASIBILITY	APPROVAL OF RELEVANT AGENCIES	This alternative is expected to be unacceptable to resource agencies as a result of agency commitments to mitigate observed biological effects.	Requirements for agency approvals are minimal and are expected to be readily obtainable.	Approvals from federal, state, and local agencies are feasible. Approvals for facility siting are uncertain but assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. Availability of approvals for facility siting are assumed feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Approvals from federal, state, and local agencies are feasible. However, disposal of untreated CDM is considered less desirable than if CDM is treated.	Disposal requirements are less stringent for treated dredge material, enhancing approval feasibility However, bench scale testing is required to demonstrate effectiveness of solidification.
		COMPLIANCE WITH ARARS AND GUIDELINES	AET levels in sediments are exceeded. No permit requirements exist. This alternative fails to meet the intent of CERCLA/SARA and NCP because of ongoing impacts.	AET levels in sediments are exceeded. This alternative fails to meet intent of CERCLA/SARA and NCP because of ongoing impacts. State requirements for source control are achieved. Coordination with TPCHD for health advisories for seafood consumption is required.	WISHA/OSHA worker protection is required. Substantive aspects of CWA and shoreline management programs must be addressed.	WISHA/OSHA worker protection required. Substantive aspects of CWA and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Substantive aspects of CWA, hydraulics, and shoreline management programs must be addressed. Alternative complies with U.S. EPA's onsite disposal policy.	WISHA/OSHA worker protection required. Alternative complies with U.S. EPA's policies for onsite disposal and permanent reduction in contaminant mobility. May require that shoreline management aspects be addressed.
	AVAILABILITY	AVAILABILITY OF SITES, EQUIPMENT, AND METHODS	All materials and procedures are available.	All materials and procedures are available to implement institutional controls.	Equipment and methods to implement alternative are readily available. Availability of open water CAD sites is uncertain. Potential upland disposal sites have been identified but none are currently available.	Equipment and methods to implement alternative are readily available. A potential nearshore disposal site has been identified and is currently available.	Equipment and methods to implement alternative are readily available. Potential upland disposal sites have been identified but none are currently available.	Disposal site availability is uncertain but feasible. Solidification equipment and methods for large-scale CDM disposal are currently unavailable.

TABLE 13-4. EVALUATION SUMMARY FOR RUSTON-PT. DEFIANCE SHORELINE

	No Action	Institutional Controls	Clamshell/ CAD/ Upland Disposal	Clamshell/ Nearshore Disposal	Hydraulic/ Upland Disposal	Clamshell/ Solidify/ Upland Disposal
Short-Term Protectiveness	Low	Low	Moderate	Moderate	High	Moderate
Timeliness	Low	Low	Moderate	Moderate	Moderate	Moderate
Long-Term Protectiveness	Low	Low	High	Moderate	Moderate	High
Reduction in Toxicity, Mobility, or Volume	Low	Low	Low	Low	Low	High
Technical Feasibility	High	High	Moderate	Moderate	Moderate	Moderate
Institutional Feasibility	Low	Low	Moderate	Moderate	Moderate	Moderate
Availability	High	High	Moderate	Moderate	High	High
Long-Term Cleanup Goal Cost[a]						
Capital	--	6	9,523	14,585	25,921	39,164
O&M	--	2,869	718	790	1,199	1,143
Total	--	2,875	10,241	15,375	27,120	40,307
Long-Term Cleanup Goal with 10-yr Recovery Cost[a]						
Capital	--	6	9,316	14,266	25,351	38,301
O&M	--	2,869	707	779	1,179	1,124
Total	--	2,875	10,023	15,045	26,530	39,425

[a] All costs are in $1,000.

for worker exposure. The clamshell dredging/solidification/upland disposal alternative is also rated moderate because of the increased potential for worker exposure, as compared with nontreatment alternatives, due to solidification-related contaminated dredged material handling, longer implementation periods, and increased air emissions. In spite of the increased exposure potential, the moderate rating is appropriate because adequate worker health and safety controls are available.

The hydraulic dredging/upland disposal alternative is rated high for short-term protectiveness because worker and public exposure potentials would be minimized by containment of all dredged materials within a pipeline system. In addition, the habitats that would be compromised for disposal are of relatively lower sensitivity.

Timeliness--

Because an excessive amount of time is necessary for sediments to recover naturally, both the no-action and institutional controls alternatives are rated low for this criterion. Natural recovery times for all the indicator compounds would require in excess of 100 yr, even with complete elimination of contaminant sources (see Section 13.3).

Moderate ratings have been applied to all the remaining alternatives. For dredging options that involve siting of upland or confined aquatic disposal facilities, approvals and construction are estimated to require a minimum of 1-2 yr. Because of the large volume of sediment requiring remediation, the clamshell/dredging/nearshore disposal option is also rated as moderate under this criterion. Placement of this material in the Blair Waterway site would consume well over half its available capacity. The equipment and methods used to carry out these alternatives require no development period, and pre-implementation testing is not expected to be extensive. These factors indicate that the dredge and disposal alternatives can be implemented in a shorter period of time than if treatment is involved. Solidification is likely to require extra time for bench-scale testing and equipment development or modification, although facility siting and technology development could be conducted concurrently. Treatment of contaminated sediments in the Ruston-Pt. Defiance Shoreline problem area would require a minimum of 480 working days even at the maximum production rate of 1,000 yd^3/day.

Long-Term Protectiveness--

The comparative evaluation for long-term protectiveness resulted in low ratings for the no-action and institutional controls alternatives because the timeframe for natural recovery is excessive. For the institutional controls alternative, the potential for exposure of resident biota to contaminated sediments would remain, albeit at declining levels following implementation of source reductions. The observed adverse biological impacts would continue.

Moderate ratings were assigned for the nontreatment dredging and disposal alternatives, including nearshore and upland disposal only, because of potential physicochemical changes due to placing contaminated dredged material in these disposal facilities. These changes, primarily from new redox conditions, would tend to alter the migration potential of the contaminants. Contaminated dredged material testing should provide the necessary data on the magnitude of these impacts. Based on dredged material testing, placement in the nearshore facility could be designed to minimize migration potential by utilizing the appropriate physicochemical environment (e.g., placement below the low tide level). Although the structural reliability of the nearshore facilities is regarded as good, the nearshore environment is dynamic in nature as a result of wave action and tidal influences. Even though the upland disposal facility is generally regarded as a more secure option because of improved engineering controls during construction, there is potential for impacts on groundwater.

The solidification and confined aquatic/upland disposal alternatives are rated high for long-term protection. Placing material in a confined, subaquatic environment generally provides a high degree of isolation, with little potential for exposure to an environment sensitive to the contaminated dredged material. Although there is uncertainty about potential contaminant partitioning and groundwater protection for the upland disposal site, these concerns can be addressed through implementation of adequate engineering controls during construction and an adequate monitoring program. In addition, shallow groundwater quality beneath the ASARCO site (assumed to be the upland disposal site) has already been compromised by past disposal and operational practices. The high degree of immobilization provided by solidification of inorganic contaminants substantially increases the long-term protectiveness of this alternative over dredge and disposal alternatives. However, it should be noted that a maximum grain size of 1 mm has been suggested for effective encapsulation of contaminants (Long, D., 3 May 1988, personal communication). The deeper areas off the slag fill area adjacent to the yacht basin have been characterized as containing relatively coarse sand and slag particles (Parametrix et al. 1988).

Reduction in Toxicity, Mobility, or Volume--

Low ratings have been assigned to all alternatives under this criterion, except the clamshell dredging/solidification/upland disposal option, which is rated high. None of the other five alternatives involves treatment of contaminated sediments. Although the confined aquatic/upland, nearshore, and upland disposal alternatives isolate contaminated dredged material from the surrounding environment, the chemistry of the material remains unaltered. For nearshore and upland disposal alternatives, the mobilization potential for untreated contaminated dredged material may actually increase with changes in physicochemical conditions. Without treatment, the toxicity of contaminated sediments remains at preremediation levels. Contaminated sediment volumes are not reduced, and may actually increase with hydraulic dredging options because of suspension of the material in an aqueous slurry.

Solidification of contaminated dredged material prior to disposal effectively encapsulates inorganic contaminants, thereby reducing mobilization potential permanently and significantly. Through isolation in the solidified matrix, this process also reduces the effective toxicity of contaminants as compared with nontreatment alternatives. Because the available data suggest that the organic contaminants present have a high particle affinity, the process may also be relatively effective in encapsulating these materials. Elutriate tests during bench-scale testing of solidified contaminated dredged material would be expected to provide data with which to substantiate or invalidate these conclusions.

Technical Feasibility--

All alternatives except no action and institutional controls are rated moderate under this criterion. Although feasible, implementation of dredging alternatives to depths of well over 100 ft in an extremely steep bathymetric setting is expected to be difficult. The variations in sediment nature and grain size documented in the interim RI report (Parametrix et al. 1988) may also compromise the effectiveness of the dredging efforts. Solidification is assigned a moderate rating for technical feasibility because of the need to conduct bench-scale testing prior to implementation. Solidification technologies for the treatment of contaminated dredged material on a large scale are conceptual at this point, although the method appears to be feasible (Cullinane, J., 18 November 1987, personal communication).

High ratings are warranted for the no-action and institutional controls alternatives because the equipment, technologies, and expertise required for effective implementation have been developed and are readily accessible.

Although monitoring requirements for the alternatives are considered in the evaluation process, these requirements are not weighted heavily in the ratings. Monitoring techniques are well established and technologically feasible, and similar methods are applied for all alternatives. The intensity of the monitoring effort, which varies with uncertainty about long-term reliability, does not influence the feasibility of implementation.

Institutional Feasibility--

The no-action and institutional controls alternatives have been assigned low ratings for institutional feasibility because compliance with CERCLA/SARA mandates would not be achieved. Requirements for long-term protection of public health and the environment would not be met by either alternative.

Moderate ratings are assigned to the four alternatives requiring dredging, excavation, or treatment because of potential difficulty in obtaining agency approvals for disposal sites, or implementation of treatment technologies. Prior to implementation of the solidification option, extensive performance testing will probably be required to demonstrate effectiveness. Agency approvals for this option are expected to require significant coordination for disposal siting and review for performance evaluation.

Although several potential nearshore and upland disposal sites have been identified in the project area, significant uncertainty remains with the actual construction and development of the sites. Although the Blair Waterway nearshore facility is expected to be available, the large volume of sediment requiring remediation in this problem area would be expected to reduce the likelihood of using that site. Although excavation and disposal of untreated, contaminated sediment is discouraged under Section 121 of SARA, properly implemented confinement should meet requirements for public health and environmental protectiveness. Agency approvals are assumed to be contingent upon a bench-scale demonstration of the effectiveness of each alternative in meeting established performance goals (e.g., treatability of dredge water and immobilization of contaminants through solidification).

Availability--

Candidate sediment remedial alternatives that can be implemented using existing equipment, expertise, and disposal or treatment facilities are rated high for availability. Because the no-action and institutional controls alternatives can be readily implemented immediately, they received a high rating.

Remedial alternatives involving dredging with confined aquatic/upland and nearshore disposal have been rated moderate because of the uncertainty associated with disposal site availability. Candidate alternatives were developed by assuming that a confined aquatic site would be available. The previously identified potential confined aquatic disposal sites (Phillips et al. 1985) have sufficient capacity for confinement of the approximately 380,000 yd^3 of sediment with arsenic contamination levels below 3,000 mg/kg (e.g., the Brown's Point site capacity has been estimated at up to 2,000,000 yd^3). However, no sites are currently approved for use and no sites are currently under construction. As indicated previously, the large volume of sediment requiring remediation significantly diminishes the likelihood of using the Blair Waterway or other identified potential nearshore disposal sites.

Alternatives involving upland disposal only have been rated high for this criterion, based on the assumption that a site could be developed on the ASARCO property. The feasibility of this option would be enhanced if disposal site development were coordinated with other site remedial actions.

Cost--

Capital costs increase with increasing complexity (i.e., from no action to the treatment option). This increase reflects the need to site and construct disposal facilities, develop treatment technologies, and implement alternatives requiring extensive contaminated dredged material or dredge water handling. Costs for conducting the hydraulic dredging/upland disposal option are significantly elevated over the clamshell dredging/nearshore disposal option primarily as a result of the additional costs required for underdrain and bottom liner installation, dredge water clarification, and use of pipeline boosters to facilitate contaminated dredged material transport to the upland site. The cost of conducting the solidification alternative increases as a result of material costs for the process, and associated labor costs for material handling and transport. Dredge water management costs are also incurred for this option.

A major component of O&M costs is the monitoring requirements associated with each alternative. The highest monitoring costs are associated with alternatives involving the greatest degree of uncertainty for long-term protectiveness (e.g., institutional controls), or where extensive monitoring programs are required to ensure long-term performance (e.g., confined aquatic disposal). Costs for monitoring of the alternative including confined aquatic disposal is significantly higher because of the need to collect sediment core samples at multiple stations, with each core being sectioned to provide an appropriate degree of depth resolution to monitor migration. Nearshore and upland disposal options, on the other hand, use monitoring well networks requiring only the collection of a single ground-water sample at each well to assess contaminant migration.

It is also assumed that the monitoring program will include analyses for all contaminants of concern (i.e., those exceeding long-term cleanup goals) in the problem area. This approach is conservative and could be modified to reflect use of key chemicals to track performance. Monitoring costs associated with the solidification alternative are significantly lower based on the degree of reduction in contaminant migration potential achieved by the process.

13.6 PREFERRED SEDIMENT REMEDIAL ALTERNATIVE

Based on the detailed evaluation of the six candidate sediment remedial alternatives proposed for the Ruston-Pt. Defiance Shoreline, clamshell dredging with upland disposal of the most highly contaminated material and confined aquatic disposal of the remaining material has been recommended as the preferred alternative. Should dredging be designated for areas with water depths exceeding 100 ft, then use of a bucketwheel dredge is recommended. Because sediment remediation will be implemented according to a performance-based ROD, the specific technologies identified in this alternative (i.e., clamshell dredging, upland disposal, confined aquatic disposal) may not be the technologies eventually used to conduct the cleanup. New and possibly more effective technologies available at the time remedial activities are initiated may replace the alternative that is currently preferred. However, any new technologies must meet or exceed the performance criteria (e.g., attainment of specific cleanup criteria) specified in the ROD. This alternative was selected for the following reasons:

- The alternative protects human health by effectively isolating contaminated sediments either in an engineered upland facility or a quiescent subaquatic environment
- Both disposal methods are technically feasible and have been demonstrated to be effective in isolating contaminated material

- The alternative is consistent with state dangerous waste regulations that may preclude confined aquatic disposal of sediments whose arsenic concentrations exceed 3,000 mg/kg (dry weight)

- The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 401 and 404 of the Clean Water Act, and other applicable environmental regulations

- The volume of contaminated sediment to be disposed of at a confined aquatic site (approximately 80 percent of the total volume, or 460,000 yd^3) is compatible with the tentatively identified disposal facilities; the remaining material (approximately 20 percent of the total volume, or 115,000 yd^3) could possibly be disposed of at an upland facility at the ASARCO site

- The costs of developing an upland facility that is secure and protective of groundwater are justified by the high concentrations of arsenic in the most highly contaminated sediments

- Estimated costs for this alternative are approximately $5 million less than those for the nearshore alternative and $16 million less than use of upland disposal as the sole disposal method.

Although this alternative is rated as moderate for most evaluation criteria, it provides a cost-effective means of addressing sediment remediation for a large volume of dredged material in a complex environmental setting. Approximately 575,000 yd^3 of sediment will need to be removed and disposed of for a cost of approximately $9,316,000. The present worth of 30 yr of environmental monitoring and O&M at the disposal sites is estimated to be $707,000. Therefore, the total estimated present worth of this alternative is $10,023,000.

The elevations above long-term cleanup goals in this problem area were among the highest observed in the study area over the largest sediment surface area. These extremely high contaminant levels warrant the added degree of protectiveness afforded by the engineering controls of a RCRA-equivalent upland disposal facility. If elutriate testing of contaminated dredged material indicates that contaminant partitioning is relatively low, it may be possible to upgrade ratings for both short- and long-term protectiveness.

Although some sediment resuspension is inherent in dredging operations, silt curtains, dredge system modifications, and other engineering controls would be expected to minimize adverse impacts associated with redistribution of contaminated dredged material. Dredging within this problem area is consistent with the Tacoma Shoreline Management Plan. Close coordination with appropriate federal, state, and local regulatory personnel will be required prior to undertaking remedial actions.

The nearshore disposal alternative was not selected because the volume of material is more compatible with confined aquatic disposal. The Blair Waterway Slip 1 disposal area is not large enough to accommodate all contaminated sediments in the Commencement Bay N/T area, nor is it appropriate for the contaminants in all sediments. Although confined aquatic disposal cannot be implemented as quickly as nearshore disposal at an available site, it offers a similar degree of protection at a lower cost.

Solidification/upland disposal was not selected as the preferred alternative since the timeframe for remedial action would be lengthened (approximately doubled) and implementation costs would be approximately 4 times as great as those of the preferred alternative. Implementation would require bench-scale and possibly pilot-scale testing. In addition, treatment itself would take a considerable period of time (approximately 4 yr), given available equipment and the large volume of contaminated sediment. Decreased mobility of contaminants due to the stabilization is not expected to significantly increase long-term protectiveness compared with selective disposal in the confined aquatic and upland sites.

It is expected that confined aquatic disposal of less-contaminated sediment coupled with upland disposal of more contaminated sediment will provide a nearly equivalent level of protection compared with the upland disposal alternative. In addition, the cost of the latter alternative is approximately $16 million greater than that of the preferred alternative.

No-action and institutional controls alternatives are ranked high for technical feasibility, availability, and capital expenditures. However, the failure to mitigate environmental and potential public health impacts far outweighs these advantages.

13.7 CONCLUSIONS

The Ruston-Pt. Defiance Shoreline was identified as a problem area because of the elevated concentrations of inorganic and organic contaminants in sediments. Arsenic, mercury, and LPAH were selected as indicator chemicals to assess source control requirements, evaluate sediment recovery, and estimate the area and volume to be remediated. In this problem area, sediments with concentrations currently exceeding long-term cleanup goals cover an area of approximately 1,176,000 yd^2, and a volume of 588,000 yd^3. Of the total sediment area currently exceeding cleanup goals, 26,000 yd^2 is predicted to recover within 10 yr following implementation of all known, available, and reasonable source control measures, thereby reducing the contaminated sediment volume by approximately 13,000 yd^3. The total volume of sediment requiring remediation is, therefore, reduced to 575,000 yd^3.

The primary identified source of problem chemicals to the Ruston-Pt. Defiance Shoreline is the ASARCO smelter facility. Source control measures required to correct the identified problems at the facility and ensure the long-term success of sediment cleanup in the problem area include the following actions:

- Reduce the amount of inorganic contaminants that are present in the groundwater and that discharge to the waterway

- Continue monitoring at the ASARCO facility outfalls and implement additional control technologies, if necessary

- Implement surface water runoff and erosion control technologies to minimize discharges originating from highly contaminated surface soils identified in the RI

- Conduct additional source investigations to confirm that all significant sources of problem chemicals have been identified and controlled

- Implement regular sediment monitoring to confirm sediment recovery predictions and successful implementation of source control measures.

It should be possible to control sources sufficiently to maintain acceptable long-term sediment quality. This determination was made by comparing the level of source control required to maintain acceptable sediment quality with the level of source control estimated to be technically achievable and observed since the shutdown of the smelter. Additional evaluations to refine these estimates will be required as part of the source control measures described above. Source control requirements were developed through application of the sediment recovery model for the indicator chemicals arsenic, mercury, and HPAH. The assumptions used in determining source control requirements were environmentally protective. It is anticipated that more detailed loading data will demonstrate that sources can be controlled to the extent necessary to maintain acceptable sediment quality. If the potentially responsible parties demonstrate that implementation of all known, available, and reasonable control technologies will not provide sufficient reduction in contaminant loadings, then the area requiring sediment remediation may be re-evaluated.

Clamshell dredging/confined aquatic/upland disposal was recommended as the preferred alternative for remediation of sediments not expected to recover within 10 yr following implementation of all known, available, and reasonable source control measures. The selection was made following a detailed evaluation of viable alternatives encompassing a wide range of general response actions. Because sediment remediation will be implemented according to a performance-based ROD, the alternative eventually implemented may differ from the currently preferred alternative. The preferred alternative meets the objective of providing protection for both human health and the environment by effectively isolating contaminated sediments in either an engineered RCRA-equivalent upland facility or at near in situ conditions in a quiescent, subaquatic environment. Upland disposal of contaminated wastes has been used extensively throughout the county. Confined aquatic disposal has been demonstrated to be effective in isolating contaminated sediments (U.S. Army Corps of Engineers 1988). The high levels of inorganic contaminant concentrations in sediment in this area appear to warrant the additional protectiveness afforded by an upland disposal facility. The effects of those high level contaminants (containing a high percentage of slag particles) is currently being evaluated as part of the ASARCO RI/FS process through extensive biological and chemical testing. In the event that these evaluations reveal that the inorganic contaminants are tightly bound in the slag particulate matrix, re-evaluation of the need for a RCRA-equivalent upland disposal facility to meet established performance goals may be required. The alternative is consistent with the Tacoma Shoreline Management Plan, Sections 404 and 401 of the Clean Water Act, and other applicable environmental requirements.

As indicated in Table 13-4, clamshell dredging/confined aquatic/upland disposal provides a cost-effective means of sediment mitigation for the large volume of sediment in this problem area. The estimated cost to implement this alternative is $9,316,000. Environmental monitoring and other O&M costs at the disposal site have a present worth of $707,000 for a period of 30 yr. These costs include long-term monitoring of sediment recovery areas to verify that source control and natural sediment recovery have corrected the contamination problems in the recovery areas. The total present worth cost of the preferred alternative is $10,023,000.

Although the best available data were used to evaluate alternatives, several limitations in the available information complicated the evaluation process. The following factors contributed to uncertainty:

- Limited data on spatial distribution of contaminants, used to estimate the area and depth of contaminated sediment

- Limited information with which to develop and calibrate the model used to evaluate the relationships between source control and sediment contamination

- Limited information on the ongoing releases of contaminants and required source control

- Limited information on disposal site availability and associated costs.

In order to reduce the uncertainty associated with these factors, the following activities should be performed during the remedial design stage or addressed in the ASARCO facility RI/FS process:

- Additional sediment monitoring to refine the area and depth of sediment contamination

- Further source investigations

- Monitoring of sources and sediments to verify the effectiveness of source control measures

- Final selection of a disposal site.

Implementation of source control followed by sediment remediation is expected to be protective of human health and the environment and to provide a long-term solution to the sediment contamination problems in the area. The proposed remedial measures are consistent with other environmental laws and regulations, utilize the most protective solutions practicable, and are cost-effective.

14.0 SUMMARY OF PREFERRED ALTERNATIVES

Ten candidate alternatives were defined for sediment remedial action in the Commencement Bay Nearshore/Tideflats study area. Detailed evaluations of applicable alternatives were performed for each of nine problem areas, using the most recent U.S. EPA guidance for feasibility studies. Evaluation criteria were grouped in three general categories: effect eness, implementability, and cost. On the basis of this analysis, preferred alternatives were identified for each problem area. These preferred alternatives are reviewed in Section 14.1. Factors affecting estimated costs and predicted recovery of sediment quality are discussed in Sections 14.2 and 14.3, respectively. Restoration of habitat disturbed by the recommended remedial activities is addressed in the final subsection.

14.1 PREFERRED ALTERNATIVES

The alternatives that were evaluated for each waterway are identified in Table 14-1. The preferred alternative selected for each problem area is also identified. Four categories of preferred alternative were selected: removal with confined aquatic disposal, removal with nearshore disposal, in situ capping, and institutional controls.

14.1.1 Removal/Confined Aquatic Disposal

Removal with confined aquatic disposal is recommended as the preferred alternative for the mouth of Hylebos Waterway, the head of City Waterway, Wheeler-Osgood Waterway, and the Ruston-Pt. Defiance Shoreline. In all cases except Ruston-Pt. Defiance, clamshell dredging is recommended, with confined disposal at a site beyond the immediate problem area. Much of the sediment requiring remediation in the Ruston-Pt. Defiance area is located at water depths that exceed the clamshell dredge's working depth of 100 ft. If removal of sediments from water depths greater than 100 ft is considered, then use of a bucketwheel dredge might be appropriate. A floating carrier bucketwheel dredge can be used in water depths greater than 300 ft. In-waterway confined aquatic disposal is believed to be too restrictive of future dredging activities in both Hylebos and City Waterways. For practical and technical considerations, local confined aquatic disposal is also not recommended in either Wheeler-Osgood Waterway or along the Ruston-Pt. Defiance Shoreline. It is recommended that contaminated sediments in Wheeler-Osgood Waterway be removed and replaced with clean sediments to preserve intertidal habitat in the waterway.

Removal with a clamshell dredged and disposal in a confined offshore site offers a high degree of protection for both public health and the environment. Contaminated dredged material will be isolated in an area well below tidal influence. The long-term reliability of the alternative is expected to be good, and performance monitoring can be effectively implemented. The dredging and disposal can be implemented in a reasonable

TABLE 14-1. ALTERNATIVES EVALUATED FOR EACH PROBLEM AREA

Waterway	No Action	Institu-tional Controls	In Situ Capping	Dredge/ Confined Aquatic Disposal	Dredge/ Nearshore Disposal	Hydraulic Dredge/ Upland Disposal	Clamshell Dredge/ Solidification/ Upland Disposal	Clamshell Dredge/ Solvent Extraction/ Upland Disposal	Clamshell Dredge/ Incineration/ Upland Disposal	Clamshell Dredge/ Land Treatment
Head of Hylebos	X	X		X	X[a]	X		X[b]	X[b]	
Mouth of Hylebos	X	X		X[a]	X	X		X	X	
Sitcum	X	X		X	X[a]	X	X			
St. Paul	X	X	X[a]	X	X	X		X	X	X
Middle	X	X		X	X[a]	X	X			
Head of City	X	X		X[a]	X	X	X			
Wheeler-Osgood	X	X	X	X[a]	X	X		X	X	X
Mouth of City	X	X[a]		X	X	X		X[b]	X[b]	
Ruston-Pt. Defiance Shoreline	X	X		X[a,c]	X	X	X			

[a] Preferred alternative.

[b] Treatment options are combined with solidification for inorganic contaminants to provide a complete alternative to remediation.

[c] In this case, most dredged sediments would be placed at a confined aquatic disposal site. The most highly contaminated sediments (i.e., >3,000 mg/kg arsenic), however, would be taken to an upland disposal facility meeting RCRA standards.

timeframe with available equipment that has proven effective in past similar operations. It is also cost-effective.

14.1.2 Removal/Nearshore Disposal

Removal with nearshore disposal is recommended as the preferred alternative for contaminated dredged material in head of Hylebos, Sitcum, and Middle Waterways. The probable nearshore disposal site is Slip 1 of Blair Waterway. Clamshell dredging is recommended for the head of Hylebos and Middle Waterways. Because of the distance between these waterways and the disposal site, it will be necessary to barge the material to Slip 1. Clamshell dredging will provide minimal water entrainment and minimal dispersion of contaminated dredged particles. Hydraulic dredging will probably be appropriate for Sitcum Waterway because of its proximity to the disposal site, and dredged material can be pumped directly to the proposed site. Proper use of silt curtains and a diffuser would limit dispersion of contaminated dredged particles. Should hydraulic dredging prove to be impractical during final remedial design, the use of a clamshell dredge would be acceptable.

This alternative is generally cost-effective and offers a sufficient degree of long-term protection to public health and the environment to warrant selection. With disposal below low water and placement of a clean cap, nearshore disposal would provide an alternative with long-term reliability. Performance monitoring can be implemented easily and effectively. Also, this alternative can be implemented in a timely manner with available equipment that has proven effective in the past.

14.1.3 In Situ Capping

In situ capping is recommended as the preferred alternative for St. Paul Waterway. Because the waterway is shallow and is not designated for use in commercial shipping, in situ capping would provide a high degree of protectiveness and may also improve valuable nearshore habitat. By preserving the physicochemical conditions of the contaminated sediments and not disturbing material, this alternative would result in lowered potential for migration or redistribution of contaminants compared with alternatives involving dredging. The weak particle affinities exhibited by the organic contaminants, however, may facilitate migration potential. Bench-scale sediment column studies could be conducted to more quantitatively evaluate contaminant mobilization potential and provide a basis for determining cap thickness. Capping contaminated sediments in St. Paul Waterway is expected to provide reliable long-term protection of both public health and the environment. The alternative can be readily implemented with available equipment, which has been used as an element of confined aquatic disposal for other problem areas. Monitoring to evaluate long-term performance of the cap would not pose technical difficulties. In situ capping also appears to be cost-effective.

14.1.4 Institutional Controls

Institutional controls are recommended as the preferred alternative for the Mouth of City Waterway. Contaminant concentrations in the Mouth of City Waterway are less than those concentrations predicted to recover to long-term cleanup goals within 10 yr. Therefore, institutional controls provide a cost-effective and environmentally protective remedial alternative. Monitoring will determine the effectiveness of institutional controls. If monitoring results suggest that institutional controls are not effectively lowering contaminant concentrations, a re-evaluation of remedial alternatives would be warranted.

14.2 COST ANALYSIS

Sediment areas, volumes, and costs of preferred alternatives have been estimated for long-term cleanup goals, for long-term cleanup goals with 10 yr of natural recovery, and for cleanup to maximum AET levels (Tables 14-2 and 14-3). As shown in Table 14-4, the estimated total volume of sediments currently exceeding long-term cleanup goals in the nine problem areas is approximately 2.8 million yd^3. If sediments recovering within 10 yr are excluded the cleanup volume is reduced approximately 36 percent to 1.8 million yd^3. The most highly contaminated sediments (i.e., those exceeding the maximum AET) are estimated to have a volume of 0.7 million yd^3. The total cleanup costs for the entire Nearshore/Tideflats (N/T) site are estimated to range from $11.3 million (maximum AET levels) to $41.2 million (long-term cleanup goals).

There is some degree of uncertainty associated with several of the factors that determine implementation costs. Some of these factors are identified and discussed in Table 14-5. The first four factors in Table 14-5 involve uncertainties in surface areas and volumes for cleanup. Implementation costs for each feasible alternative in each problem area were estimated for cleanup to both long-term cleanup goals and long-term cleanup goals with 10-yr recovery. For the preferred alternative, implementation costs were also estimated for maximum AET level surface areas and volumes. The possible implications of uncertainties of various cost evaluation factors (e.g., unit costs for dredging, treatment, and transport; disposal facility siting and construction; long-term monitoring) can be better understood by reviewing the detailed cost tables presented in Appendix D.

Additional testing will be required to better define the area and volume of sediment requiring remediation. At a minimum, potentially responsible parties will be required to define the extent and depth of contamination through additional sediment sampling and either chemical testing or testing for biological effects. A formal process for defining cleanup volumes is presented in the Integrated Action Plan for Commencement Bay (PTI 1988a).

The estimated costs of the preferred alternatives for all nine problem areas are plotted in Figure 14-1. The plots include initial costs, the present value of O&M costs, and total estimated costs. Costs are plotted as a function of volume of contamination for each of the three cleanup

TABLE 14-2. SUMMARY OF REMEDIAL SEDIMENT SURFACE AREAS AND VOLUMES[a]

Waterway	Long-Term Cleanup Goal[b]		Long-Term Cleanup Goal Plus 10-yr Recovery		Maximum AET[c]	
	Area	Volume	Area	Volume	Area	Volume
Head of Hylebos	381	381	217	217	9	9
Mouth of Hylebos	393	786	115	230	33	66
Sitcum	167[d]	167[d]	66[d]	66[d]	20	20
St. Paul	118	236	87	174	90	180
Middle	126	63	114	57	47	24
Head of City	230	575	171	426	42	104
Wheeler-Osgood	22	11	22	11	1	1
Mouth of City	27[d]	27[d]	0	0	0	0
Ruston-Pt. Defiance Shoreline	1,176	588	1,150	575	618	309
TOTAL	2,640	2,834	1,942	1,756	860	713

[a] Areas are reported in units of 1,000 yd^2. Volumes are reported in units of 1,000 yd^3.

[b] Sediments with indicator chemical concentrations currently greater than long-term cleanup goals.

[c] Sediments with indicator chemical concentrations currently greater than the lower of either the highest AET or the lowest "severe effects" AET.

[d] Includes sediment for which biological effects were observed for nonindicator compounds.

TABLE 14-3. COST SUMMARY FOR PREFERRED ALTERNATIVES
(IN MILLIONS OF DOLLARS)

Waterway	Preferred Alternative	Long-Term Cleanup Goal[a]			Long-Term Cleanup Goal with 10-Yr Recovery			Maximum AET[b]		
		Initial	O&M	Total	Initial	O&M	Total	Initial	O&M	Total
Head of Hylebos	Clamshell dredge/nearshore disposal	9.3	0.6	9.9	5.3	0.4	5.7	0.1	0.0	0.1
Mouth of Hylebos	Clamshell dredge/confined aquatic disposal	6.5	0.7	7.2	1.8	0.3	2.1	0.5	0.1	0.6
Sitcum	Hydraulic dredge/nearshore disposal	4.1	0.3	4.4	1.6	0.1	1.7	0.7	0.1	0.8
St. Paul	In situ capping	0.9	1.3	2.2	0.7	1.3	2.0	0.7	1.3	2.0
Middle	Clamshell dredge/nearshore disposal	1.5	0.2	1.7	1.4	0.2	1.6	0.6	0.1	0.7
Head of City	Clamshell dredge/confined aquatic disposal	4.5	0.6	5.1	3.3	0.5	3.8	0.8	0.1	0.9
Wheeler-Osgood	Clamshell dredge/confined aquatic disposal	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1
Mouth of City	Institutional controls	0.1	0.3	0.4	0.1	0.3	0.4	0.1	0.3	0.4
Ruston-Pt. Defiance Shoreline	Clamshell dredge/upland/confined aquatic disposal	9.5	0.7	10.2	9.3	0.7	10.0	5.0	0.5	5.5
TOTAL		36.5	4.7	41.2	23.6	3.8	27.4	8.6	2.7	11.3

[a] Sediments with indicator chemical concentrations currently greater than long-term cleanup goals.

[b] Sediments with indicator chemical concentrations currently greater than the lower of either the highest AET or the lowest "severe effects" AET.

TABLE 14-4. SEDIMENT CLEANUP SUMMARY FOR COMMENCEMENT BAY

	Long-Term Cleanup Goal[a]	Long-Term Cleanup Goal with 10-yr Recovery	Maximum AET[b]
Total sediment surface area (million yd^2)	2.6	1.9	0.9
Total sediment volume (million yd^3)	2.8	1.8	0.7
Total cost of preferred alternatives in all nine problem areas (million $)			
Initial	36.5	23.6	8.6
Operation and maintenance	4.7	3.8	2.7
Total	41.2	27.4	11.3

[a] Sediments with indicator chemical concentrations currently greater than long-term cleanup goals.

[b] Sediments with indicator chemical concentrations currently greater than the lower of either the highest AET or the lowest "severe effects" AET.

TABLE 14-5. FACTORS AFFECTING COST ESTIMATES

Factor	Discussion
Areal extent of contaminated sediment	Areas of contamination are based on limited spatial coverage of chemical data. Better definition of the extent of contamination could cause costs to increase or decrease.
Depth of contamination	On the basis of limited available sediment profile data, a uniform cleanup depth has been estimated for each problem area. With improved depth resolution, it may be possible to identify variable cleanup depths over a problem area to reduce volumes and costs.
Extent of dredging	During the remedial design it may be necessary to define dredging boundaries exceeding the irregular boundaries that now define the areas of contamination (e.g., dredging is ordinarily performed for rectangular cells). This factor could cause costs to increase.
Cleanup goals	Changing cleanup volumes based on additional biological testing during the appeals process could cause costs to increase or decrease.
Selection of a preferred alternative	Selection of a different preferred alternative for any problem area would affect the cost. The preferred alternative could change based on new technologies, technological improvements, refinement of analytical data, or improved areal and depth resolution. For each problem area, the costs of all alternatives are provided in the FS.
Cost evaluation factors	A variety of cost factors are used in the cost estimation process. For example, the present value of O&M costs was estimated with a 10 percent discount rate, as prescribed by U.S. EPA FS guidelines. With a 5 percent discount rate, the present value of O&M costs would be about 40 percent greater. Another factor is the contingency on total costs, for which 20 percent was used. A greater contingency factor would increase the total cost estimates.

TABLE 14-5. (Continued)

Recovery time calculations	The costs that incorporate natural sediment recovery are directly affected by the factors that go into the recovery analysis. Two important factors in the sediment recovery calculations are the recovery time (e.g., 10 yr) and percent source control assumed feasible. Increasing the allowable recovery time or the estimated feasible level of source control would tend to reduce cleanup volumes. Decreasing these factors would tend to increase cleanup volumes.

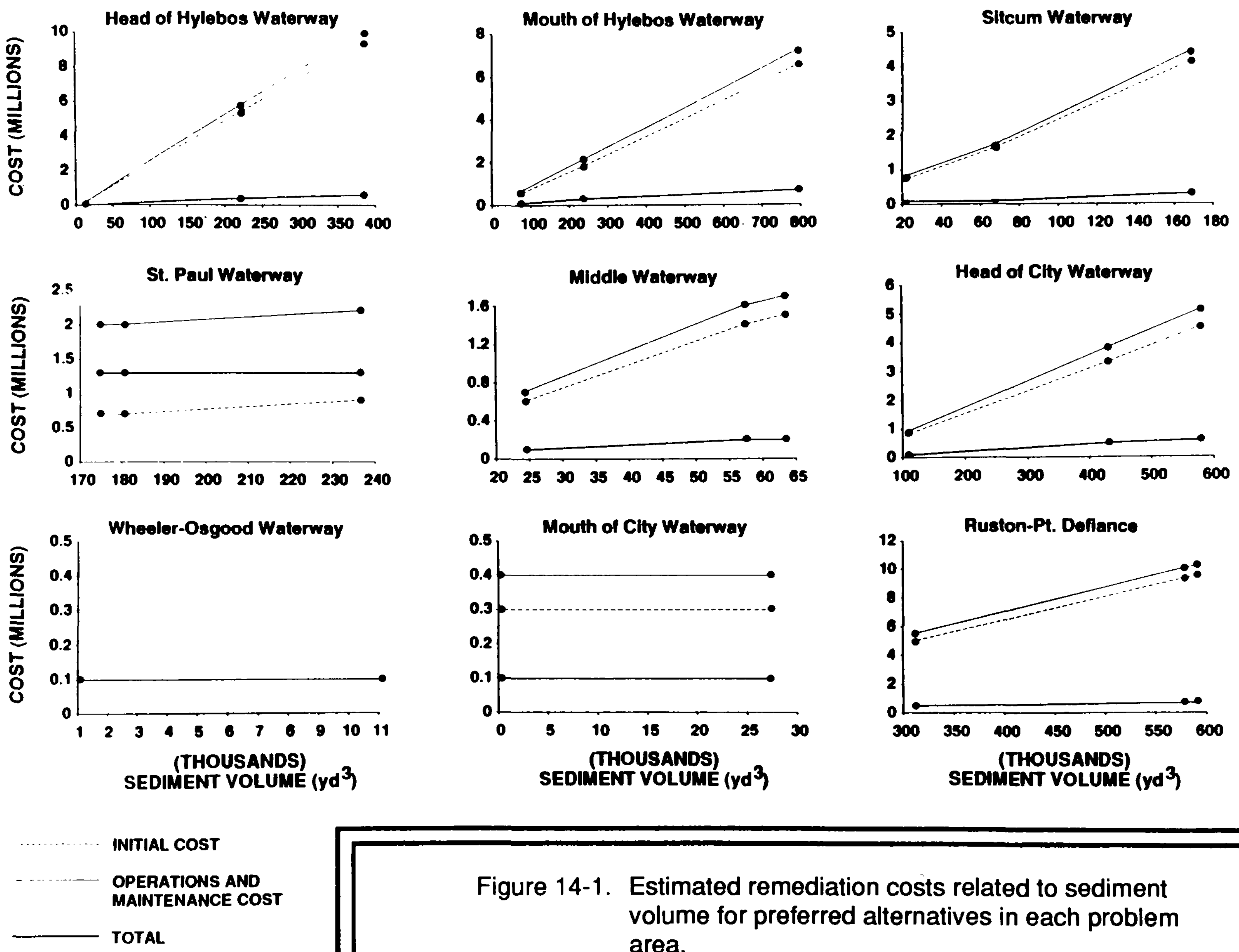


Figure 14-1. Estimated remediation costs related to sediment volume for preferred alternatives in each problem area.

levels. The highest costs are associated with cleanup to an enrichment ration of 1.0 (i.e., long-term cleanup goals). These plots can be used to estimate cleanup costs for volumes or cleanup goals within the range established for each problem area.

14.3 NATURAL SEDIMENT RECOVERY

The recovery of surface sediments through natural sedimentation has been evaluated to define areas that will return to acceptable levels of contamination over a 10-yr time period following implementation of known available and reasonable source controls. The methods used to evaluate sediment recovery are provided in Appendix A. Several key factors in the analysis are presented in Table 14-6. In addition to the factors shown in Table 14-6, 10 cm was assumed to best represent the average depth of the mixed layer throughout the Commencement Bay N/T study area.

The calculated enrichment ratio in surface sediments that will recover in 10 yr is provided in Table 14-6 for each indicator chemical in each problem area. The recovery calculations suggest that surface sediments with these enrichment ratios or less will return to enrichment ratios of 1.0 or less within 10 yr. The effects of source control and the recovery period on the results are illustrated in Table 14-7. This table can be used to define areas of recovery within periods of 5, 10, or 25 yr for a range of source control from 0 to 100 percent. The table should be consulted if it is later determined that the feasible levels of source control presented in this document are either too high or too low.

A sensitivity analysis was performed to evaluate the effect of changing the depth of the mixed layer used in the recovery calculations. The value of 20 cm was used in the sensitivity analysis, representing the maximum value of all mixed layer measurements. Increasing the mixing depth from 10 to 20 cm has the same effect as reducing the sedimentation rate used by 50 percent. The 10-yr enrichment ratios would be reduced by either increasing the mixing depth or decreasing the sedimentation rates. For example, with 70 percent source control assumed, the 10-yr enrichment ratio at the mouth of City Waterway would be reduced from 1.52 to about 1.25 by increasing the mixing depth from 10 cm to 20 cm. Likewise, with 80 percent source control assumed, the 10-yr enrichment ratio in Sitcum Waterway would be reduced from 2.91 to 1.78 by such a change. These changes would cause the 10-yr cleanup volumes to increase. Nevertheless, the 10-cm mixing depth is believed to be appropriate given the data available.

14.4 HABITAT RESTORATION

Habitat will be disturbed both in areas that are subject to sediment remediation and in disposal areas. In all, five categories of habitat could be disturbed:

- Benthic habitat in problem areas

- Intertidal habitat in problem areas

TABLE 14-6. SEDIMENT RECOVERY FACTORS

Problem Area	Estimated Sedimentation Rate (cm/yr)	Indicator Chemical	Long-Term Cleanup Goal[a]	Percent Source Control Assumed[b]	10-yr Enrichment Ratio[c]
Head of Hylebos	0.77	PCBs	150	70	1.6
		Arsenic	57	80	1.7
		HPAH	17,000	90	1.9
Mouth of Hylebos	1.77	PCBs	150	60	2.0
		Hexachloro- benzene	22	95	4.6
Sitcum	1.65	Copper	390	80	2.9
		Arsenic	57	80	2.9
St. Paul	0.70	4-Methylphenol	670	95	1.9
Middle	0.27	Mercury	0.59	70	1.2
		Copper	390	70	1.2
Head of City	0.43	HPAH	17,000	60	1.3
		Cadmium	5.1	60	1.3
		Lead	450	60	1.3
		Mercury	0.59	60	1.3
Wheeler-Osgood	0.31	HPAH	17,000	70	1.2
		Zinc	410	70	1.2
Mouth of City	0.67	HPAH	17,000	70	1.5
		Mercury	0.59	70	1.5
Ruston-Pt. Defiance Shoreline	<0.12	Arsenic	57	95	1.1
		Mercury	0.59	95	1.1
		LPAH	5,200	95	1.1

[a] Concentration, expressed as ug/kg dry weight for organics and mg/kg dry weight for metals.

[b] Average source control level assumed to be attainable within a problem area.

[c] Maximum enrichment ratio in surface sediment that will recover (i.e., return to 1.0) in 10 yr.

TABLE 14-7. MAXIMUM ENRICHMENT RATIOS THAT ARE PREDICTED TO RECOVER TO ACCEPTABLE LEVELS IN A GIVEN TIME PERIOD

Percent Source Control	Recovery Period			Recovery Period			Recovery Period		
	5 yr	10 yr	25 yr	5 yr	10 yr	25 yr	5 yr	10 yr	25 yr
	Head of Hylebos Waterway			Mouth of Hylebos Waterway			Sitcum Waterway		
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.03	1.06	1.09	1.06	1.09	1.11	1.06	1.09	1.11
20	1.07	1.12	1.20	1.13	1.20	1.25	1.13	1.20	1.25
30	1.10	1.19	1.34	1.21	1.33	1.42	1.21	1.33	1.42
40	1.14	1.26	1.51	1.30	1.49	1.65	1.30	1.49	1.65
50	1.18	1.35	1.73	1.41	1.70	1.97	1.40	1.69	1.97
60	1.23	1.46	2.02	1.53	1.98	2.45	1.53	1.97	2.45
70	1.28	1.58	2.44	1.68	2.36	3.24	1.67	2.35	3.23
80	1.33	1.72	3.07	1.87	2.93	4.75	1.85	2.91	4.74
85	1.36	1.80	3.52	1.97	3.34	6.21	1.96	3.30	6.18
90	1.39	1.89	4.13	2.09	3.87	8.95	2.08	3.82	8.90
95	1.42	1.98	5.00	2.23	4.60	16.03	2.21	4.52	15.85
100	1.45	2.09	6.34	2.38	5.68	76.73	2.36	5.55	72.65
	St. Paul Waterway			Middle Waterway			Head of City Waterway		
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.03	1.05	1.09	1.01	1.02	1.05	1.02	1.04	1.07
20	1.06	1.11	1.20	1.03	1.05	1.11	1.04	1.07	1.15
30	1.10	1.18	1.33	1.04	1.07	1.17	1.06	1.12	1.25
40	1.14	1.26	1.50	1.05	1.10	1.24	1.08	1.16	1.36
50	1.18	1.34	1.71	1.07	1.13	1.32	1.11	1.21	1.49
60	1.22	1.44	2.00	1.08	1.16	1.41	1.13	1.26	1.65
70	1.27	1.56	2.40	1.09	1.19	1.51	1.16	1.32	1.85
80	1.32	1.69	2.99	1.11	1.23	1.63	1.18	1.39	2.11
85	1.34	1.77	3.42	1.12	1.25	1.70	1.20	1.42	2.27
90	1.37	1.85	3.99	1.13	1.26	1.77	1.21	1.46	2.45
95	1.40	1.94	4.78	1.13	1.28	1.85	1.22	1.50	2.66
100	1.43	2.04	5.96	1.14	1.30	1.93	1.24	1.54	2.92
	Wheeler-Osgood Waterway			Mouth of City Waterway			Ruston-Pt. Defiance		
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.01	1.03	1.06	1.03	1.05	1.09	1.01	1.01	1.03
20	1.03	1.06	1.12	1.06	1.11	1.19	1.01	1.02	1.06
30	1.05	1.09	1.19	1.09	1.17	1.32	1.02	1.04	1.09
40	1.06	1.12	1.28	1.13	1.24	1.48	1.02	1.05	1.12
50	1.08	1.15	1.37	1.17	1.32	1.68	1.03	1.06	1.15
60	1.09	1.19	1.48	1.21	1.41	1.95	1.04	1.07	1.19
70	1.11	1.23	1.61	1.25	1.52	2.32	1.04	1.09	1.23
80	1.13	1.27	1.76	1.29	1.64	2.86	1.05	1.10	1.27
85	1.14	1.29	1.85	1.32	1.71	3.23	1.05	1.11	1.29
90	1.15	1.32	1.94	1.34	1.78	3.72	1.06	1.12	1.31
95	1.16	1.34	2.05	1.37	1.86	4.38	1.06	1.12	1.34
100	1.17	1.36	2.17	1.40	1.95	5.33	1.06	1.13	1.36

- Benthic habitat in confined aquatic disposal areas
- Intertidal habitat in nearshore disposal areas
- Habitats at or adjacent to upland disposal areas.

14.4.1 Benthic Habitat in Problem Areas

Contaminated habitat in problem areas will be disturbed over the short term. However, over the long term, sediment remediation is designed to restore benthic habitat to precontamination conditions. The abundance of benthic organisms should ultimately be similar to their abundance in similar uncontaminated sites.

14.4.2 Intertidal Habitat in Problem Areas

Some intertidal habitat is likely to be disturbed in each problem area. Estimates of surface areas and associated sediment volumes that could be disturbed by remediation efforts for each of the three cleanup levels are shown in Table 14-8. For dredging alternatives, these habitats will be restored through replacement with clean fill. Replacement costs have been included in the remedial cost estimates. In St. Paul Waterway, the intertidal habitat at the mouth of the waterway may actually be enhanced by capping activities. Although in all cases habitat will be disturbed over the short term, the long-term goal of the sediment remediation effort is to create an improved habitat.

14.4.3 Benthic Habitat in Confined Aquatic Disposal Areas

Benthic communities will be displaced by placement of contaminated dredged material. However, by capping with clean material, benthic organisms should be able to return to abundances at or near predisturbance levels.

14.4.4 Intertidal Habitat in Nearshore Disposal Areas

Slip 1 of Blair Waterway is not considered to be an intertidal habitat. Therefore, through the exclusive use of this site for nearshore disposal, intertidal habitat should not be affected.

14.4.5 Habitats at or Adjacent to Upland Disposal Sites

The only problem area requiring an upland disposal site is the Ruston-Pt. Defiance Shoreline. Of the sediment requiring remediation, 20 percent (115,000 yd^3) will require upland disposal. It was assumed that a location within the ASARCO property could be identified. This property has been in industrial land use for decades, and development of an upland disposal site is not expected to cause loss of important upland habitat.

Should an alternative other than the one recommended in this report be selected as the preferred alternative, it is possible that some upland habitats would be disturbed. Through proper siting and design this disturbance could be limited to minimal short-term effects.

TABLE 14-8. ESTIMATED INTERTIDAL SURFACE AREAS AND VOLUMES TO BE DISTURBED BY SEDIMENT REMEDIAL ACTION[a]

Waterway	Long-Term Cleanup Goal[b]		Long-Term Cleanup Goal Plus 10-yr Recovery		Maximum AET[c]	
	Area	Volume	Area	Volume	Area	Volume
Head of Hylebos	16	12	9	7	0	0
Mouth of Hylebos	90	181	0	0	0	0
Sitcum	0	0	0	0	0	0
St. Paul	5	10	1	2	1	2
Middle	10	5	2	1	1	1
Head of City	5	13	5	13	2	6
Wheeler-Osgood	17	9	17	9	1	1
Mouth of City	0	0	0	0	0	0
Ruston-Pt. Defiance Shoreline	32	16	32	16	32	16
TOTAL	175	246	66	48	37	26

a Areas are reported in units of 1,000 yd^2. Volumes are reported in units of 1,000 yd^3.

b Sediments with indicator chemical concentrations currently greater than long-term cleanup goals.

c Sediments with indicator chemical concentrations currently greater than the lower of either the highest AET or the lowest "severe effects" AET.

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