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Assessment of Potential Toxic Problems in Non-Urban Areas of Puget Sound

Final Report

FINAL REPORT

ASSESSMENT OF POTENTIAL TOXIC PROBLEMS IN NON-URBAN AREAS OF PUGET SOUND

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EXECUTIVE SUMMARY

INTRODUCTION

This report compiles and interprets information on potential environmental degradation from toxic chemical contaminants in nonurban areas within Puget Sound. Prior to this publication, information on toxic contaminants in the areas of concern was scattered among numerous locations in forms not readily usable.

The objectives of the study are 1) to identify, by interpreting existing information, nonurban areas in Puget Sound that may have serious contamination or biological problems and 2) to prioritize those areas for future detailed studies.

GEOGRAPHICAL COVERAGE

The information in this report is grouped according to the 12 regions of Puget Sound used in the Puget Sound Environmental Atlas (Evans-Hamilton, Inc., and D.R. Systems, Inc. 1987). Within each region, informational summaries for specific sites are presented in alphabetical order by site name. Source and station locations are plotted on each regional map; the accuracy of the locations varies according to the amount of detail that was available in the original information source.

SOURCES AND TYPES OF INFORMATION

For each embayment, three categories of information were gathered. These are: known and suspected sources of toxic substances, the results of sediment chemistry analyses, and information on local toxicity problems. These categories are consistent with the types of information used by PSEP's Urban Bay Action Program (U.S. EPA 1986a) for assessment of environmental degradation in urban portions of Puget Sound.

The information contained in this report was obtained from a variety of existing sources; site inspections and field studies were beyond the scope of the project. The principle sources of information included the scientific literature; reports published by the federal governments of the United States and Canada and by state and local agencies; unpublished federal and state agency file documents; and reports generated by the private sector. Additional information was obtained from interviews with environmental professionals familiar with Puget Sound.

Sources of Toxic Substances

Information on possible sources of toxic substances is included in this report to determine whether contamination might be expected to exist in an

area. These sources included permitted industrial and municipal discharges and hazardous waste sites. This information was used to evaluate sites that had not been sampled.

Information on the volume and types of chemicals released by dischargers was not generally available. Within a given industry, the potential for the release of toxic materials is dependent on the processes used. Detailed evaluations of the releases at individual sites were beyond the scope of this project. Permitted dischargers and hazardous waste generators are merely noted. Sewage discharges are partitioned by the volume of the effluent into large and small sources. Hazardous waste sites are evaluated according to available information.

Sediment Condition

Sediment condition is evaluated in this report for sites where sediment chemistry data are available. Contaminated sediments are known to alter benthic community structure and introduce toxic chemicals into the food chain. Therefore, sediment chemistry data provide an important index of environmental contamination. Two indices of sediment contamination are included in this report: Elevation Above Reference (EAR) and Apparent Effects Threshold (AET). Both indices are used in EPA's Urban Bay Approach (EPA 1986a) [e.g., Commencement Bay (Tetra Tech 1985b)].

EAR compares the concentration of a chemical at a study site to that measured at a reference site where the contaminant is assumed to be at "background" concentrations. Thus, EAR does not provide direct evidence that the particular chemical is causing environmental degradation.

AET indicates whether the concentration of a chemical in an area is higher than the concentration known to be associated with environmental impacts. An AET is defined as a sediment concentration of a chemical above which adverse biological effects are always observed (Tetra Tech 1986). Thus, AET values are empirically derived from existing data and are used to predict impacts at sites where biological studies have not been conducted.

In this report, AET values are considered to be exceeded when the concentration of a given chemical exceeds the lowest AET concentration established for either sediment bioassays on the amphipod, Rhepoxyinius abronius, the larvae of the oyster, Crassostrea gigas, or depression of the abundance of a major taxon (i.e., polychaetes, molluscs, or crustaceans) in the benthic community.

Biological Impacts

Four types of biological indexes are used in this report to measure the extent of environmental degradation: bioassays, bioaccumulation, fish histopathological abnormalities, and fish kill information. Because of the lack of a substantial database, several other indices of biological impacts were excluded from the report (e.g., invertebrate pathology, and species diversity indexes). Fish kills known to have been caused by low dissolved oxygen concentrations were excluded from the report.

ASSESSMENT MATRICES

For each site included in the study, the data on sources of toxic substances, sediment condition, and biological impacts are incorporated into an assessment matrix for that region of the sound in which the site is located. In the assessment matrices, the data in each of these categories were evaluated for 1) the level of concern (LOC) or attention that an area should received based upon available contaminant information and 2) the degree of certainty (DOC) or probability that the information assessed, hence LOC, is correct. Ratings of low, medium, and high were assigned separately for LOC and DOC for each data category, based on available information.

Overall ratings were obtained by calculating the mean of the ratings based on sources of toxic substances, sediment condition, and biological impacts. The data in these categories are reported qualitatively, but, to calculate mean ratings for LOC and DOC, values of 1, 2, and 3 were given to the low, medium, and high ratings, respectively, for each data category. These means were converted back to qualitative ratings by rounding to the nearest whole number and assigning a low, medium, or high value accordingly. If data were not available for a particular category of information (e.g.,sediment condition), that category was excluded from determination of the overall ratings.

Qualitative values of LOC and DOC are used in the assessment matrices because the purpose of this report is to provide an initial screening of available information rather than to produce an in-depth determination of the contaminant problems experienced in specific areas. Moreover, the types and amounts of available data vary widely among sites, precluding the use of a quantitative, statistical approach.

CONCLUSIONS

Of the 97 nonurban areas of Puget Sound evaluated in this study by the Environmental Assessment Matrix technique, only 6 received a ranking of HIGH which may qualify them for consideration as sites for future, detailed investigations. The areas of significant concern are: the Guemes/Fidalgo Channel (Region 2), Port Angeles Harbor (Region 3), Crescent Harbor (Region 4), Richmond Beach (Region 8), Liberty Bay (Region 9), and East Passage (Region 11).

Forty-two (42) other areas received a MEDIUM ranking. As might be expected, industrialized regions contained the larger numbers of MEDIUM sites. The results can be grouped according to the number of MEDIUMs within each region as follows: Regions 3 and 7 each had 1, Regions 2, 5, 6, and 10 had 2, Region 1 had 3, Region 4 and 11 each had 4, Region 12 had 5, Region 8 had 6, and Region 9 had 10. All other sites were ranked low.

This assessment employed an environmentally protective approach towards ranking. A rank of MEDIUM does not necessarily mean an area is in imminent danger of becoming highly contaminated, but only that one or more of the evaluation criteria were exceeded. The intent of this approach was to identify areas of possible toxic contamination problems in non-urbanized areas of Puget Sound before sever or widespresd environmental problems manifest themselves.

INTRODUCTION

BACKGROUND

This report compiles and interprets information on potential environmental degradation from toxic chemical contaminants in nonurban areas within Puget Sound. The objectives of the study are to identify, by interpreting existing information, nonurban areas that might have serious contamination problems or biological impacts and to assign priorities for more detailed studies of nonurban areas in the future. The study was funded by the U.S. Environmental Protection Agency (EPA) Office of Marine and Estuarine Protection (OMEP) and the U.S. EPA Region X Puget Sound Estuary Program (PSEP).

As a result of investigations by EPA, the Washington Department of Ecology (Ecology), the National Oceanic and Atmospheric Administration (NOAA), and others, a number of urban areas within Puget Sound [e.g.,Elliott Bay (near Seattle) and Commencement Bay (near Tacoma)] have been identified as having serious toxic chemical contamination problems. These chemicals may damage biological communities and enter the food chain, causing public concern over potential human health impacts from eating contaminated seafood. In response to such problems, PSEP has developed an Urban Bay Action Program to develop abatement and remedial action strategies appropriate to the urban bays (U.S. EPA 1986a).

Although the information gathered under the Urban Bay Action Program (e.g., Tetra Tech 1985a) has improved EPA's understanding of contamination in selected urban areas of Puget Sound, EPA has also concluded that information is needed to evaluate toxic contamination outside of urban areas. Toxic chemical accumulation in an area may be caused by either accidential spills, direct dumping, or discharges from urban and industrial sources.

This report was prepared as an initial attempt to estimate and evaluate levels of toxic contaminants in nonurban portions of Puget Sound. Prior to this report, the information available on toxic contaminants in nonurban bays was scattered among numerous locations, and was not readily assessable. The results will be used to help prioritize nonurban areas for possible detailed literature reviews and field studies to quantify the extent of actual problems. Evaluation criteria include historic and present sources of toxic chemicals, sediment condition, and biological effects. Environmental problems such as paralytic shellfish poisoning and low dissolved oxygen concentrations are also important concerns in Puget Sound, but are beyond the scope of this study.

The scope of this study imposed limitations on the content of the report. Because of the size of the study area, it was not possible to conduct detailed literature studies for every possible site in the sound. Moreover, little or no information exists on toxic contaminants concentrations in many areas. Therefore, although this report is as comprehensive as possible; it is intended only to provide a focus for possible future

investigations of expected problems based on "gray literature", anecdotes, and miscellaneous scientific studies.

OBJECTIVES

The development of a useful compendium of information on toxic chemical contamination and biological anomolies in nonurban areas of Puget Sound required that the report meet the following objectives:

- Compilation of all available information
- Development of criteria to classify and interpret the compiled information
- Incorporation of the above criteria into an assessment matrix so that the complied data could be adequately assessed
- Based upon matrix assessment, recommend nonurban areas that should receive more detailed study.

ORGANIZATION OF THE REPORT

The report is divided into sections which describe the study's design, results, and conclusions. The study design section describes categories of information, geographic divisions of Puget Sound, and the interpretation of the data. The results section presents the major sources of data, followed by text, site maps, and assessment matrices for each region of the sound. Conclusions are presented for each region at the end of each regional section. Embayments thought to be in need of further study are identified.

STUDY DESIGN

This section contains descriptions of the geographical coverage in the report (i.e., types of areas studied and the geographical organization of the report), the types and sources of compiled information, and methods of data interpretation.

GEOGRAPHICAL COVERAGE

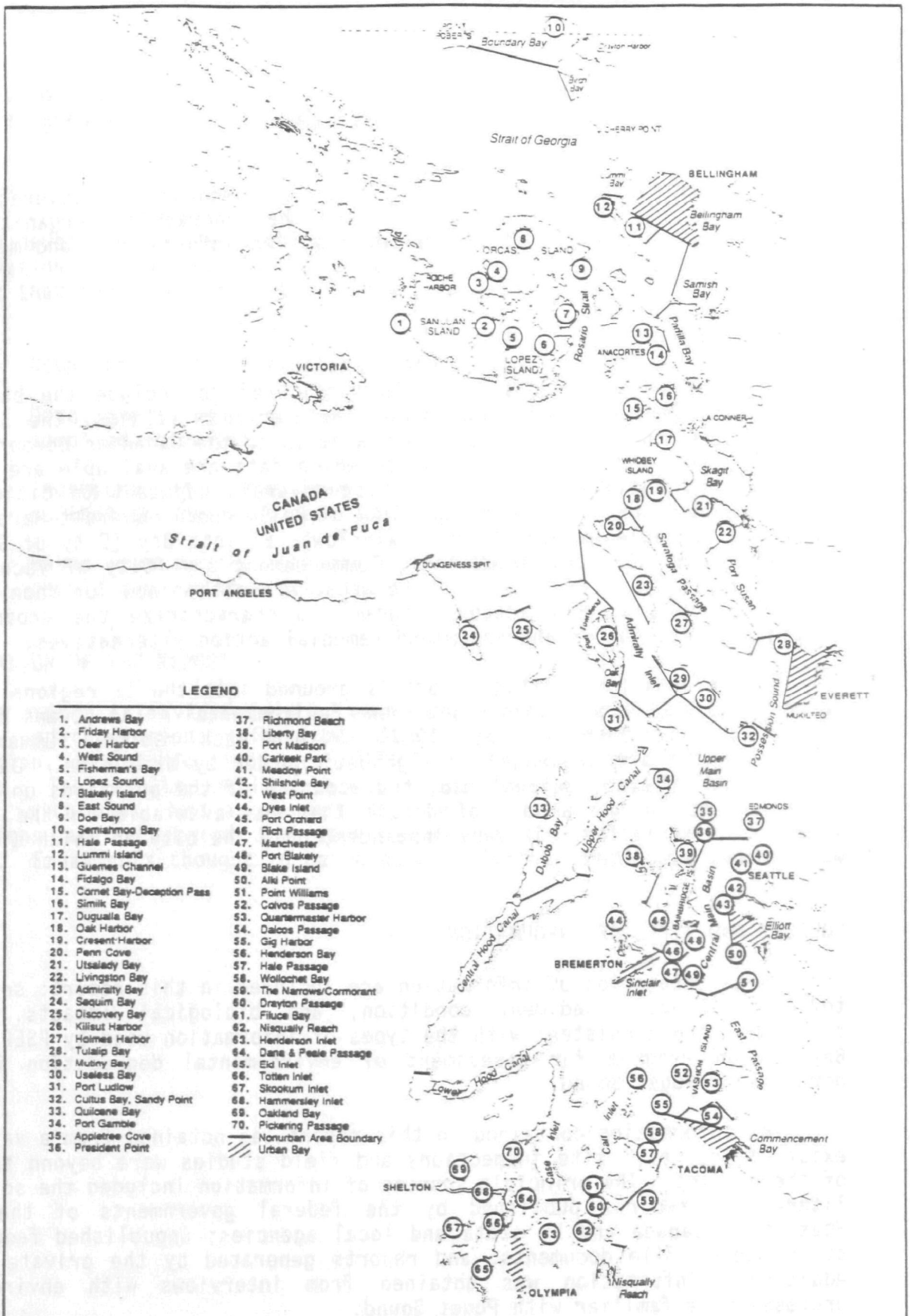
In this report, Puget Sound is considered to include the basins and embayments south of Admiralty Inlet, the San Juan Islands, the Strait of Juan de Fuca, and the Strait of Georgia north to the Canadian border (Figure 1). All sites within Puget Sound for which data are available are included in the study, with the exception of seven areas adjacent to cities. The areas excluded are Bellingham Bay (City of Bellingham), Everett Harbor (City of Everett), Eagle Harbor (City of Winslow), Elliott Bay (City of Seattle), Sinclair Inlet (City of Bremerton), Commencement Bay (City of Tacoma), and Budd Inlet (City of Olympia). These areas are either now, or soon will be, the focus of U.S. EPA action programs to characterize the urban site's contamination problems and recommend remedial action alternatives.

The information in this report is grouped into the 12 regions of Puget Sound (Figure 2) used in the Puget Sound Environmental Atlas (Evans Hamilton, Inc., and D.R. Systems, Inc. 1987). Within each region, summaries for specific sites are presented in alphabetic order by site name. Datapoints are plotted on each regional map; the accuracy of the positions on the maps is dependent on the amount of detail that was available in the original source of information. In many instances, only the city in which a facility was located was cited.

SOURCES AND TYPES OF INFORMATION

Three categories of information are included in this report: sources of toxic substances, sediment condition, and biological impacts. These categories are consistent with the types of information used by PSEP's Urban Bay Action Program for assessment of environmental degradation in urban portions of Puget Sound.

The information contained in this report was obtained from a variety of existing sources; site inspections and field studies were beyond the scope of the project. The principle sources of information included the scientific literature; reports published by the federal governments of the United States and Canada and by state and local agencies; unpublished federal and state agency file documents; and reports generated by the private sector. Additional information was obtained from interviews with environmental professionals familiar with Puget Sound.



LEGEND

1. Andrews Bay
2. Friday Harbor
3. Deer Harbor
4. West Sound
5. Fisherman's Bay
6. Lopez Sound
7. Blakely Island
8. East Sound
9. Doe Bay
10. Semiahmoo Bay
11. Hale Passage
12. Lummi Island
13. Guemes Channel
14. Fidalgo Bay
15. Cornet Bay-Deception Pass
16. Similk Bay
17. Dugualla Bay
18. Oak Harbor
19. Cresent Harbor
20. Penn Cove
21. Utsalady Bay
22. Livingston Bay
23. Admiralty Bay
24. Sequim Bay
25. Discovery Bay
26. Kilisut Harbor
27. Holmes Harbor
28. Tulalip Bay
29. Mutiny Bay
30. Useless Bay
31. Port Ludlow
32. Cultus Bay, Sandy Point
33. Quilcene Bay
34. Port Gamble
35. Appletree Cove
36. President Point
37. Richmond Beach
38. Liberty Bay
39. Port Madison
40. Carkeek Park
41. Meadow Point
42. Shilshole Bay
43. West Point
44. Dyes Inlet
45. Port Orchard
46. Rich Passage
47. Manchester
48. Port Blakely
49. Blake Island
50. Alki Point
51. Point Williams
52. Colvos Passage
53. Quartermaster Harbor
54. Dalcos Passage
55. Gig Harbor
56. Henderson Bay
57. Hale Passage
58. Wollochet Bay
59. The Narrows/Cormorant
60. Drayton Passage
61. Filuce Bay
62. Nisqually Reach
63. Henderson Inlet
64. Dana & Pesle Passage
65. Eld Inlet
66. Totten Inlet
67. Skookum Inlet
68. Hammersley Inlet
69. Oakland Bay
70. Pickering Passage

Nonurban Area Boundary
Urban Bay

0 5 10 miles
0 5 10 kilometers

Figure 1. Locations of Puget Sound basins and bays.

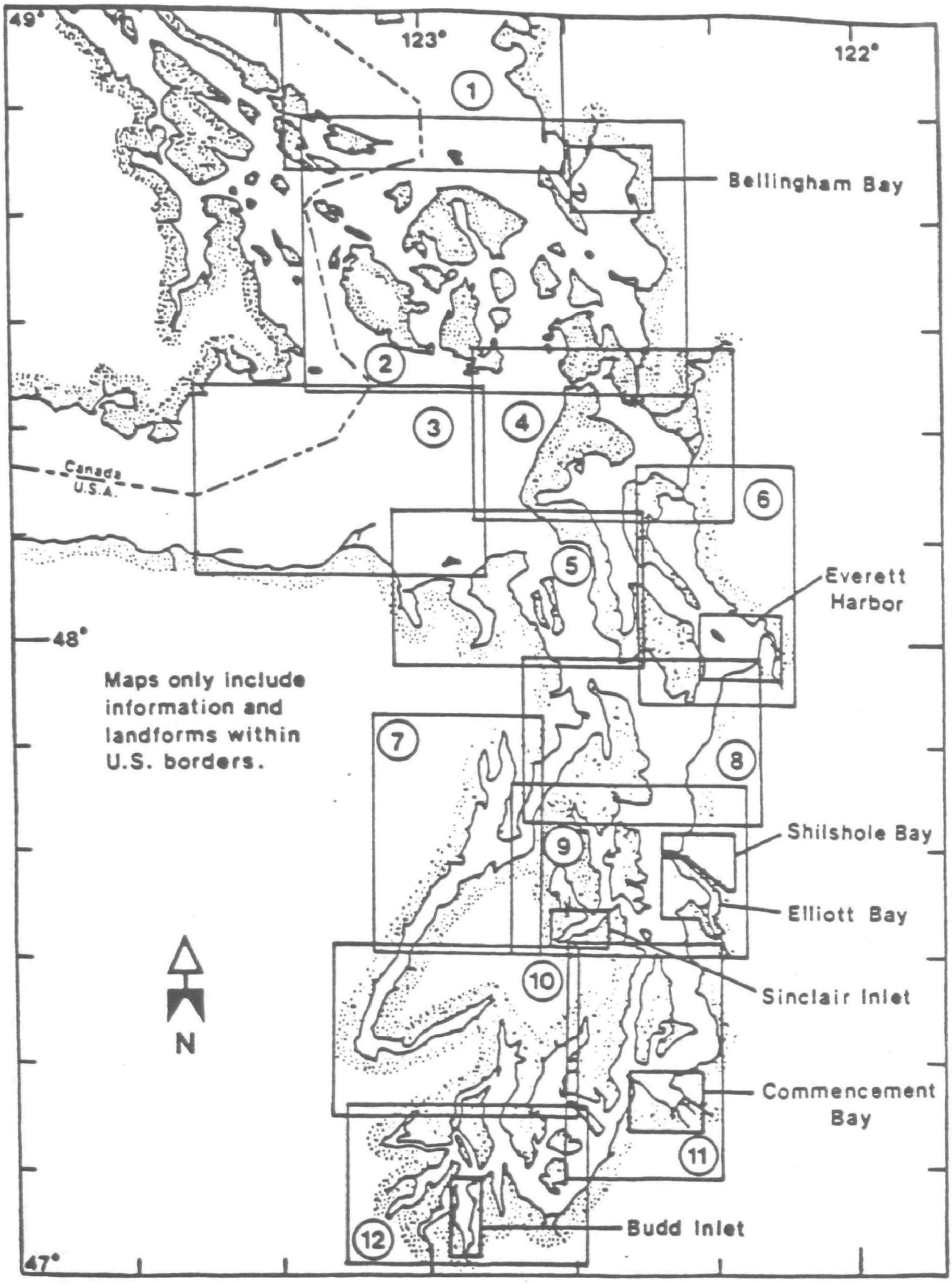


Figure 2. Index map of Puget Sound showing Regions 1 - 12 and the seven embayments.

Sources of Toxic Substances

Information on possible sources of toxic substances is included in this report to determine whether contamination might be expected to exist in an area. These sources included permitted industrial and municipal discharges and hazardous waste sites. This information was used to evaluate sites that had not been sampled.

The industries and other dischargers discussed in this report are included because of their capacity for generating toxic wastes or by-products. Information regarding the volume and types of chemicals released by these dischargers was not generally available. Within a given industry, the potential for the release of toxic materials is dependent on the processes used. Detailed evaluations of the releases at individual sites were beyond the scope of this project. Permitted dischargers and hazardous waste generators are merely noted. Sewage discharges are partitioned by the volume of the effluent into large and small sources. Hazardous waste sites are evaluated according to available information. A substantial portion of the information on discharges was obtained from state agency listings of permitted discharges. Over 400 municipal and industrial dischargers are permitted to release effluents in the counties bordering Puget Sound under the National Pollutant Discharge Elimination System (NPDES) [Puget Sound Water Quality Authority (PSWQA) 1986]. Lists of NPDES permitted and indirect dischargers (current through 1985) were obtained from the State of Washington Department of Ecology (Ecology). Several historical lists of manufacturers were also obtained (e.g., Puget Sound Lumberman 1893; Manufacturers Association of Washington 1926; Pacific Pulp and Paper Industry 1932). Other historical information on possible dischargers and hazardous waste generators was obtained from sources such as U.S. Federal Water Pollution Control Agency (FWPCA) and a listing of marinas (Oceanographic Institute of Washington 1978).

A substantial portion of the information on hazardous waste sites was obtained from governmental files and reports. Two major listings of hazardous waste sites were obtained from Ecology (Ecology 1986a, 1986b). These lists included existing and proposed National Priorities List (Superfund) and other sites under investigation or remediation. Other current information was obtained from the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) list (U.S. EPA 1986b) and the Defense Environmental Restoration Program (DERP) site inventory (U.S. Department of Defense 1985). Historical information on hazardous waste sites was obtained from Stradley et al. (1975) and House of Representatives (1979). The authors realize that the marina size data (Ocean Institute 1978) presented herein is dated, but this information is the most recent survey of its kind.

Sediment Condition

Sediment condition is evaluated in this report for sites where sediment chemistry data are available. Toxic chemicals in the water column generally adsorb onto suspended particulate matter and become incorporated into

sediments (Stumm and Morgan 1983). Contaminated sediments are known to alter benthic community structure and introduce toxic chemicals into the food chain. Therefore, sediment chemistry data provide an important index of environmental contamination. Unfortunately, sediment chemistry data are relatively rare for sites outside of the urban areas of Puget Sound. Much of the data from such sites were originally obtained to serve as reference values in studies of contaminated urban areas.

Two indices of sediment contamination are included in this report: Elevation Above Reference (EAR) and Apparent Effects Threshold (AET). Both indices are used in EPA's Urban Bay Approach [Elliott Bay Action Program: Evaluation of Potential Contaminant Sources (Tetra Tech 1988)].

EAR compares the concentration of a chemical at a study site to that measured at a reference site where the contaminant is assumed to be at "background" concentrations. Thus, EAR does not provide direct evidence that the particular chemical is causing environmental degradation. EAR for a given chemical at a given site is calculated by dividing the highest measured concentration of that chemical at the site, assuming a sample number > 1, by the mean concentration of that chemical at the reference site. In keeping with EPA studies of urban bays [e.g., Commencement Bay (Tetra Tech 1985b)], chemical concentrations in Carr Inlet were used to calculate the EAR values. The concentrations of chemicals that were used as reference values are given in Table 1.

In the Puget Sound Estuary Program, determination of significant contamination for a given chemical in sediments is based on comparisons with the maximum concentration for that chemical in Puget Sound wide reference areas. However, such a determination was beyond the scope of this investigation. In this report, the degree of EAR (above Carr Inlet) is simply used to state the potential severity of chemical contamination and to classify sites in terms of need for further study. Thus the concentration of a chemical at a site is considered highly elevated above the reference value, if EAR > 10.

AET values are used to indicate whether the concentration of a chemical in an area is higher than the concentration known to be associated with environmental impacts. An AET is defined as a sediment concentration of a chemical above which adverse biological effects are always observed (Tetra Tech 1986). Thus, AET values are empirically derived from existing data and are used to predict impacts at sites where biological studies have not been conducted.

In this report, AET values are considered to be exceeded when the concentration of a given chemical exceeds the lowest AET concentration established for either sediment bioassays on the amphipod, Rhepoxynius abronius, the larvae of the oyster, Crassostrea gigas, or depression of the abundance of a major taxon (i.e., polychaetes, molluscs, or crustaceans) in the benthic community. Because of its extreme sensitivity and ongoing refinement of the methodology, bioassay data for the luminescent bacterium, Photobacterium phosphoreum was not used. When more than one sediment sample

TABLE 1. CARR INLET MEAN REFERENCE VALUES FOR ORGANIC CHEMICALS (UG/KG DRY WEIGHT) AND TRACE METALS (MG/KG DRY WEIGHT)

CHEMICAL	MEAN CONCENTRATION
TOTAL LOW MOLECULAR WEIGHT PAH (LPAH)	40.74
Acenapthene	3.50
Acenapthylene	3.50
Anthracene	7.63
Fluorene	4.10
Naphthalene	5.73
Phenanthrene	10.83
TOTAL HIGH MOLECULAR WEIGHT PAH (HPAH)	78.70
Benzo(a)anthracene	5.88
Benzo(a)pyrene	5.72
Benzo(g,h,i)perylene	4.60
Total benzofluoranthenes	12.60
Chrysene	9.87
Dibenzo(a,h)anthracene	4.08
Fluoranthene	15.17
Indeno(1,2,3-c,d)pyrene	4.80
Pyrene	13.83
TOTAL PCB's	6.00
TOTAL CHLORINATED BENZENES	20.83
1,2-Dichlorobenzene	3.50
1,3-Dichlorobenzene	3.50
1,4-Dichlorobenzene	3.50
Hexachlorobenzene (HCB)	6.83
1,2,4-Trichlorobenzene	3.50
TOTAL ORGANIC ACIDS (PHENOLS)	
2,4-Dimethylphenol	6.83
Pentachlorophenol	33.43
Phenol	327.67
2,4,5-Trichlorophenol	10.00
TOTAL CHLORINATED BUTADIENES (CBD)	62.33
TOTAL TRICHLORINATED BUTADIENES	15.17
TOTAL TETRACHLORINATED BUTADIENES	15.17

TABLE 1. (Continued)

CHEMICALS	MEAN CONCENTRATION
TOTAL PENTACHLORINATED BUTADIENES	15.17
MISCELLANEOUS EXTRACTABLES	
1,1-Biphenyl	1.00
Dibenzothiophene	1.00
Hexachorobutadiene	16.83
2-Methylnaphthalene	3.67
1-Methylphenanthrene	1.00
N-nitrosodiphenylamine	4.10
Retene	26.87
TOTAL PHTHALATES	
Bis(2-ethylhexyl)phthalate	16.83
Butyl benzyl phthalate	16.83
Diethyl phthalate	11.00
Dimethyl phthalate	40.10
Di-n-butyl phthalate	174.00
Di-n-octyl phthalate	20.10
METALS	
Antimony	0.11
Arsenic	3.37
Barium	6.88
Beryllium	0.09
Cadmium	1.50
Chromium	14.82
Copper	6.37
Iron	8755.00
Lead	9.20
Manganese	109.67
Mercury	0.04
Nickel	17.38
Selenium	0.70
Silver	0.09
Thallium	0.16
Zinc	18.95

Reference: Tetra Tech (1985b)

has been analyzed for a particular chemical at a site, the highest concentration measured is used in this report for comparison to the AET for that chemical..

Biological Impacts

Four types of biological indexes are used in this report to measure the extent of environmental degradation: bioassays, bioaccumulation, fish histopathological abnormalities, and fish kill information. Because of the lack of a substantial database, several other types of biological information were excluded from the report [e.g., invertebrate pathology, chemical analysis of fish stomach contents and bile, indices of community structure (e.g.,species diversity)]. Criteria used to interpret the four impacts analyzed are summarized below.

Bioassays--

The development of toxic conditions in sediments and the water column is an important indication of an environmental impact (Tetra Tech 1986). Toxicity of sediments and water is measured by mortality and/or developmental abnormalities that occur in test organisms during laboratory studies. Rates of mortality or developmental abnormality above 40 percent per test interval are considered significant in this report. These levels are consistent with those used in the Puget Sound Environmental Atlas (Evans Hamilton, Inc. and D.R. Systems, Inc. 1987) and the Elliott Bay Action Plan (Tetra Tech 1987). Because low salinity may cause mortality or developmental abnormalities in marine bioassay organisms (Cardwell et al. 1979), bioassays in which the test salinity was <20 ppt were excluded from consideration.

Unfortunately, some studies only indicate whether mortality and abnormality rates exceeded 50 percent. Control information was not always discussed. In the absence of raw data, it was necessary to use a significance criterion of 50 percent mortality or abnormality. These exceptions are noted where they occur in the report.

Bioaccumulation--

The concentrations of chemical contaminants may become elevated in the tissues of organisms that inhabit contaminated areas. Bioaccumulation in muscle and liver tissue of English sole (Parophrys vetulus) and muscle tissue of Dungeness crab (Cancer spp.) are included in this report. Bioaccumulation data for other organisms (e.g., macroalgae) were unavailable. Tissue concentrations of individual organic compounds and metals are considered elevated if they exceed 5x the mean tissue concentration in specimens collected in two reference areas, Carr Inlet and Discovery Bay (Table 2).

Fish Histopathology--

The prevalence of adverse pathological conditions in the livers of

TABLE 2. SELECTED BIOACCUMULATION DATA FOR PUGET SOUND REFERENCE AREAS[f]

PPB	Pollutant	Malins et al. 1980 English sole, liver Port Madison (1.1)g	Malins et al. 1980 English sole, liver Case Inlet (1.1)g	Tetra Tech, 1985a English sole, liver Carr Inlet (normal) (20,2)g	Gahler et al. 1982 English sole, muscle Discovery Bay (1.5)g	Tetra Tech, 1985a English sole, muscle Carr Inlet (1.4-10)g	Gahler et al. 1982 Dungeness crab, muscle Discovery Bay (4,4)g	Tetra Tech, 1985a Cancer spp., muscle Carr Inlet (1.7)g
	Phenols							
65	phenol			U 50.000	U 10.000	U 20.00	U 10.000	U 23.00
34	2,4-dimethylphenol			U 50.000	U 20.000	U 20.00	U 20.000	U 20.00
	Substituted Phenols							
21	2,4,6-trichlorophenol			U 100.000	U 80.000	U 20.00	U 80.000	U 20.00
22	para-chloro-meta cresol			U 50.000	U 40.000	U 20.00	U 40.000	U 20.00
24	2-chlorophenol			U 50.000	U 10.000	U 20.00	U 10.000	U 20.00
31	2,4-dichlorophenol			U 50.000	U 40.000	U 20.00	U 40.000	U 20.00
57	2-nitrophenol			U 50.000	U 20.000	U 20.00	U 20.000	U 20.00
58	4-nitrophenol			U 200.000	U 2000.000	U 100.00	U 2000.000	U 100.00
59	2,4-dinitrophenol			U 200.000	U 4100.000	U 100.00	U 4100.000	U 100.00
60	4,6-dinitro-o-cresol			U 200.000	U 250.000	U 25.00	U 250.000	U 25.00
64	pentachlorophenol			U 200.000	U 40.000	U 68.00	U 40.000	U 80.00
	Organonitrogen Compounds							
5	benzidine							
28	3,3'-dichlorobenzidine							
35	2,4-dinitrotoluene			U 100.000	U 50.000	U 20.00	U 50.000	U 20.00
36	2,6-dinitrotoluene			U 50.000	U 20.000	U 20.00	U 20.000	U 20.00
37	1,2-diphenylhydrazine			U 50.000	U 5.000	U 10.00	U 5.000	U 10.00
56	nitrobenzene			U 50.000	U 10.000	U 20.00	U 10.000	U 20.00
61	N-nitrosodimethylamine				U 500.000		U 500.000	
62	N-nitrosodiphenylamine			U 50.000	U 30.000	U 10.00	U 30.000	U 10.00
63	N-nitrosodipropylamine			U 50.000	U 500.000	U 20.00	U 500.000	U 20.00
	Low Molecular Weight Aromatic Hydrocarbons							
1	acenaphthene	< 1.20	< 1.050	U 25.000	U 10.000	U 10.00	U 10.000	U 10.00
35	naphthalene	< 1.20	< 1.050	< 92.500	U 2.000	54.00	U 2.000	U 10.00
77	acenaphthylene	< 1.20	< 1.050	U 25.000	U 2.000	U 10.00	U 2.000	U 10.00
78	anthracene	< 1.40	< 1.260	U 25.000	U 5.000	U 10.00	U 5.000	U 10.00
81	phenanthrene	< 1.20	< 1.050	U 25.000	U 5.000	U 10.00	U 5.000	U 10.00
80	fluorene	< 1.20	< 1.050	U 25.000	U 5.000	U 10.00	U 5.000	U 10.00
	High Molecular Weight PAH							
39	fluoranthene	< 1.40	< 1.260	U 25.000	U 30.000	U 10.00	U 30.000	U 10.00
72	benzo(a)anthracene	< 4.00	< 2.100	U 25.000	U 70.000	U 10.00	U 70.000	U 10.00
73	benzo(a)pyrene	< 2.00	< 1.890	U 25.000	U 40.000	U 10.00	U 40.000	U 10.00
74	benzo(b)fluoranthene	< 2.00 a	< 1.890 a	U 25.000	U 200.000	U 10.00	U 200.000	U 10.00
75	benzo(k)fluoranthene			U 25.000	U 60.000	U 10.00	U 60.000	U 10.00
76	chrysene	< 1.80	< 1.680	U 25.000	U 60.000	U 10.00	U 60.000	U 10.00
79	benzo(ghi)perylene			U 25.000	U 300.000	U 10.00	U 300.000	U 10.00
82	dibenzo(a,h)anthracene			U 50.000	U 240.000	U 10.00	U 240.000	U 10.00
83	indeno(1,2,3-cd)pyrene			U 25.000	U 300.000	U 10.00	U 300.000	U 10.00
84	pyrene	< 1.40	10.500	U 25.000	U 20.000	U 10.00	U 20.000	U 10.00
	Chlorinated Aromatic Hydrocarbons							
8	1,2,4-trichlorobenzene			U 50.000	U 20.000	U 20.00	U 20.000	U 20.00
9	hexachlorobenzene	2.00	2.100	U 25.000	U 1.000	U 10.00	U 1.000	U 10.00
20	2-chloronaphthalene			U 25.000	U 5.000	U 10.00	U 5.000	U 10.00
29	1,2-dichlorobenzene	4.40 b	< 0.400 b	U 50.000	U 5.000	U 20.00	U 5.000	U 20.00
26	1,3-dichlorobenzene			U 50.000	U 5.000	U 20.00	U 5.000	U 33.00
27	1,4-dichlorobenzene			U 50.000	U 5.000	U 20.00	U 5.000	U 20.00

TABLE 2. (Continued)

PPO	Pollutant	Malins et al. 1980 English sole, liver Port Madison	Malins et al. 1980 English sole, liver Case Inlet	Tetra Tech, 1985a English sole, liver Carr Inlet (normal)	Gahler et al. 1982 English sole, muscle Discovery Bay	Tetra Tech, 1985a English sole, muscle Carr Inlet	Gahler et al. 1982 Dungeness crab, muscle Discovery Bay	Tetra Tech, 1985a Cancer spp., muscle Carr Inlet
	Chlorinated Aliphatic Hydrocarbons							
52	hexachlorobutadiene	0.20	< 0.210	U 50.000	U 30.000	U 40.00	U 30.000	U 40.00
12	hexachloroethane			U 100.000	U 10.000	U 40.00	U 10.000	U 40.00
53	hexachlorocyclopentadiene				U 500.000		U 500.000	
	Halogenated Ethers							
18	bis(2-chloroethyl)ether			U 50.000	U 5.000	U 20.00	U 5.000	U 20.00
40	4-chlorophenyl ether			U 25.000	U 200.000	U 10.00	U 200.000	U 10.00
41	4-bromophenyl ether			U 50.000	U 40.000	U 10.00	U 40.000	U 10.00
42	bis(2-chloroisopropyl)ether			U 50.000	U 5.000	U 20.00	U 5.000	U 20.00
43	bis(2-chloroethoxy)methane			U 50.000	U 5.000	U 20.00	U 5.000	U 20.00
	Phthalates							
66	bis(2-ethylhexyl)phthalate			U 25.000	U 10.000	35.00	U 10.000	1331.00
67	butyl benzyl phthalate			U 25.000	U 20.000	U 10.00	U 20.000	U 10.00
68	di-n-butyl phthalate			< 512.000	U 3.000	21.00	U 3.000	540.00
69	di-n-octyl phthalate			U 25.000	U 10.000	18.00	U 10.000	53.00
70	diethyl phthalate			U 25.000	U 50.000	U 10.00	U 50.000	U 10.00
71	dimethyl phthalate			U 25.000	U 5.000	U 10.00	U 5.000	U 10.00
	PCBs							
106-112	ΣPCBs	>94.00	336.000	260.000	< 13.000	36.00	U 10.000	22.00
	Miscellaneous Oxygenated Compounds							
129	TCDD (dioxin)							
54	isophorone			U 25.000		U 10.00		U 10.00
	Pesticides							
89	aldrin	< 0.08	< 0.042	U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
90	dieldrin			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
91	chlordane	< 0.08 c	< 0.042 c	U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
92	4,4'-DDT	12.00	6.300	U 100.000	< 1.000 e	U 50.00	U 1.000 e	U 50.00
93	4,4'-DDE	20.00 d	12.600 d	U 100.000	3.000 e	U 50.00	5.000 e	U 50.00
94	4,4'-DDD			U 100.000	U 1.000 e	U 50.00	U 1.000 e	U 50.00
95	alpha-endosulfan			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
96	beta-endosulfan			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
97	endosulfan sulfate			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
98	endrin			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
99	endrin aldehyde			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
100	heptachlor	< 0.08	< 0.105	U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
101	heptachlor epoxide			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
102	alpha-HCH			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
103	beta-HCH			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
104	delta-HCH			U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
105	gamma-HCH	< 0.08	< 0.063	U 100.000	U 1.000	U 50.00	U 1.000	U 50.00
113	toxaphene				U 1.000		U 1.000	
	Volatile Haloyenated Alkanes							
6	tetrachloromethane				U 10.000	U 5.00	U 10.000	
10	1,2-dichloroethane				U 10.000	U 10.00	U 10.000	
11	1,1,1-trichloroethane				U 10.000	U 5.00	U 10.000	
13	1,1-dichloroethane				U 10.000	U 5.00	U 10.000	
14	1,1,2-trichloroethane				U 10.000	U 5.00	U 10.000	
15	1,1,2,2-tetrachloroethane				U 10.000	U 5.00	U 10.000	
16	chloroethane				U 10.000	U 10.00	U 10.000	
23	chloroform				U 10.000	U 5.00	U 10.000	
32	1,2-dichloropropane				U 10.000	U 10.00	U 10.000	
44	dichloromethane				U 10.000		U 10.000	
45	chloromethane				U 10.000	U 10.00	U 10.000	
46	bromomethane				U 10.000	U 10.00	U 10.000	
47	bromoform				U 10.000	U 10.00	U 10.000	
48	dichlorobromomethane				U 10.000	U 5.00	U 10.000	
51	chlorodibromomethane				U 10.000	U 5.00	U 10.000	

TABLE 2. (Continued)

PPB	Pollutant	Malins et al. 1980 English sole, liver Port Madison	Malins et al. 1980 English sole, liver Case Inlet	Tetra Tech, 1985a English sole, liver Carr Inlet (normal)	Ganier et al. 1982 English sole, muscle Discovery Bay	Tetra Tech, 1985a English sole, muscle Carr Inlet	Kahler et al. 1982 Dungeness crab, muscle Discovery Bay	Tetra Tech, 1985a Cancer spp., muscle Carr Inlet
	Volatile Halogenated Alkenes							
29	1,1-dichloroethylene				U 10.000	U 5.00	U 10.000	
30	1,2-trans-dichloroethylene				U 10.000	U 5.00	U 10.000	
33	1,3-dichloropropene				U 20.000	U 20.00	U 20.000	
85	tetrachloroethylene				U 10.000	7.00	U 10.000	
87	trichloroethylene				U 10.000	U 5.00	U 10.000	
88	vinyl chloride				U 10.000	U 10.00	U 10.000	
	Volatile Aromatic Hydrocarbons							
4	benzene				U 10.000	U 5.00	U 10.000	
38	ethylbenzene				U 10.000	U 5.00	U 10.000	
86	toluene				U 10.000	11.00	U 10.000	
	Volatile Chlorinated Aromatic Hydrocarbons							
7	chlorobenzene				U 10.000	U 5.00	U 10.000	
	Volatile Unsaturated Carbonyl Compounds							
2	acrolein				U 200.000	U 100.00	U 200.000	
3	acrylonitrile				U 100.000	U 100.00	U 100.000	
	Volatile Ethers							
19	2-chloroethylvinylether				U 10.000	U 100.00	U 10.000	
	Metals							
114	antimony				U 0.070	< 1.07	U 0.070	U 1.00
115	arsenic				3.200	7.94	7.200	2.37
117	beryllium			U 0.001	U 0.005		U 0.005	
118	cadmium	1.49U		0.40U	< 0.006	< 0.02	0.021	0.15
119	chromium	U			0.060	< 0.19	0.060	< 0.24
120	copper	3.060		7.200	0.420	U 0.38	4.300	5.06
122	lead				0.460	0.22	0.360	< 0.20
123	mercury			0.06U	0.04U	< 0.06	0.07U	< 0.04
124	nickel	U		0.380	0.230	< 0.12	1.600	< 0.11
125	selenium				U 0.070	< 0.17	U 0.070	< 0.14
126	silver	U		0.160	U 0.010	0.01	0.195	0.20
127	thallium			< 0.020	U 0.040		U 0.04U	
128	zinc	28.400		24.600	5.200	3.72	52.600	47.43

[a]Values are for benzofluoranthenes, presumably both (b) and (k) isomers.

[b]Author does not specify which isomer of dichlorobenzene.

[c]Values are for α-chlordane only.

[d]Values are for both o,p and p,p isomers.

[e]Value is assumed to represent both o,p and p,p isomers.

[f]Organic compounds reported as ppb wet weight. Metals reported as ppm wet weight.
Blank indicates that analysis was not conducted for that chemical.

[g]First number in parentheses is the number of individual organisms per sample.
Second number is the number of replicate samples represented by values in table.
"N" indicates that information on sample size was not available.

bottomfishes is strongly associated with high concentrations of toxic contaminants in sediments (Malins et al. 1987). Three conditions of the livers of bottomfishes are included as indices of pathology: neoplasms, pre neoplasms, and megalocytic hepatosis (Tetra Tech 1985b). Data from the English sole (Parophrys vetulus) comprise the majority of the available information.

The criteria for assessing the significance of the frequency of the three pathological conditions used in this report are >5 percent for neoplasms and >15 percent for pre-neoplasms and megalocytic hepatosis. These criteria are consistent with those used in the Puget Sound Environmental Atlas (Evans Hamilton, Inc. and D.R. Systems, Inc. 1987).

Fish Kills--

Fish kills may be induced by the presence of toxic substances (e.g., from a spill) or by other adverse environmental conditions (e.g., low dissolved oxygen concentrations or a disease). Information concerning fish kills is included in this report regardless fo whether the cause of the kill is known to be related to toxic chemicals or is unknown. Fish kills believed to be caused by low dissolved oxygen concentrations were excluded from the report. Information on fish kills was obtained from Kittle (March 1987, personal communication) and from LeVander (1987).

ASSESSMENT MATRICES

For each site included in the study, source data, sediment condition, and biological impact information was incorporated into an environmental assessment matrix which ranked the sites within a given region of the sound according to the extent of their possible contamination. In the assessment matrices, the data in each of these categories were evaluated for 1) the level of concern (LOC) or attention that an area should received based upon available contaminant information and 2) the degree of certainty (DOC) or probability that the information assessed, hence LOC, is correct. Ratings of low, medium, and high were assigned separately for LOC and DOC for each data category, based on criteria given in Table 3.

Overall ratings were obtained by calculating the mean of the ratings based on sources of toxic substances, sediment condition, and biological impacts. The data in these categories are reported qualitatively, but, to calculate mean ratings for LOC and DOC, values of 1, 2, and 3 were given to the low, medium, and high ratings (respectively) for each data category. These means were converted back to qualitative ratings by rounding to the nearest whole number and assigning a low, medium, or high value accordingly. If data were not available for a particular category of information (e.g.,sediment condition), that category was excluded from determination of the overall ratings.

TABLE 3. CRITERIA USED IN ASSESSMENT MATRICES FOR LEVEL OF CONCERN (LOC) AND DEGREE OF CERTAINTY (DOC)

SOURCES OF TOXIC SUBSTANCES

LEVEL OF CONCERN

Rank	Criterion
N/A	- No information available (i.e., no reported sources present)
LOW	- One or more of the following sources present o Historical lumber mill or manufacturer o NPDES/state permitted sources o Small sewage outfall (<5 MGD) o Anecdotal information on historical sources o CERCLIS site with low hazard potential o Small marina (<400 slips) with no repair facilities
MEDIUM	- One or more of the following sources present o Hazardous waste generator o Large sewage outfall (>5 MGD) o CERCLIS site with observed or inferred leakage o Large marina (>400 slips) with repair facilities o U.S. Department of Defense DERA/DERP site
HIGH	- Presence of confirmed uncontrolled source o Designated National Priorities List (NPL, i.e., Superfund) site

DEGREE OF CERTAINITY

Assigned individually, based on the apparent reliability of the data (e.g., discharges from permitted sources were assigned a high degree of certainty; inputs from marinas were assigned a low degree of certainty).

TABLE 3. (Continued)

SEDIMENT CONDITION

LEVEL OF CONCERN

Rank	Criterion
N/A	- No information available
LOW	- EAR < 10x for all toxic chemical concentrations at all stations
MEDIUM	- EAR > 10x for one or more toxic chemical concentrations at any station
HIGH	- AET exceeded for one or more toxic chemical concentrations at any station

DEGREE OF CERTAINITY

Rank	Criterion
N/A	- Not available (i.e., no stations sampled)
LOW	- 1 to 4 stations sampled
MEDIUM	- 5 to 9 stations sampled
HIGH	- 10 or more stations sampled

TABLE 3. (Continued)

BIOLOGICAL INDEXES

LEVEL OF CONCERN

Rank	Criterion
N/A	- No information available
LOW	- No statistically significant response of a biological index
MEDIUM	- 1 statistically significant response of a biological index
HIGH	- 2 or more statistically significant responses of biological indices

DEGREE OF CERTAINITY

N/A	- No information available
LOW	- 1 biological index measured
MEDIUM	- 2 biological indices measured
HIGH	- 3 or more biological indices measured

Qualitative values of LOC and DOC are used in the assessment matrices because the purpose of this report is to provide an initial screening of available information rather than to produce an in-depth determination of the contaminant problems experienced in specific areas. Moreover, the types and amounts of available data vary widely among sites, precluding the use of a quantitative, statistical approach. For example, a statistical test cannot determine whether a moderate level of sediment toxicity that is based on 25 samples in one area is significantly more important (or less important) problem than is a large, but unsampled, source of toxic substances in another area.

TOXIC PROBLEM ASSESSMENT OF REGION 1:
STRAIT OF GEORGIA
(Figure 3)

BIRCH BAY

Rank Low

Sources

The only known source of toxic materials in Birch Bay is a small marina which has fuel and repair facilities available on-site (Ocean. Inst. 1978).

Sediment Condition

Chapman et al. (1982), summarizing of the work of Brown et al. (1981), reported low PAH concentrations in sediments and mussels at five stations located in Birch Bay. Elevations above reference were not calculated for these chemicals.

Toxicity Indexes

Oyster Larvae Receiving Water Bioassay--

Oyster larvae mortalities exceeded 50 percent at one mid-bay station in Birch Bay in 1968 (Cardwell and Woelke 1979). Oyster larvae abnormalities were not observed to be elevated during the period of study.

Other Bioassays--

Surface sediment (top 6 cm) was collected at five stations in Birch Bay (Chapman et al. 1982). Bioassays were performed with the oligochaete Monopylephorus cuticulatus, the amphipod Eogammarus confervicolus, and the threespine stickleback (Gasterosterus aculeatus). No substantial mortalities or abnormalities were observed using the Birch Bay sediments. Mortality rates were less than 15 percent at all stations.

BOUNDARY BAY

Rank Low

Sources

A spill of 45,000 liters of sodium tetra/pentachlorophenates (salts of chlorophenols) occurred at the Cloverdale Paint plant at Hyland Creek on 4 March 1984 (Colodey 1986).

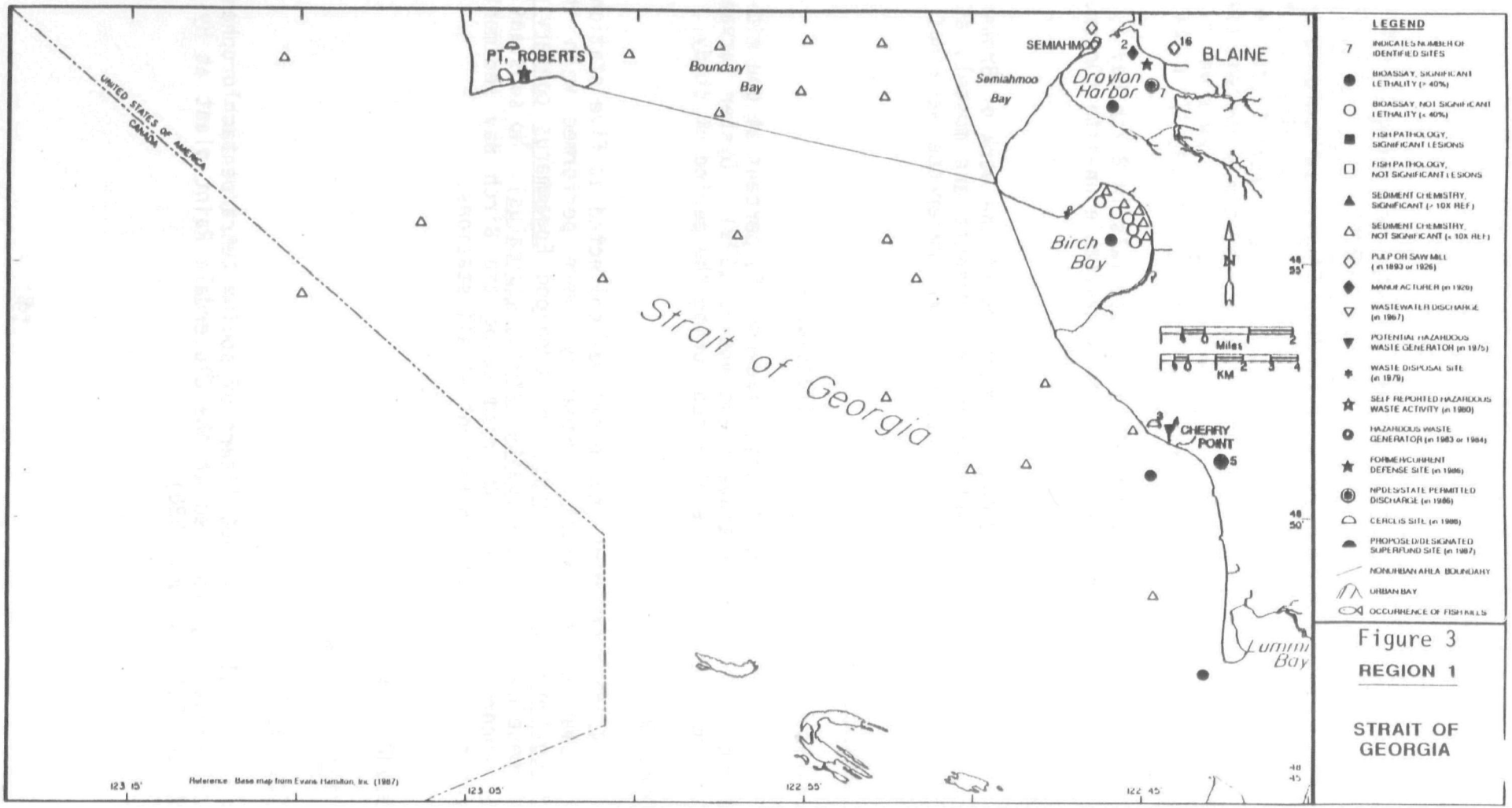


Figure 3

REGION 1

STRAIT OF GEORGIA

Sediment Condition

Between March 1984 and March 1985, Colodey (1986) collected sediment samples from seven stations in the U.S. portion of Boundary Bay and from seven stations in the Strait of Georgia. Sediments were analyzed for chlorophenols, PCBs, dioxins and furans. None of these chemicals were detected. Colodey concluded that rapid dilution and dispersion apparently prevented the spilled chlorophenates from adsorbing into the sediments.

Toxicity Indexes

Fish Kills--

Over 5,000 fish were killed in Hyland Creek and the Serpentine River as a result of the chlorophenate spill of 4 March 1984 (Colodey 1986). The marine impact was less severe. Small numbers of marine fish, including flounder and sculpins, were killed at the mouth of the Serpentine River.

Bioaccumulation in Tissues--

Colodey (1986) sampled oysters and crabs between March 1984 and March 1985. Tissue samples were analyzed for chlorophenols and for chlorinated dibenzo-dioxins and dibenzo-furans which may be present in chlorophenate solutions and for PCBs which may be a source of furans. Tissue samples collected 5 weeks after the spill showed high chlorophenate concentrations. However, 11 weeks after the spill, chlorophenates were not detected in the tissues. Very low levels of dioxins and furans were measured in crab hepatopancreas tissue taken from Boundary Bay and Cates Park in 1985. The bioaccumulation results are not mapped.

Benthic Community Impacts--

According to Colodey (1986), benthic communities were not adversely affected by the chlorophenate spill in Boundary Bay. Sediment samples taken 5 weeks after the spill showed a healthly, diverse benthic community.

CHERRY POINT

Rank Medium

Sources

There are four hazardous waste generators (U.S. EPA no date) and five point sources with National Pollutant Discharge Elimination System (NPDES) permits at Cherry Point (U.S. EPA 1986). The NPDES permittees are the Atlantic Richfield Company (ARCO) refinery, Mobile Oil petroleum refinery, Intalco Aluminum Corporation, and Liquid Carbonic Corporation. The ARCO, Intalco, and Mobile Oil Corporation sites are listed on the 1987 CERCLIS (U.S. EPA 1987) register as potential hazardous waste sites. These facilities are discussed in detail below.

Atlantic Richfield Company--

The ARCO refinery at Cherry Point was listed as a potential hazardous waste site (CERCLIS 1986). The refinery produces gasoline and other fuels at a crude rate of 100,000 bbl/day (U.S. EPA no date). Hazardous wastes are generated and stored at the Cherry Point Refinery. This site was used for hazardous waste disposal from 1972-1979 (U.S. House of Representatives 1979) and is a potential source of lead contamination from leaded tank bottoms and a Bender catalyst (U.S. EPA no date). By 1979, approximately 3,200 tons of metallic, organic, inorganic, and miscellaneous waste materials had been stored in pits, ponds, or lagoons, by land farming or neutralization treatment (U.S. EPA no date).

A preliminary assessment conducted at this site found measurable soil contamination and potential groundwater contamination (CERCLIS 1987). Concentrations of chlorobrompropane in soils were measured at 21.0 mg/L. According to a preliminary assessment conducted by the U.S. EPA, this site is in compliance with (CERCLIS 1987). The company disposes of oily sludge and low-lead tank bottoms using landfarming practices that are approved procedures for handling this waste. Heat exchanger corrosion products are used as landfill at this site. Organic chemicals in groundwater samples did not show elevated concentrations. However, the regional geologist who worked on the site inspection observed that the "down-gradient monitoring wells are not at locations suited to monitor the land farming operation and that the interim detection monitoring program is inadequate" (Sceva, J., 12 September 1984, personal communication).

Intalco Aluminum Corporation--

Intalco Aluminum Corporation produces 26,000 tons/mo of aluminum and is a U.S. EPA CERCLIS site (1986). In the mid-1970s, this plant was permitted to discharge 570 lbs/day of fluoride (U.S. EPA no date). Also, an estimated 400-1,000 tons/mo of spent potlining material was stockpiled at this site in the mid-1970s (U.S. EPA no date). The results of a preliminary assessment of this site were obtained from CERCLIS files (U.S. EPA 1987). At least 11 areas on site have been used for dumping at least 272,000 tons of potliners and other wastes. The current dumpsite is atop a concrete pad which has a runoff collection system. The older dumpsites were not syntheticaly lined, althought wastes were contained by an impermeable, natural clay liner. Waste piles cover approximately 40 to 70 ac. Potliners and similar wastes contain unknown amounts of cyanide and fluoride. Baghouse interceptors, disposed of at this site, contain fairly high concentrations of PAHs. Large amounts of hazardous wastes were stored on this site and the leachate contains high levels of fluorides. These wastes are classified as solid wastes and are not RCRA-designated hazardous wastes. According to the preliminary assessment, groundwater contamination is likely. Ecology is working with this facility to correct some of the problems on this site and to develop appropriate means of stabilizing wastes in the North Dump area. This facility has a NPDES permit to discharge fluorides to marine waters near Cherry Point. On several occasions, fluoride discharge limits have been exceeded.

Mobil Oil Corporation--

CERCLIS (1986) lists Mobil Oil Corporation's petroleum refinery at Cherry Point. It produces gasoline, jet fuel, and fuel oils. A mid-1970 U.S. EPA report (U.S. EPA no date) on generators of hazardous wastes identified some questionable waste management practices at this site in the 1970s, such as land farming of lead sludge and onsite storage of an estimated 50 tons/yr of spent activated alumina silicate catalyst (29.66 percent fluorine). Wastewater treatment sludges and crude tank sludge (containing heavy metals and phenols) were also disposed of by land farming. According to a preliminary assessment (CERCLIS 1987), this site is in compliance with pertinent regulations. Most hazardous wastes are now transported to other sites for disposal. Some wastes from storage tank bottoms are land farmed on a 5 to 6 ac parcel.

Sediment Condition

NOAA (Brown et al., 1981) collected sediment samples at one station near Cherry Point on three dates between June 1978 to March 1979. The samples were analyzed for 23 aromatic hydrocarbons, including 4 LPAHs, 7 HPAHs, 3 benzene compounds, and 9 miscellaneous extractables. No substantial sediment contamination was detected at this site.

Toxicity Indexes

Oyster Larvae Receiving Water Bioassays--

Oyster larvae mortalities exceeded 50 percent at one nearshore station south of Cherry Point in 1971 and oyster larvae abnormalities exceeded 50 percent at the same station in 1976 (Cardwell and Woelke 1979).

DRAYTON HARBOR

Rank Medium

Sources

Drayton Harbor in Blaine was the site of 10 lumber and shingle mills in 1893 (Puget Sound Lumberman 1893). The mills ranged in size from the Blaine Lumber Company which produced less than 12,000 bd ft/yr of lumber to one of the largest shingle manufacturers in Puget Sound, The International Mill produced over 200,000 board feet of shingles in 1893 (Puget Sound Lumberman 1893). Other mills were operated by Cain Brothers, Drayton Mill Company, Perley Brothers, Davies & Hunter, Smith & Engle, C.F. Stoops, J.M. Lindsey, and the Blaine Shingle Company.

By 1926, only six lumber and shingle mills remained. These were: the Baeton Lumber Company, the Shady Brook Lumber Company, the Union Timber Company, the Blaine Manufacturing Company, the Northern Shingle Company, and

the Saginaw Shingle Company. Two newspapers (Manu. Assoc. of Washington 1926) also operated in the area.

Blaine is the site of a former U.S. Air Force station (U.S. Dept. of Defense 1986; a boat building company (Ecology 1982); a medium-size boat harbor having 362 wet slips, fuel, and repair facilities (Ocean. Inst. 1978); and seven NPDES-permitted dischargers. The latter include the Municipality of Blaine and the Birch Bay Water District, four fish processing plants, and the First Washington Net Factory (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Receiving Water Bioassays--

Oyster larvae mortalities exceeded 50 percent for one station in south central Drayton Harbor in 1968 and 1969. Oyster larvae abnormalities were not substantially elevated at any time during the monitoring period (Cardwell and Woelke 1979a).

POINT ROBERTS

Rank Medium.

Sources

The Point Roberts landfill is a potential hazardous waste site (CERCLIS 1986). A preliminary assessment of possible toxic contamination at the Point Roberts landfill found potential for soil, surface, and groundwater contamination. As of 15 October 1987, a site inspection had not been conducted to confirm the extent of toxic contamination at this site.

A very large marina with over 1,000 wet slips and full boat repair facilities is located at Point Roberts (Ocean. Inst. 1978).

Chevron USA, Inc. operates the Ukiah Bulk Plant at Point Roberts. This plant was a self-reported hazardous waste generator in 1980 (U.S. EPA 1980).

Sediment Condition

No information available.

Toxicity Indexes

No information is available.

SEMIAHMOO BAY

Rank Low

Sources

One small saw and shingle mill was located in Semiahmoo in 1893. This mill produced less than 12,000 bd ft of lumber and 30,000-50,000 bd ft of shingles (Puget Sound Lumberman 1893).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

OTHER AREAS IN THE STRAIT OF GEORGIA

Rank Low

Sources

No information available.

Sediment Condition

Barrick and Prahl (1986) measured the concentrations of phenanthrene and retene in sediments from five stations. These stations were located west of Cherry Point, Neptune Beach, and Birch Bay. Chemical concentrations of phenanthrene and retene at these five stations were not substantially elevated above Carr Inlet reference values.

Toxicity Indexes

No information available.

REGION 1 ASSESSMENT MATRIX RESULTS

As seen if Table 4, Cherry Point, Drayton Harbor, and Point Roberts ranked medium in this assessment. All other areas ranked low. However, data concerning sediment conditions and toxicity indexes do not exist for these areas. Therefore, their overall rankings are subject to change as more data becomes available. No areas of concern in Region 1 received a high ranking.

TABLE 4: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION 1

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Birch Bay	LOW	LOW	N/A	N/A	LOW	MEDIUM	LOW
Boundary Bay	LOW	HIGH	LOW	MEDIUM	LOW	HIGH	LOW
Cherry Point	MEDIUM	HIGH	LOW	LOW	LOW	LOW	MEDIUM
Drayton Harbor	MEDIUM	MEDIUM	N/A	N/A	LOW	LOW	MEDIUM
Pt. Roberts	MEDIUM	MEDIUM	N/A	N/A	N/A	N/A	MEDIUM
Semiahmoo Bay	LOW	LOW	N/A	N/A	N/A	N/A	LOW
Other areas	N/A	N/A	LOW	MEDIUM	N/A	N/A	LOW

TOXIC PROBLEM ASSESSMENT OF REGION 2:
SAN JUAN ISLANDS AND NORTHERN PUGET SOUND
(Figure 4)

GUEMES CHANNEL AND FIDALGO BAY

Rank High

Sources

In 1893, five saw and shingle mills were located at Anacortes. One large shingle mill, the Anacortes Coop Company, produced 60,000-100,000 bd ft during 1893. The other four mills were small and had an total, annual production of less than 15,000 bd ft of lumber (Puget Sound Lumberman 1893).

By 1926, 14 lumber and logging companies, Fidalgo Pulp Manufacturing, 3 printing shops, Schwartz Iron Works, Puget Sound Glass Company, Robert M. Smith (boatbuilder), a laundry, Anacortes Wood Turning Company, and a dairy had located in Anacortes (Manu. Assoc. of Washington 1926). Expansion continued and by 1932, the Puget Sound Pulp and Timber Company (a division of Fidalgo) had been built and was producing 80 tons/yr of wood pulp (Pacific Pulp & Paper Industry 1932).

In 1967, wastewater discharge permits were issued to eight dischargers (U.S. FWPCC 1967). These dischargers included five fisheries (canneries), the state ferry dock, J.E. Trafton & Sons (type of industry unknown), and the Pioneer Shingle Company. None of these businesses possess current NPDES permits.

The five marinas clustered in Anacortes have a total of 197 wet slips (Ocean. Inst. 1978). A large marina with 437 wet slips and boat repair facilities is located at Capsante. Another large marina with 459 wet slips is located in Burrows Bay near Fidalgo Point.

In 1986, 12 NPDES permitted discharges were located near Anacortes and March Point (U.S. EPA 1986). NPDES permittees at March Point include two petroleum refineries (Texaco and Shell Oil), Northwest Petrochemical Corporation, and the Allied Chemical Company. In Anacortes, NPDES permittees include Scott Paper Company (now closed), Anacortes Veneer (a plywood company), the Sunquist Marine Laboratory, two fish processors, two municipal sewage outfalls for the City of Anacortes, and the Northwest Fur Breeders Coop (U.S. EPA 1986).

Barrick and Prahl (1986) reported flare towers at the March Point petroleum refineries as one possible source of combustion-related PAHs.

Kruger (1983) lists three hazardous waste generators near Anacortes: Snelson-Anvil, Inc. (type of industry unknown), Texaco, and the Shell Oil

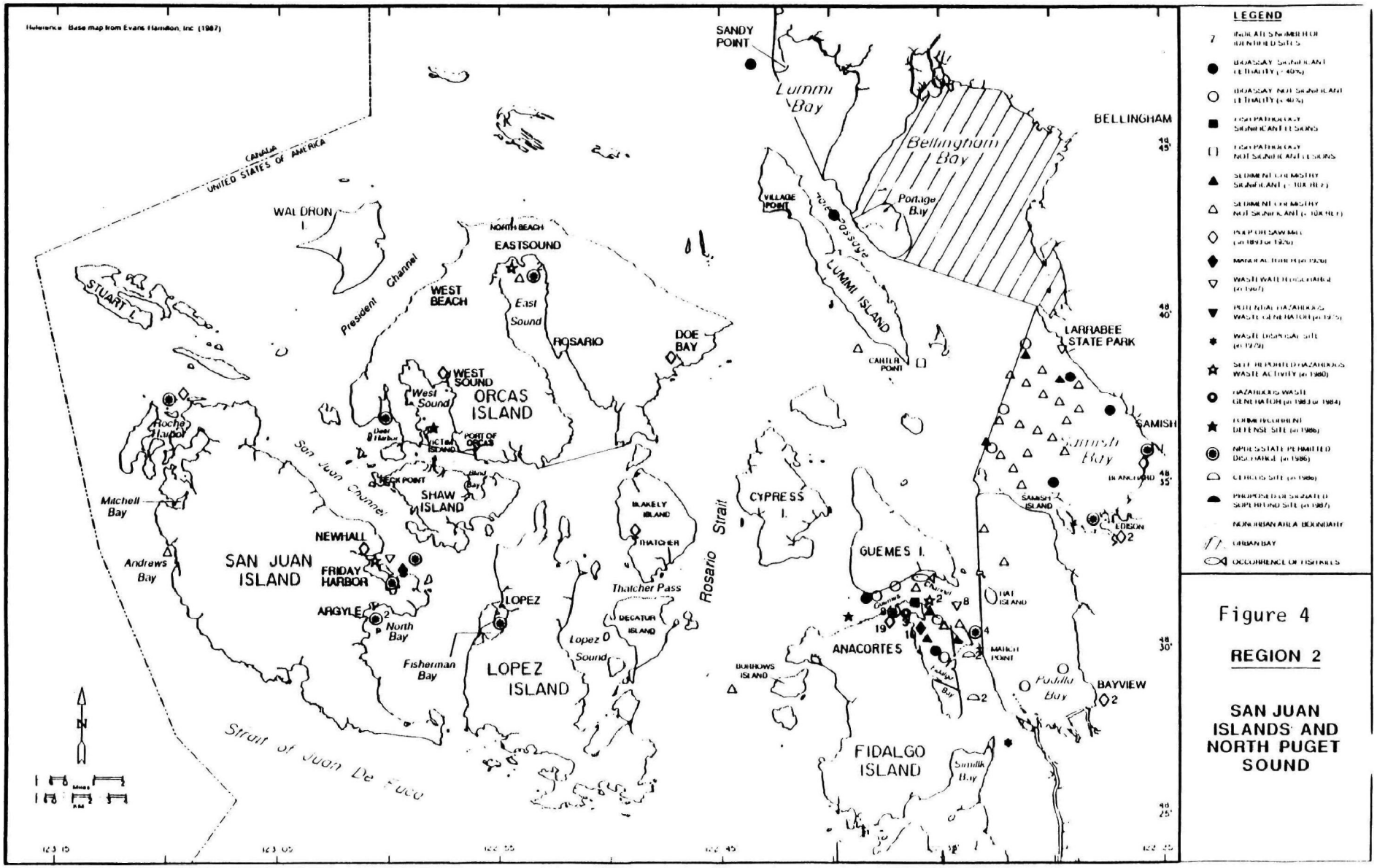


Figure 4

REGION 2

SAN JUAN ISLANDS AND NORTH PUGET SOUND

Company. In addition, two self-reported hazardous waste generators, Publishers Forest Products Company of Washington, Inc. and the Stearns-Roger, Inc. Oil Separating Factory were located in Anacortes in 1980 (U.S. EPA 1980).

Ecology conducted preliminary assessments to identify potential toxic and hazardous contamination for the Northwest Petrochemical Corporation at March Point and the PM Northwest Dump near Anacortes (CERCLIS 1986). Site inspections were conducted for Allied Chemical Corporation (now General Chemical) located between the two refineries at March Point and the Skagit County March Point landfill (CERCLIS 1986). Multiple site inspections were conducted for Shell Oil Company and Texaco, Inc. at March Point.

No potential or observed contamination was found at the Texaco refinery site on March Point (CERCLIS 1987). Soil and groundwater contamination were observed at the Shell Oil Company and the Allied Chemical Corporation sites. The potential for surface water contamination was recorded at Shell Oil (CERCLIS 1987). Measurable soil contamination was observed at the PM Northwest Dump and the potential for surface and groundwater contamination was noted at this site. As of 15 October 1987, chemical concentrations had not been sampled at the Northwest Petrochemical Corporation site, but the preliminary assessment concluded that there was potential for soil contamination and surface and groundwater contamination at this site (CERCLIS 1987).

Detailed information regarding the manufacturing processes for several of the largest dischargers is summarized below.

Shell Oil Company's March Point refinery produced 91,000 bbl/day of gasoline, liquified petroleum gases, distilled fuel oil, and residual fuel oil at their refinery in Anacortes (U.S. EPA no date). As of the mid-1970s, periodic tests of the groundwater for oil and metals leaching from the disposal site had not detected unacceptable levels of hazardous or toxic substances (U.S. EPA no date). The disposal of lead wastes from this refinery has been by on-site land farming (U.S. House of Representatives 1979).

Texaco's oil refinery at March Point produced more than 3 MGD of oil. This refinery produces jet and motor fuels, liquid petroleum, burner oils, bunker fuel, and diesel fuel. A U.S. EPA study reported questionable sludge management practices and land farming at this site in the mid-1970s that could limit future uses of the land (U.S. EPA no date). This 1980 report did not explain what was meant by land farming.

The Anacortes Works which was located at an unspecified site, was used as a disposal site for hazardous wastes such as acid solutions (pH less than 3), heavy and trace metals, inorganic compounds, and miscellaneous waste material. Disposal utilized open pits, neutralization treatment, reprocessing, and recycling (U.S. House of Representatives 1979).

Ecology is currently investigating the Northwest Petrochemical Company at March Point for improper storage and disposal of hazardous waste materials containing phenols (Seattle Post-Intelligencer 1987). Tars were also stored

openly on the site.

The Skagit County March Point landfill is an abandoned, mixed industrial waste disposal site that was used from 1957 to 1974. Metallic wastes, inorganic compounds, and miscellaneous materials were disposed of at this site (U.S. House of Representatives 1979). After a detailed site inspection of the March Point Landfill, no further action was taken (U.S. EPA 1986).

Allied Chemical Corporation on March Point produces a variety of chemicals, including sulfuric acid (Weaver and Rolfson no date). This company generates, treats, and disposes of hazardous wastes in an underground injection well (U.S. EPA 1980).

Sediment Condition

Barrick and Prahl (1986) measured phenanthrene and retene concentrations in sediments at one mid-channel station in eastern Guemes Channel. Concentrations of phenanthrene and retene at this station were not substantially elevated above Carr Inlet reference values.

Malins (1985) sampled sediments from five stations near Anacortes in June and July of 1984 and 1985. Sediments were analyzed for 18 aromatic hydrocarbons, 27 chlorinated compounds, and metals. Aromatic hydrocarbons analyzed included five LPAHs, eight HPAHs, and five miscellaneous extractables. Chlorinated compounds included 8 chlorinated biphenyls, 5 chlorinated butadienes, 13 pesticides, and 2 miscellaneous extractables. Several aromatic hydrocarbons were highly elevated in sediments from two stations in inner Anacortes harbor (see Table 5). Concentrations of aromatic hydrocarbons dropped with distance from the inner harbor and were not substantially elevated in two outer Anacortes stations near the Texaco pier north of March Point and another station in eastern Guemes Channel. Chlorinated organic compounds were only detected in trace amounts and metal concentrations were not substantially elevated in sediments at any of the five Anacortes stations.

In an earlier NOAA study, Brown et al. (1981) measured concentrations of 23 aromatic hydrocarbons at a nearshore station near March Point on 3 dates between June 1978 and March 1979. Aromatic hydrocarbons analyzed included four LPAHs, seven HPAHs, three non-chlorinated benzene compounds, and nine miscellaneous extractables. Only benzo(a)anthracene was found to be substantially elevated above reference values (12.1 times reference) in a single sediment sample taken in the fall of 1978. Chemical concentrations were not substantially elevated in sediment samples taken on other dates.

Toxicity Indexes

Oyster Larvae Bioassays--

Pacific oyster larvae bioassays were conducted at four stations near Anacortes on May 1963 and August 1965 (U.S. FWPCC 1967). Stations were located on the western edge of Guemes Channel, eastern Guemes Channel, near

TABLE 5. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT TWO ANACORTES STATIONS

Chemical	Elevation Above Reference	
	N Anacortes	Anacortes Inner Harbor
Acenaphthene	16	NS[a]
Benzo(a)anthracene	25	63
Benzo(a)pyrene	16	40
Chrysene	27	81
Fluoranthene	49	112
Fluorene	23	NS
2-methylnaphthalene	14	15
1-methylphenanthrene	46	54
Naphthalene	54	32
Phenanthrene	34	46
Pyrene	34	79

[a] = Not substantially elevated.

Reference: Malins et al. (1985).

the Texaco Pier, and in the center of Fidalgo Bay. A mean abnormality percentage for the four stations of 28.5 indicated no contamination effects. While the mean overall abnormality rate was not substantially elevated, the abnormality rates for individual bioassays were as high as 100 percent when sulfite waste liquor concentration in the nearby waters were high. The percent abnormalities fell to near zero when a labor dispute temporarily closed the Scott pulp mill. These bioassays do not reflect the worst case conditions near Anacortes, since receiving water samples were taken far from potential toxic inputs.

Cardwell and Woelke (1979) conducted bioassays for two stations in Guemes Channel and two stations in Fidalgo Bay. Oyster larvae mortality rates were substantially elevated (>50 percent) at one station in central Fidalgo Bay in 1964, 1965, 1971, and 1974. Abnormalities were also substantially elevated in bioassays conducted at this same station in 1965 and 1971. Bioassays conducted at the other Fidalgo Bay station located northwest of March Point off the Texaco pier were not substantially elevated during the monitoring period.

Bioassay mortalities were substantially elevated for one of the two Guemes Channel stations in the western portion of Guemes Channel (Cardwell and Woelke 1979). Bioassay abnormalities were also substantially elevated at this station in 1961, 1962, 1964, 1972, and 1975. Bioassay results at the other Guemes Channel station in central Guemes were not substantially elevated during the monitoring period.

Fish Kills--

According to L. Kittle (March 1987, personal communication), an oil spill in 1971 killed thousands of fish and shellfish in a 5-mi area around Anacortes.

Fish Histopathology--

According to Malins (1985, personal communication) a fish survey conducted near Anacortes netted fewer than 20 fish, of which 12 Great Sculpin had pre-neoplasms, 75 percent had megalocytic hepatosis, and 50 percent had severe megalocytic hepatosis.

ANDREWS BAY, SAN JUAN ISLAND

Rank Low

Sources

No information available.

Sediment Condition

Brown et al. (1981) sampled sediments for one nearshore station in Andrews Bay, San Juan Island between June 1978 and March 1979. Chemical concentrations of 23 aromatic hydrocarbons of the station were not substantially elevated above Carr Inlet reference values. Aromatic hydrocarbons measured in this study included four LPAHs, seven HPAHs, three benzene compounds, and nine miscellaneous extractables.

Toxicity Indexes

No information available.

BLAKELY ISLAND

Rank Low

Sources

A lumber mill of unknown size was located in Thatcher, on Blakely Island, in 1926 (Manu. Assoc. of Washington 1926). One marina is located on Blakely Island (Ocean. Inst. 1978). Boats are repaired at this marina.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

DOE BAY, ORCAS ISLAND

Rank Low

Sources

In 1893, a small lumber mill, operated by Coffelt and Veirech, produced less than 12,000 bd ft of lumber (Puget Sound Lumberman 1893).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

EAST SOUND, ORCAS ISLAND

Rank LOW

Sources

Two small marinas are located in East Sound, one at Rosario and the other at the head of East Sound (Ocean. Inst. 1978). Two NPDES permittees, the East Sound Water District and Rosario Resort, are located in East Sound (U.S. EPA 1986). Chevron, Inc. operates an East Sound Bulk Plant that generates and stores hazardous wastes (U.S. EPA 1980).

Sediment Condition

Concentrations of phenanthrene and retene were not substantially elevated above reference values in sediments from a single sampling station located near the head of East Sound (Barrick and Prahl 1987).

Toxicity Indexes

No information available.

FISHERMAN BAY, LOPEZ ISLAND

Rank Low

Sources

Fisherman Bay has one NPDES permit for the Fisherman Bay Sewage District outfall (U.S. EPA 1986). There are two small marinas in Fisherman Bay with fuel onsite and repairs nearby (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

FRIDAY HARBOR-EAST SAN JUAN ISLAND

Rank LOW

Sources

In 1893, the Cascade Bay Lumber Company in Newhall produced 30,000-50,000 bd ft of shingles and 12,000-15,000 bd ft of sawn lumber (Puget Sound Lumberman 1893). A local newspaper, The Journal, began publication in Friday Harbor before 1926 (Manu. Assoc. of Washington 1926).

In 1967, the Water Pollution Control Commission reported two discharges:

the Friday Harbor Lab and a municipal sewage discharge for the town of Friday Harbor.

U.S. EPA (1980) lists the Chevron USA, Inc. Friday Harbor Bulk Plant as a self-reported hazardous waste generator. Ecology's latest list of hazardous waste generators does not list this Chevron facility and no NPDES permit is currently issued for this plant (U.S. EPA 1986).

Four marinas, with over 500 wet slips and, fuel and repair facilities onsite, are located near Friday Harbor (Ocean. Inst. 1978).

A shipyard is located in the San Juan Channel near Friday Harbor (personal communication). NPDES permits have been issued for the Friday Harbor Sand & Gravel Company, a fishery near Argyle on North Bay, and the sewage discharge for the Town of Friday Harbor (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

HALE PASSAGE

Rank Low

Sources

A medium size marina is located in Fisherman's Cove on Hale Passage. This marina has 280 wet slips and fuel and repair facilities available onsite (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Bioassay mortalities were substantially elevated (>50 percent) at one mid-channel station in Hale Passage in 1965, 1966, 1969, 1972 and 1973 (Cardwell and Woelke 1979). Bioassay abnormalities were also substantially elevated from 1964-1966 and 1971-1973.

LOPEZ SOUND

Rank Low

Sources

A lumber mill of unknown size was operated by F.D. Krenppenberg in Thatcher in 1893 (Puget Sound Lumberman). There is also a marina of unknown size in Lopez Sound.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

LUMMI BAY

Rank Low

Sources

There is only one small marina in Lummi Bay with no fuel or boat repair facilities (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

In 1971, bioassay mortalities were substantially elevated (>50 percent) at one station just west of the tip of Sandy Point off Lummi Bay (Cardwell and Woelke 1979). Oyster larvae abnormalities were not substantially elevated at this site at any time during the monitoring period.

LUMMI ISLAND AND VICINITY

Rank Low

Sources

Transport of pollutants from nearby Bellingham Bay is the only reported potential source of toxic contamination at this site.

Sediment Condition

Barrick and Prahl (1986) measured phenanthrene and retene concentrations

in sediments from one station located west of the southern tip of Lummi Island. Concentrations of phenanthrene and retene at this station did not substantially exceed reference values.

Toxicity Indexes

Fish Histopathology--

Individual trawls in March 1984 collected up to six fish for each of five size classes. A total of 26 fish were caught southeast of Carter Point on Lummi Island. The incidences of liver neoplasms, pre-neoplasms, and megalocytic hepatosis were not substantially elevated in English sole collected at this site (Battelle 1986).

PADILLA BAY

Rank Low

Sources

The J.H. Croquette & Company sawmill and the W. Moeller shingle mill were located in Bayview in 1893. The W. Moeller mill produced 30,000-50,000 bd ft of shingles per year and processed less than 12,000 bd ft of lumber annually (Puget Sound Lumberman 1893). The production capacity of the other lumber mill is unknown.

According to Barrick and Prahl (1986), flare towers associated with the petroleum refineries at March Point are a possible source of combustion related PAHs. Contaminants may be transported into Padilla Bay from several petroleum refineries and other industries located on March Point.

Sediment Condition

Barrick and Prahl (1986) measured phenanthrene and retene concentrations in sediments from two stations near the mouth of Padilla Bay. Concentrations of phenanthrene and retene did not substantially exceed reference values at these two stations.

Toxicity Indexes

Oyster Larvae Bioassays--

Pacific oyster larvae bioassays were conducted with water from two stations in southern central Padilla Bay on May 1963 and August 1965 (U.S. FWPCC 1967). This study found that the mean abnormality and mortality rates were not substantially elevated (>50 percent) at these two stations.

ROCHE HARBOR

RANK Low

Sources

The Roche Harbor Lime Company produced 12,000-15,000 ft of sawn lumber and 60,000-100,000 bd ft of shingles in 1893 (Puget Sound Lumberman 1893). The Roche Harbor Lime and Cement Company was still operating in 1926 (Manu. Assoc. of Washington 1926). The Roche Harbor Lime Company has since closed (Yearsley, J., personal communication).

Currently two small marinas are located in Roche Harbor (Ocean. Inst. 1978). One NPDES-permitted source (Roche Harbor Resort) is located in Roche Harbor (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

ROSARIO STRAIT

Rank Low

Sources

In 1978, there were five marinas in Rosario Strait (Ocean. Inst. 1978).

Sediment Condition

According to Barrick and Prahl (1986), phenanthrene and retene concentrations were not substantially elevated above reference in sediments from a single station located west of Burrows Island in Rosario Strait.

Toxicity Indexes

No information.

SAMISH BAY

Rank Medium

Sources

Blanchard--

The Samish Bay Logging Company operated in Blanchard in 1926 (Manu. Assoc. of Washington 1926). In 1967, Larrabee State Park septic wastes were discharged into Samish Bay (U.S. FWPCC 1967c).

Currently, one NPDES-permitted source, the Rock Point Oyster Company, is located in the city of Blanchard.

Edison--

The Howard & Butler lumber mill was located in Edison in 1893. This mill produced less than 12,000 bd ft of sawn lumber annually (Puget Sound Lumberman 1893). By 1926, the Edison Shingle Company had built a mill in Edison (Manu. Assoc. of Washington 1926). These mills now appear to be abandoned.

According to the U.S. EPA (1986), one NPDES-permitted source is located in the city of Edison.

Sediment Condition

In April and May 1984, Battelle Pacific Northwest Laboratories (1986) sampled sediments at 20 stations throughout Samish Bay. Sediments were analyzed for eight metals, total aromatic hydrocarbons, PCBs, and selected hydrocarbons. Metals, PCBs, fluoranthene, di-n-octylphthalate, and pyrene were not substantially elevated above reference values in sediments at any of the 20 stations sampled. Concentrations of bis(2-ethylhexyl)phthalate and phenanthrene were substantially elevated above reference values at three stations near the mouth of Samish Bay (see Table 6). However, there are no known major industrial sources in the bay. Also, phenanthrene is typically a covariate of several related PAHs and the absence of these covariates makes the observed high levels of phenanthrene highly suspicious. Additional data quality checks should be conducted before any conclusions are drawn about contamination in Samish Bay.

Toxicity Indexes

Amphipod Bioassays--

Battelle Pacific Northwest Laboratories (1986) used surface sediments (top 6 cm) from Samish Bay to conduct amphipod bioassay screening surveys in the summer of 1983 and detailed surveys in the spring of 1984. Rhepoxynius abronius bioassays were conducted using the procedure developed by Swartz (1984). The results of the screening surveys and the detailed surveys were contradictory. The detailed survey of four stations in Samish Bay found no substantial (>40 percent) elevations in amphipod mortalities. On the other hand, screening surveys at 20 stations found substantially elevated abnormalities at 2 stations in west Samish Bay.

Chapman et al. (1984) collected surface sediments (top 2 cm) for two reference stations in Samish Bay in May 1983. All samples were frozen prior to analysis, so the results of the sediment bioassays do not lend themselves

TABLE 6. ELEVATIONS ABOVE REFERENCE VALUES CHEMICALS IN SEDIMENTS AT THREE SAMISH BAY STATIONS

Chemical	Elevation Above Reference		
	Northwest of Larrabee	SW of Larrabee	NE of Samish Is.
Phenanthrene	16[a]	NS[b]	NS
Bis(2-ethylhexyl)phthalate	167[a]	21[a]	45[a]

[a] These elevated levels of phenanthrene and bis(2-ethylhexyl) phthalate are suspicious since there are no known major industrial sources in the bay. See text for further explanation.

[b] NS = Not substantially elevated.

Reference: Battelle (1986).

to interpretation.

Oyster Larvae Bioassays--

Chapman et al. (1984) used surface sediments (top 2 cm) to conduct bioassays for two reference stations in Samish Bay in May 1983. All samples were frozen prior to analysis, so the results of the sediment bioassays are highly unreliable. Nonetheless, no substantial impacts on Pacific oyster larvae mortality were observed for these Samish Bay stations.

Pacific oyster larvae bioassays were conducted in Samish Bay in April and May 1984 using the top 6 cm of surface sediment. Substantial oyster larvae abnormalities were not observed at any of the four stations. Mortalities were substantially elevated (>40 percent) at one station southwest of Larrabee State Park (Battelle Pacific Northwest Laboratories 1986). Mortalities were not substantially elevated at the three stations near the mouth of Samish Bay.

Cardwell and Woelke (1979) conducted receiving water bioassays for two stations in Samish Bay. One station was located northwest of the city of Samish and the other station was located east of Samish Island. Mortalities were substantially elevated (>50 percent) at the Samish Island station in 1961, 1965, and 1974 and oyster larvae abnormalities were elevated in 1965. At the other station, mortalities were substantially elevated (>50 percent) in 1963 and 1974 and abnormalities were substantially elevated in 1962, 1974, and 1975.

WEST SOUND, ORCAS ISLAND

Rank Medium

Sources

The West Sound Mill Company was located in West Sound in 1926. The production capacity of this lumber mill was not reported (Manu. Assoc. of Washington 1926).

One medium-size marina of 106 wet slips with fuel and repair facilities) is located in West Sound (Ocean. Inst. 1978). A military installation, the Victim Island-Defense Site on West Sound, is listed on the DERP inventory as a suspected storage site for hazardous wastes (U.S. Department of Defense 1985). These suspicions have not been investigated, so the potential for contamination is unknown.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

OTHER SAN JUAN ISLANDS

Rank Low

Sources

This section combines data on marinas throughout the San Juan Islands that have not been covered in earlier discussions. There is no information on other potential sources of toxic chemicals, sediment chemistry, or biological indicators for these areas.

Small marinas are located in Lopez Sound, Deer Harbor (two marinas), the Port of Orcas, West Beach in President Channel, Village Point on Lummi Island, Mitchell Bay on San Juan Island, Blind Bay and Neck Point on Shaw Island, and North Beach on Orcas Island (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

REGION 2 ASSESSMENT MATRIX RESULTS

As seen in Table 7, Samish Bay and West Sound/Orcas Island ranked medium in this investigation. As stated previously, the data associated with Samish bay seems erroneous due to its non-industrial nature; however, taken at face value, the sediment conditions warrant a medium ranking. All other areas of concern ranked low with the exception of Guemes/Fidalgo Channel which ranked high because of the presence of toxic chemical dump sites.

Data concerning sediment conditions and toxicity indexes are not presently available for most sites in Region 2. Lummi Island source information was also not available. Therefore, the overall rankings associated with these areas of concern must be considered tentative until such time as this data is collected.

TABLE 7: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION 2

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Guemes/Fidalgo Channel	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH
Andrews Bay	N/A	N/A	LOW	LOW	N/A	N/A	LOW
Blakely Island	LOW	LOW	N/A	N/A	N/A	N/A	LOW
Doe Bay, Oreas Island	LOW	LOW	N/A	N/A	N/A	N/A	LOW
East Sound, Orcas Island	MEDIUM	MEDIUM	LOW	LOW	N/A	N/A	LOW
Fisherman Bay, Lopez Island	LOW	MEDIUM	N/A	N/A	N/A	N/A	LOW
Friday Harbor	MEDIUM	MEDIUM	N/A	N/A	N/A	N/A	LOW
Hale Passage	LOW	LOW	N/A	N/A	LOW	LOW	LOW
Lopez Sound	LOW	LOW	N/A	N/A	N/A	N/A	LOW
Lummi Bay	LOW	LOW	N/A	N/A	LOW	LOW	LOW
Lummi Island	N/A	N/A	LOW	LOW	LOW	LOW	LOW
Padilla Bay	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW
Roche Harbor	LOW	MEDIUM	N/A	N/A	N/A	N/A	LOW
Rosario Strait	LOW	LOW	LOW	LOW	N/A	N/A	LOW
Samish Bay	LOW	MEDIUM	HIGH	HIGH	LOW	LOW	MEDIUM
West Sound, Orcas Island	MEDIUM	MEDIUM	N/A	N/A	N/A	N/A	MEDIUM
Other Areas	LOW	LOW	N/A	N/A	N/A	N/A	LOW

TOXIC ASSESSMENT OF REGION 3:
STRAIT OF JUAN DE FUCA
(Figure 5)

DUNGENESS BAY

Rank N/A

Sources

No information available.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

EAST STRAIT OF JUAN DE FUCA

Rank Medium

Sources

According to CERCLIS files (U.S EPA 1987), the Boeing Company disposed of waste acids and bases from aircraft manufacturing processes in the Strait of Juan de Fuca. From about 1951 to 1965, the wastes were reportedly allowed to trickle from barges in the shipping lanes of the Strait of Juan de Fuca. The amount of waste disposed of in this manner is not known. The preliminary assessment concluded that physical processes (i.e. wind and wave action, tidal currents) dispersed and oxidized the wastes.

Monsanto has an NPDES permit to dispose of vanillin at a dump site in deep water in the Strait of Juan de Fuca (U.S. EPA 1986).

Sediment Condition

Brown et al. (1981) analyzed concentrations of 23 aromatic hydrocarbons in sediments at one nearshore station in the Strait of Juan de Fuca at the base of Dungeness Spit between June 1978 and March 1979. Aromatic hydrocarbons measured in this study include four LPAHs, seven HPAHs, three benzene compounds, and nine miscellaneous extractables. Aromatic hydrocarbons at this site were not substantially elevated above reference sediment concentrations.

In 1970-1972, Crecelius et al. (1975) analyzed metals concentrations in sediment collected from two stations in the Strait: one deep water station

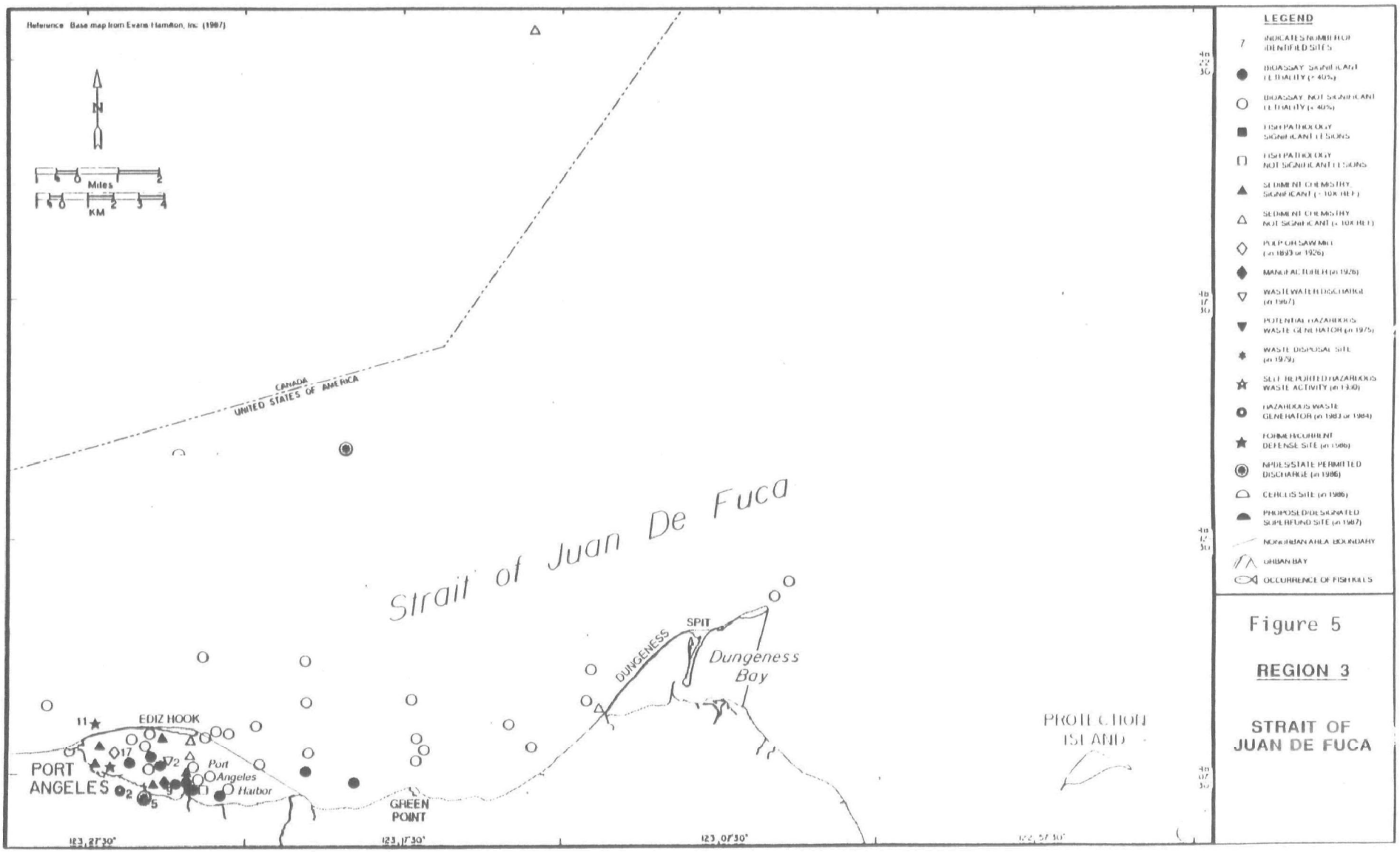


Figure 5

REGION 3

STRAIT OF JUAN DE FUCA

north of Dungeness Bay and another station northwest of Protection Island (see the Region 5 map). Metal concentrations at these two stations were not substantially elevated above reference values.

Toxicity Indexes

Oyster Larvae Bioassays--

According to Cardwell et al. (1976), oyster larvae mortalities were not substantially elevated (>50 percent) by waters from 12 nearshore stations from Dungeness Spit to the mouth of the Elwha River in the Strait of Juan de Fuca. The site at the Elwha River is too far west to appear on the Region 3 map.

Outside of Port Angeles Harbor, eight stations were sampled in the Strait of Juan de Fuca: two stations in the center of the Strait of Juan de Fuca, one station at the tip of Ediz Hook, four stations along the shore east of Port Angeles, and one station at the tip of Dungeness Spit (Cardwell et al. 1976). Oyster larvae abnormality rates were substantially elevated above reference values (>40 percent) for all stations east of Port Angeles to Green Point. Mortalities were highest at the Rayonier station where they exceeded 90 percent. According to Cardwell (1976), high levels of sulfite waste liquor were correlated with the mortalities and abnormalities.

Cardwell and Woelke (1979) found no substantially elevated (>50 percent) bioassays at six stations in the Strait of Juan de Fuca outside of Port Angeles. Four stations were located east of Morse Creek and two stations were located north of Ediz Hook. High oyster larvae mortalities were reported for one station at the mouth of Morse Creek (Cardwell and Woelke 1979).

PORT ANGELES HARBOR

Rank High

Sources

In 1893, the Puget Sound Cooperative Colony Lumber Mill, the Port Angeles Mill & Lumber Company, and the Port Angeles Cedar Lumber Company shingle mills were located in Port Angeles. These mills ranged in capacity from 12,000 to 60,000-100,000 bd ft of shingles and lumber (Puget Sound Lumberman 1893). By 1926, the lumber industry had grown and there were 14 lumber or logging companies in Port Angeles. Also in 1926, The Angeles Foundry, Northwestern Power and Manufacturing Company (electrical generating), five printing companies, the Gate City Bottling Company, and a laundry were also operating in Port Angeles (Manu. Assoc. of WA 1926).

In 1932, three pulp and paper mills (Fibreboard, Washington Pulp & Paper, and Olympic Forest Products) had been built in Port Angeles (Pacific Pulp and Paper Industry 1932). These mills produced a combined total of 390

tons of paper, 335 tons of newspaper pulp, 200 tons of bleached sulphate pulp, 84 tons of unbleached sulfite pulp, and 95 tons of sulfite in 1932. Later, ITT Rayonier built a large pulp mill that continues to operate in Port Angeles.

In 1967, Crown Zellerbach Corporation operated a lagoon for storing log debarker discharges near their Port Angeles facility (U.S. FWPCC 1967) and the Pen Plywood Company generated glue wastes at their Port Angeles plant (U.S. FWPCC 1967).

Port Angeles has three marinas with a combined total of more than 500 wet slips (Ocean. Inst. 1978). There are five NPDES-permitted sources in Port Angeles: the Merrill & Ring Lumber Mill, Crown Zellerbach Pulp and Paper Mill, ITT Rayonier Paper and Pulp Mill, the Rayonier Veneer and Plywood Plant, and a sewage discharge for the City of Port Angeles (U.S. EPA 1986). Merrill & Ring Lumber currently operates a large log sort yard in Port Angeles Harbor. Waste flows were highest at the Rayonier plant, which released 30 million gal/day of effluent.

Several oil storage tanks are located near the inner harbor in Port Angeles (Maguire, B., personal observation). A major oil spill associated with tanker operations occurred in Port Angeles Harbor in the early 1970s.

Ten military facilities are currently located in Port Angeles, including two Elwha searchlights, several combat ranges, a gun battery, and the Port Angeles Army Air Field. The Defense Environmental Restoration Program also lists one former military facility in Port Angeles (ERP), the Port Angeles Combat Range (U.S. Dept. of Defense 1985).

The U.S. EPA (1980) and Kruger (1983) listed the ITT Rayonier plant at Ennis Creek as a hazardous waste generator. ITT Rayonier ceased operations in 1984. Kruger (1983) also listed a U.S. Coast Guard facility in Port Angeles as a hazardous waste generator.

Sediment Condition

Malins (1985) measured sediment concentrations for metals and 18 aromatic hydrocarbons including 5 LPAHs, 8 HPAHs, and 5 miscellaneous extractables at three Port Angeles stations. Substantially elevated concentrations of aromatic hydrocarbons were observed at all three stations in Port Angeles (see Table 8). Concentrations of aromatic hydrocarbons were highest in sediments in the inner harbor. However, sediment concentrations of a few hydrocarbons were still substantially elevated in the outer harbor. Metal concentrations were not substantially elevated at any station. The metals concentrations followed a similar pattern, with higher concentrations in the inner harbor.

Sediments at one station near the tip of Ediz Hook were sampled from 1978 to 1981 (Malins et al. 1982). Sediments were analyzed for concentrations metals, aromatic hydrocarbons, PCBs, chlorinated pesticides, and

TABLE 8. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE PORT ANGELES STATIONS

Chemical	Elevation Above Reference		
	Outer Harbor 1	Outer Harbor 2	Inner Harbor
Acenaphthene	NS[a]	NS	19
Benzo(a)anthracene	NS	NS	16
Benzo(a)pyrene	NS	NS	18
Chrysene	NS	NS	25
Fluoranthene	NS	NS	25
2-methylnaphthalene	16	NS	35
1-methylphenanthrene	19	NS	36
Naphthalene	24	50[b]	153[b]
Phenanthrene	NS	NS	22
Pyrene	NS	NS	23

[a] NS = Not substantially elevated.

b = AET value exceeded.

Reference: Malins (1985).

other chlorinated organic compounds. Concentrations of these analytes were not substantially elevated above reference values. Total aromatic hydrocarbon concentrations were 970 ppb.

In the Brown et al. (1981) study of petroleum hydrocarbons in northern Puget Sound sediment concentrations were analyzed for metals and 23 aromatic hydrocarbons for three stations in Port Angeles. Sediments were analyzed for concentrations of four LPAHs, seven HPAHs, three benzene compounds, and nine miscellaneous extractables. The results of this analysis are summarized in Table 9. Napthalene concentrations exceeded the AET at both the Inner Harbor and the two Outer Harbor Stations. Substantially elevated sediment concentrations of aromatic hydrocarbons were observed at one station near the Port Angeles boat ramp. Chemical concentrations were not substantially elevated in sediments at another station near the tip of Ediz Hook and at a third nearshore station located halfway between the boat ramp and ITT Rayonier.

Crecelius et al. (1975) measured concentrations for seven metals in sediments collected from one station at the mouth of Port Angeles Harbor. From 1970-1972, metals were not substantially elevated above reference values.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell et al. (1976) reported oyster larvae mortalities as high as 100 percent at one station near ITT Rayonier. Mortalities were not substantially elevated (>40 percent) at the other 12 receiving water stations in Port Angeles. According to Cardwell, receiving water toxicity in Port Angeles declined dramatically in late 1975 when the ITT Rayonier pulp mill instituted incineration of its sulfite waste liquor.

Oyster larvae bioassays were conducted at nine Port Angeles stations (Woelke 1967). Abnormality rates were substantially elevated (>40 percent) at all five stations sampled. The highest abnormality rates were found at two stations in the inner harbor and two stations near the Rayonier pulp mill, where abnormality rates exceeded 90 percent.

Other Bioassays--

Survival rates of pink salmon fry in live tanks at six bioassay U.S. FWPCC (1967) were measured at stations near the Rayonier mill. Thirty seven percent of the bioassays resulted in 100 percent juvenile salmon mortalities. The mortalities appeared to correspond to high levels of sulfite waste liquor, which occassionally measured nearly 9,000 ppm at this site. Similarly, 100 percent mortalities of juvenile salmon were observed in 26 percent of the Crown Zellerbach bioassays and 33 percent of the bioassays conducted near Fibreboard.

TABLE 9. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT ONE STATION NEAR THE PORT ANGELES BOAT RAMP

Chemical	Elevation Above Reference	
	18 May	12 June
Dibenzothiophene	40	240
Fluorene	NS[a]	24
2-methylnaphthalene	19	54
1-methylphenanthrene	10	100
Phenanthrene	NS	41

[a] NS = Not substantially elevated.

Reference: Brown et al. (1981).

Fish Histopathology--

According to Malins (1985, personal communication), no pre-neoplasms or megalocytic hepatosis were found in 15 English sole livers examined at the Port Angeles site. However, results based on samples of fewer than 20 fish may not be representative and these results should be interpreted with caution.

Bioaccumulation in Tissues--

Following a small diesel oil spill in Port Angeles on 13 May 1979, Brown et al. (1981), sampled mussel tissue at an Ediz Hook station on 18 May and 12 June 1979. Blended mussel tissue from 10 to 15 mussels was collected randomly in the intertidal zone along 30 m of beach. Very low levels of aromatic hydrocarbons and alkanes (similar to No. 2 fuel) were found in Ediz Hook mussel tissue. The Brown study compared organic concentrations at the site of contamination to the concentrations at an Ediz Hook control site. One month after the oil spill, chemical concentrations had fallen to less than one-tenth of their original concentration in mussel tissue at Ediz Hook and chemical concentrations for many hydrocarbons were below detection limits.

REGION 3 ASSESSMENT MATRIX RESULTS

As seen in Table 10, Port Angeles Harbor received a high ranking due to the high level of conern associated with both its sediment condition and toxicity indexes. East Strait of Juan de Fuca ranked medium. Dungeness Bay ranked low; however, no information was available for this assessment. Therefore, the overall ranking associated with these areas of concern are tentative until such time as this data can be gathered.

TABLE 10: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 3c

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Dungeness Bay	N/A	N/A	N/A	N/A	N/A	N/A	N/A
East Strait of Juan de Fuca	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	HIGH	MEDIUM
Port Angeles Harbor	MEDIUM	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	HIGH

N/A - Not available at this time

TOXIC ASSESSMENT OF REGION 4:
NORTH WHIDBEY BASIN
(Figure 6)

CORNET BAY, DECEPTION PASS

Rank Low

Sources

Cornet Bay has a small marina with no boat repair facilities (Ocean. Inst. 1978). The Deception Pass Military Battery Site may have stored potentially hazardous wastes (U.S. Department of Defense 1985).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found substantially elevated abnormality rates (>50 percent) in receiving water bioassays conducted at one Deception Bay station in 1964 and 1972. Oyster larvae mortalities were also substantially elevated at this site in 1965, 1971, and 1972.

CRESCENT HARBOR

Rank High

Sources

The Navy Seaplane Base located on Crescent Harbor is a proposed Superfund site (U.S. EPA 1987). The Seaplane base also has an NPDES permit for septic discharges from barracks located on this site (U. S. EPA 1986) and stored solvents onsite (Ecology 1986).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found substantially elevated mortality rates

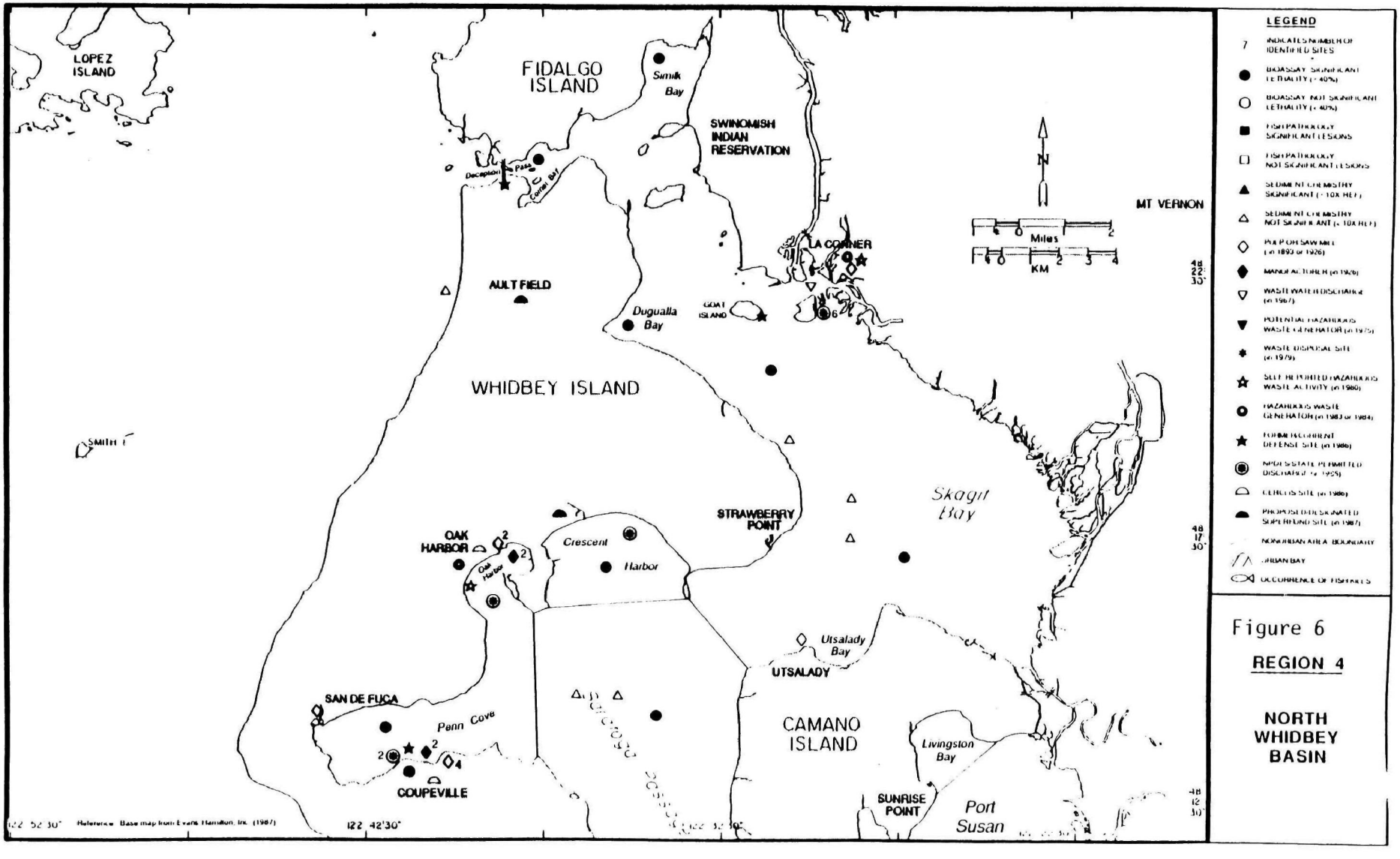


Figure 6

REGION 4

NORTH WHIDBEY BASIN

(>50 percent) in receiving water bioassays conducted at one Crescent Harbor station in 1964-1966, 1968, 1971, 1972, and 1974. Abnormality rates were also substantially elevated at this site in 1964 and 1972.

DUGUALLA BAY

Rank Medium

Sources

Drainage from the Whidbey Island Naval Air Station is the most prominent potential source of toxic contamination (U.S. EPA 1986). Ault Field on Whidbey Island, has been proposed as a Superfund site (U.S. EPA 1987). Drainage from Ault Field may be a source of polycyclic aromatic hydrocarbons (PAHs) in Dugualla Bay (Ecology 1982). Groundwater contamination has been confirmed at this site (CERCLIS 1987). Historically, Ault Field was a disposal site for battery acid and 200 gal/yr of hazardous wastes (Stradley et al. 1975). In 1983, Ault Field generated 300 tons of "characteristic" waste (Kruger 1983). Both Ault Field and the Navy Seaplane Base store solvents onsite (Ecology 1986).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found substantially elevated mortality rates (>50 percent) in bioassays conducted at one Dugulla Bay station in 1964, 1965, 1968, 1971, 1972, and 1974. Abnormality rates were also substantially elevated at this site in 1964, 1965, 1967, 1968, and 1972.

OAK HARBOR

Rank Medium

Sources

By 1926, the Oak Harbor Lumber Company and Charles Nienhuis had built lumber mills in Oak Harbor (Manu. Assoc. of Washington 1926). Other potential sources of toxic chemicals in 1926 included a newsprinter.

Currently, there is one NPDES-permitted municipal discharge for the city of Oak Harbor (U.S. EPA 1986). A medium-size marina with 316 wet slips and fuel and repair facilities is also located in Oak Harbor (Ocean. Inst. 1978). Contaminants from the Sea Plane Base Marina in nearby Crescent Harbor may be transported to Oak Harbor.

Ecology lists Melco Manufacturing as the sole hazardous waste generator in Oak Harbor (Kruger 1983). The Chevron USA Inc. Bulk Plant, located on Oak Harbor is a self-reported hazardous waste generator (U.S. EPA 1980).

The Island County landfill near Oak Harbor has been investigated by Ecology and the U.S. EPA for possible hazardous waste contamination (U.S. EPA 1986). The results of the preliminary assessment conclude that there is potential for soil, and surface and groundwater contamination at this site (CERCLIS 1987). As of 15 October 1987, no chemical measurements have been taken to confirm the potential for toxic contamination at this site.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

PENN COVE

Rank Medium.

Sources

The Whidbey Island Mill Company and W.B. Marsh lumber mills were operating in Coupeville as early as 1893. Each of these mills produced less than 15,000 bd ft of lumber annually (Puget Sound Lumberman 1893). In 1893, the Camland Mill Company lumber mill in San de Fuca (historical place name) also produced less than 12,000 bd ft of lumber.

By 1926, two lumber mills operated by J.E. Hamilton and J. Paul Lumber Company and two newspapers continued to operate in Coupeville (Manu. Assoc. of Washington 1926).

Currently, there are several potential sources of toxic hazards, including a military facility at Fort Casey in Coupeville (U.S. Department of Defense 1985), two NPDES-permitted sewage discharges for the city of Coupeville and the Penn Cove Sewage District (U.S. Environment Protection Agency 1986), and two small marinas in Penn Cove (Ocean. Inst. 1986).

The Coupeville Landfill near Penn Cove was evaluated to determine whether there is potential hazardous waste contamination at this site (CERCLIS 1986). This landfill began receiving wastes in 1946. Prior to 1969 the site was operated as a burning dump. Dry cleaning wastes and small quantities of hospital wastes were the only known hazardous substances disposed of at this site (CERCLIS 1987). Plans are in place for installation of a liner and leachate collection system. Island County Health Department conducts quarterly sampling of onsite monitoring wells for a limited number of parameters. Manganese exceeded federal drinking water standards in 1987

but no hazardous leachate has been detected. As a result of investigations, Ecology and the U.S. EPA have decided to take no further action on the Coupeville Landfill near Penn Cove.

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found substantially elevated mortality rates (>50 percent) in receiving water bioassays conducted at one Penn Cove station in 1965, 1968, 1971, 1972, and 1974. Abnormality rates were also substantially elevated in 1972.

SIMILK BAY

Rank Low

Sources

No information available.

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found substantially elevated oyster larvae mortalities (>50 percent) in receiving water bioassays conducted at one station in Similk Bay in 1965, 1971, and 1972. Abnormality rates were also substantially elevated at this site in 1972.

SKAGIT BAY

Rank Medium

Sources

In 1893, the LaConner Mill Company operated a lumber mill in LaConner (Puget Sound Lumberman 1893).

Several marinas are located throughout Skagit Bay (Ocean. Inst. 1978). LaConner has one small marina and a larger marina with 302 wet slips and boat repair facilities, including a drydock.

In 1967, the Swinomish Indian Reservation was permitted to discharge sewage wastes into Skagit Bay (U.S. FWPCC 1967).

There are six NPDES-permitted dischargers in LaConner: three sewage discharges (for the Skagit County Sewer District, Shelter Bay Community, and the town of LaConner) and three fish processing plants (U.S. EPA 1986). Potential sources of toxic contamination in Skagit Bay include a former military facility at Fort Whitman on Goat Island (U.S. Department of Defense 1985), Nasty Jack's Antique's in LaConner which generates 2 tons/yr of hazardous wastes (Kruger 1984), and the Roberts Company, Inc. at the LaConner Marina which is a self-reported generator of acetone wastes (U.S. EPA 1980).

Sediment Condition

Phenanthrene and retene concentrations were not substantially elevated above reference values in sediments sampled from a deep water station west of Strawberry Point (Barrick and Prahl 1987).

In 1970-1972, metal concentrations were not substantially elevated above reference values in sediments sampled at two stations in Skagit Bay (Crecelius et al. 1975).

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) found significantly elevated mortality rates in receiving water bioassays conducted at one station southeast of Dugualla Bay and station north of Point Brown in 1964-1968, 1971, 1972, and 1974. Oyster larvae abnormalities were also substantially elevated in 1964, 1965, 1967, 1968, and 1972.

UTSALADY BAY

Rank Low

Sources

The Puget Mill Company in Utsalady produced 60,000-100,000 bd ft of lumber in 1893 (Puget Sound Lumberman 1893). For many years, a boat maintenance and repair company operated in Utsalady (Ecology 1982; Yearsley, J., 1987, personal communication). This boat maintenance company has since been abandoned.

Sediment Condition

No information available.

Toxicity Indexes

No information available.

REGION 4 ASSESSMENT MATRIX RESULTS

As seen in Table 11, Crescent Harbor received a high ranking in this investigation because of its pending Superfund status and exhibited biological toxicity. Dugualla Bay, Oak Harbor, Penn Cove and Skagit Bay were ranked medium. All other areas of concern received low overall rankings. Sediment condition information was not available for most of the areas of concern in this region. Source information for Similt Bay was also unavailable.

TABLE 11: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 4:

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Cornet Bay, Deception Pass	LOW	HIGH	N/A	N/A	LOW	MEDIUM	LOW
Crescent Harbor	HIGH	HIGH	N/A	N/A	MEDIUM	LOW	HIGH
Dugualla Bay	MEDIUM	HIGH	N/A	N/A	LOW	LOW	MEDIUM
Oak Harbor	MEDIUM	MEDIUM	N/A	N/A	N/A	N/A	MEDIUM
Penn Cove	MEDIUM	HIGH	N/A	N/A	LOW	LOW	MEDIUM
Similt Bay	N/A	N/A	N/A	N/A	LOW	LOW	LOW
Skagit Bay	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Utsalady Bay	LOW	LOW	N/A	N/A	N/A	N/A	LOW

TOXIC ASSESSMENT OF REGION 5:
ADMIRALTY INLET AND EASTERN STRAIT OF JUAN DE FUCA
(Figure 7)

ADMIRALTY INLET

Rank Low

Sources

There is one small marina in Admiralty Inlet (Ocean. Inst. 1978).

Sediment Condition

Brown et al. (1981) collected sediment samples at one station west of Ault Field on Whidbey Island from June 1978 to March 1979. Sediments were analyzed for metals and 23 aromatic hydrocarbons, including 4 LPAHs, 7 HPAHs, 3 benzene compounds, and 9 miscellaneous extractables. These analytes were not substantially elevated above reference values at this site.

From 1970 to 1972, Crecelius et al. (1975) sampled sediments at one station between Oak Bay and Mutiny Bay in the center of Admininiralty Inlet. Metal concentrations in sediments from this station were not substantially elevated above reference values.

Toxicity Indexes

No information available.

DISCOVERY BAY

Rank Low

Sources

In 1893, the Port Discovery Mill Company operated a large mill in Port Discovery that produced 125,000-200,000 bd ft of lumber (Puget Sound Lumberman 1893).

Currently, there are two small marinas in Discovery Bay with fuel and boat repair facilities nearby (Ocean. Inst. 1978).

For many years, a large log storage area was operated by a logging company in Discovery Bay (Ecology 1982; Yearsley, 1987, personal communication).

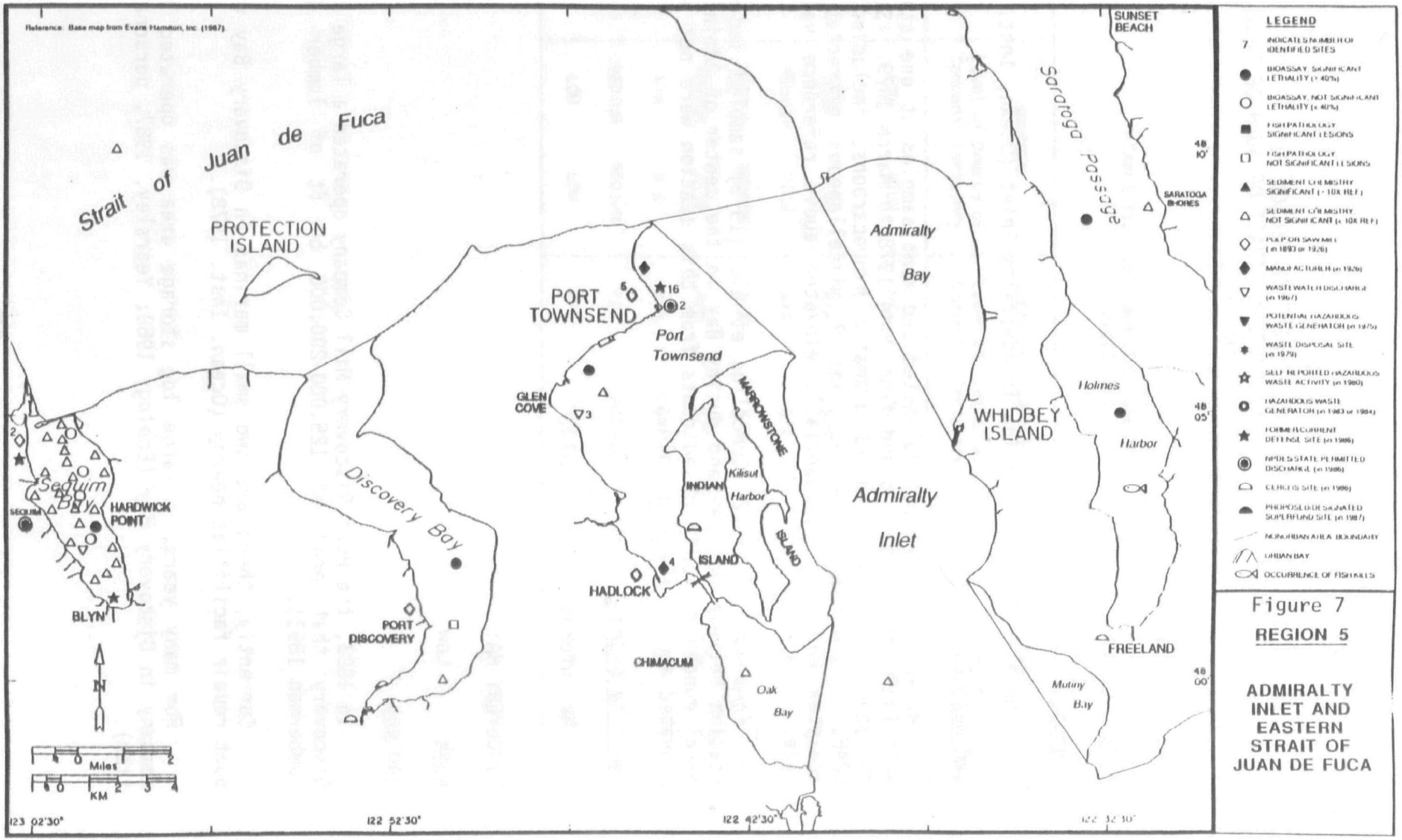


Figure 7

REGION 5

ADMIRALTY INLET AND EASTERN STRAIT OF JUAN DE FUCA

A preliminary assessment was conducted by Ecology to evaluate potential toxic problems along the Milwaukee Railroad right-of-way (U.S. EPA 1986). Toxic chemicals were found at measurable levels in surface water at this site, but the problem was not serious enough to qualify this site as a Superfund site. An Ecology visit shortly after the spill found no hazard associated with the spill. A three car train derailment occurred in 1978 causing a spill of approximately 10,000 gals of sodium chlorate on the east bank of Discovery Bay. The chlorate leaked into the ground and into Discovery Bay. As a result, no further action was taken.

Sediment Condition

Sediments from one station near the head of Discovery Bay were sampled from 1978-1981 by Malins et al. (1982). Sediments were analyzed for aromatic hydrocarbons, PCBs, chlorinated pesticides, other chlorinated organic compounds, and metals. None of the analytes were substantially elevated above reference at this site. Total aromatic hydrocarbons concentrations were low (49 ppb).

Toxicity Indexes

Oyster Larvae Bioassays--

Oyster larvae mortalities observed at one receiving water bioassay station near Port Discovery were substantially elevated (>50 percent) in 1964, 1965, 1968, and 1969 (Cardwell and Woelke 1979). Oyster larvae abnormalities were not substantially elevated at any time during the monitoring period.

Fish Histopathology--

According to Malins et al. (1984), no substantially elevated levels of neoplasms, pre-neoplasms, or megalocytic hepatosis were found in more than 20 English sole, rock sole, and Pacific staghorn sculpin examined in Discovery Bay from 1979 through 1983.

HOLMES HARBOR

Rank Medium

Sources

Currently, one small marina (Ocean. Inst. 1978) and a shipbuilding company (Ecology 1982) are located in Holmes Harbor. The Island County Freeland landfill is located near Holmes Harbor (U.S. EPA 1986). Ecology conducted a preliminary assessment at the Freeland Landfill to determine the potential for toxic contamination, and found no potential for hazardous contamination at this site (CERCLIS 1987).

Sediment Condition

No information available.

Toxicity Indexes

Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), oyster larvae mortalities were substantially elevated (>50 percent) at one receiving water station in the northern part of Holmes Harbor in 1966, 1971, 1972, and 1974. Abnormalities were also substantially elevated in 1971 and 1972.

Fish Kills--

Fish kills from unknown causes have occurred periodically in Holmes Harbor (Ecology 1982).

MUTINY BAY

Rank Low

Sources

One tiny marina with 15 wet slips is located in Mutiny Bay. Fuel and repairs are available onsite (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

OAK BAY

Rank Medium

Sources

Dredging operations related to harbor improvements are a possible source of toxic contaminants (Kittle, L., March 1987, personal communication).

Sediment Condition

PCB concentrations in sediments were not substantially elevated above reference values in 1972-1977 at one centrally located station in Oak Bay (Pavlou et al. 1977).

Toxicity Indexes

Fish Kills--

In 1979, dredging operations caused a large fish kill in Oak Bay (Kittle, L., March 1987, personal communication). Silt from dredging operations also caused a minor fish kill near Chimacum on 26 April 1972 (LeVander, L., March 1987, personal communication).

PORT TOWNSEND

Rank Medium

Sources

Hadlock--

The Washington Mill Company, located in Hadlock, produced 125,000-200,000 bd ft of lumber in 1893 (Puget Sound Lumberman 1893).

The Sehrs Shipbuilding Company, two printers, and a laundry were located in Hadlock (Manu. Assoc. of Washington 1926).

Kruger (1983) identifies one hazardous waste generator near Hadlock, the Naval Undersea Warfare Engineering Station, which produced 59 tons/yr of characteristic waste and 11 tons/yr non-specific wastes in 1983. A site inspection was conducted for the Naval Undersea Warfare Station on Indian Island found observed soil contamination and surface and groundwater contamination at this site (CERCLIS 1987).

Port Townsend--

In 1893, the G.W. Downs lumber mill in Port Townsend produced 60,000 to 100,000 bd ft of lumber (Puget Sound Lumberman 1893).

By 1926, there were four lumber and logging companies (Key City Lumber Company, Miller and Peach, Port Townsend Lumber Company, and O.L. Allen Logging Company), one laundry, and two printing companies in Port Townsend (Manu. Assoc. of Washington 1926). By 1927, the National Paper Products Company had been built in Port Townsend and was producing 60 tons/day of sulphate pulp (Baker 1927).

In 1963, Crown Zellerbach Corporation produced 350 tons/yr of paper and 400 tons/yr of pulp using a Kraft process (Pacific Pulp and Paper Industry 1963). The National Paper Products Company also produced 325 tons/yr of paper and 250 tons/yr of sulphate pulp in 1963. In addition, the National Paper Products Company produces container board and Kraft liners.

In 1967, Fort Worden and the Naval Ammunition Depot at the Indian Island Annex discharged into the waters near Port Townsend (U.S. FWPCC

1967). Other discharges in 1967 included the Crown Zellerbach Corporation pulp and paper mills (U.S. FWPCC 1967).

The Defense Environmental Restoration Program (U.S. Department of Defense 1985) lists 16 former military facilities near Port Townsend, including 4 forts (Ebey, Flagler, Townsend, and Worden), 5 military reservations, and 2 Harbor Defense Units.

A small marina and a medium-size marina are located in Port Townsend. Both marinas have fuel and repairs onsite (Ocean. Inst. 1978). NPDES-permits have been issued for the municipal sewage discharge for the City of Port Townsend and the Port Townsend Paper Company, Inc. located south of Port Townsend (U.S. EPA 1986).

In 1980, the Crown Zellerbach Corporation notified the U.S. EPA that potentially hazardous wastes might be generated by their Port Angeles mill (U.S. EPA 1980). However, Crown Zellerbach pulp and paper mills is not on Ecology's current register of hazardous waste generators (Kruger 1984). The potential for toxic contamination at this site is unknown.

Sediment Condition

In 1970-1972, Crecelius et al. (1975) measured metal concentrations in sediments from one station in Port Townsend, east of Glen Cove. Metal concentrations were not substantially elevated above reference values at this site.

Toxicity Indexes

Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), oyster larvae mortalities were substantially elevated (>50 percent) for one receiving water station near the Port Townsend pulp mill in 1970. Abnormalities were not substantially elevated above reference values at this site at any time during the monitoring period.

SEQUIM BAY

Rank Low

Sources

Soodum Lumber Company and David Burrows lumber mills (now abandoned) were located in Sequim in 1926 (Manu. Assoc. of Washington 1926). In 1967, two discharges to Sequim Bay were reported for Sequim Bay State Park septic waste and the city of Sequim (U.S. FWPCC 1967).

In 1987, a log sort yard (B. Maguire, personal observation) existed in Sequim Bay. The city of Sequim has an NPDES permit to discharge to Sequim

Bay (U.S. EPA 1986). Two military facilities, the Blyn Mountain Radio Station, and the Sequim Cantonment site are also located near Sequim Bay.

Sediment Condition

Sediment from 20 stations throughout Sequim Bay were analyzed for total aromatic hydrocarbons, PCB-1254, 6 metals, and selected aromatic hydrocarbons in April and May 1984 (Battelle Pacific Northwest Laboratory 1986). None of these analytes were substantially elevated above sediment reference values. PCBs were not detected.

Toxicity Indexes

Sediment Amphipod Bioassays--

Battelle Pacific Northwest Laboratories (1986) found no substantially elevated (>40 percent) amphipod mortalities in sediment bioassays conducted with Rhepoxynius abronius. Sediments were collected at four stations in Sequim Bay in summer 1983 and spring 1984. The bioassay procedure developed by Swartz (1984) was used in this study. Since the results are not mapped in the original report, they do not appear on the Region 5 map.

Sediment Oyster Larvae Bioassays--

Pacific oyster larvae bioassays were conducted by Battelle Laboratories in Sequim Bay in April and May 1984 (Battelle Pacific Northwest Laboratories 1986). Standard ASTM bioassays were conducted using surface sediments from the top 6 cm. No substantially elevated abnormality or mortality rates (>40 percent) were observed.

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), oyster larvae mortalities were substantially elevated (>50 percent) at one station near Hardwick Point in Sequim Bay in 1967-1971, 1973, 1974, and 1975. Abnormalities were substantially elevated in 1973, 1975, and 1976.

OTHER BAYS

Rank Low

Sources

No information is available.

Sediment Condition

No information is available.

Toxicity Indexes

No information is available.

REGION 5 ASSESSMENT MATRIX RESULTS

As seen in Table 12, Holmes Harbor and Port Townsend received medium rankings in this investigation. All other areas of concern received low rankings with the exception of Other Bays. No information was available for an accurate assessment of the Other Bays in this region. Holmes Harbor and Mutiny Bay each lacked sediment and toxicity data. No areas in Region 5 received a high ranking.

TABLE 12: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 5:

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Admiralty Inlet	LOW	LOW	LOW	LOW	N/A	N/A	LOW
Discovery Bay	MEDIUM	MEDIUM	LOW	LOW	LOW	LOW	LOW
Holmes Harbor	LOW	MEDIUM	N/A	N/A	MEDIUM	MEDIUM	MEDIUM
Mutiny Bay	LOW	LOW	N/A	N/A	N/A	N/A	LOW
Oak Bay	MEDIUM	LOW	LOW	LOW	LOW	MEDIUM	LOW
Port Townsend	MEDIUM	HIGH	LOW	LOW	LOW	LOW	MEDIUM
Sequim Bay	LOW	MEDIUM	LOW	MEDIUM	LOW	MEDIUM	LOW
Other Bays	N/A	N/A	N/A	N/A	N/A	N/A	N/A

TOXIC ASSESSMENT OF REGION 6:
PORT SUSAN AND SARATOGA PASSAGE
(Figure 8)

MUKILTEO

Rank Medium

Sources

Local anthropogenic sources in Mukilteo include a major fuel storage depot, a ferry terminal and an abandoned boat ramp (Malins 1985), and one small marina.

Two NPDES-permitted discharges are located in Mukilteo: a sewage outfall for the city of Mukilteo and a Defense Fuel Supply Point.

Oil slicks from leaking tanks left by the Northern Pacific Fuel Depot have been reported near Mukilteo (Dexter, R., 1986, personal communication).

There are two Defense Environmental Restoration Account (DERA) sites (U.S. Department of Defense 1985) near Mukilteo: the Mukilteo Defense Fuel Supply Point and the Mukilteo Explosive Loading Terminal. A preliminary assessment at the U.S. Air Force Defense Fuel Support operation near Mukilteo found potential for soil and surface water contamination from tank bottom sludges containing lead and chromium and a jet fuel storage tank leak (CERCLIS 1987). As of 15 October 1987, chemical measurements were not taken to determine the severity of the problem at this site.

Sediment Condition

Crecelius et al. (1975) measured metal concentrations in sediments from one mid-channel station southwest of Mukilteo and another midchannel station across from Penn Cove. Metal concentrations were not substantially elevated above reference values at either of these sites.

According to Pavlou et al. (1977), PCBs were detected between 1972 and 1977 at a mid-channel station northwest of Mukilteo in Possession Sound and a mid-channel station across from the mouth of Penn Cove. These PCB concentrations were not substantially elevated above reference values.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell et al. (1976) reported high oyster larvae mortality rates (>40 percent) in Possession Sound at three mid-channel receiving water stations: one station west and two stations southwest of Mukilteo. Abnormalities were also substantially elevated (>40 percent) at both stations. The highest

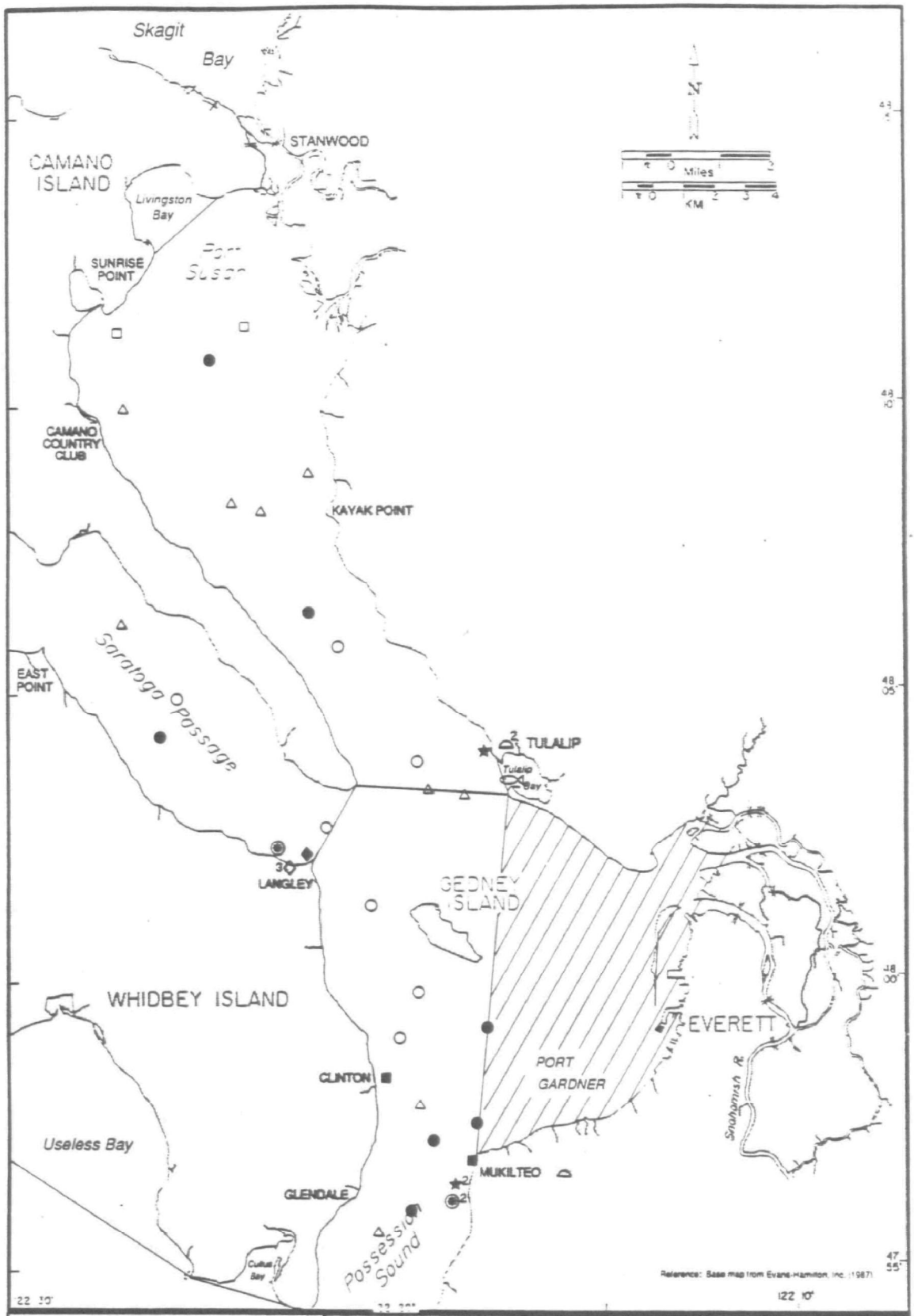


Figure 8

REGION 6

PORT SUSAN AND POSSESSION SOUND

abnormality rates (up to 96.2 percent) were reported at the station located closest to Mukilteo. Lower rates of abnormalities (54.2 percent) were observed at the stations southwest of Mukilteo.

Cardwell and Woelke (1979) found high oyster larvae mortalities at one nearshore station north of Mukilteo. The abnormality rate at this station exceeded 50 percent in 1963, 1964, and 1972, and mortalities exceeded 50 percent in 1972.

Fish Histopathology--

Malins (1985) found substantially elevated incidences of neoplasms (7.5 percent) and pre-neoplasms (16.7 percent) in 66 English sole caught near Mukilteo in June and July 1983. Krahn (1986) found no substantially elevated incidences of neoplasms, pre-neoplasms, or megalocytic hepatosis observed in fish caught near Mukilteo.

Bioaccumulation--

Concentrations of most aromatic hydrocarbons and chlorinated hydrocarbons in English sole liver tissue from Mukilteo were below chemical detection limits (Malins 1985). PCBs were detected, but not at substantially elevated levels in English sole liver tissue from Mukilteo. These results are not mapped.

PORT SUSAN AND TULALIP BAY

Rank Medium

Sources

Poor circulation and proximity to the City of Everett have been suggested as possible contributors to toxic problems in Port Susan (Ecology 1982).

One marina is located at the head of Tulalip Bay across from Stanwood (Ocean. Inst. 1978) and one NPDES-permitted sewage discharge to Port Susan is reported for the city of Stanwood (U.S. EPA 1986).

Port Susan was the site of a former military munitions storage depot at Tulalip (U.S. Department of Defense 1985).

Boeing operates an AC Test Facility in Tulalip (CERCLIS 1986). A preliminary assessment of the possibility of contamination at this site found potential for groundwater contamination (CERCLIS 1987). As of 15 October 1987, measurements had not been taken to confirm the potential for toxic contamination.

The Tulalip Indian Reservation Marine Disposal was listed as a CERCLIS (1986) site. A site inspection found measurable levels of hazardous chemicals in the surface waters near this site and the potential for soil

and groundwater contamination (CERCLIS 1987). According to the site inspection report, this unlined marine disposal landfill operated from 1964 to 1979 and covers 150 acres. Marine Disposal does not have records of the types or quantities of waste materials disposed of at the landfill, although 95 percent of the wastes were generated by commercial and industrial companies in Seattle and brought to the site by barge. The total volume of the landfill is approximately 6 million yd^3 including soil layers between wastes and the cover soil. The landfill was excavated to depths of as much as 10 ft below mean sea level. The landfill is partly located in marshlands where estuary-tidal action of the site, allowing large amounts of leacheates to be released to the water. Leachate drains to Ebey Slough, Steamboat Slough, and Possession Sound. Water quality surveys in 1971 and 1977 confirmed the presence of leachate in surface water. The landfill was closed in 1979 as the result of a U.S. District Court consent decree. The consent decree required a perimeter dike to contain the leachate. Additional remedial action required hardening of the north face of the perimeter dike at the old barge canal entrance to prevent erosion and filling of the old barge canal.

A 1984 remedial investigation of the Marine Disposal landfill estimated that 50 to 100 million gal/yr of leachate are generated at this site. Arsenic concentrations of 49 ug/L was found in leachate along the entrance road. Table 13 contains a list of concentrations of toxic metals and hydrocarbons measured at this site during the remedial investigation.

Sediment Condition

Malins (1982, OMPA-19) sampled sediments from two nearshore stations in Port Susan in 1978-1981. One station was located east of Camano Country Club and the other station was located northwest of Kayak Point. Sediment concentrations of metals and aromatic hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds were not substantially elevated above reference values at either of these sites. Total organic hydrocarbons were fairly low at these stations, with an average concentration of 240 ppb.

In 1970-1972, metal concentrations were not substantially elevated above reference values in sediments from one mid-channel station west of Kayak Point (Crecelius et al. 1975).

Phenanthrene and retene concentrations in sediments from one mid-channel station at the head of Port Susan were not substantially elevated above sediment reference values (Barrick and Prahl 1987).

PCB concentrations in sediments from 1972 to 1977 were not substantially elevated above reference values for one mid-channel station at the head of Port Susan and for another mid-channel station west of Kayak Point in the center of Port Susan (Pavlou et al. 1977).

TABLE 13: METAL AND ORGANIC CONCENTRATIONS MEASURED AT THE TULALIP INDIAN RESERVATION MARINE DISPOSAL SITE

METALS	(ug/L)	ORGANICS	(ug/L)
aluminum	18,900	alkanes	1,000
antimony	32	4-ethylbenzene	62.5
arsenic	49	4-methyl-2-pentanone	62.2
cadmium	1.4	total xylenes	21.5
chromium	415	1,2 dichloroethane d4	101
copper	758	nitro-benzene d5	62
iron	32,300	2-fluorobiphenyl	84
manganese	907		
mercury	0.91		
nickel	457		
selenium	29		
tin	261		
zinc	333		
tributyl phosphate	200		

Toxicity Indexes

Herring Spawning Mortalities--

According to Pentilla (March 1987, personal communication), mortality rates for herring spawn exceed 50 percent in the south half of Tulalip bay behind the spit. The cause of the mortality rates is unknown.

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), oyster larvae mortalities were substantially elevated (>50 percent) at two station sampled in Port Susan. One station is located in the northern part of Port Susan and the other station is southwest of Kayak Point. Both mortalities and abnormalities were substantially elevated for both stations in 1964, 1971, 1972, and 1974.

Oyster larvae mortalities and abnormalities were not substantially elevated (>40 percent) at two stations monitored by Cardwell et al. (1976). One station is located at the mouth of Port Susan and the other station is located mid-channel, approximately halfway between the mouth of Port Susan and Kayak Point.

Bioaccumulation--

Malins et al. (1981) observed bioaccumulation of metals, PCBs, PAHs, chlorinated pesticides, hexachlorobenzene (HCB), and polychlorinated butadienes (CBDs) in English sole livers and skeletal muscle. Fish samples were collected in the summer of 1980 at two stations near Kayak Point and one station near the Camano Country Club. Chromium levels in English sole muscle tissue were substantially elevated above reference values at all three Port Susan stations. Other metals concentrations were not substantially elevated above reference values and PCBs were not detected in tissue samples. This information is not mapped.

Fish Histopathology--

According to Malins et al. (1984), incidences of neoplasms, preneoplasms, or megalocytic hepatosis were not substantially elevated in more the 20 English sole, rock sole, and Pacific staghorn sculpin examined at two Port Susan stations between 1979 and 1983.

POSSESSION SOUND

Rank Low

Sources

Two NPDES-permitted discharges located in Possession Sound are the Alderwood Water District and the Olympus Terrace Sewer District. Local anthropogenic sources of toxicants include a ferry terminal in Clinton on

Whidbey Island (Malins et al. 1984), and one small marina on Gedney Island (Ocean Inst. 1978).

Sediment Condition

Total aromatic hydrocarbon concentrations in sediments sampled in the first quarter of 1984 were 650 ppb at a station near Edmonds and 199 ppb at a station near Clinton (Malins 1984). Since there are no reference values for total aromatic hydrocarbons, the elevation above reference could not be computed. Therefore, these stations are not mapped.

Toxicity Indexes

Oyster Larvae Bioassays--

Bioassays were conducted at four receiving water stations in Possession Sound (Cardwell et al. 1976). Abnormalities and mortalities were not elevated (>40 percent) at three stations sampled near Gedney Island. Toxicity was very high at the fourth station half way between Mukilteo and Gedney Island near the mouth of Port Gardner. One sample at this station resulted in 100 percent mortality and another sample resulted in abnormalities up to 78.9 percent.

Fish Histopathology--

High rates of neoplasms (12.5 percent) were observed in 16 English sole caught at Clinton in the winter of 1983 and 1984 (Krahn et al. 1986; Malins 1984). Rates of pre-neoplasms (25.5 percent) and megalocytic hepatosis (43.8 percent) were also elevated near Clinton. However, fewer than 20 fish were caught at Clinton, so these results should be interpreted with caution.

SARATOGA PASSAGE

Rank Low

Sources

Three lumber and logging operations, Bay View MIll, H.E. Lumber Company, and Langley Logging Company, were located in Langley in 1926 (Manu. Assoc. of Washington 1926). The Whidbey Record had begun publishing in Langley by 1926.

Currently, there are three small marinas (Ocean. Inst. 1978) located near Langley and one NPDES municipal discharge permit for the city of Langley Sewage Treatment Plant (U.S. EPA 1986). One marina of unreported size is located at Sunset Beach (see the Region 5 map) and another marina is located in Stanwood (Ocean Inst. 1978).

Sediment Condition

PCB concentrations in sediments were not substantially elevated above reference values for two Saratoga Passage stations sampled from 1972 to 1977 (Pavlou et al. 1977). One station was located in Saratoga Passage east of Penn cove and the other stations was located in southern Saratoga Passage east of East Point.

Crecelius et al. (1975) measured concentrations of metals in sediments at two Saratoga Passage stations from 1970 to 1972. One station is located east of Penn Cove and the other nearshore station is located west of Saratoga Shores (on the Region 5 map). Metal concentrations were not substantially elevated at either station.

Toxicity Indexes

Oyster Larvae Bioassays--

Cardwell and Woelke (1979) conducted oyster larvae bioassays for two receiving water stations in Saratoga Passage. One station is located halfway between Langley and East Point and the other station is located near Holmes Harbor. Oyster larvae mortalities were substantially elevated (>50 percent) for the station near Holmes Harbor in 1966, 1971, and 1972. Abnormalities were also substantially elevated for the same station in 1966 and 1972. Oyster larvae mortalities were substantially elevated (>50 percent) at the other bioassay site in 1964, 1965, 1968, 1971, 1972, and 1974 (Cardwell and Woelke 1979). Oyster larvae abnormalities were also elevated in 1964 and 1972.

Oyster larvae mortalities and abnormalities were not substantially elevated (>40 percent) at two stations monitored by Cardwell et al. (1976). One station is located at the mouth of Saratoga Passage and the other station is located approximately halfway between Langley and East Point.

REGION 6 ASSESSMENT MATRIX RESULTS

As seen in Table 14, Mukilteo and Port Susan/Tulalip Bay received medium rankings in this investigation. All other areas of concern were ranked low. No areas in Region 6 received a high ranking.

TABLE 14: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 6:

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Mukilteo	MEDIUM	HIGH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
Port Susan and Tulalip Bay	MEDIUM	HIGH	LOW	MEDIUM	LOW	HIGH	MEDIUM
Possession Sound	MEDIUM	MEDIUM	LOW	LOW	LOW	LOW	LOW
Saratoga Passage	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM	LOW

TOXIC PROBLEM ASSESSMENT OF REGION 7:
CENTRAL HOOD CANAL AND DABOB BAY
(Figure 9)

CENTRAL HOOD CANAL

Rank Low

Sources

In 1926, the Crosby Mill Company lumber mill was located in Seabeck (Manu. Assoc. of WA 1926). In 1940, one of the largest lumber mills in Puget Sound, the Washington Mill Company, produced 180,000 bd ft of lumber, 41 ft of spars, 400,000 laths, and 200,000 lineal ft of piles in Seabeck (Gates 1941).

Five marinas are scattered throughout Central Hood Canal (Ocean. Inst. 1978). In addition, a small marina with fuel and repairs is located at Point Beacon and a larger marina with 170 wet slips, fuel, and repairs is located in Seabeck (Ocean. Inst. 1978).

Sediment Condition

Cummins (1976) measured metal concentrations in sediments sampled from one station near Misery Point in September and October 1975.

Between 1970 and 1972, Crecelius et al. (1975) sampled sediments at one station near Olympic View, south of Bangor in the central channel of Hood Canal. Metal concentrations in sediments from this station were not significantly elevated above reference values.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Seawater was collected from Hood Canal near Misery Point at low tide on 15 September 1975. No significant elevations in mortality or abnormality rates were observed in oyster larvae bioassays conducted with this sample of receiving water (Cummins et al. 1976).

Cardwell and Woelke (1979b) conducted oyster larvae bioassays at one station east of Eldon from 1962 to 1976. Both mortalities and abnormalities were significantly elevated above reference values at this station in 1974.

DABOB BAY

Rank Low

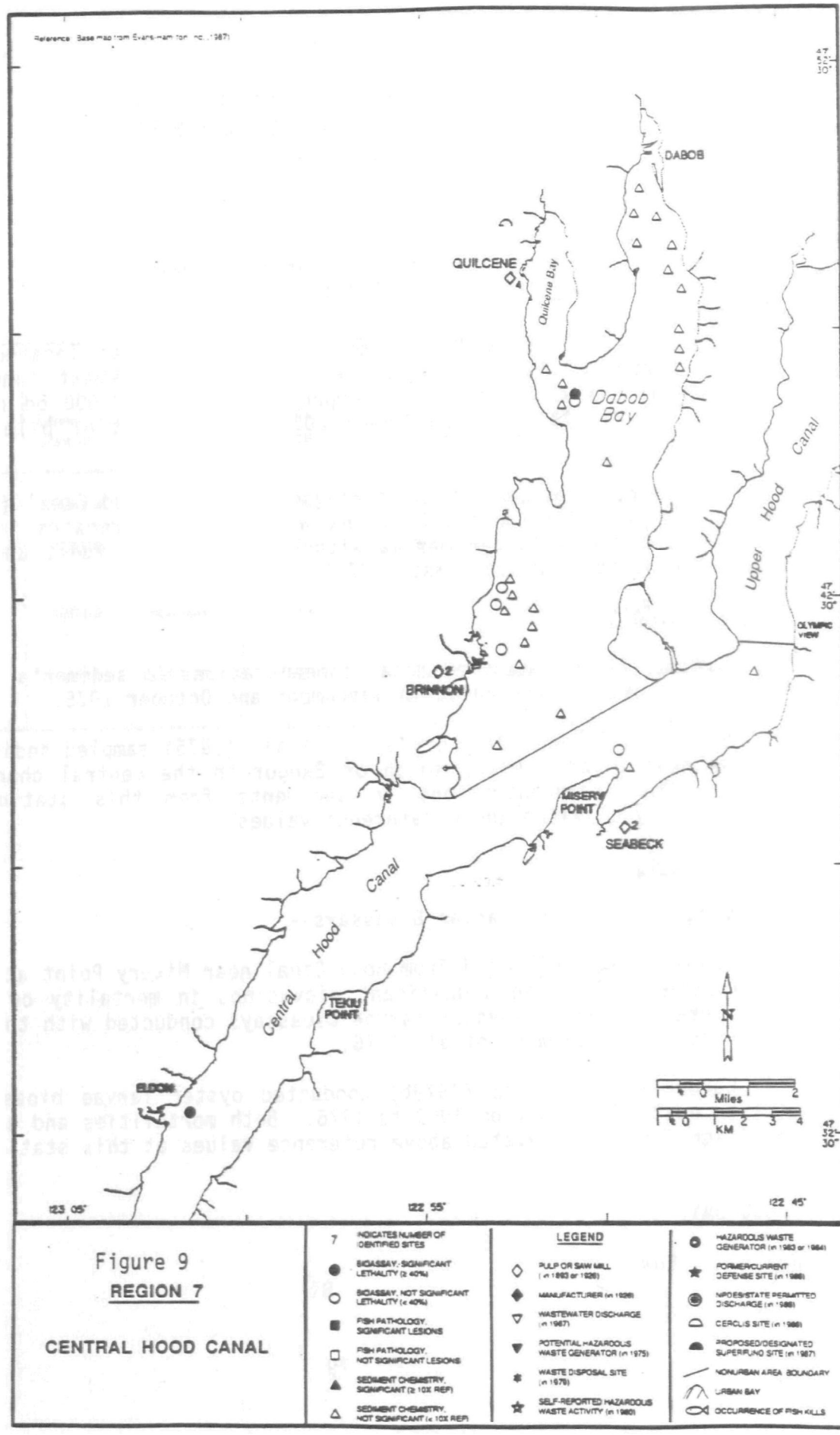


Figure 9

REGION 7

CENTRAL HOOD CANAL

Sources

In 1893, the Fred Girtanner lumber mill in Brinnon produced less than 12,000 bd ft of lumber and 30,000-50,000 ft of shingles (Puget Sound Lumberman 1893). In 1926, C B & M Logging Company was also operating in Brinnon (Manu. Assoc. of WA 1926).

Brinnon is the site of a large marina with 190 wet slips. This marina has no boat repair facilities (Ocean. Inst. 1978).

An unconfirmed source of PAHs in Dabob Bay could be from oiled telemetry cables used to monitor naval torpedo experiments (Barrick and Prahl 1987).

Sediment Condition

In April and May 1984, Battelle (1986) sampled sediments at 10 nearshore stations near the head of Dabob Bay, and at 3 nearshore and 4 deeper water stations northeast of Brinnon. Sediment concentrations were reported for total aromatic hydrocarbons, PCB-1254, eight metals, and selected hydrocarbons. None of these analytes were significantly elevated above reference values at any of the stations sampled. PCBs were not detected at any of the 17 stations sampled.

Sediment concentrations of phenanthrene and retene were not significantly elevated above reference values in sediments collected from one station southeast of the mouth of Quilcene Bay (Barrick and Prahl 1987).

PCB concentrations were not significantly elevated above reference values in sediments from one station near the mouth of Dabob Bay from 1972 to 1977 (Pavlou et al. 1977).

Crecelius et al. (1975) measured metals concentrations in sediments from a midchannel station near the mouth of Dabob Bay from 1970 to 1972. Metal concentrations were not significantly elevated above reference values.

Toxicity Indexes

Amphipod Bioassays--

Battelle (1986) conducted amphipod bioassay screening surveys in summer 1983 and detailed surveys in spring 1984 using the top 6 cm of surface sediments in Dabob Bay. A bioassay was conducted on Rhepoxynius abronius using the procedure developed by Swartz (1984). The results of the screening surveys and the detailed surveys were contradictory. The detailed survey of three stations in Dabob Bay revealed no significant ($\geq$40 percent) elevations in amphipod mortalities. However, screening surveys at 17 stations revealed significantly elevated mortalities at 2 stations at the mouth of Dabob Bay. The results of the screening surveys are not mapped.

Sediment Oyster Larvae Bioassays--

Pacific oyster larvae bioassays were conducted at three stations in Dabob Bay during April and May 1984 using standard ASTM procedures and the top 6 cm of surface sediments (Battelle 1986). Oyster larvae abnormality rates observed in sediment bioassays were not significantly elevated at these sites. These results are not mapped because Battelle did not map them in the original study.

QUILCENE BAY

Rank Medium

Sources

In 1893, the M.F. Hamilton lumber mill in Quilcene produced less than 12,000 bd ft of lumber (Puget Sound Lumberman 1893). By 1926, the number of lumber mills operating in Quilcene had grown to three. Mill operators were Kay Smith, Beck & Kruse, and the Green Mill Company (Manu. Assoc. of WA 1926).

One small marina is located in Quilcene (Ocean. Inst. 1978). Two state discharge permits have been issued for an oyster company and Olympic Testing Labs in Quilcene (U.S. EPA 1986).

Olympic Testing Laboratories is a closed mineral assay laboratory that operated precious metals processing for about 1 yr. It is a CERCLIS site and the U.S. EPA conducted a site inspection to determine whether hazards exist at this site (CERCLIS 1986). The U.S. EPA inspection revealed that measurable levels of toxic chemicals exist in the soil and surface water, and groundwater contamination is also possible. Chemicals and lead slag were stored and disposed of onsite during the laboratory's operation. Forty drums of lead slag, an uncovered slag pile, and numerous areas of soil contamination were found on the abandoned site. An uncovered drum of lead monoxide, several asbestos drums, and an unknown amount of sodium hydroxide were also discovered onsite. These substances are known to be toxic and persistent. During a remedial action, the drums and lead slag pile were moved into a building on site. Low levels of lead, zinc, arsenic, nickel, and chrome are still present in the soil (1984 CH2MHILL E&E REM/FIT Preliminary Site Inspection report of Olympic Testing Laboratories).

In 1960, Washington Department of Fisheries conducted oyster drill and ghost shrimp control tests in Quilcene Bay using Sevin and Lindane (Lindsay 1961). One 8 m x 8 m plot was treated with orthodichlorobenzene and Sevin, and the other plot was treated with furnace oil and Lindane. These toxicants were effective in killing ghost shrimp. By early summer, the plots were destroyed by shifting sediments and storms.

Sediment Condition

Battelle (1986) sampled sediments at three midchannel stations at the mouth of Quilcene Bay as part of a sediment reconnaissance study in April and May 1984. Sediments were analyzed for total aromatic hydrocarbons, PCB-1254, eight metals, and selected aromatic hydrocarbons. Sediment concentrations of metals and aromatic hydrocarbons were not substantially elevated above reference and PCBs were undetected at these three stations.

Toxicity Indexes

Amphipod Bioassays--

Battelle (1986) conducted amphipod bioassay screening surveys in summer 1983 and detailed surveys in spring 1984 using surface sediments (top 6 cm) from Quilcene Bay. A bioassay was performed on Rhepoxynius abronius using the procedure developed by Swartz (1984). The detailed survey of one station in Quilcene Bay found no substantial (≥40 percent) elevations in amphipod mortality. An earlier screening survey of three stations near the mouth of Quilcene Bay found substantially elevated bioassay mortality rates at one station at the mouth of Quilcene Bay. The results of the screening survey are not mapped.

Pacific oyster larvae bioassays were conducted at one station in Quilcene Bay in April and May 1984 using standard ASTM procedures on the top 6 cm of surface sediments (Battelle 1986). Oyster larvae abnormality rates were not substantially elevated in sediment bioassays conducted at this site.

REGION 7 ASSESSMENT MATRIX RESULTS

As seen in Table 15, Quilicene Bay received a medium ranking in this investigation. Dabob and Central Hood Canal both ranked low overall. No areas of concern in Region 7 are ranked high.

TABLE 15: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 7:

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Central Hood Canal	LOW	LOW	LOW	LOW	MEDIUM	MEDIUM	LOW
Dabob Bay	LOW	MEDIUM	LOW	MEDIUM	LOW	HIGH	LOW
Quilcene Bay	MEDIUM	MEDIUM	LOW	MEDIUM	LOW	MEDIUM	MEDIUM

TOXIC PROBLEM ASSESSMENT OF REGION 8:
UPPER MAIN BASIN AND UPPER HOOD CANAL
(Figure 10)

APPLETREE COVE

Rank Low

Sources

In 1893, the A.W. Gordon lumber mill, located in Kingston, produced less than 12,000 bd ft of lumber (Puget Sound Lumberman 1893). U.S. FWPCC (1967) listed two discharges to Class AA waters in Kingston: 1) the abandoned Nike Missile Base (and associated Army Housing) and 2) the state ferry dock.

One medium-size marina with 288 wet slips and fuel and repair facilities is located in Kingston (Ocean. Inst. 1978). One NPDES permit was issued for the sewage treatment plant for the Kitsap County Planned Unit Development to discharge to Appletree Cove (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

CULTUS BAY

Rank Low

Sources

One small marina is located in Cultus Bay (Ocean Inst. 1978).

A recent Ecology preliminary assessment was conducted for the Island County Cultus Bay Landfill, a CERCLIS site, to evaluate its potential for contamination (U.S. EPA 1986). Potential for soil, surface water, and groundwater contamination from leachate exists at this site (U.S. EPA 1987). As of 15 October 1987, measurements of chemical concentrations had not been conducted to determine the extent of the problem.

Sediment Condition

No information available.

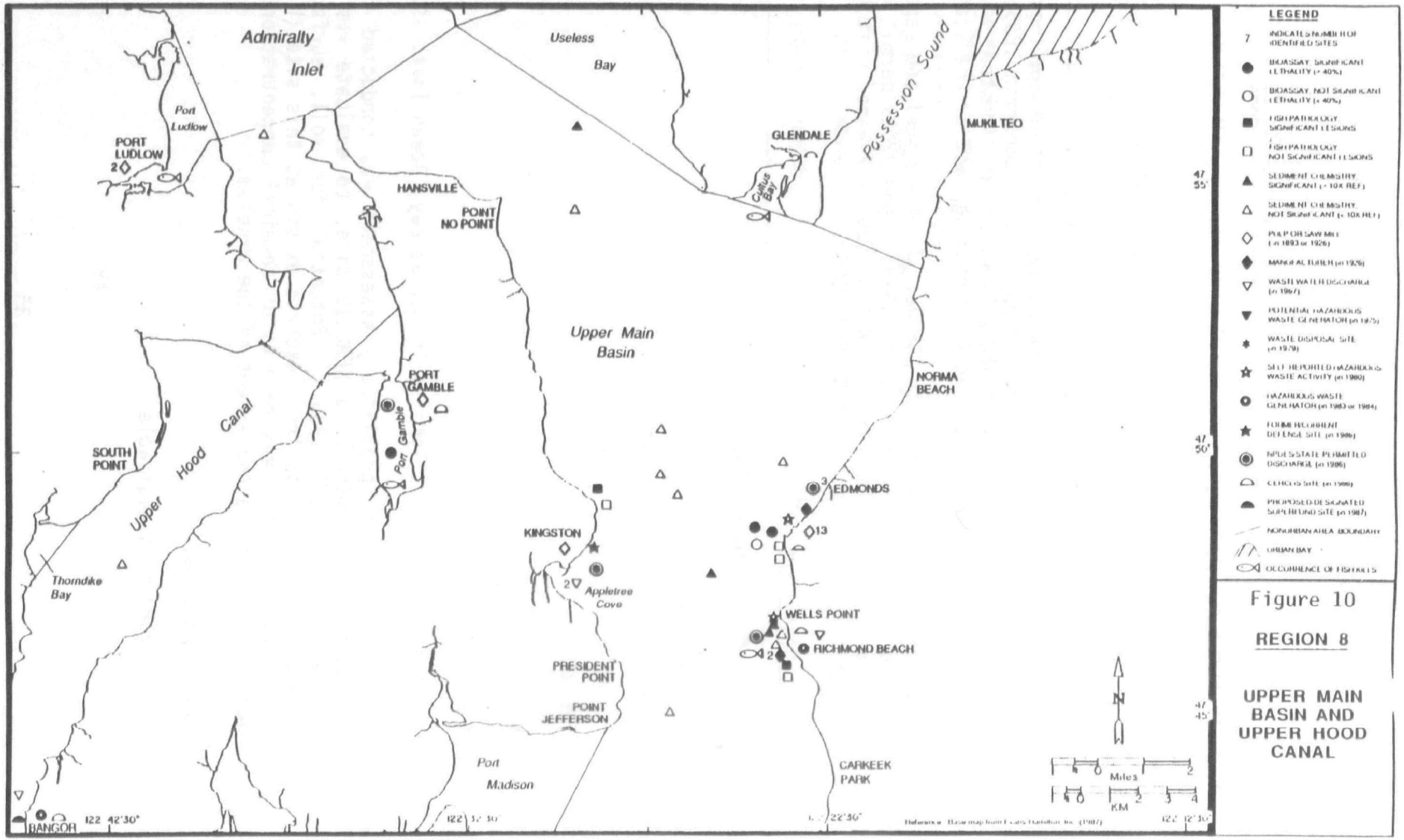


Figure 10

REGION 8

UPPER MAIN BASIN AND UPPER HOOD CANAL

Toxicity Indexes

According to L. Kittle (March 1987, personal communication), two fish kills occurred in Cultus Bay in 1978. Fish kills of approximately 200,000 herring have also occurred in Cultus Bay in the past several years. The cause of these kills is unknown.

EDMONDS

Rank Medium

Sources

In 1893, two small lumber mills were operated by George Brackett and Fish & Owen, in Edmonds. These two mills processed 12,000-15,000 bd ft of lumber. Four medium-size shingle mills were operated by J.W. Currie, Keller & Mienecker, A. Holmquist, and J.E. Peterson, and processed 30,000-50,000 ft of lumber each (Puget Sound Lumberman 1893).

By 1926, three shingle mills (operated by Oak Land Shingle Mill, Rainbow Shingle Company, and Quality Shingle Company) and three lumber mills (operated by Kelly Brothers, A & C Mill, and Edmond Mutual Mill Company) were operating in Edmonds (Manu. Assoc. of WA 1926). In addition, the Edmonds Tribune Review newspaper was being printed in 1926 (Manu. Assoc. of WA 1926). In 1927, a small pulp mill operated by the Occident Pulp and Paper Company was producing 25 tons of ground wood pulp per day (Baker 1927).

Three marinas with a combined total of about 700 wet slips, and with fuel and repair facilities are in Edmonds (Ocean. Inst. 1978).

The following are three NPDES-permitted discharges in Edmonds: Union Oil Company of California, sewage treatment plant for the city of Edmonds, and a fishery (U.S. EPA 1986). Local anthropogenic sources of toxicants include a ferry terminal, and oil transfer and storage facilities located in Edmonds (Malins et al. 1984). These sources are not mapped.

The Union Oil Company in Edmonds is a self-reported generator of hazardous wastes (U.S. EPA 1980) and a CERCLIS site (U.S. EPA 1986). This facility has been in operation since 1920 and is currently used as a bulk petroleum storage facility. No refining has occurred at this site since 1974. Union Oil Company has a tank farm, and primary and secondary detention ponds. The detention ponds are lined and any discharge is regulated by an NPDES permit. An overflow pond contains tars, sludges, and oils from the refinery operation. An asphalt refinery (now dismantled) was operated onsite from 1951 to 1974. Asphaltic tars and petroleum sludges have been deposited in landfills onsite. While Ecology indicated no known problem with the current operations, there is a potential for soil contamination from past operating practices or from oil spills. A 1987 site inspection documented the release of petroleum hydrocarbons from a leaking underground

storage tank, the former waste ponds, and the former refinery plant. A site inspection conducted at the Union Oil Company site found measurable levels of groundwater contamination and the potential for soil contamination (U.S. EPA 1987).

Sediment Condition

Metro (1984) sampled sediments at one station north of Edmonds in March 1981 to measure sediment concentrations of 16 metals and 50 aromatic hydrocarbons, including 6 LPAHs, 10 HPAHs, 11 pesticides, 5 phthalates, 4 chlorinated benzenes, 11 volatile hydrocarbons, and 3 miscellaneous extractables.

Toxicity Indexes

Amphipod Bioassays--

A Metro (1984) study found substantially elevated levels of amphipod bioassay mortalities at one station near Edmonds. Results were mixed, with high mortality rates at one station and low mortality rates at a station located further south.

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates (>50 percent) of abnormalities and mortalities for oyster larvae bioassays have been recorded at one station near Edmonds in July 1962. High rates of oyster larvae mortalities were also recorded at one station near Edmonds in July 1970.

Fish Histopathology--

Krahn (1986) found no neoplasms and no substantial elevations in the incidence of pre-neoplasms and megalocytic hepatosis in 21 English sole sampled in the waters near Edmonds.

PORT GAMBLE

Rank Medium

Sources

In 1893, the largest lumber mill in Puget Sound, the Puget Mill Company, was located in Port Gamble (Chasan 1984). This mill produced over 200,000 bd ft of lumber annually by 1893 (Puget Sound Lumberman 1893).

There is one state-permitted municipal septic system discharge to Port Gamble (Ecology 1986).

Ecology has conducted a preliminary assessment at the Hansville Landfill CERCLIS site to determine whether any potential toxic contaminants exist there (U.S. EPA 1986). This active municipal landfill, located east

of Port Gamble, formerly accepted septic sludge and demolition debris. Industrial wastes may also have been disposed of at this site. Groundwater contamination has been observed (U.S. EPA 1987) and there is potential for soil and surface water contamination. The Hansville Landfill drains to Port Gamble. Heavy metals, especially lead, were found in monitoring wells and were present at low levels in the groundwater. Since there is no record of hazardous waste disposal at this site, a low priority was assigned to it. However, the presence of heavy metals in groundwater indicates a source is present.

Sediment Condition

Ecology is currently conducting a sediment reconnaissance survey in Port Gamble. While the final results are not yet available, preliminary results indicate that organic chemical concentrations in sediments taken from Port Gamble are not substantially elevated above reference values (B. Yake, March 1987, personal communication). Since these preliminary laboratory results have not undergone quality control, the final laboratory results may be different. These results are not mapped.

Toxicity Indexes

Herring Spawning Mortalities--

According to Pentilla (February 1987, personal communication), herring spawn mortality rates along the eastern shore and upper half of the western shore of Port Gamble exceeded 20 percent between 1980 and 1986. In some years, the south and southeastern shores also had herring spawn mortalities greater than 20 percent. Ecology is conducting a sediment reconnaissance study to determine the cause of the high herring egg mortalities (see above).

Receiving Water Oyster Larvae Bioassays--

Cardwell and Woelke (1979b) found significantly elevated mortality rates at one station in the center of Port Gamble in 1971 and substantially elevated abnormalities at a different station near the mouth of Port Gamble in 1965.

PORT LUDLOW

Rank Low

Sources

In 1893, the Puget Mill Company operated a large shingle mill in Port Ludlow that produced 125,000-200,000 bd ft of shingles (Puget Sound Lumberman 1893). By 1926, the Bishop Brothers Logging Company was operating in Port Ludlow (Manu. Assoc. of WA 1926).

A small marina is located in Port Ludlow (Ocean. Inst. 1978). The Pope & Talbot Development Company has an NPDES permit to discharge to Port Ludlow (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

Herring Spawning Mortalities--

According to Kittle (March 1987, personal communication), high herring egg mortalities are reported each year on the side of the bay near the lumber mill.

PRESIDENT POINT AND POINT JEFFERSON

Rank Medium

Sources

No information available.

Sediment Condition

Metro (1984) sampled sediments from the following three stations in this area: one station east of Point Jefferson in August 1982; one deep water mid-basin station located east of Point Jefferson in March 1981; and one mid-basin station east of Appletree Cove. Sediment concentrations were measured for 16 metals and 50 aromatic hydrocarbons, including 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Metals concentrations were substantially elevated above reference values at the deep water mid-basin station. Antimony and arsenic exceeded AET values at Station 0113. Two HPAHs were substantially elevated at the station east of Point Jefferson and three HPAHs were significantly elevated at the mid-basin station east of Appletree Cove (see Table 16).

Concentrations of total aromatic hydrocarbons at a mid-basin station east of President Point were five times higher (1,100 ppb) than sediment concentrations at Point No Point (Malins, 21 November 1984, personal communication). Since reference values are not available for total aromatic hydrocarbons, an elevation above reference could not be computed. Therefore, these results are not mapped.

TABLE 16. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT TWO STATIONS NEAR POINT JEFFERSON IN UPPER MAIN BASIN

Chemical	Elevation Above Reference	
	S0041 181 m	Jeff-Cark 0113 >200 m
Antimony	NS[a]	100.0[b]
Arsenic	NS	44.5[b]
Benzo(a)anthracene	21.8	NS
Benzo(a)pyrene	23.3	NS

[a] NS = Not substantially elevated.

b = AET value exceeded

Reference: Metro (1984).

Toxicity Indexes

Fish Histopathology--

Krahn et al. (1986) found no neoplasms or pre-neoplasms in 20 English sole caught at President Point. The incidence of megalocytic hepatosis was substantially elevated (20 percent) in the same 20 sole caught at President Point.

According to Malins et al. (1985), no substantial elevations in the incidence of neoplasms or pre-neoplasms were found in a sample of 40 English sole examined at President Point in June and July 1983.

Bioaccumulation--

Concentrations of most aromatic hydrocarbons and chlorinated hydrocarbons were below detection limits in English sole liver tissue from President Point (Malins et al. 1985). PCBs were detected, but were not substantially elevated in English sole livers from fish caught near President Point. These results are not mapped.

RICHMOND BEACH

Rank High

Sources

In the late 1800s and early 1900s, damaged boats were discarded and burned on Richmond Beach (Dexter, R., March 1986, personal communication). This may have introduced metal from ship parts and PAHs from wood burning into sediments near Richmond Beach. This source is not mapped.

In 1926, the following two wood products companies were located in Richmond Beach: Washington Cooperage & Packing Company, and Walker's Trunk Factory (Manu. Assoc. of WA 1926).

A large Metro sewage treatment plant outfall has been operating at Richmond Beach since 1963. The Arrow Transportation Company and Chevron Asphalt Division, located in Richmond Beach, are self-reported generators of hazardous wastes (U.S. EPA 1980).

The Chevron Point Wells Terminal produces 36 tons of characteristic hazardous waste annually and is listed as a hazardous waste generator by Kruger (1984). The Point Wells Terminal is also an NPDES discharger (U.S. EPA 1986). Chevron USA operates an Asphalt Division at the Point Wells Terminal, just north of Richmond Beach, that generates or disposes of phenols (U.S. EPA 1980). The Chevron Asphalt Division is a CERCLIS site. As a result of a preliminary assessment in 1985, Ecology and the U.S. EPA decided to take no further action at this site (U.S. EPA 1986).

Sediment Condition

Metro (1984) measured concentrations of 16 metals and 50 aromatic hydrocarbons in sediments from six stations near the Richmond Beach outfall between April 1981 and August 1982. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Two of the six stations monitored at Richmond Beach showed substantially elevated concentrations of several organic chemicals. At one additional station, zinc was substantially elevated (see Table 17). In addition, N-nitrosodiphenylamine concentration at two stations was several times higher than the AET. These two stations are located near the Richmond Beach sewage treatment plant outfall.

Toxicity Indexes

Fish Kills--

According to L. LeVander (3 March 1987, personal communication), an unknown pollutant killed 6-11 salmonids at Richmond Beach on 5 July 1985.

Fish Histopathology--

High rates of pre-neoplasms (28.6 percent) and megalocytic hepatosis (19.0 percent) were observed in 21 English sole caught near Richmond Beach (Krahn et al. 1986).

Bioaccumulation--

Metro (1984) found substantially elevated levels of PCB and phthalate concentrations in rock crab collected in the winter of 1981 to 1982 at the Richmond Beach station. Di-octyl phthalate was also substantially elevated in English sole muscle tissue at Richmond Beach. These phthalates are only mildly toxic to marine biota. Metals were not substantially elevated in rock crab or English sole sampled at Richmond Beach. These results are not mapped.

UPPER HOOD CANAL

Rank Medium

Sources

One small marina is located in upper Hood Canal near South Point (Ocean. Inst. 1978). In addition, the U.S. FWPCC (1967) lists a discharge permit for the Naval Ammunitions Depot at Marginal Wharf, near the Naval Submarine Base at Bangor.

The most important potential source of toxic contamination in upper Hood Canal is the Naval Submarine Base at Bangor. This site has been offi

TABLE 17. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS NEAR RICHMOND BEACH

Chemical	Elevation Above Reference: Station A101 31 m	Station B101 Unknown	Station S0046 20 m
Zinc	NS[a]	16.9	NS
Chrysene	28.7	NS	NS
Fluoranthene	25.2	NS	NS
Fluorene	NS	NS	33.4
N-nitrosodiphenylamine	640.6[b]	NS	70.5[b]
Phenanthrene	42.1	NS	30.0
Pyrene	37.5	NS	43.3

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

cially designated on the National Priorities List as a Superfund site. This base generated 414 tons of characteristic hazardous waste in 1984 (Kruger 1984). According to the Seattle Times (1987), a 10-yr old gasoline leak was uncovered at the Naval Submarine Base at Bangor. At least 20,000 gal of gasoline have been leaking from this site since 1976. According to the Times, the U.S. EPA also discovered a transformer spill near the submarine base. Concentrations of PCBs resulting from this spill exceeded U.S. EPA allowable levels for PCBs (Seattle Times 1987). The U.S. EPA evaluated the Bangor Ordnance Disposal at the Submarine Base for potential contamination and found soil, surface water, and groundwater contamination.

Sediment Condition

Between 1972 and 1977, PCB concentrations were not substantially elevated above reference values in sediments sampled from a midchannel station east of Thorndike Bay (Pavlou et al. 1977).

Metal concentrations in sediments taken between 1970 and 1972 from a midchannel station at the mouth of Hood Canal were not substantially elevated above reference values (Crecelius et al. 1975).

Toxicity Indexes

No information available.

USELESS BAY

Rank Low

Sources

No information available.

Sediment Condition

Malins (1984) measured total aromatic hydrocarbon concentrations in Useless Bay sediments to establish sediment "reference" concentrations for a relatively pristine area of the Sound. In the first quarter of 1984, total aromatic hydrocarbon concentrations of 130 ug/kg were observed in sediments from one station in Useless Bay. Since Puget Sound reference values are not available for this chemical grouping, the elevation above reference could not be computed and this station is not mapped.

Phenanthrene and retene concentrations in sediments from one station located in the center of the mouth of Useless Bay were not substantially elevated above reference values (Barrick and Prahl 1987).

Toxicity Indexes

Fish Histopathology--

According to Krahn et al. (1986), no neoplasms or megalocytic hepatosis were found in 16 English sole sampled at Useless Bay. Pre-neoplasms were substantially elevated (6.2 percent) in the sample of 16 sole. These results should be interpreted with caution, because a sample size of less than 20 fish may produce unrepresentative results.

OTHER AREAS

Rank Medium

Sources

The upper main basin of Puget Sound includes several cities and towns previously discussed: Appletree Cove (Kingston), Cultus Bay, Edmonds, Port Gamble, Port Ludlow, President Point, Richmond Beach, and Useless Bay. Other areas in the central main basin are discussed below.

Hansville--

Hansville has one small marina with fuel and repair facilities (Ocean. Inst. 1978).

Norma Beach--

There is one small marina, and one large marina with 250 dry slips and fuel and boat repairs near Norma Beach (Ocean. Inst. 1978).

Sediment Condition

Phenanthrene and retene concentrations were not substantially elevated above reference values in sediments from one deep water station west of Edmonds (Barrick and Prahl 1987).

Metro (1984) collected sediment samples from one deep water station in the main basin between Point Wells and Appletree Cove. Sediment concentrations were measured for 16 metals and 50 aromatic hydrocarbons, including 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Sediment concentrations of three PAHs were substantially elevated at this site (Table 18).

Total aromatic hydrocarbons were measured at 290 ug/kg for a station east of Point No Point in the center of Admiralty Inlet (Malins, 21 November 1984, personal communication).

Pavlou et al. (1977) measured PCB concentrations in sediments from one mid-basin station west of Edmonds. PCBs were not substantially elevated above reference values at this station from 1972 to 1977.

TABLE 18. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT ONE STATION IN THE UPPER MAIN BASIN

Chemical	Elevation Above Reference Station S004 (182 m)
Fluorene	49.9
Phenanthrene	74.8
Pyrene	29.3

Reference: Metro (1984).

Crecelius et al. (1975) measured metal concentrations in sediments from one midchannel station in upper Puget Sound between Edmonds and Appletree Cove. Metal concentrations were not substantially elevated at this station.

Toxicity Indexes

No information available.

REGION 8 ASSESSMENT MATRIX RESULTS

As seen in Table 19, Richmond Beach received a high ranking due to the industrialized nature of its surroundings and the high level of concern associated with the sediment. President Point, Edmonds, Port Gamble, Upper Hood Canal, and Other Areas in Region 8 received medium rankings in this investigation. However, source data from President Point/Point Jefferson and Useless Bay were unavailable for this review. Sediment and/or toxicity data are missing for Appletree Cove, Cultus Bay, Edmonds, Port Ludlow, Upper Hood Canal, and many other sites in Region 8.

TABLE 19: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 8

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Appletree Cove	LOW	HIGH	N/A	N/A	N/A	N/A	LOW
Cultus Bay	MEDIUM	MEDIUM	N/A	N/A	LOW	LOW	MEDIUM
Edmonds	MEDIUM	MEDIUM	N/A	N/A	MEDIUM	MEDIUM	MEDIUM
Port Gamble	MEDIUM	HIGH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
Port Ludlow	LOW	LOW	N/A	N/A	LOW	LOW	LOW
President Pt and Point Jefferson	N/A	N/A	HIGH	HIGH	LOW	MEDIUM	MEDIUM
Richmond Beach	MEDIUM	HIGH	HIGH	HIGH	LOW	MEDIUM	HIGH
Upper Hood Canal	HIGH	HIGH	LOW	LOW	N/A	N/A	MEDIUM
Useless Bay	N/A	N/A	LOW	LOW	LOW	LOW	LOW
Other Areas	LOW	LOW	MEDIUM	MEDIUM	N/A	N/A	MEDIUM

TOXIC PROBLEM ASSESSMENT OF REGION 9:
CENTRAL PUGET SOUND
(Figure 11)

ALKI POINT

Rank Medium

Sources

Possible anthropogenic inputs at Alki Point include a NPDES discharge from the municipal sewage treatment plant (U.S. EPA 1986) and advective transport from Elliott Bay (Chapman et al. 1982).

Sediment Condition

In the summer and fall of 1985 and 1986, Metro (1986) sampled sediments from two stations near Alki Point and one deep water station off Alki Point. Analyses of chemical concentrations in the sediments included 12 metals, total PCBs, total LPAH, total HPAH, and selected aromatic hydrocarbons. Total PCBs were substantially elevated (16 times) above reference values at the station closer to Alki Point, while HPAHs were substantially elevated (14 times) above reference values at the station located northwest of Alki Point in deep water. Total PCB concentrations at a third deep water station off Alki were 34 times the Carr Inlet reference value for PCBs. Metro (1984) collected sediment samples from four stations located near Alki Point in November 1981. Sediment concentrations were analyzed for 16 metals and 50 aromatic hydrocarbons including 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables.

Metro also sampled sediments from five central deep basin stations located northwest of Alki Point. Three of these five stations had concentrations of several HPAHs and LPAHs substantially elevated above reference values (Table 20). Chemical concentrations at two of these stations exceeded AET values for dibenzo(a,h)anthracene. AETs were exceeded for indeno(1,2,3-c,d)pyrene and benzo(g,h,i)perylene at one station northeast of Restoration Point.

Only silver was substantially elevated at one station south of Alki Point where concentrations were 11.7 times the reference value.

Low chemical concentrations were found in sediments sampled at one station south of Alki Point (Chapman et al. 1982). Exact chemical concentrations were not reported in this study.

Sediments from one station southwest of Alki Point were sampled quarterly in 1979 by Malins et al. (1980). Sediments were analyzed for metals and 52 aromatic hydrocarbons including 6 LPAHs, 9 HPAHs, 11 pesti

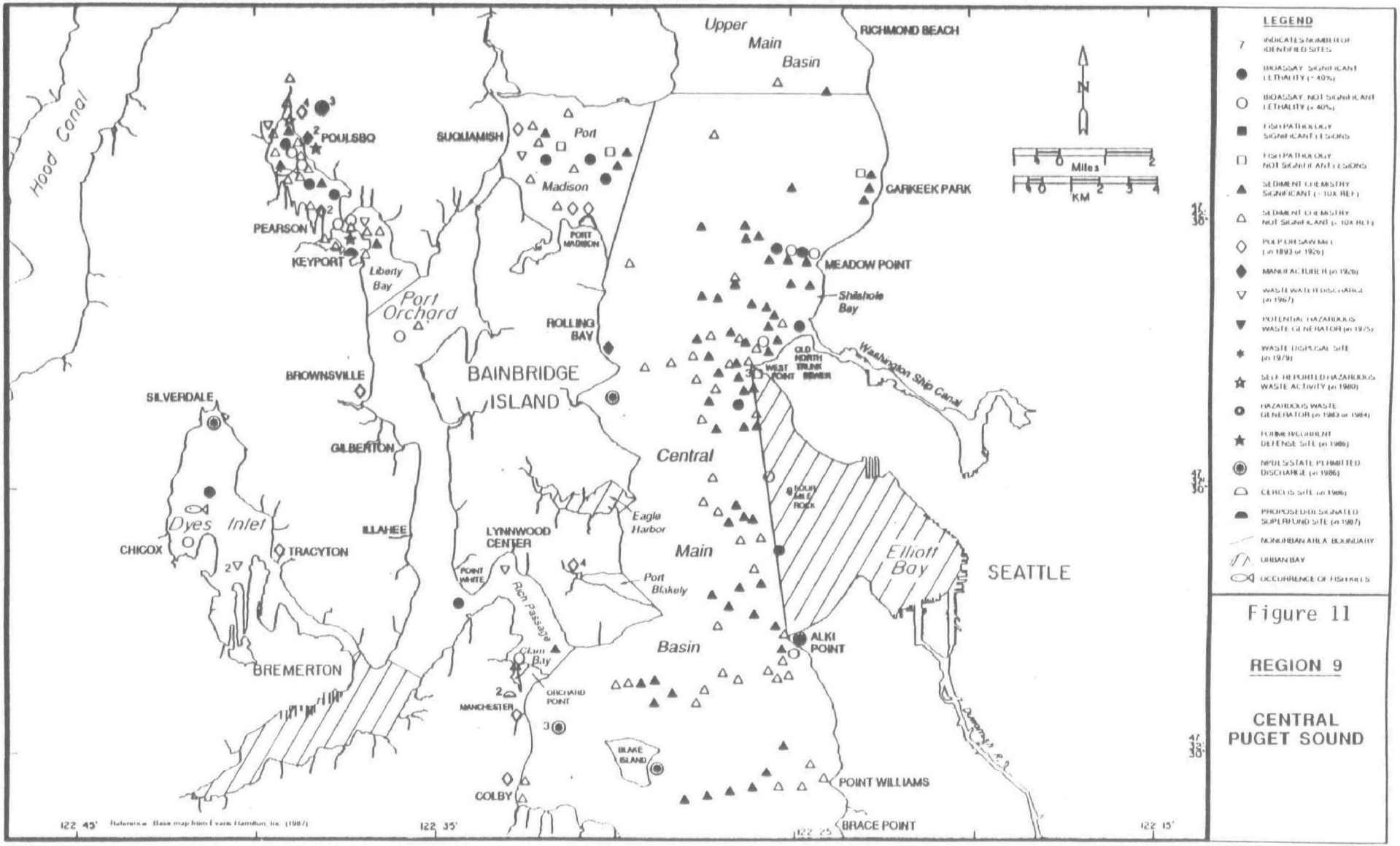


Figure 11

REGION 9

CENTRAL PUGET SOUND

TABLE 20. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS IN THE CENTRAL DEEP BASIN NORTHWEST OF ALKI POINT

Chemical	Elevation Above Reference		
	S0049 NW Alki (224 m)	S0050 NW Alki (210 m)	S0051 N Alki (200 m)
Benzo(a)anthracene	25.1	NS[a]	31.7
Benzo(a)pyrene	41.6	NS	54.6
Benzo(g,h,i)perylene	114.1	164.8[b]	33.4
Chrysene	13.3	NS	16.1
Dibenzo(a,h)anthracene	50.0	48.4	10.5
Fluoranthene	NS	56.3	17.0
Fluorene	NS	NS	NS
Indeno(1,2,3-c,d)pyrene	103.3	197.8[b]	34.1
Naphthalene	NS	NS	NS
Phenanthrene	33.7	25.8	10.4
Pyrene	NS	79.4	22.4

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

cides, 5 miscellaneous extractables, 2 nonchlorinated benzene compounds, 2 chlorinated benzenes, 8 chlorinated biphenyls, and 4 chlorinated butadienes. None of the analytes were substantially elevated at this station.

Concentrations of cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc were measured in sediments at one station near Alki Point in 1975 (Schell et al. 1977). Metal concentrations were not substantially elevated at this station.

Toxicity Indexes

Sediment Oyster Larvae Bioassays--

No information available.

Other Bioassays--

Surface sediment (top 6 cm) was collected for one station near Alki Point (Chapman et al. 1982). A progression of bioassay tests, from lethal to sensitive sublethal tests, were performed with an oligochaete (Monopylephorus cuticulatus), an amphipod (Eogammarus confervicolus), and fish (threespine stickleback, Gasterosterus aculeatus). The tests revealed no lethal or sublethal toxicity at the Alki Point station and all bioassays had a greater than 85 percent survival rate. These results were not mapped.

Bioaccumulation--

A Metro (1984) study revealed substantially elevated levels of phthalates in tissue samples from rock crab at Alki Point. Di-octyl phthalate was also substantially elevated in English sole muscle tissue taken near Alki Point. However, phthalates are mildly toxic and may not have a great impact on the organisms studied. Metals were not substantially elevated in rock crab or English sole sampled at Alki Point. These results are not mapped.

BLAKE ISLAND

Rank Low

Sources

No information.

Sediment Condition

Metro (1984) sampled sediments from two stations north of Blake Island in August 1982. Metals concentrations were not measured at these two stations. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10

HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Sediment concentrations of 7b HPAHs were substantially elevated above reference at both stations with the highest concentrations at the station northeast of the island (Table 21).

Sediments from three stations north of Blake Island were sampled in August 1982, and concentrations of 14 metals and 24 aromatic hydrocarbons, including 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables were measured (Riley et al. 1983). Concentrations of two HPAHs and two miscellaneous extractables were substantially elevated at one of the three stations north of Blake Island. Concentrations of PCBs and metals were not substantially elevated at any of the three stations.

From 1970 to 1972, Crecelius et al. (1975) found substantially elevated concentrations of antimony (3.2 mg/kg) at one station north of Blake Island. This station is located near the site where Metro (1984) observed elevated organic concentrations in sediments north of Blake Island.

Toxicity Indexes

No information available.

CARKEEK PARK

Rank Medium

Sources

A major NPDES-permitted municipal sewage outfall is located at Carkeek Park (U.S. EPA 1986).

Sediment Condition

Concentrations of 16 metals and 50 aromatic hydrocarbons were sampled by Metro (1984) in November 1981 at three stations near the Carkeek Park sewage treatment plant outfall. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. A few organic chemicals were substantially elevated at the two stations closest to the Carkeek Park outfall, and zinc concentrations were substantially elevated at all three stations (Table 22). Napthalene exceeded AET.

Concentrations of total aromatic hydrocarbons were 220 ug/kg in sediments taken from a sampling station near Carkeek Park in the first quarter of 1984 (Malins 1984).

TABLE 21. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS NEAR BLAKE ISLAND

Chemical	Elevation Above Reference		
	NG-17 NE Blake Is.[a] (201 m)	NG-18 N Blake Is.[a] (88 m)	N Blake Is.[b] (Unknown)
Benzo(a)anthracene	30.6	22.4	32.6
Benzo(a)pyrene	49.0	29.0	16.3
Benzo(g,h,i)perylene	64.3	24.8	NS[c]
Chrysene	24.6	21.0	NS
Dibenzothiophene	NS	NS	NS
Fluoranthene	18.3	15.0	NS
Indeno(1,2,3-c,d)pyrene	53.3	22.4	NS
1-Methylphenanthrene	NS	NS	17
Pyrene	25.1	17.6	NS

[a] Reference: Metro (1984).

[b] Reference: Rile et al. (1983).

[c] NS = Not substantially elevated.

TABLE 22. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS NEAR CARKEEK PARK

Chemical	Elevation Above Reference		
	Station A115 (Unknown)	Station B115 (36 m)	Station C115 (39 m)
Zinc	20.9	22.1	26.1
Fluoranthene	NS[a]	NS	32.6
Naphthalene	NS	120.1	NS
Pyrene	NS	NS	41.1

[a] NS = Not substantially elevated.

Reference: Metro (1984).

Toxicity Indexes

Bioaccumulation--

A Metro (1984) study revealed substantially elevated levels of phthalates in rock crab tissues sampled at Carkeek Park. Di-octyl phthalate was also substantially elevated in English sole muscle tissue taken from the Carkeek Park area. These phthalates are only mildly toxic to marine biota. Metals were not substantially elevated in rock crab or English sole. These results are not mapped.

Benthic Community Impacts--

Harmon and Serwold's (1977) study of benthic communities suggests possible toxic impacts near the Carkeek sewage outfall. However, the sample sizes for benthic grab samples taken in winter 1975 were too small for substantial differences to be detected at sampling stations. These results are not mapped.

Fish Histopathology--

Krahn et al. (1986) reported no neoplasms and no substantially elevated incidences of pre-neoplasms and megalocytic hepatosis in 18 English sole sampled near Carkeek Park. These results should be interpreted with caution because sample sizes of less than 20 fish may not be representative.

CENTRAL BASIN OFF ELLIOTT BAY

Rank Medium

Sources

Toxic chemicals transported from Elliott Bay may be accumulating in the central basin. Refer to the Elliott Bay Urban Bay Action Plan for a discussion of the potential sources of toxic chemicals in Elliott Bay.

Sediment Condition

In a study of the Duwamish Head outfall, sediments were sampled at four stations near the mouth of Elliott Bay (Metro 1986). Sediments were analyzed for 12 metals and the following 4 classes of organic chemicals: PCB, LPAH, HPAH, and phthalates. Chemical concentrations of these analytes were not substantially elevated at any of the stations off Elliott Bay.

Five stations sampled by Metro (1984), in the urban central deep basin off Elliott Bay had substantially elevated concentrations for several HPAHs and LPAHs. Chemical concentrations at one of these stations exceeded AET values for dibenzo(a,h)anthracene (Table 23).

TABLE 23. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT FIVE STATIONS IN THE CENTRAL DEEP BASIN OFF ELLIOTT BAY

	Elevation Above Reference				
Chemical	S0013 S Mid Bay (200 m)	S0052 Mid Bay (204 m)	CR001 Mid Bay (205 m)	S0053 N Mid Bay (197 m)	S0058 Mid Bay (187 m)
Antimony	NS[a]	NS	NS	NS	14.5
Benzo(a)anthracene	NS	44.2	NS	33.7	26.4
Benzo(a)pyrene	NS	42.5	59.9	63.9	85.3
Benzo(g,h,i)perylene	NS	33.9	105.5	NS	66.3
Chrysene	NS	35.5	NS	30.2	22.3
Dibenzo(a,h)anthracene	NS	18.4	NS	NS	74.8[b]
Fluoranthene	63.9	22.8	14.0	44.2	26.1
Fluorene	NS	NS	NS	NS	NS
Indeno(1,2,3-c,d)pyrene	NS	32.5	77.4	NS	50.8
Naphthalene	247.0[b]	NS	NS	NS	NS
Phenanthrene	46.2	NS	NS	18.9	16.4
Pyrene	78.4	29.3	NS	53.7	59.5

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

In 1975, Schell et al. (1977) measured metal concentrations for one deep water station off Elliott Bay. Metals were not substantially elevated above reference at this station.

Toxicity Indexes

No information available.

DYES INLET

Rank Low

Sources

In 1893, the Tracyton Mill Company lumber mill in Tracyton produced 12,000-15,000 bd ft of sawn lumber (Puget Sound Lumberman 1893). In 1967, the Manette and Charleston sewage treatment plants for the city of Bremerton was discharging to Dyes Inlet (U.S. FWPCC 1967). Three marinas are located in Dyes Inlet (Ocean. Inst. 1978). And, one NPDES-permitted source, the Photo Dynamics Company in Silverdale, discharges to Dyes Inlet (U.S. EPA 1986).

Advective transport from the U.S. Naval Shipyard near Bremerton may contribute to pollution in Dyes Inlet (Ecology 1982). This shipyard produces caustic chemicals and acids at the rate of 10,000 gal/yr.

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates of bioassay mortality (>50 percent) were observed in September 1977 at one station between Chico and Silverdale. Substantially elevated rates of abnormalities were observed at this station in September 1976 and September 1977. No substantially elevated rates of abnormalities or mortalities were observed for the other Dyes Inlet station near Chico between 1962 and 1976.

Fish Kills--

According to L. Kittle (March 1987, personal communication), 90 percent of the fish in a 2 ac area of Dyes Inlet were killed due to an unknown cause in 1984. On 13 May 1984, an unknown pollutant entered Dyes Inlet via Silver Creek, killing 200 fish (LeVander, 30 March 1987, personal communication).

LIBERTY BAY

Rank High

Sources

In the 1940s and 1950s, mercuric chloride, copper sulfate, cuprous chloride, cupric chloride, and lead nitrate were applied to sediments to control oyster drill pests in Liberty Bay (Cummins 1976). Sevin and Lindane were also applied to sediments in Liberty Bay by the Washington Department of Fisheries in July 1960, to control ghost shrimp and oyster drills (Lindsay 1961). Barrier plots, 16 by 16 ft, were treated with ortho-dichlorobenzene and Sevin. The barrier plots were dissipated by winter storms. More plots (125 by 70 ft) were constructed in November 1960 and in July 1961.

Most of the reported industrial point sources in Liberty Bay are in the towns of Keyport, Pearson, and Poulsbo.

Keyport--

One small marina is located in Keyport (Ocean. Inst. 1978). In 1967, the Kitsap County Sewer District also discharged to Class AA waters near Keyport (U.S. FWPCC 1967).

A large Naval Undersea Torpedo Station and Warfare Engineering Station is located in Keyport. In 1983, those Naval stations generated 2,780 tons of characteristic wastes and 1,317 tons of nonspecific hazardous waste (Kruger 1983). A recent U.S. EPA site inspection confirmed reports of groundwater contamination at the U.S. Navy Undersea Warfare Station (U.S. EPA 1987). This site has been proposed for Superfund designation on the National Priority List (U.S. EPA 1987).

Poulsbo--

In 1926, the Poulsbo Lumber Company, Danielson Brothers & Tuedt, John Rogers and Company lumber mills; the Squamish Shingle Company; and two newspaper publishers were located in Poulsbo (Manu. Assoc. of WA 1926).

There are three NPDES-permitted discharges for the city of Poulsbo: the Kitsap County Public Works, the Coast Oyster Company, and T. & C. Photo Lab, Inc. (U.S. EPA 1986). Two marinas with a combined total of 173 wet slips are located in Poulsbo (Ocean. Inst. 1978).

Chevron USA Inc. operates a Poulsbo Bulk Plant Generator, that generates, transports, and stores hazardous wastes (U.S. EPA 1980). A former NIKE Battery site is also located in Poulsbo (U.S. Dept. of Defense 1985).

Pearson--

In 1926, the Babcock Mill Company and George Hanson & Sons lumber mills were located in Pearson (Manu. Assoc. of WA 1926).

Sediment Condition

Between 1978 and 1981, Malins et al. (1982) analyzed sediment concentrations of metals, aromatic hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds in sediments from one nearshore sampling station in the center of Liberty Bay. Concentrations of these analytes were not substantially elevated above reference. Reported concentrations of total aromatic hydrocarbons (860 ug/kg) were somewhat higher than concentrations observed in other less urbanized areas. These results are not mapped.

In September and October 1975, Cummins et al. (1975) surveyed sediments in Liberty Bay to investigate reports of heavy metal contamination and high mortality of Pacific oyster embryos there. Sediments were sampled at 18 stations in Liberty Bay and two reference stations, one near Misery Point and the other in Clam Bay. No major sources of mercury or serious mercury contamination were found. Metal concentrations were highest in the fine-grained sediments of the central to upper bay. Cadmium concentrations were 16 times reference values at one Liberty Bay station. Lead and zinc were substantially elevated (21 and 19 times, resepectively, reference values) at another Liberty Bay station.

Toxicity Indexes

Sediment Bioassays--

Cummins (1976) conducted sediment bioassays using refrigerated (not frozen) sediments and a technique described by Woelke (1972). Mortality rates were not substantially elevated at any of the Liberty Bay stations. According to Cummins (1976), sediment toxicities appeared to be more closely related to total volatile solids concentrations in sediments than to metal or sulfide concentrations. The chemical concentrations of organic components of the sediments were not measured in this study.

Receiving Water Oyster Larvae Bioassays--

From October 1974 to August 1975, Sea Farms, Inc. in Poulsbo was experiencing heavy oyster mortalities. Cummins et al. (1976) conducted an investigation to identify the potential cause of Pacific oyster embryo mortalities at the Sea Farm oyster hatchery. The Sea Farm hatchery operation, effluent from the Poulsbo STP, dredging of the Poulsbo marina in early 1975, and metal-laden wastes from the U.S. Navy's Keyport Torpedo Station were investigated as possible causes of the oyster larvae mortalities (Cummins et al. 1976). The study was inconclusive.

Oyster larvae bioassays were performed with seawater collected at low tide on 15 September 1975. Bioassay mortalities were not substantially elevated during low tide near the Naval station, Poulsbo STP, or the Sea Farm oyster hatchery. However, 100 percent mortalities were observed near a dinoflagellate bloom in central Liberty Bay. At high tide, mortalities followed the migration of the dinoflagellate bloom to the nearshore sites,

with mortalities rising to nearly 80 percent at the Sea Farm site and 59 percent near Poulsbo.

Oyster larvae abnormalities followed the same patterns stated above. At low tide, abnormalities were low at all stations. At high tide, 96 percent of oyster larvae developed abnormally in the vicinity of the algal bloom near the Sea Farm oyster hatchery.

Cardwell and Woelke (1979a) found no substantial elevations in oyster larvae mortalities and abnormalities in bioassays conducted using receiving water from one station in Liberty Bay.

Oyster larvae mortalities were substantially elevated (>50 percent) near the head of Liberty Bay in 1962 and 1967 (Cardwell and Woelke 1979b). Oyster larvae abnormalities were also elevated at the same site in 1976.
Effluent Bioassays.

Other Bioassays--

Effluent from the Poulsbo STP proved to be more toxic to oyster larvae than effluents from the U.S. Navy Torpedo Station or from Keyport (Cummins et al. 1976). Poulsbo effluent resulted in both higher bioassay mortalities and abnormalities than the U.S. Navy and Keyport effluents. These bioassay results are not mapped.

Fish Kills--

In December 1970, an oil spill by the Island Transport Company caused unknown numbers of fish and shellfish deaths along a 5-mi stretch of shoreline (Kittle, March 1987, personal communication). According to LeVander (30 March 1987, personal communication), waste oil from an unknown source killed oysters in commercial beds on 17 June 1974.

Bioaccumulation in Tissues--

Cummins et al. (1976) found mercury and metal concentrations in fish and shellfish tissue taken from Liberty Bay that were below the FDA Action Level of 0.5 ug/g. PCBs in the southwest portion of Liberty Bay were slightly elevated in tissue samples from Japanese littleneck clams, but tissue concentrations were not substantially elevated above reference. (These results are not mapped.)

MANCHESTER/COLBY

Rank Medium

Sources

In 1893, the Bruescke Manufacturing Company operated a lumber and shingle mill in Manchester that produced 12,000-15,000 bd ft of lumber and 125,000-200,000 ft of shingles (Puget Sound Lumberman 1893). Also, a medium

size shingle mill operated by M. Patton in Colby produced 30,000-50,000 bd ft of shingles in 1893 (Puget Sound Lumberman 1893).

Currently, one small marina (Ocean. Inst. 1978) and three NPDES-permitted sources are located near Manchester. The NPDES permits were issued for the U.S. EPA Manchester Lab, the Manchester Naval Supply Depot, and a Kitsap County municipal sewage discharge (U.S. EPA 1986).

Oils, petroleum, and hydrocarbon wastes generated by the U.S. Naval Shipyard near Bremerton were barged to the oily waste treatment system at Manchester Naval center for disposal.

There are two CERCLIS sites near Manchester: the Navy Supply Center near Orchard Point and the U.S. EPA Manchester Lab (U.S. EPA 1986). The Naval Supply Center, located at Orchard Point approximately 500 ft southwest of Clam Bay near Manchester, is a CERCLIS site (U.S. EPA 1986). The supply center produces 11 tons of characteristic hazardous wastes annually including tetraethyl-lead residues from petroleum storage (Kruger 1983). A site investigation to identify potential toxic or hazardous waste problems at this site revealed low potential for hazards there.

A site inspection at the U.S. EPA Manchester Lab found measurable levels of toxic chemicals in the soil at this site and the potential for groundwater contamination (CERCLIS 1987). More detail was not available on 3 December 1987 since the site was undergoing an investigation.

Sediment Condition

Sediments from two stations east of Colby were sampled in August 1982 to measure sediment concentrations of 14 metals and 24 aromatic hydrocarbons, including 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables (Riley at al. 1983). None of these analytes were substantially elevated in sediments from either of these stations.

Toxicity Indexes

No information available.

MEADOW POINT

Rank Medium

Sources

Advective transport of pollutants from Shilshole Bay and other urban areas is a potential source of toxicants in this area.

Sediment Condition

Metro (1984) measured concentrations of 16 metals and 50 aromatic hydrocarbons from seven stations off Meadow Point. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Concentrations of several HPAHs and LPAHs were substantially elevated at all seven stations near Meadow Point as well as phenol which exceeded AET (see Table 24).

Toxicity Indexes

Sediment Amphipod Bioassays--

A Metro (1984) study found substantially elevated levels of amphipod bioassay mortalities at two of the four stations sampled near Meadow Point. Results were mixed with high mortality and low mortality rates at alternate stations.

POINT WILLIAMS

Rank Medium

Sources

No information available.

Sediment Condition

Metro (1984) measured sediment concentration at one deep water (203 m) station west of Point Williams in January 1982. Concentrations of 16 metals and 50 aromatic hydrocarbons were measured and included 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Two HPAHs were measured at substantially elevated concentrations at this site. Pyrene was 70.4 times its reference value and fluoranthene was 70.0 times its reference value. Neither chemical exceeded the AET value for that chemical.

Sediments were collected at seven stations from April 1982 to April 1984 in a transect from Point Williams to the center of the basin (Nevissi et al. 1984). Silver concentrations were substantially elevated at all four deeper water stations (2.1-3.6 ppm). Metal concentrations were not substantially elevated at the three nearshore stations.

According to Schell et al. (1977), metal concentrations were not substantially elevated above reference values in sediments collected in 1975 from one nearshore station west of Point Williams.

In 1970-1972, Crecelius et al. (1975) found substantially elevated concentrations of antimony in sediments from one station northeast of Point

TABLE 24. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT SEVEN STATIONS OFF MEADOW POINT

	Elevation Above Reference						
Chemical	NW Pt 400110 32 m	NW Pt 400121 74 m	NW Pt 400130 96 m	NW Pt 400160 189 m	W Mdw Pt CR003 220 m	NW Pt 400165 195 m	Madn-Mead S0040 181 m
Benzo(a)anthracene	NS[a]	24.3	NS	42.2	NS	35.9	NS
Benzo(a)pyrene	NS	45.5	22.6	40.3	NS	18.4	84.7
Benzo(g,h,i)perylene	11.5	62.2	28.4	43.3	32.4	25.7	NS
Chrysene	NS	21.0	NS	32.1	NS	33.1	NS
1,4-Dichlorobenzene	NS	NS	NS	NS	43.4	NS	NS
Fluoranthene	NS	NS	NS	22.8	NS	23.2	14.9
Fluorene	15.5	NS	NS	NS	NS	NS	NS
Indeno(1,2,3-c,d)pyrene	11.0	70.4	37.6	42.0	28.8	19.9	NS
Phenanthrene	NS	NS	NS	19.9	NS	15.4	NS
Phenol	NS	71.4[b]	NS	NS	NS	NS	NS
Pyrene	NS	NS	16.0	29.1	19.5	29.0	17.6

[a] NS = Not substantially elevated.

b = Value exceeded AET

Reference: Metro (1984).

Williams.

Toxicity Indexes

No information available.

PORT MADISON

Rank Medium

Sources

Port Madison Mills produced 30,000-50,000 bd ft of sawn lumber in 1893 (Puget Sound Lumberman 1893). By 1926, there were two lumber mills on Port Madison: the Kitsap Alder Company in Suquamish and the Andrew Olsen lumber mill in Port Madison (Manu. Assoc. of WA 1926).

Currently, Port Madison has one small marina with fuel and repairs, and one state discharge permit for the city of Suquamish STP operated by Kitsap County Public Works (U.S. EPA 1986).

Sediment Condition

Metro (1984) measured sediment concentrations of 16 metals and 50 organic hydrocarbons. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Several chemical concentrations were significantly elevated at two of the three sediment sampling stations in Port Madison (Metro 1984). One nearshore station (S0071) and the deeper water station (S0073) had chemical concentrations that were substantially elevated (see Table 25). Station S0072, located slightly south of S0071, had no substantially elevated chemical concentrations.

From 1978 to 1981, Malins et al. (1982) measured sediment concentrations of metals, aromatic hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds in sediments from two Port Madison stations. Of these analytes, only silver concentrations were substantially elevated at the nearshore station near Kitsap (23 times reference values) and the station in the outer harbor (17 times reference values). The location of the outer harbor station coincides roughly with the outer harbor stations in the Malins et al. (1980) study and the Chapman et al. (1982) study. Total aromatic hydrocarbon concentrations were reported at 720 ug/kg near Kitsap and 240 ug/kg in the outer harbor.

Low concentrations of PAHs, PCBs, and other chlorinated organic compounds were found in the sediments at six stations sampled in Port Madison (Chapman et al. 1982). Since chemical concentrations were not reported in the Chapman study, chemical elevations above reference could not be computed. These results are not mapped.

TABLE 25. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT TWO STATIONS NEAR PORT MADISON

Chemical	Elevation Above Reference: Station S0071 18 m	Elevation Above Reference: Station S0073 92 m
Benzo(a)pyrene	NS[a]	20.1
Benzo(g,h,i)perylene	17.8	28.1
Fluoranthene	NS	13.1
Indeno(1,2,3-c,d)pyrene	20.5	NS

[a] NS = Not substantially elevated.

Reference: Metro (1984).

Malins et al. (1980, OMPA-2) conducted quarterly sampling of two Port Madison stations in 1979. Sediment concentrations of petroleum hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds were analyzed. Except for selenium, analytes were not substantially elevated above reference values in Port Madison sediments. Selenium was substantially elevated for one station in north Port Madison where the concentration was 22 times the reference value.

Toxicity Indexes

Sediment Amphipod Bioassays--

Metro (1984) found substantially elevated levels of amphipod mortalities in sediment bioassays at three stations in Port Madison. Results were mixed, with high mortality levels scattered among stations yielding low mortality rates. These results may be suspect since frozen sediments were used in the bioassay tests.

Sediment Oyster Larvae Bioassays--

In summer 1982, oyster larvae bioassays were conducted with sediment taken from five replicate 0.1-m2 Van Veen grab samples. While the rate of oyster larvae abnormalities was low, oyster larvae mortalities were substantially elevated (>50 percent) at the Port Madison station (Chapman et al. 1983). Sediments were frozen prior to analysis, so these bioassay results are unreliable and are not mapped.

Other Bioassays--

Surface sediment, composed of the top 6 cm, was collected for six stations in Port Madison (Chapman et al. 1982). A progression of bioassay tests, from lethal to sensitive sublethal tests, were performed with an oligochaete (Monopylephorus cuticulatus), an amphipod (Eogammarus confervicolus), and a fish (threespine stickleback, Gasterosterus aculeatus). The bioassay tests revealed no lethal or sublethal toxicity at the Port Madison stations; all bioassays had a greater than 85 percent survival rate. These results are not mapped.

Fish Histopathology--

Malins (1984) found no substantially elevated levels of neoplasms, pre-neoplasms, or megalocytic hepatosis in more than 20 English sole, rock sole, and Pacific staghorn sculpin collected 1979-1983 at two stations in Port Madison. The rate of pre-neoplasms in Port Madison was slightly, but not substantially, elevated (9.1 percent). Likewise, no pre-neoplasms were found in English sole or rock sole sampled in Port Madison in 1979. The incidence of megalocytic hepatosis was not substantially elevated in fish caught in Port Madison (Malins et al. 1980).

Bioaccumulation--

One to two ring aromatic hydrocarbons, phenanthrene, benz(a)anthracene, and benzo(a)pyrene were not detected in liver tissue from English and rock sole caught in Port Madison. Levels of three to five ring aromatic hydrocarbons, chlorinated butadienes, hexachlorobenzene, and PCBs were detected but were not substantially elevated above reference value in fish liver tissue obtained from Port Madison (Malins et al. 1980). These results are not mapped.

PORT ORCHARD

Rank Low

Sources

In 1926, the Berg Brothers lumber mill was located in Brownsville (Manu. Assoc. of WA 1926).

Currently, three marinas are located in the Port Orchard Area, including one small marina in Illahee, one small marina with repair facilities on Bainbridge Island near Gilberton, and one medium-size 244 wet slip marina with fuel and repair facilities near Brownsville (Ocean. Inst. 1978).

Sediment Condition

Phenanthrene and retene concentrations were measured in sediments at one midchannel station in Port Orchard near the mouth of Liberty Bay. Concentrations were substantially elevated above reference values (Barrick and Prahl 1987).

Toxicity Indexes

Sediment Amphipod Bioassays--

Bioassay tests conducted by Metro (1984) using sediments from Port Orchard found no substantial amphipod mortalities. However, the results of these sediment bioassays are inconclusive since tests were still being developed at the time that standard procedures were not yet established.

Receiving Water Oyster Larvae Mortality--

Although high oyster larvae bioassay mortalities ($\geq$40 percent) were observed at one station near White Point in Port Orchard in July 1974 and September 1977 (Cardwell and Woelke 1979), abnormalities were not substantially elevated at this site between 1962 and 1977.

RICH PASSAGE, BAINBRIDGE ISLAND

Rank Low

Sources

In 1967, one discharge to Class AA waters was located at Lynnwood Center on Bainbridge Island (U.S. FWPCC 1967). Formerly, a coal gasification plant was operated near Washington Narrows in Rich Passage (Dexter, 1986, personal communication).

Sediment Condition

Cummins et al. (1976) found antimony concentrations substantially elevated above reference values (32 times reference values) at one station in Clam Bay in 1970-1972.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Oyster larvae bioassays conducted with Clam Bay seawater collected at low tide on 15 September 1975 did not result in substantially elevated mortality or abnormality rates (Cummins et al. 1976).

SHILSHOLE BAY/LAKE WASHINGTON SHIP CANAL

Rank Medium

Sources

Three marinas, with more than 1,600 wet slips and extensive boat repair facilities, are located in Shilshole Bay (Ocean. Inst. 1978). The Washington Ship Canal drains into Shilshole Bay. Formerly, the Old North Trunk Sewer dumped untreated municipal wastes from settlements around Lake Washington and Lake Union into Puget Sound south of Shilshole Bay.

Sediment Condition

From March 1981 to January 1983 Metro (1984) measured concentrations of 16 metals and 50 aromatic hydrocarbons in sediments sampled from eight stations off the Lake Washington Ship Canal and 11 stations off the Old North Trunk sewer outfall. Aromatic hydrocarbon concentrations were measured for 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables.

Chemical concentrations of HPAHs and LPAHs in sediments from Shilshole Bay near the mouth of the Lake Washington Ship Canal were many times higher than the established AET values for these chemicals. Chemical concentrations continued to be elevated at some distance from Shilshole. Results are summarized in Table 26.

The highest levels of toxic chemicals in less developed areas of Puget Sound were found in the area off the old North Trunk sewer outfall near

TABLE 26. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT EIGHT STATIONS OFF LAKE WASHINGTON SHIP CANAL/SHILSHOLE

	Elevation Above Reference							
Chemical	S0006 20 m	S0108 50 m	S0107 75 m	S0012 80 m	S0106 94 m	S0045 234 m	0127 286 m	400275 244 m
Acenaphthene	53.6	NS[a]	NS	NS	NS	NS	NS	NS
Anthracene	NS	NS	74.7	NS	NS	NS	NS	NS
Benzo(a)anthracene	220.5[b]	39.2	171.1	387.2[b]	22.3	NS	107.3	109.0
Benzo(a)pyrene	375.1[b]	88.3	376.1[b]	217.9	103.9	148.6	NS	300.4[b]
Benzo(g,h,i)perylene	315.9[b]	150.5[b]	510.6[b]	360.7[b]	102.1	268.9[b]	NS	NS
Chrysene	237.5[b]	35.0	187.0[b]	230.6[b]	NS	167.1[b]	66.6	28.3
Dibenzo(a,h)anthracene	NS	NS	406.7?	NS	NS	NS	NS	NS
Fluoranthene	92.7	27.9	132.8[b]	NS	14.5	118.9[b]	69.3	17.1
Fluorene	38.2	NS	NS	NS	NS	NS	NS	NS
Indeno(1,2,3-c,d)pyrene	309.3[b]	44.35[b]	489.4[b]	NS	72.0	NS	NS	19.2
N-nitrosodiphenylamine	NS	NS	NS	86.3[b]	NS	462.0[b]	NS	NS
Phenanthrene	80.8	NS	150.2	16.5	NS	140.3[b]	NS	NS
Pyrene	142.1	58.4	157.7	16.9	19.9	335.4[b]	NS	29.0

[a] NS = Not substantially elevated.

[b] AET value was exceeded.

Reference: Metro (1984).

Shilshole (Metro 1984). HPAH concentrations were substantially elevated at stations near the Old North Trunk sewer. Chemical concentrations were several times as high as the AET values at 8 of the 11 stations. At one station (400310) near the previous outfall of the Old North Trunk sewer, the fluoranthene concentrations were 55 times higher than the AET value and 4,702 times the Carr Inlet reference value. For stations north (400210) and west (S0099 and S0100) of the Old North Trunk outfall, chemical concentrations were considerably lower but still elevated above reference and AET threshold values. The results of the sediment chemistry analyses are summarized in Table 27.

Toxicity Indexes

Sediment Amphipod Bioassays--

A Metro (1984) study found substantially elevated levels of amphipod mortalities in bioassays conducted with sediments from a station near Shilshole Bay.

Benthic Community Impacts--

Mortalities were not substantially elevated at a third station located further from the shore of Shilshole Bay. Harmon and Serwold's (1977) study of benthic communities suggests possible toxic impacts in Shilshole Bay at 15-50 fathoms where suspended materials settle. Toxic impacts are also suspected near the former dump site, in an offshore area north of West Point that tends to accumulate debris, in areas adjacent to the West Point outfall, and near the Old North Trunk sewer.

WEST POINT

Rank Medium

Sources

Anthropogenic inputs at West Point include the large West Point Metro NPDES-permitted sewage outfall and possible advective transport from Elliott Bay and from the Washington Ship Canal (Chapman et al. 1982).

Sediment Condition

Metro (1984) sampled sediments at 17 stations near West Point from March 1981 to January 1983. Sediment concentrations were measured for 16 metals and 50 aromatic hydrocarbons, including 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. PAHs and other organic compounds were substantially elevated at 13 of the 17 stations sampled near West Point. The highest levels were found west of West Point where levels of benzo(a)pyrene at one station was approximately 630 times reference values. Chemical

TABLE 27. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT ELEVEN STATIONS OFF THE OLD NORTH TRUNK SEWER OUTFALL

Chemical	400310 N Trunk 39 m	S0101 NW Pt 55 m	S0102 NW Pt 18 m	S0103 NW Pt 38 m	S0104 NW Pt 18 m	S0008 NW Pt 71 m	S0005 NW Pt ???	400210 N of Outf 40 m	S0105 NW Pt 39 m	S0099 W of Outf 37 m	S0100 W of 49 m
Antimony	NS[a]	NS	NS	15.0	25.0	NS	NS	85.7	NS	NS	NS
Lead	NS	NS	NS	NS	14.6	NS	NS	48.5	NS	NS	NS
Silver	13.3	NS	NS	NS	NS	NS	NS	20.0	NS	NS	NS
Zinc	NS	NS	NS	12.9	23.2	28.1	NS	66.4	NS	NS	NS
Acenaphthene	266.9[b]	NS	NS	NS	86.4	NS	NS	NS	NS	11.4	NS
Acenaphthylene	455.5[b]	26.4	61.7	40.2	654.5	NS	NS	NS	NS	55.7	25.4
Anthracene	452.9[b]	12.0	48.2	48.7	547.4	NS	NS	23.5	12.5	36.2	10.2
Benzo(a)anthracene	1,868.3[b]	112.0	553.7	267.7	1,325.3	13.5	NS	143.9	NS	215.5[b]	165.1[b]
Benzo(a)pyrene	2,658.6[b]	186.0	1,168.6	956.0	3,541.7[b]	56.4	78.4	180.5	247.0[b]	639.7[b]	295.3[b]
Benzo(g,h,i)perylene	2,131.7[b]	448.0	1,664.4	2,945.1[b]	14,921.5[b]	NS	NS	188.8[b]	472.4[b]	822.3[b]	343.5[b]
Chrysene	1,863.6[b]	43.7	190.7	98.6	413.3	30.3	13.3	217.9[b]	NS	90.7[b]	61.9
Dibenzo(a,h)anthracene	231.0[b]	55.3	322.1	249.0	1,151.8	NS	NS	53.7[b]	78.7[b]	225.5[b]	34.3
Fluoranthene	3,567.6[b]	85.6	369.1	200.8	916.2	27.4	42.0	63.9	78.7	271.9[b]	99.1[b]
Fluorene	960.9[b]	18.2	51.0	29.5	418.8	13.7	NS	14.6	28.9	47.7	17.2
Indeno(1,2,3-c,d)pyrene	1,818.5[b]	342.6	1,422.8	1,124.5	6,544.5[b]	NS	NS	383.6[b]	241.5[b]	901.9[b]	369.9[b]
Naphthalene	205.3	NS	15.5	NS	120.8	NS	NS	NS	NS	NS	NS
N-nitrosodiphenylamine	24.1[b]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Phenanthrene	2,101.9[b]	69.2	327.2	77.8	1,472.5	11.1	20.8	44.0	79.6	190.7[b]	82.6[b]
Pyrene	3,489.5[b]	109.8	507.1	230.6	1,163.5[b]	36.5	59.3	100.6	102.1	331.6[b]	176.1[b]

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

concentrations exceeded AET values for seven chemicals at six sampling stations. No other stations exhibited levels greater than AET. See Table 28 for a summary of the results.

Chapman et al. (1982) detected very high concentrations of PAHs in sediments from one West Point station. Because chemical concentrations were not reported by Chapman, chemical elevations above reference values could not be calculated and these results are not mapped.

In 1979, quarterly sampling was conducted at one station near West Point (Malins et al. 1980) to analyze sediment concentrations of petroleum hydrocarbons, PCBs, chlorinated pesticides, other chlorinated organic compounds, and metals. None of these analytes were substantially elevated above reference values.

Sediment concentrations of cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc were not substantially elevated above reference values at four stations near West Point in 1972-1977 (Schell et al. 1977).

Crecelius et al. (1975) measured metal concentrations at five deep water and nearshore stations near West Point in 1970-1972. Metal concentrations were not substantially elevated above reference values at the four nearshore stations. Mercury (2.4 mg/kg) was substantially elevated at one midchannel station south of West Point.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Mortalities and abnormalities were not substantially elevated above reference for one station near West Point (Cardwell and Woelke 1979).

Cardwell and Woelke (1979b) observed substantially elevated (>50 percent) oyster larvae mortalities at one station slightly north of West Point in 1970. Abnormalities were not substantially elevated during the monitoring period.

Other Bioassays--

Surface sediment (top 6 cm) was collected at one station near West Point (Chapman et al. 1982). A progression of bioassay tests, from lethal to sensitive sublethal tests, were performed with an oligochaete (Monopylephorus cuticulatus), an amphipod (Eogammarus confervicolus), and fish (threespine stickleback Gasterosterus aculeatus). These tests revealed no lethal or sublethal toxicity at the West Point stations (all bioassays had a greater than 85 percent survival rate). These results are not mapped.

TABLE 28. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT SEVEN STATIONS ON A TRANSECT FROM WEST POINT

	Elevation Above Reference					
	NW 400330 90 m	W 400430 88 m	NE of ZID[c] S0010 75 m	W 400530 94 m	W 400621 86 m	400375 235 m
Acenaphthene	35.4	28.4	23.4	NS[a]	NS	NS
Acenaphthylene	NS	49.3	NS	NS	NS	NS
Anthracene	NS	16.4	NS	NS	NS	NS
Benzo(a)anthracene	42.6	214.4[b]	51.1	34.1	24.3	36.2
Benzo(a)pyrene	57.7	423.8[b]	64.6	75.5	38.0	58.8
Benzo(g,h,i)perylene	32.7	247.0[b]	112.7	30.0	28.5	25.8
Chrysene	46.6	108.3[b]	29.7	28.0	11.6	19.4
Dibenzo(a,h)anthracene	NS	34.3	NS	NS	NS	NS
Fluoranthene	42.9	137.2[b]	74.6	30.7	20.1	17.1
Fluorene	30.0	64.7	23.4	NS	NS	NS
Indeno(1,2,3-c,d)pyrene	30.0	202.4[b]	73.2	38.2	28.5	18.9
Naphthalene	NS	23.7	NS	NS	NS	NS
N-nitrosodiphenylamine	NS	NS	NS	NS	97.3[b]	NS
Phenanthrene	29.8	72.9	37.0	16.2	18.6	NS
Pyrene	50.7	209.6[b]	82.9	47.0	25.9	23.4

[a] NS = Not substantially elevated.

[b] AET value was exceeded.

[c] Zone of Initial Dilution

Reference: Metro (1984).

Fish Histopathology--

A reconnaissance study of six bays (Krahnetal 1986) revealed no neoplasms and no substantial elevation in the rates of pre-neoplasms and megalocytic hepatosis in 20 English sole sampled near West Point. Another study by Battelle (1986) revealed that the rates of neoplasms, pre-neoplasms, and megalocytic hepatosis were not substantially elevated in 30 Dover sole caught at West Point.

Bioaccumulation--

A Metro (1984) study displayed substantially elevated levels of PCB concentrations in rock crab tissue collected in winter 1981 and 1982 at West Point stations. Phthalates were also substantially elevated in these rock crab. Di-octyl phthalate and PCBs were substantially elevated in English sole muscle tissue from West Point. Metals were not substantially elevated in rock crab or English sole sampled at West Point.

OTHER AREAS

Rank Medium

Sources

Pollutants may be transported from urban bays, such as Elliott Bay. Most of the reported industrial point sources for other areas in the central main basin of Puget Sound are concentrated in a few cities and towns including Port Blakely and Rolling Bay. Each of these places are discussed below.

Port Blakely--

In 1893, the Port Blakely Mill Company was one of the largest mills in Puget Sound (Puget Sound Lumberman 1893). This lumber mill produced over 200,000 bd ft of sawn lumber annually. The smaller Hall Brothers mill in Port Blakely produced 12,000-15,000 ft of lumber in 1893. By 1926, the Anderson Brothers logging company and the Day Shingle Company were operating in Port Blakely (Manu. Assoc. of WA 1926).

Rolling Bay--

In 1926, the Bainbridge Island Review published a newspaper in Rolling Bay (Manu. Assoc. of WA 1926).

Sediment Condition

Phenanthrene and retene concentrations were not substantially elevated above reference values in sediments from one sampling station in the main basin southeast of Port Madison (Barrick and Prahl 1987).

Metro (1984) sampled sediments from one station in deep water off Skiff Point, one nearshore station near Skiff Point, and one station in the Northern Central Basin in deep water west of Carkeek. Sediment concentrations were measured for 16 metals and 50 hydrocarbons including 6 LPAHs, 10 HPAHs, 11 pesticides, 11 volatile hydrocarbons, 5 phthalates, 4 chlorinated benzenes, and 3 miscellaneous extractables. Substantially elevated concentrations of HPAHs and LPAHs were found in sediments from all three stations (see Table 29)

Schell et al. (1977) measured metal concentrations in sediments from one station east of Skiff Point in 1975. Metal concentrations were not substantially elevated above reference values. Another study by Crecelius et al. (1975) analyzed sediments from one station east of Port Madison in the northern part of the central basin in 1970-1972. Metal concentrations in this study were not substantially elevated above reference values (Crecelius et al. 1975).

Toxicity Indexes

No information available.

REGION 9 ASSESSMENT MATRIX RESULTS

As seen in Table 30, Liberty Bay received a high ranking for the high level of toxicity shown in the area. Alki Point, Carkeek Park, Centarl Basin off Elliott Bay, Manchester and Colby, Meadow Point, Point Williams, Port Madison, West Point, Shilshole Bay/Lake Washington Ship Canal and Other Areas in Region 9 received medium rankings. Source data from Blake Island, Meadow Point, and Point Williams was not available for this investigation. All other areas of concern received low rankings.

TABLE 29. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS IN THE CENTRAL SOUND NEAR SKIFF POINT, BAINBRIDGE ISLAND

	Elevation Above Reference		
Chemical	0125 250 m	400575 232 m	Madn-Cark S0042 185 m
Acenaphthene	NS[a]	NS	--
Acenaphthylene	NS	NS	--
Anthracene	--	NS	--
Benzo(a)anthracene	53.7	29.6	47.5
Benzo(a)pyrene	211	NS	42.8
Benzo(g,h,i)perylene	52.1	29.9	82.0
Chrysene	37.3	20.8	42.7
Dibenzo(a,h)anthracene	20.6	NS	NS
1,4-Dichlorobenzene	--	--	NS
Fluoranthene	NS	156.7[b]	39.1
Fluorene	NS	115.9	NS[a]
Indeno(1,2,3-c,d)pyrene	26.3	19.2	58.6
Naphthalene	--	NS	--
N-nitrosodiphenylamine	225.7[b]	34.0[b]	--
Phenanthrene	NS	NS	19.8
Phenol	--	--	NS
Pyrene	17.8	20.9	81.4

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

TABLE 30: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 9

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Alki Point	LOW	HIGH	HIGH	HIGH	LOW	MEDIUM	MEDIUM
Blake Island	N/A	N/A	MEDIUM	HIGH	N/A	N/A	LOW
Carkeek Park	LOW	HIGH	HIGH	LOW	LOW	MEDIUM	MEDIUM
Central Basin off Elliott Bay	HIGH	HIGH	HIGH	HIGH	N/A	N/A	MEDIUM
Dyes Inlet	LOW	MEDIUM	N/A	N/A	LOW	LOW	LOW
Liberty Bay	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	HIGH	HIGH
Manchester and Colby	MEDIUM	HIGH	LOW	LOW	N/A	N/A	MEDIUM
Meadow Point	N/A	N/A	HIGH	HIGH	LOW	LOW	MEDIUM
Point Williams	N/A	N/A	MEDIUM	MEDIUM	N/A	N/A	MEDIUM
Port Madison	LOW	MEDIUM	MEDIUM	HIGH	LOW	HIGH	MEDIUM
Port Orchard	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Rich Passage, Bainbridge Island	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW
Shilshole Bay & Lake Washington Ship Canal	LOW	MEDIUM	HIGH	HIGH	LOW	MEDIUM	MEDIUM
West Point	LOW	HIGH	HIGH	HIGH	LOW	HIGH	MEDIUM
Other areas	LOW	LOW	HIGH	HIGH	N/A	N/A	MEDIUM

TOXIC PROBLEM ASSESSMENT OF REGION 10:
LOWER HOOD CANAL
(Figure 12)

CASE INLET

Rank Medium

Sources

In 1893, the A Van Slyke & Son lumber mill was located in Allyn and the O. Mealy lumber mill was located in Vaughn (Puget Sound Lumberman 1893). Each of these mills individually processed less than 12,000 bd ft of lumber in 1893. By 1926, two lumber mills were operated by Austin, Wm. and Vaughn Lumber Company in Vaughn, and two lumber mills were operated by E.E. Overton and Trout Lake Timber Company in Allyn (Manu. Assoc. of WA 1926). All four of these lumber mills appear to be abandoned.

Currently, the area has one small marina (9's Fairharbor Marina) at Allyn (Ocean. Inst. 1978) and one NPDES permit issued for the Sargent Oyster Company in Allyn (U.S. EPA 1986).

Sediment Condition

In a reconnaissance study of eight bays in Puget Sound in April and May 1984, Battelle (1986) examined sediment samples at 20 stations scattered throughout upper and lower Case Inlet. Except for phenol, concentrations of the analytes were not substantially elevated above reference values at any of the stations sampled. Phenol concentrations were 93 times reference values at one station southwest of Herron Island. Thiobis-methane was detected at 630 ug/kg and dimethyl-disulfide was detected at 60 ug/kg in the ediments from one station in Case Inlet. Because reference values were not available for thiobis-methane and dimethyl-disulfide, elevations above reference could not be computed for these compounds.

In August 1982, Riley et al. (1983) measured concentrations for 14 metals and 24 aromatic hydrocarbons at two stations in Case Inlet to determine the impacts of chemical contamination on sediments and marine birds. Aromatic hydrocarbons measured included 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. Substantially elevated concentrations of 1-methylphenanthrene (10 times reference values) were found in sediments from one station near Dougall Point at the entrance to Pickering Passage. None of the analytes were substantially elevated above reference at the other station located west of Whitmans Cove.

Between 1978 and 1981, concentrations of metals, aromatic hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds were measured in sediments from two stations in Case Inlet (Malins 1982, OMPA-19). Except for silver, none of the analytes were substantially elevated above

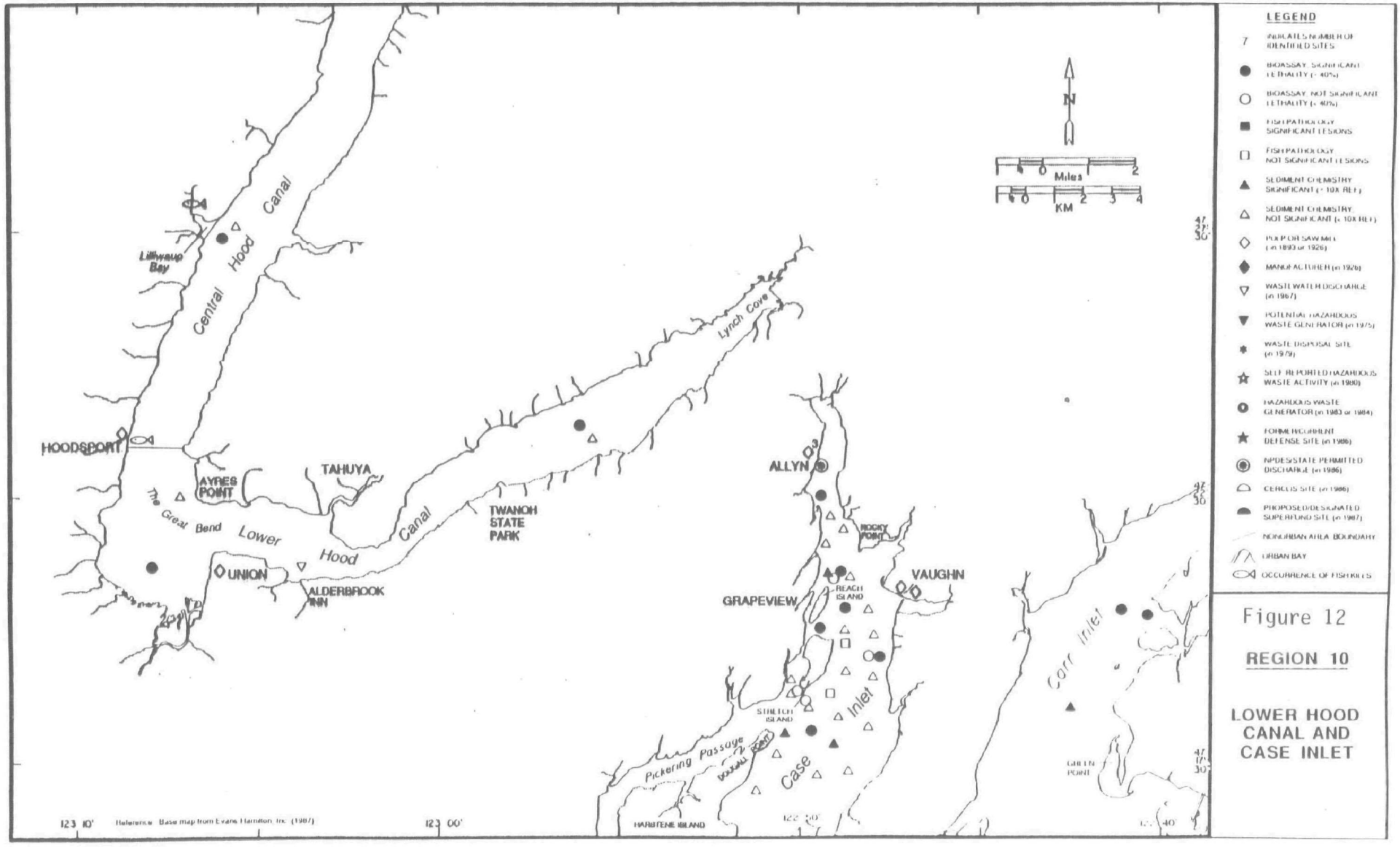


Figure 12

REGION 10

LOWER HOOD CANAL AND CASE INLET

reference values. Silver concentrations were substantially elevated at both stations, with concentrations 25 times reference values at the station north of Reach Island, and 20 times reference values at the station southeast of Stretch Island. Total aromatic hydrocarbon concentrations were 650 ug/kg at the Reach Island station and 60 ug/kg at the Stretch Island station.

In a 1979 NOAA study, Malins (1980, OMPA-2) conducted quarterly sampling of sediments for two stations in Case Inlet. Concentrations of petroleum hydrocarbons, PCBs, chlorinated pesticides, and other chlorinated organic compounds were measured in sediment samples. Except for selenium, none of these analytes were substantially elevated above reference values. The selenium concentration was 40 times the Carr Inlet reference value in sediments from one station north of Reach Island.

In 1972-1977, Pavlou et al. (1977) found PCB concentrations were not substantially elevated in sediments from one station in lower Case Inlet south of Wilson Point.

In 1970-1972, Crecelius et al. (1975) found antimony concentrations were substantially elevated (1.5 mg/kg) in sediments from one station in the middle of Case Inlet east of Dougall Point. The other Case Inlet station, at the mouth of the inlet, also showed substantially elevated concentrations of antimony (1.7 mg/kg).

Toxicity Indexes

Sediment Amphipod Bioassays--

Surface sediments (top 6 cm) were used to conduct amphipod bioassay screening surveys in summer 1983 and detailed surveys in spring 1984 (Battelle 1986). Rhepoxynius abronius bioassays were conducted using the procedure developed by Swartz (1984). The results of the screening surveys and the detailed surveys were contradictory. The detailed survey in Case Inlet found substantial (>40 percent) elevations in amphipod mortalities at two of the four stations sampled. Mortalities were substantially elevated at one station east of Stretch Island and one station north of Reach Island (Battelle 1986). Oyster larvae mortalities were not substantially elevated at one station at the south tip of Stretch Island and one station south of Herron Island. Screening surveys were also conducted at twenty stations. The screening surveys found substantially elevated mortalities at five of the mid-bay stations in Case Inlet near Pickering Passage and one station in southern Case Inlet. The results of the screening surveys are not mapped.

Sediment Oyster Larvae Bioassays--

Pacific oyster larvae bioassays were conducted with surface sediment (top 6 cm) from Case Inlet in April and May 1984 using standard ASTM procedures (Battelle 1986). These sediment bioassays did not result in substantially elevated oyster larvae abnormality rates.

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), substantially elevated bioassay mortalities were reported for all four Case Inlet stations. High rates of mortality (>40 percent) occurred at the North Bay station near Allyn in 1962, 1964, 1968, 1970, 1971, and 1973-1977. Abnormalities at this station were only substantially elevated in later years (1974 and 1975). At the Rocky Point station near the Head of Case Inlet, oyster larvae mortalities were substantially elevated in 1962, 1964, 1966, 1970, 1971, 1973, and 1976. Abnormalities were only substantially elevated at this site in 1976. Cardwell and Woelke attributed the mortalities to simultaneous occurrences of red tide. Further south of Stretch Island oyster larvae mortalities were substantially elevated in 1962, 1966, 1968, 1970, 1973-1975, and 1977. High rates of oyster larvae abnormalities were more common at the Stretch Island station, and occurred in 1968, 1975, and 1977.

Oyster larvae mortalities were substantially elevated (>50 percent) at a station between Stretch Island and Reach Island in 1962, 1964, 1966, 1968, 1970, and 1973-1976 (Cardwell and Woelke 1979b). Oyster larvae mortalities were also elevated in North Bay at the head of Case Inlet in 1962, 1964, 1967, 1968, and 1973. Oyster larvae abnormalities were also elevated at this station in 1968 and 1975 and at the north bay station in 1968 and 1973 (Cardwell and Woelke 1979b).

Fish Histopathology--

According to Krahn et al. (1986) the incidence of neoplasms, pre-neoplasms, or megalocytic hepatosis were not substantially elevated in more than 20 English sole collected east of Stretch Island. The samples were collected between 1979 and 1983 at two stations in Case Inlet.

Incidences of neoplasms, pre-neoplasms, and megalocytic hepatosis were not substantially elevated in liver tissue from 30 English sole caught in southern Case Inlet in March 1984 (Battelle 1986).

No pre-neoplasms were found in English sole or rock sole liver tissue examined from fish caught in Case Inlet in 1979. A few cases of Megalocytic hepatosis were found, but were not substantially elevated (3 percent incidence) in English sole caught east of Stretch Island in Case Inlet (Malins et al. 1980).

Bioaccumulation in Tissues--

One to two ring aromatic hydrocarbons, phenanthrene, benzo(a)anthracene, and benzo(a)pyrene, were not detected in English and rock sole livers from Case Inlet. Three to five ring aromatic hydrocarbons, chlorinated butadienes, hexachlorobenzene, and PCBs were detected at concentrations not substantially elevated above reference in English sole from Case Inlet (Malins et al. 1980). These results are not mapped.

LOWER HOOD CANAL

Rank Medium

Sources

In 1893, the John McReavy lumber mill in Union produced 12,000-15,000 bd ft of lumber (Puget Sound Lumberman 1893). By 1926, the Damman & Harris lumber mill had also been built at Hoodsport (Manu. Assoc. of WA 1926). Both of these lumber mills have been abandoned.

In 1967, a wastewater discharge permit was issued for a septic discharge from the Alderbrook Inn (U.S. FWPCA 1967).

There are nine marinas in the lower portion of Hood Canal (Ocean. Inst. 1978). Three small marinas are located east of Union and a small marina is located in Tahuya. Another five marinas, with a combined total of 72 wet slips, are clustered near Hoodsport. Two marinas in Union and one marina at Hoodsport provide fuel and repairs onsite.

Sediment Condition

PCB concentrations in sediments were not substantially elevated above reference at one station sampled near Lilliwaup Bay from 1972 to 1977 (Pavlou et al. 1977).

In 1970-1972, metal concentrations were not substantially elevated above reference at one nearshore station at Ayres Point in the Great Bend and another station near the western edge of Lynch Cove (Crecelius et al. 1975).

Toxicity Indexes

Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates of mortality and abnormality (>40 percent) occurred at one station near Twanoh State Park in Hood Canal sampled during November 1973 and February 1974. High rates of mortalities and low abnormalities were observed at this site in July 1977.

Receiving Water Oyster Larvae Bioassays--

Cardwell and Woelke (1979b) performed bioassays for three stations in lower Hood Canal. One station was located in the center of Great Bend, one station was located east of Lilliwaup Bay, and one station was located on the western edge of Lynch Cove. At Great Bend, oyster larvae mortalities and abnormalities were substantially elevated (>50 percent) in 1974. At the station near Lilliwaup Bay, mortalities were substantially elevated in 1968 and mortalities and abnormalities were elevated in 1972. Near Shady Beach on the edge of Lynch Cove, mortalities were elevated in 1973-1975. Abnor-

malities were not substantially elevated near Lynch Cove at any time during the monitoring period.

Fish Kills--

In 1979, an anhydrous ammonia spill on Mikes Creek above Lilliwaup resulted in the deaths of 10,000 fish and all shellfish within 5 ac (Kittle, L., March 1987, personal communication). According to LeVander (30 March 1987, personal communication), an earlier fish kill occurred when herbicides were sprayed near Hoodsport on 26 April 1972. The number of fish killed was not reported.

REGION 10 ASSESSMENT MATRIX RESULTS

As seen in Table 31, both Case Inlet and Lower Hood Canal received medium rankings in this investigation.

TABLE 31: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 10

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Case Inlet	LOW	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM
Lower Hood Canal	LOW	MEDIUM	LOW	MEDIUM	MEDIUM	HIGH	MEDIUM

TOXIC PROBLEM ASSESSMENT OF REGION 11:
THE NARROWS AND EAST PASSAGE
(Figure 13)

COLVOS PASSAGE

Rank Medium

Sources

In 1893, two small lumber mills operated by David Carlson and the Ollala Saw Mill were located in Ollala (Puget Sound Lumberman 1893). Colvos Passage was also the former site of a Nike Battery at Olalla (U.S. DOD 1975). A state ferry dock and one small marina are located at Southworth in Colvos Passage.

King County operates the Vashon Landfill in Sunset Beach near Colvos Passage. A site inspection revealed measurable soil contamination and the potential for surface and groundwater contamination at the Vashon Landfill (CERCLIS 1987). This site is located 0.7 mi from Colvos Passage. The landfill has served as a municipal landfill from the 1940s to the present and receives some industrial wastes, including wastes from K2 Corporation. It is alleged that 2,600 bbls of methylethylketone were disposed of here from 1975 to 1980. Groundwater monitoring revealed low levels of heavy metals, but groundwater samples were not analyzed for organic compounds. In 1979, the local fire department registered concern about the frequency of fires at the landfill caused by highly volatile materials. The site was regraded in 1984 to mitigate the leachate problem. This site is non-conforming due to the potential for hazardous waste leachate from the solvent dumped here from 1975 to 1980. Further investigation is needed to assess solvent concentrations in leachates from this site.

Sediment Condition

Sediment samples were collected from one station in the center of Colvos Passage across from Ollala (Barrick and Prahl 1987). Phenanthrene and retene concentrations in sediments from this site were not substantially elevated above reference values at this station.

Of the five stations sampled in Colvos Passage between April 1982 and April 1984, only silver was substantially elevated above reference values (1.4 mg/kg silver) at one station near Fern Cove. Metal concentrations were not substantially elevated at the other four nearshore stations located north of Fern Cove at Peter's Point and in southern Colvos Passage (Nevissi et al. 1984).

In August 1982, sediment concentrations of 14 metals and 24 aromatic hydrocarbons were not substantially elevated above reference values at one station sampled in the northern portion of Colvos Passage north of Ollalla in August 1982 (Riley et al. 1983). Aromatic hydrocarbon concentrations

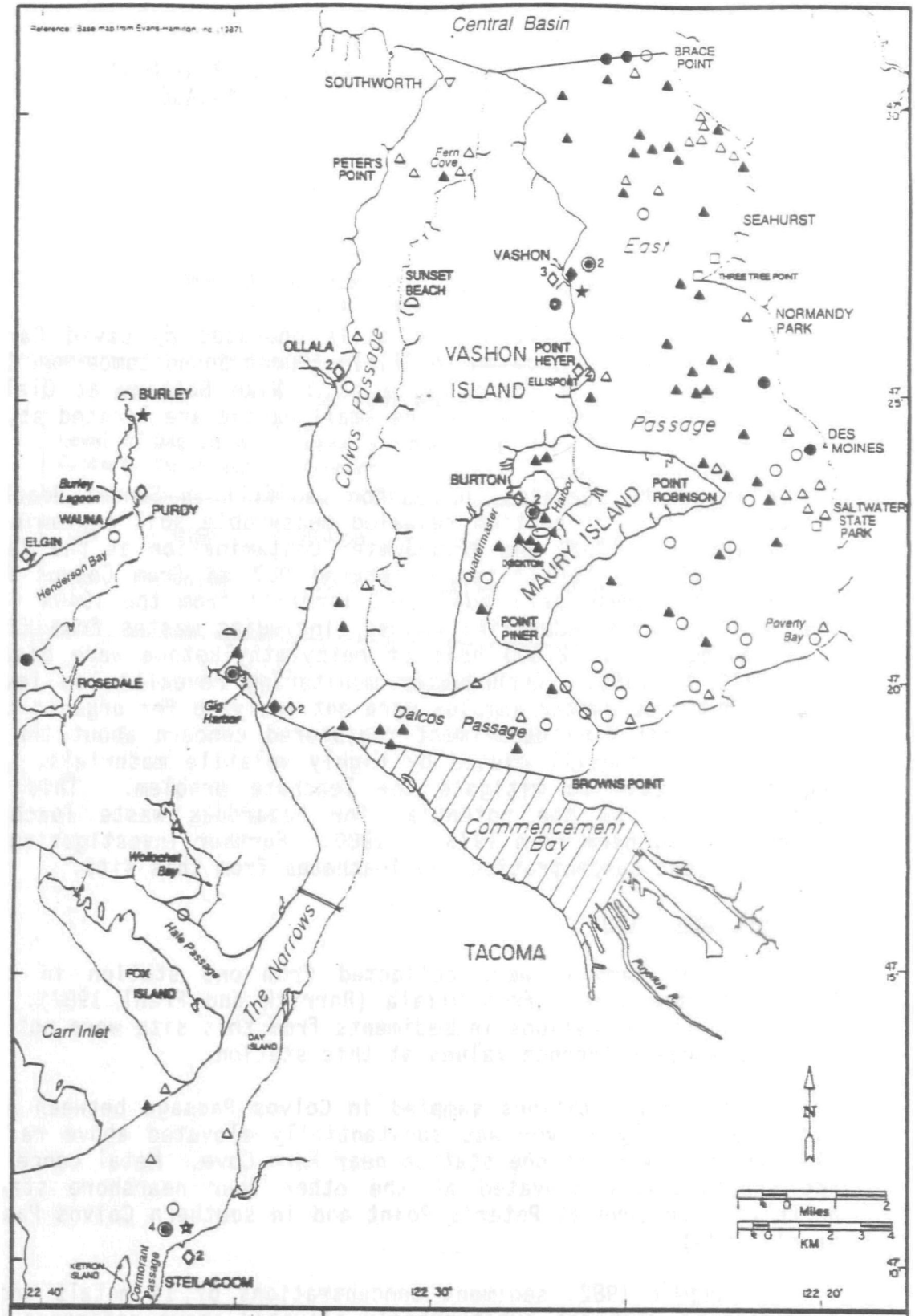


Figure 13

REGION 11

EAST PASSAGE AND TACOMA NARROWS

measured include 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. PCBs were not detected at this station. In 1975, Schell et al. (1977) collected sediments from one mid-channel station east of Peter's Point. Metal concentrations were not substantially elevated above reference in sediments collected at this station.

Antimony concentrations were substantially elevated (2.2 and 2.4 mg/kg) at two stations near the southern end of Colvos Passage in 1970-1972 (Crecelius et al. 1975).

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

From 1961 to 1977, oyster larvae mortalities and abnormalities were not substantially elevated above reference values at one station in Colvos Passage near Ollala (Cardwell and Woelke 1979).

CORMORANT PASSAGE AND TACOMA NARROWS

Rank Low

Sources

The Crystal Bay Lumber Company in Steilacoom produced 12,000-15,000 bd ft of lumber in 1893 (Puget Sound Lumberman 1893). In 1963, the West Tacoma Newsprint Company in Steilacoom produced 175 tons of wood pulp and 200 tons/day of paper (Bryant 1963).

The South Sound Marina, with 31 wet slips is located near Steilacoom (Ocean. Inst. 1978). Both fuel and repairs are available onsite.

There are four NPDES-permitted sources in Steilacoom for Boise Cascade, and three municipal sewer systems (City of Steilacoom, Ketron Island Enterprises, and Washington Corrections on McNeil Island) (U.S. EPA 1986). In 1980, Boise Cascade Corporation was a self-reported generator of hazardous asbestos wastes (U.S. EPA 1980).

Sediment Condition

Phenanthrene and retene concentrations were not substantially elevated above reference values in sediments from one station near Hyde Point on McNeil Island (Barrick and Prahl 1987).

In August 1982, Riley et al. (1983) measured chemical concentrations of 14 metals and 24 aromatic hydrocarbons in sediments collected at one station north of Sandy Point on Anderson Island (see the Region 12 map). Aromatic hydrocarbons measured include 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. None of these analytes were substantially elevated above reference at this site and no PCBs were detected.

Pavlou et al. (1977) measured PCB concentrations in sediments collected for one station located halfway between Steilacoom and Day Island from 1972 to 1977. PCB concentrations were not substantially elevated above reference values for sediment concentrations.

In 1970-1972, heavy metal concentrations were not substantially elevated above reference in sediments from one mid-channel station south of Fox Island in the Tacoma Narrows (Crecelius et al. 1975).

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

From 1973 to 1977, no substantially elevated oyster larvae mortalities or abnormalities were found for one station east of Ketron Island in Cormorant Passage (Cardwell and Woelke 1979).

Oyster larvae mortalities and abnormalities were not substantially elevated above reference for one station near Steilacoom (Cardwell and Woelke 1979).

DALCOS PASSAGE

Rank Low

Sources

No information available.

Sediment Condition

Phenanthrene and retene concentrations were not substantially elevated in sediments from one station located halfway between Commencement Bay and the head of Quartermaster Harbor in the center of Dalcos Passage (Barrick and Prahl 1987).

Crecelius et al. (1975) collected sediments from six stations in Dalcos Passage at the mouth of Commencement Bay in 1970-1972. Antimony concentrations were elevated at all stations, with the highest concentration (4.6 mg/kg) near the site of the former ASARCO smelter. This value is approximately 1.5 times the AET.

Toxicity Indexes

Sediment Amphipod Bioassays--

Schwartz (1984) conducted bioassays using sediments collected from Dalcos Passage south of Piner Point. Amphipod mortality rates were not substantially elevated above reference at this site.

EAST PASSAGE

Rank High

Sources

A marina at Normandy Park did not report the size or types of facilities available. A large marina located in Des Moines has over 700 wet slips and fuel and boat repair facilities onsite (Ocean. Inst. 1978).

Sediment Condition

Organic chemicals were substantially elevated at 8 of the 10 stations sampled in the Central Puget Sound Basin and East Passage (Metro 1984). The eight stations were located between Brace Point (Seola) and Vashon Island, between Point Robinson and Des Moines, at Point Williams, and two stations were located north of Blake Island. Organic chemical concentrations at these stations did not exceed AET values. Chemical concentrations at Point Robinson, Point Heyer, and Point Piner exceeded the AET for several chemicals. Sediment concentrations of acenaphthylene near Point Piner were 20 times the AET value set for this compound and exceeded the Carr Inlet reference value by 3237 times. The results of the Metro (1984) study are presented in Table 32.

Phenanthrene and retene concentrations were not substantially elevated in sediments from one station in the central channel near Seahurst (Barrick and Prahl 1987).

In 1970-1972, Crecelius et al. (1975) measured metal concentrations at five stations at the center of East Passage. Antimony concentrations were substantially elevated at all five stations (2.4-3.6 mg/kg) and arsenic concentrations were substantially elevated at one station east of Three Tree Point (35 mg/kg).

Between April 1982 and April 1984, sediments were sampled during the Renton Seahurst study (Nevissi et al. 1984) on transects across the Sound in the vicinity of Three Tree Point and the proposed Seahurst sewage outfall. Forty two stations were sampled to determine metal concentrations in East Passage. For the most part, silver concentrations were not substantially elevated at the nearshore stations, while all but one or two deep water stations had substantially elevated silver concentrations. Seventeen deep water stations had substantially elevated concentrations of silver, while eight nearshore stations (Brace Point, Ellisport, Point Robinson, Seahurst, and South Maury Island, Three Tree Point) also had elevated concentrations of silver.

TABLE 32. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT SIX STATIONS IN EAST PASSAGE

Williams	Elevation Above Reference					
	S0016 Piner Pt 176 m	S0017 Pt Robins 188 m	0152 Des Moine 214 m	S0018 Pt Heyer 196 m	0151 Vash-Seola 240 m	S0019 Pt 203 m
Antimony	NS[a]	29.1	NS	NS	NS	NS
Silver	30.0	NS	NS	NS	21.0	NS
Acenaphthene	NS	371.4[b]	NS	357.1[b]	NS	NS
Acenaphthylene	3,237.1[b]	NS	NS	336.7[b]	NS	NS
Anthracene	152.6[b]	30.6	NS	NS	NS	NS
Benzo(a)anthracene	NS	243.7[b]	28.3	60.6	NS	NS
Benzo(a)pyrene	NS	64.2	25.9	62.6	15.5	NS
Benzo(g,h,i)perylene	NS	NS	28.5	38.6	23.3	NS
Chrysene	28.6	505.3	20.2	36.1	NS	NS
Dibenzo(a,h)anthracene	NS	NS	NS	29.4	NS	NS
Fluoranthene	22.0	96.8	15.0	33.3	14.3	70.1
Fluorene	138.2[b]	187.0[b]	NS	183.0[b]	NS	NS
Indeno(1,2,3-c,d)pyrene	NS	NS	29.3	25.1	23.7	NS
Naphthalene	545.9	124.1	NS	169.4	NS	NS
N-nitrosodiphenylamine	NS	187.0[b]	NS	183.0[b]	NS	NS
Phenanthrene	552.5[b]	187.5[b]	NS	19.1	NS	NS
Pyrene	NS	74.6	14.2	36.4	15.7	88.0

[a] NS = Not substantially elevated.

[b] AET value exceeded.

Reference: Metro (1984).

Toxicity Indexes

Sediment Amphipod Bioassays--

A Metro (1984) study revealed substantially elevated levels of amphipod bioassay mortalities at two of the three stations sampled near Brace Point. Results were mixed, with high mortality levels at the two deeper stations and low mortality rates at the one station nearer to shore.

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates of abnormalities were recorded (93 percent during July 1967) and substantially elevated rates of mortalities were recorded July 1967 and July 1971 at one station near Des Moines on East Passage.

Cardwell and Woelke (1979b) also found substantially elevated (>50 percent) levels of oyster larvae mortalities in receiving water sampled at an East Passage site south of Normandy Park.

Fish Histopathology--

Landolt et al. (1984) studied histopathology for 667 demersal fish and 226 pelagic fish collected at Seahurst Park, Point Pully (Three Tree Point), and Saltwater State Park from May 1982 to November 1983. Neoplasms were nonexistent in English, Dover, and Slender sole, and Quillback rockfish collected at Three Tree Point and Saltwater State Park. Some neoplasms were found in English and Dover sole near Seahurst, but they were not substantially elevated.

GIG HARBOR

Rank Medium

Sources

In 1893, the E.S. Prentice shingle mill in Gig Harbor produced 30,000-50,000 bd ft of shingles (Puget Sound Lumberman 1893). By 1926, the Austin Company and Wollochet Bay Lumber Company lumber mills and the Bay Island Newspaper were operating in Gig Harbor (Manu. Assoc. of WA 1926).

Six marinas with a combined total of more than 350 wet slips and facilities for boat repairs and refueling are located in Gig Harbor (Ocean. Inst. 1978).

Three NPDES discharge permits have been issued for the city of Gig Harbor, a harbor club, and an oyster company (U.S. EPA 1986).

Sediment Condition

Riley et al. (1983) measured concentrations of 14 metals and 24 aromatic hydrocarbons in the sediments from one station near the center of Gig Harbor in August 1982. The aromatic hydrocarbons included 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. Sediment concentrations of three HPAHs and 1-methylphenanthrene were substantially elevated above reference values for one station near the head of Gig Harbor (see Table 33). PCBs were detected at this station, but were not substantially elevated above reference values.

Toxicity Indexes

No information available.

HALE PASSAGE AND FOX ISLAND

Rank Low

Sources

Currently, one yacht club (size not reported) is located on Fox Island.

Five marinas with over 300 wet slips are clustered on the Tacoma side of the Narrows near Day Island (Ocean. Inst. 1978). Fuel and repair facilities are available at several of the Day Island marinas.

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

No substantially elevated oyster larvae mortalities and abnormalities were found in bioassays conducted at one station in Wollochet Bay near Hale Passage from 1973 to 1977 (Cardwell and Woelke 1979).

HENDERSON BAY AND BURLEY LAGOON

Rank Low

Sources

In 1893, a small sawmill in Purdy, operated by T.A. Sherman, produced less than 12,000 bd ft of lumber (Puget Sound Lumberman 1893). In the same year, the Mintur Shingle Factory near Elgin produced 60,000-100,000 bd ft

TABLE 33. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT ONE STATION IN GIG HARBOR

Chemical	Elevation Above Reference Central Harbor
Benzo(a)anthracene	57
Benzo(a)pyrene	28
Chrysene	36
1-methylphenanthrene	56

Reference: Riley et al. (1983).

of shingles. Both of these mills are abandoned. Large log sort yards associated with these two mills are potential sources of organic toxicants in Henderson Bay (Duxbury, A., (date), personal communication).

A National Guard Target-Firing Range is located in Burley Lagoon (U.S. DOD 1985).

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassay--

Mortalities and abnormalities were not substantially elevated from 1962 to 1977 in bioassays conducted at one station near Wauna in Henderson Bay (Cardwell and Woelke 1979).

High rates of mortality (>40 percent) were observed in June 1970 in bioassays conducted using water samples collected at one station in Henderson Bay near Rosedale (Cardwell and Woelke 1979). Abnormalities were not substantially elevated at this station at any time during the monitoring period from 1962 to 1977.

QUARTERMASTER HARBOR

Rank Medium

Sources

In 1893, the M.F. Hatch shingle mill in Quartermaster Harbor produced 30,000-50,000 bd ft of sawn lumber (Puget Sound Lumberman 1893). By 1926, the Vashon Island Mill had also been built on Quartermaster Harbor at Burton (Manu. Assoc. of WA 1926). Both of these lumber mills have been abandoned.

By 1907, the first drydock in Puget Sound was completed in Dockton on Maury Island (Chasan 1984). This drydock was later abandoned.

Currently, Quartermaster Harbor has one small and one medium-size marina with 112 wet slips and fuel and repairs. According to U.S. EPA (1986), two NPDES-permitted sources are located on Quartermaster Harbor: the City of Burton municipal sewage district, and the Island Springs, Inc. food-processing company.

Sediment Condition

To determine possible causes for high herring egg mortalities in Quartermaster Harbor, Yake (1986) sampled sediments near Dockton and compared his results to data from the Metro (1984) study. Yake found that metal concentrations were not substantially elevated above reference values

at any station and concentrations of aromatic hydrocarbons were substantially elevated in sediments at only one of the Dockton stations (see Table 34). Metro (1984) also found low metal concentrations in sediments (Yake 1986). Metals and organic concentrations of metals and organics were generally highest near the head and lowest near the mouth of the harbor. At the mouth, only one analyte (di-n-octyl phthalate) was substantially elevated above reference values, while several organic chemicals were elevated above reference at the other two sites. None of the observed chemical concentrations were high enough to account for the elevated herring egg mortalities.

The Renton Seahurst study (Nevissi et al. 1984) revealed substantially elevated silver concentrations at all three Quartermaster Harbor stations. Sampling stations were located at the head, at Dockton, and at the mid point of the harbor. Silver concentrations ranged from 1.5 to 2.7 mg/kg. Arsenic concentrations (45 mg/kg) were also substantially elevated at the station near the center of the harbor.

In 1970-1972, Crecelius et al. (1975) found substantially elevated concentrations in sediments from two of the three stations sampled in Quartermaster Harbor. Arsenic concentrations (50 and 54 mg/kg) and antimony concentrations (3.2 and 3.6 mg/kg) were also elevated at the station near the head of the harbor and the station near Dockton. Crecelius attributes these elevated metal concentrations to atmospheric deposition from the former ASARCO smelter. Metal concentrations were not substantially elevated at the third sediment sampling station near the mouth of Quartermaster Harbor (Crecelius et al. 1975).

Toxicity Indexes

Sediment Amphipod Bioassays--

A Metro (1984) study revealed no substantially elevated levels of amphipod bioassay mortalities near Quartermaster Harbor.

Herring Spawning Mortalities--

Previous studies have shown high herring egg mortalities on the shoreline near Dockton in Quartermaster Harbor. According to Lew Kittle (March 1987, personal communication) annual herring egg mortality rates reach 80 percent near Dockton. Dan Pentilla (March 1987, personal communication) describes the area affected by spawning problems as lying between the north side of the point and King County Park. Pentilla also stated that there are no known outfalls in the area and the reasons for high mortalities are unknown.

TABLE 34. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT THREE STATIONS IN QUARTERMASTER HARBOR

Chemical	Elevation Above Reference			
	Docton[a]	Head[b]	Central[b]	Mouth[b]
LOW WEIGHT PAHs				
Phenanthrene	NS[c]	NS	64	NS
HIGH WEIGHT PAHs				
Benzo(a)anthracene	NS	NS	20	NS
Benzo(a)pyrene	NS	30	16	NS
Benzo(g,h,i)perylene	NS	48	18	NS
Total benzoflouranthenes	NS	20	NS	NS
Fluoranthene	NS	33	16	NS
Indeno(1,2,3-c,d)pyrene	NS	40	17	NS
Pyrene	13.7	38	17	NS
Other:				
Di-n-octyl phthalate	28.7	14	14	39

[a] Reference from Yake (1986).

[b] Reference from Metro (1984).

[c] NS = Not substantially elevated.

VASHON ISLAND

Rank Medium

Sources

McLean & Durkee operated a small sawmill and shingle manufacturer in Vashon that produced less than 12,000 bd ft of lumber and 30,000-50,000 ft of shingles in 1893 (Puget Sound Lumberman 1893). By 1926, the V.W. Covey lumber mill, the Helmar Steen lumber mill, Helmar & Steen Box manufacturing, and the Vashon Island News Record were located on Vashon Island (Manu. Assoc. of WA 1926). Two lumber mills operated by F.A. & H.O. Fuller and the Stine Mill Company were also located in Ellisport (Manu. Assoc. of WA 1926).

U.S. EPA (1986) lists two NPDES-permitted sources for Vashon Island: the City of Vashon Sewer District and the K-2 Corporation, a ski manufacturer. The K-2 Corporation is also listed as a hazardous waste generator and produced 18 tons of characteristic hazardous wastes in 1983 (Kruger 1983).

Sediment Condition

Nevissi et al. (1984) measured metal concentrations in sediments from two nearshore stations near Ellisport. Silver concentrations were substantially elevated above sediment reference values at the southern station, but metal concentrations were not substantially elevated above reference values at the second station east of Point Heyer.

Toxicity Indexes

No information available.

WOLLOCHET BAY AND HALE PASSAGE

Rank Low

Sources

No information available.

Sediment Condition

In August 1982, Riley et al. (1983) analyzed concentrations of 14 metals and 24 aromatic hydrocarbons in sediments collected from one station near the head of Wollochet Bay. Aromatic hydrocarbons analyzed included 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. None of these analytes were substantially elevated above Carr Inlet reference values and PCBs were not detected in sediments at this site.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Cardwell and Woelker (1979b) conducted oyster larvae bioassays at one station at the head of Wollochet Bay from 1962 to 1977. The observed oyster larvae mortality and abnormality rates were not substantially elevated at any time during this period.

REGION 11 ASSESSMENT MATRIX RESULTS

As seen in Table 35, East Passage received a high ranking in this investigation due to a high degree of sediment contamination and extensive biological toxicity exhibited at this site. Colcos Passage, Gig Harbor, Quartermaster Harbor, and Vashon Island ranked medium. All other areas of concern ranked low. Sediment and toxicity data were not available for several of the areas of concern. Source data for Dalcos Passage, Wollochet Bay and Hale Passage was also unavailable.

TABLE 35: ENVIRONMENTAL ASSESSEMENT MATRIX FOR REGION # 11

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Colvos Passage	MEDIUM	HIGH	MEDIUM	LOW	LOW	LOW	MEDIUM
Cormorant Passage and Tacoma Narrows	MEDIUM	MEDIUM	LOW	MEDIUM	LOW	MEDIUM	LOW
Dalcos Passage	N/A	N/A	HIGH	LOW	LOW	LOW	LOW
East Passage	LOW	LOW	HIGH	HIGH	MEDIUM	HIGH	HIGH
Gig Harbor	LOW	MEDIUM	MEDIUM	LOW	N/A	N/A	MEDIUM
Hale Passage & Fox Island	LOW	LO	N/A	N/A	LOW	LOW	LOW
Henderson Bay & Burley Lagoon	LOW	LOW	N/A	N/A	LOW	LOW	LOW
Quartermaster Harbor	LOW	MEDIUM	MEDIUM	HIGH	LOW	MEDIUM	MEDIUM
Vashon Island	MEDIUM	HIGH	MEDIUM	LOW	N/A	N/A	MEDIUM
Wollochet Bay & Hale Passage	N/A	N/A	LOW	LOW	LOW	LOW	LOW

TOXIC PROBLEM ASSESSMENT OF REGION 12: SOUTH SOUND (Figure 14)

CARR INLET

Rank Low

Sources

In 1893, a small lumber mill operated by Lorenz & Company in Lakebay produced less than 12,000 ft of sawn lumber (Puget Sound Lumberman 1893).

A marina is located in Lakebay (Ocean. Inst. 1978).

Transport of pollutants from a contaminated site in Burley Lagoon are a potential source of contaminants in Carr Inlet (see map and discussion for Region 11).

Sediment Condition

Riley et al. (1983) measured sediment concentrations of 14 metals and 24 aromatic hydrocarbons at three stations in Carr Inlet during August 1982. Aromatic hydrocarbons analyzed in Riley's study include 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. A few chemicals were significantly elevated above reference at one of the Wyckoff Shoal stations and at the station east of Van Geldern Cove (see Table 36).

In 1972-1977, PCB concentrations were measured in sediments from one station north of Wyckoff Shoal off McNeil Island and another station located midchannel east of Von Geldern Cove (Pavlou et al. 1977). PCBs were not detected.

Crecelius et al. (1975) measured metal concentrations in sediments from two Carr Inlet stations between 1970 and 1972. Concentrations of arsenic (39 mg/kg) and antimony (12 mg/kg) were substantially elevated above reference values at one midchannel station near the mouth of Carr Inlet. Antimony was also substantially elevated above reference values (1.8 mg/kg) at one station located northwest of Green Point (see the Region 10 map).

Toxicity Indexes

No information available.

DANA PASSAGE AND PEALE PASSAGE

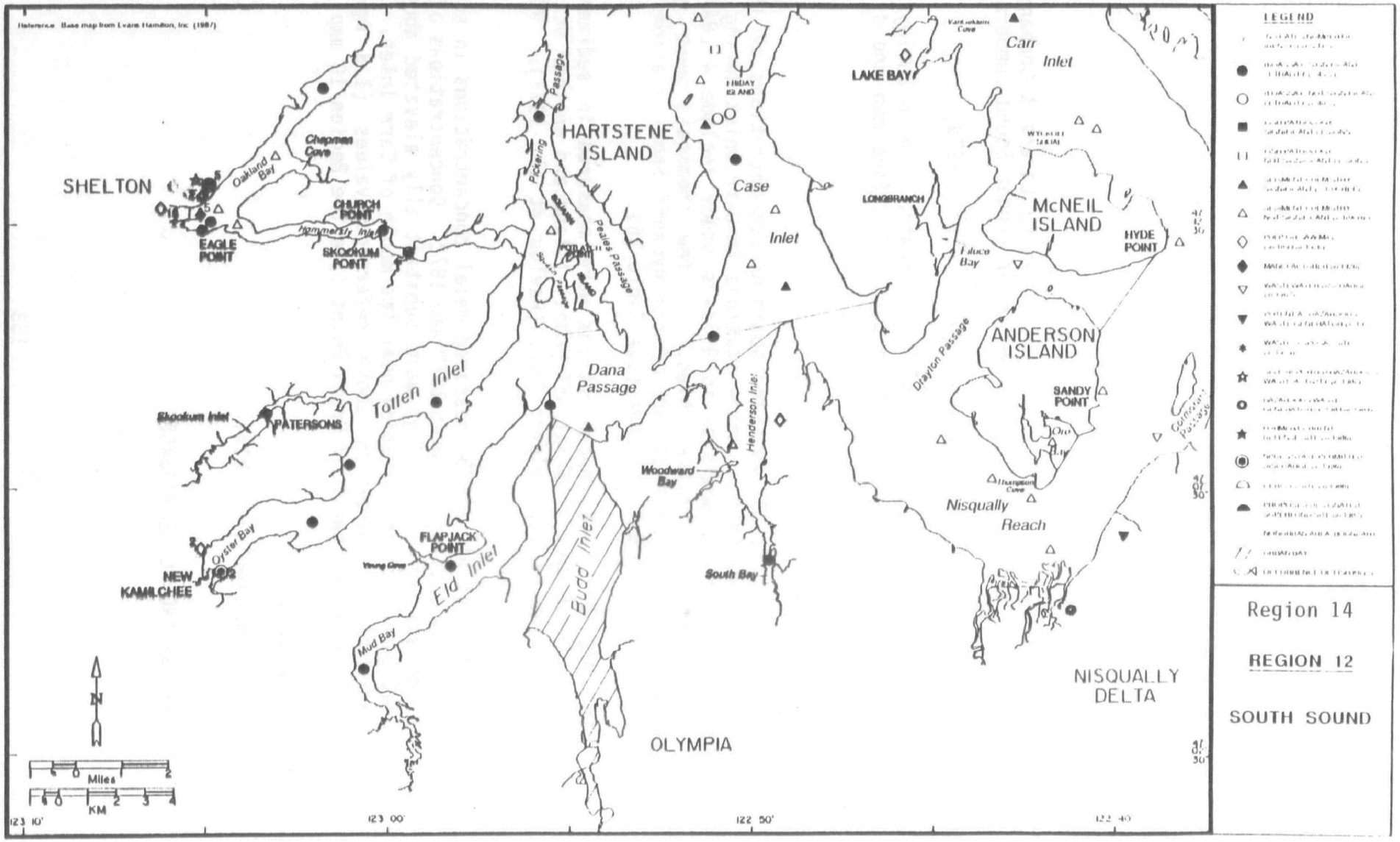

Reference Base map from Evans Hamilton, Inc. (1987)
SHELTON
Oakland Bay
Chapman Cove
CHURCH POINT
Hammersley Inlet
EAGLE POINT
SKOOKUM POINT
Pickering Passage
HARTSTENE ISLAND
Peales Passage
Case Inlet
FRIDAY ISLAND
LAKE BAY
Carr Inlet
LONGBRANCH
McNEIL ISLAND
HYDE POINT
Filucy Bay
Drayton Passage
ANDERSON ISLAND
SANDY POINT
Dana Passage
Skookum Inlet
PATERSONS
Totten Inlet
Henderson Inlet
Woodward Bay
Nisqually Reach
Oyster Bay
NEW KAMILCHEE
FLAPJACK POINT
Young Cove
Eld Inlet
Budd Inlet
South Bay
Mud Bay
OLYMPIA
NISQUALLY DELTA
N
Miles
KM
123 10'
123 00'
122 50'
122 40'
LEGEND
Region 14
REGION 12
SOUTH SOUND

TABLE 36. ELEVATIONS ABOVE REFERENCE VALUES FOR CHEMICALS IN SEDIMENTS AT TWO STATIONS IN CARR INLET

Chemical	Elevation Above Reference	
	Wyckoff Shoal	Van Geldern Cove
Benzo(a)anthracene	23	37
Benzo(a)pyrene	NS[a]	15
1-methylphenanthrene	15	NS

[a] NS = Not substantially elevated.

Reference: Riley et al. (1983).

Rank Medium

Sources

No information available.

Sediment Condition

In 1970-1972, Crecelius et al. (1975) found substantially elevated levels of antimony (1.7 mg/kg) in sediments from one station at the head of Budd Inlet in Dana Passage.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassay

Oyster larvae mortalities were substantially elevated (>40 percent) for one station in Dana Passage in September 1976. The oyster larvae abnormalities were not substantially elevated at this station from 1973 to 1977 (Cardwell and Woelke 1979).

ELD INLET

Rank Medium

Sources

No information available.

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979) high rates of mortality (>50 percent) occurred at Flapjack Point in Eld Inlet in 1966, 1968, 1970, 1971, and 1973 to 1977. Abnormalities were not substantially elevated at Flap Jack Point from 1961 to 1977.

Rates of mortalities were substantially elevated near the head of Eld Inlet in 1977 (Cardwell and Woelker 1979). Abnormalities were not substantially elevated at this site from 1975 to 1977. Near the mouth of Eld Inlet, mortalities were high in 1968 and 1973 but abnormalities were never substantially elevated from 1973 to 1974. Mortalities in Eld Inlet were associated with red tide.

FILUCE BAY

Rank Low

Sources

The Longbranch Improvement Club marina is currently located at Longbranch in Filuce Bay. This marina has no fuel or repair facilities (Ocean. Inst. 1978).

Sediment Condition

No information available.

Toxicity Indexes

No information available.

HENDERSON INLET

Rank Low

Sources

Henderson Inlet is the site of an abandoned Weyerhaeuser lumber mill and accompanying large log storage areas (Ecology 1982).

A very small marina, and a larger marina with 152 wet slips and fuel and repair facilities are located in Henderson Inlet (Ocean. Inst. 1978).

Sediment Condition

In August 1982, Riley et al. (1983) measured sediment concentrations of 14 metals and 24 aromatic hydrocarbons, including 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables, at one nearshore station north of Woodward Bay in Henderson Inlet. Only 1-methylphenanthrene was substantially elevated (10 times) above sediment reference values.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates of mortality (>40 percent) were observed in bioassays conducted at one station in South Bay off Henderson Inlet during September 1977. The mortalities in Henderson Inlet were believed to be associated with a red tide. No substantially elevated abnormalities were found at this site from 1976 to 1977.

NISQUALLY REACH AND DRAYTON PASSAGE

Rank Medium

Sources

In 1967, Fort Lewis and the Federal Penitentiary on McNeil Island discharged to Class AA Waters in Drayton Passage (U.S. FWPCC 1967).

The DuPont De Nemours explosives manufacturing plant located in Nisqually Reach is a recognized hazardous waste generator (Kruger 1983). This plant produces 25 mm lbs of dynamite, uses 15 mm lbs of water gel, and generates 15,000 tons of sulfuric acid, and 12 tons of explosive wastes per year (U.S. EPA no date). Sulfuric acid produced in manufacturing explosives is resold as a lower grade acid. Other wastes from the manufacturing process are disposed of by open burial. Desirable waste management techniques were being practiced at this site (U.S. EPA no date). There is also a DuPont drum site that stores nitroglycerine.

Sediment Condition

Riley et al. (1983) analyzed sediment concentrations of 14 metals and 24 aromatic hydrocarbons in sediments from one station in Oro Bay on Anderson Island. Aromatic hydrocarbons measured included 4 LPAHs, 7 HPAHs, and 13 miscellaneous extractables. None of the analytes were substantially elevated above reference values and PCBs were not detected.

Phenanthrene and retene concentrations were not substantially elevated above reference in sediments from one station west of Thompson Cove (Barrick and Prahl 1987).

PCB concentrations were not substantially elevated above reference values in sediments from one station at the southern tip of Anderson Island (Pavlou et al. 1977).

Crecelius et al. (1975) found no substantially elevated metals concentrations in sediments from one nearshore station in Nisqually Reach and another station at the southwest tip of Anderson Island.

Toxicity Indexes

No information available.

OAKLAND BAY AND HAMMERSLEY INLET

Rank Medium

Sources

Two small to medium size lumber mills, Mason County Ry Company and Willey Brothers, were located in Shelton in 1893 (Puget Sound Lumberman 1893). In 1926, 12 lumber mills and logging companies, The Jackson Millwork Company (a manufacturer of doors and ironing boards), a steam laundry, the A.C. Smith sheet metal shop, and two printing facilities were located in Shelton (Manu. Assoc. of WA 1926). By 1927, the Rainier Pulp and Paper Company had been built and was producing 110 tons/yr of bleached sulphite pulp and 135 tons/yr of unbleached sulphite pulp per day (Baker 1927).

One small marina, the Shelton Marina, is located in Shelton (Ocean. Inst. 1978).

The major NPDES discharges to marine waters near Shelton are ITT Rayonier, Inc., Simpson Timber Company (Simpson), two fisheries, and a municipal sewage discharge for the city of Shelton (U.S. EPA 1986).

The Simpson produces sawn lumber, plywood, and hardwood veneers and operates a steam generating plant. In 1963, Simpson also produced insulation board (Bryant 1963). Simpson is known to generate dioxin wastes and to use pentachlorophenol to treat wood (Burkhalter, 1987, personal communication). Simpson has also operated a thermal/mechanical pumping operation (Burkhalter, personal communication) and had a massive log storage area near Shelton (Collias, personal communication).

Another major discharger, ITT Rayonier, Inc. ceased operations at their pulp mill in 1957 (Cardwell and Woelke 1979). ITT Rayonier, Inc. continues to operate the Olympic Research Division, a self-reported generator of hazardous wastes (U.S. EPA 1980).

According to Ecology, another hazardous waste generator, Certified Manufacturing in Shelton, generates approximately 3 tons of hazardous waste annually (Kruger 1983; Kruger 1984).

Sediment Condition

Malins et al. (1982) measured metal, aromatic hydrocarbon, PCB, chlorinated pesticide, and other chlorinated organic chemical concentrations in sediments from one station east of Eagle Point in Hammersley Inlet. None of these analytes were substantially elevated above reference values. Total aromatic hydrocarbon concentrations reported for this station were 310 ug/kg.

PCB concentrations were not substantially elevated above reference values in sediments from two stations sampled in Oakland Bay near Shelton and Chapman's Cove (Pavlou et al. 1977).

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

According to Cardwell and Woelke (1979), high rates of mortality (>50 percent) occurred at three stations in Oakland Bay and one station in Hammersley Inlet. High mortality and very high abnormality rates were found

for oyster larvae grown in water samples taken near the ITT Rayonier plant in 1961. However, neither abnormalities nor mortalities were substantially elevated after this date. The Eagle Point station and the oil dock station near Shelton, the Oakland Narrows station, and the station near Chapman's Cove off Oakland Bay had no substantially elevated rates of oyster larvae mortality or abnormality from 1961 to 1975. The low rate of mortalities and the absence of dinoflagellate blooms in Oakland Bay has been a paradox. The Hammersley Inlet station between Skookum Point and Church Point had one incident of elevated mortalities in 1968. This incident was accompanied by slightly higher abnormalities, but abnormality rates were not high enough to be considered substantial. Cardwell and Woelke (1979b) also found substantially elevated mortalities at one station east of Skookum Point in Hammersly Inlet.

PICKERING PASSAGE AND SQUAXIN PASS

Rank Low

Sources

No information available.

Sediment Condition

PCB concentrations were not substantially elevated above reference values in sediments from one nearshore station north of Potlatch Point on the west side of Squaxin Island in Pickering Passage (Pavlou et al. 1977).

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Oyster larvae mortalities were elevated in one incident in 1968 (Cardwell and Woelke 1979). This incident occurred in Squaxin Pass and the number of abnormalities were near zero from 1968 to 1976.

SKOOKUM INLET

Rank Low

Sources

No information available.

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Oyster larvae mortalities were substantially elevated at one station near Patersons in Skookum Inlet in 1962, 1964, 1968, 1973, and 1976 (Cardwell and Woelke 1979). Abnormalities were only elevated at this station in 1976.

TOTTEN INLET

Rank Medium

Sources

In 1926, two lumber mills operated by Balstin Brothers Lumber and R.R. McDonald were located in New Kamilche near Oyster Bay (Puget Sound Lumberman 1893). Two NPDES permitted oyster companies, John A. Sales and Olympia Oyster Company in Oyster Bay, are discharging to Totten Inlet (U.S. EPA 1986).

Sediment Condition

No information available.

Toxicity Indexes

Receiving Water Oyster Larvae Bioassays--

Oyster larvae mortalities were substantially elevated (>50 percent) at the Burns Point station in Totten Inlet in 1968 and 1973 (Cardwell and Woelke 1979b). Abnormalities were low at this station from 1961 to 1977.

The pattern of oyster larvae bioassay results were similar at Dahman's in Totten Inlet, with mortalities elevated in 1968, 1970, and 1973 and no substantially elevated abnormalities for any of those years (Cardwell and Woelke 1979b).

At a station just east of the Little Skookum Inlet, mortalities were elevated in 1965, 1968, 1970, 1971, 1973, and 1977 (Cardwell and Woelke 1979b). Abnormalities were not elevated at this station at any time during the monitoring period.

REGION 12 ASSESSMENT MATRIX RESULTS

As seen in Table 37, Dana and Peale Passages, Eld Inlet, Nisqually Reach and Drayton Passage, Oakland Bay and Hammerly Inlet, and Totten Inlet received medium rankings. All other areas of concern received low rankings. Sediment and toxicity data are not available for most of the areas of concern in this region. Likewise, source data are not available for Dana and Peale Passages, Eld Inlet, Pickering Passage and Squakin Pass, and Skookum Inlet.

TABLE 37: ENVIRONMENTAL ASSESSMENT MATRIX FOR REGION # 12

LOCATION	SOURCES		SEDIMENT CONDITION		TOXICITY INDEXES		RANK
	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	Level of Concern	Degree of Certainty	
Carr Inlet	LOW	LOW	MEDIUM	LOW	N/A	N/A	LOW
Dana Passage & Peale Passage	N/A	N/A	MEDIUM	LOW	MEDIUM	LOW	MEDIUM
Eld Inlet	N/A	N/A	N/A	N/A	MEDIUM	MEDIUM	MEDIUM
Filuce Bay	LOW	LOW	N/A	N/A	N/A	N/A	LOW
Henderson Inlet	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW
Nisqually Reach & Drayton Passage	MEDIUM	HIGH	LOW	MEDIUM	N/A	N/A	MEDIUM
Oakland Bay & Hammersley Inlet	MEDIUM	HIGH	LOW	LOW	HIGH	HIGH	MEDIUM
Pickering Passage & Squakin Pass	N/A	N/A	LOW	LOW	MEDIUM	LOW	LOW
Skookum Inlet	N/A	N/A	N/A	N/A	MEDIUM	LOW	LOW
Totten Inlet	LOW	LOW	N/A	N/A	MEDIUM	MEDIUM	MEDIUM

CONCLUSIONS

Of the 97 nonurban areas of Puget Sound evaluated in this study by the Environmental Assessment Matrix technique, only 6 received a ranking of HIGH which would qualify them for consideration as sites for future, detailed investigations. The areas of significant concern are: the Guemes/Fidalgo Channel (Region 2), Port Angeles Harbor (Region 3), Crescent Harbor (Region 4), Richmond Beach (Region 8), Liberty Bay (Region 9), and East Passage (Region 11).

Forty-two (42) other areas received a MEDIUM ranking. As might be expected, industrialized regions contained the larger numbers of MEDIUM sites. The results can be grouped according to the number of MEDIUMs within each region as follows: Regions 3 and 7 each had 1, Regions 2, 5, 6, and 10 had 2, Region 1 had 3, Regions 4 and 11 each had 4, Region 12 had 5, Region 8 had 6, and Region 9 had 10. All other sites were ranked LOW.

This assessment employed an environmentally protective approach towards ranking. A rank of MEDIUM does not necessarily mean an area is in imminent danger of becoming highly contaminated, but only that one or more of the evaluation criteria were exceeded. The intent of this approach is to identify areas of possible toxic contamination problems in non-urbanized areas of Puget Sound before environmental problems manifest themselves.

The following is a detailed listing of the areas of concern and the ranking they received.

AREAS OF CONCERN

REGION 1: STRAIT OF GEORGIA

Birch Bay	LOW
Boundary Bay	LOW
Cherry Point	MEDIUM
Drayton Harbor	MEDIUM
Point Roberts	MEDIUM
Semiahmoo Bay	LOW
Other Areas	LOW

REGION 2: SAN JUAN ISLANDS AND NORTH PUGET SOUND27

Guemes Channel/Fidalgo Bay	HIGH
Andrews Bay/San Juan Island	LOW
Blakely Island	LOW
Doe Bay/Orcas Island	LOW
East Sound/Orcas Island	LOW
Fisherman Bay/Lopez Island	LOW

Friday Harbor-East San Juan	LOW
Hale Passage	LOW
Lopez Sound	LOW
Lummi Bay	LOW
Lummi Island	LOW
Padilla Bay	LOW
Roche Harbor	LOW
Rosario Strait	LOW
Samish Bay	MEDIUM
West Sound/Orcas Island	MEDIUM
Other San Juan Islands	LOW

REGION 3: STRAIT OF JUAN DE FUCA

Dungeness Bay	LOW
East Strait of Juan de Fuca	MEDIUM
Port Angeles Harbor	HIGH

REGION 4: NORTH WHIDBEY BASIN

Cornet Bay-Deception Bay	LOW
Crescent Harbor	HIGH
Duguall Bay	MEDIUM
Oak Harbor	MEDIUM
Penn Cove	MEDIUM
Similk Bay	LOW
Skagit Bay	LOW
Utsalady Bay	LOW

REGION 5: PORT TOWNSEND AND ADMIRALTY INLET

Admiralty Inlet	LOW
Discovery Bay	LOW
Holmes Harbor	MEDIUM
Mutiny Bay	LOW
Oak Bay	LOW
Port Townsend	MEDIUM
Sequim Bay	LOW
Other Bays	LOW

REGION 6: PORT SUSAN AND SARATOGA PASSAGE

Mukilteo	MEDIUM
Port Susan/Tulalip Bay	MEDIUM
Possession Sound	LOW
Saratoga Passage	LOW

REGION 7: CENTRAL HOOD CANAL AND DABOB BAY

Central Hood Canal	MEDIUM
Dabob Bay	LOW
Quilcene Bay	MEDIUM

REGION 8: UPPER HOOD CANAL AND POSSESSION SOUND

Appletree Cove	LOW
Cultus Bay	MEDIUM
Edmonds	MEDIUM
Port Gamble	MEDIUM
Port Ludlow	LOW
President Point/Point Jefferson	MEDIUM
Richmond Beach	HIGH
Upper Hood Canal	MEDIUM
Useless Bay	LOW
Other Areas	MEDIUM

REGION 9: CENTRAL SOUND AND BAINBRIDGE ISLAND

Alki Point1	MEDIUM
Blake Island1	MEDIUM
Carkeek Park	MEDIUM
Central Basin Off Elliott Bay	HIGH
Dyes Inlet	LOW
Liberty Bay	HIGH
Manchester/Colby	MEDIUM
Meadow Point	MEDIUM
Point Williams	MEDIUM
Port Madison	MEDIUM
Port Orchard	LOW
Rich Passage/Bainbridge Island	LOW
Shilshole Bay/Lk Washington Canal	MEDIUM
West Point	MEDIUM
Other Areas	MEDIUM

REGION 10: LOWER HOOD CANAL

Case Inlet	MEDIUM
Lower Hood Canal	LOW

REGION 11: THE NARROWS AND EAST PASSAGE

Colvos Passage	MEDIUM
Cormorant Passage/Tacoma Narrows	LOW
Dalcos Passage	MEDIUM
East Passage	HIGH
Gig Harbor	MEDIUM
Hale Passage/Fox Island	LOW
Henderson Bay/Burley Lagoon	LOW
Quartermaster Harbor	MEDIUM
Vashon Island	MEDIUM
Wollochet Bay/Hale Passage	LOW

REGION 12: SOUTH SOUND

Carr Inlet	LOW
Dana and Peale Passage	MEDIUM
Eld Inlet	MEDIUM
Filuce Bay	LOW
Henderson Inlet	LOW
Nisqually Reach/Drayton Passage	MEDIUM
Oakland Bay/Hammerly	MEDIUM
Pickering Passage/Squaxin Pass	LOW
Skookum Inlet	MEDIUM
Totten Inlet	MEDIUM

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