Puget Sound Estuary Program

BUDD INLET ACTION PLAN:

Initial Data Summaries and Problem Identification

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BUDD INLET ACTION PLAN: INITIAL DATA SUMMARIES AND PROBLEM IDENTIFICATION

by

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for

U.S. Environmental Protection Agency
Region X - Office of Puget Sound
Seattle, Washington

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BUDD INLET ACTION PLAN

The Puget Sound Estuary Program (PSEP) is a forum for interagency cooperation to identify and recommend solutions to water quality problems in Puget Sound. Under this program, the U.S. Environmental Protection Agency (EPA) has identified Budd Inlet as a priority area for evaluation of environmental degradation. The goals of the Budd Inlet Action Plan are to protect the marine and estuarine ecosystem of Budd Inlet against further degradation from anthropogenic inputs of contaminants, to identify degraded areas that are amenable to restorative action, and to protect recreational uses from contamination.

This report provides a synthesis of information describing the geographic extent and severity of environmental degradation in Budd Inlet. Summaries of existing data are provided for the following indicators of environmental degradation: contaminant sources, eutrophication, microbial contamination, and chemical contamination of sediment and biota. Data that were collected from 1982 to 1987 are presented in this report. The year 1982 is significant because the Cities of Lacey, Olympia, and Tumwater, and Thurston County (LOTT) wastewater treatment plant (WWTP) began secondary treatment in August 1982. Recent data are also used to represent present conditions in Budd Inlet, and to ensure that data were collected and analyzed using current methods. Occasionally, older data were used when more recent data were unavailable in the same geographic area.

PHYSICAL SETTING

Budd Inlet is a shallow estuary at the extreme southern end of Puget Sound. It includes the area south of a line joining Cooper Point and Dover Point (see Figure 1 in "Introduction"). The Deschutes River is the major freshwater source to Budd Inlet. Most urban and industrial activity is located in the Cities of Olympia and Tumwater at the southern end of the inlet. Although Capitol Lake is a point source to Budd Inlet, it is not included in the study area.

DECISION-MAKING FRAMEWORK

A decision-making framework was developed to evaluate environmental degradation in Budd Inlet. The decision-making framework includes 1) a review of available environmental data, 2) analyses of spatial and temporal trends of eutrophication, microbial contamination, and toxic contamination in Budd Inlet, 3) a limited ranking of problem areas for interim corrective actions, and 4) identification of data gaps. The decision-making framework used in this report is based on the framework developed for the Elliott Bay (Tetra Tech 1985b) and Everett Harbor (Tetra Tech 1985c) Action Plans.

Data were compiled and evaluated according to the following pollutant categories: contaminant sources (including groundwater and surface water), eutrophication, microbial contamination, and chemical contamination of sediment and biota, including sediment contamination, bioaccumulation in shellfish, sediment and water toxicity bioassays, benthic infaunal communities, and fish pathology. These key variables were then used to develop indices of contamination and biological effects that are based on comparisons with either a reference site in Budd Inlet, reference conditions for Puget Sound [i.e., elevation above reference (EAR) values], or regulatory standards [e.g., apparent effects threshold (AET) values] and criteria. Resultant information was used to identify problem areas.

CONTAMINANT SOURCES

The following six major categories of point and nonpoint sources of contaminants to Budd Inlet were identified and discussed: WWTP, combined sewer overflows (CSO), surface runoff, industrial sources, groundwater, and accidental spills. The LOTT, Tamoshan, Beverly Beach, and Seashore Villa WWTP discharge to Budd Inlet. The City of Olympia currently has one CSO that discharges to West Bay and one CSO that discharges to East Bay via Moxlie Creek. These CSOs are reported to flow infrequently. The LOTT WWTP currently has one manually operated emergency overflow that enters Budd Inlet. Over 50 City of Olympia storm drain outfalls discharge to Budd Inlet. Except for the West Bay drain on Port of Olympia property, CSOs and storm drains have not been investigated for annual flow estimates or chemical composition. In addition to the four WWTP, two National Pollutant Discharge Elimination System (NPDES) permits are issued to Chevron U.S.A. and Delson Lumber Company/Olympia Forest Products. Based on analyses of sediment and groundwater data, an NPDES permit may be required for the Cascade Pole Company site. Analytical results from sediment and effluent samples collected at the Cascade Pole Company former NPDES-permitted outfall and the West Bay drain, and groundwater and product seep samples from the Cascade Pole site indicate that these areas are highly contaminated with polynuclear aromatic hydrocarbons (PAH).

Other ongoing and historical contaminant sources may include unpermitted waste discharges, a former metal plating facility, the U.S. Maritime Mothball Fleet, plywood fabricating facilities, five marinas, historical landfills, bulk petroleum storage facilities, petroleum spills, and surface runoff. Over 80 percent of the surface runoff flows into Budd Inlet via natural drainage channels. The major pollutant sources to Budd Inlet are the Cascade Pole Company and the LOTT WWTP.

EUTROPHICATION

Water quality studies were reviewed to identify the relationship between nutrient concentrations and dissolved oxygen in Budd Inlet. Data were compiled from the records of four WWTP, the Port of Olympia (i.e., East Bay Marina), the Ecology ambient water quality monitoring program, URS (1986), and the Washington Department of Natural Resources Marine Station. Spatial and temporal trends of concentrations of dissolved oxygen and nutrients were analyzed, and dissolved oxygen data were compared with Washington State standards. A seasonal depletion in nitrogen was evident at stations away from the LOTT WWTP outfall. A seasonal decline in dissolved oxygen was observed at all sampling stations established to monitor water quality. Oxygen depletion occurred to levels below 3.0 mg/L at Ecology Station BUD002 in West Bay, at the Capitol Lake outfall, and in the East Bay

Marina. The Washington State Class B water quality standard (5.0 mg/L) was violated at each of the previously mentioned stations, in the Fiddlehead Marina, north of the LOTT 30-in diameter outfall, and in the navigation channel northeast of the Cascade Pole Company. The distribution of dissolved oxygen at the water-sediment interface was not investigated, although oxygen levels may be lowest at this interface due to sediment oxygen demand (Rhoads, D., 18 November 1987, personal communication).

MICROBIAL CONTAMINATION

Microbial concentrations (i.e., fecal coliform bacteria) in Budd Inlet have been determined primarily by a comprehensive study of circulation and water quality in Budd Inlet (URS 1986), in the ambient water quality monitoring program conducted by Ecology (U.S. EPA, 7 January 1988, personal communication), by the City of Olympia (Alan, R., 24 September 1987, personal communication), and by U.S. EPA/Washington Department of Social and Health Services (Armstrong, J., 17 November 1987, personal communication). Results of these studies indicate that water quality standards for fecal coliform bacteria, as measured by the geometric mean concentrations, were violated in several areas. Moxlie Creek was the only site to exceed Washington State Class B water quality standards. High geometric mean concentrations were also calculated for Ellis Cove, Butler Cove, Boston Harbor, Priest Point, southern Tykle Cove, and areas near the Tamoshan WWTP, Beverly Beach WWTP, Seashore Villa WWTP, and Athens Beach. Seasonal variability of fecal coliform bacteria concentrations were not observed at offshore stations, but were observed at nearshore stations. Data collected by URS (1986) indicated that the major sources of bacteria loading were Moxlie Creek, LOTT WWTP, and Capitol Lake (as determined at the tidal gate).

Nonpoint sources of microbial contamination in Budd Inlet include contributions from surface runoff from hobby farms, live-aboards in five Olympia marinas, and general boating activity. These sources have not been qualitatively or quantitatively investigated.

CHEMICAL CONTAMINATION OF SEDIMENTS AND BIOTA

Sediment Contamination

Limited data on sediment contamination are available for Budd Inlet. EAR values were calculated for the available data, and these data were also compared with Puget Sound AET values. Elevated concentrations of organic compounds have been detected in sediments near the Cascade Pole Company (Johnson, A., 22 July 1985, personal communication; Norton, 5 February 1986, personal communication). Concentrations of PAH in sediments from this area were higher than concentrations of PAH observed in Commencement Bay (Tetra Tech 1985a), Elliott Bay (Tetra Tech 1985b), and Everett Harbor (Tetra Tech 1985c). Elevated concentrations of organic compounds were also detected near the West Bay drain, which is adjacent to the Cascade Pole Company site (Norton, D., 5 February 1986, personal communication). Concentrations of copper, lead, zinc, and cadmium appeared to be elevated near the Fiddlehead Marina (Alan, R., 24 September 1987a, personal communication).

Bioaccumulation

Recent bioaccumulation data for marine organisms in Budd Inlet are limited to the concentrations of PAH in clams collected near Cascade Pole Company and Priest Point (Norton, D., 5 February 1986, personal communication). Concentrations of PAH in those clams were similar to high concentrations reported for clams from Eagle Harbor (Yake et al. 1984). Concentrations of PAH in clams collected near the West Bay storm drain were similar to the lower range of values found in other Puget Sound urban bays. Malins et al. (1980) found that concentrations of certain non-toxic metals in English sole were considerably higher in Budd Inlet than in other urban areas, while concentrations of organic compounds in fish from Budd Inlet were generally less than concentrations observed in other urban bays.

Toxicity Bioassays

Bioassay tests using the amphipod Rhepoxynius abronius were conducted on sediments collected from a station located north of the Cascade Pole Company near the navigation channel (Schiewe, M., 19 November 1987, personal communication), and on sediments from near the Olympia Yacht Club [U.S. Army COE, no date (c)]. Results of these bioassays indicate that neither site is a potential problem area. Oyster larvae (Crassostrea gigas) bioassays were also conducted on sediments collected north of the Cascade Pole Company. Low mortality rates were reported.

Benthic Infaunal Communities

No benthic community data are available from 1982 to 1987 in Budd Inlet. An earlier study (Evergreen State College 1974) identified an apparently diverse community in the upper inlet. However, data collection and laboratory analysis methods used in this study were inadequate to allow for characterization of benthic infaunal communities and identification of problem areas.

Fish Pathology

From 1982 to 1987, no fish pathology data were collected in Budd Inlet. Earlier data collected by Malins et al. (1980) indicated that certain pathological abnormalities were present in English sole and rock sole collected within Budd Inlet. The incidence of these abnormalities varied between 0 and 30 percent.

IDENTIFICATION OF PROBLEM AREAS

The selected data for indicators of eutrophication, microbial contamination, and chemical contamination in sediments and biota were integrated to identify and prioritize problem areas in Budd Inlet. The evaluation included comparisons with regulatory standards, sediment quality criteria (i.e., AET values), and EAR values.

The highest priority problem areas for eutrophication were Ecology Station BUD002 in West Bay, the Capitol Lake outfall, and the East Bay Marina. Dissolved oxygen levels at these sites were less than 3.0 mg/L during late summer. Secondary priority areas for eutrophication were located at the Fiddlehead Marina, north of the LOTT 30-in diameter outfall, and in the navigation channel northeast of Cascade Pole Company. The highest priority problem areas for microbial contamination occurred at Moxlie Creek, Boston Harbor, Ellis Creek, and south of Tykle Cove. Concentrations of fecal coliform bacteria in these areas exceeded 10 times the Washington State water quality standard. Secondary priority problem areas for microbial contamination were identified at Tamoshan WWTP, Beverly Beach WWTP, Athens Beach WWTP, Butler Cove, and north of Priest Point. The highest priority problem areas for sediment chemistry were located near the Cascade Pole Company and the West Bay drain. Concentrations of organic compounds in sediments exceeded 100 times the reference values at these locations. Secondary priority problem areas were located in West Bay offshore from the West Bay drain, and in Fiddlehead Marina. No problem areas were identified using sediment toxicity tests. Problem areas based on benthic infaunal communities and fish pathology indicators could not be identified because data are unavailable.

IDENTIFICATION OF DATA GAPS

Limited data are available for each category of data reviewed for Budd Inlet. The available data confirm that a seasonal problem of low concentrations of dissolved oxygen occurs in East and West Bays. However, the geographic extent and short-term temporal variability of the problem are unknown. Dissolved oxygen should be monitored in the upper inlet during the seasonal decline in oxygen (i.e., July to September) to enable the boundaries of low dissolved oxygen concentrations to be identified. Microbial contamination problem areas were identified using the available data. A monitoring program of fecal coliform bacteria concentrations at known sources would allow an assessment of the magnitude of microbial contamination under varying water flow conditions. Sediment contamination has been identified near the Cascade Pole Company. Additional studies are needed to determine the spatial extent of contamination. Sediments near known point sources (e.g., Moxlie Creek) should also be investigated. Except for bioaccumulation of PAH in clams collected near the Cascade Pole Company, biological effects of sediment contamination remain uninvestigated.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology), in cooperation with other federal, state, and local agencies, are investigating the extent and severity of environmental degradation in Budd Inlet (Figure 1). The identification of degraded areas may lead to remedial action to correct problems associated with eutrophication, microbial contamination, and toxic contamination. Remedial actions may include source control to reduce nutrient, microbial, and toxicant emissions; and cleanup of contaminated sediments. This report provides a synthesis of information describing the geographic extent and severity of environmental degradation in Budd Inlet. Those data that were collected from 1982 to 1987 are presented in this report. The year 1982 is significant because the Lacey, Olympia, Tumwater and Thurston County (LOTT) wastewater treatment plant (WWTP) began secondary treatment in August 1982. Occasionally, older data were used when more recent data were unavailable in the same geographic area. The evaluation focuses on the following questions concerning the study area:

1. Is Budd Inlet, or parts of Budd Inlet, subject to environmental degradation due to eutrophication, microbial contamination, or toxic contamination?

2. Does eutrophication or toxic contamination result in adverse biological effects?

3. Is there a potential threat to public health?

4. Can the sources of contamination be identified?

Answering these questions involved the synthesis of complex information including data on contaminant sources, fates, and effects, and resulted in a preliminary identification of presently known problem areas (e.g., areas

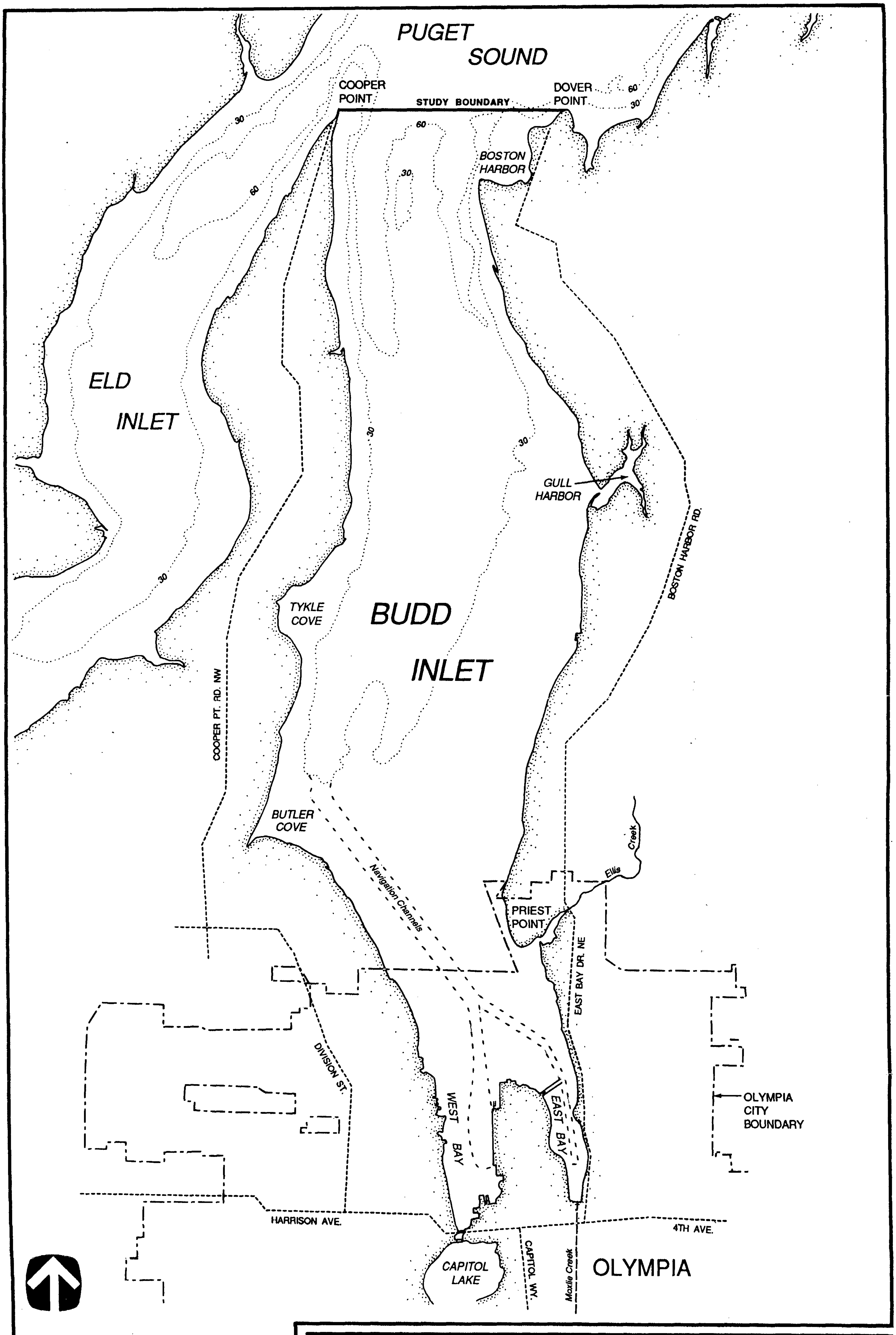


Figure 1. Budd Inlet study area.

with high concentrations of nutrients and fecal coliform bacteria, low levels of dissolved oxygen, contaminated sediments, and contaminated shellfish). Gaps in the existing data are summarized and recommendations are made for additional data collection to enable a more comprehensive assessment of the geographic extent and severity of problem areas.

Environmental degradation associated with eutrophication and microbial contamination was evaluated by comparing the data with Washington State water quality standards. Although gaps in the available information were present on both temporal and spatial scales, sufficient data were available to identify areas subject to water quality degradation. The decision-making approach for toxic contamination and biological effects that was used in the development of similar action plans for Elliott Bay (Tetra Tech 1985b) and Everett Harbor (Tetra Tech 1985c) was adapted to evaluate toxic and microbial contamination problems.

The report is organized into five major sections. The first section describes the decision-making approaches for evaluating environmental problems associated with eutrophication and toxic contamination. The discussion includes the rationale for choosing the water quality, chemical, ecological, and toxicological indicators used for evaluating environmental degradation. The second section provides descriptions of the physical setting, including project location, physical oceanography, geology, drainage patterns, climate, land use, and beneficial use. The third section provides summaries of existing data for the following indicators of environmental degradation: 1) contaminant sources, 2) eutrophication, 3) microbial contamination, and 4) chemical contamination of sediment and biota. The fourth section identifies problem areas based on existing information for the environmental indicators. Although other indicators could be used to identify problem areas (e.g., fish distribution, fish kills), the selected variables are statistically sensitive to a wide range of ecosystem properties. The final section provides a description of existing data gaps and additional information required for a more thorough delineation and better understanding of the problem areas.

DECISION-MAKING FRAMEWORK FOR EVALUATION OF ENVIRONMENTAL DEGRADATION

Eutrophication, microbial pathogens, and toxic chemical contamination are the three areas of concern for evaluating environmental degradation of Budd Inlet. Information on the geographic extent and severity of these pollution problems was compiled and used in a decision-making framework to prioritize areas within Budd Inlet for cleanup or source control. The decision-making framework is a method designed to consolidate and integrate detailed environmental information in a form that can be readily used and evaluated by regulatory decision-makers and easily revised as new information becomes available (Figure 2). The decision-making approach used for Budd Inlet was adapted from that used for the Elliott Bay and Everett Harbor Action Plans (Tetra Tech 1985b,c) to 1) include an evaluation of eutrophication and microbial contamination, and 2) accommodate the use of qualitative or semiquantitative information because of the lack of synoptic data. Details of the decision-making framework and its application in Budd Inlet are provided below.

OVERVIEW OF DECISION-MAKING FRAMEWORK

The decision-making approach developed for the Budd Inlet Action Plan incorporates a "preponderance-of-evidence" approach to identify problem areas associated with pollution problems (Figure 3). First, information concerning sources of pollution associated with eutrophication, microbial contamination, and toxic chemical contamination were reviewed to identify potential problem areas. The available physical, chemical, and biological data for each pollutant category were then reviewed. Key variables that could be used meaningfully in a qualitative or quantitative characterization of the spatial and temporal extent of pollutant impacts were identified. Quantitative relationships and statistically significant associations among these key variables were also identified where possible. The various key variables were then used to develop indices of contamination and biological

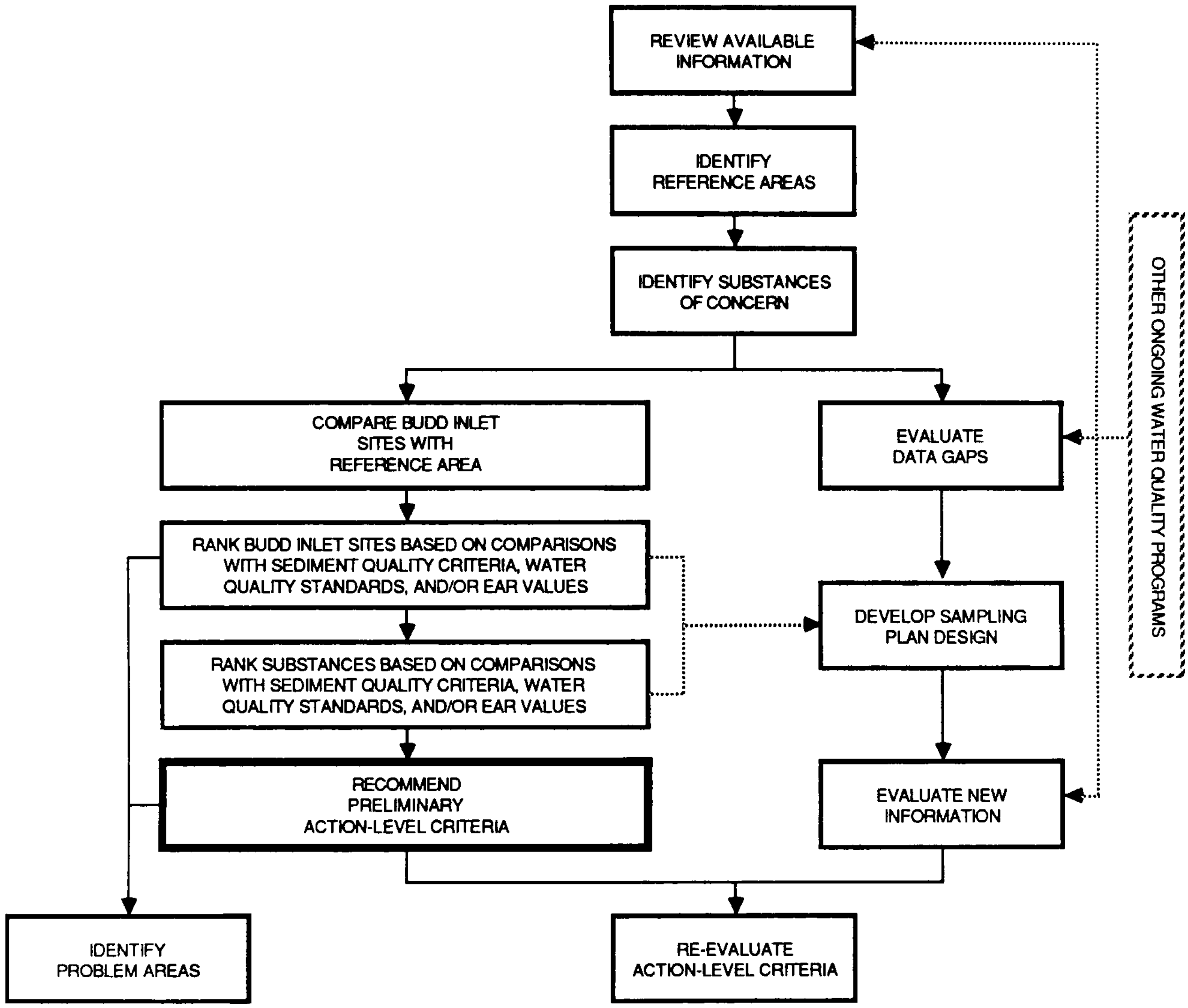


Figure 2. Comprehensive decision-making framework for evaluation of environmental degradation.

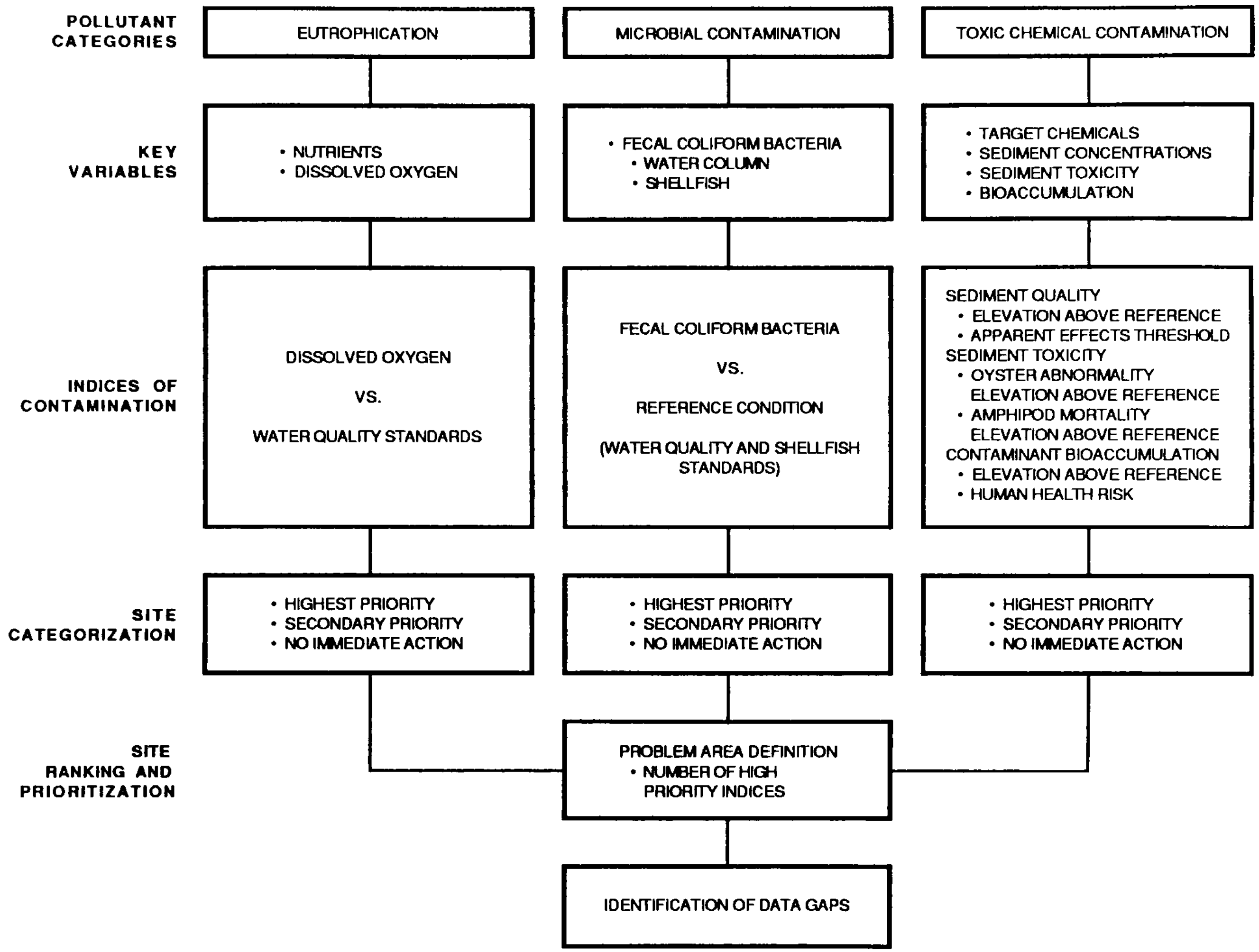


Figure 3. Preponderance-of-evidence approach to evaluate eutrophication, microbial contamination, and toxic chemical contamination in Budd Inlet.

effects that are based on comparisons with either a reference site in Budd Inlet, reference conditions for Puget Sound, or regulatory standards and criteria. These indices of contamination or biological effects were used to rank various sites within Budd Inlet, identify key problem areas, and prioritize sites for further action.

IDENTIFICATION AND EVALUATION OF POLLUTANT VARIABLES

The identification and evaluation of pollutant variables is a multi-step process that involves:

- An overview of the processes and kinds of physical, chemical, and biological data that may be used to characterize eutrophication, microbial contamination, and toxic chemical contamination

- An evaluation of available site-specific information

- A final selection of variables and site-specific data that can be used to characterize the spatial and temporal extent of impacts in Budd Inlet, and to develop indices of contamination or biological effects.

Key variables used in the decision-making framework to characterize each category of pollution are briefly summarized below, and described in detail in the section entitled "Data Summaries."

Eutrophication

Nitrogen is the primary nutrient of concern because it is the limiting nutrient in Budd Inlet (URS 1986). Nitrogen enters the inlet through the circulation of Puget Sound water, point sources such as the LOTT WWTP, and nonpoint sources. Seasonal fluctuations of nitrogen result from dense nitrogen-consuming phytoplankton blooms during the summer and decreased flushing rates with the associated reduction in nitrogen renewal. The development of dense phytoplankton blooms in a poorly flushed area such as upper Budd Inlet ultimately leads to dissolved oxygen depletion caused by decomposition of the phytoplankton. The magnitude of oxygen depletion is a function of organic enrichment, temperature, and flushing. Oxygen depletion in the bottom water may stress the resident biota and may cause widespread mortality if low oxygen levels are prolonged. Although phosphate is not limiting to phytoplankton in Budd Inlet, it is discharged into Budd Inlet through the LOTT WWTP.

Key variables used in the characterization of eutrophication in Budd Inlet were nutrient concentrations (nitrate, nitrite, ammonium, and phosphate) and dissolved oxygen concentrations. Note that these variables are influenced by other factors such as temperature, salinity, rainfall, tidal exchange, and flushing rates. Where possible, these additional factors were considered qualitatively, but were otherwise not used to rank and prioritize sites on the basis of eutrophication.

Microbial Contamination

The concentrations of fecal coliform bacteria in the water column and in shellfish provide an indication of the presence of sewage-derived material from point and nonpoint sources, and are also indicative of a variety of other bacterial and viral pathogens that pose a public health risk. Thus, concentrations of fecal coliform bacteria in water and shellfish were used to evaluate microbial contamination of water and shellfish in Budd Inlet. Data on concentrations of other microbial pathogens were not available for Budd Inlet.

Toxic Chemical Contamination

The primary kinds of data related to toxic contamination that are used in problem area identification and priority ranking are shown in Table 1. Although many other variables are evaluated throughout the decision-making approach, those shown in Table 1 form the basis for the identification of toxic problem areas. The kinds of data evaluated include chemical concentrations in sediments, and biological effects potentially associated with chemically contaminated sediments and water.

TABLE 1. PRIMARY KINDS OF DATA USED IN PROBLEM AREA IDENTIFICATION AND PRIORITY RANKING

General Category	Data Type	Specific Indicator Variables
Habitat condition	Sediment quality	■ Contaminant concentrations
Toxicity	Acute lethal	■ Amphipod mortality
	Sublethal	■ Oyster larvae abnormality
Indigenous organisms	Bioaccumulation	■ Contaminant concentrations in tissues of shellfish
	Benthic community structure	■ Total abundance ■ Species richness ■ Dominance ■ Amphipod abundance
	Fish pathology	■ Prevalence of liver lesions in English sole

A preliminary list of conventional and chemical contaminants of concern for Budd Inlet is given in Table 2. Chemical substances on this list are of concern because they may bioaccumulate or are potentially toxic to marine organisms and humans. U.S. EPA priority pollutants that may have been discharged into the study area in the past, or are probably discharged now, are included on the list. Compounds not on the U.S. EPA list of priority pollutants also have been considered on the basis of their local potential significance. Conventional sediment quality variables (i.e., grain size, total volatile solids, and total organic carbon) are also evaluated because they provide a means of comparing areas with different bulk chemical or physical properties. The list of target chemicals was then used to identify and select all chemicals or chemical groups of concern from the available data for Budd Inlet.

Selection of individual biological and toxicological variables was based on the following considerations:

- Use of the variable in past or ongoing studies in Puget Sound

- Documented sensitivity of the variable to contaminant effects

- Ability to quantify the variable within the resource and time constraints of the program.

Biological effects variables that were evaluated included a variety of bioassays used to measure toxicity of receiving waters and sediments; bioaccumulation of contaminants in shellfish; benthic infaunal community structure; and pathological disorders in fishes.

INDICES OF CONTAMINATION

The foregoing environmental variables were used to develop a variety of indices to assess the relative magnitude of contamination in Budd Inlet, to identify problem chemicals, and to rank and prioritize sites for remedial action. The various indices used in each category of pollution (i.e.,

TABLE 2. PRELIMINARY LIST OF CONTAMINANTS AND CONVENTIONAL VARIABLES OF CONCERN IN BUDD INLET

Metals

- Silver
- Arsenic
- Cadmium
- Chromium
- Copper
- Mercury
- Nickel
- Lead
- Antimony
- Selenium
- Zinc

Volatiles

- Benzene
- Bromoform
- Carbon tetrachloride
- Chloroform
- Chloroethane
- Chlorodibromomethane
- Dichloromethane
- Dichlorobromomethane
- Ethylbenzene
- Tetrachloroethane
- 1,1,1-Trichloroethylene
- Toluene
- 1,1-Dichloroethane
- 1,1-Dichloroethylene
- 1,2-trans-Dichloroethylene
- Xylene

Base/Neutrals (excluding PCBs)

Halogenated Compounds

- Hexachloroethane
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 1,2,4-Trichlorobenzene
- 2-Chloronaphthalene
- Hexachlorobenzene
- Hexachlorobutadiene
- Bis(2-chloroethoxy)methane
- N-nitrosodiphenylamine

Base/Neutrals (cont.)

Low Molecular Weight Aromatic Hydrocarbons

- Azobenzene
- Naphthalene
- 2-Methylnaphthalene
- 1-Methylnaphthalene
- 2,6-Dimethylnaphthalene
- 1,3-Dimethylnaphthalene
- 2,3-Dimethylnaphthalene
- 2,3,6-Trimethylnaphthalene
- 2,3,5-Trimethylnaphthalene
- Acenaphthene
- Acenaphthylene
- Fluorene
- Biphenyl
- 1-Methylphenanthrene
- 2-Methylphenanthrene
- 3-Methylphenanthrene

High Molecular Weight Aromatic Hydrocarbons

- Fluoranthene
- Pyrene
- 1-Methylpyrene
- Benzo(a)anthracene
- Dibenzo(a,h)anthracene
- Benzofluoranthenes
- Benzo(e)pyrene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Benzo(g,h,i)perylene

Phthalate Esters

- Diethyl phthalate
- Bis(2-ethylhexyl) phthalate
- Butylbenzyl phthalate
- Di-n-butyl phthalate
- Dimethyl phthalate
- Di-n-octyl phthalate

TABLE 2. (Continued)

Acid Extractables	**Miscellaneous Substances**
Cresol	Manganese
Phenol	Iron
2-Chlorophenol	Coprostanol
2,4-Dichlorophenol	alpha-Tocopherol acetate
2,4,6-Trichlorophenol	Carbazoles
Pentachlorophenol	Retene
p-Chloro-m-cresol	Dibenzothiophene
4-Nitrophenol	Chloromethylbenzene
	Methylated benzenes
Pesticides and PCBs	1-Propenalbenzene
	2-Ethylnaphthalene
Chlordane	3,4,5,6-Tetramethyl phenanthrene
Aldrin	4H-Cyclopenta[DEF]phenanthrene
Endosulfan	11H-Benzo(a)fluorene
alpha-Hexachlorocyclohexane (HCH)	Benzo(b)thiophene
beta-HCH	1-Ethylidene-1H-indene
delta-HCH	Dibenzofuran
gamma-HCH (lindane)	4-Methyldibenzofuran
4,4'-DDD	7-Methylbenzofuran
4,4'-DDE	[1',1'-Biphenyl]-carboxy aldehyde
4,4'-DDT	2-Chloro-1,3,5-cycloheptatriene
PCB-1242	
PCB-1248	**Conventional Variables**
PCB-1254	
PCB-1260	Grain size
	Oil and grease
Hazardous Substance List Compounds	Sulfides
	Total organic carbon
Benzoic acid	Total volatile solids
2-Methylphenol	
4-Methylphenol	
2,4,5-Trichlorophenol	
Aniline	
Benzyl alcohol	
4-Chloroaniline	
Dibenzofuran	
2-Nitroaniline	
3-Nitroaniline	
4-Nitroaniline	

eutrophication, microbial contamination, and toxic chemical contamination) are described below, and further explained in the section "Data Summaries." It should be noted that these indices are not used in lieu of the original data (e.g., contaminant concentrations), but in addition to them. The original data are used to identify and characterize detectable levels of contaminants and their effects on the environment. The indices are used to reduce large data sets into interpretable numbers that reflect the relative magnitudes of the different variables among areas, and thereby aid in the decision-making process.

Eutrophication

Impacts associated with eutrophication were evaluated based on direct comparisons of dissolved oxygen concentrations in Budd Inlet with Washington State water quality standards and with established values below which biological communities are considered stressed. Dissolved oxygen was selected to represent eutrophication because oxygen depletion may directly impact the biota. Nutrient depletion is not know to results in environmental degradation.

Microbial Contamination

The relative magnitude of fecal coliform bacteria concentrations was quantified using a simple index. The index is the ratio between the geometric mean concentration at a site and the water quality standard for fecal coliform concentrations in that portion of Budd Inlet. The ratio is structured so that the value of the index increases as the deviation from the water quality standard increases. The index for fecal coliform bacteria (FCBI) is expressed as:

$$FCBI_{ij} = C_{Sij}/C_{WQSij}$$

where:

$FCBI_{ij}$ = Index for medium i (i.e., water or shellfish) in area j

C_{Sij} = Geometric mean concentration in medium i at Budd Inlet study area j

C_{WQSij} = Concentration that is the water quality standard for medium i in Budd Inlet study area j.

Note that regulatory standard for fecal coliform concentrations vary depending on the medium (i.e., shellfish vs. water) and the state classification of local waters.

Toxic Chemical Contamination

There were too few data to adequately characterize contaminant concentrations and biological effects in the water column. Consequently, contaminant and biological effects indices were only developed for chemical concentrations in sediments, sediment toxicity bioassays, and bioaccumulation of chemicals in shellfish.

Sediment Chemistry Indices--

Two kinds of indices were used to characterize concentrations of chemical contaminants in sediments. Chemical contaminants measured in Budd Inlet sediments were compared with Puget Sound wide reference conditions using EAR values. AET values were used to determine the potential toxicity of chemical concentrations in sediments, and to identify specific chemicals or compound groups that are of major concern in Budd Inlet.

EAR values for chemical contaminants measured in Budd Inlet were calculated using the expression:

$$EAR_{sij} = C_{sij}/C_{sir}$$

where:

EAR_{sij} = EAR for sediment concentration of chemical i at Budd Inlet study area j

C_{sij} = Sediment concentration of chemical i at Budd Inlet study area j

C_{sir} = Average concentration of chemical i in Carr Inlet reference sediments.

An EAR value that is greater than 1 indicates that the concentration for a particular chemical and study area in Budd Inlet exceeded the average reference concentration for that chemical in Carr Inlet sediments. However, because sediment chemistry samples are not replicated, statistical comparisons between concentrations of chemicals in contaminated areas and those in the Carr Inlet reference area was not possible. Consequently, the significance of an EAR value for a given chemical is determined by comparison with Puget Sound wide reference data. If the concentration of a given chemical in Budd Inlet sediments is greater than the maximum concentration for that chemical in all Puget Sound reference areas, the EAR value for that chemical is judged to be significantly elevated. Thus, it is possible to have EAR values greater than 1 (i.e., that exceed average Carr Inlet reference conditions) that are not deemed to be significantly elevated because they fall with the range of all Puget Sound reference conditions.

AET values have been developed for many Puget Sound contaminants of concern. AET values are based on sediment chemistry data, toxicity data, and benthic infauna abundance data for wide number of contaminated sites and reference areas throughout Puget Sound. For a given chemical and a specified biological indicator (e.g., amphipod mortality), the AET is the concentration above which statistically significant biological effects occurred in all samples of sediments analyzed. Thus, comparison of contaminant concentrations for individual chemicals measured in Budd Inlet sediments with their corresponding AET values is a means of determining the potential severity of biological effects in Budd Inlet, and of selecting and prioritizing chemically contaminated areas for remedial action.

Puget Sound AET values are particularly relevant to the evaluation of sediment contaminant concentrations and potential biological effects in Budd Inlet. Specifically, the AET database includes contaminant data from Eagle Harbor that includes a suite of compounds with high concentrations that are similar to the compounds with high concentrations in Budd Inlet. This similarity is probably due to the occurrence of wood treatment facilities on the shores of both embayments. The AET database contains information on sediment toxicity and biological effects from areas of low, moderate, and high sediment contamination, as well as from areas with different kinds of contamination (e.g., metals and organic substances). Thus, the AET values integrate a wide range of chemical contaminant and biological effects information from other Puget Sound studies that can be used to predict environmental effects and prioritize study areas in Budd Inlet.

Biological Effects Indices--

Biological effects indices for chemical bioaccumulation in shellfish and for sediment toxicity (i.e., amphipod mortality and oyster larval abnormality bioassays) were developed using the EAR approach described above.

The analysis of EAR values for contaminant bioaccumulation was limited to the available data for clams. Bioaccumulation data were not available for fish or other kinds of shellfish in Budd Inlet. The EAR index for bioaccumulation was calculated using the expression:

$$EAR_{tij} = C_{tij}/C_{tir}$$

where:

EAR_{tij} = EAR for chemical i in tissue t (i.e., shellfish) at Budd Inlet study area j

C_{tij} = Concentration of chemical i in tissue t at a Budd Inlet study area j

C_{tir} = Concentration of chemical i in tissue t at reference area j.

Determination of the significance of EAR values for bioaccumulation was not possible because methods for such a determination have not been established. However, bioaccumulation data were also used to assess potential human health risks associated with ingestion of contaminated shellfish from Budd Inlet. Thus, EAR values may be judged significant for those substances and areas that pose an unacceptably high human health risk that is associated with ingestion of chemically contaminated shellfish.

EAR analysis for toxicity of Budd Inlet sediments was based on available data for mortality measured in the amphipod (Rhepoxynius abronius) sediment bioassay, and for developmental abnormality measured in the oyster larval (Crassostrea gigas) sediment bioassay. The EAR indices for sediment toxicity are comparable with those for sediment contamination and bioaccumulation, and were calculated using the expression:

$$EAR_{ij} = R_{ij}/R_{ir}$$

where:

EAR_{ij} = EAR for the toxicity response of bioassay species i at Budd Inlet study area j

R_{ij} = Toxicity response of bioassay species i to sediments from Budd Inlet study area j

R_{ir} = Toxicity response of bioassay species i to sediments from reference area r.

Significance of the EAR values was determined by statistical comparisons of individual bioassay responses to sediments from the study area with response to sediments from an appropriate reference area.

PROBLEM AREA IDENTIFICATION

As indicated in the foregoing sections, the preponderance-of-evidence approach used in the decision-making framework is largely based on development of indices for contamination and biological effects relative to a reference site or reference condition. In the action plans developed for Elliott Bay and Everett Harbor (Tetra Tech 1985b,c), the various contaminant and biological effects indices were compiled into an action assessment matrix that could be used to collectively assess the magnitude and spatial extent of impacts relative to reference conditions. In the Elliott Bay and Everett Harbor Action Plans, the number and magnitude of the various indices were used to score and rank potential problem areas.

In the case of Budd Inlet, the development of an action assessment matrix and a systematic scoring procedure was not feasible because such an approach is based on the availability of synoptic data for a number of complementary variables (i.e., chemistry, toxicity, fish histopathology, and biological communities) as measured at a large number of sites. The Budd Inlet data are derived from a wide number of studies conducted at various times during the past 5-10 yr, and which varied considerably in study objectives, study design, sampling locations, sampling variables, and analytical methods. Consequently, problem area definition for Budd Inlet was based on a more general categorization of the contaminant and biological effects indices.

As shown in Table 3, three priority levels were established depending on the magnitude of the various indices for each type of pollution problem (i.e., eutrophication, microbial contamination, and toxic chemical contamination). Each study area in Budd Inlet was therefore prioritized in terms of further action, if any, needed to remediate problems associated with eutrophication, microbial contamination, and toxic chemical contamination.

TABLE 3. CRITERIA FOR PRIORITIZING PROBLEM AREAS IN BUDD INLET[a]

Data Category	Highest Priority	Secondary Priority	No Immediate Action
Eutrophication	Minimum dissolved oxygen <3.0 mg/L	Minimum dissolved oxygen 3.0-5.0[b] mg/L	Minimum dissolved oxygen >5.0[b] mg/L
Toxic contamination[c]			
Sediment chemistry	Metals: EAR >50 Organics: EAR >100	Metals: EAR 10-50 Organics: EAR 10-100	Metals: EAR <10 Organics: EAR <10
Bioassay	Amphipod >50% mortality Oyster >50% mortality	Amphipod 25-50% mortality Oyster 25-50% mortality	Amphipod <25% mortality Oyster <25% mortality
Microbial contamination	Fecal coliform bacteria EAR >10	Fecal coliform bacteria EAR 1[d]-10	Fecal coliform bacteria EAR <1[d]

[a] See text for explanation of criteria.

[b] Class B water quality standard for marine waters.

[c] Criteria for water column chemistry, bioaccumulation, benthic infaunal communities, and fish histopathology were not established because of the lack of data for Budd Inlet.

[d] Fecal coliform bacteria EAR value of 1 corresponds to the appropriate water quality standard for Class A or Class B marine waters.

PHYSICAL SETTING

PROJECT LOCATION

Budd Inlet is a shallow estuary located at the extreme southern end of Puget Sound (see Figure 1). It includes the area south of a line joining Cooper Point and Dover Point. The inlet is approximately 6.9 mi long with an average width of 1.15 mi, and a maximum width of 1.61 mi. The Deschutes River is the major freshwater source to Budd Inlet and enters the inlet at its southernmost point. In 1951, Capitol Lake was created when a dam was constructed over the tidal flats where the Deschutes River empties into Budd Inlet. Capitol Lake is not considered part of the study area. However, the Capitol Lake outfall is considered a point source to Budd Inlet. Budd Inlet is the most developed estuary in southern Puget Sound. Most urban and industrial activity is located in the Cities of Tumwater and Olympia at the southern end of the inlet. Much of the remaining shoreline is relatively undisturbed. Physical oceanography, geological setting, drainage patterns, climate, land use, and beneficial use are described below.

PHYSICAL OCEANOGRAPHY

Budd Inlet is a partially mixed shallow estuary with muddy substrates. The average depth of the inlet is 27 ft at mean lower low water (MLLW), and maximum depth near the mouth is about 110 ft. There is no entrance sill. The shoreline and intertidal areas are moderately steep. The only intertidal mud flats are located at the southern end of the inlet. They result largely from sediment deposited by the Deschutes River.

Puget Sound enters Budd Inlet through the Tacoma Narrows and Dana Passage, and is diluted at the inlet head by the Deschutes River. Water properties in Budd Inlet reflect these salt water and freshwater sources. Temperature ranges in Budd Inlet (7-21^{o} C) exceed those in the Puget Sound main basin (8-18^{o} C). The range of salinity in Budd Inlet (11-31 ppt) exceeds that of the Puget Sound main basin (23-30 ppt; Oclay 1959). At times of high runoff, a surface layer of low salinity water is observed (Oclay 1959).

The circulation pattern in Budd Inlet is a weak two-layered system. The lower water column flows south toward the head of the inlet, and the upper water column flows north out of the inlet (URS 1986). URS (1986) found evidence of a counter-clockwise gyre off Tykle Cove and the eastward movement of surface water from West Bay to East Bay.

URS (1986) used a field-calibrated box model to estimate the residence time of water parcels in Budd Inlet. The study area was extended approximately 1 mi south of Cooper Point to 3/8 mi north of the Port of Olympia peninsula. Estimates of residence times were not made for the Olympia Harbor area including East and West Bays. Although the box model assumed a steady-state net circulation throughout the inlet, those portions of the inlet most influenced by tidal exchange would have proportionately shorter residence times. The model estimated that a parcel of water would require approximately 4 days to travel from near the head of the inlet to near the mouth, and that the maximum residence time of a parcel entering the inlet throughout the mouth would be approximately 14 days. The mean residence time, given variability in circulation and flushing characteristics throughout the inlet, was estimated to be 8 days.

Dissolved oxygen near the head of Budd Inlet is depleted during late summer due to a combination of factors including stratification, reduced flushing rate, and algal blooms. Oxygen values are commonly below the 5.0-mg/L Washington State Class B water quality criterion south of Priest Point (Egge, E., 25 January 1987, personal communication; Alan, R., 24 September 1987, personal communication; U.S. EPA, 7 January 1988, personal communication). Near-bottom oxygen levels may be less than 3.0 mg/L in East and West Bays.

GEOLOGY

The Budd Inlet region is geologically and topographically similar to other coastal regions in southern Puget Sound, reflecting the influence of mountain building and glacial activity. The steep terrain of the upper Deschutes basin was formed during periods of sediment deposition followed by uplift and mountain building. The underlying bedrock is therefore volcanic (basalt and andesite) or sedimentary (sandstone and siltstone). Lowland areas in the basin are composed of unconsolidated glacio-fluvial materials. The subsurface layer of glacial outwash mainly consists of unconsolidated sands and gravels (McNicholas 1984). The porosity of these soils results in poorly developed drainage patterns in the basin.

The high permeability of the soils also allows for rapid uptake of winter rainfall thereby recharging an extensive aquifer. Porous soils in much of the region overlay a shallow substructure of hard pan that is within 40 ft of the surface in some places. Because this shallow hardpan results in a very shallow aquifer, groundwater is available at relatively shallow depths. In over 80 percent of the wells, the water level is within 50 ft of the surface (Arvid Grant and Associates 1973).

The subsurface rock bordering the inlet is heavily fractured and elevations may vary from 0 to 300 ft above sea level in as little as 2 mi. These soils consist of a layer of Vashon till overlying an assortment of glacial deposits (Arvid Grant and Associates 1973).

The intertidal beaches of Budd Inlet are moderately steep. Much of the subtidal area consists of recent bay muds, fine-grained glacial sand and silt, and lake sediments. The bay muds are recent deposits of silty organic clays [U.S. Army Corps of Engineers (COE) 1980]. These are very soft, low density, and possess a high water content. Muds are replenished by biodegradation and silts are deposited by the Deschutes River.

The annual sediment load of the Deschutes River is approximately 18,300 tons; 80 to 85 percent is transported during November and December. The majority of this sediment load originates from the erosion of streambeds and banks along the mainstem of the river (Moore and Anderson 1979). Capitol Lake acts as a settling basin for sediment transported by the river. Between 1951 and 1976, Capitol Lake trapped 2 million tons of sands, silts, and clays eroded from streambanks and slopes in the watershed (McNicholas 1984). Sedimentation is also a problem in Budd Inlet at the Capitol Lake outfall and in East Bay, which require dredging by both the Olympia Yacht Club and the Port of Olympia. The U.S. Army COE conducts maintenance dredging of the shipping lanes, with the average dredging operation yielding 400,000 yd^3 of sediment, largely of Deschutes River origin (McNicholas 1984).

DRAINAGE PATTERNS

The Budd Inlet drainage area encompasses primarily undeveloped rural and forest lands in the Deschutes River drainage basin (Figure 4). This watershed is bound on the east by the Nisqually River Watershed and on the west by the drainage of the Black River and western Puget Sound. In addition to the Deschutes River, the basin includes several other small streams, including Percival and Moxlie Creeks. The drainage pattern of the basin is not well developed due to the high groundwater storage capabilities of the soil. During periods of heavy precipitation, the permeability of surface soils and subsoils results in infiltration and groundwater recharge rather than overland flow to surface water drainages.

The Deschutes River originates in the Bald Hills and from Cougar Mountain, flows northwest for 57 mi, and empties into the southern end of Budd Inlet. The flow regime is typical of the rainfed streams in western Washington. Peak flows occur in the winter months and may exceed 5,000 ft^3/sec/mo (Arvid Grant and Associates 1973). Minimum flow occurs in the late fall, typically 66-100 ft^3/sec, with average annual flows of 409 ft^3/sec (Moore and Anderson 1979).

The Deschutes drainage basin encompasses approximately 166 mi^2 (McNicholas 1984). The upper portion of the watershed comprises heavily forested land and rugged terrain. Rural communities and agricultural land dominate the lower basin. Less than 21 mi^2 of the Deschutes basin is urbanized

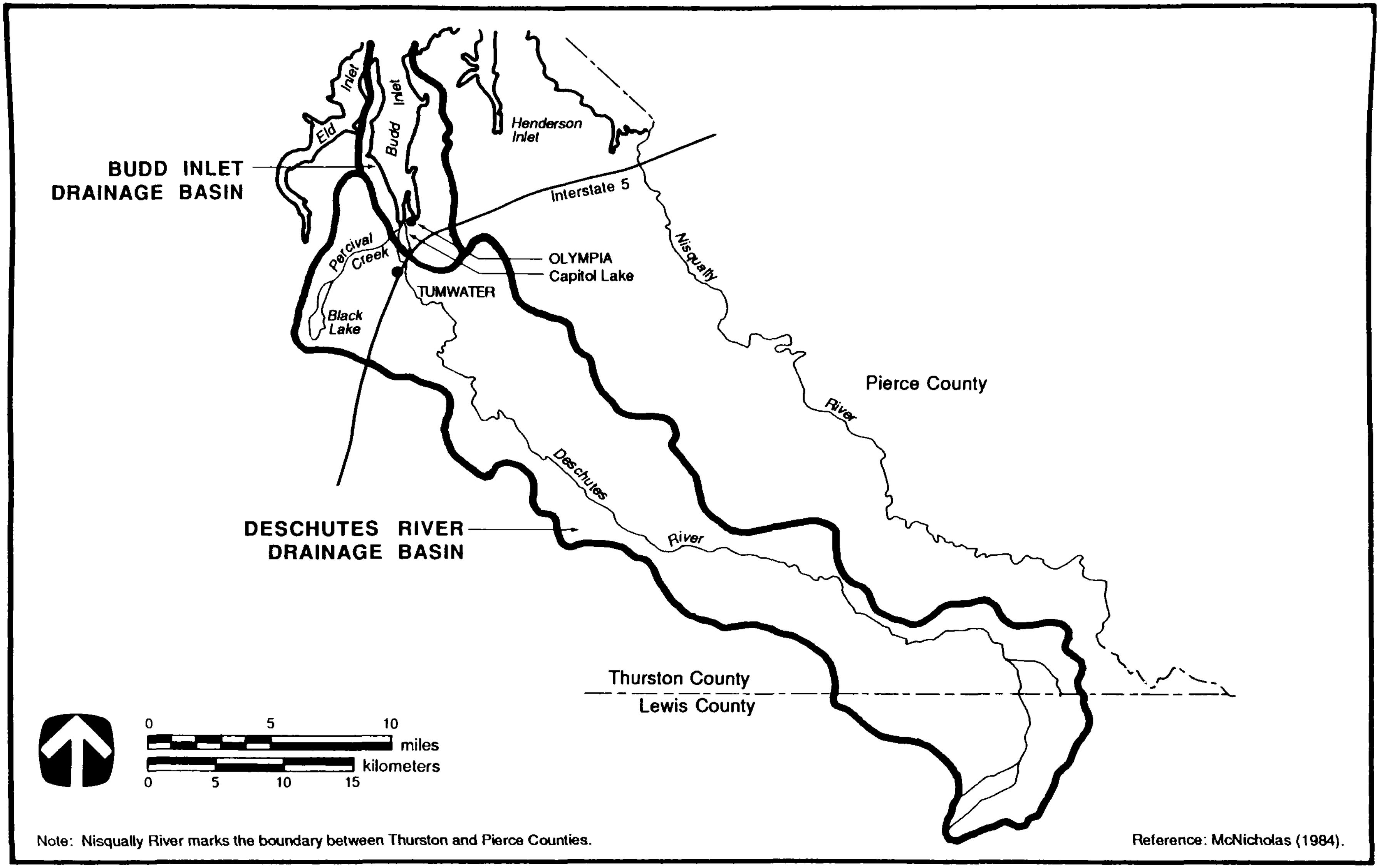


Figure 4. Budd Inlet and Deschutes River drainage boundaries.

(Arvid Grant and Associates 1973). An additional 59 mi^2 drains directly to Budd Inlet from surrounding slopes.

CLIMATE

Climate in the Budd Inlet region is characterized by mild, wet winters and warm, dry summers. Daily and seasonal variations in temperature are relatively small. During the summer, daytime temperatures range from about 70° to upper 80° F and usually ranges from 40° to upper 50° F at night. Winter temperatures range from about 30° to low 50° F (Arvid Grant and Associates 1973). Freezing seldom occurs and snowmelt is rarely a significant contributor to stream flow or runoff. Severe storms are rare.

Rainfall, accompanied by prolonged cloudy periods, is the dominant feature during the winter months. Eighty-five percent of the total annual precipitation occurs from October through April (Arvid Grant and Associates 1973). Most of the precipitation is light to moderate rainfall, occurring continuously for long periods of time. The summer months are usually dry, occasionally with no measurable rainfall for periods up to 30 days. While mean annual precipitation at the Olympia airport is 52 in/yr, precipitation may be greater at higher elevations (McNicholas 1984).

LAND USE

Historically, the region surrounding Budd Inlet has been largely rural or undeveloped. Industrial and urban activities are concentrated at the southern end of the inlet in the Olympia and Tumwater area. Many areas in this vicinity are sites of greatly increased growth and development. For example, in the Percival Creek basin, employment increased 2,870 percent from 1970 to 1980, and the population increased 255 percent (Thurston Regional Planning Council 1985). This urbanization of the watershed is cited as the probable cause of increased streamflow and runoff to Percival Creek (McNicholas 1984). Similarly, land use changes resulting in decreased natural vegetation are expected to increase storm drainage problems, while population increases will result in greater demands on sewage and septic systems.

The Cities of Lacey, Olympia, and Tumwater possess the only formal sewage collection systems in the basin. All of these cities use the LOTT WWTP for final treatment and discharge into Budd Inlet. The central business district and older areas of Olympia are served by both a sanitary and storm sewer system. The sanitary sewer systems feed into the LOTT WWTP and storm sewers discharge directly into Budd Inlet. There are two CSOs that divert peak flows past the LOTT WWTP and directly into Budd Inlet. Specific information on the LOTT WWTP is provided in the third section entitled Contaminant Sources.

In rural and less-developed areas of the basin, sewage is generally discharged into septic tanks and leaching fields. The efficiency of these systems depends to a large degree on the ability of the soil to absorb the waste material. Over two-thirds of the area is considered to have severe soil limitations due to poor drainage (Arvid Grant and Associates 1973). Much of the rural area of the basin has no problem with septic tank usage, but problems are apparent in localized areas due to both soil characteristics and population densities (e.g., Cooper Point and Summit Lake). If the present trend of increased development and growth continues, problems with septic tank usage are expected to increase.

BENEFICIAL USE

Budd Inlet is used for a variety of purposes ranging from marine transportation to salmon rearing, and from beach combing to boating. In the context of this study, the term "beneficial use" refers to activities that depend on a high degree of environmental quality and that do not, as a direct consequence, adversely affect that quality. Beneficial uses can be placed into two categories: 1) resource using, and 2) nonresource using. Resource-using activities include shellfish harvesting and fishing. Nonresource-using activities include scuba diving, beach combing, and recreational boating.

Fish and shellfish are important resources in Budd Inlet. Five species of anadromous fish spawn in the Deschutes basin: chinook, coho, and chum salmon; sea-run cutthroat; and steelhead trout (U.S. Army COE 1980). The Washington Department of Fisheries manages an extensive salmon propagation program in Capitol Lake. Other fish species harvested recreationally in Budd Inlet include cod, surf perch, sole, flounder, and herring. Surf smelt spawn on the beaches around the inlet.

In 1987, Ecology issued an advisory notice recommending that shellfish from lower Budd Inlet not be consumed or harvested (Bradley, D., 12 January 1987, personal communication). That recommendation was based on the following factors:

- Concentrations of polycyclic aromatic hydrocarbons (PAH) in clams from near the Cascade Pole Company in southern Budd Inlet are significantly higher than concentrations in clams from less-contaminated areas in the Puget Sound region and are similar to those reported in clams from Eagle Harbor

- Based on procedures developed for the Puget Sound Estuary Program (PSEP) (Tetra Tech 1986a), it appears that long-term consumption of shellfish with concentrations of PAH similar to those reported in clams from Budd Inlet represents a significant health risk.

Individual lifetime carcinogenic risks associated with the ingestion of these contaminated shellfish range from $1.5x10^{-4}$ to $1.5x10^{-3}$ (Bradley, D., 12 January 1987, personal communication). These levels exceed the $1x10^{-6}$ lifetime risk level that is often used as a reference point for the management and regulation of carcinogenic chemicals. A range of PAH concentrations in shellfish (i.e., 278-940 ug/kg wet weight) and additional assumptions concerning exposure duration (35 yr) and seafood ingestion rates were used to generate risk estimates (Bradley, D., 12 January 1987, personal communication).

DATA SUMMARIES

CONTAMINANT SOURCES

Contaminant sources in the study area can be divided into six major categories: wastewater treatment plants (WWTP), combined sewer overflows (CSOs), surface runoff, industrial sources, groundwater, and accidental spills. There are four WWTP in the study area: Tamoshan Development/Thurston County Public Works, Beverly Beach Utilities Association, Seashore Villa Mobile Home Park, and LOTT (for Lacey, Olympia, Tumwater, and Thurston County) (Figure 5). During storm events, untreated wastewater overflows from city combined sewer lines through two CSO outfalls in Olympia. Surface runoff originates from excess precipitation draining from the land surface. This runoff is discharged to Budd Inlet from storm drains, natural drainage channels, and direct surface runoff. Groundwater includes any subsurface transport of contaminants into the inlet. Industrial discharges comprise permitted discharges of wastewater and storm water, and unpermitted (e.g., storm drains) discharges of storm water from individual industrial sites. The accidental spills category includes those contaminants that are released to Budd Inlet from spills in the study area. A more detailed description of these six categories of contaminant sources is provided below.

Wastewater Treatment Plants

Effluent limitations are shown in Table 4 for each of the four WWTP named above. These WWTP are permitted under the Clean Water Act, Section 301(h) National Pollutant Discharge Elimination System (NPDES). Although Shorewood Estates operates a treatment plant, this facility does not have an NPDES permit because it discharges to a drainfield.

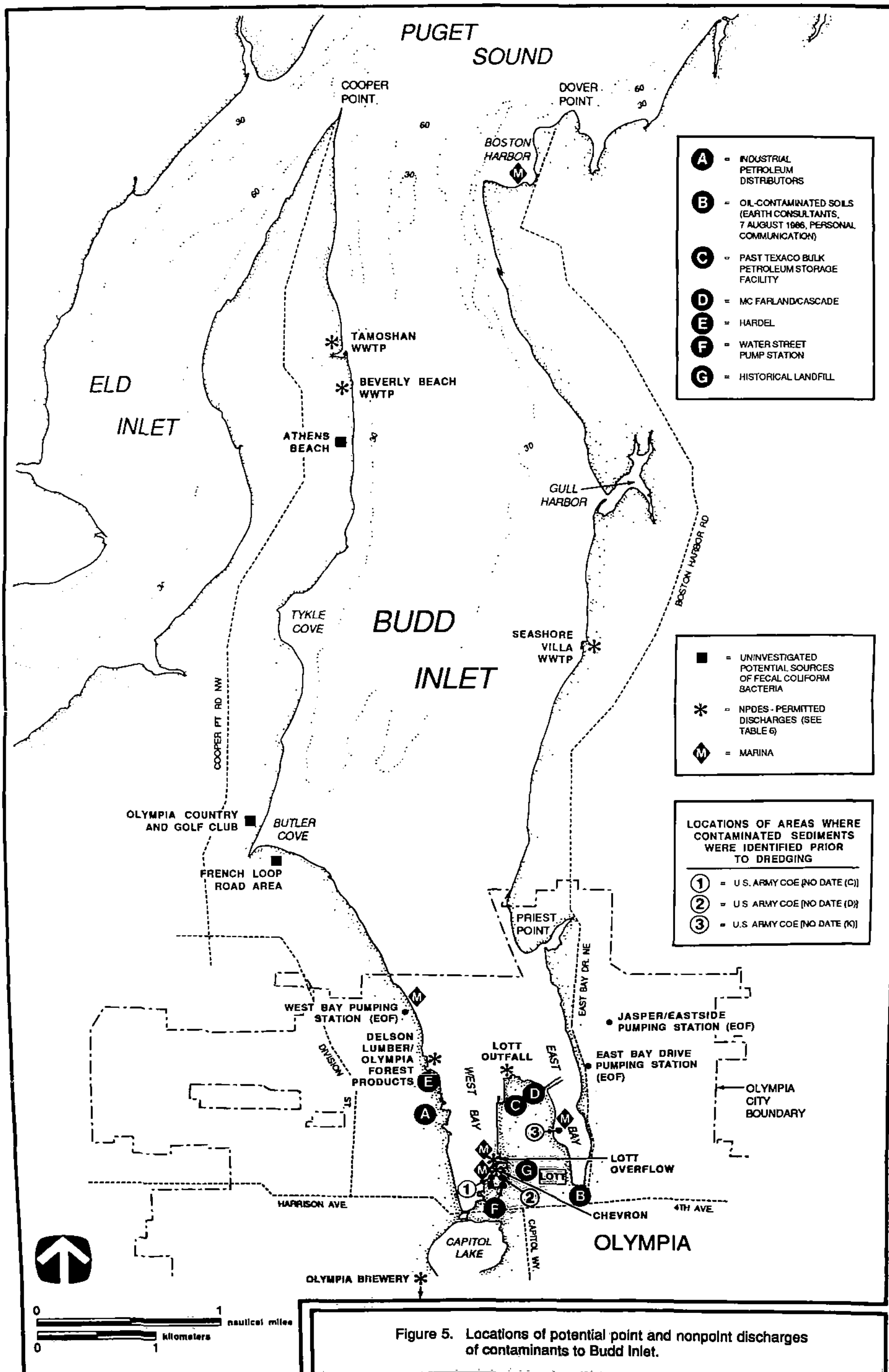


Figure 5. Locations of potential point and nonpoint discharges of contaminants to Budd Inlet.

TABLE 4. LIST OF NPDES-PERMITTED WASTE DISCHARGES TO BUDD INLET

Facility	Facility Description	Effluent Limitations[a]	Comments
Cascade Pole Co.	Wood treatment	See Comments	Permit for stormwater runoff discharge expired 7 November 1985. Facility closed prior to 13 March 1987. Ecology maintains that product is currently discharging from the site, and that the discharge should be permitted (Peeler, M., 12 January 1988, personal communication).
Chevron U.S.A., Inc.	Bulk petroleum storage	15 mg/L O & G[b]	Stormwater runoff from truck loading area and building roof drains routed to oil-water separator. Automatic pump from separator discharges effluent into storm drain. Permit expires 25 June 1990 (Ecology 1985a).
Delson Lumber, Inc./ Olympia Forest Products Co., Inc.	Lumber mill	15 mg/L O & G Minimum contribution of solids (e.g., chips, wood debris) from site	Stormwater runoff. Permit is in effect only when facility is in operation. Permit expires 16 December 1990 (Ecology 1985b).
Beverly Beach Utilities Association	Secondary WWTP	30 mg/L (1.25 lb/day) BOD 30 mg/L (1.25 lb/day) SS 20/100 mL fecal coliform bacteria	Average flow is $\leq$3,000 gal/day. Approximately 18 homes are connected to the WWTP. Permit expires 28 August 1990 (Ecology 1980).
City of Olympia/LOTT	Regional secondary WWTP	Outfalls 1-2: 16.3 MGD 30 mg/L (4,000 lb/day) BOD 30 mg/L (4,000 lb/day) SS 200/100 mL fecal coliform bacteria	Existing design capacity limited to 22 MGD (maximum average wet-weather flow). WWTP online August 1982. Permit expires 25 September 1992 (Ecology 1987).
Seashore Villa Mobile Home Park	Secondary WWTP	0.015 MGD 30 mg/L (3.8 lb/day) BOD 30 mg/L (3.8 lb/day) SS 200/100 mL fecal coliform bacteria	Average flow is 3,600 gal/day. Permit expires 25 May 1989 (Ecology 1979).
Tamoshan Development/ Thurston County Public Works	Secondary WWTP	0.035 MGD 30 mg/L (916 lb/day) BOD 30 mg/L (916 lb/day) SS 200/100 mL fecal coliform bacteria	Seventy-four residences in development. Discharge monitoring reports from January 1982 to December 1985 indicate problems with meeting effluent limitations for SS and fecal coliform bacteria. Permit expires 20 October 1991 (Ecology 1986).

[a] Effluent limitations are listed as monthly averages for wastewater treatment plants (WWTPs) and daily averages for other permits, unless otherwise noted. All discharges into Budd Inlet must be within pH 6-9. All WWTPs must also meet permit requirements for residual chlorine. O&G = oil and grease, BOD = 5-day biochemical oxygen demand, SS = suspended solids.

[b] Daily maximum effluent limitation.

LOTT WWTP--

The LOTT treatment plant is located on City of Olympia property in the southern portion of Budd Inlet (see Figure 5). This regional facility services portions of the Cities of Lacey, Olympia, and Tumwater, and Thurston County. In August 1982, the LOTT plant was upgraded to provide secondary treatment of municipal and industrial wastewater. The most current information listed the average wet-weather flow as approximately 11 MGD (Parametrix 1987c). Based on effluent requirements in the NPDES permit (Ecology 1987), the monthly average flow is limited to 16.3 MGD, and the design criteria for the plant are 11.8 MGD (monthly average dry-weather flow), 16.3 MGD (monthly average wet-weather flow), and 25.9 MGD (maximum daily flow). Upon completion of certain hydraulic and other improvements, the plant has an existing design capacity of 22 MGD (average daily flow), 27 MGD (maximum daily flow), and 35 MGD (peak flow) (Parametrix 1987b).

The LOTT plant currently discharges treated effluent to Budd Inlet via a 30-in diameter principal outfall and a 48-in diameter backup outfall (see Figure 6). The 30-in diameter principal outfall line extends past the northern tip of Washington Street with an additional 600 ft of submerged line and a 300-ft diffuser section. The 48-in diameter backup outfall discharges through an open-ended pipe into the Fiddlehead Marina area. Prior to construction of the 30-in diameter principal outfall, LOTT discharged primary-treated effluent via the 48-in diameter outfall, which extended about 100 yd offshore (Alan, R., 19 January 1988, personal communication). The 48-in diameter outfall currently serves as a backup line to handle flows that exceed the capacity of the 30-in diameter principal outfall (i.e., flows of >10-12 MGD; Alan, R., 19 January 1988, personal communication). All effluent is treated before it is discharged from this outfall. Because of plant hydraulics and the need to use the chlorination units for disinfection, the 48-in diameter backup outfall is used several times each day (Ecology 1987). The calculation of the actual volume of effluent diverted and discharged through the 48-in outfall at any given tidal height is not possible at this time (URS 1986). However, by overlaying tidal cycles upon LOTT discharge flows, URS determined the volume of effluent discharged during two sampling periods. During a 5-day period in

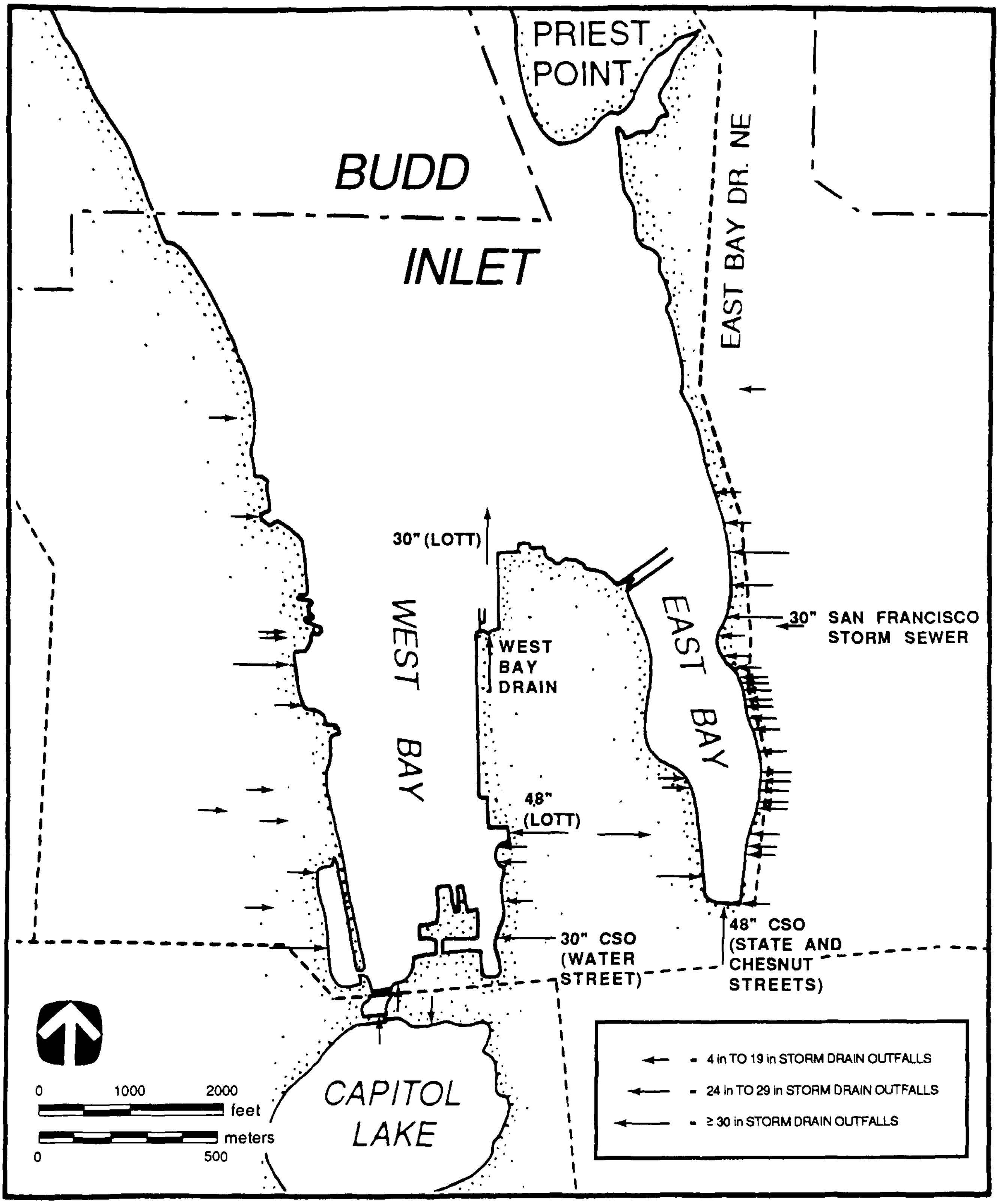


Figure 6. Locations of storm drain outfalls in Budd Inlet.

September 1984, four events of 7-8 MGD and two events of 4-6 MGD occurred. During a 5-day period in May 1985, two events of 9-12 MGD, three events of 7-8 MGD, and two events of 4-6 MGD occurred. Mr. R. Alan (25 March 1988, personal communication) stated that there are currently no annual or monthly estimates of the volume of effluent that is discharged via the 48-in diameter outfall. Mr. R. Alan estimated that approximately 10-20 percent of LOTT's daily flow is discharged via the 48-in outfall. Future plans include the elimination of the 48-in diameter backup outfall during the expansion of the LOTT facility (Parametrix 1987a). This expansion is planned to occur within the next 2-3 yr (Alan, R., 25 March 1988, personal communication). According to Mr. R. Alan, LOTT plans to build a second 30-in diameter outfall parallel to the existing 30-in diameter outfall. Future plans at LOTT also include nutrient removal from the effluent, which is a form of advanced or tertiary wastewater treatment (Colby, T., 28 March 1988, personal communication).

The LOTT collection system is largely a separate sanitary sewer system. However, a portion of the downtown Olympia system is combined with the storm sewer system and impacts peak storm flows to the WWTP. Various commercial and small industrial flows also enter the collection system. URS (1980) completed an industrial waste survey for the City of Olympia, in which they identified commercial industrial users that discharge or have the potential to discharge liquid and solid wastes to the municipal sewer system. Thirty-four of the 37 industries that were contacted responded to URS's questionnaire. Nineteen of those 34 industries discharged process water to the municipal WWTP. Prior to URS's survey, U.S. EPA indicated that in 1976 national categorical pretreatment standards would be issued for 21 types of industries that were potentially capable of discharging priority pollutants to WWTP. Those industries have been referred to as primary industries. In the URS (1980) survey, seven of the 19 industries that discharged to the municipal WWTP were primary industries. Those seven industries are Hardel Mutual Plywood Corporation, D.G. Parrott & Son, Star Cleaners & Foundry, Ann's Car Wash, Jerry's Shell Service, Olympia Auto Detailing, and Rich's Auto Detailing.

In addition to those seven industries, URS (1980) identified other industries that discharged potentially contaminated wastewater to the municipal WWTP. Survey responses indicated that wastewater from the Olympia Brewing Company may have exhibited excessive pH, temperature, 5-day biochemical oxygen demand (BOD_5), and suspended solids, and that they may have contained halomethanes. According to Ecology (1987), the Olympia Brewery is the only major industrial impact to the LOTT WWTP. Currently, the brewery discharges up to 2 MGD of effluent, 21,000 lb/day of BOD_5, and pH ranges from 6 to 10. Ecology (1987) data indicate that in recent years the brewery has occasionally violated the pH limits, which substantiates results from the URS (1980) survey. Olympia Brewery's permit has expired and a new permit application is under review by Ecology.

Survey responses from URS (1980) also indicated that the Olympia Medical Laboratory process wastes may have contained concentrations of chromium, nitrophenols, and cyanide. Wastewater discharged to the sewer system from St. Peter Hospital may have contained mercury, benzene, chlorinated naphthalenes, chloroform, and phenols. Process wastes from two radiator shops in the survey area may have contained concentrations of antimony, lead, zinc, and copper.

Although few priority pollutants were identified from survey results, URS (1980) recommended that a general scan for priority pollutants in influent and effluent wastewater at the treatment facility should be conducted to characterize system wastewater. This information would also be used to implement an industrial pretreatment program for the current LOTT WWTP. Currently, the LOTT WWTP does not have a pretreatment program. Each governmental entity regulates discharges into their portions of the collection system. Under the new NPDES permit (Ecology 1987), a pretreatment interjurisdictional agreement must be developed and implemented by 1 April 1988, and an industrial waste survey must be completed by 30 September 1988.

Parametrix (1987c) has recently prepared a draft environmental impact statement for the <u>LOTT Urban Area Wastewater Management Plan</u>. This plan will provide a comprehensive regional program for wastewater collection, treatment, disposal, and management, and a discussion on the protection of the area's aquifers. The plan addresses the development of an interceptor system for wastewater collection, and improvements to the treatment and disposal system at the existing LOTT facility.

Tamoshan WWTP--

The Tamoshan WWTP is located approximately 5 mi north of downtown Olympia on the Cooper Point peninsula (see Figure 5). The facility provides secondary municipal treatment for wastewater from the residential community of Tamoshan. This development consists of approximately 74 residences (Ecology 1986) with a population of approximately 140 persons (Clark, D., 27 January 1986, personal communication). A review of 1980 discharge monitoring reports (DMRs) showed an average discharge of 0.0134 $\pm$ 0.0009 MGD (Determan, T., 19 February 1981, personal communication) and a review of 1983 DMRs showed a yearly average discharge of 0.018 MGD (URS 1986). According to the NPDES permit (Ecology 1986), the monthly average quantity of effluent discharged shall not exceed 0.035 MGD. Because the facility does not have a flow meter, its wastewater flows are estimated based on the number of sump pump cycles/day and sump volume. According to DMRs for 1983, flow from the Tamoshan facility account for loadings of 3.0 lb/day total nitrogen and 0.8 lb/day total phosphorous to Budd Inlet (URS 1986).

At the Tamoshan facility, chlorinated effluent is collected in a wet well. When the well becomes full, effluent is pumped into the outfall line. As a result, the discharges into Budd Inlet are intermittent (Kendra, W. and T. Determan, 6 November 1985, personal communication). Effluent is reportedly discharged to Budd Inlet via a pipe with a length of 738 ft (Kendra, W. and T. Determan, 6 November 1985, personal communication). Although conflicting information is presented by Mr. D. Clark (27 January 1986, personal communication) (i.e., a 1,500 ft 6-in pipe) and Mr. T. Determan (19 February 1981, personal communication) (i.e., a 328-ft pipe), Mr. D. Anderson (6 April 1988, personal communication) indicated that the pipe is approximately 740 ft. Based on dye studies, the high density and compact nature of the emergent dye patch suggests lack of a diffuser (Kendra, W. and T. Determan, 6 November 1985, personal communication).

Tamoshan DMRs from November 1979 through November 1980 showed fecal coliform bacteria arithmetic averages ranging from 43 to 67,000 counts/100 mL (Determan, T., 19 February 1981, personal communication). Seven of nine DMRs indicated that fecal coliform bacteria levels in samples collected inside the plant violated effluent limitations. However, the expected fecal coliform bacteria levels at the actual discharge point or in the dilution zone adjacent to the diffuser could not be determined due to the lack of data. The DMRs from January 1982 to December 1985 indicate that Tamoshan's discharge exceeded effluent limitations for suspended solids and fecal coliform bacteria. During a limited Class II inspection of this facility in 1985, two fecal coliform bacteria samples exceeded both the monthly and weekly average for NPDES permit effluent limitations (Clark, D., 27 January 1986, personal communication). High fecal coliform bacteria levels were also observed in the nearshore areas of the facility. The DMRs suggest that fecal coliform bacteria contamination of Tamoshan nearshore waters is an historic and recurring problem. Ecology initially suggested that broken lines or a small stream located near the facility may have contributed to these high concentrations of fecal coliform bacteria (Kendra, W. and T. Determan, 6 November 1985, personal communication). However, the inadequate disposal of domestic wastes by shoreside residences was later identified as the most likely source. Ecology concluded that the Tamoshan WWTP does not appear to be the source of the high counts of fecal coliform bacteria and that it has little impact on receiving water quality (Kendra, W. and T. Determan, 6 November 1985, personal communication). However, because effluent discharge is intermittent, dilution and dispersion of the effluent plume may not have been fully characterized.

Beverly Beach WWTP--

The Beverly Beach community, which is located approximately 0.4 mi south of Tamoshan (see Figure 5) and comprises approximately 18 homes (Ecology 1980). The Beverly Beach WWTP provides secondary wastewater treatment for approximately 50 persons (Clark, D., 21 November 1985, personal communication). Although the plant is designed to treat about 5,000 gal/day, the flow is estimated at less than 3,000 gal/day (Ecology 1980; URS 1986). Because the facility does not have a flow meter, wastewater flows from the facility are estimated based on the resident population served. Also, although effluent is discharged continuously from the Beverly Beach WWTP, the discharges are characterized by periodic flow surges that coincide with plant aeration cycles (Kendra, W. and T. Determan, 6 November 1985, personal communication). According to 1983 DMRs, average loadings of 0.5 lb/day total nitrogen and 0.13 lb/day total phosphorous entered Budd Inlet from the Beverly Beach WWTP discharge (URS 1986). The effluent discharges through a 6-in gravity-fed line approximately 2 m offshore at a depth of 0.25 m at mean lower low water (MLLW) (Clark, D., 21 November 1985, personal communication). During low tides, the treated effluent discharges above MLLW and flows down the beach to the receiving water.

During a limited Class II inspection of this facility in June 1985, samples analyzed for BOD_5 and fecal coliform bacteria exceeded the NPDES weekly and monthly average effluent permit limits (Clark, D., 21 November 1985, personal communication). Ecology concluded that sanitary problems at the Beverly Beach facility are caused by sporadic chlorination inefficiency and the shallow depth of discharge. Ecology determined that the Beverly Beach discharge affects the receiving waters because the initial dilution of the effluent discharge is minimal due to shallow discharge depth, and the chlorination efficiency of the WWTP is inadequate during flow surges (Kendra, W. and T. Determan, 6 November 1985, personal communication).

Seashore Villa WWTP--

The Seashore Villa Mobile Home Park is located between Priest Point and Gull Harbor on the east side of Budd Inlet (see Figure 5). The Seashore Villa WWTP services wastewater from over 50 mobile homes and a population of approximately 174 persons (Clark, D., 25 March 1986, personal communication). According to the NPDES permit, the monthly average quantity of effluent discharged is not to exceed 0.015 MGD (Ecology 1979), which is equivalent to the flow based on the design capacity of the plant. In 1979, Ecology (1979) estimated that the average flow was 0.0036 MGD, and in 1986 the flow was estimated to be 0.0115 MGD (Clark, D., 25 March 1986, personal communication). According to DMRs from 1983, the Seashore Villa WWTP contributed loadings of 2.5 lb/day total nitrogen and 0.6 lb/day total phosphorous to Budd Inlet (URS 1986).

The Seashore Villa WWTP effluent discharges to Budd Inlet through a 275-yd, 3-in diameter pipe. During a Class II inspection in July 1985, the depth of the discharge was 2 m at MLLW (Kendra, W. and T. Determan, 6 November 1985, personal communication). Measurements of BOD_5 and total suspended solids in effluent samples exceeded the NPDES permit limits, and Mr. D. Clark (25 March 1986, personal communication) concluded that the facility did not appear to meet NPDES permit requirements. However, Ecology also indicated that effluent discharged from Seashore Villa had little or no effect in the discharge zone (Kendra, W. and T. Determan, 6 November 1985, personal communication). Fecal coliform bacteria were virtually absent from surface waters in the mixing zone at Seashore Villa. Seven of 10 samples collected had fewer than 1 organism/100 mL. However, Ecology stated that the presence of an algal bloom during the survey may have masked effluent impacts.

Areas Not Serviced by WWTP--For many years, the Boston Harbor area (see Figure 5) has been plagued by failing septic systems due to poor soil conditions. Boston Harbor has reportedly experienced septic system failures at more than three times the second highest surveyed septic system failure rate in Thurston County, and more than eight times the rate of failures in other similar shoreline areas (R.W. Beck and Associates 1986). In April 1984, the Thurston County Public Works, Planning, and Health Departments conducted a survey of the operational condition of the septic systems in the Boston Harbor area. Over 68 percent of the septic systems were determined questionable or failing. Data collected in this study show that failing drainfield systems are predominant, and that increasing concentrations of septic wastes are discharged into the area's ditches and marine waters (R.W. Beck and Associates 1986). The Boston Harbor Wastewater Facilities Planning Study for Thurston County (R.W. Beck and Associates 1986) was prepared to assess means of handling septic wastes discharged to Boston Harbor. One option will likely include the construction of a secondary WWTP.

The Thurston County Health Department identified the following three unconfirmed areas that may have onsite sewage disposal problems and thus be sources of fecal coliform bacteria to Budd Inlet: Athens Beach, the French Loop Road area, and the Olympic Country and Golf Club (Gibbs, T., 20 January 1988, personal communication). The Olympia Country and Golf Club has a drainfield on the west side of Cooper Point Road that services their facilities, and possibly some local residences. Wastewater flows downhill to a collection site and is pumped uphill to the drainfield. The wastewater in the drainfield reportedly does not flow into Budd Inlet (Haggerty, K., 18 January 1988, personal communication).

Combined Sewer Overflows

Flows to CSOs result from an overflow of the combined sanitary and storm sewer system. During a heavy rain storm, additional flow from storm runoff exceeds the hydraulic capacity of the collection system. The excess flow, a mixture of storm runoff and raw sewage, is discharged from CSO discharge points into surrounding waters. With the exception of two known CSO discharge points, the City of Olympia has separated all storm and sewer lines in the study area (Moore, D., 17 November 1987, personal communication). The first CSO is a 48-in diameter outfall that enters a 72-in pipe approximately 100 ft south of East Bay near State and Chestnut Streets (Alan, R., 25 March 1988, personal communication). This 72-in diameter pipe subsequently flows into an 84-in diameter pipe that contains flow from both Moxlie and Indian Creeks (Moore, D., 29 March 1988, personal communication). The terminus of the 84-in diameter pipe discharges into East Bay. The second CSO is a 30-in diameter outfall that enters West Bay near Water Street (see Figure 6) (Moore, D., 9 December 1987, personal communication). The City of Olympia is currently preparing a CSO reduction plan, the draft of which will be submitted to Ecology by 31 July 1988 (Moore, D., 9 December 1987, personal communication).

These CSOs have not been monitored for flow or chemical composition, and their flow frequency is unknown (Cunningham, J., 21 September 1987, personal communication; Alan, R., 25 March 1988, personal communication). The CSO that enters East Bay via Moxlie Creek may not flow more than once per year

(O'Brien, E., 12 November 1987, personal communication). Mr. R. Alan (25 March 1988, personal communication) stated that neither CSO discharged in 1987 or 1988. Since 1987, LOTT employees visually check the CSOs for flow when high waters cause the overflow alarms to sound.

Prior to March 1988, untreated sanitary sewage could also enter Budd Inlet via emergency overflows (EOF). Discharges from EOF are not associated with a storm event, but result from an equipment failure or a power failure. EOF are generally located at lift stations to discharge excess flow if the pump fails. Prior to March 1988, the LOTT facility had two EOF that discharged into Budd Inlet: the West Bay pump station (2200 West Bay Drive) and the East Bay pump station (1621 East Bay Drive). The Jasper and Eastside pump station (1208 Eastside Street) discharged into Mission Creek. The locations of these pumping stations are shown in Figure 5. According to Mr. R. Alan (25 March 1988, personal communication), these overflows have been eliminated. Two EOF were plugged, and a manual valve replaced the existing automatic overflow at the West Bay pump station.

Surface Runoff

Storm water runoff has long been suspected as a potential source of pollution to the marine environment. Recently, it has received more attention as the problems of toxic input from urban runoff have been recognized. Because a large portion of the study area's drainage basin is rural and agricultural, the City of Olympia has the only storm drain system. Over 80 percent of the surface runoff from the study area flows into Budd Inlet via natural drainage channels (e.g., streams, creeks). Surface runoff also enters Budd Inlet from the Deschutes River and Capitol Lake.

Surface storm water runoff that occurs within the City of Olympia boundaries is primarily collected by the city storm sewer system. City storm drains that discharge directly to Budd Inlet are shown in Figure 6 (City of Olympia 1987; McCarthy, B., 15 January 1988, personal communication). Within City of Olympia boundaries, surface runoff can also be collected in the municipal combined sewer system and then treated at LOTT.

Storm water can also discharge to Budd Inlet via natural drainage channels and as disperse surface runoff.

Storm drain flow was not calculated because information on the size and land use of the contributing area was not known for each storm drain. There are essentially no data available to characterize storm drain discharges. Between 9 and 17 April 1985, URS (1986) estimated flows from 34 pipes, culverts, and storm drain outfalls that discharge into Budd Inlet. Flow rates were measured with a Pygmy current meter, and estimates ranged from 0 to 0.284 cubic ft per second (cfs). Flow from the San Francisco storm drain was between 0.02 and 0.025 cfs. On 10 September 1985, flow estimates from 15 storm water discharges ranged from 0 to 1.203 cfs. Flow from the San Francisco storm drain was estimated at 0.01 cfs. URS (1986) also intended to use data collected from the San Francisco storm drain outfall (see Figure 6) to be representative of urban runoff for determination of loadings to Budd Inlet. However, because the lack of rainfall during the source survey resulted in very low loadings of BOD_5, fecal coliform bacteria, dissolved oxygen, and algal nutrients, these data could not be extrapolated to represent total urban runoff under more normal wet-weather conditions (URS 1986).

Private industries along the shore of Budd Inlet may also have storm drain systems that discharge into Budd Inlet. These storm drains were not characterized as part of this study, but are discussed below in the section on point discharges to Budd Inlet.

Industrial Sources

Industrial sources can be divided into point and nonpoint sources. Point sources consist of discrete discharges from an identifiable source. They are composed primarily of NPDES-permitted discharges and unpermitted industrial storm drains. The nonpoint sources include any offsite migration of contaminants resulting from contaminant storage, treatment, and handling practices. The potential contaminant sources that were identified in the project area are shown in Figure 5.

Point Sources--

Permitted Discharges--Ecology is responsible for issuing NPDES permits. Ecology statewide policy limits industrial discharges to noncontact cooling water and storm water. A list of the six existing NPDES-permitted waste discharges to Budd Inlet is presented in Table 4. Permits have been issued to four WWTP (i.e., Tamoshan, LOTT, Beverly Beach, and Seashore Villa). Permits for storm water runoff have been issued to two industries (i.e., Chevron and Delson Lumber Company/Olympia Forest Products). Although an NPDES permit does not currently exist for the Cascade Pole Company site, Ecology maintains that organic contaminants are currently discharged from the site and that the discharge requires an NPDES permit (Peeler, M., 12 January 1988, personal communication). Information on discharges from the four NPDES-permitted WWTP discharges is provided in the previous section entitled "Wastewater Treatment Plants." Information on discharges from the Chevron facility and Olympia Forest Products is provided below. Discharges from the Cascade Pole Company are discussed in the section entitled "Unpermitted Discharges."

Chevron U.S.A. operates a bulk petroleum storage facility near the Port of Olympia on private property. As identified by Ecology (1985a), the discharge from this facility consists of storm water collected from the truck loading areas and building roof drains. This discharge is routed to an oil-water separator that is located in a bermed area. The oil is drawn from the separator and discharged into an adjacent buried tank. Waste oils are pumped from the tank yearly, and hauled to Tacoma by the pumping contractor. An automatically operated pump discharges effluent into the storm sewer. Thus, the effluent consists of an irregular and undetermined amount of storm water discharge.

As identified by Ecology (1985b), Delson Lumber Company/Olympia Forest Products owns and operates a saw mill and log storage pond on the west shore of Budd Inlet. This facility discharges undetermined quantities of accumulated storm water and, occasionally, washdown water directly into Budd Inlet.

Unpermitted Discharges--Industries along the shoreline of Budd Inlet are served by unpermitted private storm drains that discharge directly to marine waters. Although flows from these storm drains should be relatively small, the potential for contamination due to industrial practices could make private storm drains a significant source of contaminants. U.S. EPA and Ecology are currently addressing this issue by including industrial storm drains in the NPDES program.

In the Budd Inlet study area, the locations of most industrial storm drains have never been defined. Within the study boundaries, the Port of Olympia operates the largest area serviced by a private storm drain system [see Port of Olympia (29 February 1988, personal communication) for current lessees]. The types of operations conducted by lessees and the locations of the Port of Olympia private storm drains have not been identified. However, two storm drain outfalls (i.e., West Bay drain outfall and the former Cascade Pole NPDES-permitted outfall) on Port of Olympia property have been identified as potential contaminant sources. According to Ecology (Norton, D., 5 February 1986, personal communication), the West Bay drain is the major storm water discharge point for runoff from the northern portion of the Port of Olympia property. This drain also receives storm water collected along Capitol Way in downtown Olympia. Contaminated groundwater beneath the Cascade Pole Company facility, located east of the West Bay drain, may also flow into this drainage system. Recent studies have shown that the former Cascade Pole NPDES-permitted outfall contributes contaminants to Budd Inlet. Data on concentrations of contaminants in water and sediments collected near the West Bay drain and Cascade Pole facility are presented below. Additional information on results of chemical analyses on sediments collected near the Cascade Pole outfall are presented in the section entitled "Sediment Contamination."

Available Data--On 13 February 1985, Ecology collected water samples from Cascade Pole's former NPDES-permitted outfall and the West Bay drain (Johnson, A., 22 July 1985, personal communication; Norton, D., 5 February 1986, personal communication). The West Bay drain was resampled on 14 August 1985. In the sample collected from the Cascade Pole outfall, 10 ug/L of total PAH and 1,700 ug/L of pentachlorophenol (PCP) were detected. In the sample collected in February from the West Bay drain, 395 ug/L of PAH and 17 ug/L of PCP were detected. In the sample collected in August from the West Bay drain, 56 ug/L of PAH and 11 ug/L of PCP were detected. Low molecular weight PAH (LPAH) accounted for 80 and 85 percent of the total PAH in the February and August 1985 samples, respectively. High concentrations of LPAH is attributed to the predominance of these compounds in creosote, and because these compounds are more water soluble than high molecular weight PAH (HPAH). Lower concentrations of LPAH in August may have resulted from tidal influence at the sampling location. The specific conductivity of the water sample was 15,500 umhos/cm, suggesting that the sample was primarily seawater (Norton, D., 5 February 1986, personal communication). Ecology calculated a 20 lb/yr flux of PCP to Budd Inlet from the Cascade Pole Company outfall. Ecology calculated a 300 lb/yr flux of PCP from the West Bay drain based on the February 1985 results and 30 lb/yr flux based on the August 1985 results. Ecology concluded that because seawater was present in the sewer lines, the actual loads to Budd Inlet may be lower than these values.

In July 1985, Applied Geotechnology (1986a) collected surface water samples from standing water in the Port Detention Basin (PDB) and from the Cascade Pole outfall. Samples were analyzed for PAH and phenols. Results of these investigations showed no detectable PAH in the PDB or the outfall sample. Phenols were not detected in water from the PDB. Concentrations of PCP were detected at 27 ug/L in the Cascade Pole outfall sample. Differences between results from Ecology and Applied Geotechnology (1986a) may be due to seasonal effects, tidal effects, variations in sampling or analytical laboratory procedures, or a change in discharge quality caused by plant activities. Applied Geotechnology and Ecology concluded that additional sampling efforts should be conducted to characterize the storm-water system. In March or April 1988, Ecology will be sampling and tracing the West Bay storm drain system (Peeler, M., 22 February 1988, personal communication). Sediment samples will be collected from eight manholes and six catch basins to determine the connection between the Cascade Pole site and the West Bay drain outfall.

Nonpoint Sources--

The nonpoint source category includes all other potential indirect sources of pollution. Offsite migration of contaminants can occur when surface runoff picks up contaminants as it moves across a contaminated area of the property, or when contaminants percolate into the groundwater system where they can be transported to the waterways via groundwater flow. Groundwater data are presented in the following section. Potential toxic and microbial contamination from other nonpoint sources is discussed below.

Landfills--Historical landfills may also have contributed contaminants to Budd Inlet. During construction of the LOTT WWTP, an old landfill was observed in the area in which the secondary clarifiers were built (Oblas, V., 29 February 1988, personal communication). The landfill was used prior to 1950 as a general municipal dump and apparently was operated by the City of Olympia (Alan, R., 14 March 1988, personal communication; Oberlander, J., 24 February 1988, personal communication). The material that was removed from the secondary clarifier area was disposed of at the Thurston County Landfill on Margaret Road (Oblas, V., 29 February 1988, personal communication). According to Mr. R. Alan (14 March 1988, personal communication), landfill materials remain on the LOTT WWTP site in the area northeast of the secondary clarifiers.

Commercial and Recreational Marinas--The following five marinas currently operate in Budd Inlet: West Bay Marina, Olympia Yacht Club, Fiddlehead Marina, East Bay Marina, and Boston Harbor Marina (see Figure 5). Although boat painting is allowed at all but the East Bay Marina, boat repair facilities are only offered at the West Bay Marina. Historically, the One Tree Island Marina existed near the Fiddlehead Marina. Sediments contaminated with metals were identified in this area in 1985. As mentioned below, a plating facility was once located in this area.

Nonpoint sources of microbial contamination in Budd Inlet include contributions from live-aboards in these Olympia marinas and general boating activity. These contributions have not been qualitatively or quantitatively identified.

In addition to these marinas, a U.S. Maritime Fleet ("Mothball Fleet") was moored in eastern Budd Inlet near Gull Harbor (Jamison, D., 21 January 1988, personal communication; Newall, G., 10 February 1988, personal communication). This Mothball Fleet may have comprised over 100 boats including merchant ships, tankers, freighters, and troop transports (Newall, G., 10 February 1988, personal communication). Scrap material, which may have included waste oils, solvents, and paints, was reportedly discarded from the ships into Budd Inlet (Oberlander, J., 29 January 1988, personal communication). Additional information is not available.

Other Nonpoint Sources--Historical industrial practices may have contributed contaminants to Budd Inlet. At one time, the Hardel Mutual Plywood facility located on West Bay Drive (see Figure 5) discharged process wastes into their onsite septic system (URS 1980). These process wastes included caustic substances, oil, and phenolic glue wastes (URS 1980). Over time, these wastes may have leached into Budd Inlet (Oberlander, J., 29 January 1988, personal communication). Also, a plating facility was once located in the area near One Tree Island Marina [see Figure 5; U.S. Army COE no date (d)]. This operation may have contributed to the high concentrations of cadmium detected in West Bay (Pierce, R., 20 January 1988, personal communication).

Groundwater

The impact of toxic contaminants from groundwater flow into the study area is difficult to determine. To date, no studies have defined regional groundwater conditions in the immediate area of Budd Inlet. The shallow water table aquifers are most important when evaluating groundwater problems because of their vulnerability to contamination from surface activities.

The LOTT Urban Area Wastewater Management Plan (Parametrix 1987b) has addressed groundwater movement and quality in Thurston County, including identification of sensitive aquifer areas. Much of the area is characterized by porous soils that allow rapid infiltration of water from onsite disposal systems into groundwater. According to this plan:

> "Approximately 65 percent of Thurston County is underlain by relatively permeable glacial deposits which overlay unprotected or shallow aquifers. Nearly 100 percent of domestic water supplies are derived from these sources. Due to the generally permeable nature of soils in the County and the location of these aquifers the entire [study area] is effectively an aquifer recharge area. Approximately 80,000 people currently dispose of domestic waste through on-site disposal systems into the study area's aquifer recharge area. . .. Recent groundwater contamination occurrences and lake quality degradation that is occurring in the Hicks and Long Lakes area suggest that the regional assimilation capacity for on-site disposal systems may be approaching its limit in selected areas. . .. Due to the sensitivity of County aquifers to groundwater contamination, the State Department of Ecology has adopted a State regulation reserving approximately 41,000 gpm of the area's groundwater resources for future public water supply needs."

Because the region's groundwater aquifers are recharged primarily from within the LOTT study area, the continued use of onsite waste disposal systems for existing uses and new developments without mitigation threatens the public health in the urban area (Parametrix 1987b).

Groundwater Contamination--

Substantial creosote and PCP contamination of groundwater at the Cascade Pole Company facility was first documented in 1983 (Norton, D., 5 February 1986, personal communication). A subsequent investigation by Ecology in February 1985 confirmed the presence of creosote and in ground-water onsite. Ecology determined that contamination extended to marine discharges and intertidal sediments in the vicinity of the facility (Johnson, A., 22 July 1985, personal communication). A subsequent remedial investigation by Applied Geotechnology (1986a,b) provided detailed information on PAH and phenols in soils and groundwater near the site. High concentrations of PAH and phenols were present in surface soils in the immediate vicinity of the pole-treating plant (up to 40,000 mg/kg PAH and up to 400 mg/kg phenols). Preservative fluid was found floating on the water table in three wells immediately adjacent to the plant. Concentrations of PAH and phenols were highest in subsurface soils within a few feet above or below the water table at sites in the southwestern portion of the property and along the southern shoreline of the plant. Concentrations of PAH and phenols in groundwater were highest near the plant and in the southwestern portion of the property. Using three different methods, Applied Geotechnology (1986a) calculated the flux (i.e., transport) of PAH and phenols from the fill aquifer to Budd Inlet. The flux of PAH and phenols to Budd Inlet from groundwater and surface runoff was estimated to range between 143 and 190 lb/yr (Applied Geotechnology 1986a). PCP accounted for 12 percent (or 17-23 lb/yr) of the total flux of PAH and phenols to Budd Inlet, and about 23 percent of the total flux of phenols to Budd Inlet.

The only shallow groundwater seep discharges into Budd Inlet that have been characterized were sampled during investigations conducted at the Cascade Pole site. On 13 February 1985, Ecology collected water samples from a shoreline seep located off the Cascade Pole site (Johnson, A., 22 July 1985, personal communication; Norton, D., 5 February 1986, personal communication). Concentrations of PAH and PCP in the shoreline seep sample were 2.3 ug/L and 8.6 ug/L, respectively.

In July 1985, Applied Geotechnology (1986a) collected surface water samples from a seep that discharged beneath the riprap on the eastern shoreline of the Cascade Pole site. Samples were analyzed for PAH and phenols. PAH and phenols were undetected in the seep samples. On 24 June 1987, Ecology observed "numerous product seeps" along the shoreline adjacent to the Cascade Pole site (White, M., 30 July 1987, personal communication). The product seeps were primarily observed east of Cascade Pole's NPDES-permitted discharge outfall and approximately 100 ft west of the East Bay Marina dock. Groundwater seeps were also observed in that area. Ecology collected a sample from a product seep (Sample CP1) and from an adjacent groundwater seep (Sample CP2), which were located approximately 100-150 ft northwest of the East Bay Marina dock. A water sample was also collected from a groundwater seep (Sample CP3) located approximately 25 ft southeast of Cascade Pole's NPDES-permitted discharge outfall. Samples were also collected from a product seep (Sample CP4) and from an adjacent groundwater seep (Sample CP5), both located approximately 50 ft northeast of the outfall and 40 ft offshore from the riprap. Samples were analyzed for the acid/base/neutral extractable organic compounds and volatile organic compounds on the U.S. EPA priority pollutant list. Sample CP4 was also analyzed for tentatively identified organic compounds. Analytical results for these samples are presented in Table 5. Groundwater seep samples collected southeast of the outfall and from near the East Bay Marina dock did not appear to be contaminated. In the groundwater seep sample (Sample CP5) collected northeast of the outfall, concentrations of volatile organics compounds ranged from 30 to 270 ug/L. Concentrations of organic compounds ranged from 1,200 to 430,00 ug/L in the product seep sample that was collected adjacent to the groundwater seep sample. In the second product seep sample (Sample CP1), elevated concentrations of volatile organic compounds and PAH were detected. These PAH are typical components of creosote.

During this investigation, Ecology also surveyed groundwater monitoring wells for product. Floating product in the wells was estimated by measuring the distance between the air-oil interface and the oil-water interface. Floating product was undetected in two wells and detected at $\leq$0.01 ft in three wells. The thickness of floating product in the remaining three wells, which are located 50 ft south of the Cascade Pole building, ranged from 4.11 to 7.49 ft. Well N24B was probed for sinking product and none was encountered.

On 9 March 1988, Ecology detected 1.5 ft of sinking product in groundwater well SP1 located on the Cascade Pole Company site (Peeler, M., 15 March 1988, personal communication). The well was installed by Applied Geotechnology in mid-July 1987 but was never developed or sampled. Ecology collected samples of the sinking product and surface sheen at this well and submitted the samples for analysis. Ecology also collected seep samples onsite on 8 March 1988. Based on these results and negotiations between Ecology and the Cascade Pole Company, an extensive groundwater sampling effort may be conducted in the near future.

Although groundwater contamination beneath other industrial areas is also likely, it has not been investigated. The only past petroleum storage facilities on Port of Olympia property were operated by Olympia Oil and Wood

TABLE 5. CONCENTRATIONS (ug/L) OF VOLATILE AND EXTRACTABLE ORGANIC COMPOUNDS IN PRODUCT AND GROUNDWATER SEEP SAMPLES COLLECTED IN JUNE 1987 FROM CASCADE POLE COMPANY[a]

	Product			Groundwater		
	Aqueous Fraction		Oil Fraction			
	CP1	CP1[b]	CP1	CP2	CP3	CP5
Volatile Organics[c]						
Acetone	U	430E	U			
	U	U	U			
Benzene	35	40	1,500M	U	U	30
Toluene	190	230	32,000	U	U	100
Ethylbenzene	390E	540E	131,000	U	2.1	130
Styrenes	130E	190E	42,000	U	U	U
Total xylenes	780E	1,000E	236,000	U	0.7M	270

	Product		Groundwater	
Extractable Organics[c]	CP1	CP4	CP2	CP3
Naphthalene	2.06E	430,000	U	11J
2-methylnaphthalene	860,000	240,000	1J	U
Acenaphthylene	18,000	U	U	U
Acenaphthene	720,000	130,000	5J	6J
Dibenzofuran	340,000	58,000	2J	1J
Fluorene	410,000	80,000	3J	0.7J
Phenanthrene	1.3E6	220,000	9J	1J
Anthracene	150,000	37,000	1J	U
Fluoranthene	690,000	82,000	9J	1J
Pyrene	420,000	98,000	5J	1J
Benzo(a)anthracene	120,000	16,000	1J	U
Chrysene	110,000	18,000	1J	U
Benzo(b)fluoranthene	82,000	10,000	U	U
Benzo(k)fluoranthene	82,000	10,000	U	U
Benzo(a)pyrene	42,000	5,300J	U	U
Indeno(1,2,3-cd)pyrene	12,000J	1,200J	U	U
Benzo (g,h,i) pyrelene	12,000J	1,400J	U	U

Tentatively Identified Organics[c,d]	CP4
1-Methylnaphthalene	490,000J
2-Ethanylnaphthalene	170,000J
2-Methylanthracene	46,000J
Benzoa(b)thiophene	40,000J
Dibenzothiophene	180,000J
1-H Indene	100,000J
2,3,-Dihydro-1H indene	67,000J
Carbazole	45,500J
Trimethylnaphthalene	360,000J

[a] Only chemicals with detected concentrations are included in this table.

[b] Duplicate sample.

[c] Data Qualifiers: E=estimated value; J=estimated value is less than the specified detection limit; M=estimated value of analyte found and confirmed by analyst but with low spectral match parameters; U=compound was analyzed, but not detected.

[d] Tentatively identified organic compounds for Samples CP1, CP2, and CP3 are not listed because concentrations were estimated at $\leq$19 ug/L.

Reference: Adapted from M. White (30 July 1987, personal communication).

Company and Texaco (Applied Geotechnology 1986a). Applied Geotechnology (1986a) provided the following information:

> "The Olympia Oil and Wood company, opened in 1931, was located just west of the Georgia Pacific mill [on the southwestern portion of the peninsula]. Olympia Oil and Wood had a 250,000 gallon tank for No. 6 oil, two 125,000 gallon tanks for No. 5 oil, and two tanks of unknown capacity to store diesel fuel. Sludge reportedly was cleaned from the tanks every two to three years, containerized, and shipped to an oil reclaimer. The bulk storage facility, which handled approximately 10 to 15 million gallons of oil per year, was dismantled between 1972 and 1973.
>
> Texaco operated a bulk fuel storage facility west of CPC [Cascade Pole Company] from 1945 to 1965. The facility had one 105,000 gallon, one 420,000 gallon, and four 630,000 gallon storage tanks used for kerosene and two grades of gasoline. Annual volume through the facility was estimated at 25 to 30 million gallons."

In the 1970s, a groundwater investigation was conducted of petroleum seeps that were observed in an area that was occupied by Standard Oil (Pierce, R., 20 January 1988, personal communication; Oberlander, J., 29 January 1988, personal communication). The petroleum storage tanks onsite were removed (Oberlander, J., 29 January 1988, personal communication). Additional information on this study was not available.

During LOTT's construction of the Water Street Pump Station (see Figure 6), gasoline-contaminated sediments were observed (Ecology 1984; Oberlander, J., 29 January 1988, personal communication). Groundwater was found to be "heavily contaminated" by petroleum, and over 83 barrels of contaminated groundwater were removed from the excavation site between December 1977 and May 1978 (Ecology 1984). A bulk petroleum storage facility was reportedly operated in this area by the Mobil Company. However, attempts to finger print the oil were inconclusive. Ecology conducted a preliminary assessment at this site and determined that no action was necessary (Ecology 1984; Spencer, M., 1 February 1988, personal communication). Surface water contamination has not been observed near the pump station, but is highly probable given the proximity (<200 ft) of the contaminated groundwater to Budd Inlet (Ecology 1984). However, because of the bulkheads that exist between this site and Budd Inlet waters, the gasoline may not be leaching into Budd Inlet (Oberlander, J., 29 January 1988, personal communication).

Oil-contaminated soils were also observed during the development of the farmer's market area of Olympia (Pierce, R., 20 January 1988, personal communication). This contamination was reportedly attributable to bulk petroleum storage and transfer facilities that had operated in the area.

During demolition of an old gasoline station at the intersection of East Bay Drive and State Avenue, oil-contaminated soils were also identified. The gasoline station was reportedly constructed in 1956, and prior to this date the site was occupied by a grocery store that also had underground fuel storage facilities. Earth Consultants (1985) conducted a study for ARCO at this site and installed six monitoring wells. Groundwater was present at a depth of 9 ft below the surface, and no hydrocarbon accumulations were noted on the surface of the groundwater. Groundwater samples were collected and analyzed using gas chromatography. All concentrations of hydrocarbons were below the 25 ppm detection limit. This value is much higher than the generally accepted maximum detection limits (e.g., 0.001-5 mg/L). Hydrocarbon levels in soils were also measured using infrared (IR) spectrophotometry and silica gel separation. Results indicated that the existing and previous underground tanks or distribution systems had leaked. In soils collected from backhoe trenches, Earth Consultants (7 August 1986, personal communication) reported that "2,500 ppm diesel and 3,400 ppm motor oil were detected." Gasoline was not detected. In July 1986, Earth Consultants conducted additional analyses for PCBs and metals using EP toxicity procedures. Metals were undetected, and PCBs were detected at 0.03 mg/kg. This concentration is below the 1 mg/kg regulatory action threshold, which was set as an acceptable cleanup criteria by Ecology (Bradley, D., 30 March 1988, personal communication). The materials removed from this site were ultimately disposed at the Thurston County landfill, and no contaminated soils remain onsite (Pierce, R., 20 January 1988, personal communication).

The Thurston County Health Department is currently involved in a 3-yr groundwater management study (Pierce, R., 17 November 1987, personal communication). Existing groundwater data are being collected, including information on aquifers and recharge areas. This groundwater plan will be prepared to assess management alternatives for protecting aquifers and will be available in the near future.

Accidental Spills

Information on accidental spills in the region is contained in files of complaints reported to Ecology by private citizens. The spills and complaints reported to Ecology since 1986 have been entered into a database. That database lists the following information: investigator, date of investigation, alleged violator, material spilled, media code (e.g., surface water), waterway (e.g., Budd Inlet), and comments. In most cases, the alleged violator is unknown and there is not enough detailed information to determine the exact location of the spill or to calculate contaminant loading.

The 22 reports listed in the database (Ecology, 9 December 1987, personal communication) are summarized below:

- Nine oil sheens were observed on waterway or beaches
- Five algal blooms were observed
- Fifty gallons of oil were spilled into Budd Inlet via a storm drain
- "Strip and wax" materials and emulsifiers were dumped into storm drains that entered Budd Inlet
- Bark and wood wastes from Dunlap Towing, cattle feed waste, and paint scrapings were discharged to Budd Inlet
- Two unidentified spills were reported.

The only fully documented petroleum spill in Budd Inlet occurred in 1987. Industrial Petroleum Distributors (IPD), Inc. stored process waste oil at an abandoned ARCO bulk petroleum storage facility on West Bay Drive

(Anderson, D., 29 October 1987, personal communication; Cloud, G., 30 October 1987, personal communication). Waste oil was spilled onsite, and an unspecified volume of oil entered Budd Inlet. The oil slick spread at least as far as Olympia Shoals, and at-sea recovery was attempted. (Cloud, G., 30 October 1987, personal communication). Ecology brought an enforcement action against IDP. Waste oils were tested for PCBs, and none were detected (Cloud, G., 30 October 1987, personal communication). Results of a bioassay on the "remaining contaminated soils" at the IDP site indicated that the soils were not toxic, and thus they were not designated hazardous wastes (Anderson, D., 22 December 1986, personal communication). However, onsite cleanup of oil-contaminated soils may have been conducted by AIRO Services (Cloud, G., 30 October 1987, personal communication).

EUTROPHICATION

Eutrophic conditions in Budd Inlet have been documented since the 1950s when Collias et al. (1962) reported oxygen values below 2.0 mg/L on 4 September 1957 off the Port of Olympia peninsula. Since then, dense phytoplankton blooms and low dissolved oxygen have been chronic problems in the southern half of the inlet. Low dissolved oxygen concentrations in the water column may stress fishes and benthic organisms, and may regulate benthic infauna communities in the sediments. Therefore, oxygen depletion may be equally important as toxic contamination for the health of biological resources.

A total of six data sets were accepted for the review of water quality in Budd Inlet. The following reports contain data generated since January 1982: Mr. W. Kendra and Mr. T. Determan (6 November 1985, personal communication), URS (1986), Mr. R. Alan (24 September 1987, personal communication), Mr. E. Egge (25 January 1987, personal communication), Mr. T. Mumford (25 September 1987, personal communication), and the U.S. EPA STORET data files for Ecology ambient monitoring data, 1982-1986 (U.S. EPA, 7 January 1988, personal communication). Data contained in these documents have been used to determine annual fluctuations, sources, and budgets of nutrients and dissolved oxygen, in addition to the effects of WWTP discharges on marine receiving water quality. These data were collected at the water quality stations shown in Figure 7.

Relationship Between Nutrients and Dissolved Oxygen Depletion

Oxygen depletion typically occurs in the near-bottom water (0-2 m above the sediment surface) when flushing is inadequate to renew bottom water, and vertical mixing is reduced or eliminated due to a density-stratified water column (Yake, B., 6 July 1981, personal communication; Welsh, B., 18 November 1987, personal communication). These conditions frequently exist in shallow estuaries with an established thermocline during the late summer. Oxygen depletion is enhanced by the addition of organic materials because they provide the necessary nutrients for algal growth. Dense algal blooms often result under such conditions. Algal production of oxygen in the near-surface water may supersaturate it, but as these organisms die and sink to the sediment, their subsequent decomposition [in addition to regular sediment oxygen demand (SOD)] depletes available oxygen in the bottom water. A vertical profile of dissolved oxygen in a water column experiencing similar conditions might show oxygen concentrations ranging from 12 to over 15 mg/L near the water surface and concentrations of less than 3.0 mg/L near the bottom. A typical vertical profile showing oxygen depletion in an area similar to Budd Inlet is depicted in Figure 8. The most rapid decreases in oxygen concentration with depth usually occur in the photic layer. Under conditions of poor flushing, a rapid decline in dissolved oxygen caused by SOD may also occur approximately 0-2 m above the sediment. In the absence of vertical mixing or flushing, these conditions would persist until the algal bloom became nutrient limited and growth subsided.

Dinoflagellates, specifically _Cerative fusus_, and _Noctiluca scitallaus_ (in 1977; Kruger 1979), and _Gymorodinium_ spp. and _Ceratium_ spp. (in 1984; URS 1986), dominate the severe late summer algal blooms. Because dinoflagellates may migrate diurnally, they may be net producers of oxygen in the surface waters during the day, and consumers of oxygen in the bottom waters at night. URS (1986) suggested that vertical migration of dinoflagellates was a major contributor to oxygen depletion of near-bottom water in Budd

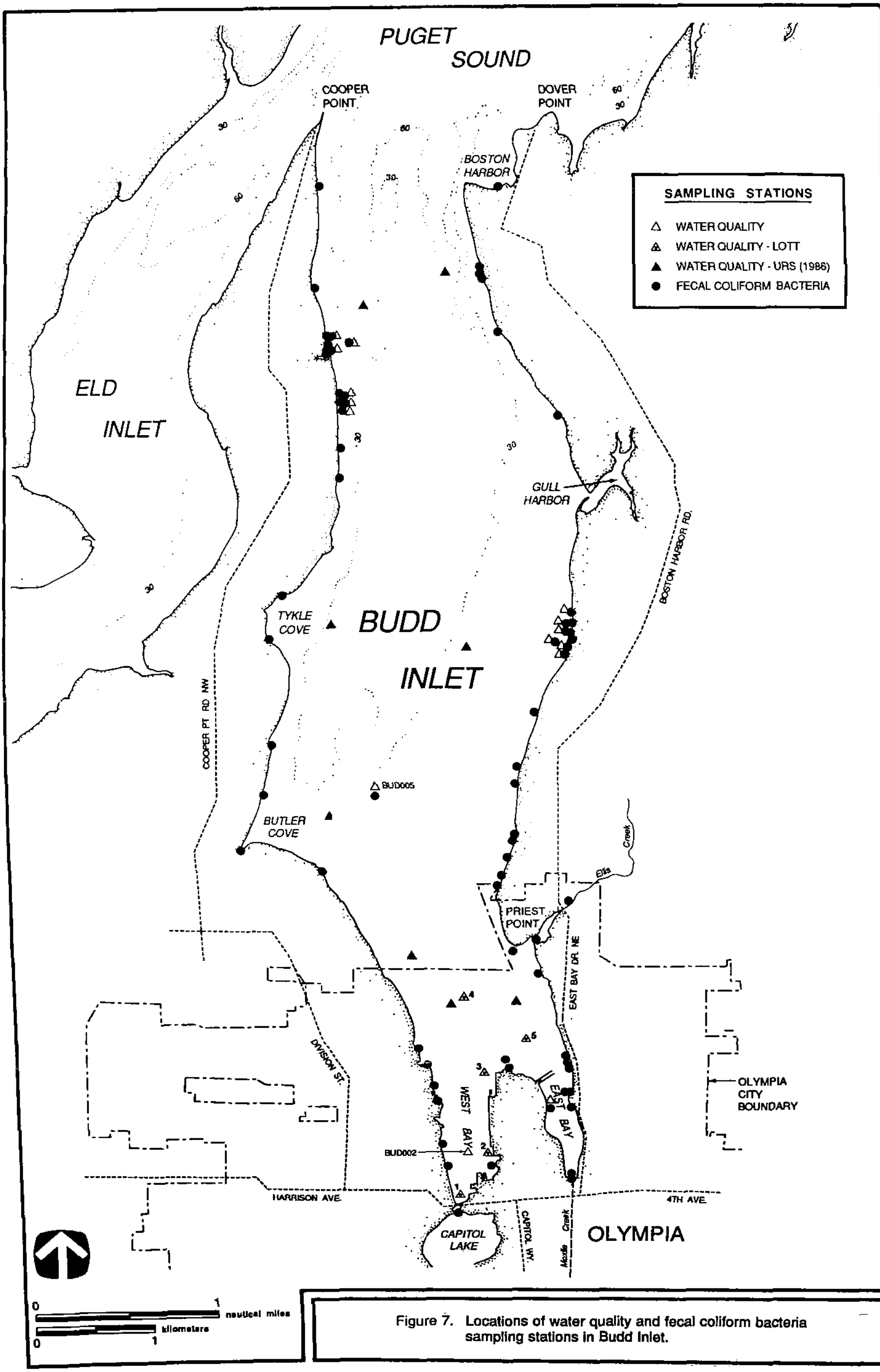


Figure 7. Locations of water quality and fecal coliform bacteria sampling stations in Budd Inlet.

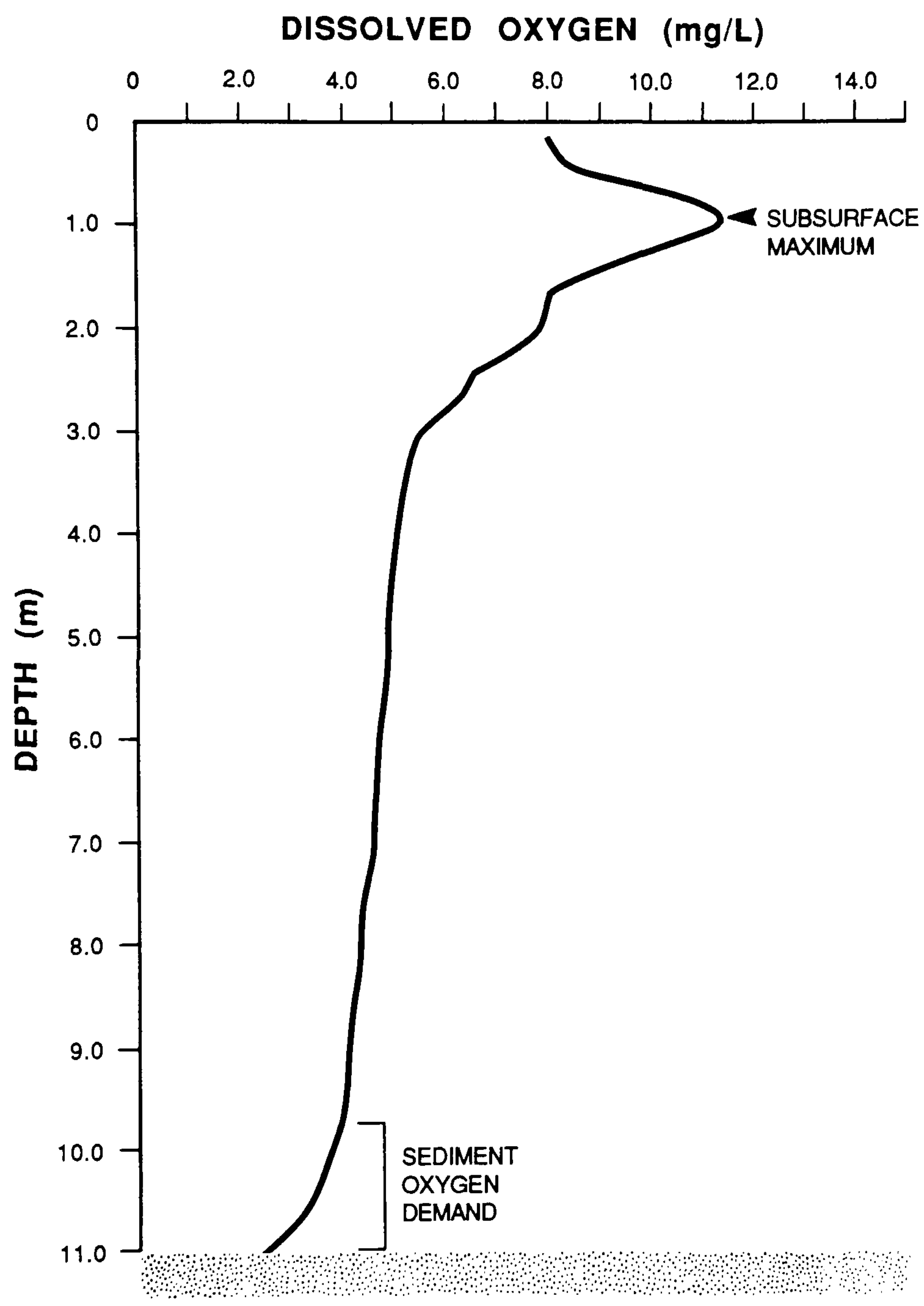


Figure 8. Theoretical example of vertical profile of dissolved oxygen.

Inlet during the late summer. Further field studies are required to substantiate this theory.

Nutrients

Nutrients enter the Budd Inlet water column through tidal exchange and flushing from Puget Sound, benthic flux, and nutrient loading from point and nonpoint sources within the inlet. Each of these sources contributes a substantial amount of nutrients, and collectively they provide enough nutrients to sustain dense phytoplankton blooms. URS (1986) determined that the limiting nutrient for algal growth in Budd Inlet is nitrogen. Typically, nitrogen is the limiting nutrient in marine systems, whereas phosphate is the limiting nutrient in freshwater systems. Nitrogen and phosphate concentrations in Budd Inlet fluctuate during the year in response to changes in the nutrient concentration of Puget Sound, uptake by phytoplankton, and source loadings.

Water quality data were collected from December 1981 to October 1982 near the Washington Department of Natural Resources (WDNR) Marine Station, located south of Gull Harbor (Mumford, T., 25 September 1987, personal communication). This sampling site is adjacent to the Seashore Villa WWTP discharge, and may be affected by the discharge of sewage effluent. These are the only Budd Inlet nutrient data collected for a complete year. The Ecology ambient monitoring program currently requires the collection of surface and bottom water quality data at two Budd Inlet stations [i.e., Station BUD002 north of Fiddlehead Marina in West Bay and Station BUD005 south of Olympia Shoals (U.S. EPA, 7 January 1988, personal communication)]. Water quality at Station BUD002 is influenced by the LOTT 48-in diameter outfall at the Fiddlehead Marina, the LOTT 30-in diameter primary outfall, and the Capitol Lake outfall. Analytical results of samples collected at Station BUD005 suggest minimal anthropogenic influences. The water quality at this station should be similar to that at the WDNR Marine Station.

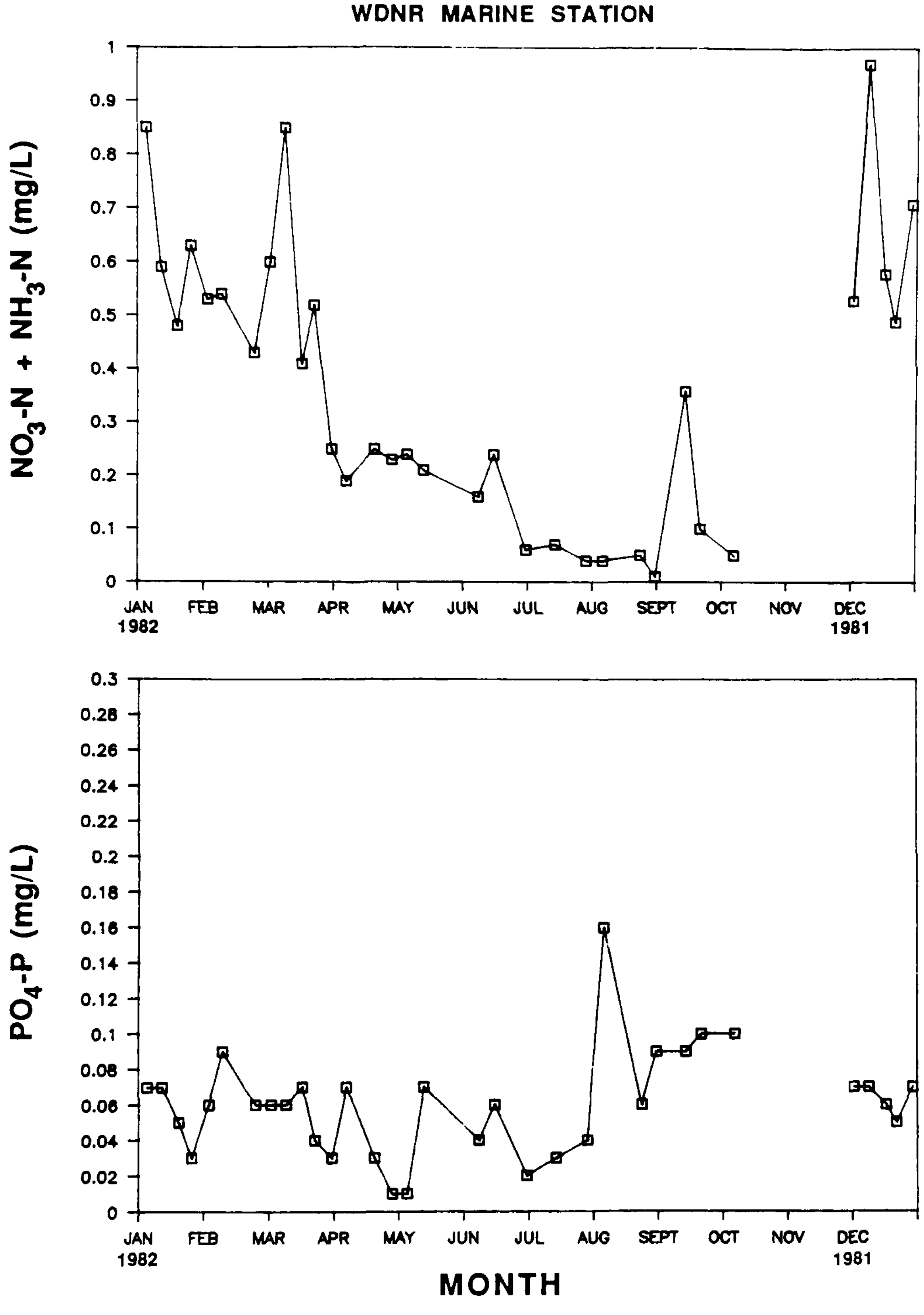
Nitrogen--

Nitrogen concentration in water is presented as the sum of nitrate and ammonium. These are the forms of nitrogen that are most readily assimilated by phytoplankton, and therefore reflect the nitrogen available for algal growth. The maximum concentration at the WDNR Marine Station was 0.97 mg/L in early December, while the minimum concentration was 0.01 mg/L at the end of August (Figure 9) (Mumford, T., 25 September 1987, personal communication). Nitrogen appeared to have been higher during the spring and fall at the WDNR Marine Station than at Ecology Station BUD005, possibly in response to the Seashore Villa WWTP effluent discharge. Ecology examined water quality in relation to this discharge and found that some nutrient levels inshore of the discharge were slightly elevated (Kendra, W. and T. Determan, 6 November 1985, personal communication).

Normal seasonal variability between 1982 and 1986 is most easily reflected in the monthly mean nitrogen concentrations at Station BUD005. Maximum nitrogen concentrations decreased from 0.18 mg/L between April and July to 0.09 mg/L between July and mid-September. In September, the water column generally becomes mixed due to strong winds and the influx of Puget Sound water, which contains higher nutrient concentrations. Nitrogen levels increased at Station BUD005 and were more variable (range 0.01-0.12 mg/L) during the fall.

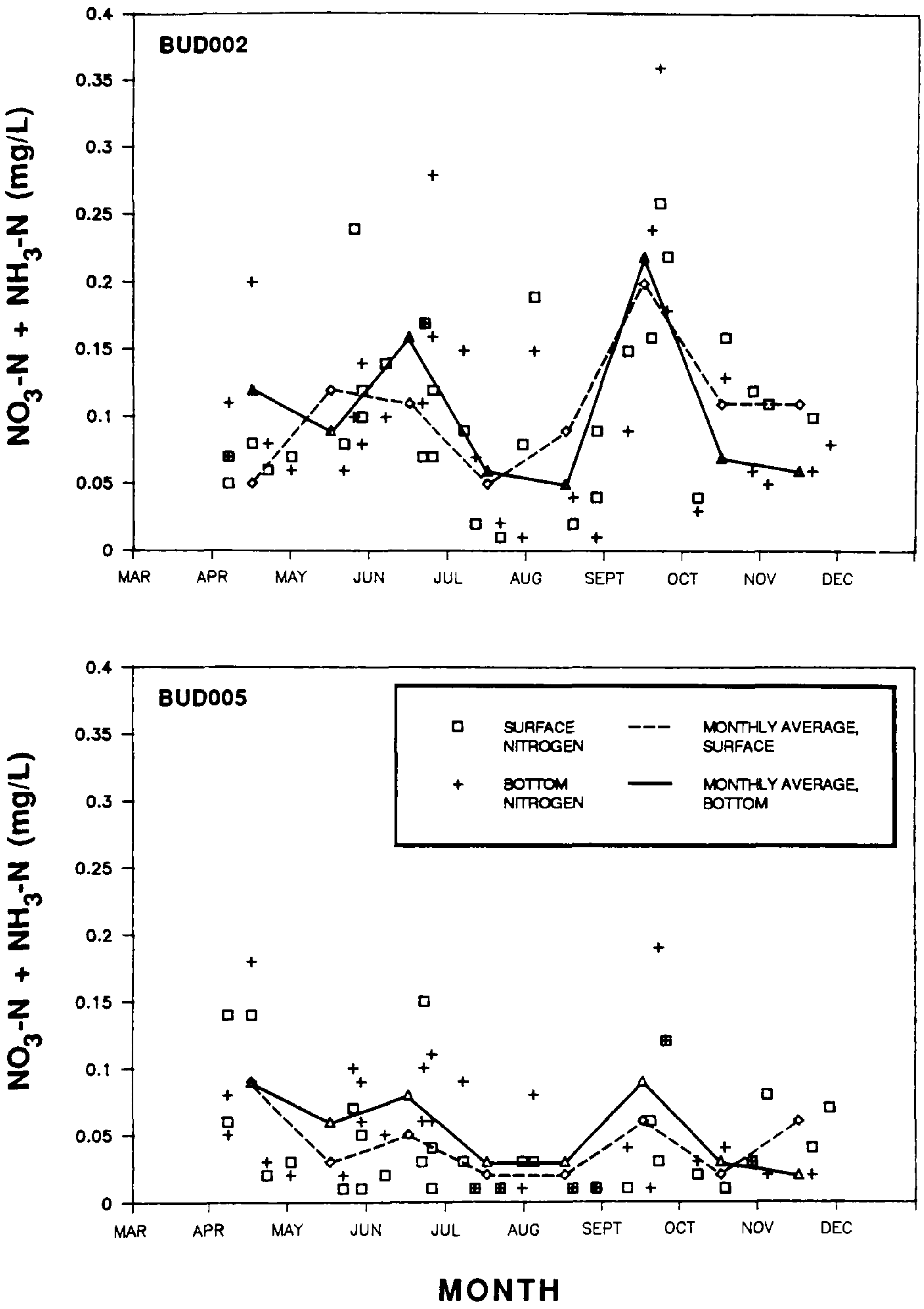
Average nitrogen values in both the surface water and bottom water were lower at Station BUD005 than at Station BUD002. Nutrient concentrations may be elevated at Station BUD002 because of its proximity to the LOTT outfall at the Fiddlehead Marina and to the Capitol Lake outfall (Figure 10). Effluent released from the LOTT WWTP at Station BUD002 results in higher concentrations of nitrogen at Station BUD002 and greater variability than at Station BUD005. The lowest nitrogen concentrations that occurred between 1982 and 1986 were during summer.

Source surveys and dynamic modeling were conducted by URS (1986) to identify the relative contributions of specific sources to the Budd Inlet



Reference: Data from Mumford, T. (25 September 1987, personal communication).

Figure 9. Annual variation in nitrogen and phosphate in surface waters at the WDNR Marine Station, 1981-1982.



Reference: Data are provided in Appendix B.

Figure 10. Temporal variation in nitrogen [sum of nitrate (NO_3) and ammonium (NH_3)] at Ecology ambient water quality monitoring stations BUD002 and BUD005, 1982-1986.

nutrient budget. A two-dimensional box model for Budd Inlet included point sources, flushing rates, and benthic release. Puget Sound water was found to supply approximately 60 percent of all the nitrogenous nutrients to the inlet. Both the LOTT WWTP and bottom sediments (i.e., benthic release) supplied about 20 percent of nitrogen each. A survey of point sources provided a relative breakdown of inputs. Nearly 100 percent of the nitrite, and the majority of the nitrate, originated from the LOTT WWTP (URS 1986). The relative contribution of major sources of nitrogen to Budd Inlet and to the upper 3 m of the water column is shown in Table 6. Elevated concentrations of nitrogen at Station BUD002 (compared with Station BUD005) result from nitrogenous compounds discharged from the LOTT WWTP through both the LOTT outfall and the Fiddlehead Marina outfall. The relative contribution of specific sources exclusively to southern Budd Inlet were not determined.

Phosphate--

Phosphate is reported as orthophosphate (PO_4-P), the form most readily assimilated by phytoplankton. This nutrient is not generally limiting to marine phytoplankton growth at any time of the year. Phosphate data from the WDNR Marine Station indicate that concentrations were generally below 0.1 mg/L (Mumford, T., 25 September 1987, personal communication), and seasonal depletion was not evident in Budd Inlet (see Figure 9).

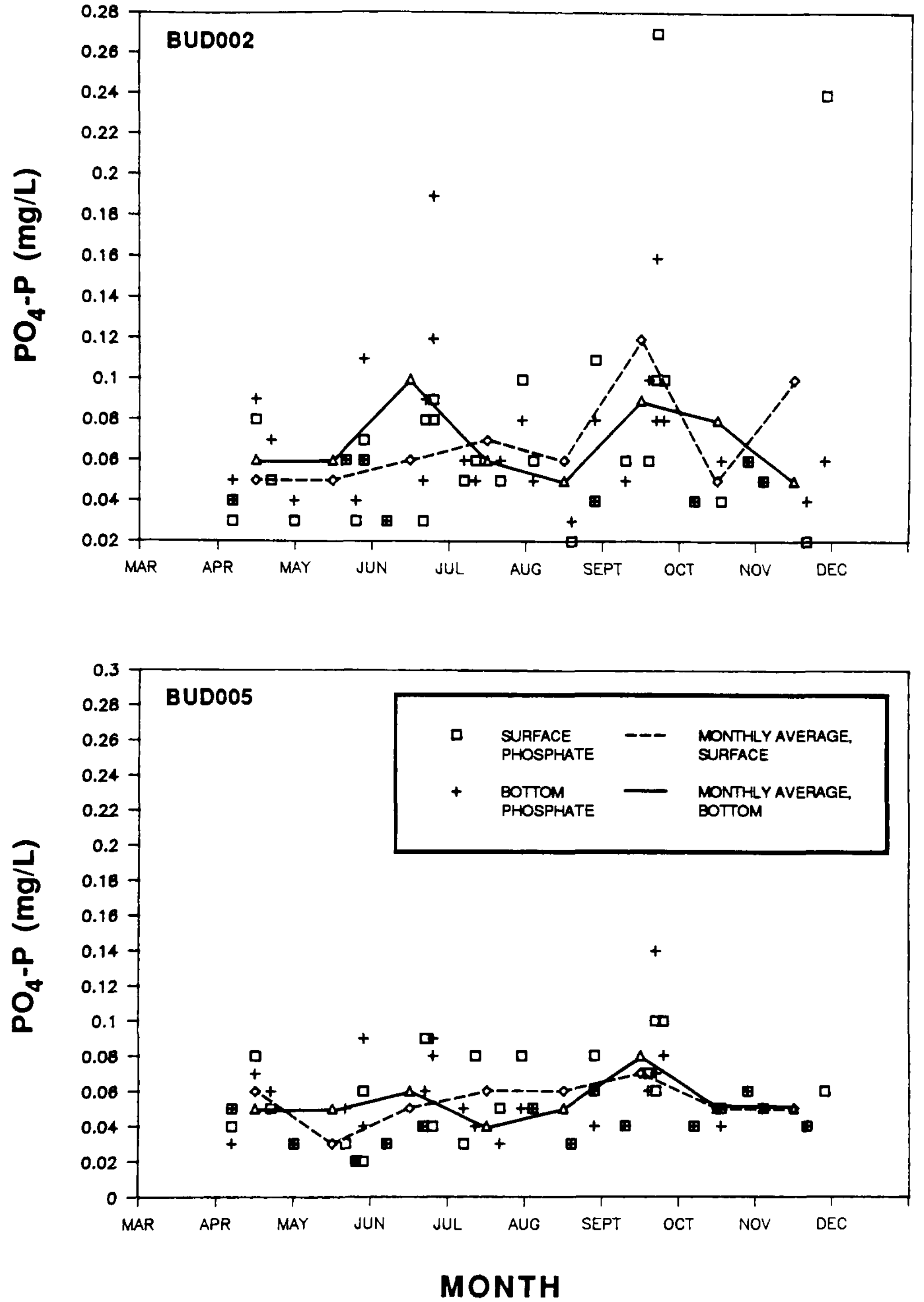
The primary difference between phosphate concentrations at Station BUD005 and at Station BUD002 is that Station BUD002 occasionally exhibits very high concentrations of phosphate (Figure 11). It is doubtful that these concentrations are the result of natural fluctuations. The fluctuations probably result from nutrient inputs by the LOTT WWTP. The Budd Inlet source study conducted by URS (1986) revealed that the LOTT WWTP contributed over 90 percent of the phosphate from known point sources.

The temporal variability in nitrogen and phosphorus concentrations at Station BUD002 from 1982 to 1986 were remarkably similar, most likely in response to nutrient loadings from the LOTT WWTP. In most cases, very high nitrogen values corresponded to very high phosphate values. For example, samples collected on 23 September 1985 contained the highest recorded

TABLE 6. RELATIVE CONTRIBUTION OF SOURCES OF NITROGEN TO BUDD INLET

Source	Nitrate and Nitrite (Percent)	Ammonium (Percent)
A) Upper 3 m of water column		
Puget Sound	78	20
LOTT WWTP	22	80
Bottom sediments (i.e., benthic release)	--	--
B) Entire Water Column		
Puget Sound	92	20
LOTT	8	36
Bottom sediments (i.e., benthic release)	--	44

Reference: URS (1986).



Reference: Data are provided in Appendix B.

Figure 11. Temporal variation in phosphate at Ecology ambient water quality monitoring stations BUD002 and BUD005, 1982-1986.

surface and bottom water nitrogen, highest recorded surface water phosphate, and second highest recorded bottom water phosphate. The bottom water on 25 June 1984 contained the highest recorded phosphate and second highest nitrogen. Monthly average concentrations of nitrogen and phosphate (see Figures 10 and 11) followed similar patterns.

Water quality investigations at the three WWTP in central and northern Budd Inlet also demonstrated the effect of municipal effluents on water quality. Surveys were conducted at control, mixing zone, and nearshore sites at Tamoshan WWTP and Seashore Villa WWTP, and at control and mixing zone sites at Beverly Beach WWTP (Kendra, W. and T. Determan, 6 November 1985, personal communication). Nutrient concentrations in the mixing zone at the Tamoshan WWTP were less than at the upcurrent control, but in all other cases, nutrient concentrations were greater than at control sites. Beverly Beach WWTP exhibited the highest nitrate, orthophosphate, and total phosphate concentrations, while Tamoshan WWTP exhibited the highest ammonium concentrations.

Dissolved Oxygen

Dissolved oxygen is a sensitive indicator of the health of a water body because it is the result of complex interactions among physical and biological variables. Oxygen levels vary naturally as a result of seasonal changes in solar radiation, wind, vertical mixing, flushing, nutrient levels, algal blooms, and sediment oxygen demand. When oxygen concentrations are less than 3 mg/L (termed hypoxia), organisms become stressed due to the lack of oxygen (Rhoads, D., 18 November 1987, personal communication). Mobile species often move away from hypoxic areas while seeking more oxygenated water (Welsh, B., 18 November 1987, personal communication). Tolerant sedentary species will survive provided that the duration of the hypoxic event is short and the oxygen concentrations generally remain above 1.0 mg/L. Anoxia, defined as 0.1 mg/L oxygen or less, results in widespread mortality of vertebrates and invertebrates in the affected area (Welsh, B., 18 November 1987, personal communication).

Budd Inlet experiences large fluctuations in oxygen concentration that result from the complex interactions between physical, biological, and anthropogenic variables (e.g., nutrient loadings from municipal effluents; URS 1986). It is not unusual for dissolved oxygen concentrations in the southern portion of the inlet in late summer and early fall to be below the Washington Station Class B water quality standard 5.0 mg/L. During this time of the year the water column is frequently well stratified due to lengthy periods of calm sunny days that increase the near-surface water temperature and, in conjunction with high nutrient loadings from the LOTT WWTP, provide suitable conditions for dense algal blooms (URS 1986). Flushing is reduced during this time of year and Puget Sound water contains less oxygen. Also, the discharge of ammonia from the WWTP combined with warmer water temperatures increase the rate of nitrification resulting in more localized oxygen depletion near the WWTP outfalls.

A total of five data sets, including the Ecology ambient monitoring data, were available for the review of dissolved oxygen data in Budd Inlet from 1982 to 1987 (see Appendix A, Table A-5). These reports, in addition to a number of older publications, indicate that oxygen depletion has been a severe problem in Budd Inlet for several decades. Although the magnitude and geographic extent of oxygen depletion vary annually, the most severe depletion usually occurs south of Priest Point. For example, in August 1977 the oxygen concentrations were below the 5.0 mg/L Class B water quality standard from Olympia to nearly Tykle Cove, with the lowest values of less than 1.0 mg/L in East and West Bays (Figure 12) (U.S. Army COE 1977).

Variability in Dissolved Oxygen--

Dissolved oxygen is routinely monitored 1) by the LOTT WWTP at five locations (Stations 1-5) (Alan, R., 24 September 1987, personal communication), 2) by the Port of Olympia in the East Bay Marina (Egge, E., 1 February 1988, personal communication), and 3) by Ecology at Stations BUD002 and BUD005 (U.S. EPA, 7 January 1988, personal communication) (see Figure 7). The only data that were collected over an entire year are the LOTT WWTP data in 1986 (Figure 13). The distribution of dissolved oxygen at the five stations was remarkably similar, although the absolute concentrations often

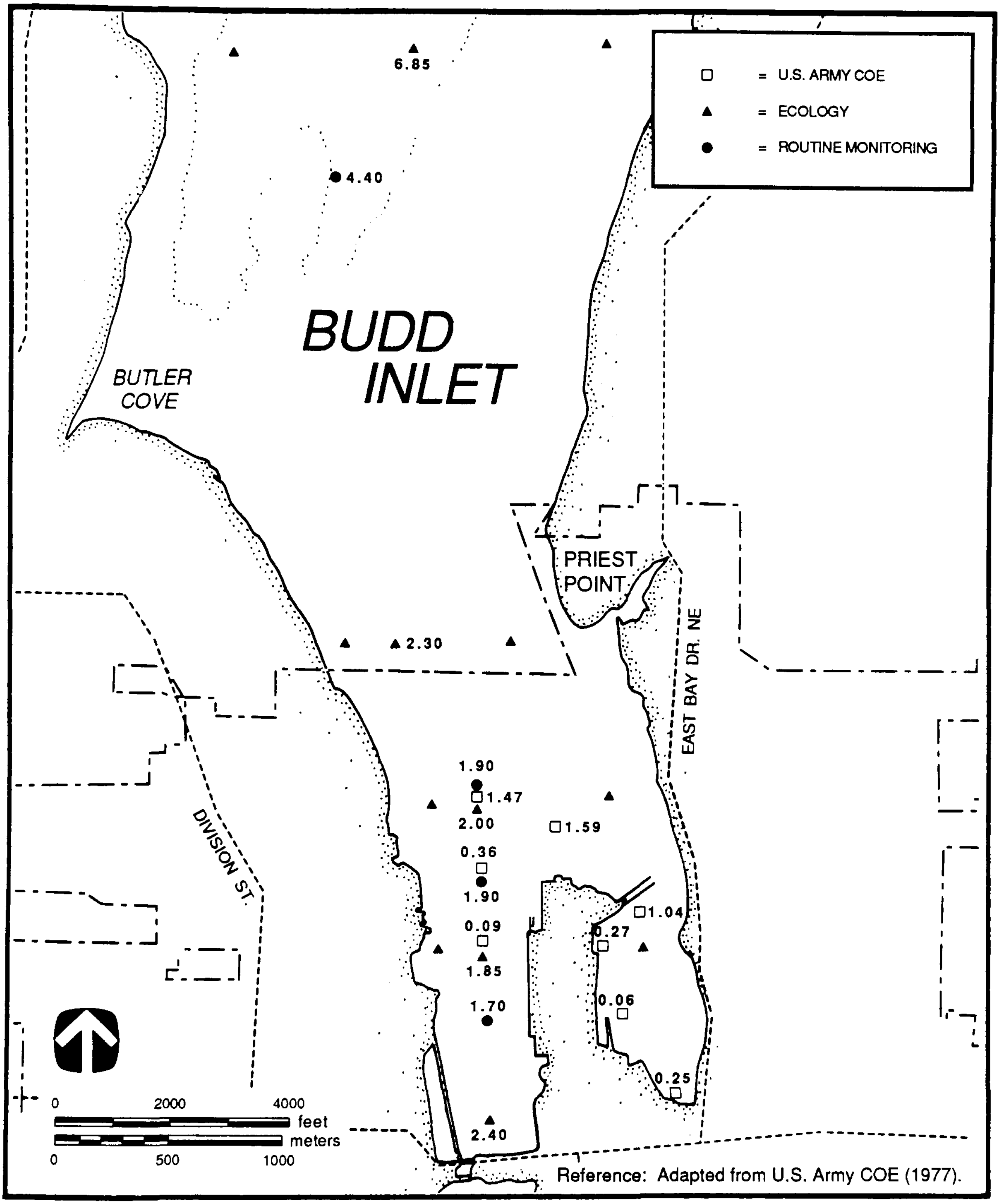
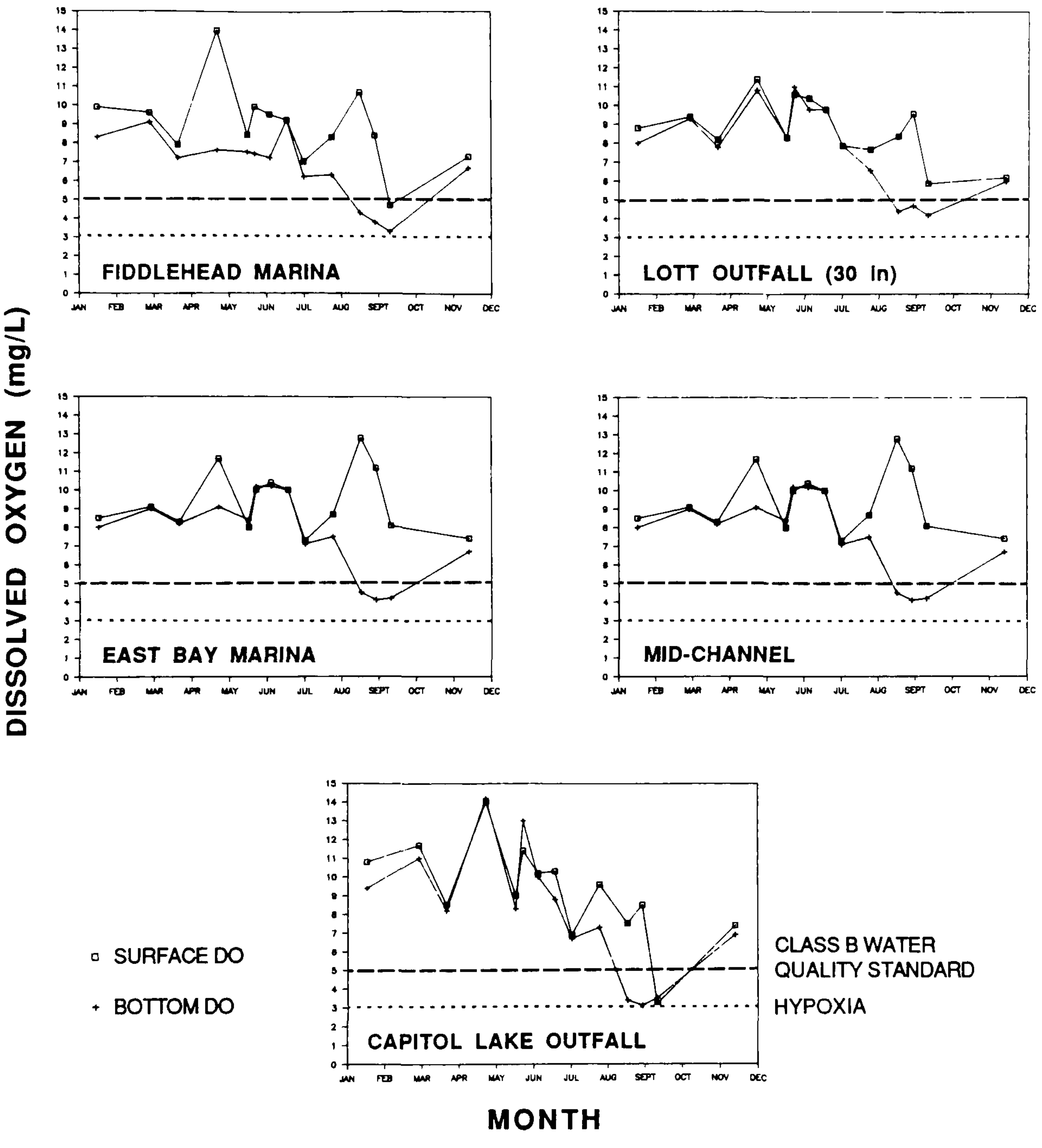


Figure 12. Distribution of dissolved oxygen in the bottom waters of upper Budd Inlet, 17-18 August 1977.



Reference: Data from Alan, R. (24 September 1987, personal communication).

Figure 13. Monthly variation in dissolved oxygen (DO) measured at the five LOTT WWTP monitoring stations in 1986.

differed. Oxygen depletion was most severe at the Capitol Lake outfall where oxygen levels 2.0 ft above the sediment were less than 4.0 mg/L. Near-bottom oxygen levels below the 5.0 mg/L Class B water quality standard occurred consistently at the other stations.

Dissolved oxygen data collected between 1982 and 1986 at Stations BUD002 and BUD005 followed a similar pattern, although levels at Station BUD005 were generally higher than at Station BUD002 (Figure 14). Mean oxygen levels in the surface water were usually 1.0-3.0 mg/L higher than mean bottom water concentrations. In late summer, the mean bottom water concentration over the 5-yr period was less than the 5.0 mg/L Class B dissolved oxygen standard. On two occasions, values below 3.0 mg/L were observed.

The remaining dissolved oxygen data were collected by the Port of Olympia at the East Bay Marina (Egge, E., 25 January 1987, personal communication). These data were collected using a Leeds and Northrup model 7931 dissolved oxygen probe or by Winkler titrations of water samples. Values generated with the Leeds and Northrup probe frequently varied by 30-50 percent from the Winkler values despite the probe's stated accuracy of $\pm$ 1 percent. Because data generated with Winkler titrations are considered more reliable than data generate with probes, only these data were reviewed for this report.

The East Bay Marina maintains an aeration system with 18 aerators located throughout the marina docks (Egge, E., 1 February 1988, personal communication). Operation of this system is supposed to be based on dissolved oxygen fluctuations. When dissolved oxygen is less than 6 mg/L for over 6 h (consecutive), the aerators are turned on. They remain on until dissolved oxygen levels exceed 6 mg/L. Because the oxygen probe was not reliable, other criteria such as wind and length of sunny periods are often used in conjunction with oxygen concentration to determine operation of the aerators (Arden, H., 11 February 1988, personal communication). Diver observations confirmed that use of the aeration system does not cause sediment resuspension (Arden, H., 10 February 1988, personal communication). Dissolved oxygen measurements are taken at two locations in the East Bay Marina: at the end of the transient moorage dock (Dock A; minimum depth 4 m)

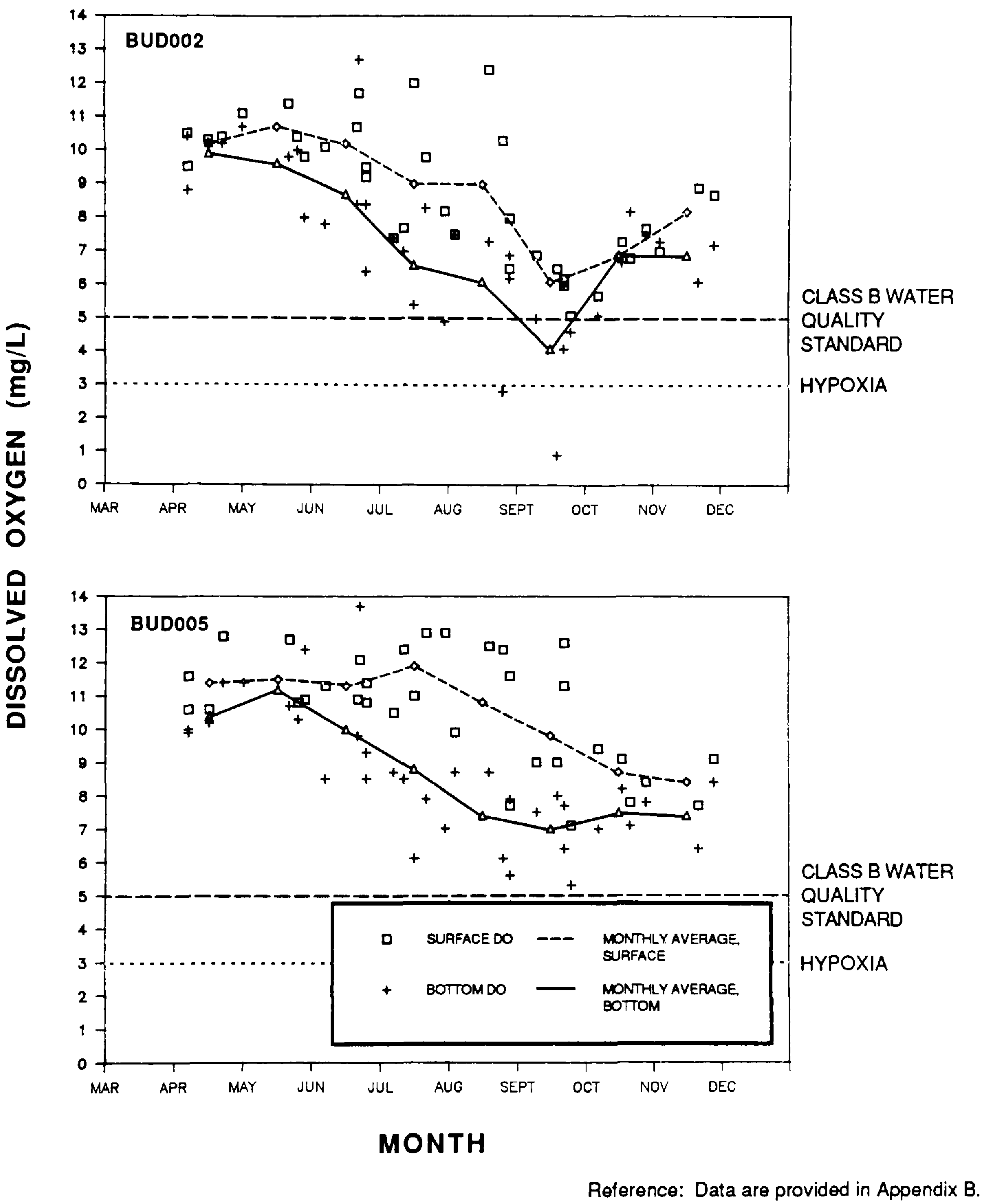


Figure 14. Temporal variation in dissolved oxygen (DO) at Ecology ambient water quality monitoring stations BUD002 and BUD005, 1982-1986.

and at the base of Dock J (minimum depth 2.7 m). The measurements are taken almost daily from Monday to Friday. Dissolved oxygen declines throughout the summer, and the aeration system is unable to prevent dissolved oxygen from declining below the 5 mg/L Class B water quality standard (Figure 15). Bottom water dissolved oxygen at Station J is frequently hypoxic in August and September (i.e., less than 3.0 mg/L).

It was noted by Port of Olympia personnel that the aeration system is used less when oxygen levels are determined with Winkler titrations than when oxygen is measured with the probe (Egge, E., 1 February 1988, personal communication). Winkler titrations are collected near the water surface, in the middle of the water column, and at the bottom where the probe is situated. Operation of the aeration system is therefore not always based on oxygen levels in the bottom water layer, which are usually lowest due to SOD. Reoxygenation of the bottom water might occur more readily if the data used to determine use of the aeration system were obtained from the bottom of the water column rather than the middle or surface of the water column.

Qualitative information on low dissolved oxygen levels was provided by the Salmon Culture Division of the Department of Fisheries (Peck, L., 18 March 1988, personal communication). During the past 5 yr, the Salmon Culture Division has been actively involved with trapping adult chinook salmon at the Fourth Street bridge from mid-August to mid- or late-September. During this operation, dissolved oxygen levels have been measured at 2.5 mg/L and below. The most severe levels of dissolved oxygen occurred during high slack tides, and it was observed that levels could vary dramatically within any 24-h period.

Dynamics of Dissolved Oxygen in Budd Inlet--

The comprehensive water quality study conducted by URS (1986) in Budd Inlet was designed to determine the cause of oxygen depletion, and to identify measures that might alleviate the problem. The following discussion summarizes some of their findings.

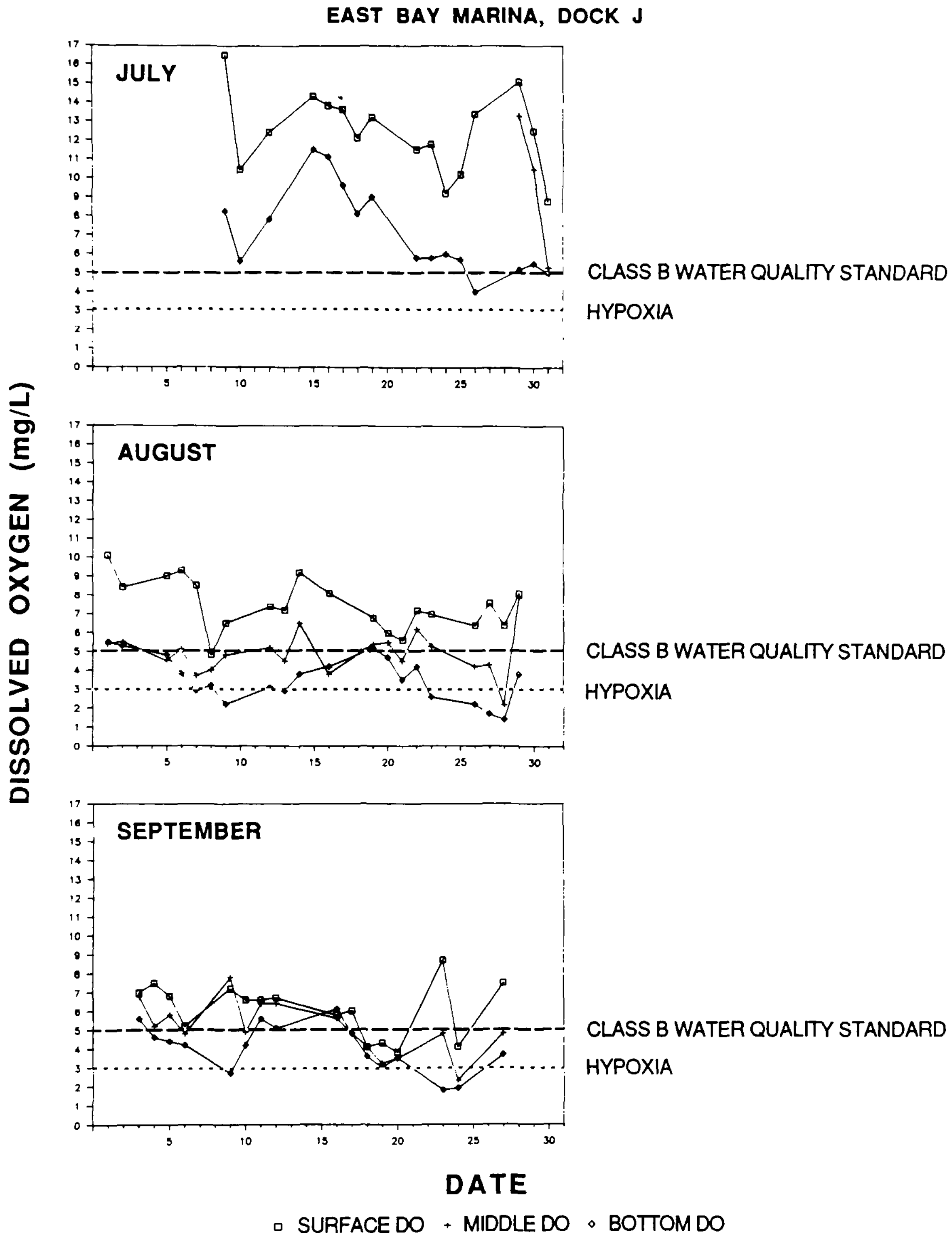


Figure 15. Daily variation in dissolved oxygen (DO) in the surface, middle, and bottom waters near the East Bay Marina, summer 1986.

Data were generated from two intensive surveys and from field-verified steady-state and dynamic models. In September 1984 and May 1985, dissolved oxygen was measured at eight stations distributed throughout the inlet (see Figure 7). These data were used to calibrate the models. In September 1984, oxygen levels were extremely high near the water surface (18-20 mg/L) and low near the bottom (<5 mg/L), indicating a highly stratified water column. A dense dinoflagellate bloom was observed in the surface waters. During this intensive survey, a storm moved through the study area and the accompanying winds disrupted the vertical stratification of the water column. This storm caused a change in oxygen concentrations in the water column, and bottom concentration increased from 4 to 5 mg/L while surface concentration decreased from 20 to 9 mg/L. Oxygen concentrations the following May 1985 ranged from a near-surface high of approximately 15 mg/L, to a near-bottom low of about 9 mg/L. An algal bloom composed of diatoms was observed.

Both a steady-state and a dynamic water quality model were fit to Budd Inlet to determine the combinations of LOTT WWTP discharge volume, effluent nutrient removal, and outfall location that would minimize the dissolved oxygen problem. The biochemical processes that were incorporated into the dynamic model included SOD, BOD_5, chlorophyll a, phaeopigments, fecal pellets, organic nitrogen, ammonium, nitrite, and nitrate. Physical processes that were incorporated included wind; waterbody geometry; time-varying boundary condition data; source, sink, and reaction rates for each of the constituents being simulated; and hydraulic and physical variables. The dissolved oxygen simulations were limited to use of the May 1985 data because no quantitative dynamic model of the September 1984 dinoflagellate bloom exists. However, the effect of nutrient addition on the strength and duration of the September 1984 dinoflagellate bloom may be greater than the effect of nutrient addition on the May 1985 diatom bloom. Diatom blooms are limited by available light, whereas dinoflagellates have the ability to grow at lower light levels and to migrate to their optimum light level. Because dinoflagellates also have the ability to take up nutrients during the day and night, the magnitude of the bloom would likely be nutrient-limited rather than light-limited. Because of the readily available nutrient supply from LOTT, dinoflagellate blooms may exist for extended periods of time, and may result in severe oxygen depletion. The duration of these blooms is probably controlled by meterological and hydrodynamic conditions that disrupt the vertical stratification of the water column and the vertical migrations of the dinoflagellates. The reader is directed to URS (1986) for details of the model and calibration procedures.

Dynamic modeling results showed that the spring diatom bloom is enhanced at least 30 percent in the inner portions of Budd Inlet by the existing nutrient loadings from the LOTT WWTP. However, those model results were not supported by data collected at the WDNR Marine Station, which indicated that the concentration of nitrogen is not a limiting nutrient in the spring. The model indicated that aside from elimination of this discharge, the best option to reduce the diatom blooms is to remove nutrients from the effluent. Relocation of the LOTT discharge pipe away from the inner inlet would reduce the strength of the bloom. But, regardless of the discharge location, the bloom without nutrient removal would be 30-50 percent stronger than the bloom with nutrient removal. Predicted SOD was directly related to diatom production. It was predicted to be 10-15 percent greater in the inner inlet without nutrient removal than with nutrient removal.

Summary and Recommendations--

Water quality conditions in Puget Sound in late summer and early fall aggravate the oxygen depletion problem. Flushing rates are lower than in the spring, as are dissolved oxygen concentrations in the water that flushes Budd Inlet. Water temperature and SOD are higher in late summer and early fall than in spring. Coupled with blooms of vertically migrating dinoflagellates, oxygen depletion becomes a severe problem at this time of the year.

Recommendations for changes to the LOTT discharge configuration were developed based on the conclusion that the presence and persistence of dinoflagellate blooms in late summer and early fall were the probable cause of the low dissolved oxygen problems. Under state water quality standards, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by anthropogenic activities. The results of these modeling efforts indicate that this standard is frequently exceeded. Under recommendations from Ecology, URS (1986) concluded that a maximum algal bloom enhancement of 10 percent above the no-discharge scenario would be acceptable, and would reduce the potential magnitude of oxygen depletion during the late summer and early fall to acceptable levels. To achieve these levels, URS (1986) recommended that at the present outfall location, the average wet weather flow (AWWF) of 16.3 MGD be maintained in addition to removal of at least 90 percent of the nutrients from April through October. For any outfall location within the inlet, or for a flow increase of up to 22 MGD (AWWF). URS (1986) recommended at least 90 percent nutrient removal.

MICROBIAL CONTAMINATION

General Overview

Microbial contamination of water and shellfish has long been considered a public health risk. Swimming in water or consuming shellfish that are contaminated with enteric bacteria and viruses can result in gastroenteritis, nausea, diarrhea, typhoid fever, cholera, and hepatitis. Based on past research, the bacteria of primary concern are enteric pathogens excreted in human and animal feces, such as *Salmonella* spp., *Yersini enterocolitica*, *Campylobacter fetus*, *Vibrio parahaemolyticus*, and *Vibrio cholerae* (Munger et al. 1979).

The current Washington State standards for commercial shellfish harvesting and recreational use are based on the concentration of fecal coliform bacteria in water and shellfish tissue [Washington Administration Code (WAC) 173-201-045; Lilja, J., 6 June 1985, personal communication]. The Washington State fecal coliform bacteria standard for waters used for harvesting shellfish is the same as the standards adopted by the Interstate Shellfish Sanitation Conference (Lilja, J., 25 March 1988, personal communication). Because shell fish feed on small particles filtered from the water, these standards are stricter than the U.S. EPA standards for primary recreational waters. Some free-living bacteria and viruses that are attached to particles become concentrated in the gut of filter-feeding bivalves (Colwell and Liston 1960; Kelly et al. 1960; Mitchell et al. 1966).

Because there are no documented cases of human illness resulting from eating commercially harvested shellfish from the State of Washington, the standards for allowable concentrations of fecal coliform bacteria in the water column and shellfish tissue are considered conservative (Lilja, J., 6 June 1985, personal communication).

Data Synthesis

Choice of Indicators--

Because fecal coliform bacteria have been widely used as a microbial indicator of water quality, the following analysis is based on available data for fecal coliform bacteria concentrations in Budd Inlet. Data on microbial indicators other than fecal coliform bacteria are not available for the project area. However, U.S. EPA has proposed the use of enterococci bacteria in place of fecal coliform bacteria because a close correspondence in the distributions of enterococci bacteria and pathogenic microbes has been found, and enterococci are associated with human illness (e.g., gastroenteritis).

Available Data and Station Locations--

Bacteriological measurements in Budd Inlet have been made primarily in a comprehensive study of circulation and water quality in Budd Inlet (URS 1986), in the ambient water quality monitoring program conducted by Ecology (U.S. EPA, 7 January 1988, personal communication), and by the City of Olympia (Alan, R., 24 September 1987, personal communication). Sampling stations are depicted in Figure 7. Other data were supplied for Boston Harbor (R.W. Beck and Associates 1986), WWTP (Kendra, W. and T. Determan, 6 November 1985, personal communication), and the East Bay Marina (Pierce, R., 22 October 1987, personal communication). Data were also available for shellfish collected near Priest Point (Armstrong, J., 17 November 1987, personal communication). Data on microbial contamination from nonpoint sources (e.g., live-aboards in Olympia marinas, general boating activities in Budd Inlet, hobby farms, failing septic systems) were not available.

Reference Data--

Reference data are based on Washington State standards for fecal coliform bacteria concentrations in water [Ecology and Washington Department of Social and Health Services (DSHS)] and in shellfish (DSHS). Ecology standards for fecal coliform bacteria for the waters of the project area are listed below:

- Class A Marine - "...shall not exceed a geometric mean value of 14 organisms/100 mL with not more than 10 percent of samples exceeding 43 organisms/100 mL" [WAC 173-201-045(2)-(c)(i)(B)]

- Class B Marine - "...shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10 percent of samples exceeding 200 organisms/100 ml" [WAC 173-201-045(3)-(c)(i)(B)].

The maximum allowable fecal coliform bacteria levels for commercial shellfish harvesting areas certified by DSHS are listed below:

- Shellfish tissue - 230 organisms/100 g (U.S. Food and Drug Administration guidelines)

- Water - A median of 14 organisms/100 mL with not more than 10 percent of the samples exceeding 43 organisms/100 mL (note: this is virtually identical to the standard for Class A marine waters; see above).

Elevation Above Reference (EAR) Analysis--

The geometric means for fecal coliform bacteria concentrations were calculated from all available information. Fecal coliform data from Ecology Stations BUD002 and BUD005 were averaged over 1982-1986. Data from five stations sampled by the City of Olympia were averaged over 1986. Approximately half of the 57 stations surveyed for the URS (1986) report were sampled once while the remaining stations were sampled twice. The data are reported as averages when possible. All data from Boston Harbor were averaged because specific sampling locations were unclear. Data from individual sites along the shores of Budd Inlet (URS 1986) were grouped by area to obtain a sufficient sample size for calculation of a geometric mean.

EAR values were calculated by dividing the geometric mean bacterial concentration by the appropriate standard stipulated in WAC 173-201-045 (Table 7). For example, the geometric mean concentration at Station BUD005 (located near Olympia Shoals in Class A marine waters) was 2 organisms/100 mL and the calculated EAR is 0.14 based on the Class A marine water standard (see Table 7). In addition, none of the samples exceeded this standard of a maximum of 43 organisms/100 mL. EAR values were calculated in a similar manner for the remaining data (Figure 16, Table 7). Note that the water quality standards differ between Class A and Class B marine waters.

EAR values greater than 1 indicate that the geometric mean concentration exceeded the standard. EAR values below 1 indicate that the geometric mean concentration was below the water quality standard. The calculated EAR values (see Table 7) indicate that water quality standards were not exceeded at the Ecology Ambient Water Quality Monitoring Program stations (BUD002 and BUD005), nor were they exceeded off the LOTT WWTP outfalls. Moxlie Creek was the only site to exceed Class B water quality standards (EAR=21.9). Class A standards were exceeded near the Tamoshan and Beverly Beach WWTP, in Boston Harbor, in Ellis Cove, south of the Seashore Villa WWTP, off Athens Beach, north of Butler Cove, and in Butler Cove. More than 10 percent of the samples collected between Priest Point and Seashore Villa, in Boston Harbor, and off the Tamoshan WWTP exceeded standards.

TABLE 7. FECAL COLIFORM BACTERIA DATA AND MEAN EAR VALUES FOR BUDD INLET, 1982-1987[a]

Area	Number of Stations	Number of Samples per Station	Fecal Coliform Bacteria/100mL Minimum Value	Fecal Coliform Bacteria/100mL Maximum Value	Fecal Coliform Bacteria/100mL Geometric Mean	EAR	Marine Water Use Classification[b]	Reference
West Bay offshore	1	36	3	70	16	0.16	Class B	U.S. EPA (7 January 1988)[c]
Western shoreline, West Bay	6	1	0	25	4	0.04	Class B	URS (1986)
Capitol Lake outfall	1	14	2	60	13	0.13	Class B	Alan (24 September 1987)[c]
Fiddlehead Marina	1	14	1	60	9	0.09	Class B	Alan (24 September 1987)[c]
Near LOTT 30-in outfall	3	Varied	0	33	6	0.06	Class B	URS (1986), Alan (24 September 1987)[c]
East Bay Marina	3	Varied	1	23	5	0.05	Class B	Alan (24 September 1987)[c], Pierce (22 October 1987)[c]
Moxlie Creek	1	2	2,000	2,400	2,190	21.9[d]	Class B	URS (1986)
Eastern shoreline, East Bay	5	1 or 2	2	870	59	0.59[d]	Class B	URS (1986), Pierce (22 October 1987)[c]
Ellis Cove	2	2	75	1,230	334	23.9[d]	Class A	URS (1986)
Priest Point	1	7	18	7,000	206	0.90[e]	Shellfish	Armstrong (17 November 1987)[c]
Priest Point to Seashore Villa	8	1 or 2	0	2,000	34	2.5	Class A	URS (1986)
Seashore Villa	7	1-3	0	920	9	0.7[d]	Class A	URS (1986), Kendra and Determan (6 November 1985)[c]
Gull Harbor to Dofflemeyer Point	6	1 or 2	0	2,400	11	0.8[d]	Class A	URS (1986)
Boston Harbor	28	1 or 2	23	2,400	151	10.8[e]	Class A	URS (1986) R.W. Beck and Assoc. (1986)
Cooper Point to Tamoshan	3	1	0	1,020	10	0.72[d]	Class A	URS (1986)
Tamoshan	6	1 or 2	0	2,000	28	2.04[e]	Class A	URS (1986), Kendra and Determan (6 November 1985)[c]
Beverly Beach	2	1 or 4	0	1,141	19	1.36[d]	Class A	URS (1986), Kendra and Determan (6 November 1985)[c]

TABLE 7. (Continued)

Area	Number of Stations	Number of Samples per Station	Fecal Coliform Bacteria/100mL Minimum Value	Maximum Value	Geometric Mean	EAR	Marine Water Use Classification[b]	Reference
Athens Beach	3	1 or 2	0	2,400	19	1.35[d]	Class A	URS (1986)
Tykle Cove	2	1	0	0	0	0[d]	Class A	URS (1986)
Olympia Shoals	1	36	1	26	2	0.15	Class A	U.S. EPA (7 January 1988)[c]
Between Tykle and Butler Coves	1	2	310	370	339	24.2[c]	Class A	URS (1986)
Butler Cove	3	2	0	800	15	1.11[c]	Class A	URS (1986)

[a] All entries are for fecal coliform bacteria concentrations in water samples except for the Priest Point entry, which is for fecal coliform bacteria concentrations in shellfish.

[b] Washington State standards for fecal coliform bacteria in the water column are defined in the text.

[c] Personal communication.

[d] Inadequate number of samples to determine if 10 percent of the samples exceeded standard.

[e] More than 10 percent of the samples exceeded Washington State standards.

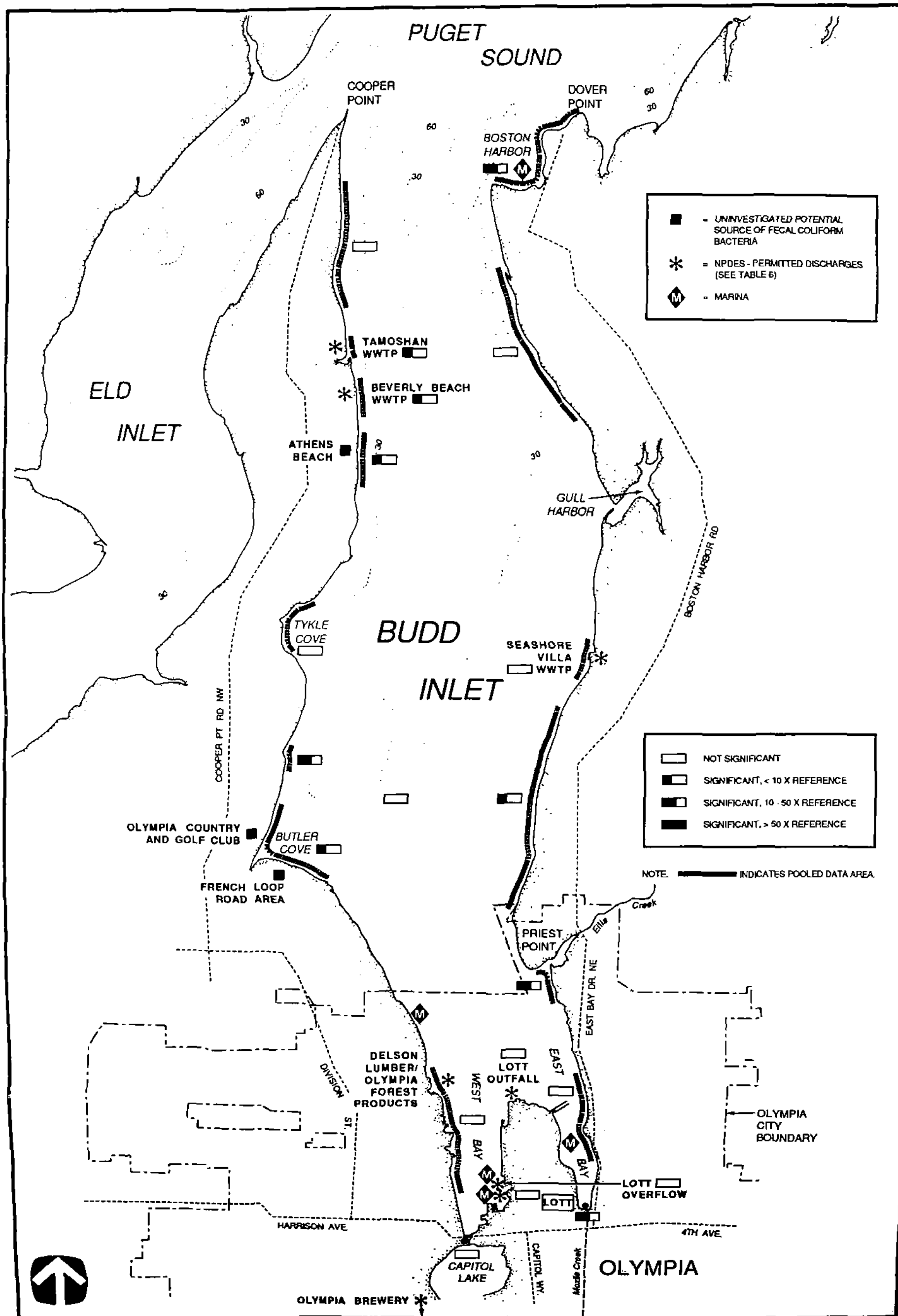


Figure 16. EAR values for concentrations of fecal coliform bacteria in water samples from Budd Inlet.

Additional fecal coliform bacteria data were summarized by URS (1986). These data were collected at five point sources on five occasions. The San Francisco storm drain and Ellis Creek contributed less than 3 percent of the fecal coliform bacteria loading to Budd Inlet over the five sampling periods. Moxlie Creek contributed the majority of the bacteria loading in September 1984, April 1985, and June 1985. The major source of fecal coliform bacteria in February 1985 was Capitol Lake, and the major source in May 1985 was the LOTT WWTP.

Nonpoint sources of microbial contamination in Budd Inlet include contributions from surface runoff from hobby farms, live-aboards in the five Olympia marinas, and general boating activity. These contributions have not been qualitatively or quantitatively identified.

CHEMICAL CONTAMINATION OF SEDIMENTS AND BIOTA

Chemical contamination of sediments and biota are discussed in the following sections. The paucity of data precludes an overview of temporal trends and detailed spatial trends. For selected indicators (i.e., sediment contamination, bioaccumulation), data from recent studies were available to help describe conditions.

Sediment Contamination

The physical and chemical characteristics of sediments in the Budd Inlet study area are reviewed in the following sections.

General Overview--

Conventional Variables--Data on sediment total volatile solids (TVS) and total organic carbon (TOC) are summarized in Figures 17 and 18. The data are too limited to provide detailed characterization of any area in Budd Inlet. Recently collected information is available only near the Port of Olympia peninsula (in East and West Bays). Older data from Malins et al. (1980) were collected from three stations in Budd Inlet (i.e., the south end entrance channel, Priest Point, and Olympia Shoals). These data indicate

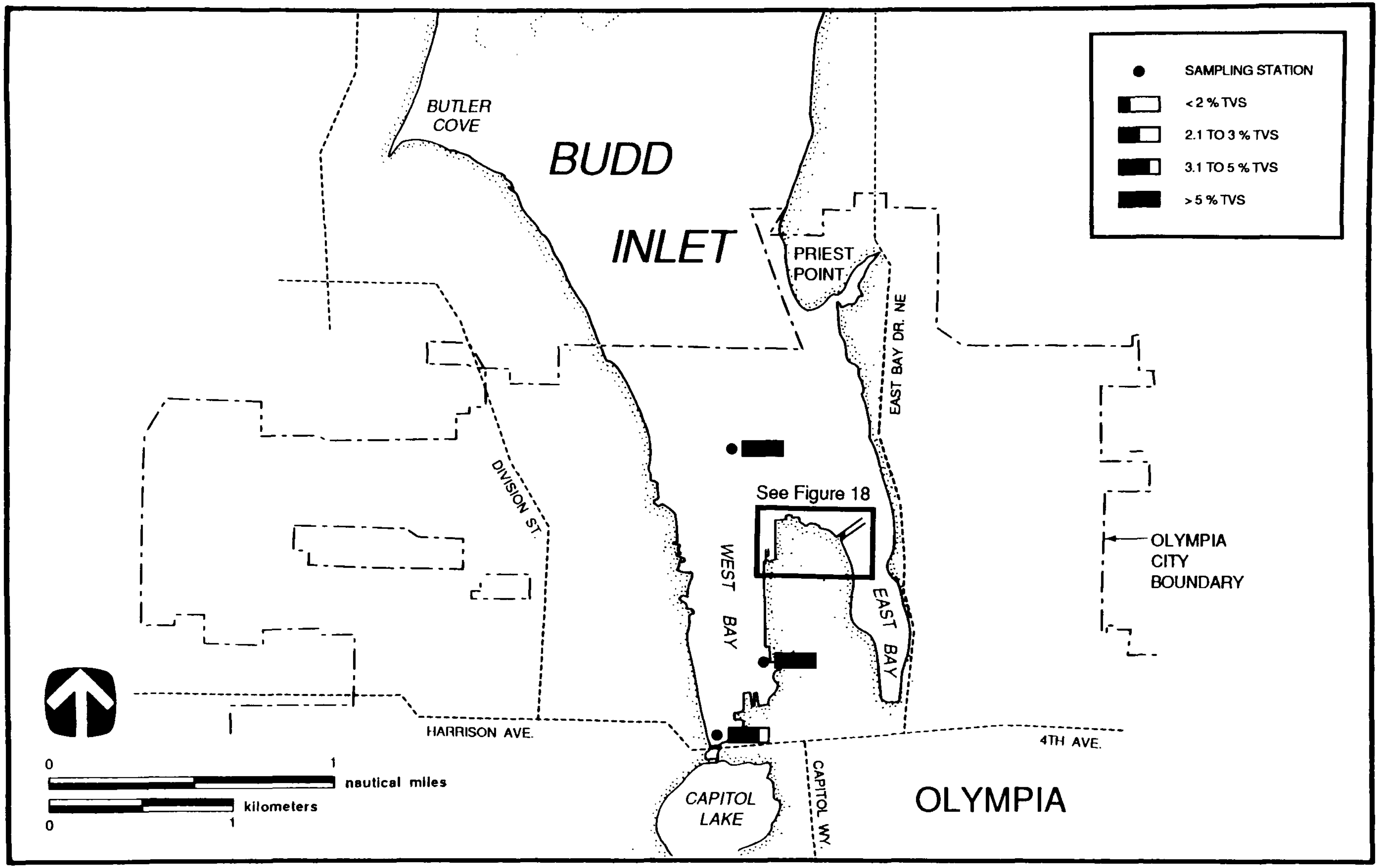


Figure 17. Percent total volatile solids (TVS) measured in sediments at stations in the East and West Bays of Budd Inlet.

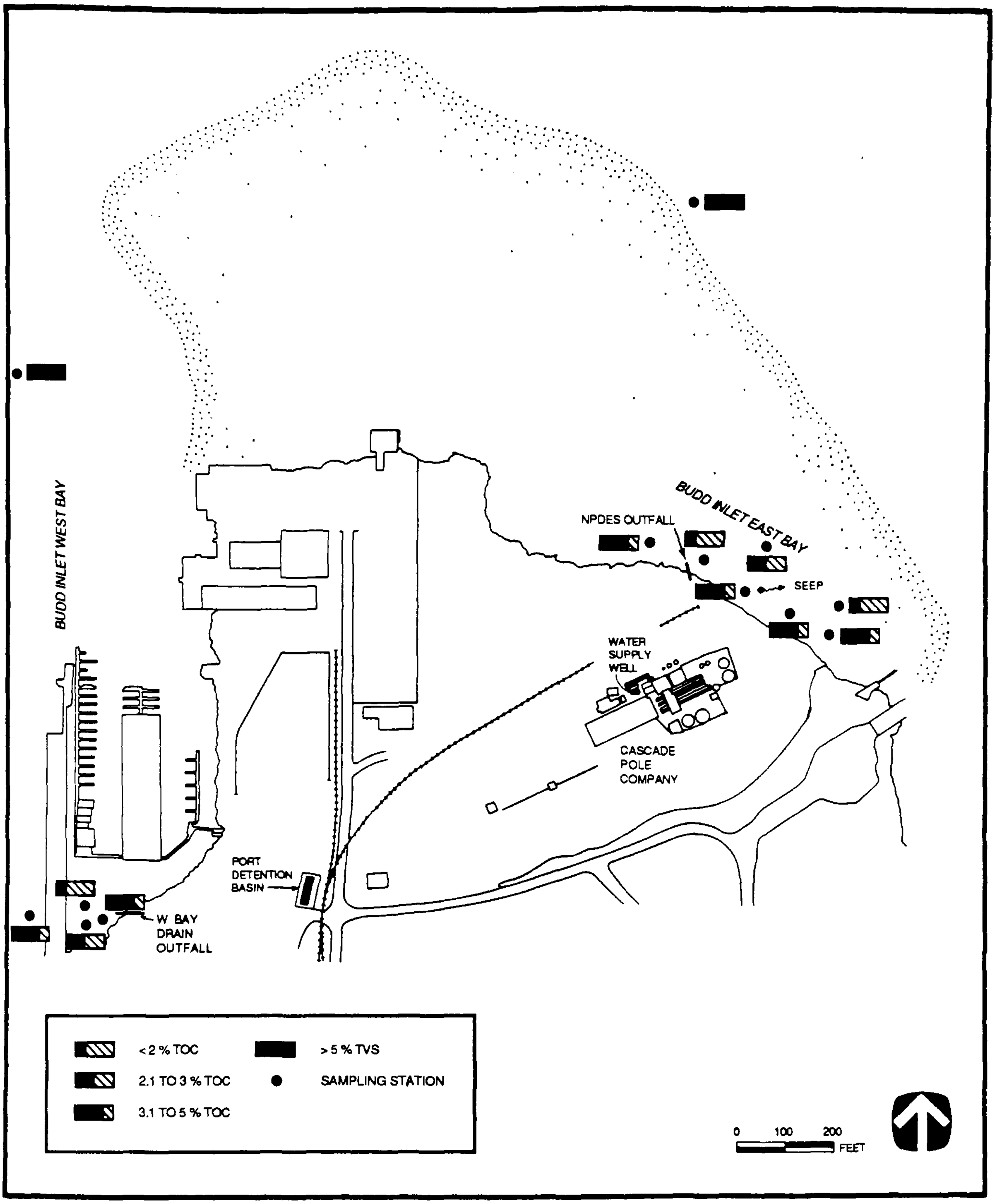


Figure 18. Percent total volatile solids (TVS) and percent total organic carbon (TOC) measured in sediments at stations in the East and West Bays of Budd Inlet.

that TOC values at these stations have been similar to TOC values in recent years. The most recent data on sediment grain size were collected by Malins et al. (1980) and Westley et al. (1975). Data from Westley et al. (1975) indicate that intertidal and subtidal sediments in the southern end of Budd Inlet are largely silts and clays (approximately 91 percent). TVS content of these sediments was approximately 10 percent. Data from Malins et al. (1980) indicate that the subtidal sediments are primarily silt and clay. The area near Priest Point appears to have a higher sand content than the two other sampled areas. In general, the shallower areas are expected to have coarser sediments and lower TOC than sediments in deeper areas. Protected backwater areas and slips along the waterfront would be expected to accumulate fine-grained, TOC-enriched sediments, but supporting data are very limited. The available data indicate that lower concentrations of TOC exist in intertidal sediments than in subtidal sediments, and that sediments near the northern end of the Port of Olympia peninsula have TOC concentrations similar to concentrations in other areas of Puget Sound (see Figures 17 and 18). No TOC data are available for any other areas of Budd Inlet.

Toxic Chemicals--Past studies of toxic chemicals in the sediments of Budd Inlet have been limited. Studies conducted prior to 1982 are considered as historical studies for several reasons. First, the primary objective of this report is to document current conditions in Budd Inlet. Second, the LOTT WWTP began operation in August 1982. Changes in outfall location and treatment efficiency could potentially alter contaminant loading. Third, the precision of analytical methods has increased in the last 5 yr and data comparable to data generated today were generally not available prior to 1982. Only three recent studies (Alan, R., 24 September 1987, personal communication; Johnson, A., 22 July 1985, personal communication; Norton, D., 5 February 1986, personal communication), discussed below, were of acceptable quality to be used in the evaluation of sediment chemistry. The geographic coverage of these studies is limited to the southern end of Budd Inlet. Most areas of Budd Inlet, particularly north of Priest Point, have not been sampled for sediment chemistry (Figures 19 and 20).

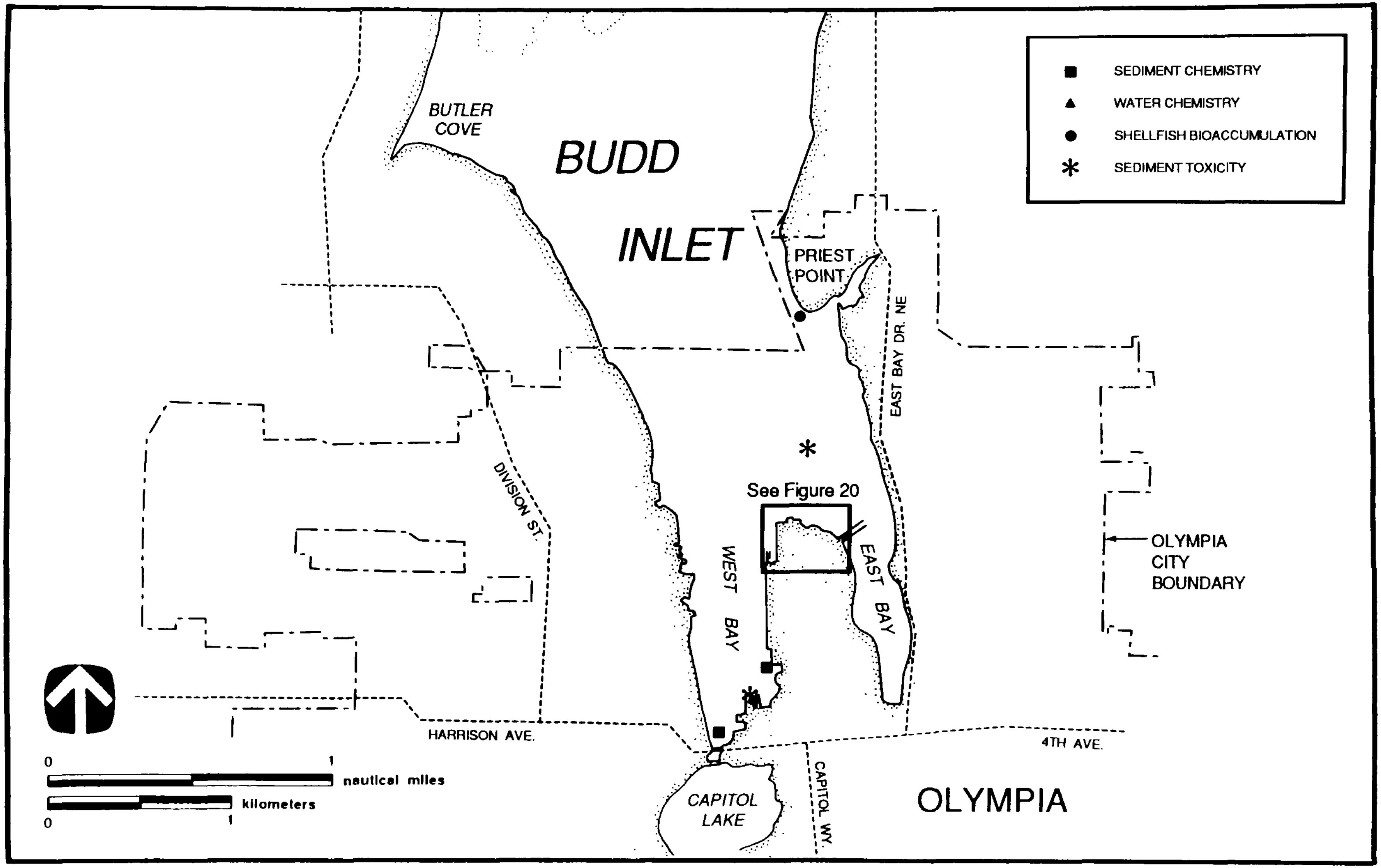


Figure 19. Locations of sediment chemistry, water chemistry, shellfish bioaccumulation, and sediment toxicity sampling stations in the East and West Bays of Budd Inlet, 1982-1987.

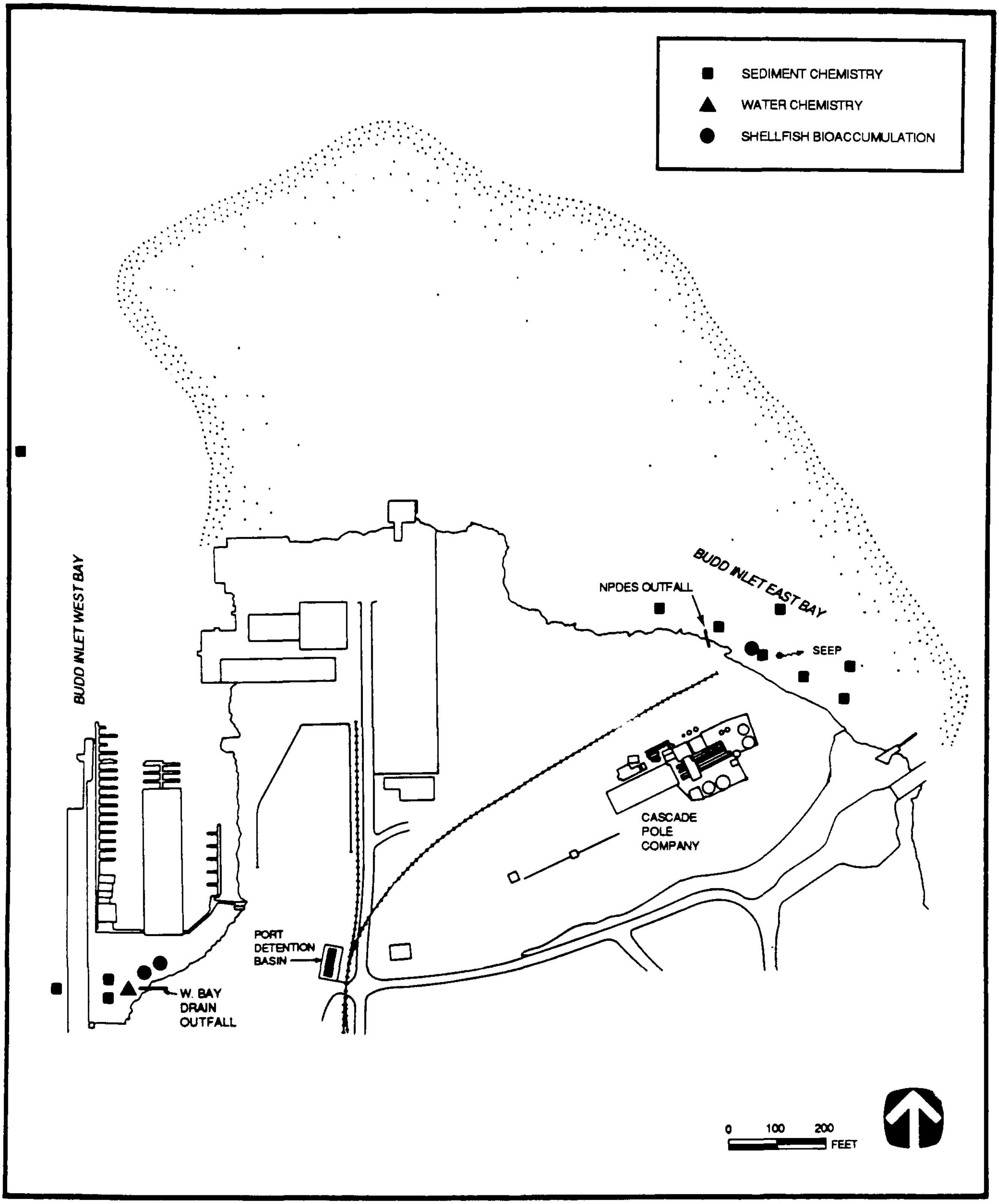


Figure 20. Locations of sediment chemistry, water chemistry, and shellfish bioaccumulation sampling stations at the north end of the Port of Olympia peninsula.

Limited sampling for sediment chemistry was conducted at three stations in Budd Inlet by Malins et al. (1980) as part of a larger study that documented the occurrence and fluxes of contaminants of special concern in central and southern Puget Sound. Budd Inlet stations were located at the entrance channel (southern end of inlet; Station 1), off Priest Point (Station 2), and at Olympia Shoals (Station 3). Sediment samples at these three stations were analyzed for petroleum hydrocarbons, PCBs, chlorinated pesticides, other chlorinated organic compounds, and metals. Results of the analyses indicated that Station 2 was the least impacted of the three stations and exhibited low concentrations of most chemicals. Stations 1 and 3 exhibited higher concentrations of most chemicals, particularly arsenic, copper, and HPAH. This was the only study that collected sediment chemistry samples north of Priest Point (Station 3). Considerable additional sampling is needed in this area to determine the extent of the chemical contamination.

The most recent available data indicate that the East Bay area near the Cascade Pole Company facility, and the area near the West Bay storm drain have elevated chemical concentrations in sediments. The number of chemicals for which analyses were conducted in both of these areas was fewer than that in many other areas of Puget Sound (e.g., Elliott and Commencement Bays), so the full extent of any possible contamination cannot be established using only the presently available data. The data from both areas indicate that the problems are associated primarily with organic chemicals, and that concentrations are among the highest observed in many other areas of Puget Sound (e.g., Commencement and Elliott Bays) (Tetra Tech 1985a,b). From the limited data available, it appears that concentrations of metals in sediments near East and West Bays are similar to other areas of Puget Sound (Tetra Tech 1985a,b). However, the area near the Fiddlehead Marina exhibited high concentrations of cadmium in 1986 (Alan, R., 24 September 1987, personal communication) which may indicate a potential problem exists there.

Available Data--A detailed analysis of sediment conditions between 1985 and 1986 was developed primarily from data reported in the following documents:

- Mr. R. Alan (24 September 1987, personal communication) and Mr. F. Kessler (18 December 1987, personal communication)-data from the LOTT WWTP Receiving Water Sampling Program performed in 1986

- Mr. A. Johnson (22 July 1985, personal communication) - a report on the nature and extent of creosote and pentachlorophenol in intertidal areas near Cascade Pole wood-treating facility

- Mr. D. Norton (5 February 1986, personal communication) - a report presenting results of U.S. EPA priority pollutant analyses on water, sediment, and clam samples collected in lower Budd Inlet near Cascade Pole wood-treating facility.

In addition to these data, 11 U.S. Army Corps of Engineers dredging permits have been issued in the vicinity of Budd Inlet since 1980. Information on these permits, which include identification of contaminated sediments that were dredged from Budd Inlet, is summarized in Appendix C.

These studies represent all recent data that provide information on at least one of the indicator chemicals. Field collections of the selected data were conducted in 1985. In general, data from these studies were supported by quality assurance/quality control (QA/QC) programs, and the methods used to measure contaminant concentrations were appropriate. Results of the data evaluations for all studies, and a summary of the sampling intensity and variables measured from these accepted documents are shown in Appendix A, Tables A-3 and A-7.

Data Synthesis--

Choice of Indicators--About 50 organic compounds and metals have been measured in sediments collected in Budd Inlet. These chemicals include many of the trace metals that are considered toxic, and representative compounds from nearly all the major types of toxic organic substances (see Table 2). Many of the chemicals were detected at levels near the limits of the analytical procedures, and were found in relatively few of the sediment samples. Also, in some of the studies, substances were not measured accurately or with sufficient sensitivity. Therefore, only data for selected chemicals are discussed below. The following chemical indicators were used to establish the level of sediment contamination:

- Sum of LPAH
- Sum of HPAH
- Sum of concentrations of copper, lead, and zinc
- Cadmium
- Arsenic.

Concentrations of related substances were summed when the individual chemicals were found to strongly covary in their distributions in the sediments. The composite indicators (i.e., LPAH, HPAH, sum of copper, of lead, and of zinc) were found to be reasonable surrogates for a broad range of individual substances with similar distributions in the system. They also represent a range of sources and transport mechanisms. Finally, the composite indicators are known to cause toxic responses in organisms under laboratory conditions.

Table 8 shows the data limitations of the selected studies discussed above. Not all composite indicator substances were measured at all stations sampled during these studies.

Station Locations--Station locations for the selected studies are given in Figures 19 and 20. A nonuniform allocation of sampling efforts is obvious. Most areas of Budd Inlet have received almost no study, while other areas (e.g., East and West Bays) have been sampled with greater intensity. Such spatial heterogeneity makes it difficult to distinguish spatial trends in contaminant concentrations.

TABLE 8. DATA LIMITATIONS OF SELECTED STUDIES USED IN DETAILED ANALYSIS OF SEDIMENT CHEMISTRY

Study	Conventionals		Chemicals Analyzed				
	TOC	TVS	LPAH	HPAH	PCB	Cu+Pb+Zn	As
Alan (24 September 1987)[a]	No[b]	Yes[c]	NA[d]	NA	NA	Acc[e]	NA
Johnson (22 July 1985)[a]	Yes	No	Acc	Acc	NA	NA (Copper)	Acc
Norton (5 February 1986)[a]	Yes	No	Acc	Acc	NA	NA	NA

[a] Personal communication.

[b] No = Not sampled or analyzed.

[c] Yes = Sampled and analyzed.

[d] NA = Not Analyzed.

[e] Acc = Acceptable data.

Reference Area Data--The ranges of sediment concentrations of metals and organic compounds for up to nine Puget Sound reference areas are summarized in Tables 9 and 10. It is assumed that this range of reference concentrations provides a reasonable measure of the variability of concentrations in relatively uncontaminated sediments (Tetra Tech 1985b,c). The full range of Puget Sound reference area data (collected from 1979 to 1985) is used to determine whether EAR values are significant (i.e., whether the contamination exceeds all Puget Sound reference conditions). This approach was successfully used to evaluate EAR significance in Elliott Bay and Everett Harbor (Tetra Tech 1985b,c).

The reference area data used to calculate EAR values were a subset of the full Puget Sound reference data. Data from six Carr Inlet stations sampled in 1984 were averaged and used to calculate EAR conditions for the following reasons:

- The most complete reference data set is available for Carr Inlet and it includes synoptic data for metals, organic compounds, grain size, organic carbon, and other conventional variables

- The lowest reference detection limits for most substances of concern in Puget Sound embayments are available for Carr Inlet

- EAR values for other urban embayments (e.g., Elliott Bay, Everett Harbor, Commencement Bay) have been calculated using the data, and therefore, will be directly comparable with EAR values for Budd Inlet

- Chemical concentrations for samples analyzed from Carr Inlet were comparable to or lower than concentrations in other reference areas, and therefore, appear to be reasonably representative of Puget Sound reference conditions.

TABLE 9. SUMMARY OF METAL CONCENTRATIONS IN SEDIMENTS FROM PUGET SOUND REFERENCE AREAS

	Range (mg/kg dry wt)	Mean (mg/kg dry wt)	Detection Frequency	Reference Sites[a]
Antimony	U 0.1[b] - 1.7	0.32[c] - 0.38[d]	12/32	1,2,3,4,7,8,9
Arsenic	1.9 - 17	7.2	34/34	1,2,3,4,7,8,9
Beryllium	0.07 - 5.5	2.3	26/26	1,2,3,4,5,9
Barium	5.6 - 7.8	6.9	4/4	1
Cadmium	0.1 - 1.9	0.67	24/24	1,2,3,4,6,9
Chromium	9.6 - 130	54	38/38	1-9
Copper	5 - 74	32	28/28	1,2,3,4,5,6,9
Lead	U 0.1 - 24	9.8[c] - 9.8[d]	21/28	1,2,3,4,5,6,9
Mercury	0.01 - 0.28	0.08	38/38	1-9
Nickel	4 - 47	28	26/26	1,2,3,4,5,9
Selenium	U 0.1 - 1.0	0.36[c] - 0.62[d]	16/24	1,2,3,4,6,9
Silver	0.02 - 3.3	1.2	26/26	1,2,3,4,5,9
Thallium	U 0.1 - 0.2	0.05[c] - 0.12[d]	8/22	1,2,3,4,9
Zinc	15 - 100	62	26/26	1,2,3,4,5,9

[a] Reference sites: 1. Carr Inlet 2. Samish Bay 3. Dabob Bay 4. Case Inlet 5. Port Madison 6. Port Susan 7. Nisqually Delta 8. Hood Canal 9. Sequim Bay

[b] U: Undetected at the method detection limit shown.

[c] Mean calculated using 0.00 for undetected values.

[d] Mean calculated using the reported detection limit for undetected values.

Reference:

(Site 1) Tetra Tech (1985a); Crecelius et al. (1975).
(Site 2 and 3) Battelle Northwest (1983).
(Site 4) Crecelius et al. (1975); Malins et al. (1980).
(Site 5) Malins et al. (1980).
(Site 6) Malins (1981).
(Site 7) Crecelius et al. (1975).
(Site 8) Crecellius et al. (1975).
(Site 9) Battelle Northwest (1983).

TABLE 10. SUMMARY OF ORGANIC COMPOUND CONCENTRATIONS IN SEDIMENTS FROM PUGET SOUND REFERENCE AREAS

Substance		Range (ug/kg dry wt)	Mean (ug/kg dry wt)	Detection Frequency	Reference Sites[a]
Phenols					
65	Phenols	U 10 62[b]	11[c] 37[d]	3/13	1,2,3
HSL	2-methylphenol	U 10	--	0/4	--
HSL	4-methylphenol	U 10 32	14 20	2/4	1
34	2,4-dimethylphenol	U 1 U 10	--	0/6	1
Substituted Phenols					
24	2-chlorophenol	U 0.5 U 5	--	0/6	1
31	2,4-dichlorophenol	U 0.5 - U 10	--	0/6	1
22	4-chloro-3-methylphenol	U 0.5 U 10	--	0/6	1
21	2,4,6-trichlorophenol	U 0.5 U 10	--	0/6	1
HSL	2,4,5-trichlorophenol	U 10	--	0/4	1
64	pentachlorophenol	0.1 U 50	0.02 33	1/6	1
57	2-nitrophenol	0.1 U 10	--	1/6	1
59	2,4-dinitrophenol	U 0.5	--	0/6	1
60	4,6-dinitro-o-cresol	U 0.5 U 100	--	0/6	1
58	4-nitrophenol	U 0.5 - U 100	--	0/6	1
Low Molecular Weight Polynuclear Aromatic Hydrocarbons					
55	naphthalene	U 0.5 U 40	5.6 - 22	10/20	1,2,3,4,5,6
77	acenaphthylene	U 0.1 U 40	0.08 - 17	1/20	1,2,3,4,5,6
1	acenaphthene	U 0.1 U 40	0.48 17	4/20	1,2,3,4,5,6
80	fluorene	U 0.1 40	3.0 19	7/21	All
81	phenanthrene	5 170	19 35	11/17	1,2,3,6,7
78	anthracene	U 0.5 U 40	2.7 22	7/17	1,2,3,6,7
HSL	2-methylnaphthalene	1 20	7.5 9.5	6/10	1,4,5,6
High Molecular Weight Polynuclear Aromatic Hydrocarbons					
39	fluoranthene	7 100	32 41	17/22	All
84	pyrene	8 120	30 41	16/22	All
72	benzo(a)anthracene	4 - U 40	3.7 23	8/17	1,2,3,6,7
76	chrysene	U 5 U 40	6.4 26	8/17	1,2,3,6,7
74	benzo(b)fluoranthene	U 5 94	17 - 33	12/21	All
75	benzo(k)fluoranthene	U 5 - 94	17 33	12/21	All
73	benzo(a)pyrene	U 0.37 40	9.3 - 10	10/14	1,3,4,5,6,7
83	indeno(1,2,3-c,d)pyrene	U 0.37 30	7.4 - 9.2	6/12	1,4,5,6,7
82	dibenzo(a,h)anthracene	0.4 - U 5	0.08 - 4.1	1/5	1
79	benzo(g,h,i)perylene	3 20	3.8 7.2	2/6	1,7
Chlorinated Aromatic Hydrocarbons					
26	1,3-dichlorobenzene	U 0.06 U 40	0.004 19	1/18	1,2,3,4,5
27	1,4-dichlorobenzene	U 0.06 - U 40	0.004 19	1/18	1,2,3,4,5
25	1,2-dichlorobenzene	U 0.06 U 40	0.004 - 19	1/18	1,2,3,4,5
8	1,2,4-trichlorobenzene	U 0.5 - U 5	--	0/6	1
20	2-chloronaphthalene	U 0.5 U 50	--	0/6	1
9	hexachlorobenzene (HCB)	0.01 U 10	0.07 3.5	6/12	1,4,5,6
Chlorinated Aliphatic Hydrocarbons					
12	hexachloroethane	U 0.5 U 50	--	0/6	1
xx	trichlorobutadiene	U 0.03 U 25	0.27 7.9	5/12	1,4,5,6
xx	tetrachlorobutadiene isomers	U 0.04 - U 25	1.6 - 9.2	5/12	1,4,5,6
xx	pentachlorobutadiene isomers	0.03 - U 25	0.15 7.7	5/12	1,4,5,6
52	hexachlorobutadiene	U 0.03 - U 25	0.07 - 8.5	5/12	1,4,5,6
53	hexachlorocyclopentadiene	**not analyzed**			

TABLE 10. (Continued)

Halogenated Ethers					
18	bis(2-chloroethyl) ether	0.3 U 10	--	1/4	1
42	bis(2-chloroisopropyl) ether	U 0.5 U 10	--	0/6	1
43	bis(2-chloroethoxy)methane	U 10	--	0/6	1
40	4-chlorophenyl phenyl ether	U 0.5 U 5	--	0/6	1
41	4-bromophenyl phenyl ether	U 0.5 U 5	--	0/6	1
Phthalate Esters					
71	dimethyl phthalate	U 0.5 U 50	--	0/5	1
70	diethyl phthalate	9.0 11	4 8	4/5	1
68	di-n-butyl phthalate	U 20 760	160 170	3/5	1
67	butyl benzyl phthalate	U 0.5 U 25	--	0/5	1
66	bis(2-ethylhexyl)phthalate	U 0.5 U 25	--	0/5	1
69	di-n-octyl phthalate	U 0.5 U 25	--	0/5	1
Miscellaneous Oxygenated Compounds					
54	isophorone	U 0.5 U 130	--	0/5	1
HSL	benzyl alcohol	U 10	--	0/4	1
HSL	benzoic acid	U 25 - 430	210 216	3/4	1
129	2,3,7,8-tetrachlorodibenzo-p-dioxin	**not analyzed**			
HSL	dibenzofuran	U 5	--	0/4	1
Organonitrogen Compounds					
HSL	aniline	U 1.0 U 20	--	0/6	1
56	nitrobenzene	U 0.5 U 5	--	0/5	1
63	n-nitroso-di-n-propylamine	U 0.5 U 10	--	0/5	1
HSL	4-chloroaniline	U 50	--	0/4	1
HSL	2-nitroaniline	U 50	--	0/4	1
HSL	3-nitroaniline	U 50	--	0/4	1
HSL	4-nitroaniline	U 50	--	0/4	1
36	2,6-dinitrotoluene	U 0.5 U 10	--	0/5	1
35	2,4-dinitrotoluene	U 0.5 U 5	--	0/5	1
62	n-nitrosodiphenylamine	U 0.5 U 5	--	0/5	1
37	1,2-diphenylhydrazine	U 0.5 U 5	--	0/6	1
5	benzidine (4,4'-diamino-biphenyl)	U 0.5	--	0/2	1
28	3,3'-dichlorobenzidine	U 0.5 U 100	--	0/6	1
Pesticides					
93	p,p'-DDE	U 10 U 25	--	0/5	1
94	p,p'-DDD	U 10 U 25	--	0/6	1
92	p,p'-DDT	U 10 U 25	--	0/5	1
89	aldrin	U 10 U 25	--	0/6	1
90	dieldrin	U 10 U 25	--	0/6	1
91	chlordane	U 10 U 25	--	0/6	1
95	alpha-endosulfan	U 10 - U 25	--	0/5	1
96	beta-endosulfan	U 10 - U 25	--	0/5	1
97	endosulfan sulfate	U 10 U 25	--	0/5	1
98	endrin	U 10 - U 25	--	0/6	1
99	endrin aldehyde	U 10 U 25	--	0/5	1
100	heptachlor	U 10 U 25	--	0/6	1
101	heptachlor epoxide	U 10 U 25	--	0/6	1
102	alpha-HCH	U 10 U 25	--	0/6	1
103	beta-HCH	U 10 U 25	--	0/6	1
104	delta-HCH	U 10 U 25	--	0/6	1
105	gamma-HCH (lindane)	U 10 U 25	--	0/6	1
113	toxaphene	U 10	--	0/2	1
PCBs					
xx	Total PCBs (primarily 1254/1260)	3.1 U 20	1.8 12	7/19	1,2,3,4,6,7

TABLE 10. (Continued)

Volatile Compounds					
85 tetrachloroethene	U 4.1	U 16	--	0/8	2,3
38 ethylbenzene	U 4.1	U 16	--	0/8	2,3

[a] Reference sites: 1. Carr Inlet 2. Samish Bay 3. Dabob Bay 4. Carr Inlet 5. Port Madison 6. Port Susan 7. Nisqually Delta

[b] An anomalously high phenol value of 1800 ug/kg dry weight was found at one Carr Inlet station. For the purpose of reference area comparisons, this value has been excluded.

[c] Mean calculated using 0.00 for undetected values.

[d] Mean calculated using the reported detection limit for undetected values.

Reference:

(Site 1) Tetra Tech (1985a); Mowrer et al. (1977).
(Site 2) Battelle Northwest (1983).
(Site 3) Battelle Northwest (1983); Prahl and Carpenter (1979).
(Site 4) Malins et al. (1980); Mowrer et al. (1977).
(Site 5) Malins et al. (1980).
(Site 6) Malins (1981).
(Site 7) Barrick and Prahl (in review); Mowrer et al. (1977).

The Carr Inlet samples collected in 1984 provide the most comprehensive reference data for Puget Sound. These data include blank-corrected analyses for 13 U.S. EPA priority pollutant metals, 3 additional metals (including iron and manganese as natural indicators), 78 U.S. EPA extractable priority pollutant compounds, 12 additional U.S. EPA Hazardous Substance List compounds, and selected tentatively identified compounds. Data for almost all of the organic compounds were corrected for potential losses during sample preparation and analysis using isotope mass spectroscopy. The comprehensive nature of these data is a major reason for their sole use in calculating elevations above reference values.

The most commonly analyzed contaminants in other reference areas (see Tables 9 and 10) were metals and neutral organic compounds (especially hydrocarbons). With the exception of selected hydrocarbon data from the Nisqually River delta and Dabob Bay, analytical recovery data were not available for evaluation of the organic compound data from the other reference data sets. Phthalate data were available for some of the other reference areas, but were rejected because the data apparently were not corrected for potential laboratory contamination, a common problem with this group of compounds.

Detection limits for some reference areas exceeded 50 ug/kg dry weight for several organic compounds. Detection limits for the recent Carr Inlet samples ranged from 0.5 to 50 ug/kg dry weight for almost all compounds. To provide a comparable data set, a maximum detection limit of 50 ug/kg dry weight was set for the acceptance of data from other reference areas included in the ranges reported in Table 10. For the few reference data sets affected by this cutoff, most of the relevant compounds have either been found at levels below 50 ug/kg dry weight, or have been undetected at low concentrations in the remaining reference areas. This cutoff makes the determination of the significance of Budd Inlet contamination less sensitive to limitations of analytical methods and more sensitive to the actual levels of compounds in reference areas.

<u>Elevations Above Reference (EAR) Analysis</u>--Dry weight concentrations of selected chemical indicators in the sediments of Budd Inlet were divided by

the average concentration for those indicators measured in sediments of the Carr Inlet reference area. Detailed spatial distributions of the EAR values for selected indicators are presented in Figures 21-26.

The calculated EAR values for the selected indicators are presented by station in Table 11. Of the selected indicators, the organic compounds (i.e., LPAH and HPAH) exhibited much higher EAR values than did the metals. EAR values for LPAH and HPAH exceeded 100 at most stations, while those for metals rarely exceeded 3. Specific characteristics of East and West Bays are discussed below.

The intertidal area in East Bay near the Cascade Pole Company facility exhibited the highest elevations for all indicator chemicals in the project area. EAR values for both LPAH and HPAH exceeded 50 at all stations. These chemical elevations were all above the significance level (i.e., the concentrations were greater than the highest concentrations observed in any reference area in Puget Sound; Tetra Tech 1985a,b). Concentrations of LPAH and HPAH at Station 2 were much higher than those noted in other contaminated areas of Puget Sound (Tetra Tech 1986b) (see Table 11). EAR values for LPAH and HPAH were highest in intertidal sediments at Stations 1-3 and tended to decrease in subtidal areas (see Table 11). Possible sources of contaminants that caused these high concentrations are multiple seeps that occur in East Bay (White, M., 21 January 1988, personal communication). Arsenic concentrations were fairly typical of other nonreference areas in Puget Sound (Tetra Tech 1985a,b). The associated EAR values did not exceed 3 (see Table 11). Data for other indicator chemicals were not collected.

Contaminant concentrations in sediment and associated EAR values near the West Bay storm drain, which is in contact with contaminated groundwater beneath Cascade Pole Company site varied (Johnson, A., 22 July 1985, personal communication). EAR values for LPAH and HPAH were highest at the intertidal station located just south of the outfall, while the intertidal station to the north of the outfall had the lowest EAR values for LPAH and HPAH. The subtidal station exhibited intermediate concentrations. Actual concentrations were much lower than the highest values reported for stations in East

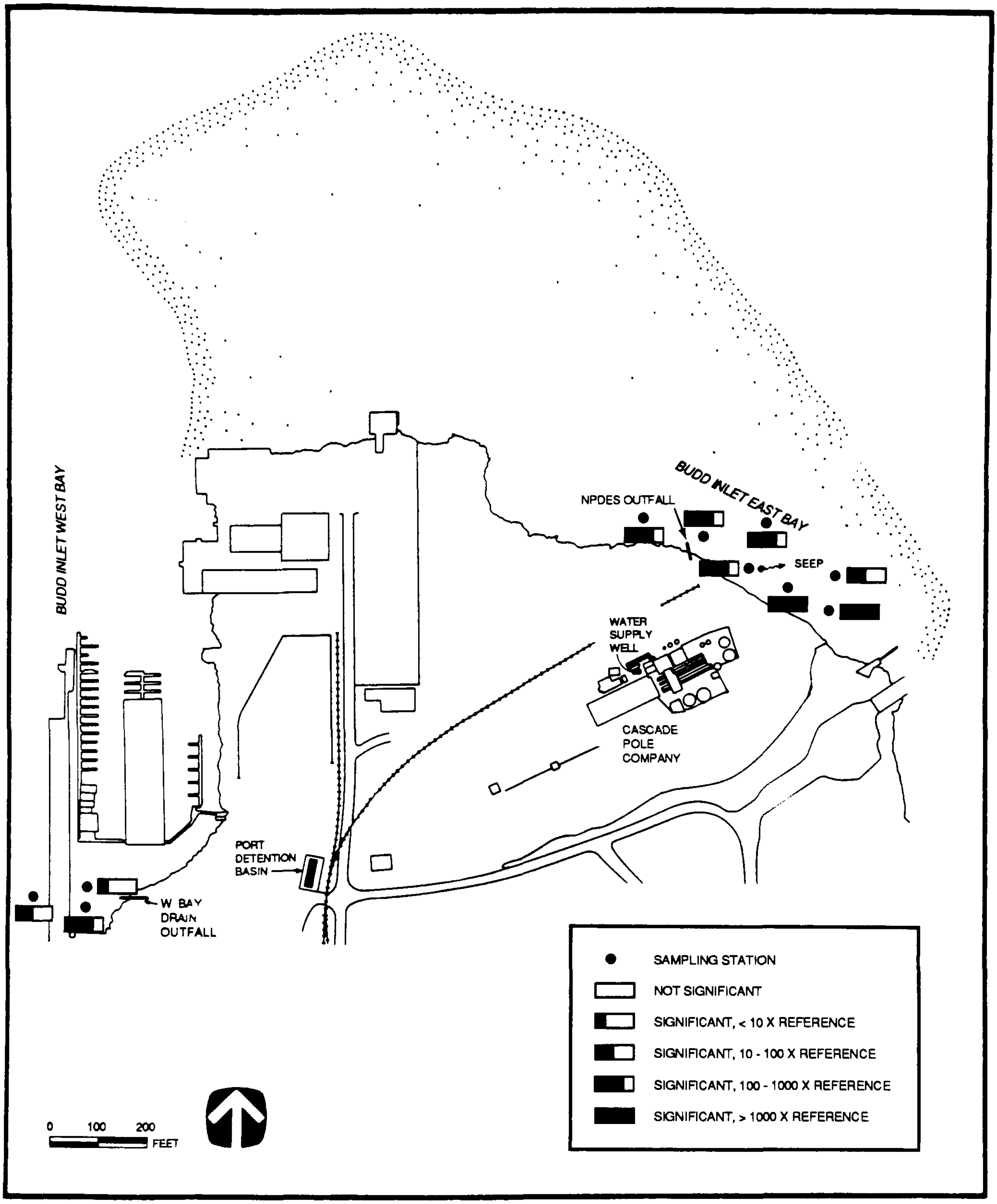


Figure 21. EAR values for concentrations of LPAH in sediments from the East and West Bays of Budd Inlet.

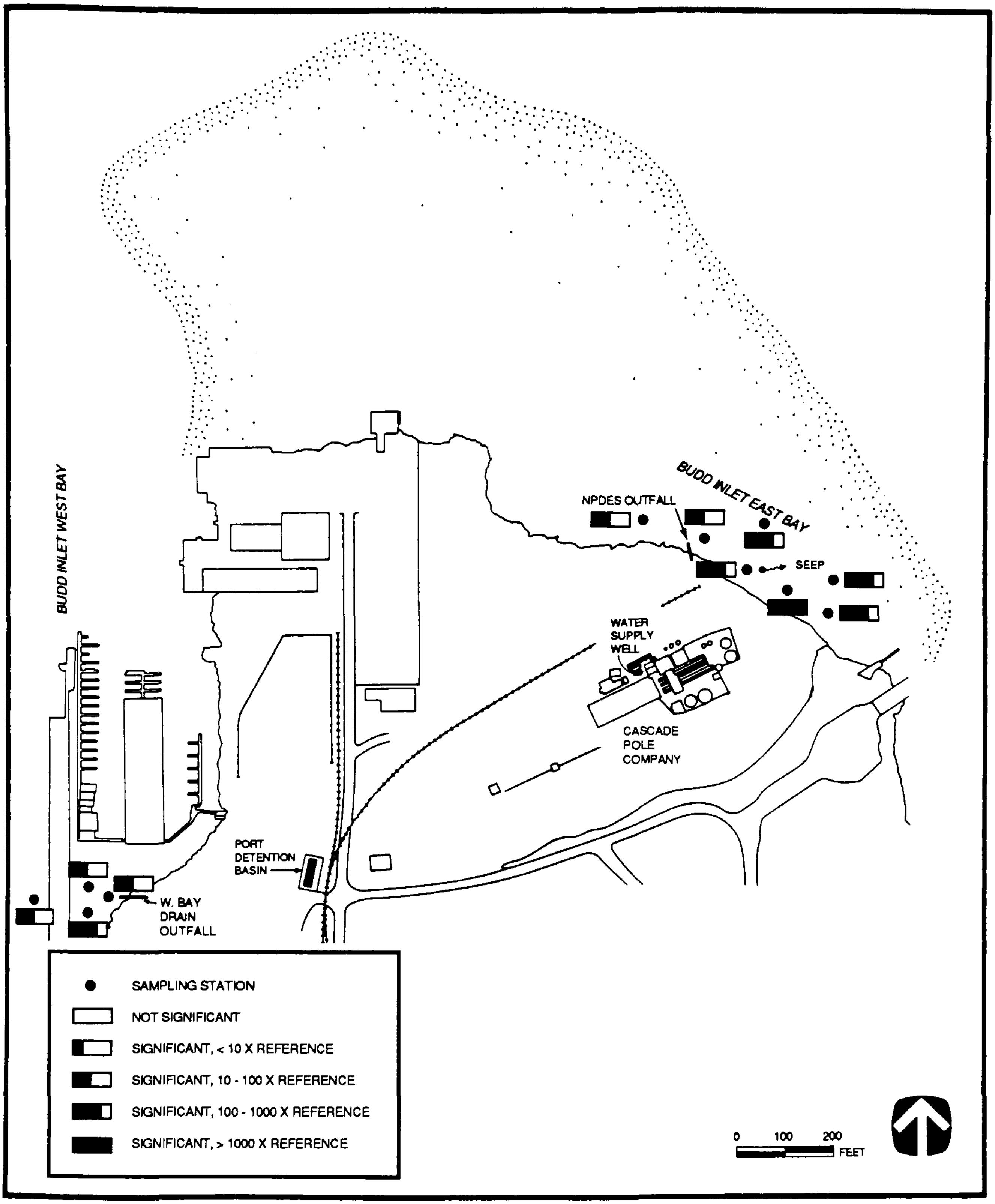


Figure 22. EAR values for concentrations of HPAH in sediments from the East and West Bays of Budd Inlet.

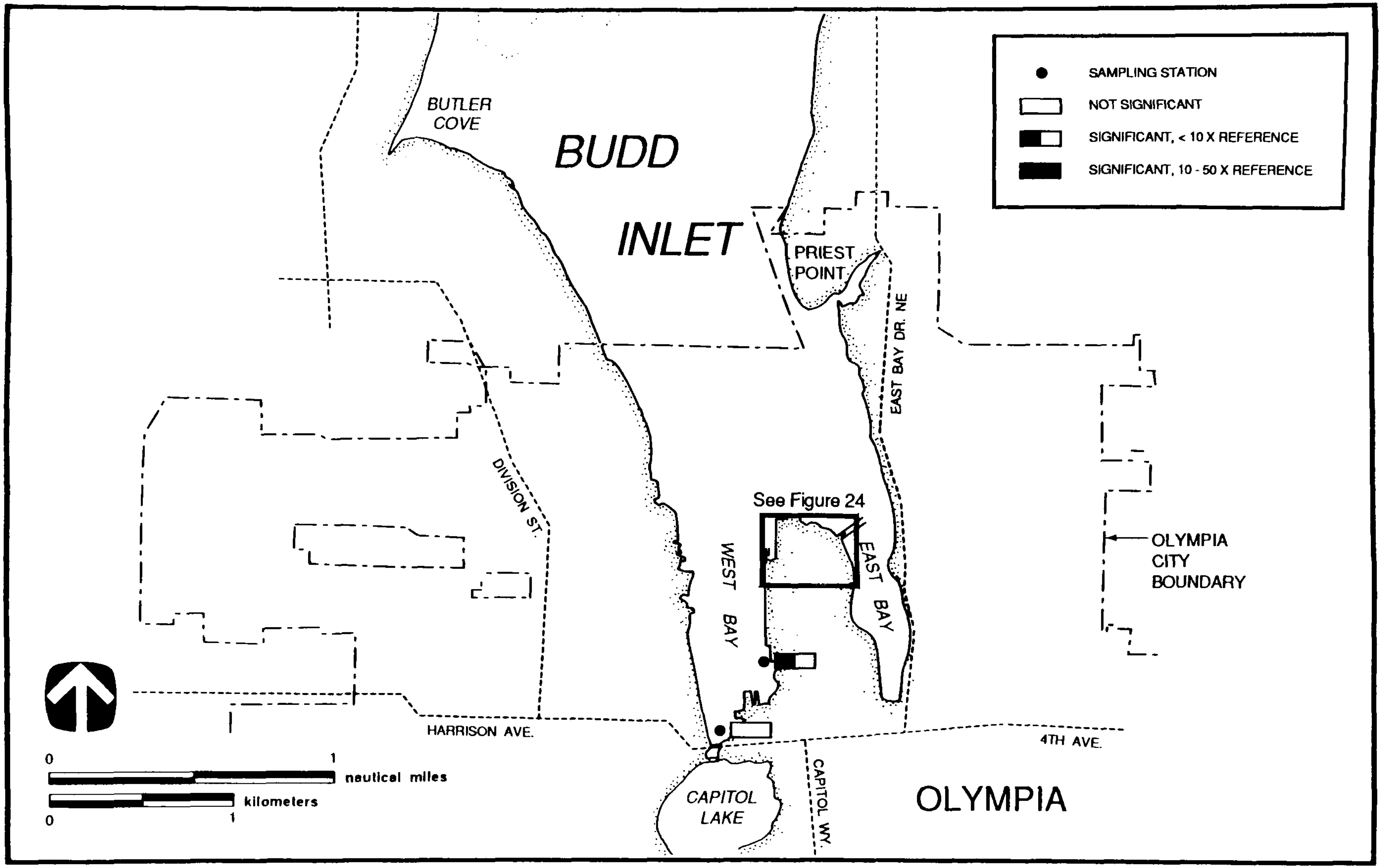


Figure 23. EAR values for concentrations of copper, lead, and zinc in sediments from the East and West Bays of Budd Inlet.

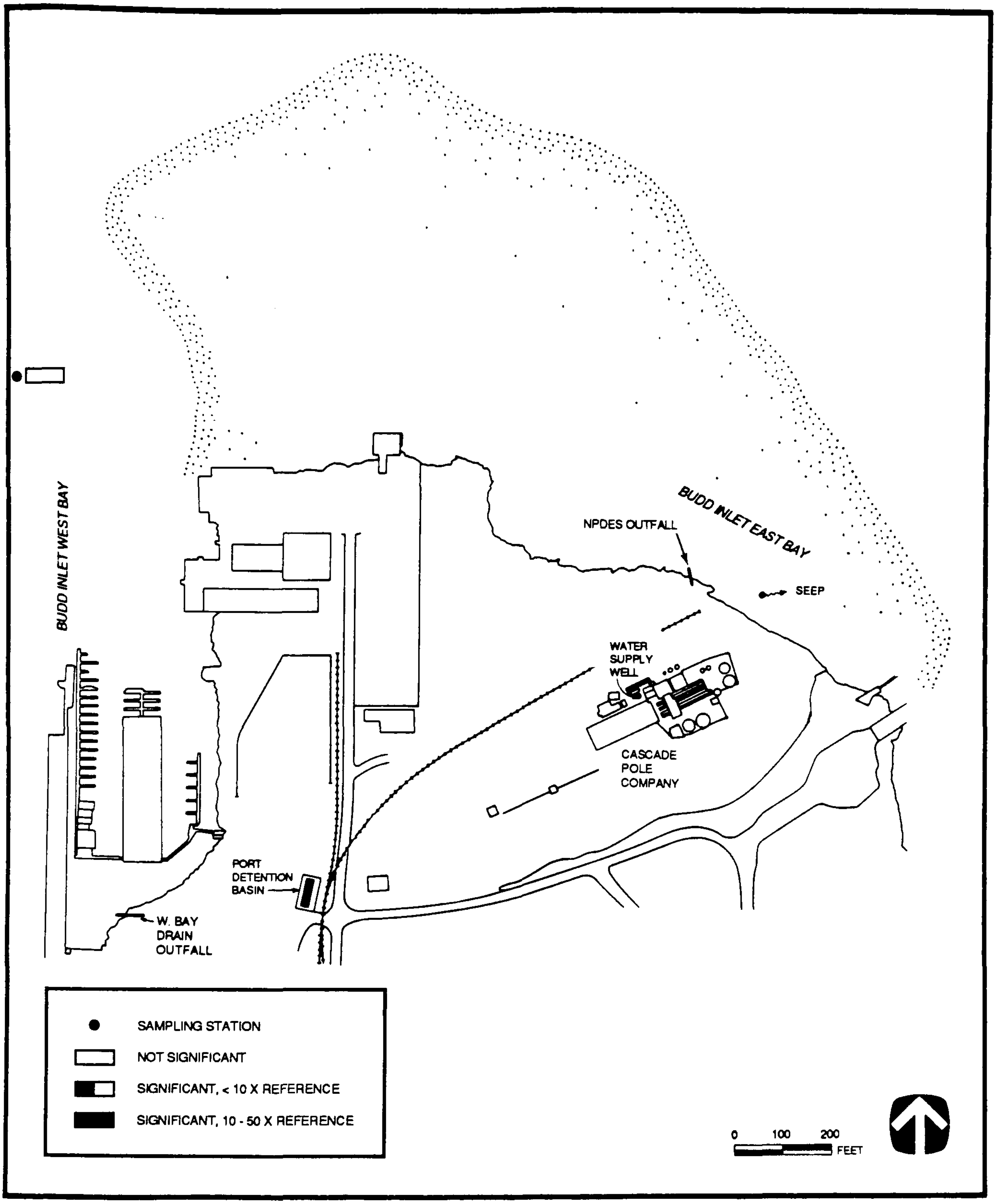


Figure 24. EAR values for concentrations of copper, lead, and zinc in sediments from the East and West Bays of Budd Inlet.

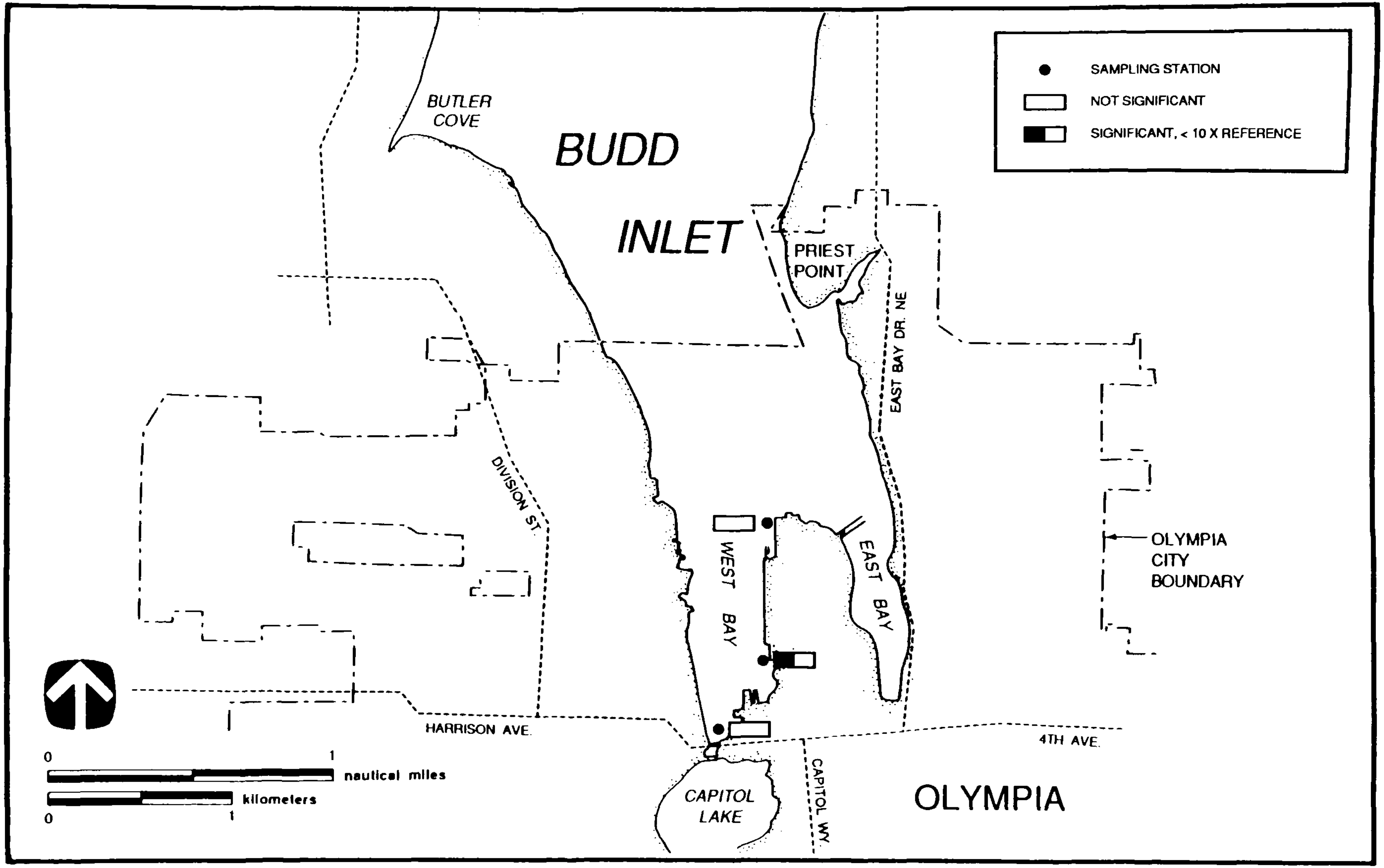


Figure 25. EAR values for concentrations of cadmium in sediments from the East and West Bays of Budd Inlet.

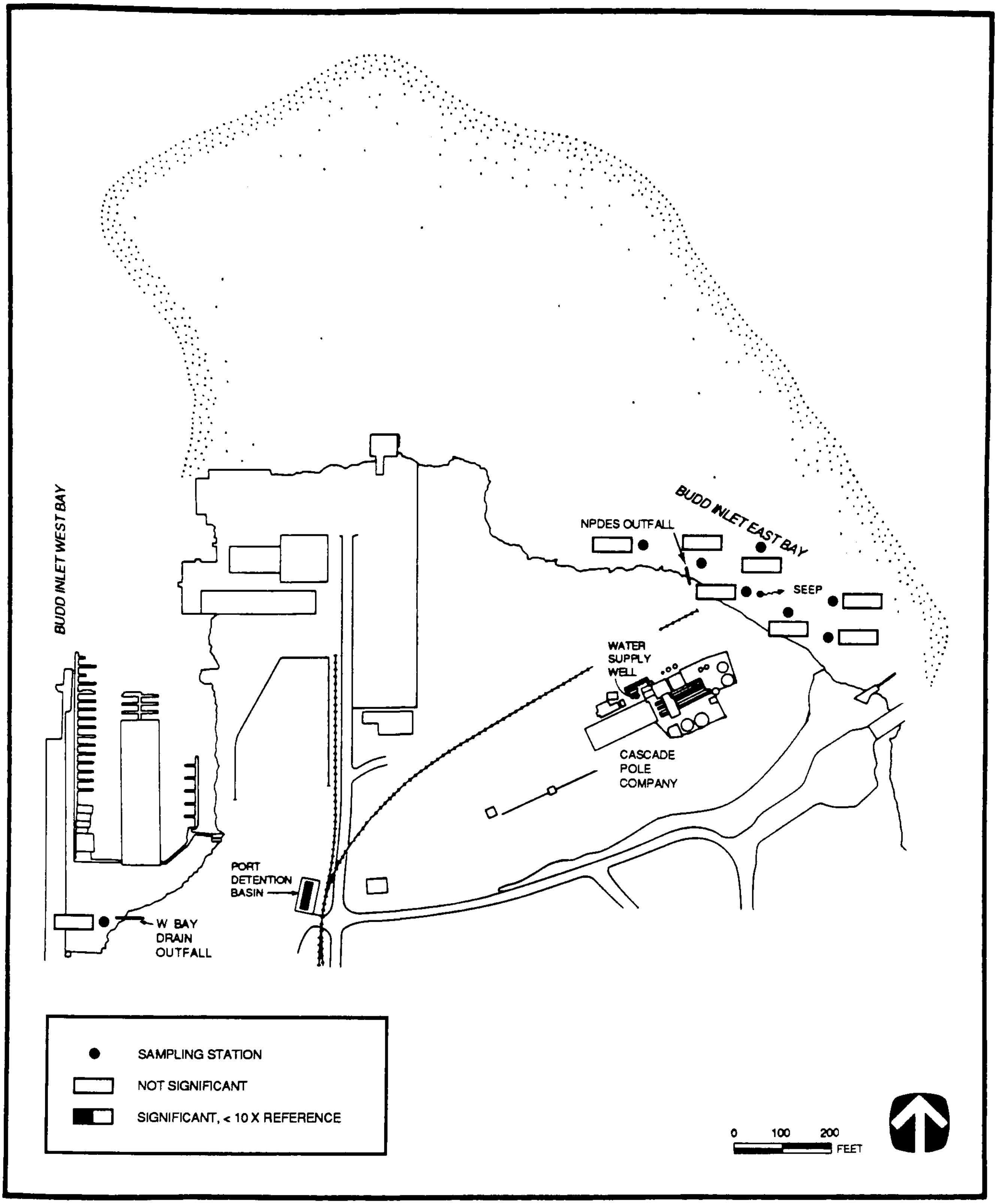


Figure 26. EAR values for concentrations of arsenic in sediments from the East and West Bays of Budd Inlet.

TABLE 11. CONCENTRATIONS AND EAR VALUES FOR SELECTED CHEMICAL INDICATORS IN BUDD INLET[a]

Area	Station	LPAH Conc.[b]	LPAH EAR	HPAH Conc.[b]	HPAH EAR	Cu+Pb+Zn Conc.[c]	Cu+Pb+Zn EAR	As Conc.[c]	As EAR	Cd Conc.[c]	Cd EAR	EAR RANK[a] LPAH	EAR RANK HPAH	EAR RANK Cu+Pb+Zn	EAR RANK As	EAR RANK Cd
East Bay (Intertidal)	1	48,800	1,198*	75,100	954*	--[d]	--	8.0	2	--	--	2	3	--	e	--
" "	2	1,745,000	42,833*	1,258,000	15,985*	--	--	5.7	2	--	--	1	1	--		--
" "	3	22,540	553*	95,800	1,217*	--	--	10.7	3	--	--	3	2	--		--
" "	4	9,060	222*	10,150	129*	--	--	11.0	3	--	--	5	6	--		--
"	5	12,640	310*	4,240	54*	--	--	5.5	2	--	--	4	7	--		--
East Bay (Offshore)	6	5,180	127*	15,500	197*	--	--	7.6	2	--	--	6	4	--		--
" "	7	1,702	42*	14,080	179*	--	--	7.3	2	--	--	7	5	--		--
Area Average		263,560	6,469*	210,410	2,674*			8.0	2							
West Bay Outfall (Intertidal)	8	f	f	880	11*	--	--	9.0	3	--	--	f	4	--	--	--
" "	338035	210	5*	1,300	17*	--	--	--	--	--	--	3	3	--	--	--
"	338034	6,100	150*	16,000	203*	--	--	--	--	--	--	1	1	--	--	--
West Bay Outfall (Subtidal)	338036	880	27*	3,200	41*	--	--	--	--	--	--	2	2	--	--	--
" "	3	--	--	--	--	165.5	4.8	--	--	0	0	--	--	2	--	e
Capitol Lake Outfall	1	--	--	--	--	38.5	1.1	--	--	0	0	--	--	3	--	e
Fiddlehead Marina	2	--	--	--	--	256.3	7.4*	--	--	5.6	5.9*	--	--	1	--	(1)
Area Average		2,397	59*	5,345	68*	153.4	4.4			1.9	2.0					

[a] Asterisk indicates significant EAR (i.e., chemical concentration in study area is greater than the maximum value observed in all Puget Sound reference areas; Tetra Tech 1986b).
[b] Concentration = ug/kg.
[c] Concentration = mg/kg.
[d] No data collected.
[e] Since none of the EAR values were significant, they were not ranked.
[f] All LPAH compounds were undetected with a detection limit of 100 ug/L at this station.

Bay, however, all EAR values were significant when compared with Puget Sound reference areas.

Other areas in West Bay were only sampled for metals. The composite indicator for copper, lead, and zinc exhibited a significant EAR for sediments near the Fiddlehead Marina. In addition, the cadmium concentration in sediments from a station near Fiddlehead Marina exhibited significant EAR values. The lack of data in the remaining areas of West Bay and Budd Inlet does not allow for a comprehensive discussion of sediment contamination.

Comparison to Apparent Effects Threshold (AET) Values--The AET values were used to identify concentrations of specific contaminants in sediments above which biological concentrations of specific contaminants in sediments above which biological effects are expected to occur. AET values are based on sediment chemistry data, toxicity data (i.e., amphipod, oyster larva, and Microtox bioassays), and benthic infauna abundance. For a given chemical and a specified biological indicator, the AET is the concentration above which statistically significant biological effects occurred in all samples of sediments analyzed. Because of limited biological (e.g., benthic infauna, bioassay) data in Budd Inlet, contaminant concentrations in budd Inlet sediments have been compared to these Puget Sound AET values to predict potentially significant biological effects. The range and mean of each chemical detected in sediments from lower Budd Inlet can be compared to AET values in Table 12. Raw data are provided in Appendix D.

The minimum concentrations of all organic and inorganic chemicals were below the lowest AET (LAET) values in all cases except the following: 2,4-dimethylphenol, 2-methylphenol, 1-methylnaphthalene, dibenzothiophene, and biphenyl. The maximum concentrations of all organic compounds exceeded the LAET values except for acenaphthylene, benzo(g,h,i)pyrelene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, 4-methylphenol, and phenol. The maximum concentration of chromium exceeded its LAET value. The maximum concentration of cadmium (5.6 mg/kg) is similar to the LAET for cadmium (5.8 mg/kg). Cascade Pole is the most likely source of these contaminants.

TABLE 12. COMPARISONS OF CONTAMINANT CONCENTRATIONS[a] IN BUDD INLET SEDIMENTS WITH PUGET SOUND AET VALUES

		Budd Inlet Data				Puget Sound Apparent Effects Threshold (AET) Values[b]					
Class	Chemical	N	Mean	Min	Max	Amphipod	Oyster	Benthic	Microtox	LAET	HAET
LPAH	acenaphthene	12	32,844	20	370,000	980	500	500	500	500	980
	acenaphthylene	12	175	20	400	560	> 560	640	> 560	560	640
	anthracene	12	13,500	20	150,000	1,900	960	1,300	960	960	1,900
	fluorene	12	17,398	20	200,000	1,800	540	640	540	540	1,800
	naphthalene	12	19,961	39	210,000	2,400	2,100	2,100	2,100	2,100	2,400
	phenanthrene	12	69,221	100	800,000	5,400	1,500	3,200	1,500	1,500	5,400
HPAH	benzo(a)anthracene	12	9,876	20	95,000	3,000	1,600	4,500	1,300	1,300	4,500
	benzo(a)pyrene	12	3,822	20	40,000	2,400	1,600	6,800	1,600	1,600	6,800
	benzo(g,h,i)perylene	12	156	20	400	960	720	5,400	670	670	5,400
	benzofluoranthenes	12	7,764	50	73,000	3,700	3,600	8,000	3,200	3,200	8,000
	chrysene	12	12,134	20	120,000	5,000	2,800	6,700	1,400	1,400	6,700
	dibenzo(a,h)anthracene	4	93	20	200	510	230	1,200	230	230	1,200
	fluoranthene	12	52,414	220	530,000	9,800	2,500	6,300	1,700	1,700	9,800
	indeno(1,2,3-cd)pyrene	12	156	20	400	880	690	> 5,200	600	600	880
	pyrene	12	38,682	450	400,000	11,000	3,300	> 7,300	2,600	2,600	11,000
TPAH	Total PAH	4	7,370	880	23,000						
Phthalates	bis(2-ethylhexyl)phthalate	8	2,468	100	15,000	> 3,100	1,900	1,900	1,900	1,900	1,900
Phenols	2,4-dimethylphenol	8	188	100	400	> 72	29	29	29	29	29
	2-methylphenol	8	188	100	400	63	63	> 72	> 72	63	63
	4-methylphenol	8	190	100	400	1,200	670	670	670	670	1,200
	pentachlorophenol	12	156	20	400	> 140	> 140	> 140	> 140		
	phenol	8	188	100	400	670	420	1,200	1,200	420	1,200
Miscellaneous Extractables	1-methylnaphthalene	3	261,633	2,100	780,000	310	370	370	370	310	370
	2-methylnaphthalene	15	1,533	20	15,000	670	670	670	670	670	670
	biphenyl	3	725	540	910	260	260	270	270	260	270
	dibenzofuran	12	11,559	20	130,000	540	540	540	540	540	540
	dibenzothiophene	3	270,000	270,000	270,000	240	240	250	250	240	250
Volatile Organics	ethylbenzene	8	76	5	510	> 50	37	37	33	33	37
	total xylenes	8	55	5	400	> 160	120	120	100	100	120
Metals	arsenic	8	8.1	5.5	11.0	93	700	85	700	85	700
	cadmium	3	1.9	0.0	5.6	6.7	9.6	5.8	9.6	5.8	9.6
	chromium	11	31.6	3.7	55.6	> 130	> 37	59	27	27	59
	copper	11	63.7	0.0	131.5	800	390	310	390	310	800
	lead	3	16.4	6.5	33.4	700	660	300	530	300	700
	mercury	1	0.2	0.2	0.2	2.10	0.59	0.88	0.41	0.41	2.10
	nickel	3	23.1	2.7	41.7	> 120	39	49	28	28	49
	zinc	3	86.1	29.3	116.9	870	1,600	260	1,600	260	1,600

[a] Concentrations of organic contaminants expressed in units of ug/kg dry wt, and concentrations of trace metals expressed in units of mg/kg dry wt.

[b] LAET=lowest AET; HAET=highest AET; >=actual AET value is greater than the value shown and threshold value has not been determined.

Reference: Adapted from: Alan, R. (24 September 1987, personal communication); Norton, D. (5 February 1986, personal communication); and Johnson, A. (22 July 1985, personal communication).

Bioaccumulation

General Overview--

Bioaccumulation data collected since December 1981 for marine organisms in Budd Inlet are limited to the concentration of PAH in tissues of clams from four stations (see Figures 19 and 20). In the sample of clams collected in East Bay near the Cascade Pole Company facility, the concentrations of PAH were at the upper end of concentrations reported in other Puget Sound urban bays (i.e., 1,100 ug/kg total PAH), and were similar to concentrations detected in Eagle Harbor clams (Norton, D., 5 February 1986, personal communication). Concentrations of total PAH (99 and 190 ug/kg) in clams from West Bay were approximately an order of magnitude lower than those observed in East Bay. PAH were undetected in clams collected at Priest Point.

In 1986 and 1987, DSHS (1987) analyzed clam tissues from Priest Point Park for heavy metals and selected organic compounds. Because of quality assurance issues, these data were not made available in time to be incorporated into this report.

Because of the limited recent bioaccumulation data, older data (i.e., Malins et al. 1980) are included to provide an indication of the concentrations of contaminants detected in bottomfish. In 1979, elevated concentrations of some metals were found in liver tissues of English sole collected from Budd Inlet (Malins et al. 1980). However, specific station locations for these data were not presented. Concentrations of strontium in liver tissues of English sole from Budd Inlet were reportedly 39 times greater than concentrations detected in Sinclair Inlet, 17 times greater than concentrations detected along the Elliott Bay waterfront, and 25 to 31 times greater than concentrations detected in Hylebos Waterway. Strontium is not considered toxic (Malins et al. 1980). However, these elevations in English sole liver tissue suggest a source of strontium in Budd Inlet. Calcium was also elevated by over an order of magnitude compared to concentrations in fish livers collected from Case and Sinclair Inlets, Duwamish River, Seattle

Waterfront, and Hylebos and Sitcum Waterways. Naphthalene, acenaphthalene, dichlorobenzene, and trichlorobutadiene in composite samples containing English sole livers collected throughout Budd Inlet appeared elevated in comparison with Port Madison, Case Inlet, and Sinclair Inlet. However, because detection limits were not reported, these results should be interpreted with caution.

Data Synthesis--

An analysis of bioaccumulation data collected since 1982 will be used to define toxic contamination problems in the study area. The following analysis deviates from the traditional action assessment approach used in other urban embayments (e.g., Elliott Bay, Everett Harbor), because bioaccumulation data exists for clams only. Although one station in Budd Inlet was considered a reference station by Mr. D. Norton (5 February 1986, personal communication), all contaminants were undetected in the sample from that station. However, the detection limits in that study were higher than detection limits used in other recent bioaccumulation studies.

Available Data--Recent data on priority pollutant concentrations in clam tissues were compiled from Mr. D. Norton (5 February 1986, personal communication). These were the only data available for the study period 1982-1987.

Choice of Indicators--Chemical indicators chosen for analysis of bioaccumulation in clam tissues were:

- Sum of LPAH
- Sum of HPAH.

These indicators represent a subset of the chemicals that are usually investigated in tissue samples. Data on PCBs and metals were not available, and are needed to identify the biological effects that may be induced by these environmental contaminants.

Station Locations--Two stations were located near the West Bay storm drain outfall and one station was located near the Cascade Pole Company facility (see Figure 20). A reference station was located near Priest Point (see Figure 19).

Reference Area Data--Reference concentrations of LPAH and HPAH in clams were obtained from the Puget Sound Environmental Atlas (Evans-Hamilton and D.R. Systems 1986). These reference data use a compilation of data from Malins et al. (1980) and Yake et al. (1984). The database from which reference values for bioaccumulation of contaminants in clams is determined is limited since bioaccumulation is traditionally investigated in bottom-dwelling fish and crabs.

EAR Analysis--Bioaccumulation data for clams are summarized in Table 13. Metals were not included in the analyses. However, 10 organic priority pollutants were identified in the clams that were collected from near the Cascade Pole Company. A total of six LPAH and ten HPAH compounds were analyzed. Acenaphthylene was the only undetected LPAH compound. Of the HPAH, benzo(a)pyrene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene were undetected.

Bioaccumulation of LPAH and HPAH was greatest at the station off the Cascade Pole facility in East Bay. Concentrations of LPAH and HPAH were 169 and 938 ug/kg wet weight, respectively. These values fall within the range of values observed from Eagle Harbor. EAR values were 5.0 for LPAH and 12.3 for HPAH. Bioaccumulation in clams collected at the two stations near the West Bay drain were 27 and 83 ug/kg (wet wt) for total LPAH and 72 and 110 ug/kg (wet wt) for total HPAH. These values are similar to lower values obtained from other urban embayments in Puget Sound (Norton, D., 5 February 1986, personal communication).

The limited data available for analysis of bioaccumulation in Budd Inlet suggest that PAH are accumulating to abnormally high levels in clams in the vicinity of Cascade Pole Company. The earlier data by Malins et al. (1980) suggest the bioaccumulation of strontium and calcium in abnormally high concentrations. Until further studies are conducted, the significance

TABLE 13. SUMMARY OF BIOACCUMULATION DATA FOR BUDD INLET

Sample Type	Station	n[a]	LPAH Concentration[b]	LPAH EAR	HPAH Concentration[b]	HPAH EAR
Clams[c]	Priest Point	31	--	--	--	--
	East Bay	11	169	5.0	938	12.3
	West Bay Drain-1	27	83	2.4	108	1.4
	West Bay Drain-2	27	27	0.8	72	0.9

[a] n = number of clams composited into one sample.

[b] Concentration is expressed in ug/kg wet weight.

[c] *Protothaca staminea*, *Tapes japonica*, and *Mya arenaria*.

Reference: D. Norton (5 February 1986, personal communication).

of these elevations can not be ascertained. Acenaphthylene was the only LPAH undetected in all tissue samples. Benzo(a)pyrene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene were undetected in all tissue samples.

Toxicity Bioassays

Bioassays are conducted to test organism response to bioavailable toxic substances in contaminated effluent and sediments. Presently, this cannot be determined by routine chemical analytical techniques. Therefore, bioassays should be used in conjunction with chemical data when characterizing ecological impacts of contaminated sediments or water on organisms. Three types of bioassays are used to test receiving water toxicity, sediment toxicity, and effluent toxicity. Simultaneous consideration of benthic infaunal community, chemistry, and bioassay data is effective for conducting site-specific analysis of conditions in the sedimentary environment (Tetra Tech 1985b,c; Long and Chapman 1985).

Overview--

Receiving water bioassays were conducted during 1973-1976 at six stations in Budd Inlet. Recent data are not available. Two types of sediment bioassays (i.e., amphipod and oyster larva) were performed on sediments collected in March 1985 at a single station in Budd Inlet. Effluent bioassays are not a component of the NPDES permit requirements for the LOTT WWTP (Alan, R., 9 February 1988, personal communication).

Receiving Water Toxicity--Receiving water bioassays were not conducted in Budd Inlet during the study period for this report (i.e., 1982-1987). However, receiving water bioassays were conducted during the period 1973-1976 at six stations (Washington Department of Fisheries 1979). The six stations were located in central Budd Inlet near Gull Harbor, south of Gull Harbor, near Butler Cove, near Priest Point, near the old LOTT outfall (i.e., approximately 100 yd off Fiddlehead Marina), and at the Port of Olympia docks near the head of West Bay. No stations were located in East Bay. Water samples were collected at the surface and at various depths in the water column. Oyster larvae (Crassostrea gigas) bioassays were conducted on each of the samples. Sample collection methods and laboratory QA/QC procedures were adequate and included the use of a reference toxicant.

At all stations, percent abnormality and percent mortality showed considerable variability. Percent mortality was generally higher than percent abnormality, except near the LOTT outfall where these values were approximately equal. Percent abnormality and percent mortality ranged between 0 and 100 percent at stations located south of Gull Harbor, and near Butler Cove, Priest Point, and the LOTT outfall. Percent abnormality and percent mortality were generally lower at the Port of Olympia docks than at other stations in Budd Inlet; values from the station near the Port of Olympia docks were similar to those from stations sampled near Dana Passage and Ketron Island.

Sediment Toxicity--Two types of sediment bioassays have been performed in Budd Inlet. The Rhepoxynius abronius sediment bioassay, developed by Swartz et al. (1985), was used for bioassays conducted on sediment from one station located north of the Port of Olympia peninsula, and on sediment collected at the Olympia Yacht Club (see Figure 19). The oyster larvae (Crassostrea gigas) bioassay was also conducted using sediment from the station located north of the Port of Olympia peninsula.

Sample collection methods for the Olympia Yacht Club sample deviated from the preferred practice in Puget Sound. The PSEP protocols (Tetra Tech 1986a) recommend the collection of 2 cm of surface sediments for sediment chemistry and bioassay analyses. The Olympia Yacht Club sample was composited from a 4-ft vertical core, which integrates a much longer period of potential contaminant accumulation time than does the 2-cm sample. Because additional data generated from samples collected from the surface 2 cm of sediment are not available, the Olympia Yacht Club samples will be included in this analysis.

Data Synthesis--

Recent sediment bioassay data are synthesized below for analysis of EAR values. State reasons for omitting effluent and rece4iving water bioassays and focus on sediment bioassays.

Choice of Indicators--Because of the frequent use of the amphipod and oyster bioassays and the existence of standardized techniques for both (Chapman and Morgan 1983; Swartz et al. 1985), these assays were selected as indicators of sediment toxicity. An extensive discussion comparing data generated with amphipod and oyster larvae bioassays is provided in Tetra Tech (1985b).

Available Data and Station Locations--The available amphipod bioassay data were reviewed to determine whether the bioassays had been conducted on previously frozen sediments, or whether a minimum of four replicates had been conducted. Data from Everett Harbor suggest that toxicity is altered by freezing the sediments (Tetra Tech 1985c). Because the ability of the amphipod bioassay to distinguish differences in survival between control and treatment sediments is dependent on the number of replicates and on the number of individuals per replicate (see Table 1 in Swartz et al. 1985), only those studies with a minimum of four replicates and 20 amphipods per replicate were accepted. Based on the above criteria, data generated for the U.S Army COE [no date (c)], and data collected off the Port of Olympia peninsula (Schiewe, M., 19 November 1987, personal communication) were accepted. Each of these data sets was from one station.

Only one study used oyster larvae bioassays. Mr. M. Schiewe (19 November 1987, personal communication) conducted one replicated oyster larvae bioassay on sediments collected off the Port of Olympia peninsula. Quality control was adequate and the data were accepted.

To fully characterize sediment toxicity in Budd Inlet, additional data are required from East and West Bays, the area north of the Port of Olympia peninsula, and in the remainder of the inlet.

Reference Area Data--Sediments used as native sand controls in the accepted amphipod studies were used as reference sediments. Mr. M. Schiewe (19 November 1987, personal communication) used sediment from Bowman's Bay as reference material, while the U.S. Army COE [no date (c)] used sediment from the amphipod collection site off West Beach, Whidbey Island as reference material. Mean survival off the Port of Olympia peninsula was 99 percent and mean survival at the Port of Olympia Yacht Club was 100 percent. The oyster larvae bioassay reference was a seawater control. Mean oyster larvae abnormality in seawater was 2 percent and mean mortality in seawater was 0 percent.

Elevation Above Reference (EAR) Analysis--Within each study, mortality or abnormality (as appropriate) was compared between test and reference conditions using appropriate statistical methods. Test sediment means for each station were divided by the reference mean to yield the EAR. This ratio indicates the relative magnitude of sediment toxicity. Results of these analyses are provided in Table 14.

EAR values for amphipod and oyster mortality at the station off Cascade Pole Company were 20 and 15, respectively. These EAR values are significantly elevated according to the criteria established for the Everett Harbor Action Plan (Tetra Tech 1985c). The mean reference mortality rate for the amphipod bioassay off the Cascade Pole Company site was 1 percent, which was comparable to the mean reference in Everett Harbor (Tetra Tech 1985c). The mean oyster larvae mortality reference value was also 1 percent. This value is 0.6 percent lower than the mean reference value obtained in Everett Harbor (Tetra Tech 1985c).

The mean EAR for amphipod bioassays at the Olympia Yacht Club was 4.5. This value was obtained using an amphipod control mortality rate of 1 percent. Sediment toxicity at the Olympia Yacht Club was not significant according to the criteria established for the Everett Harbor Action Plan (Tetra Tech 1985c).

TABLE 14. SUMMARY OF EAR VALUES FOR AMPHIPOD AND OYSTER LARVAE SEDIMENT BIOASSAYS

Study	Station	Mean Amphipod Mortality (%)	Amphipod EAR	Mean Oyster Mortality (%)	Oyster EAR
Scheiwe (19 November 1987)[b]	North of Port of Olympia peninsula	20	20[a]	15	15[a]
U.S. Army COE [no date(c)]	Olympia Yacht Club composite 1/2	6	6[c]		
	Olympia Yacht Club composite 3/4	3	3[c]		

[a] EAR calculation based on amphipod control mortality rate of 1.0 percent and oyster control mortality rate of 1.0 percent.

[b] Personal communication.

[c] Mortality rate for amphipod control was 0.0 percent, however, to permit calculation of EARs, a mortality rate of 1.0 percent was used.

The lack of bioassay data for the remainder of Budd Inlet precludes a comprehensive understanding of possible sediment toxicity. The data presented in Table 14 should be considered preliminary, and conclusions regarding sediment toxicity should be delayed until further data are collected.

Benthic Infaunal Communities

Acceptable data that describe benthic communities in Budd Inlet are lacking. A single study (Evergreen State College 1974) was conducted in 1974 at 37 stations located in upper Budd Inlet. However, sample collection and laboratory analytical procedures were inconsistent with accepted PSEP protocols. A review of these data suggests that a relatively diverse assemblage of benthic infauna exists within the study area. However, the data are inadequate to examine spatial gradients, and define and interpret benthic communities.

Reliable benthic infauna data, including species richness and total abundances, must be generated prior to the analysis of benthic infaunal communities in Budd Inlet. Any sampling effort should provide adequate spatial coverage, including the location of stations in West Bay, East Bay, along the entrance channel, and in outer Budd Inlet.

Fish Pathology

Fish pathology data in Budd Inlet are lacking for the period 1982-1987. The only available data were generated from samples collected by Malins et al. (1980) in the winter, spring, summer, and fall of 1979. Data on liver lesions and other pathological diseases in bottomfish, crabs, and shrimp were collected and analyzed.

Most types of abnormalities were not observed in English sole, rock sole, crabs, or shrimp captured in Budd Inlet. However, gill respiratory epithelial hyperplasia was observed in 13 percent of the English sole, which is a lower frequency than that observed in English sole from Hylebos Waterway and Browns Point. Also, hepatocellular necrosis was observed in 11 percent of the rock sole (ranked third behind the frequency of disease in rock sole from Duwamish River and Case Inlet) and in 6 percent of the English sole (ranked first with frequency of disease in English sole from Hylebos Waterway, Case Inlet, and outer Elliott Bay). Because the raw data were not available, the incidence of individual disorders cannot be linked to particular stations. Summary information for English sole, rock sole, and Pacific tomcod showed similar prevalences of abnormalities at Priest Point (9.5 percent) and Olympia Shoals (13 percent). Data for samples collected in West Bay were not presented independently. Higher incidences of abnormalities were observed in crabs.

Although the cause of abnormalities in field-captured specimens has not been determined, morphologically similar abnormalities have been induced in laboratory mammals and fishes following exposure to carcinogens (Malins et al. 1984). Thus, it is possible that the presence of such abnormalities in organisms inhabiting Budd Inlet represents the effects of toxic substances with carcinogenic characteristics.

Additional data are needed to provide a statistically valid interpretation of histopathological abnormalities in bottomfish inhabiting Budd Inlet. Bottom fish should be analyzed from East and West Bays, and the central and northern portions of the inlet.

Fish Kills--

Prior to 1981, two fish kills were reported in Budd Inlet. Anaerobic waters that entered Budd Inlet from Capitol Lake were determined to have caused fish mortalities, and a fish kill occurred in the Deschutes River near the Olympia Brewery (Kittle, L., 29 January 1988, personal communication). The most recent documented fish kill in Budd Inlet occurred in September 1981 near the 4th Avenue and 5th Avenue Bridges in downtown Olympia (Kittle, L., and H. Tracy, 19 January 1982, personal communication). A discharge of anaerobic saltwater, which contained high concentrations of hydrogen sulfide, entered Budd Inlet from Capitol Lake. The total estimate of fish mortality was 314,098 non-salmonid fish and 100 salmonid fish of which 50 were adults. Since that occurrence, no fish kills have been reported in Budd Inlet (Kittle, L., 29 January 1988, personal communication; Singleton, L., 29 January 1988, personal communication). However, Mr. L. Kittle noted that when Capitol Lake is lowered by the Washington Department of Fisheries to release salmon fingerlings, mortalities may occur as freshwater fish species enter the marine environment.

The formation of the anaerobic water in Capitol Lake that entered Budd Inlet and caused massive fish mortalities was discussed in a memorandum (Schmitten, R., 16 October 1981, personal communication) to Governor J. Spellman:

> "According to Ecology's findings, a deep hole has recently been formed inside the lake [south of the gate] caused by backflushing the lake with salt water from Budd Inlet for a variety of operations. It is sometimes necessary and desirable to flush the lake with salt water for fish releases, scrap fish control and weed control in the spring. Under normal conditions the salt water is replaced by Deschutes River water and the lake is operated as a freshwater body for fish rearing and recreation. However, in the fall when Deschutes River flows are naturally low, any salt water entering the lake on extreme high tide through the fish ladder or small leaks at the dam sinks to the bottom in the deep hole and under certain conditions can stagnate. This stagnant water which forms toxic hydrogen sulfide was the primary cause of the September, 1981 fish kills in Budd Inlet."

The Washington Department of General Administration (WDGA), which manages Capitol Lake, determined that it would not be plausible to fill in the hole. Entranco Engineers (1983) completed an historical data review and recommended appropriate actions to remedy the problem. In early 1987, a 12-in diameter line was installed which operates as a siphon between Capitol Lake and Budd Inlet. The intake for the siphon is located at a depth of 40 ft in the hole in Capitol Lake, and the siphon discharges directly north of the tidal gate at a depth of 27 ft in Budd Inlet. Although the siphon can be turned off, it is currently operating at all times and thus constantly drains waters from within the area of the hole (Helmlinger, J., 23 March 1988, personal communication). The flow of water through the pipe is not known (Sweet, B. 13 April 1988, personal communication). The WDGA currently monitors waters from the area of the Capitol Lake hole from July to October (Helmlinger, J., 13 April 1988, personal communication). Six water samples are collected at 2-m intervals from the surface to the bottom of the hole and analyzed for dissolved oxygen. the frequency of sampling is dependent on tide levels, algal blooms, and weather. at a minimum monitoring occurs 2 times/mo. According to Mr. Butch Sweet (23 March 1988, personal communication), the siphon appears to be working because the levels of dissolved oxygen have never exceeded the limits established by Ecology (i.e., 2 mg/L). These dissolved oxygen data have not been summarized but are available in a daily field notebook from WDGA.

IDENTIFICATION OF PROBLEM AREAS

The identification of problem areas is limited by the amount of available data for Budd Inlet. Large gaps in data coverage exist for eutrophication and toxic contamination, and an understanding of temporal variability of microbial concentrations is lacking. Data gaps for these categories will be discussed in the following section. Known problem areas based on the available data are identified in this section.

Problem areas are ranked in this report at a level that is more general than the numerical ranking in the decision-making approach. Therefore, if additional data are collected, the results of the ranking presented in this report should be re-evaluated by implementing the decision-making approach. Criteria are established to define problem areas, and three levels of problem severity are defined within each category: highest priority, secondary priority, and no immediate action. Highest priority problem areas are recommended for further source and remedial action evaluation. Secondary priority problem areas should be thoroughly studied to define the extent and severity of the problem. Areas designated for no immediate action are recommended for future monitoring.

EUTROPHICATION

Nutrient and dissolved oxygen concentrations were discussed in the "Data Summaries" section for eutrophication. Elevated or depressed nutrient concentrations are not environmental problems by themselves. However, elevated nutrient concentrations may provide the essential ingredients for algal blooms that contribute to dissolved oxygen depletion in Budd Inlet. Low oxygen concentration is an environmental problem because resident fish and invertebrates cannot support normal metabolic activities when oxygen levels decline. The amount of oxygen required to support normal metabolic rates varies among species. However, oxygen concentrations less than 3.0 mg/L are considered detrimental to both fish and invertebrates (Welsh, B., 18 November 1987, personal communication). The highest priority problem areas for eutrophication are defined as those areas experiencing less than 3.0 mg/L dissolved oxygen at least once during the period 1982-1987 (Table 15). Secondary priority problem areas are defined as having dissolved oxygen concentrations of 3.0-5.0 mg/L during the same period. The Class B water quality standard of 5.0 mg/L was used as the upper limit for the secondary priority designation. Areas where oxygen levels remain above 5.0 mg/L throughout the year are not problem areas and require no immediate action. Class A water quality criteria (i.e., 7 mg/L) should be the desired endpoint of water quality remediation programs.

The highest priority problem areas for eutrophication were Ecology Station BUD002 in West Bay, the City of Olympia station at the Capitol Lake outfall to Budd Inlet, and the Port of Olympia stations in the East Bay Marina (see Table 3). Dissolved oxygen concentrations in late summer were less than 3.0 mg/L at the bottom of the water column at these stations. Secondary priority areas were City of Olympia stations at the Fiddlehead Marina, north of the LOTT 30-in diameter outfall, and in the navigation channel northeast of Cascade Pole Company. No problem areas were identified north of East and West Bays, but there was only one sampling station where dissolved oxygen was monitored (i.e., Ecology Station BUD005 just south of Olympia Shoals).

MICROBIAL CONTAMINATION

Identification of microbial contamination problem areas is based on departures from the Washington State water quality standards described in the microbial contamination section of "Data Summaries." The fecal coliform bacteria EAR values were derived from calculations of geometric means within each portion of Budd Inlet depicted in Figure 16. EAR values for areas within Class A waters were calculated using the Class A water quality criteria of 14 organisms/100 mL as reference. EAR values for areas within Class B waters incorporated the Class B water quality criteria of 100 organisms/100 mL.

TABLE 15. LIST OF PRIMARY AND SECONDARY PROBLEM AREAS IN BUDD INLET[a]

	Primary	Secondary
Eutrophication		
	Ecology Station BUD002	Fiddlehead Marina
	Capitol Lake outfall to Budd Inlet	North of LOTT 30-in outfall
	East Bay Marina	Northeast of Cascade Pole Co., middle of channel
Toxic Contamination		
Sediment Chemistry	Cascade Pole Co.	West Bay, near the West Bay drain
	West Bay drain	Fiddlehead Marina
Microbial Contamination		
	Moxlie Creek	Tamoshan
	Boston Harbor	Beverly Beach
	Ellis Creek	Athens Beach
	South of Tykle Cove	Butler Cove
		North of Priest Point

[a] Criteria for prioritizing problem areas are found in Table 3, and are discussed in the text.

The criteria for identifying problem areas were based on the logarithmic scale. Fecal coliform bacteria EAR values in the highest priority areas exceeded 10. Secondary priority areas for fecal coliform bacteria had EAR values between 1 and 10. Areas with fecal coliform bacteria EAR values below 1 were not considered for immediate action.

The highest priority problem areas for fecal coliform bacteria in Budd Inlet were Moxlie Creek, Boston Harbor, Ellis Creek, and a creek entering Budd Inlet south of Tykle Cove. Secondary priority problem areas included Tamoshan WWTP, Beverly Beach WWTP, Athens Beach, Butler Cove, and north of Priest Point. The variability inherent in the bacterial counts at stations sampled more than once suggests that routine sampling at these stations is essential to better assess the spatial extent and magnitude of the problem areas. Fecal coliform bacteria samples have not been collected at all potential sources. Point sources of microbial contamination to Budd Inlet that have not been adequately characterized, include the Tamoshan, Beverly Beach, and Seashore Villa WWTP. Nonpoint sources that have not been characterized include the contribution of microbial contamination from failing septic systems, local hobby farms, live-aboards in Olympia marinas, and general boating activities in Budd Inlet.

TOXIC CONTAMINATION

The following six data categories were discussed in the "Data Summaries" section for toxic contamination: water column contamination, sediment contamination, bioaccumulation, bioassay results, benthic communities, and fish pathology. The following discussion of toxic problem areas will be limited to sediment chemistry and bioassay results. Bioaccumulation of clam tissues is not included because of the high detection limits of the reference data. Water column contamination, benthic communities, and fish pathology are not included because of a lack of data or a lack of Budd Inlet reference criteria.

Because the lack of data precluded following the guidelines set forth in the decision-making approach, the criteria for sediment chemistry and bioassays are derived from the Everett Harbor Action Plan (Tetra Tech

1985c). The highest priority problem areas for sediment chemistry in Budd Inlet are defined as those stations where the EAR values for metals exceeds 50, or where the EAR for organic compounds exceeds 100 (see Table 3). These values correspond to the maximum EAR categories in the Everett Harbor Action Plan (Tetra Tech 1985c). Secondary priority problem areas are defined as areas where the EAR for sediment metals is between 10 and 50, or where the EAR for organic compounds is between 10 and 100. No immediate action areas are those with EAR values below 10.

The highest priority sediment chemistry problem areas in Budd Inlet are near the Cascade Pole Company site and at the West Bay storm drain. These are the only locations where sediment chemical analyses for organic compounds were conducted. Additional sampling and analysis is required to fully describe the geographic extent of contamination in these areas. Secondary priority problem areas were located in West Bay off of the West Bay storm drain (sediment organic compounds), and in the Fiddlehead Marina (sediment metals). Sediment metals were investigated at the Capitol Lake outfall but were found at levels that required no immediate action. The remainder of Budd Inlet has not been investigated for sediment contamination.

Problem areas for sediment bioassay results were defined based on percent mortality instead of the EAR value because the EAR value is greatly influenced by percent mortality in the control bioassay test. For example, if the mortality in the test sediment was 25 percent, the EAR based on a 1 percent control mortality would be 25. The EAR based on a 3 percent control mortality would be 8.3. Conclusions drawn from these two EAR values could be very different. Only those data having less than 5 percent mortality in the control test were accepted for this review.

Highest priority problem areas are defined as those areas where either the amphipod bioassay or the oyster bioassay resulted in greater than 50 percent mortality (see Table 3). This mortality corresponds to the maximum value EAR in the Everett Harbor and the Elliott Bay Action Plans (Tetra Tech 1985b,c). Secondary priority problem areas occur where either of the bioassay mortality rates were between 25 and 50 percent. Stations with less than 25 percent mortality for either of the bioassays requires no immediate action.

Bioassays were conducted at only two stations in Budd Inlet. Neither the station off the Port of Olympia peninsula nor the station at the Olympia Yacht Club require immediate action.

IDENTIFICATION OF DATA GAPS

Intensive synoptic sampling programs have not been conducted in Budd Inlet. As discussed in "Identification of Problem Areas," this lack of synoptic data has greatly hindered the identification of problem areas. All appropriate data were used to identify problem areas caused by eutrophication, toxic contamination, and microbial contamination. More complete characterization of Budd Inlet will require the collection and analysis of additional data. The objective of this final section is to identify data gaps that, when filled, will enable full use of the decision-making approach to characterize environmental conditions in Budd Inlet.

The following discussion provides information that may be used to design a preliminary field investigation. A detailed sampling and analysis plan for development of the Budd Inlet Action Program will be prepared at a future date.

EUTROPHICATION

The problem of eutrophication in upper Budd Inlet has been well documented (URS 1986). However, the boundaries of the geographic area impacted by high nutrient levels and low dissolved oxygen have not been delineated. Existing data were collected to monitor specific areas (i.e., Fiddlehead Marina, Capitol Lake outfall, East Bay Marina). Additional sampling efforts should be conducted south of Priest Point to generate data that could define the spatial extent of problem areas in southern Budd Inlet. Stations located north of Priest Point would provide reference conditions.

Information on dissolved oxygen and nutrients should be collected to fill gaps in the available eutrophication data because both types of measurements are necessary to define the spatial extent and magnitude of the eutrophication problem. A detailed dissolved oxygen data collection effort coupled with a smaller nutrient data collection effort at overlapping stations would be a cost-effective method for obtaining the necessary information. Detailed information on dissolved oxygen concentrations is most important because of the deleterious effects of low dissolved oxygen on the resident biota. Oxygen measurements at each station should occur at the sediment surface and in the water column to provide information on the oxygen levels to which the plankton, nekton, benthic epifauna, and benthic infauna are subjected. Additionally, nonpoint sources of nitrogen (including atmospheric deposition) should be quantified.

Oxygen depletion is a seasonal phenomenon. Lowest oxygen levels occur in late summer and early fall in the bottom water. An intensive weekly sampling effort from July through September would provide the necessary information to understand this annual event. Sampling stations should overlap with existing monitoring stations. Information collected at the existing monitoring stations between October and June would provide the necessary data for the remainder of the year.

MICROBIAL CONTAMINATION

Considerable data exists for fecal coliform bacteria contamination in Budd Inlet. Data collected from shoreline sources were generally higher in September 1985 than in April 1985 (URS 1986). The cause of this variability may have been differences in the flow rates of the freshwater sources that were sampled. It was suggested that higher flow rates may correspond to increased fecal coliform bacteria concentrations (URS 1986).

Information from offshore monitoring stations indicated that fecal coliform concentrations in offshore surface waters were within Washington State standards between 1982 and 1986. Continuation of these programs will be sufficient to help understand fecal coliform bacterial distributions in offshore areas.

Routine data collection for fecal coliform bacteria and water flow at selected locations would help define the relationship between these variables. Sampling locations might include sites receiving storm water discharges from urban areas and sites receiving discharges from rural areas. Moxlie Creek should be sampled for the purpose of monitoring urban runoff since it is an identified problem area for microbial contamination. Moxlie Creek enters East Bay via an 84-in diameter pipe and enters the pipe near Plum and Union Streets in Olympia. Approximately 100 ft before the outfall terminus, the East Bay CSO discharges into Moxlie Creek (see the section entitled "Contamination Sources"). Sites such as Ellis Creek or the creek entering Budd Inlet between Tykle Cove and Butler Cove might be suitable for monitoring rural runoff. Both of these sites are also known problem areas.

Fecal coliform bacteria monitoring in marine waters should also occur near the Tamoshan, Beverly Beach, and Seashore Villa WWTP. Monitoring stations located in streams or culverts and in marine waters near Athens Beach and the French Hill Road would also be appropriate.

TOXIC CONTAMINATION

Sources of Contamination

The limited sediment chemistry data presently available for Budd Inlet clearly indicated that the upper inlet is receiving contaminated material from the Port of Olympia peninsula. The only point source of contamination that has been sampled is the West Bay storm drain. According to Mr. R. Alan (25 March 1988, personal communication), LOTT has not conducted any sampling off the CSOs. Other sources, including NPDES-permitted discharges, storm drains carrying storm runoff from urban areas, and seeps and groundwater at the Cascade Pole Company site should also be investigated. This information is required to identify contaminant sources for remedial action.

Sediment Chemistry

At the present time, Budd Inlet sediments have not been analyzed for all of the Budd Inlet contaminants of concern (see Table 2). Analyses of sediments near the Cascade Pole Company have been limited to organic chemicals present in creosote and the suspected breakdown products of creosote. Analyses of sediment metals are limited to three City of Olympia stations, and seven stations near the Cascade Pole Company. The full suite of metals of concern were not investigated at these stations.

A sampling program was proposed by Tetra Tech (1987) for sediments near the Cascade Pole Company. If this plan is implemented, the chemical results will adequately describe sediment contamination in the immediate area. However, sampling efforts in East Bay are needed to document the geographic extent of organic contamination from the Cascade Pole Company. This sampling would also indicate whether sediments have been contaminated by Moxlie Creek, by any of the East Bay storm drains, or by the East Bay Marina.

Sampling in West Bay is needed to gather data to determine potential sediment contamination from storm drains, CSOs, the LOTT 48-in diameter outfall at Fiddlehead Marina, and from other industrial discharges and marinas. Sediment chemistry information from sampling north of the Port of Olympia peninsula will provide information on the geographic extent of sediment contamination north of the industrial portions of Budd Inlet.

Sediment chemistry information from near Gull Harbor is needed to determine whether environmental degradation resulted from the extended anchorage of the Mothball Fleet. This maritime fleet contained over 100 vessels between the end of World War II and the early to mid 1960s (Jamison, D., 21 January 1988, personal communication; Newall, G., 10 February 1988, personal communication). Solvents, waste oils, and unknown objects were reportedly dumped into the inlet from the ships and shore-based facilities.

Bioaccumulation

The bioaccumulation of organic contaminants in Budd Inlet clams was investigated near the Cascade Pole Company and the West Bay storm drain. No additional data are available for the study period. The majority of the bioaccumulation data from other urban embayments in Puget Sound are for English sole muscle and liver tissues. Information on bioaccumulation of organic compounds and metals in English sole is needed to determine the bioavailability of contaminants in Budd Inlet, and to enable comparisons between conditions in Budd Inlet and conditions in other urban bays.

Collection of English sole for bioaccumulation analysis should occur in East and West Bays, near the Port of Olympia peninsula, near Priest Point, near Gull Harbor, and in areas of Budd Inlet that could provide reference data. The information collected would enable differences between East and West Bays to be defined, and would provide information on the geographic extent of bioaccumulation north of the industrialized portions of the inlet. The sampling area near Gull Harbor would provide information on bioavailability of sediment contaminants that may have come from the Mothball Fleet.

Sediment Toxicity

Sediment toxicity was investigated north of the Port of Olympia peninsula and at the Olympia Yacht Club. No toxicity data are available for the sediments near the Cascade Pole Company that are known to be highly contaminated with organic chemicals. Similarly, no toxicity data are available for sediments near NPDES-permitted discharges, CSOs, and storm drains.

Bioassay tests of sediments collected near known and suspected contaminant sources would provide important information about the magnitude of environmental degradation at those locations. Bioassay tests are needed for sediments in East and West Bays, north of the Port of Olympia peninsula, near Priest Point, and near Gull Harbor. Tests using both amphipods and oyster larvae would enable comparisons to be made with toxicity information from other Puget Sound urban bays. Microtox tests might also be considered to determine the relative toxicity of sediment contaminants to bacteria.

Benthic Infaunal Communities

As mentioned in the "Data Summaries" section, there are no acceptable data concerning benthic infaunal communities in Budd Inlet. A solid understanding of the composition of the benthic community in Budd Inlet is important for determining the effects of sediment contaminants and the effects of low dissolved oxygen on the resident biota. The selection of sampling locations for benthic community analyses must be carefully considered. Stations where sediments are known to be contaminated (determined by sediment chemistry analyses), and stations where sediments are known to be influenced by low dissolved oxygen (determined by water quality surveys) must be sampled. Stations should exhibit similar grain size distributions, and should be located at similar depths so that resulting data may be compared. Under these conditions, the individual effects of sediment contamination and low dissolved oxygen concentrations may be determined.

A series of stations north of the Port of Olympia should be sufficient to identify the extent of benthic degradation to the north. Selection of appropriate reference stations is very important because reference conditions for benthic infauna in Budd Inlet may differ from reference conditions established in other parts of Puget Sound. Reference data from areas such as Carr Inlet (Tetra Tech 1985a) may not be appropriate for comparison with data from Budd Inlet.

Fish Histopathology

Available data for fish histopathology in Budd Inlet are lacking for the study period 1982-1987. Earlier data collected by Malins et al. (1980) indicated that the incidence of certain pathological lesions in English sole and rock sole was similar to the incidence of these lesions in other urban bays. A data collection effort is needed to determine the incidence of bottomfish histopathological disorders in Budd Inlet. English sole should be used in the collection effort so that data on histopathology in Budd Inlet may be compared with data on histopathology in other Puget Sound urban bays.

Histopathological data should be generated at the same areas as were described for bioaccumulation studies. Data would therefore be collected from areas suspected to have elevated sediment contaminants, and from reference areas that are not suspected to be contaminated.

OTHER DATA GAPS

Data on motile epifauna and bottomfish are also necessary to fully define the effects of eutrophication and oxygen depletion. Considerable data on the impact of oxygen depletion on fish distributions (Johnson, M., 18 November 1987, personal communication) are now being collected on the Atlantic coast in Long Island Sound. These data demonstrate that as oxygen concentration declines, motile epifauna and bottomfish move out of the affected area possibly seeking water containing higher oxygen concentrations. Bottom trawl sampling could help determine the composition of the fish community in relation to dissolved oxygen concentration, and would provide valuable information on the effects of oxygen depletion. Weekly or semi-monthly trawls in East and West Bays, and in one or two reference areas would provide information to determine whether oxygen depletion was impacting the motile fauna in Budd Inlet.

REFERENCES

Alan, R. 24 September 1987. Personal Communication (information to Ms. Karen L. Keeley; Budd Inlet sample survey, Department of Public Works, City of Olympia). LOTT Sewage Treatment Facility, Olympia, WA. 12 pp.

Alan, R. 19 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on LOTT outfalls). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 9 February 1988. Personal Communication (phone by Ms. Betsy Day; determination that effluent bioassays were not conducted by LOTT). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 14 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 25 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT sewage treatment facility, Olympia, WA.

Anderson, D. 22 December 1986. Personal Communication (letter to Mr. Dennis O. Cole, Industrial Petroleum Distributors, Inc., Tacoma, WA; Olympia facility, contaminated soils, Ecology Order No. DE 86-S133). Washington Department of Ecology, Olympia, WA. 2 pp.

Anderson, D. 29 October 1987. Personal Communication (phone by Ms. Karen L. Keeley; Budd Inlet). Washington Department of Ecology, Olympia, WA. 1 pp.

Anderson, D. 6 April 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Applied Geotechnology. 1986a. Volume I. Remedial investigation, Cascade Pole Company, Olympia, Washington. AGI Job No. 14,825.104. Prepared for McFarland Cascade, Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA. 103 pp.

Applied Geotechnology. 1986b. Volume II. Remedial investigation - appendices, Cascade Pole Company, Olympia, Washington. AGI Job No. 14,825.104. Prepared for McFarland Cascade, Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA.

Applied Geotechnology. 1987. Intertidal sediment study: polycyclic aromatic hydrocarbons and phenols, Cascade Pole Company, Olympia, Washington. AGI Project No. 14,825.107. Prepared for Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA.

Arden, H. 10 February 1988. Personal Communication (phone by Ms. Betsy Day; information concerning sediment resuspension by the East Bay Marina aerators). U.S. Army Corps of Engineers, Seattle, WA.

Arden, H. 11 February 1988. Personal Communication (phone by Ms. Betsy Day; criteria for operation of East Bay Marina aeration system). U.S. Army Corps of Engineers, Seattle, WA.

Armstrong, J. 17 November 1987. Personal Communication (information to Ms. Karen L. Keeley; microbiological sample results for fecal coliforms/100 gm shellfish tissue, 30 June 1987, Washington Department of Social and Health Services and U.S. Environmental Protection Agency study). U.S. Environmental Protection Agency Region X, Seattle, WA. 3 pp.

Arvid Grant and Associates. 1973. Water pollution control and abatement plan for Deschutes River basin. State of Washington Water Resources Inventory Area No. 13 in Thurston and Lewis Counties. Prepared for Thurston Regional Planning Council, Olympia, WA. Arvid Grant and Associates, Inc., Olympia, WA. 117 pp. + 15 figures and appendix.

Barrick, R.C., and F.G. Prahl. (In review). Hydrocarbon geochemistry of the Puget Sound Region III. Polycyclic aromatic hydrocarbons in sediment.

Battelle Northwest. 1983. Draft tables of chemical and biological analyses of selected sediments from Puget Sound. U.S. Environmental Protection Agency Region X, Seattle, WA. 27 pp.

Bernhardt, J., and B. Yake. 22 June 1983. Personal Communication (memorandum to Mr. Frank Monahan, Washington Department of Ecology; LOTT Phase II receiving water considerations). Washington Department of Ecology, Olympia, WA. 15 pp.

Bradley, D. 12 January 1987. Personal Communication (letter to Mr. Richard Pierce, Thurston County Health Department, Environmental Health Division, Olympia, WA). Washington Department of Ecology, Olympia, WA. 33 pp.

Bradley, D. 30 March 1988. Personal Communication (phone by Mr. J. Portele). Washington Department of Ecology, Olympia, WA.

Calambokidis, J., J. Peard, G.H. Steiger, and J.C. Cubbage. 1984. Chemical contaminants in marine mammals from Washington State. NOAA Technical Memorandum NOS OMS 6. National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, MD. 167 pp. including appendices.

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

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

Clark, D. 21 November 1985. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Beverly Beach wastewater treatment plant limited Class II inspection, June 17-18, 1985). Washington Department of Ecology, Olympia, WA. 12 pp.

Clark, D. 27 January 1986. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Tamoshan wastewater treatment plant limited Class II inspection, June 17-18, 1985). Washington Department of Ecology, Olympia, WA. 13 pp.

Clark, D. 25 March 1986. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Seashore Villa wastewater treatment plant limited Class II inspection, July 1-2, 1985). Washington Department of Ecology, Olympia, WA. 11 pp.

Cloud, G. 30 October 1987. Personal Communication (phone by Ms. Karen L. Keeley; Budd Inlet Industrial Petroleum Distributors, Inc., waste oil spill). Washington Department of Ecology, Olympia, WA. 1 pp.

Colby, J. 28 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT Sewage Treatment Facility, Olympia, WA.

Collias, E., et al. 1962. Physical and chemical data for southern Puget Sound, August 1957-October 1958. Technical Report No. 67. University of Washington, Department of Oceanography, Seattle, WA.

Colwell, R.R., and J. Liston. 1960. Microbiology of shellfish. Bacteriological study of the natural flora of Pacific oysters (<u>Crassostrea gigas</u>. Appl. Microbiol. 8:194-209.

Crecelius, E.A., M.H. Bothner, and R. Carpenter. 1975. Geochemistry of arsenic, antimony, mercury, and related elements in sediments of Puget Sound. Environ. Sci. Technol. 9:325-333.

Cunningham, J. 21 September 1987. Personal Communication (phone by Ms. Karen L. Keeley). City of Olympia Engineering Department, Olympia, WA.

Department of Social and Health Services. 1987. Chemicals and bacteriological organisms in non-commercial shellfish. Draft Report. DSHS, Olympia, WA.

Determan, T. 19 February 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; effects of Tamoshan STP outfall on water quality at Silver Spit, Budd Inlet). Washington Department of Ecology, Olympia, WA. 10 pp.

Earth Consultants. 1985. Supplemental soil hydrocarbon content evaluation, proposed Arco station, East Bay Drive and State Avenue, Olympia, WA. Prepared for Barghausen Consulting Engineers, Inc., Kent, WA. Earth Consultants, Inc., Bellevue, WA. 11 pp. + tables.

Earth Consultants. 7 August 1986. Personal Communication (letter to Mr. Al Kendall, Barghausen Consulting Engineers, Kent, WA; supplemental chemical analysis of soils, proposed Arco station, East Bay Drive and State Avenue, Olympia, WA). Earth Consultants, Inc., Bellevue, WA. 2 pp.

Egge, E. 25 January 1987. Personal Communication (information to Ms. Karen L. Keeley; Port of Olympia East Bay Marina dissolved oxygen monitoring data). Port of Olympia, Olympia, WA.

Egge, E. 1 February 1988. Personal Communication (phone by Ms. Betsy Day; information on operation fo East Bay marina aeration system). Port of Olympia, Olympia, WA.

Entranco Engineers. 1983. Capitol Lake restoration analysis. Prepared for Washington Department of General Administration. Entranco Engineers, Bellevue, WA. 128 pp. + appendices.

Evans-Hamilton and D.R. Systems. 1987. Puget Sound environmental atlas. Volume 2. Prepared for U.S. Environmental Protection Agency, Puget Sound Water Quality Authority, and U.S. Army Corps of Engineers. Evans-Hamilton, Inc., Seattle, WA, and D.R. Systems, Inc., Seattle, WA. 46 maps.

Evergreen State College. 1974. Environmental assessment study of the Port of Olympia. Final Report. Seacoast Management Group Contract. The Evergreen State College, Olympia, WA. 28 pp. + 4 figures, 7 tables, and appendix.

GeoEngineers. 1987. Dredge spoil evaluation, Berth 3 reconstruction, Olympia, Washington for the Port of Olympia. Prepared for the Port of Olympia, Olympia, WA. GeoEngineers, Incorporated, Bellevue, WA. 6 pp. + appendices.

Gibbs, T. 20 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on areas in Budd Inlet with uninvestigated onsite sewage disposal problems). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Haggerty, K. 18 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on Olympia Golf and Country Club septic drainfield and surface water runoff retention pond). Olympia Golf and Country Club, Olympia, WA.

Helmlinger, J. 23 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on the Capitol Lake siphon). Washington Department of General Administration, Olympia, WA.

Helmlinger, J. 13 April 1988. Personal Communication (information to Ms. Karen L. Keeley; Capitol Lake siphon system and water quality monitoring). Washington Department of General Administration, Olympia, WA.

Jamison, D. 21 January 1988. Personal Communication (information to Ms. Karen L. Keeley). Washington Department of Natural Resources, Olympia, WA.

Johnson, A. 22 July 1985. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology; receiving environment survey in Budd Inlet at McFarland/Cascade, 13 February 1985). Washington Department of Ecology, Olympia, WA. 7 pp.

Johnson, M. 18 November 1987. Personal Communication (information to Ms. Betsy Day; distribution of fish in relation to oxygen depletion in Long Island Sound). Long Island Sound Hypoxia-Modeling Workshop, University of Connecticut, Groton, CT.

Kelley, C.B., W. Areisz, and M.W. Pusnell. 1960. Bacterial accumulation by oyster Crassostrea virginica on the Gulf Coast. Tech. Report F60-4, U.S. Department of Public Health Services, Washington, DC.

Kendra, W., and T. Determan. 6 November 1985. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology; effects of three small sewage treatment plants on Budd Inlet receiving waters). Washington Department of Ecology, Olympia, WA. 22 pp.

Kessler, F. 18 December 1987. Personal Communication (letter to Ms. Karen L. Keeley; LOTT wastewater treatment plant receiving water sampling program in Budd Inlet). LOTT Sewage Treatment Facility, Olympia, WA. 70 pp. + 3 figures.

Kittle, L. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Kittle, L., and H. Tracy. 19 January 1982. Personal Communication [memorandum to Mr. Bruce Cameron, Washington Department of Ecology; lower Budd Inlet marine resource damage assessment (MRDA), September 10, 1981]. Washington Department of Ecology, Olympia, WA. 23 pp.

Kruger, D.M. 1979. Effects of point-source discharges and other inputs on water quality in Budd Inlet, Washington. DOE 79-11. Washington Department of Ecology, Olympia, WA. 40 pp. + appendices.

Lilja, J. 6 June 1985. Personal Communication (phone by Mr. Peter Nix). Washington Department of Social and Health Services, Olympia, WA.

Lilja, J. 25 March 1988. Personal Communication (phone by Ms. Betsy Day). Washington Department of Social and Health Services, Olympia, WA.

Long, E.R., and P.M. Chapman. 1985. A sediment quality triad: measures of sediment contamination, toxicity, and infaunal community composition in Puget Sound. Mar. Pollut. Bull. 16:405-415.

Malin, R. 25 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; information on dredging permit 071-OYB-2-010937). Port of Olympia, Olympia, WA.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, and H.O. Hodgins. 1980. Chemical contaminants and biological abnormalities in central and southern Puget Sound. NOAA Technical Memorandum OMPA-2. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 295 pp. including appendices.

Malins, D.C. 1981. Data from sediments collected from central Puget Sound, 1979-1980. National Marine Fisheries Service, Seattle, WA. 5 pp.

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

McCarthy, B. 15 January 1988. Personal Communication (phone by Ms. Lynne M. Kilpatrick-Howard). City of Olympia, Public Works Department, Olympia, WA.

McNicholas, R. 1984. Stream corridor management plan for the Deschutes River, Washington. Project No. 82-145A. Prepared for Washington State Department of General Administration, Olympia, WA. Thurston County Conservation District, Olympia, WA. 65 pp. including appendices.

Mitchell, J.R., M.W. Presnell, E.W. Akin, J.M. Cummins, and O.C. Lice. 1966. Accumulation and elimination of poliovirus by the eastern oyster. J. Epidem. 84:40-50.

Moore, D. 17 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; City of Olympia combined sewer overflow locations). City of Olympia, Engineering Department, Olympia, WA.

Moore, D. 9 December 1987. Personal Communication (letter to Ms. Karen L. Keeley; City of Olympia combined sewer overflow locations). City of Olympia, Engineering Department, Olympia, WA.

Moore, D. 29 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT Sewage Treatment Facility, Olympia, WA.

Moore, A., and D. Anderson. 1979. Deschutes River basin suspended sediment transport study. Project Report No. DOE-PR-7. Washington Department of Ecology, Water and Wastewater Monitoring Section, Olympia, WA. 21 pp.

Mowrer, J., J. Calambokidis, N. Musgrove, B. Drager, M.W. Beug, and S.G. Herman. 1977. Polychlorinated biphenyls in cottids, mussels, and sediment in southern Puget Sound, Washington. Bull. Environ. Contam. Toxicol. 18:588-594.

Mumford, T.F., Jr. 25 September 1987. Personal Communication (information to Ms. Karen L. Keeley; water quality data in Budd Inlet collected near the Washington Department of Natural Resources Marine Station). Washington Department of Natural Resources, Aquatic Lands Division, Olympia, WA. 17 figures and tables.

Munger, S.F., A.A. Heywood, R.T. Dutton, and R.G. Swartz. 1979. A survey of the microbiological quality of shellfish on King County beaches. Municipality of Metropolitan Seattle, Seattle, WA.

Newall, G. 10 February 1988. Personal Communication (phone by Ms. Betsy Day; information on the moth-balled maritime fleet in Budd Inlet). Olympia, WA.

Norton, D. 5 February 1986. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology, Southwest Regional Office; results of priority pollutant analyses on water, sediment, and clam samples collected in lower Budd Inlet near McFarland/Cascade, Olympia, WA, 14 August 1985). Washington Department of Ecology, Olympia, WA. 16 pp.

Oberlander, J. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Oberlander, J. 24 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). Metro, Seattle, WA.

Oblas, V. 29 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). Metro, Seattle, WA.

O'Brien, E. 12 November 1987. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Seattle, WA.

Oclay, N. 1959. Oceanographic conditions near the head of southern Puget Sound. Master's Thesis, University of Washington, Seattle, WA.

Olympia, City of. 1987. *Storm sewer maps 1" = 100'*. City of Olympia, Department of Public Works, Olympia, WA.

Parametrix. 1987a. LOTT urban area wastewater management plan: plan summary. Draft. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 7 pp. + figures, tables, and map.

Parametrix. 1987b. LOTT urban area wastewater management plan. Draft. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 42 pp. + appendices and map.

Parametrix. 1987c. LOTT urban area wastewater management plan. Draft Environmental Impact Statement. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 64 pp. + appendices and map.

Peck, L. 18 March 1988. Personal Communication (memorandum to T. Hooper, Washington Department of Fisheries; Budd Inlet water quality). Washington Department of Fisheries, Olympia, WA.

Peeler, M. 12 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; status of Cascade Pole Company NPDES permit). Washington Department of Ecology, Olympia, WA.

Peeler, M. 15 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Peeler, M. 22 February 1988. Personal Communication (letter to Ms. Karen L. Keeley; additional information regarding intertidal sediment sampling at the former Cascade Pole Company site). Washington Department of Ecology, Olympia, WA.

Pierce, R. 22 October 1987. Personal Communication (information to Ms. Karen L. Keeley; water bacteriological analysis for the new Port of Olympia marinas, and shellfish sampling program conducted in southern Puget Sound during 1985 and 1986). Thurston County Health Department, Environmental Health Division, Olympia, WA. 3 pp.

Pierce, R. 17 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; information on groundwater management plan). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Pierce, R. 20 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on disposal of sediments from proposed ARCO site). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Port of Olympia. 29 February 1988. Personal Communication (information to Ms. Karen L. Keeley; map showing current lessees of Port of Olympia property). Port of Olympia, WA.

Prahl, F.G., and R. Carpenter. 1979. Role of zooplankton fecal pellets in the sedimentation of polycyclic aromatic hydrocarbons in Dabob Bay, Washington. Geochim. Cosmochim. Acta 43:1959-1972.

R.W. Beck and Associates. 1986. Boston Harbor wastewater facilities planning study for Thurston County. R.W. Beck and Associates, Seattle, WA. 60 pp. + figures, tables, and appendices.

Rhoads, D.C. 18 November 1987. Personal Communication (information to Ms. Betsy Day; effects of oxygen depletion on benthic communities). Long Island Sound Hypoxia-Modeling Workshop, University of Connecticut, Groton, CT.

Schiewe, M. 19 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; results of amphipod and oyster larvae bioassay samples from Budd Inlet). National Oceanic and Atmospheric Administration, Northwest and Alaska Fisheries Center, Seattle, WA.

Schmitten, R. 16 October 1981. Personal Communication (memorandum to Governor John Spellman; recent Budd Inlet fish kills). Washington Department of Fisheries, Olympia, WA.

Singleton, L. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Spencer, M. 1 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information about Water Street pump station). Washington Department of Ecology, Olympia, WA.

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

Sweet, B. 23 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on the Capitol Lake siphon). Washington Department of General Administration, Olympia, WA.

Sweet, B. 13 April 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of General Administration, Olympia, WA.

Tetra Tech. 1985a. Commencement Bay nearshore/tideflats remedial investigation. Final Report. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1985b. Elliott Bay toxics action plan: Initial data summaries and problem identification. Draft Report, EPA contract 68-03-1977. Prepared for U.S. Environmental Protection Agency Region X, Office of Puget Sound. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1985c. Everett Harbor toxics action plan: initial data summaries and problem identification. Draft Report. Prepared for U.S. Enviornmental Region X, Office of Puget Sound, Seattle, WA. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1986a. Recommended protocols for measuring selected environmental variables in Puget Sound. Prepared for U.S. Environmental Protection Agency, Office of Puget Sound, Seattle, WA. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1986b. Users manual for pollutant of concern matrix. Prepared for U.S. Environmental Protection Agency Region X, Seattle, WA.

Tetra Tech. 1987. Sediment sampling and analysis plan for the Cascade Pole Company, Olympia, Washington. Prepared for Black & Veatch, Olympia, WA and Washington Department of Ecology, Olympia, WA. Tetra Tech, Inc., Bellevue, WA. 22 pp.

Thurston County Health Department. 1985. Southern Puget Sound water quality assessment study: bacteriological survey of Budd Inlet, April 1985. Objective B, Tasks 1,2, and 3 Interim Data Report. Draft. Thruston County Health Department, Environmental Health Division, Olympia, WA. 15 pp.

Thurston Regional Planning Council. 1985. Percival Creek corridor plan. Volume I: canyon and middle reaches. Thurston Regional Planning Council, Olympia, WA. 116 pp. including appendix and 13 maps.

Turpin and Associates. 1985. Dredging plan, One Tree Island Marina. Thurston County, WA. Turpin and Associates, Olympia, WA.

U.S. Army Corps of Engineers. No Date (a). Application and associated materials for Department of the Army permit for the City of Olympia, Reference Number 071-OYB-2-010618. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (b). Application and associated materials for Department of the Army permit for the Martin Marina, Reference Number 071-OYB-2-008536. U.S. Army Corp of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (c). Application and associated materials for Department of the Army permit for the Olympia Yacht Club, Reference Number 071-OYB-2-010788. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (d). Application and associated materials for Department of the Army permit for the One Tree Island Marina, Reference Number 071-OYB-2-009749-R. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (e). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-1-006165. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (f). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-2-010937. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (g). Application and associated materials for Department of the Army permit for the Tamoshan Homeowners' Association, Reference Number 071-OYB-2-007996. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (h). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-2-007306. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (i). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-2-007709. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (j). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-4-008715. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (k). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-2-006297. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. 1977. Results of Corps of Engineers water quality sampling in East Bay, Olympia Harbor, WA, 10 June 1977 through 13 October 1977. U.S. Army Corps of Engineers, Seattle, WA.

U.S. Army Corps of Engineers. 1980. East Bay Marina, Olympia, Thurston County, Washington: final detailed project report. Section 107, 1960 river and harbor act and environmental impact statement. U.S. Army Corps of Engineers, Seattle, WA. 148 pp. + appendices and exhibits.

U.S. Army Corps of Engineers. 27 October 1987. Personal Communication (information to Ms. Karen L. Keeley; computerized listing of U.S. Army Corps of Engineers dredging permits in Budd Inlet since 1975). U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA. 1 pp.

U.S. Environmental Protection Agency. 7 January 1988. Personal Communication (unpublished data from STORET). U.S. EPA Region X, Seattle, WA.

URS. 1980. State of Washington industrial waste survey, City of Olympia. Prepared for Washington Department of Ecology, Olympia, WA. URS Company, Seattle, WA. 32 pp. + appendices.

URS. 1986. Southern Puget Sound water quality assessment study. Final report: comprehensive circulation and water quality study of Budd Inlet. Prepared for Washington Department of Ecology, Olympia, WA. URS Corporation, Seattle, WA. 222 pp. + references and appendices.

Washington Department of Ecology. 1979. National pollutant discharge elimination system waste discharge permit. Seashore Villa Mobile Home Park. Permit No. WA-003727-3. Washington Department of Ecology, Olympia, WA. 9 pp.

Washington Department of Ecology. 1980. National pollutant discharge elimination system waste discharge permit. Beverly Beach Utilities Association. Permit No. WA-003806-7. Effective date 16 September 1980. Washington Department of Ecology, Olympia, WA. 10 pp.

Washington Department of Ecology. 1984. Potential hazardous waste site preliminary assessment: Water Street pump station. Site identification No. WA D980835144. Washington Department of Ecology, Olympia, WA. 6 pp.

Washington Department of Ecology. 1985a. National pollutant discharge elimination system waste discharge permit. Chevron U.S.A., Inc. Permit No. WA-003871-7. Effective date 25 June 1985. Washington Department of Ecology, Olympia, WA. 10 pp.

Washington Department of Ecology. 1985b. National pollutant discharge elimination system waste discharge permit. Delson Lumber, Inc./DWS International, Inc., and Olympia Forest Products Company. Permit No. WA-002154-7. Effective date 16 December 1985. Washington Department of Ecology, Olympia, WA. 12 pp.

Washington Department of Ecology. 1986. National pollutant discharge elimination system waste discharge permit. Thurston County Public Works, Tamoshan Development. Permit No. WA-003729-0. Effective date 20 October 1986. Washington Department of Ecology, Olympia, WA. 14 pp.

Washington Department of Ecology. 1987. National pollutant discharge elimination system waste discharge permit. Cities of Tumwater and Lacey, Thurston County, and the City of Olympia. Permit No. WA-003706-1. Effective date 25 September 1987. Washington Department of Ecology, Olympia, WA. 21 pp.

Washington Department of Ecology. 9 December 1987. Personal Communication (information to Ms. Karen L. Keeley; computer data listing from Washington Department of Ecology for reported spills and complaints regarding Budd Inlet, September 1986 to November 1987). Washington Department of Ecology, Olympia, WA. 1 p.

Washington Department of Fisheries. 1979. Marine water quality compendium for Washington State. Volume II Data. Grant No. R805032010. Prepared for U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. Washington Department of Fisheries, Research and Development Division, Olympia, WA. 528 pp.

Welsh, B. 18 November 1987. Personal Communication (information to Ms. Betsy Day; causes and effects of oxygen depletion in Long Island Sound). Long Island Sound Hypoxia-Modeling Workshop, University of Connecticut, Groton, CT.

Westley, R.E., E. Finn, M.E. Carr, M.A. Tarr, A.J. Scholz, L. Goodwin, R.W. Sternberg, and E.E. Collins. 1975. Evaluation of effects of channel maintenance dredging and disposal on the marine environment in southern Puget Sound, Washington. Washington State Department of Fisheries, Olympia, WA. 308 pp.

White, M. 30 July 1987. Personal Communication (memorandum to Cascade Pole Company file; field notes from sampling of product seeps and survey of wells for product on 24 June 1987). Washington Department of Ecology, Olympia, WA.

White, M. 21 January 1988. Personal Communication (information to Ms. Karen L. Keeley; intertidal seps from Cascade Pole Company). Washington Department of Ecology, Olympia, WA.

Yake, B. 6 July 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; interpretation of June 3, 1981 Budd Inlet data with particular respect to oxygen depletion). Washington Department of Ecology, Olympia, WA.

Yake, B., J. Joy, and A. Johnson. 1984. Chemical contaminants in clams and crabs from Eagle Harbor, Washington State, with empahsis on polynuclear aromatic hydrocarbons. Segment No. 25-00-01. Washington Department of Ecology, Olympia, WA.

APPENDIX A

DATA EVALUATION SUMMARY TABLES

APPENDIX A: DATA EVALUATION SUMMARY TABLES

Data evaluations are summarized for water quality, contaminant sources, sediment contamination, bioaccumulation, and sediment toxicity in Appendix A. Two summaries are provided for each type of data. The first table (Tables A-1, 2, 3, 4) lists evaluation summaries for documents reviewed for Budd Inlet during the 1982-1987 study period. The adequacy of procedures for sample collection, sample handling, quality assurance, and analytical methods are evaluated. Analytical methods refers to statistical analyses in biological studies and to laboratory analytical techniques in all other studies. The decision to accept or reject each study is based on adequacy of the procedures. Full references for each study can be found in the Budd Inlet bibliography (Appendix E).

The second table (Tables A-5, 6, 7, 8) provides a summary of data within the accepted studies. Each summary includes author/year citation, period of study, type of samples collected, variables measured or analyzed, number of stations, number of replicates per station, and number of times a station was sampled during the study period.

TABLE A-1. DATA EVALUATION SUMMARY FOR WATER QUALITY STUDIES[a,b]

Reference	Acceptable	SC	SH	QA	AM	Comments
Alan (24 September 1987)[c]	Yes	A	N	N	A	LOTT WWTP
Armstrong (17 November 1987)[c]	Yes	N	N	N	N	Priest Point
Bernhardt and Yake (22 June 1983)[c]	No					Review of data before LOTT became a secondary WWTP
Egge (25 January 1987)[c]	Yes	A	N	N	A	East Bay Marina
Kendra and Determan (6 November 1985)[c]	Yes	A	N	N	A	Tamoshan, Beverly Beach, and Seashore Villa WWTPs
Kessler (18 December 1987)[c]	Yes	A	N	N	A	Provides methods for Alan (24 September 1987a)[c]
Mumford (25 September 1987)[c]	Yes	N	N	N	N	WDNR Marine Station
Pierce (22 October 1987)[c]	Yes	N	N	N	N	Fecal coliform bacteria - Budd Inlet
Pierce (22 October 1987)[c]	Yes	N	N	N	N	Fecal coliform bacteria - Olympia Marina
R.W. Beck and Associates (1986)	Yes	N	N	N	A	Fecal coliform bacteria - Boston Harbor
Thurston County Health Department (1985)	Yes	A	A	N	A	Fecal coliform bacteria - Budd Inlet
URS (1986)	Yes	A	A	N	A	Fecal coliform bacteria - Budd Inlet

[a] Refer to summary of accepted water quality studies (Table A-5) for variables measured.

[b] A = adequate, N = not available, SC = sample collection, SH = sample handling, QA = quality assurance/quality control, AM = analytical methods.

[c] Personal communication.

TABLE A-2. DATA EVALUATION SUMMARY FOR CONTAMINANT SOURCE STUDIES[a,b]

Reference	Acceptable	SC	SH	QA	AM	DL	Comments
Applied Geotechnology (1986a,b)	Yes	A	A	A	A	A	Soils, groundwater at Cascade Pole Company
Johnson (22 July 1985)[c]	Yes	A/I	N	N	N	N	Storm drain, seep near Cascade Pole Company
Norton (5 February 1986)[c]	Yes	A	A	A/N	A	N	Storm drain, sediment near Cascade Pole Company

[a] Refer to summary of accepted contaminant source studies (Table A-6) for variables measured.

[b] A = adequate, I = inadequate, N = not available, SC = sample collection, SH = sample handling, QA = quality assurance/quality control, AM = analytical methods, DL = detection limits.

[c] Personal communication.

TABLE A-3. DATA EVALUATION SUMMARY FOR SEDIMENT CONTAMINATION AND BIOACCUMULATION STUDIES[a,b]

Reference	Acceptable	SC	SH	QA	AM	DL	Comments
Alan (24 September 1987)[c,d]	Yes	A	N	N	A	N	LOTT WWTP
Applied Geotechnology (1987)	No	I	A	A	A	A	Cascade Pole Company
Calambokidis et al. (1984)	No	N	N	N	A	A	Southern Puget Sound
Calambokidis et al. (1985)	No	N	N	N	A	A	Southern Puget Sound
GeoEngineers (1987)	No	I	A	N	A	A	Port of Olympia - Berth 3
Johnson (22 July 1985)[c]	Yes	A/I	N	N	N	N	Cascade Pole Company
Norton (5 February 1986)[c]	Yes	A	A/I	A	A	N	Cascade Pole Company
Turpin and Associates (1985)	No	I	N	A	A	A	One Tree Island Marina
U.S. Army COE [no date (c)]	No	I	N	A	N	N	Olympia Yacht Club

[a] Refer to summary of accepted sediment contamination and bioaccumulation studies (Table A-7) for variables measured.

[b] A = adequate, I = inadequate, N = not available, SC = sample collection, SH = sample handling, QA = quality assurance/quality control, AM = analytical methods, DL = detection limits.

[c] Personal communication.

[d] Field and laboratory methods are presented in Kessler (18 December 1987, personal communication).

TABLE A-4. DATA EVALUATION SUMMARY FOR SEDIMENT TOXICITY STUDIES[a]

Reference	Acceptable	SC	SH	QA	AM	A/O	Comments
Schiewe (19 November 1987)[b]	Yes	A	A	A	A	A/O	North of Port of Olympia
U.S. Army COE [no date (c)]	Yes	N	N	A	A	A	Olympia Yacht Club

[a] A = adequate, I = inadequate, N = not available, SC = sample collection, SH = sample handling, QA = quality assurance/quality control, AM = analytical methods, A/O = amphipod/oyster larvae bioassay.

[b] Personal communication.

TABLE A-5. SUMMARY OF ACCEPTED WATER QUALITY STUDIES[a]

Reference	Sample Type	Variables	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Alan (24 September 1987)[b]	WC	Nu, FC, TSS, BOD, pH, T, S, D	1/15/86-11/12/86	5	1	Varied	LOTT WWTP
Armstrong (17 November 1987)[b]	Sh	FC	6/10/86-6/22/87	1	1	5	Priest Point
Egge (25 January 1987)[b]	WC	T, C	7/9/85-10/28/87	2	1	Varied	East Bay Marina
Kendra and Determan (6 November 1985)[b]	WC	Nu, FC, TSS, pH, T, S, D	6/17/85-7/2/85	26	1	1	Tamoshan, Beverly Beach, and Seashore Villa WWTPs
Mumford (25 September 1987)[b]	WC	Nu, pH, T, S, D	12/1/81-11/17/82	1	1	44	WDNR Marine Station
Pierce (22 October 1987)[b]	Sh	FC	7/85-3/86	24	1	1	Budd Inlet
Pierce (22 October 1987)[b]	WC	FC	8/15/85	3	2	1	Port of Olympia Marina
R.W. Beck and Associates (1986)	WC	FC	4/19/84	9	1	1	Boston Harbor
Thurston County Health Department (1985)	WC	FC	4/9,15,17/85	57	1	1	Budd Inlet
URS (1986)	WC	FC	9/10,11/85	57	1	1	Budd Inlet
URS (1986)	WC, SD	Nu, FC, BOD	4/9,15,17/85, 9/10,11/85	11	1	2	Budd Inlet
URS (1986)	WC	T, S, D, CM	9/84, 5/85	8	1	2	Budd Inlet

[a] WC = water column, Sh = shellfish, SD = storm drain, Nu = nutrients, FC = fecal coliform bacteria, TSS = total suspended solids, BOD = 5-day biochemical oxygen demand, T = temperature, S = salinity, D = dissolved oxygen, CM = current meter.

[b] Personal communication.

TABLE A-6. SUMMARY OF ACCEPTED CONTAMINANT SOURCE STUDIES[a]

Reference	Sample Type	Variables	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Applied Geotechnology (1986a,b)	G, SW	Org	7/85	Varied	Varied	Varied	Cascade Pole Company outfall, groundwater seep
Johnson (22 July 1985)[b]	Water, G	Org, Conv	2/13/85	3	1	1	Cascade Pole Company outfall, West Bay drain, groundwater seep
Norton (5 February 1986)[b]	Water	Org, Conv	8/14/85	1	1	1	West Bay drain
White (30 July 1987)[b]	Water, product	Org	6/24/87	5	0	1	Cascade Pole Company groundwater and product seeps

[a] G = groundwater, SW = surface water, SD = storm drain, Org = organics, Conv = conventionals (e.g., grain size, total organic carbon).

[b] Personal communication.

TABLE A-7. SUMMARY OF ACCEPTED SEDIMENT CONTAMINATION AND BIOACCUMULATION STUDIES[a]

Reference	Sample Type	Variables	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Alan (24 September 1987)[b]	Sed	Me, Nu, TS, TVS	4/23/86	3	1	1	LOTT WWTP
Johnson (22 July 1985)[b]	Sed	Me, Org	2/13/85	8	1	1	Cascade Pole Company
Norton (5 February 1986)[b]	Sed, B	Org, Conv	8/14/85	7	1	1	Cascade Pole Company

[a] Sed = sediment, B = bioaccumulation, Me = metals, Org = organics, Nu = nutrients, TS = total solids, TVS = total volatile solids, Conv = conventionals (e.g., grain size).

[b] Personal communication.

TABLE A-8. SUMMARY OF ACCEPTED SEDIMENT TOXICITY STUDIES[a]

Reference	Sample Type	Variables	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Schiewe (19 November 1987)[b]	Sed	O, A	3/85	1	NA	1	North of Port of Olympia Peninsula
U.S. Army COE [no date (c)]	Sed	A	N	1	5	1	Olympia Yacht Club

[a] Sed = sediment, O = oyster, A = amphipod, NA = not available.

[b] Personal communication.

APPENDIX B

MONTHLY AVERAGES OF WATER QUALITY DATA AT ECOLOGY AMBIENT MONITORING STATIONS BUD002 AND BUD005

TABLE B-1. MONTHLY AVERAGES OF WATER QUALITY DATA COLLECTED FROM 1982 TO 1986 AT ECOLOGY AMBIENT WATER QUALITY MONITORING STATIONS BUD002 AND BUD005[a]

Station	Month	Surface DO[b]	Bottom DO	Surface $NH_3^+NH_4^-$ [c]	Bottom $NH_3^+NH_4^-$	Surface O-PO_4 [d]	Bottom O-PO_4
BUD002	April	10.2/0.5	9.9/0.7	0.5/0.1	0.12/0.06	0.05/0.02	0.06/0.02
	May	10.7/0.7	9.6/1.2	0.12/0.07	0.09/0.03	0.05/0.02	0.06/0.03
	June	10.2/1.0	8.7/2.4	0.11/0.04	0.16/0.07	0.06/0.03	0.10/0.06
	July	9.0/1.9	6.6/1.4	0.05/0.04	0.06/0.06	0.07/0.02	0.06/0.01
	August	9.0/2.4	6.1/1.9	0.09/0.08	0.05/0.07	0.06/0.04	0.05/0.02
	September	6.1/0.7	4.1/1.9	0.20/0.05	0.22/0.11	0.12/0.09	0.09/0.04
	October	6.9/0.9	6.9/1.3	0.11/0.06	0.07/0.05	0.05/0.01	0.08/0.05
	November	8.2/1.0	6.9/0.67	0.11/0.01	0.06/0.02	0.10/0.12	0.05/0.01
BUD005	April	11.4/1.1	10.4/0.7	0.09/0.06	0.09/0.07	0.06/0.02	0.05/0.02
	May	11.5/1.1	11.2/0.9	0.03/0.03	0.06/0.04	0.03/0.02	0.05/0.03
	June	11.3/0.5	10.0/2.2	0.05/0.06	0.08/0.03	0.05/0.03	0.06/0.03
	July	11.9/1.1	8.8/2.9	0.02/0.01	0.03/0.04	0.06/0.02	0.04/0.01
	August	10.8/2.0	7.4/1.5	0.02/0.01	0.03/0.04	0.06/0.02	0.05/0.01
	September	9.8/2.7	7.0/1.1	0.06/0.05	0.09/0.08	0.07/0.03	0.08/0.04
	October	8.7/0.7	7.5/0.6	0.02/0.01	0.03/0.01	0.05/0.01	0.05/0.01
	November	8.4/1.0	7.4/1.4	0.06/0.02	0.02/0.0	0.05/0.01	0.05/0.01

[a] Values expressed as mean/one standard deviation (mg/L).

[b] DO dissolved oxygen.

[c] $NH_3^+NH_4^-$ - nitrate plus ammonium.

[d] O-PO_4 ortho-phosphate.

APPENDIX C

HISTORY OF SEDIMENT DREDGING IN BUDD INLET

APPENDIX C

HISTORY OF SEDIMENT DREDGING IN BUDD INLET

The most recent maintenance dredging of navigation channels in Budd Inlet occurred in 1973 (Parker, B., 6 October 1987, personal communication). At this time, Washington State evaluated the effects of channel maintenance dredging and disposal of sediments on the marine environment (Westley, R.E., et al. 1975). A computerized list of all dredging permits issued by U.S. Army COE since January 1975 in Budd Inlet, Capitol Lake, and the Deschutes River was obtained. Since 1980, 11 permits have been issued. These permits were reviewed and are summarized in Table D-1. In some cases, it was determined that dredged materials were contaminated, and the locations of these contaminated soils are plotted on Figure 5. If the contaminated sediments are disposed offshore, the disposal process is managed by U.S. Army COE. If the soils are deposited on an upland site, Ecology is responsible for management.

In early 1988, the U.S. Army COE (Babcock, S., 6 October 1987, personal communication) will publish a reconnaissance survey document entitled "Olympia Harbor, Washington, Navigation Improvements." The purpose of this document is to conduct a preliminary appraisal of a plan to modify the deepwater Olympia channel that enters West Bay. Although this report will not summarize environmental data, sediment testing may be required if the channel is modified.

TABLE C-1. LIST OF DREDGING PERMITS ISSUED FOR BUDD INLET SINCE 1980

Permittee[a]	Date Permit Issued[b]	Purpose	Reference
City of Olympia	29 January 1987	Provide public access, bank protection, and replacement of existing tide grids; excavate 320 yd^3 of bank material with upland disposal; place 190 yd^3 riprap and approximately 900 yd^3 additional fill.	U.S. ACOE[c] [No Date (a)]
Fiddlehead Marina	16 April 1982	Improve and expand moorage in commercial marina; 4,000 yd^3 removed and barged to East Bay fill site; 21,200 yd^3 of dredged material deposited at Dana Passage deep-water disposal site.	U.S. ACOE [No Date (h)]
Martin Marina	10 May 1983	Increase facility for commercial moorage; dredge approximately 6,000 yd^3 of sand and gravel and dispose of on upland site; place approximately 150 yd^3 sand and gravel as fill.	U.S. ACOE [No Date (b)]
Olympia Yacht Club	7 January 1987	Provide additional boat moorage and adequate water depth; dredge approximately 33,700 yd^3 sand and silt and dispose of at Steilacoom deep-water disposal site; dredge 500 yd^3 contaminated material and dispose of at upland site; two 4-ft sediment cores collected and analyzed; data analysis indicated high concentrations of lead.	U.S. ACOE [No Date (c)]
One Tree Island Marina	18 July 1986	Provide additional boat moorage; dredge 3,900 yd^3 contaminated sediments; excavate containment basin and dispose contaminated sediments; cap containment basin with $\geq$4 ft clean material; dredge 9,400 yd^3 clean material and dispose of at Steilacoom deep-water disposal site. Results of sediment chemistry analyses are provided in Turpin and Associates (1985).	U.S. ACOE [No Date (d)]
Port of Olympia - East Bay Marina	11 June 1981	Provide recreational boat moorage and launching facilities; permit expired 11 June 1985 and 70 percent of work was completed.	U.S. ACOE [No Date (e)]
Port of Olympia - East Bay Marina	15 May 1981	Provide protection and adequate depth of water for boat movement within marina, and to and from an existing navigation channel; fill to provide area for cargo handling, parking, and marina support facilities; dredged 475,000 yd^3 organic silt and sand from moorage basin and place behind retaining berm.	U.S. ACOE [No Date (k)]
Port of Olympia	12 May 1987	Upgrade existing cargo area; dredge approximately 4,250 yd^3 and dispose of on upland site; place 8,000 tons riprap and 500 yd^3 backfill; upland disposal site has not been identified yet, and work has not been completed (Malin R., 25 November 1987, personal communication).	U.S. ACOE [No Date (f)]

TABLE C-1. (Continued)

Permittee[a]	Date Permit Issued[b]	Purpose	Reference
Tamoshan Homeowners Association	15 June 1982	Erosion prevention; excavate and place 200 yd^3 beach materials and 60 yd^3 coarse gravel adjacent to existing bulkhead (the gravel may not have been deposited on the beach to protect surf smelt spawning areas).	U.S. ACOE [No Date (g)]
Washington Department of Fisheries	1 March 1982	Maintenance dredging in Capitol Lake; 1,500 yd^3 sediments deposited on state-owned upland disposal site.	U.S. ACOE [No Date (i)]
Washington Department of Fisheries	3 June 1983	Erosion prevention in Deschutes River (immediately downstream of Capitol Way).	U.S. ACOE [No Date (j)]

[a] U.S. Army COE permit numbers are identified in the references. Permit number 071-OYB-2-006974 (Olympia Yacht Club) was not available for review.

[b] U.S. Army COE, 27 October 1987, personal communication.

[c] U.S. ACOE = U.S. Army Corps of Engineers.

APPENDIX D

CONTAMINANT CONCENTRATIONS IN BUDD INLET SEDIMENTS

TABLE D-1. CONTAMINANT CONCENTRATIONS IN BUDD INLET SEDIMENTS

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
1	1	1	4/23/86	10	lead	9.2
2	1	1	4/23/86	10	copper	0.0
3	1	1	4/23/86	10	zinc	29.3
4	1	1	4/23/86	10	chromium	3.7
5	1	1	4/23/86	10	nickel	2.7
6	1	1	4/23/86	10	cadmium	0.0
7	1	2	4/23/86	10	lead	33.4
8	1	2	4/23/86	10	copper	106.0
9	1	2	4/23/86	10	zinc	116.9
10	1	2	4/23/86	10	chromium	55.6
11	1	2	4/23/86	10	nickel	41.7
12	1	2	4/23/86	10	cadmium	5.6
13	1	3	4/23/86	10	mercury	0.2
14	1	3	4/23/86	10	lead	6.5
15	1	3	4/23/86	10	copper	47.0
16	1	3	4/23/86	10	zinc	112.0
17	1	3	4/23/86	10	chromium	43.1
18	1	3	4/23/86	10	nickel	25.0
19	1	3	4/23/86	10	cadmium	0.0
20	2	79023	2/13/85	1	acenaphthene	100u
21	2	79023	2/13/85	1	acenaphthylene	100u
22	2	79023	2/13/85	1	naphthalene	100u
23	2	79023	2/13/85	1	fluorene	100u
24	2	79023	2/13/85	1	anthracene	100u
25	2	79023	2/13/85	1	phenanthrene	100u
26	2	79023	2/13/85	2	fluoranthene	220
27	2	79023	2/13/85	2	benzo(a)anthracene	100u
28	2	79023	2/13/85	2	chrysene	100u
29	2	79023	2/13/85	2	pyrene	660
30	2	79023	2/13/85	2	benzofluoranthenes	100u
31	2	79023	2/13/85	2	benzo(a)pyrene	100u
32	2	79023	2/13/85	2	dibenzo(a,h)anthracene	100u
33	2	79023	2/13/85	2	indeno(1,2,3-cd)pyrene	100u
34	2	79023	2/13/85	2	benzo(g,h,i)perylene	100u
35	2	79023	2/13/85	2.1	Total PAH	880
36	2	79023	2/13/85	8	dibenzofuran	100u
37	2	79023	2/13/85	7	pentachlorophenol	100u
38	2	79023	2/13/85	8	2-methylnaphthalene	100u
39	2	338035	8/14/85	1	acenaphthene	20u
40	2	338035	8/14/85	1	acenaphthylene	20u
41	2	338035	8/14/85	1	naphthalene	94
42	2	338035	8/14/85	1	fluorene	20u
43	2	338035	8/14/85	1	anthracene	20u
44	2	338035	8/14/85	1	phenanthrene	120
45	2	338035	8/14/85	2	fluoranthene	330
46	2	338035	8/14/85	2	benzo(a)anthracene	20u
47	2	338035	8/14/85	2	chrysene	20u
48	2	338035	8/14/85	2	pyrene	630
49	2	338035	8/14/85	2	benzofluoranthenes	330j
50	2	338035	8/14/85	2	benzo(a)pyrene	20u
51	2	338035	8/14/85	2	dibenzo(a,h)anthracene	20u
52	2	338035	8/14/85	2	indeno(1,2,3-cd)pyrene	20u
53	2	338035	8/14/85	2	benzo(g,h,i)perylene	20u
54	2	338035	8/14/85	2.1	Total PAH	1500
55	2	338035	8/14/85	8	dibenzofuran	20u
56	2	338035	8/14/85	7	pentachlorophenol	20u
57	2	338035	8/14/85	8	2-methylnaphthalene	20u
58	2	338034	8/14/85	1	acenaphthene	2000
59	2	338034	8/14/85	1	acenaphthylene	200u
60	2	338034	8/14/85	1	naphthalene	170
61	2	338034	8/14/85	1	fluorene	730

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
62	2	338034	8/14/85	1	anthracene	1200
63	2	338034	8/14/85	1	phenanthrene	2000
64	2	338034	8/14/85	2	fluoranthene	6300
65	2	338034	8/14/85	2	benzo(a)anthracene	1600
66	2	338034	8/14/85	2	chrysene	2000
67	2	338034	8/14/85	2	pyrene	4200
68	2	338034	8/14/85	2	benzofluoranthenes	1500
69	2	338034	8/14/85	2	benzo(a)pyrene	810
70	2	338034	8/14/85	2	dibenzo(a,h)anthracene	200u
71	2	338034	8/14/85	2	indeno(1,2,3-cd)pyrene	200u
72	2	338034	8/14/85	2	benzo(g,h,i)perylene	200u
73	2	338034	8/14/85	2.1	Total PAH	23000
74	2	338034	8/14/85	8	dibenzofuran	880
75	2	338034	8/14/85	7	pentachlorophenol	200u
76	2	338034	8/14/85	8	2-methylnaphthalene	200u
77	2	338036	8/14/85	1	acenaphthene	140
78	2	338036	8/14/85	1	acenaphthylene	50u
79	2	338036	8/14/85	1	naphthalene	39j
80	2	338036	8/14/85	1	fluorene	69
81	2	338036	8/14/85	1	anthracene	50u
82	2	338036	8/14/85	1	phenanthrene	630
83	2	338036	8/14/85	2	fluoranthene	1300
84	2	338036	8/14/85	2	benzo(a)anthracene	390j
85	2	338036	8/14/85	2	chrysene	540j
86	2	338036	8/14/85	2	pyrene	980
87	2	338036	8/14/85	2	benzofluoranthenes	50u
88	2	338036	8/14/85	2	benzo(a)pyrene	50u
89	2	338036	8/14/85	2	dibenzo(a,h)anthracene	50u
90	2	338036	8/14/85	2	indeno(1,2,3-cd)pyrene	50u
91	2	338036	8/14/85	2	benzo(g,h,i)perylene	50u
92	2	338036	8/14/85	2.1	Total PAH	4100
93	2	338036	8/14/85	8	dibenzofuran	50u
94	2	338036	8/14/85	7	pentachlorophenol	50u
95	2	338036	8/14/85	8	2-methylnaphthalene	50u
96	3	79016	2/13/85	99	benzene	9u
97	3	79016	2/13/85	9	ethylbenzene	18
98	3	79016	2/13/85	99	toluene	9u
99	3	79016	2/13/85	9	total xylenes	9u
100	3	79016	2/13/85	1	naphthalene	5800
101	3	79016	2/13/85	8	2-methylnaphthalene	790
102	3	79016	2/13/85	1	acenaphthylene	330
103	3	79016	2/13/85	1	acenaphthene	14000
104	3	79016	2/13/85	8	dibenzofuran	5300
105	3	79016	2/13/85	1	fluorene	5200
106	3	79016	2/13/85	1	phenanthrene	20000
107	3	79016	2/13/85	1	anthracene	2700
108	3	79016	2/13/85	2	fluoranthene	32000
109	3	79016	2/13/85	2	pyrene	20000
110	3	79016	2/13/85	2	benzo(a)anthracene	8000
111	3	79016	2/13/85	2	chrysene	8300
112	3	79016	2/13/85	2	benzofluoranthenes	6600
113	3	79016	2/13/85	2	benzo(a)pyrene	100u
114	3	79016	2/13/85	2	indeno(1,2,3-cd)pyrene	100j
115	3	79016	2/13/85	2	benzo(g,h,i)perylene	100j
116	3	79016	2/13/85	7	phenol	100u
117	3	79016	2/13/85	7	2-methylphenol	100u
118	3	79016	2/13/85	7	4-methylphenol	100u
119	3	79016	2/13/85	7	2,4-dimethylphenol	100u
120	3	79016	2/13/85	7	pentachlorophenol	100u
121	3	79016	2/13/85	5	bis(2-ethylhexyl)phthalate	760
122	3	79016	2/13/85	99	chlorobenzene	9u
123	3	79016	2/13/85	10	copper	86.3

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
124	3	79016	2/13/85	10	chromium	38.8
125	3	79016	2/13/85	10	arsenic	8
126	3	79017	2/13/85	99	benzene	4j
127	3	79017	2/13/85	9	ethylbenzene	510
128	3	79017	2/13/85	99	toluene	48
129	3	79017	2/13/85	9	total xylenes	400
130	3	79017	2/13/85	1	naphthalene	210000
131	3	79017	2/13/85	8	2-methylnaphthalene	15000
132	3	79017	2/13/85	1	acenaphthylene	400u
133	3	79017	2/13/85	1	acenaphthene	370000
134	3	79017	2/13/85	8	dibenzofuran	130000
135	3	79017	2/13/85	1	fluorene	200000
136	3	79017	2/13/85	1	phenanthrene	800000
137	3	79017	2/13/85	1	anthracene	150000
138	3	79017	2/13/85	2	fluoranthene	530000
139	3	79017	2/13/85	2	pyrene	400000
140	3	79017	2/13/85	2	benzo(a)anthracene	95000
141	3	79017	2/13/85	2	chrysene	120000
142	3	79017	2/13/85	2	benzofluoranthenes	73000
143	3	79017	2/13/85	2	benzo(a)pyrene	40000
144	3	79017	2/13/85	2	indeno(1,2,3-cd)pyrene	400u
145	3	79017	2/13/85	2	benzo(g,h,i)perylene	400u
146	3	79017	2/13/85	7	phenol	400u
147	3	79017	2/13/85	7	2-methylphenol	400u
148	3	79017	2/13/85	7	4-methylphenol	400u
149	3	79017	2/13/85	7	2,4-dimethylphenol	400u
150	3	79017	2/13/85	7	pentachlorophenol	400u
151	3	79017	2/13/85	5	bis(2-ethylhexyl)phthalate	15000
152	3	79017	2/13/85	99	chlorobenzene	8u
153	3	79017	2/13/85	10	copper	69.6
154	3	79017	2/13/85	10	chromium	35
155	3	79017	2/13/85	10	arsenic	5.7
156	3	79018	2/13/85	99	benzene	7u
157	3	79018	2/13/85	9	ethylbenzene	7u
158	3	79018	2/13/85	99	toluene	7u
159	3	79018	2/13/85	9	total xylenes	7u
160	3	79018	2/13/85	1	naphthalene	7200
161	3	79018	2/13/85	8	2-methylnaphthalene	640
162	3	79018	2/13/85	1	acenaphthylene	400u
163	3	79018	2/13/85	1	acenaphthene	4800
164	3	79018	2/13/85	8	dibenzofuran	1400
165	3	79018	2/13/85	1	fluorene	1300
166	3	79018	2/13/85	1	phenanthrene	2900
167	3	79018	2/13/85	1	anthracene	5700
168	3	79018	2/13/85	2	fluoranthene	42000
169	3	79018	2/13/85	2	pyrene	27000
170	3	79018	2/13/85	2	benzo(a)anthracene	7500
171	3	79018	2/13/85	2	chrysene	9700
172	3	79018	2/13/85	2	benzofluoranthenes	6900
173	3	79018	2/13/85	2	benzo(a)pyrene	2700
174	3	79018	2/13/85	2	indeno(1,2,3-cd)pyrene	400u
175	3	79018	2/13/85	2	benzo(g,h,i)perylene	400u
176	3	79018	2/13/85	7	phenol	400u
177	3	79018	2/13/85	7	2-methylphenol	400u
178	3	79018	2/13/85	7	4-methylphenol	400u
179	3	79018	2/13/85	7	2,4-dimethylphenol	400u
180	3	79018	2/13/85	7	pentachlorophenol	400u
181	3	79018	2/13/85	5	bis(2-ethylhexyl)phthalate	1100
182	3	79018	2/13/85	99	chlorobenzene	7u
183	3	79018	2/13/85	10	copper	131.5
184	3	79018	2/13/85	10	chromium	40.2

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
185	3	79018	2/13/85	10	arsenic	10.7
186	3	79019	2/13/85	99	benzene	5u
187	3	79019	2/13/85	9	ethylbenzene	5u
188	3	79019	2/13/85	99	toluene	5u
189	3	79019	2/13/85	9	total xylenes	5u
190	3	79019	2/13/85	1	naphthalene	3500
191	3	79019	2/13/85	8	2-methylnaphthalene	640
192	3	79019	2/13/85	1	acenaphthylene	100j
193	3	79019	2/13/85	1	acenaphthene	1500
194	3	79019	2/13/85	8	dibenzofuran	310
195	3	79019	2/13/85	1	fluorene	670
196	3	79019	2/13/85	1	phenanthrene	2000
197	3	79019	2/13/85	1	anthracene	650
198	3	79019	2/13/85	2	fluoranthene	3100
199	3	79019	2/13/85	2	pyrene	4300
200	3	79019	2/13/85	2	benzo(a)anthracene	670
201	3	79019	2/13/85	2	chrysene	740
202	3	79019	2/13/85	2	benzofluoranthenes	880
203	3	79019	2/13/85	2	benzo(a)pyrene	360
204	3	79019	2/13/85	2	indeno(1,2,3-cd)pyrene	100u
205	3	79019	2/13/85	2	benzo(g,h,i)perylene	100u
206	3	79019	2/13/85	7	phenol	100u
207	3	79019	2/13/85	7	2-methylphenol	100u
208	3	79019	2/13/85	7	4-methylphenol	120
209	3	79019	2/13/85	7	2,4-dimethylphenol	100u
210	3	79019	2/13/85	7	pentachlorophenol	100u
211	3	79019	2/13/85	5	bis(2-ethylhexyl)phthalate	100u
212	3	79019	2/13/85	99	chlorobenzene	5u
213	3	79019	2/13/85	10	copper	37.4
214	3	79019	2/13/85	10	chromium	20.5
215	3	79019	2/13/85	10	arsenic	11
216	3	79020	2/13/85	99	benzene	5u
217	3	79020	2/13/85	9	ethylbenzene	5u
218	3	79020	2/13/85	99	toluene	5u
219	3	79020	2/13/85	9	total xylenes	5u
220	3	79020	2/13/85	1	naphthalene	9600
221	3	79020	2/13/85	8	2-methylnaphthalene	560
222	3	79020	2/13/85	1	acenaphthylene	100j
223	3	79020	2/13/85	1	acenaphthene	620
224	3	79020	2/13/85	8	dibenzofuran	250
225	3	79020	2/13/85	1	fluorene	300
226	3	79020	2/13/85	1	phenanthrene	1100
227	3	79020	2/13/85	1	anthracene	360
228	3	79020	2/13/85	2	fluoranthene	1300
229	3	79020	2/13/85	2	pyrene	1500
230	3	79020	2/13/85	2	benzo(a)anthracene	330
231	3	79020	2/13/85	2	chrysene	410
232	3	79020	2/13/85	2	benzofluoranthenes	510
233	3	79020	2/13/85	2	benzo(a)pyrene	190
234	3	79020	2/13/85	2	indeno(1,2,3-cd)pyrene	100u
235	3	79020	2/13/85	2	benzo(g,h,i)perylene	100u
236	3	79020	2/13/85	7	phenol	100u
237	3	79020	2/13/85	7	2-methylphenol	100u
238	3	79020	2/13/85	7	4-methylphenol	100u
239	3	79020	2/13/85	7	2,4-dimethylphenol	100u
240	3	79020	2/13/85	7	pentachlorophenol	100u
241	3	79020	2/13/85	5	bis(2-ethylhexyl)phthalate	120
242	3	79020	2/13/85	99	chlorobenzene	5u
243	3	79020	2/13/85	10	copper	32
244	3	79020	2/13/85	10	chromium	20.2
245	3	79020	2/13/85	10	arsenic	5.5

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
246	3	79021	2/13/85	99	benzene	7u
247	3	79021	2/13/85	9	ethylbenzene	7u
248	3	79021	2/13/85	99	toluene	7u
249	3	79021	2/13/85	9	total xylenes	7u
250	3	79021	2/13/85	1	naphthalene	2400
251	3	79021	2/13/85	8	2-methylnaphthalene	200u
252	3	79021	2/13/85	1	acenaphthylene	200u
253	3	79021	2/13/85	1	acenaphthene	660
254	3	79021	2/13/85	8	dibenzofuran	220
255	3	79021	2/13/85	1	fluorene	200u
256	3	79021	2/13/85	1	phenanthrene	1300
257	3	79021	2/13/85	1	anthracene	820
258	3	79021	2/13/85	2	fluoranthene	7300
259	3	79021	2/13/85	2	pyrene	450
260	3	79021	2/13/85	2	benzo(a)anthracene	3500
261	3	79021	2/13/85	2	chrysene	1900
262	3	79021	2/13/85	2	benzofluoranthenes	1600
263	3	79021	2/13/85	2	benzo(a)pyrene	750
264	3	79021	2/13/85	2	indeno(1,2,3-cd)pyrene	200u
265	3	79021	2/13/85	2	benzo(g,h,i)perylene	200u
266	3	79021	2/13/85	7	phenol	200u
267	3	79021	2/13/85	7	2-methylphenol	200u
268	3	79021	2/13/85	7	4-methylphenol	200u
269	3	79021	2/13/85	7	2,4-dimethylphenol	200u
270	3	79021	2/13/85	7	pentachlorophenol	200u
271	3	79021	2/13/85	5	bis(2-ethylhexyl)phthalate	640
272	3	79021	2/13/85	99	chlorobenzene	7u
273	3	79021	2/13/85	10	copper	62.6
274	3	79021	2/13/85	10	chromium	35.2
275	3	79021	2/13/85	10	arsenic	7.6
276	3	79022	2/13/85	99	benzene	5u
277	3	79022	2/13/85	9	ethylbenzene	5u
278	3	79022	2/13/85	99	toluene	5u
279	3	79022	2/13/85	9	total xylenes	5u
280	3	79022	2/13/85	1	naphthalene	530
281	3	79022	2/13/85	8	2-methylnaphthalene	100j
282	3	79022	2/13/85	1	acenaphthylene	100j
283	3	79022	2/13/85	1	acenaphthene	190
284	3	79022	2/13/85	8	dibenzofuran	78j
285	3	79022	2/13/85	1	fluorene	82j
286	3	79022	2/13/85	1	phenanthrene	400
287	3	79022	2/13/85	1	anthracene	300
288	3	79022	2/13/85	2	fluoranthene	4900
289	3	79022	2/13/85	2	pyrene	3800
290	3	79022	2/13/85	2	benzo(a)anthracene	1300
291	3	79022	2/13/85	2	chrysene	1800
292	3	79022	2/13/85	2	benzofluoranthenes	1600
293	3	79022	2/13/85	2	benzo(a)pyrene	680
294	3	79022	2/13/85	2	indeno(1,2,3-cd)pyrene	100u
295	3	79022	2/13/85	2	benzo(g,h,i)perylene	100u
296	3	79022	2/13/85	7	phenol	100u
297	3	79022	2/13/85	7	2-methylphenol	100u
298	3	79022	2/13/85	7	4-methylphenol	100u
299	3	79022	2/13/85	7	2,4-dimethylphenol	100u
300	3	79022	2/13/85	7	pentachlorophenol	100u
301	3	79022	2/13/85	5	bis(2-ethylhexyl)phthalate	420
302	3	79022	2/13/85	99	chlorobenzene	5u
303	3	79022	2/13/85	10	copper	71.5
304	3	79022	2/13/85	10	chromium	35.2
305	3	79022	2/13/85	10	arsenic	7.3

Seq. No.	Document Number[a]	Sample Number	Sample Date	Class Number	Chemical	Concentration[b]
306	3	79023	2/13/85	99	benzene	5u
307	3	79023	2/13/85	9	ethylbenzene	54
308	3	79023	2/13/85	99	toluene	5u
309	3	79023	2/13/85	9	total xylenes	5u
310	3	79023	2/13/85	1	naphthalene	100u
311	3	79023	2/13/85	8	2-methylnaphthalene	100u
312	3	79023	2/13/85	1	acenaphthylene	100u
313	3	79023	2/13/85	1	acenaphthene	100u
314	3	79023	2/13/85	8	dibenzofuran	100u
315	3	79023	2/13/85	1	fluorene	100u
316	3	79023	2/13/85	1	phenanthrene	100u
317	3	79023	2/13/85	1	anthracene	100u
318	3	79023	2/13/85	2	fluoranthene	220
319	3	79023	2/13/85	2	pyrene	660
320	3	79023	2/13/85	2	benzo(a)anthracene	100u
321	3	79023	2/13/85	2	chrysene	100u
322	3	79023	2/13/85	2	benzofluoranthenes	100u
323	3	79023	2/13/85	2	benzo(a)pyrene	100u
324	3	79023	2/13/85	2	indeno(1,2,3-cd)pyrene	100u
325	3	79023	2/13/85	2	benzo(g,h,i)perylene	100u
326	3	79023	2/13/85	7	phenol	100u
327	3	79023	2/13/85	7	2-methylphenol	100u
328	3	79023	2/13/85	7	4-methylphenol	100u
329	3	79023	2/13/85	7	2,4-dimethylphenol	100u
330	3	79023	2/13/85	7	pentachlorophenol	100u
331	3	79023	2/13/85	5	bis(2-ethylhexyl)phthalate	1600
332	3	79023	2/13/85	99	chlorobenzene	10
333	3	79023	2/13/85	10	copper	56.6
334	3	79023	2/13/85	10	chromium	20.6
335	3	79023	2/13/85	10	arsenic	9
336	3	79017	2/13/85	8	1-methylnaphthalene	780000
337	3	79017	2/13/85	8	2-methylnaphthalene	
338	3	79017	2/13/85	8	dibenzothiophene	270000
339	3	79017	2/13/85	8	biphenyl	
340	3	79019	2/13/85	8	1-methylnaphthalene	2800
341	3	79019	2/13/85	8	2-methylnaphthalene	
342	3	79019	2/13/85	8	dibenzothiophene	
343	3	79019	2/13/85	8	biphenyl	540
344	3	79020	2/13/85	8	1-methylnaphthalene	2100
345	3	79020	2/13/85	8	2-methylnaphthalene	
346	3	79020	2/13/85	8	dibenzothiophene	
347	3	79020	2/13/85	8	biphenyl	910

[a] Reference:
1. Alan, R. (24 September 1987, personal communication).
2. Norton, D. (5 February 1986, personal communication).
3. Johnson, A. (22 July 1985, personal communication).

[b] Expressed in mg/kg dry wt for trace metals and ug/kg dry wt for organic substances.

APPENDIX E

BUDD INLET BIBLIOGRAPHY

BUDD INLET BIBLIOGRAPHY

Advanced Engineering. 6 June 1986. Personal Communication (information to Dunlap Towing Company, Olympia, WA; chip storage pile dust analysis, Appendix I-2 through I-7 to Olympia Staff/Committee Report for Olympia Planning Department file number SH-OLY-3-85). Advanced Engineering, Olympia, WA.

Alan, R. 24 September 1987a. Personal Communication (information to Ms. Karen L. Keeley; Budd Inlet sample survey, Department of Public Works, City of Olympia). LOTT Sewage Treatment Facility, Olympia, WA. 12 pp.

Alan, R. 24 September 1987b. Personal Communication (information to Ms. Karen L. Keeley; draft 1988 monitoring program of the LOTT facility, Olympia, WA). LOTT Sewage Treatment Facility, Olympia, WA. 2 pp.

Alan, R. 19 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on LOTT's outfalls). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 9 February 1988. Personal Communication (phone by Ms. Betsy Day; information on effluent bioassays conducted by LOTT). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 14 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). LOTT Sewage Treatment Facility, Olympia, WA.

Alan, R. 25 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT sewage treatment facility, Olympia, WA.

Anderson, D. 22 December 1986. Personal Communication (letter to Mr. Dennis O. Cole, Industrial Petroleum Distributors, Inc., Tacoma, WA; Olympia facility, contaminated soils, Ecology Order No. DE 86-S133). Washington Department of Ecology, Olympia, WA. 2 pp.

Anderson, D. 29 October 1987. Personal Communication (phone by Ms. Karen L. Keeley; Budd Inlet). Washington Department of Ecology, Olympia, WA. 1 pp.

Anderson, D. 6 April 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Applied Geotechnology. 1986a. Volume I. Remedial investigation, Cascade Pole Company, Olympia, Washington. AGI Job No. 14,825.104. Prepared for McFarland Cascade, Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA. 103 pp.

Applied Geotechnology. 1986b. Volume II. Remedial investigation-appendices, Cascade Pole Company, Olympia, Washington. AGI Job No. 14,825.104. Prepared for McFarland Cascade, Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA.

Applied Geotechnology. 1987. Intertidal sediment study: polycyclic aromatic hydrocarbons and phenols, Cascade Pole Company, Olympia, Washington. AGI Project No. 14,825.107. Prepared for Cascade Pole Company, Olympia, WA. Applied Geotechnology, Inc., Bellevue, WA.

Arden, H. 26 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). U.S. Army Corps of Engineers, Seattle, WA.

Arden, H. 10 February 1988. Personal Communication (phone by Ms. Betsy Day; information concerning sediment resuspension by the East Bay Marina aerators). U.S. Army Corps of Engineers, Seattle, WA.

Arden, H. 11 February 1988. Personal Communication (phone by Ms. Betsy Day; criteria for operation of East Bay Marina aeration system). U.S. Army Corps of Engineers, Seattle, WA.

Armstrong, J. 17 November 1987. Personal Communication (information to Ms. Karen L. Keeley; microbiological sample results for fecal coliforms/100 gm shellfish tissue, 30 June 1987, Washington Department of Social and Health Services and U.S. Environmental Protection Agency study). U.S. Environmental Protection Agency Region X, Seattle, WA. 3 pp.

Arvid Grant and Associates. 1973. Water pollution control and abatement plan for Deschutes River basin. State of Washington Water Resources Inventory Area No. 13 in Thurston and Lewis Counties. Prepared for Thurston Regional Planning Council, Olympia, WA. Arvid Grant and Associates, Inc., Olympia, WA. 117 pp. + 15 figures and appendix.

Babcock, S. 6 October 1987. Personal Communication (phone by Ms. Karen L. Keeley). U.S. Army Corps of Engineers, Engineering Division, Seattle, WA.

Barghausen Consulting Engineers. 7 August 1986. Personal Communication (letter to Mr. Gary Kato, Thurston County Health Department, Environmental Health Division, Olympia, WA; disposal of solid waste material/proposed ARCO FAC #5301, State Street and East Bay, Olympia, WA). Barghausen Consulting Engineers, Inc., Kent, WA. 6 pp.

Bauchman, J.W. 1974. Saving a beautiful lake: an overview of the economic and recreational benefits of reclamation and proposed recreational profiles for the future of Capitol Lake and the visual basin. Olympia, WA. 35 pp.

Bernhardt, J. 13 August 1981. Personal Communication (memorandum to Mr. Jim Krull, Washington Department of Ecology; Budd Inlet fish kill). Washington Department of Ecology, Olympia, WA. 19 pp.

Bernhardt, J., and B. Yake. 22 June 1983. Personal Communication (memorandum to Mr. Frank Monahan, Washington Department of Ecology; LOTT Phase II receiving water considerations). Washington Department of Ecology, Olympia, WA. 15 pp.

Black & Veatch. 1987. Cascade Pole Company feasibility study work plan. Prepared for Washington Department of Ecology, Olympia, WA. Black & Veatch, Olympia, WA, and Tetra Tech, Inc., Bellevue, WA. 49 pp.

Bradley, D. 12 January 1987a. Personal Communication (letter to Mr. Richard Pierce, Thurston County Health Department, Environmental Health Division, Olympia, WA). Washington Department of Ecology, Olympia, WA. 33 pp.

Bradley, D. 12 January 1987b. Personal Communication (memorandum to McFarland Cascade file; potential health risks associated with consumption of shellfish from Budd Inlet). Washington Department of Ecology, Olympia, WA. 3 pp.

Bradley, D. 30 March 1988. Personal Communication (phone by Mr. J. Portele). Washington Department of Ecology, Olympia, WA.

Calambokidis, J., J. Peard, G.H. Steiger, and J.C. Cubbage. 1984. Chemical contaminants in marine mammals from Washington State. NOAA Technical Memorandum NOS OMS 6. National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, MD. 167 pp. including appendices.

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

Capitol Lake Restoration Committee. 1987. Capitol Lake action plan. Capitol Lake Restoration Committee, Olympia, WA. 57 pp. + appendices.

CH2M Hill. 1978. Water quality in Capitol Lake, Olympia, Washington. Prepared for Washington Department of Ecology and Washington Department of General Administration. CH2M Hill, Bellevue, WA. 79 pp. + appendices.

CH2M. 1972. Thurston County: a comprehensive water and sewerage plan. Volume III sewerage plan. CH2M, Bellevue, WA. 57 pp. + appendices.

Clark, D. 21 November 1985. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Beverly Beach wastewater treatment plant limited Class II inspection, June 17-18, 1985). Washington Department of Ecology, Olympia, WA. 12 pp.

Clark, D. 27 January 1986. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Tamoshan wastewater treatment plant limited Class II inspection, June 17-18, 1985). Washington Department of Ecology, Olympia, WA. 13 pp.

Clark, D. 25 March 1986. Personal Communication (memorandum to Mr. Darrel Anderson, Washington Department of Ecology, Southwest Regional Office; Seashore Villa wastewater treatment plant limited Class II inspection, July 1-2, 1985). Washington Department of Ecology, Olympia, WA. 11 pp.

Cloud, G. 30 October 1987. Personal Communication (phone by Ms. Karen L. Keeley; Budd Inlet Industrial Petroleum Distributors, Inc., waste oil spill). Washington Department of Ecology, Olympia, WA. 1 pp.

Colby, J. 28 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT Sewage Treatment Facility, Olympia, WA.

Collias, E., et al. 1962. Physical and chemical data for southern Puget Sound, August 1957-October 1958. University of Washington, Department of Oceanography Technical Report No. 67.

Cox, J.M., C.C. Ebbesmeyer, C.A. Coomes, L.R. Hinchey, J.M. Helseth, G.A. Cannon, and C.A. Barnes. 1981. Index to observations of currents in Puget Sound, Washington, from 1908-1980. NOAA Technical Memorandum OMPA-5. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 51 pp. including appendices.

Cunningham, J. 21 September 1987. Personal Communication (phone by Ms. Karen L. Keeley). City of Olympia Engineering Department, Olympia, WA.

Dames & Moore. 1973. Report of soils investigation, proposed East Bay development program, Port of Olympia, Olympia, Washington. Prepared for Port of Olympia, Olympia, WA. Dames & Moore, Seattle, WA. 18 pp. + plates and appendices.

Dames & Moore. 1974. Report of bottom sediment sampling and analyses, proposed East Bay dredging and landfill, Olympia, Washington. Prepared for Port of Olympia, Olympia, WA. Dames & Moore, Seattle, WA. 11 pp. + tables.

Department of Social and Health Services. 1987. Chemicals and bacteriological organisms in non-commercial shellfish. Draft Report. DSHS, Olympia, WA.

Determan, T. 19 February 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; effects of Tamoshan STP outfall on water quality at Silver Spit, Budd Inlet). Washington Department of Ecology, Olympia, WA. 10 pp.

Determan, T. 5 March 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; effects of Tamoshan STP outfall on water quality at Silver Spit, Budd Inlet). Washington Department of Ecology, Olympia, WA. 8 pp.

Devitt, R.C. 2 June 1983. Personal Communication (memorandum to Mr. Ron Robinson, Mr. Mike Pierce, and Mr. Gene Asselstine, Washington Department of

Ecology; Olympia STP, Budd Inlet dye survey and aerial photographs). Washington Department of Ecology, Southwest Regional Office, Olympia, WA. 17 pp.

Dexter, R.N., D.E. Anderson, E.A. Quinlan, L.S. Goldstein, R.M. Strickland, S.P. Pavlou, J.R. Clayton, Jr., R.M. Kocan, and M. Landolt. 1981. A summary of knowledge of Puget Sound related to chemical contaminants. NOAA Technical Memorandum OMPA-13. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 435 pp.

Dexter, R.N., L.S. Goldstein, P.M. Chapman, and E.A. Quinlan. 1985. Temporal trends in selected environmental parameters monitored in Puget Sound. NOAA Technical Memorandum NOS OMA 19. National Oceanic and Atomspheric Administration, National Ocean Service, Rockville, MD. 166 pp.

Duxbury, A.C., M.A. Freibertshauser, and E.P. Richey. 1972. Budd Inlet circulation and flushing study. Appendix A. Submitted to Arvid Grant and Associates, Inc., Olympia, WA. 12 pp.

Earth Consultants. 1985. Supplemental soil hydrocarbon content evaluation, proposed Arco station, East Bay Drive and State Avenue, Olympia, WA. Prepared for Barghausen Consulting Engineers, Inc., Kent, WA. Earth Consultants, Inc., Bellevue, WA. 11 pp. + tables.

Earth Consultants. 7 August 1986. Personal Communication (letter to Mr. Al Kendall, Barghausen Consulting Engineers, Kent, WA; supplemental chemical analysis of soils, proposed Arco station, East Bay Drive and State Avenue, Olympia, WA). Earth Consultants, Inc., Bellevue, WA. 2 pp.

Edison, D. 21 January 1988. Personal Communication (information to Ms. Karen L. Keeley; Port of Olympia properties). Port of Olympia, WA.

Egge, E. 25 January 1987. Personal Communication (information to Ms. Karen L. Keeley; Port of Olympia East Bay Marina dissolved oxygen monitoring data). Port of Olympia, Olympia, WA.

Egge, E. 1 February 1988. Personal Communication (phone by Ms. Betsy Day; information on operation of East Bay Marina aeration system). Port of Olympia, WA.

Entranco Engineers. 1983. Capitol Lake restoration analysis. Prepared for Washington Department of General Administration. Entranco Engineers, Bellevue, WA. 128 pp. + appendices.

ERT. 1987a. Risk assessment to accompany the feasibility study of the Cascade Pole Company site, Olympia, Washington. Draft Report. Document No. P-E464-200. Prepared for Cascade Pole Company, Olympia, WA. ERT, Concord, MA. 54 pp. + appendix.

ERT. 1987b. Final risk assessment to accompany the feasibility study of the Cascade Pole Company site, Olympia, Washington. Document No. P-E464-200.

Prepared for Cascade Pole Company, Olympia, WA. ERT, Concord, MA. 68 pp. + appendices.

ERT. 30 April 1987. Personal Communication (letter to Mr. David A. Bradley, Washington Department of Ecology, Olympia, WA, regarding Cascade Pole Company site, Olympia, WA; ERT Document No. E420-600-1). ERT, Concord, MA. 13 pp.

Evans-Hamilton and D.R. Systems. 1987. Puget Sound environmental atlas. Volume 2. Prepared for U.S. Environmental Protection Agency, Puget Sound Water Quality Authority, and U.S. Army Corps of Engineers. Evans-Hamilton, Inc., Seattle, WA, and D.R. Systems, Inc., Seattle, WA. 46 maps.

Evergreen State College. 1974. Environmental assessment study of the Port of Olympia. Final Report. Seacoast Management Group Contract. The Evergreen State College, Olympia, WA. 28 pp. + 4 figures, 7 tables, and appendix.

Evergreen State College. 1975. Distribution and biomagnification of polychlorinated biphenyls in the benthic community. The Evergreen State College, Olympia, WA. 40 pp.

Faigenblum, J. 17 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; Budd Inlet fecal coliform data for shellfish collected in Fall 1987). Washington Department of Social and Health Services, Shellfish Protection Section, Olympia, WA. 1 pp.

GeoEngineers. 1987. Dredge spoil evaluation, Berth 3 reconstruction, Olympia, Washington for the Port of Olympia. Prepared for the Port of Olympia, Olympia, WA. GeoEngineers, Incorporated, Bellevue, WA. 6 pp. + appendices.

Gibbs, T. 20 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on areas in Budd Inlet with uninvestigated onsite sewage disposal problems). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Haggerty, K. 18 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on Olympia Golf and Country Club septic drainfield and surface water runoff retention pond). Olympia Golf and Country Club, Olympia, WA.

Hanson, N. No date. Puget Sound water quality nonpoint program update. Puget Sound Water Quality Authority, Seattle, WA. 1 pp.

Heggen, D. 16 October 1987. Personal Communication [information to Ms. Karen L. Keeley; Washington Department of Natural Resources photographic survey (single frame Super-8) in Budd Inlet during 1979]. Washington Department of Natural Resources, Aquatic Lands Division, Olympia, WA. 3 pp.

Helmlinger, J. 23 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on the Capitol Lake siphon). Washington Department of General Administration, Olympia, WA.

Helmlinger, J. 13 April 1988. Personal Communication (information to Ms. Karen L. Keeley; Capitol Lake siphon system and water quality monitoring). Washington Department of General Administration, Olympia, WA.

Hough, G.H. 1981. Deschutes River report. Thurston County Conservation District, Olympia, WA. 14 pp. + appendices.

Jamison, D. 21 January 1988. Personal Communication (information to Ms. Karen L. Keeley). Washington Department of Natural Resources, Olympia, WA.

Johnson, A., and S. Prescott. 13 August 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; water quality measurements in Budd Inlet, July 2, 1981). Washington Department of Ecology, Olympia, WA. 3 pp.

Johnson, A. 22 July 1985. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology; receiving environment survey in Budd Inlet at McFarland/Cascade, February 13, 1985). Washington Department of Ecology, Olympia, WA. 7 pp.

Joy, J. 10 June 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; sulfide concentrations in vicinity of LOTT STP bypass outfall, Budd Inlet). Washington Department of Ecology, Olympia, WA. 10 pp.

JRB Associates. 1984. Water quality dependent water uses in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency, Washington DC. JRB Associates, Inc., Bellevue, WA. 158 pp. + appendices.

Kendra, W., and T. Determan. 6 November 1985. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology; effects of three small sewage treatment plants on Budd Inlet receiving waters). Washington Department of Ecology, Olympia, WA. 22 pp.

Kessler, F. 18 December 1987. Personal Communication (letter to Ms. Karen L. Keeley; LOTT wastewater treatment plant receiving water sampling program in Budd Inlet). LOTT Sewage Treatment Facility, Olympia, WA. 70 pp. + 3 figures.

Kittle, L. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Kittle, L., and H. Tracy. 19 January 1982. Personal Communication [memorandum to Mr. Bruce Cameron, Washington Department of Ecology; lower Budd Inlet marine resource damage assessment (MRDA), September 10, 1981]. Washington Department of Ecology, Olympia, WA. 23 pp.

Konasewich, D.E., P.M. Chapman, E. Gerencher, G. Vigers, and N. Treloar. 1982. Effects, pathways, processes, and transformation of Puget Sound contaminants of concern. NOAA Technical Memorandum OMPA-20. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 357 pp.

Kramer, Chin & Mayo. 1973. An engineering study of the Percival Creek drainage basin. Prepared for the City of Olympia, WA. Kramer, Chin & Mayo, Inc., Seattle, WA. 46 pp. + appendices.

Kramer, Chin & Mayo. 1975. Receiving-water quality objectives. Prepared for Lacey, Olympia, Tumwater, and Thurston County (LOTT) Complex Facility Planning Study, Administrative Committee, Olympia, WA. Kramer, Chin & Mayo, Inc., Seattle, WA. 28 pp. including appendix.

Kruger, D.M. 1979. Effects of point-source discharges and other inputs on water quality in Budd Inlet, Washington. DOE 79-11. Washington Department of Ecology, Olympia, WA. 40 pp. + appendices.

Lilja, J. 25 March 1988. Personal Communication (phone by Ms. Betsy Day). Washington Department of Social and Health Services, Olympia, WA.

Malin, D. 18 November 1987. Personal Communication (information to Ms. Karen L. Keeley; Port of Olympia ownerships in Budd Inlet). Port of Olympia, Olympia, WA. 1 pp.

Malin, D. 25 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; information on dredging permit 071-OYB-2-010937). Port of Olympia, Olympia, WA.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, and H.O. Hodgins. 1980. Chemical contaminants and biological abnormalities in central and southern Puget Sound. NOAA Technical Memorandum OMPA-2. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 295 pp. including appendices.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins, and S.-L. Chan. 1982. Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound. NOAA Technical Memorandum OMPA-19. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Boulder, CO. 168 pp. including appendix.

McCallum, M. 1985. Recreational and subsistence catch and consumption of seafood from three urban industrial bays of Puget Sound: Port Gardner, Elliot Bay and Sinclair Inlet. Washington State Department of Social and Health Services, Division of Health, Epidemiology Section, Olympia, WA. 59 pp. including appendices.

McCarthy, B. 15 January 1988. Personal Communication (phone by Ms. Lynne M. Kilpatrick-Howard). City of Olympia, Public Works Department, Olympia, WA.

McNicholas, R. 1984. Stream corridor management plan for the Deschutes River, Washington. Project No. 82-145A. Prepared for Washington State Department of General Administration, Olympia, WA. Thurston County Conservation District, Olympia, WA. 65 pp. including appendices.

Mih, W.C. 1976. Supplemental flow and sediment tests of Capitol Lake hydraulic model. Prepared for Washington State Department of General Administration, Olympia, WA. Washington State University, College of Engineering, Albrook Hydraulics Laboratory, Pullman, WA. 11 pp.

Moore, A. 13 April 1982. Personal Communication (memorandum to Ms. Joan Thomas, Washington Department of Ecology; outfall sampling to Capitol Lake during March 1982 drawdown). Washington Department of Ecology, Olympia, WA. 6 pp.

Moore, D. 17 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; City of Olympia combined sewer overflow locations). City of Olympia, Engineering Department, Olympia, WA.

Moore, D. 9 December 1987. Personal Communication (letter to Ms. Karen L. Keeley; City of Olympia combined sewer overflow locations). City of Olympia, Engineering Department, Olympia, WA.

Moore, D. 29 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). LOTT Sewage Treatment Facility, Olympia, WA.

Moore, A., and D. Anderson. 1979. Deschutes River basin suspended sediment transport study. Project Report No. DOE-PR-7. Washington Department of Ecology. Water and Wastewater Monitoring Section, Olympia, WA. 21 pp.

Mowrer, J., J. Calambokidis, N. Musgrove, B. Drager, M.W. Beug, and S.G. Herman. 1977. Polychlorinated biphenyls in cottids, mussels, and sediment in southern Puget Sound, Washington. Bull. Environ. Contam. Toxicol. 18:588-594.

Mumford, T.F., Jr. 25 September 1987. Personal Communication (information to Ms. Karen L. Keeley; water quality data in Budd Inlet collected near the Washington Department of Natural Resources Marine Station). Washington Department of Natural Resources, Aquatic Lands Division, Olympia, WA. 17 figures and tables.

Newall, G. 10 February 1988. Personal Communication (phone by Ms. Betsy Day; information on the moth-balled maritime fleet in Budd Inlet). Olympia, WA.

Nortec. No date. A numerical hydrodynamic, water quality model for southern Puget Sound. Nortec, Redmond, WA. 1 pp.

Norton, D. 5 February 1986. Personal Communication (memorandum to Mr. Tom Eaton, Washington Department of Ecology, Southwest Regional Office; results of priority pollutant analyses on water, sediment, and clam samples collected in lower Budd Inlet near McFarland/Cascade, Olympia, WA, August 14, 1985). Washington Department of Ecology, Olympia, WA. 16 pp.

O'Brien, E. 12 November 1987. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Seattle, WA.

Oberlander, J. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Oberlander, J. 24 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). Metro, Seattle, WA.

Oblas, V. 29 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on historical landfill located near LOTT facility). Metro, Seattle, WA.

Oclay, N. 1959. Oceanographic conditions near the head of southern Puget Sound. Master's Thesis, University of Washington, Seattle, WA.

Orsborn, J.F., J.E. Ongerth, G.C. Bailey, S.K. Bhagat, W.H. Funk, C.C. Lomax, and W.C. Mih. 1975. Hydraulic and water quality research studies and analysis of Capitol Lake sediment and restoration problems, Olympia, Washington. Prepared for Washington Department of General Administration, Olympia, WA. Washington State University, Department of Civil and Environmental Engineering, Pullman, WA. 315 pp.

Olympia, City of. 1985. Plan for parks and recreation facilities. City of Olympia, Olympia Parks Advisory Committee, Olympia Parks and Recreation Department, and Olympia Planning Department, Olympia, WA. 44 pp. + appendices.

Olympia, City of. 1987. Storm sewer maps 1" = 100'. City of Olympia, Department of Public Works, Olympia, WA.

Parametrix. 1984. LOTT Phase II urban wastewater management plan. Phase I report. Prepared for Lacey, Olympia, Tumwater and Thurston County, Washington. Parametrix, Inc., Sumner, WA, with Economic and Engineering Services, Inc., Olympia, WA, and J.W. Morrissette and Associates, Olympia, WA. 37 pp.

Parametrix. 1985. LOTT Phase II urban wastewater management plan. Phase II report. Prepared for Lacey, Olympia, Tumwater and Thurston County, Washington. Parametrix, Inc., Sumner, WA, with Economic and Engineering Services, Inc., Olympia, WA, and J.W. Morrissette and Associates, Olympia, WA. 13 pp. + 7 tables and 4 figures.

Parametrix. 1986. Phase III report: LOTT urban area wastewater management plan. Parametrix, Inc., Sumner, WA, and Economic and Engineering Services, Inc., Olympia, WA. 56 pp. + appendices.

Parametrix. 1987a. LOTT urban area wastewater management plan: plan summary. Draft. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 7 pp. + figures, tables, and map.

Parametrix. 1987b. LOTT urban area wastewater management plan. Draft. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 42 pp. + appendices and map.

Parametrix. 1987c. LOTT urban area wastewater management plan. Draft Environmental Impact Statement. Prepared for Thurston County Planning Department, Olympia, WA. Parametrix, Inc., Sumner, WA and Economic and Engineering Services, Inc., Olympia, WA. 64 pp. + appendices and map.

Parker, B. 10 October 1987. Personal Communication (phone by Ms. Karen L. Keeley). U.S. Army Corps of Engineers, Navigation and Planning Section, Seattle, WA.

Peck, L. 18 March 1988. Personal Communication (memorandum to T. Hooper, Washington Department of Fisheries; Budd Inlet water quality). Washington Department of Fisheries, Olympia, WA.

Peeler, M. 12 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; status of Cascade Pole NPDES permit). Washington Department of Ecology, Olympia, WA.

Peeler, M. 22 February 1988. Personal Communication (letter to Ms. Karen Keeley; additional information regarding intertidal sediment sampling at the former Cascade Pole Company site). Washington Department of Ecology, Olympia, WA.

Peeler, M. 15 March 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Phillips, K. 10 September 1987. Personal Communication (information to Ms. Karen L. Keeley; draft memo entitled "Assumptions used in forecasting dredging volumes and conducting cost analysis"). U.S. Army Corps of Engineers, Seattle District, Seattle, WA. 19 pp.

Pierce, R. 20 June 1983. Personal Communication (memorandum to Mr. Frank Monahan, Washington Department of Ecology, District Supervisor; status of LOTT as of May 1983). Washington Department of Ecology, Olympia, WA. 8 pp.

Pierce, R. 15 September 1987. Personal Communication (information to Ms. Karen L. Keeley; areas on Budd Inlet with uninvestigated onsite sewage disposal problems). Thurston County Health Department, Environmental Health Division, Olympia, WA. 1 pp.

Pierce, R. 22 October 1987a. Personal Communication (information to Ms. Karen L. Keeley; Budd Inlet water samples from Thurston County Public Health

Department). Thurston County Health Department, Environmental Health Division, Olympia, WA. 3 pp.

Pierce, R. 22 October 1987b. Personal Communication (information to Ms. Karen L. Keeley; shellfish sampling program conducted in southern Puget Sound during 1985 and 1986). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Pierce, R. 22 October 1987c. Personal Communication (information to Ms. Karen L. Keeley; water bacteriological analysis for the new Port of Olympia marinas). Thurston County Health Department, Environmental Health Division, Olympia, WA. 3 pp.

Pierce, R. 17 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; information on groundwater management plan). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Pierce, R. 20 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on disposal of sediments from proposed ARCO site). Thurston County Health Department, Environmental Health Division, Olympia, WA.

Port of Olympia. 29 February 1988. Personal Communication (information to Ms. Karen L. Keeley; map showing current lessees of Port of Olympia property). Port of Olympia, WA.

Port of Olympia. 1988. Comprehensive plan revision 1988. Port of Olympia, Olympia, WA. 27 pp.

Port of Olympia Commission. 1974. Comprehensive plan for utilization of Olympia Harbor, Olympia, Washington. Port of Olympia Commission, Olympia, WA. 55 pp. + 22 figures.

Prescott, S. 2 October 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; Capitol Lake fecal coliform levels and lake flushing). Washington Department of Ecology, Olympia, WA. 5 pp.

Price, M., and K. V. Ladd. 1978. The role of south-central Puget Sound as a public food source: impact of heavy metals. National Science Foundation Student-Originated Studies. Grant #SMI77-05257. Evergreen State College, Olympia, WA. 194 pp. including appendices.

Puget Sound Water Quality Authority. 1986. The state of the sound 1986. Puget Sound Water Quality Authority, Seattle, WA, and Entranco Engineers, Inc., Kirkland, WA. 84 pp. + glossary and references.

Puget Sound Water Quality Authority. 1987. Puget Sound ambient monitoring program detailed design considerations. Draft. Puget Sound Water Quality Authority, Seattle, WA. 55 pp.

Quinlan, E.A., P.M. Chapman, R.N. Dexter, D.E. Konasewich, C.C. Ebbesmeyer, G.A. Erickson, B.R. Kowalski, and T.A. Silver. 1985c. Toxic chemicals and biological effects in Puget Sound: status and scenarios for the future. Draft Report. NOAA Contract #NA82RAC00162. National Oceanic and Atmospheric Administration, National Ocean Services, Ocean Assessment Division, Coastal and Estuarine Assessments Branch, Seattle Project Office, Seattle, WA. 334 pp. including appendices.

R.W. Beck and Associates. 1986. Boston Harbor wastewater facilities planning study for Thurston County. R.W. Beck and Associates, Seattle, WA. 60 pp. + figures, tables, and appendices.

Rhoads, D.C. 18 November 1987. Personal Communication (information to Ms. Betsy Day; effects of oxygen depletion on benthic communities). Long Island Sound Hypoxia-Modeling Workshop, University of Connecticut, Groton, CT.

Riley, R.G., E.A. Crecelius, D.C. Mann, K.H. Abel, B.L. Thomas, and R.M. Bean. 1980. Quantitation of pollutants in suspended matter and water from Puget Sound. NOAA Technical Memorandum ERL MESA-49. Prepared for National Oceanic and Atmospheric Administration, Marine Ecosystem Analysis (MESA) Puget Sound Project, Seattle, WA. Battelle Pacific Northwest Laboratories, Richland, WA. 99 pp.

Riley, R.G., E.A. Crecelius, R.E. Fitzner, B.L. Thomas, J.M. Gurtisen, and N.S. Bloom. 1983. Organic and inorganic toxicants in sediment and marine birds from Puget Sound. Prepared for National Oceanic and Atmospheric Administration, National Ocean Services, Ocean Assessment Division. Battelle Pacific Northwest Laboratories, Richland, WA. 125 pp. including appendices.

Schiewe, M. 19 November 1987. Personal Communication (phone by Ms. Karen L. Keeley; results of amphipod and oyster larvae bioassay samples from Budd Inlet). National Oceanic and Atmospheric Administration, Northwest and Alaska Fisheries Center, Seattle, WA.

Schmitten, R. 16 October 1981. Personal Communication (memorandum to Governor John Spellman; recent Budd Inlet fish kills). Washington Department of Fisheries, Olympia, WA.

Seiler, K. 4 December 1986. Personal Communication (memorandum to files; information on inspection and sampling conducted at the Cascade Pole Company). Washington Department of Ecology, Olympia, WA.

Singleton, L. 1982. Deschutes River/Capitol Lake water quality assessment. Washington Department of Ecology, Water Quality Investigations Section, Olympia, WA. 26 pp. + tables.

Singleton, L. 29 January 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of Ecology, Olympia, WA.

Skidmore, D., and K.K. Chew. 1985. Mussel aquaculture in Puget Sound. University of Washington, Washington Sea Grant Program, Seattle, WA. 57 pp.

Spencer, M. 1 February 1988. Personal Communication (phone by Ms. Karen L. Keeley; information about Water Street pump station). Washington Department of Ecology, Olympia, WA.

Swanson, L. 13 January 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on Thurston County's stormwater drainage into Budd Inlet). Thruston County Public Works Department, Olympia, WA.

Sweet, B. 23 March 1988. Personal Communication (phone by Ms. Karen L. Keeley; information on the Capitol Lake siphon). Washington Department of General Administration, Olympia, WA.

Sweet, B. 13 April 1988. Personal Communication (phone by Ms. Karen L. Keeley). Washington Department of General Administration, Olympia, WA.

Tetra Tech. 1987. Sediment sampling and analysis plan for the Cascade Pole Company, Olympia, Washington. Prepared for Black & Veatch, Olympia, WA and Washington Department of Ecology, Olympia, WA. Tetra Tech, Inc., Bellevue, WA. 22 pp.

Thurston County Health Department. 1985. Southern Puget Sound water quality assessment study: bacteriological survey of Budd Inlet, April 1985. Objective B, Tasks 1,2, and 3 Interim Data Report. Draft. Thurston County Health Department, Environmental Health Division, Olympia, WA. 15 pp.

Thurston County Planning Department. 1986. Map of drainage basins. Comprehensive plan, Thurston County, Washington. Thurston County Planning Department, Olympia, WA. 1 pp.

Thurston Regional Planning Council. 1982. Shoreline adjacent lands analysis for the Thurston region. Contract No. G83-046B. Thurston Regional Planning Council, Olympia, WA. 33 pp.

Thurston Regional Planning Council. 1983a. Stormwater management in north Thurston County. Volume I: recommendations. Thurston Regional Planning Council, Olympia, WA. 19 pp. + map.

Thurston Regional Planning Council. 1983b. Stormwater management in north Thurston County. Volume II: technical appendices. Thurston Regional Planning Council, Olympia, WA. 6 appendices.

Thurston Regional Planning Council. 1985a. An assessment of water-related reports for Thurston County, Washington. Thurston Regional Planning Council, Olympia, WA. 29 pp. + appendices.

Thurston Regional Planning Council. 1985b. Percival Creek corridor plan. Volume 1: canyon & middle reaches. Thurston Regional Planning Council, Olympia, WA. 116 pp. including appendix + 13 maps.

Thurston Regional Planning Council. 1986. Percival Creek corridor plan. Volume 2: upper reach. Thurston Regional Planning Council, Olympia, WA. 82 pp. including appendix + 12 figures.

Thurston Regional Planning Council. 1987. Deschutes River corridor recreation plan. Pamphlet. Thurston County Planning Council, Olympia, WA.

Tracy, H. 9 October 1981. Personal Communication (memorandum to Mr. John Spencer, Washington Department of Ecology, Olympia, WA; mechanics of the H_2S releases from Capitol Lake into Budd Inlet). Washington Department of Ecology, Olympia, WA. 8 pp.

Tracy, H. 24 June 1982. Personal Communication (memorandum to Mr. Mike Palko and Mr. Bruce Cameron, Washington Department of Ecology; Capitol Lake). Washington Department of Ecology, Olympia, WA. 3 pp.

Turpin and Associates. 1985. Dredging plan, One Tree Island Marina. Thurston County, WA. Turpin and Associates, Olympia, WA.

U.S. Army Corps of Engineers. No Date (a). Application and associated materials for Department of the Army permit for the City of Olympia, Reference Number 071-OYB-2-010618. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (b). Application and associated materials for Department of the Army permit for the Martin Marina, Reference Number 071-OYB-2-008536. U.S. Army Corp of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (c). Application and associated materials for Department of the Army permit for the Olympia Yacht Club, Reference Number 071-OYB-2-010788. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (d). Application and associated materials for Department of the Army permit for the One Tree Island Marina, Reference Number 071-OYB-2-009749-R. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (e). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-1-006165. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (f). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-2-010937. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (g). Application and associated materials for Department of the Army permit for the Tamoshan Homeowners'

Association, Reference Number 071-OYB-2-007996. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (h). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-2-007306. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (i). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-2-007709. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (j). Application and associated materials for Department of the Army permit for the Washington Department of Fisheries, Reference Number 071-OYB-4-008715. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. No Date (k). Application and associated materials for Department of the Army permit for the Port of Olympia, Reference Number 071-OYB-2-006297. U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA.

U.S. Army Corps of Engineers. 1977. Results of Corps of Engineers water quality sampling in East Bay, Olympia Harbor, WA, 10 June 1977 through 13 October 1977. U.S. Army Corps of Engineers, Seattle, WA.

U.S. Army Corps of Engineers. 1980. East Bay Marina, Olympia, Thurston County, Washington: final detailed project report. Section 107, 1960 river and harbor act and environmental impact statement. U.S. Army Corps of Engineers, Seattle, WA. 148 pp. + appendices and exhibits.

U.S. Army Corps of Engineers. 27 October 1987. Personal Communication (information to Ms. Karen L. Keeley; computerized listing of U.S. Army Corps of Engineers dredging permits in Budd Inlet since 1975). U.S. Army Corps of Engineers, Regulatory Functions Branch, Seattle, WA. 1 pp.

U.S. Department of Agriculture. 1986. Water quality planning and implementation activities of the USDA, Soil Conservation Service, Puget Sound area Washington, January 31, 1986. Prepared for Puget Sound Water Quality Authority, Seattle, WA. USDA, Soil Conservation Service, Olympia, WA. 22 pp.

U.S. Department of the Interior. 1974. Sediment transport by streams in the Deschutes and Nisqually River basins, Washington, November 1971 - June 1973. Open-File Report. Washington Department of Ecology, Olympia, WA, and U.S. Department of the Interior, Geological Survey, Water Resources Division, Tacoma, WA. 33 pp.

U.S. Environmental Protection Agency. 7 January 1987. Personal Communication (Unpublished data from STORET). U.S. EPA Region X, Seattle, WA.

URS. 1980. State of Washington industrial waste survey, City of Olympia. Prepared for Washington Department of Ecology, Olympia, WA. URS Company, Seattle, WA. 32 pp. + appendices.

URS. 1985. Southern Puget Sound water quality assessment study. Part I final report: discharge zone classification system for southern Puget Sound. Prepared for Washington Department of Ecology, Olympia, WA. URS Corporation, Seattle, WA. 38 pp. + appendices.

URS. 1986. Southern Puget Sound water quality assessment study. Final report: comprehensive circulation and water quality study of Budd Inlet. Prepared for Washington Department of Ecology, Olympia, WA. URS Corporation, Seattle, WA. 222 pp. + references and appendices.

Warren Consultants, Inc. 1985. Thurston County coordinated water system plan: area-wide supplement. Prepared for Thurston County Water Utility Coordinating Committee, Olympia, WA. Warren Consultants, Inc., Seattle, WA. 73 pp. + maps.

Washington Department of Ecology. 1978. National pollutant discharge elimination system waste discharge permit. Olympia Brewing Company. Permit No. WA-000130-9. Washington Department of Ecology, Olympia, WA. 10 pp.

Washington Department of Ecology. 1979. National pollutant discharge elimination system waste discharge permit. Seashore Villa Mobile Home Park. Permit No. WA-003727-3. Washington Department of Ecology, Olympia, WA. 9 pp.

Washington Department of Ecology. 1980a. Deschutes River basin instream resources protection program including proposed administrative rules. Water Resources Inventory Area 13. Washington Department of Ecology, Water Resource Policy Development Section. Washington State Department of Printing, Olympia, WA. 29 pp. + appendices.

Washington Department of Ecology. 1980b. National pollutant discharge elimination system waste discharge permit. Beverly Beach Utilities Association. Permit No. WA-003806-7. Effective date 16 September 1980. Washington Department of Ecology, Olympia, WA. 10 pp.

Washington Department of Ecology. 1980c. National pollutant discharge elimination system waste discharge permit. Cascade Pole Company. Permit No. WA-000101-5. Washington Department of Ecology, Olympia, WA. 8 pp.

Washington Department of Ecology. 1980d. National pollutant discharge elimination system waste discharge permit. City of Olympia. Permit No. WA-003706-1. Effective date 11 April 1980. Washington Department of Ecology, Olympia, WA. 18 pp.

Washington Department of Ecology. 1984a. Potential hazardous waste site preliminary assessment: Water Street Pump Station site investigation No. WA D980835144. Washington Department of Ecology, Olympia, WA. 6 pp.

Washington Department of Ecology. 1984b. Shellfish protection strategy. Washington Department of Ecology, Shorelands Division, Olympia, WA. 38 pp. + appendices.

Washington Department of Ecology. 1985a. National pollutant discharge elimination system waste discharge permit. Chevron U.S.A., Inc. Permit No. WA-003871-7. Effective date 25 June 1985. Washington Department of Ecology, Olympia, WA. 10 pp.

Washington Department of Ecology. 1985b. National pollutant discharge elimination system waste discharge permit. Delson Lumber, Inc./DWS International, Inc., and Olympia Forest Products Company. Permit No. WA-002154-7. Effective date 16 December 1985. Washington Department of Ecology, Olympia, WA. 12 pp.

Washington Department of Ecology. 1986. National pollutant discharge elimination system waste discharge permit. Thurston County Public Works, Tamoshan Development. Permit No. WA-003729-0. Effective date 20 October 1986. Washington Department of Ecology, Olympia, WA. 14 pp.

Washington Department of Ecology. 1987. National pollutant discharge elimination system waste discharge permit. Cities of Tumwater and Lacey, Thurston County, and the City of Olympia. Permit No. WA-003706-1. Effective date 25 September 1987. Washington Department of Ecology, Olympia, WA. 21 pp.

Washington Department of Ecology. 9 December 1987. Personal Communication (information to Ms. Karen L. Keeley; computer data listing from Washington Department of Ecology for reported spills and complaints regarding Budd Inlet, September 1986 to November 1987). Washington Department of Ecology, Olympia, WA. 1 p.

Washington Department of Fisheries. 1973. Evaluation of effects of channel maintenance dredging and disposal on the marine environment in Southern Puget Sound, Washington. Prepared for U.S. Army Corps of Engineers, Seattle District, Seattle, WA. Washington Department of Fisheries, Management and Research Division, Olympia, WA. 308 pp. including appendices.

Washington Department of Fisheries. 1975. Chemical and biological factors for consideration in the management of the Deschutes River-Capitol Lake. Supplemental Progress Report, Fish Farm Investigations. Washington Department of Fisheries, Management and Research Division, Olympia, WA. 30 pp. including appendices.

Washington Department of Fisheries. 1979. Marine water quality compendium for Washington State. Volume II Data. Grant No. R805032010. Prepared for U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. Washington Department of Fisheries, Research and Development Division, Olympia, WA. 528 pp.

Washington Department of Fisheries. 1981. Significant areas for certain species of food fish and shellfish in Puget Sound. Technical Report 59.

Washington Department of Fisheries, Research and Development Division, Olympia, WA. 46 pp.

Washington Department of General Administration. 1983. Capitol Lake: preliminary restoration plan. Washington Department of General Administration, Olympia, WA. 10 pp.

Washington Department of Natural Resources. 1984. Puget trough coastal wetlands: a summary report of biologically significant sites. Contract No. C-83061. Prepared for Washington Department of Ecology, Olympia, WA. Washington Department of Natural Resources, Natural Heritage Program, Olympia, WA. 154 pp. including appendices.

Washington Department of Social and Health Services. 1980. Preliminary assessment for the greater Olympia area. Washington Department of Social and Health Services, Water Supply and Waste Section, Olympia, WA. 52 pp. including appendices.

Welsh, B. 18 November 1987. Personal Communication (information to Ms. Betsy Day; causes and effects of oxygen depletion in Long Island Sound). Long Island Sound Hypoxia-Modeling Workshop, University of Connecticut, Groton, CT.

Westley, R.E., E. Finn, M.E. Carr, M.A. Tarr, A.J. Scholz, L. Goodwin, R.W. Sternberg, and E.E. Collins. 1975. Evaluation of effects of channel maintenance dredging and disposal on the marine environment in southern Puget Sound, Washington. Washington State Department of Fisheries, Olympia, WA. 308 pp.

White, M. 30 July 1987. Personal Communication (memorandum to Cascade Pole Company file; field notes from sampling of product seeps and survey of wells for product on 24 June 1987). Washington Department of Ecology, Olympia, WA.

White, M. 21 January 1988. Personal Communication (information to Ms. Karen L. Keeley; intertidal seeps from Cascade Pole Company). Washington Department of Ecology, Olympia, WA.

Yake, B. 6 July 1981. Personal Communication (memorandum to Mr. John Bernhardt, Washington Department of Ecology; interpretation of June 3, 1981 Budd Inlet data with particular respect to oxygen depletion). Washington Department of Ecology, Olympia, WA. 15 pp.

Yake, B. 22 December 1981. Personal Communication (memorandum to Mr. Dick Cunningham, Washington Department of Ecology; seasonal nutrient depletion at ambient marine stations in Puget Sound; implications for discharge of nutrients to embayments like Budd Inlet). Washington Department of Ecology, Olympia, WA. 3 pp.

Yake, B., J. Joy, and A. Johnson. 1984. Chemical contaminants in clams and crabs from Eagle Harbor, Washington State, with emphasis on polynuclear aromatic hydrocarbons. Segment No. 25-00-01. Washington Department of Ecology, Olympia, WA.