Publication No. 83-4

WILLAPA BAY WATER QUALITY MANAGEMENT PLAN

DEPARTMENT OF ECOLOGY

MAY 1983

83-4

JOHN SPELLMAN
GOVERNOR

DONALD W. MOOS
DIRECTOR

WILLAPA BAY
WATER QUALITY MANAGEMENT
PLAN

WASHINGTON STATE DEPARTMENT OF ECOLOGY
WATER QUALITY PLANNING AND MANAGEMENT SECTION

May 1983

Department of Ecology Report
No. 83-4

Complied by Charles J. Carelli

John Spellman
Governor

Donald W. Moos
Director

Acknowledgments

This report is compiled from work conducted by CH2M-Hill (Bacteriological Survey of Willapa Bay - September, 1981) for the Department of Ecology and material compiled by Jim Sachet (WDOE 1983). This report has borrowed Liberally Prom the two above sources.

This report was prepared using funds provided in part by the Environmental Protection Agency (208 Water Quality Management Planning) and the Office of Coastal Zone Management.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Willapa Bay is the largest producer of oysters in the State of Washington. Significant quantities of salmon, bottom fish, crabs, and clams are also harvested in the area. Oyster production has declined in the area over the past decade (Shotwell, 1977). The declines can be attributed to several factors including: habitat loss, water pollution, and increasing utilization of imported oysters. On a national scale, shellfish production has decreased at a significant rate with over four million acres of productive area lost since about 1900 (Council on Environmental Quality, 1979). This trend places additional emphasis on maintaining water quality and habitat in Willapa Bay which will sustain the desired level of oyster and other shellfish production.

Over the last few years, there has been growing concern by the oyster growers of possible water quality degradation in the oyster beds due to municipal, industrial, and food processing wastes which enter the bay. Special concern also is being focused on fecal coliform contamination from new and existing domestic housing around the bay, especially along the eastern shores of North Beach Peninsula. The high water table and closeness of septic drainfields to the bay are reasons for concern.

The livelihood of the oyster industry and maintenance of other beneficial uses of water depends on a high quality water with low fecal coliform bacteria counts. Oyster culturing operations are extremely vulnerable to bacterial pollution and even slight increases above ambient conditions can result in their condemnation as a food source.

Oyster harvesting is prohibited in the Willapa River mouth east of a line at 123° 52' 38.16" West. This area was decertified by the Department of Social and Health Services (DSHS) due to excessive fecal coliform counts in the water as well as in the tissue of the oysters.

The effects of point and nonpoint source pollutants on other beneficial uses of water in the Willapa Basin must also be considered. Existing, and projected, domestic, municipal, and industrial uses may be impaired. Residents of the planning area and tourists derive various recreational and scenic benefits. Willapa Bay and its tributaries support substantial populations of chinook, coho, pink, and chum salmon; rock and bottom fish; crab; steelhead; cutthroat; and rainbow trout.

Willapa National Wildlife Refuge is located on Long Island at the southern end of Willapa Bay, and at Cape Shoalwater west of Tokeland at the north end of the bay. Numerous resident and migratory species of birds, as well as resident wildlife, inhabit the refuge.

Willapa Ray and its tributaries are listed in the Water Quality Assessment porkion of the State/EPA Agreement (WDOE, 1982). Fecal coliform contamination, pH, turbidity, and low dissolved oxygen levels are listed as problems. Roth point and nonpoint source problems have been identified as contributing to problems in the bay.

The Washington State Department of Ecology (WDOE) coordinated the acquisition of water quality data and development of this Water Quality Management Plan (WQMP). Funding for the project was provided through two sources; the National Oceanographic and Atmospheric Administration under the Coastal Zone Management Act (CZM) (P.L. 92-583, and amerrdments) and the U.S. Environmental Protection Agency under Section 208 of the Federal Clean Water Act (P.L. 95-217). CZM funds supported the water quality data collection, cause and effect examination, and data analysis tasks. Section 208 funds were used for analysis of sources of water pollution, examination of effects on beneficial rises, public participation, and report preparation elements of the WQMP.

STUDY OBJECTIVES AND SCOPE

Objectives

This study was initiated to address five (5) separate objectives;

1. Document sources of fecal coliform bacteria;
2. Identify locations where applicable water quality criteria for fecal coliform bacteria are frequently violated;
3. Identify and recommend management steps to control significant sources of fecal coliform bacteria;
4. Discuss continued water quality monitoring needs; and
5. Provide an implementation schedule for recommended actions.

These study objectives were established with the assistance of a local water quality committee in the Willapa Bay area. The motivation behind doing this study was to determine the extent, if any, of water quality degradation and hence potential problems for the shellfish industry located in Willapa Ray.

Scope

This report documents the extent of water quality problems and pollution sources in Willapa Bay caused by fecal coliform. No attempt has been made to categorize all sources of polltition entering Willapa Bay.

Likewise, only areas directly tributary to or adjacent to Willapa Bay have been included in these water quality investigations and this management document. Figure 1 shows the geographic exte t of this study.

This report is not an update of the Willapa Basin 303(e) Water Quality Management Plan (WDOE, 1979). It does provide a source of information pertaining to the study area that is, and will continue to be, used by WDOE as management decisions pertaining to Willapa Hay are made.

Three reasons exist for emphasizing fecal coliform bacteria concentrations and sources in this plan. These include: 1) previous identification of major problems with fecal coliform bacteria loading - particularly

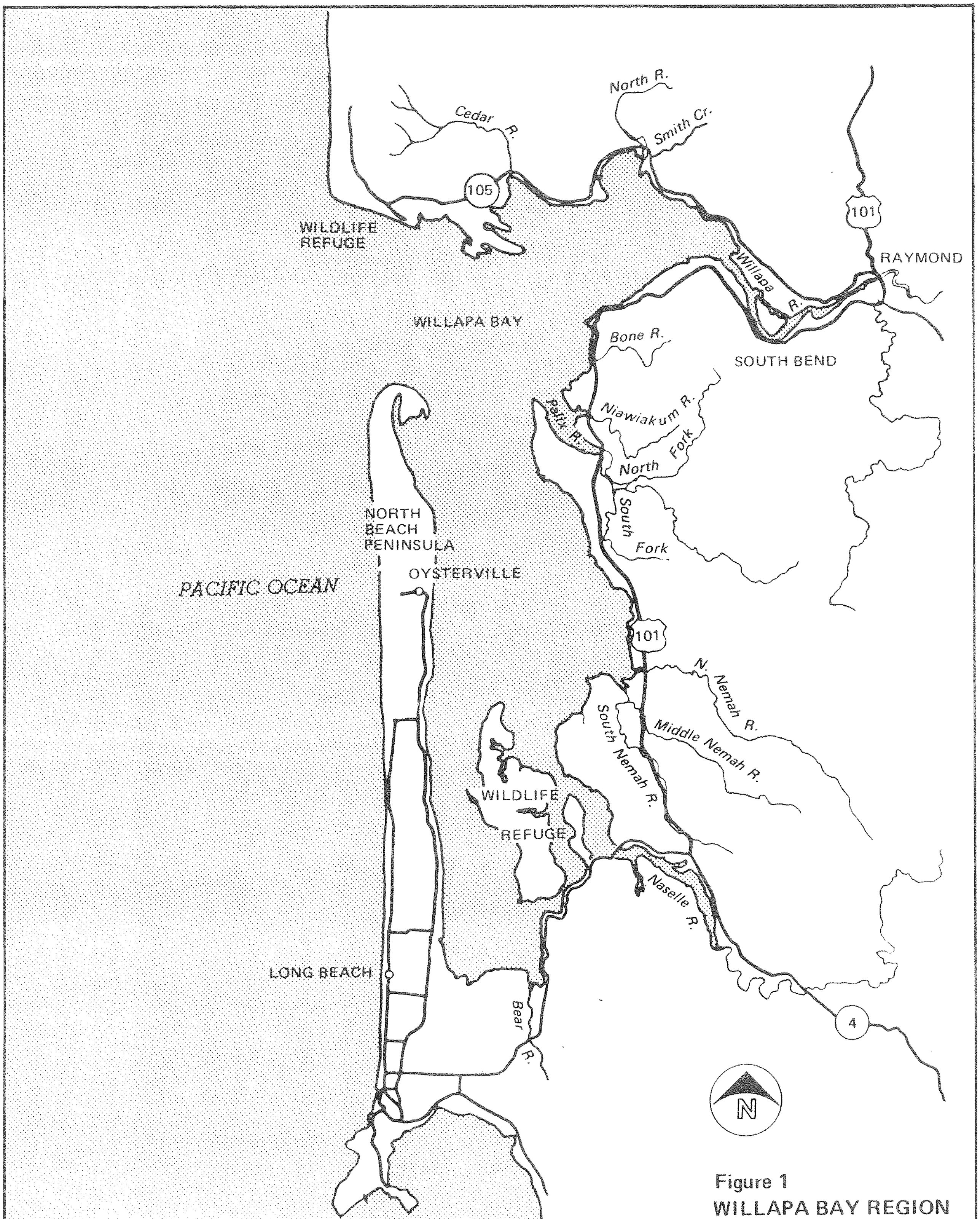

Figure 1
WILLAPA BAY REGION

in the lower Willapa River; 2) increasing concern by a major water user group--oyster growers--regarding the possibility of further water quality degradation from municipal, industrial, and food processing waste discharges; and 3) the presence of new and existing housing developments around the bay. Proposed housing developments--particularly on the bay side of the North Beach Peninsula--add to this third concern.

Point sources in the Willapa planning area include municipal sewage treatment plant discharges and industrial discharges. Runoff from urban areas, pasture lands, and leaking household septic systems or failing drainfields are identified as nonpoint sources of fecal coliform bacteria (Pacific Co. Planning Council).

MANAGEMENT PLAN

Water quality in the bay was found to be good, with no threat to the oyster industry or other water-related uses. Based on the available data collected during the 1960s and 1970s, water quality in the bay appears to have improved. Elimination or reduction of pollution sources in the lower Willapa River Basin would probably bring the entire estuary into compliance with Class "A" water quality standards.

Management Analysis

Preparation of this Water Quality Management Plan (WQMP) focused on review and update of existing water quality planning documents, review of Phase I water quality monitoring results, and development of a public participation program.

WDOE formed a steering committee to provide assistance and advice in the preparation of this WQMP. The Steering Committee was composed of representatives from the public, the private sector, and local and state government agencies. The Steering Committee membership is included in Appendix B.

Functions of the Steering Committee and its individual members included:

- Representation of constituents;
- Establish, if appropriate, a water quality goal or goals for Willapa Bay and its tributaries;
- Review and interpret results from Phase I water quality survey results;
- Review of previous water quality management plans and related information;
- Recommend specific management steps to appropriate agencies to achieve established water quality goal(s).
- Assist and advise WDOE in preparation of the WQMP update and implementation schedule.

Intergovernmental and public participation were recognized as key elements In the successful development and implementation of a WQMP. Management of resources in the basin fall under the jurisdiction of a wide array of local, regional, state, and federal agencies. Planning for the protection and management of a single resource - water quality - necessarily involves coordination among all levels of government.

Involvement of informed persons from the public and area businesses was also needed to understand local issues and respond to the desires of residents, landowners, business persons, and resource users in the area.

The primary mechanism for obtaining governmental, public, and private participation was the Steering Committee. A public participation program was also instituted which involved distribution of a newsletter, meeting with the Pacific County commissioners, and contacts with local newspapers. In addition, the state 208 Policy Advisory Committee (PAC) acted as a advisory committee to the program through status reports by WDOE to the PAC.

By undertaking these activities, WDOE staff attempted to meet the objectives of coordinating the program with the various levels of government and receiving the advice from the public and private sectors. Compliance with federal regulations addressing public participation was also attained (40 CFR Part 25, Public Participation Programs, Federal Resource Conservation and Recovery Act; Federal Safe Drinking Water Act; and the Federal Glean Water Act.)

Conclusions

The Steering Committee was Involved in the review of work conducted during the Phase I Bacteriological Survey of Willapa Bay. The major study findings of the Phase I survey as presented to the Steering Committee are as follows:

- Water quality in Willapa Bay is generally good and beneficial uses are not being threatened beyond existing conditions (i.e., sanitary shellfish line).

- High bacterial counts were measured at some locations; the most consistent high counts were measured in the Willapa River. Sources in the Willapa River were identified as; Raymond primary sewage treatment plant, storm/sewer outfalls, Wilson Creek, and housing developments such as Old Willapa. High counts were measured at the uppermost sampling station on the Willapa River but no monitoring was done to identify upstream sources.

- High counts were also measured at; Pauls Slough and Tar-latt Slough (North Beach Peninsula), South Naselle River, and O'Connor Creek, the state salmon hatchery on the North Nemah River, creek in Lions Club Park near Raymond, and Pacific County drainage ditch No. 1 near Tokeland. Those problems were judged to be less significant than those in the Willapa River, except that Tarlatt Slough, however, may impact some other oyster beds. Additional monitoring is recommended.

- Monitoring indicated that runoff from dairies and livestock is not a significant bacterial source except during large storms when fields are flooded.

- Dilution and dispersion of river water occurs rapidly; within 1 to 1-1/2 hours freshwater is mixed to 90 percent oh original salinity.

- One-half the volume of the bay is exchanged during each tidal cycle.

- Current county standards for setback distances, set apart distances, and soils (sands) for septic systems for new housing on the North Beach Peninsula are at this time, adequately controlling household septic sources.

- The tidelands east of the existing sanitary line have little commercial value to oystermen. The muddy bottom, steep channel sides, and rapid currents make it difficult to hold oysters on the bottom.

- The methods for determining species of bacteria (API) is based upon clinical applications and is of questionable value when identifying species in nonclinical situations.

- Additional, long-term monitoring stations would be best located in the Willapa River and along the North Beach Peninsula.

Concluding its review of the Phase I survey findings, it was the concern of the Steering Committee (supported by WDOE staff) that Phase II water quality management planning as originally envisioned should not be carried out. The committee, in making such a recommendation, took into consideration the generally high water quality of Willapa Bay, the noted problems identified during the Phase I survey, and a number of obvious steps that could be taken to continue to protect water quality. Additionally, the Steering Committee was cognizant of the underlying purpose for conducting the Willapa Bay studies in the first place; that purpose being shellfish protection, and in particular, protection of the Willapa Bay oyster beds.

Recommendations

This section presents five recommendations which are intended to protect or enhance the quality of water in Willapa Bay and its tributary streams.

Construction Grants for South Bend and Raymond

Fecal coliform bacteria are present in concentrations in excess of the Glass A freshwater or marine criteria in the lower Willapa River. Sources include combined storm/sewer overflows in Raymond and South Bend, (refer to earlier description).

In December 1981, the Raymond sewage treatment plant and pump stations became inoperable. A public health emergency was declared on December 9, 1981. It is recommended that state or federal construction grant funds be provided to Raymond arid South Bend Lor repair and upgrade of sewage collection and treatment facilities at the earliest possible date. If it is determined that the limiting factor in providing such funding is difficulty in obtaining local matching funds, then the possibility of providing low interest or no interest loans should be thoroughly investigated and pursued.

Implement Management Practices for Nonpoint Source Pollution Control

State, county, and municipal regulatory and permitting mechanisms are available to reduce or avoid the adverse water quality impacts which can arise from nonpoint source activities. Such mechanisms address: 1) on-site (household) sewage disposal systems; 2) small community sewage disposal systems; 3) livestock and dairy wastes; 4) silvicultural practices; 5) dredging and filling; and 6) agricultural practices. It is recommended that these management practices be fully implemented to minimize the bacterial, sediment, chemical, dissolved oxygen, and temperature impacts which can result from such nonpoint source activities.

Establish a Long-Term Monitoring Program for Willapa Bay

Willapa Bay contains beneficial uses of water which are commercially, aesthetically, or uniquely significant. To facilitate Identification of trends in the condition of water quality in the bay, it is recommended that an expanded long-term monitoring program be established.

Focus on Willapa River

The most significant water quality problems in the Willapa Basin are located in the Willapa River. It is recommended the nonpoint source management practices be fully implemented for activities located in the drainage basin of the Willapa River.

Additional Coliform Study

Because of the high fecal coliform concentration observed, additional study of fecal coliform bacteria sources should be conducted by the Deprtment of Ecology in the following areas:

Nemah River
Wilson Creek
Lions Club Park
Tarlatt Slough

Although fecal coliform levels were not high enough to cause a significant impact in bacterial levels in Willapa Bay, additional monitoring is necessary along the east shore of Long Beach Peninsula level due to Low circulation levels and low salinity levels.

PROBLEM STATEMENT

Willapa Bay is a 100 square-mile estuary situated along the southern coast of Washington (Figure 1). Steeply rising uplands border the bay to the north and east. To the south, across a low ridge, lies the Columbia River. The western margin of the bay is formed by a long, narrow sand spit - North Beach Peninsula - apparently formed by deposits from the Columbia River.

The drainage basin of Willapa Bay encompasses approximately 720 square miles, including most of Pacific County and portions of Grays Harbor, Lewis, and Wahkiakum counties. Rivers which flow into the bay include the Cedar, North, Willapa, Bone, Niawaikum Palex, Nemah, Naselle, and Bear.

Willapa Bay is characterized as one of the cleanest and most productive bays along the Pacific Coast, perhaps in the United States (Shotwell and Corps of Engineers). Salmon, bottom fish, oysters, crabs, clams, and shrimp are taken from bay waters. Between 1976 and 1981, commercial harvest of chinook, chum, and silver salmon ranged between 60,000 and 1.06 million pounds per year with a dealer reported value ranging between $945,000 and $1.3 million for that period (Table 1).

Over 50 percent of the Japanese or Pacific oyster production in Washington occurs in Willapa Bay (Shotwell). Approximately 15,000 acres of tideland are used for oyster production while another 27,500 acres may be suitable for use (Shotwell). Harvest and reported value of oysters from 1976 to 1981 averaged approximately 2,834,000 pounds and $2,531,000, (Table 2). This resource is particularly dependent upon high quality water.

The volumes and rates of mixing of ocean water and bay water, volume of freshwater inflow, and circulation of water within the bay are factors which have a profound influence on dispersion and dilution of wastes carried into the bay by rivers or discharged directly into the bay

The shape and depth of Willapa Bay influence the rate of tidal flushing. Most of the bay is broad and shallow with about 55 percent of the area exposed at lower tides. The difference in the volume of water between highest tides and lowest tides - or tidal prism - is approximately 45 percent of the bay volume. Thus, it would appear that nearly one-half of the water in the bay can be exchanged during a single tide cycle (U.S. Army Corps of Engineers, 1976).

However, the situation is more complex than a simple exit of bay water and replacement of ocean water. Conditions in the ocean determine how much water leaving the bay will return on the next incoming tide. According to the U.S. Army Corps of Engineers (1976), periods of ocean upwelling in summer promote thorough mixing of bay water and ocean water. Mixing also occurs during storm periods with high wave action. At other times, a plume of water from the Columbia River, acting as a discrete mass of water, tends to prevent mixing from occurring. Water from the bay can then move back and forth for several days. Survival of free swimming oyster spat in the bay long enough to set is viewed as evidence that complete exchange of bay water may take more than 20 days.

Freshwater inflow into the bay from tributary rivers is very low. The combined average daily runoff of all rivers is approximately 0.004 percent of the volume of the bay. Even during periods of winter storm runoff, the river flow is 0.10 percent of the tidal prism (U.S. Army Corps of Engineers, 1976). Circulation patterns, dilution, and dispersion will be discussed in more detail in the Water Quality Assessment section of this plan.

Table 1

Willapa District Commercial Salmon Harvest in Round Pounds and Total **Dealer** Reported Value, 1976 to 1981

	1976	1977	1978	1979	1980	1981
Chinook						
Round pounds	563,585	585,001	211,662	324,083	481,395	325,365
(Reported value)	($846,663)	($1,007,975)	($317,431)	($624,808)	($805,276)	($582,109)
Chum						
Round pounds	390,826	81,253	321,328	11,003	317,192	213,988
(Reported value)	($321,315)	($54,908)	($320,426)	($8,802)	($216,656)	($166,047)
Coho						
Round pounds	106,884	52,263	59,655	275,378	229,939	238,677
(Reported values)	($111,439)	($56,192)	($94,931)	($437,150)	($257,331)	($247,497)
Total						
Round pounds	1,061,295	718,517	592,645	610,464	1,028,526	778,030
(Reported value)	($1,279,417)	($1,119,075)	($732,788)	($1,070,760)	($1,279,263)	($945,653)

Data Source: Washington State Department of Fisheries

Table 2

Willapa District Commercial Harvest of Pacific Oysters, Dungeness Crab, and Pink Shrimp in Round Pounds and Reported Dealer Value, 1976 to 1981

	1976	1977	1978	1979	1980	1981
Pacific Oysters						
Round pounds	2,458,314	2,915,570	3,282,131	2,803,825	2,717,302	2,827,454
(Reported value)	($3,090,100)	($4,229,111)	($2,350,544)	($2,080,586)	($1,933,036)	($1,504,301)
Dungeness Crab						
Round pounds	1,643,505	2,807,459	1,672,603	1,707,255	1,643,717	822,377
(Reported value)	($846,826)	($1,185,966)	($1,072,111)	($1,103,514)	($1,015,279)	($715,930)
Pink Shrimp						
Round pounds	5,083,160	5,178,355	5,654,484	5,095,763	33,684,703	3,070,793
(Reported values)	($836,568)	($1,044,311)	($1,296,421)	($1,838,608)	($1,853,882)	($1,481,829)
Total						
Round pounds	9,184,979	10,901,384	10,609,218	9,606,843	8,045,722	6,720,624
(Reported value)	($4,773,494)	($6,459,388)	($4,719,076)	($5,022,708)	($4,799,197)	($3,702,060)

Data Source: Washington State Department of Fisheries

The Willapa Basin is basically a rural environment. This is reflected in the fact that in 1981 approximately 63 percent (11,214) of Pacific County residents lived in unincorporated areas. The remaining 37 percent (6,586) of county residents lived in four incorporated communities - Ilwaco, Long Beach, Raymond, and South Bend.

The economic base of the Willapa Basin rests heavily upon forest and marine resources. However, seasonal recreation and tourism are becoming increasingly important.

Major employment industries include: manufacturing, food processing, forest products, fishing, loggrng, retail trade, other services, and government.

WATER QUALITY

The livelihood and continued existence of the oyster industry in Willapa Bay depend on high quality water with low counts of fecal coliform bacteria. Oyster culturing operations are extremely vulnerable to bacterial pollution, and even slight increases above ambient conditions can result in their condemnation as a food source. The current water quality criterion for oyster growing waters is a geometric mean of 14 fecal coliforms per 100 mL, with no more than 10 percent of the samples over 43 fecal coliforms per 100 mL.

Fecal coliform bacteria originate from the intestines of warm blooded animals, both human and nonhuman. After leaving their animal or human hosts, the bacteria enter waterways from either point or nonpoint sources. The State of Washington Department of Natural Resources mapped six point sources contributing to the bay and its tributaries (treatment plants, seafood processors, and a rock quarry).

Each source is important to the formulation of management plans for the Willapa Bay. Each river should also be viewed as a point source. For basinwide management plans, an assessment of the relative contributions of each source is needed for each river.

Several nonpoint sources exist in the Willapa Bay basin. Waterfowl in the wildlife refuges and many sloughs and mudflats of the bay represent a major potential source of bacteria pollution. Previous studies by CH2M-Hill (1978) have shown waterfowl to produce approximately 10 trillion fecal coliforms per bird per year. The cattle herds kept in pastures both near the bay and along rivers that empty into the bay are an additional nonpoint source of animal origin.

A potential human nonpoint source of bacteria is seepage from septic tanks and leach lines. The amount of bacteria reaching the bay from human sources depends upon the amount of bacteria produced, their filtration through the soil, and the level of mortality that occurs before they reach the receiving waters. The distance and amount of bacteria percolating through soil vary widely and depend upon the type of soil and distance traveled. Sandy soils, such as those of North Beach Peninsula, can percolate bacteria rapidly. The rate of percolation will change with the tidal height, ground water table, and proximity to receiving waters.

Previous Studies

There have been a number of studies that describe or address water quality problems in Willapa Bay. Routine monitoring of the bay by WDOE and DSHS is reported in various forms (unpublished and often untitled). The Washington Department of Fisheries, For a number of years, has collected data on temperature, salinity, dissolved oxygen, nitrogen, and phosphorus. Weycrhaeuser Company (Smith and Herrmann, 1972) incorporated much of the data collected by the Department of Fisheries into their summary of water quality and shellfish distribution and habitat.

Excellent summaries of the history and resources of Willapa Bay have been prepared by Shotwell (1977a, 1977b). Fisheries, the shellfish industry, and water quality problems are thoroughly reviewed. Planning documents address some aspects of water quality problems in general, and pollution from wastewater more specifically (Pacific County Regional Planning Council, 1973, 1974; WDOE, 1975; URS, 1977). Unfortunately, when bacterial concentrations are reported in the earlier studies, results were reported in total coliforms, instead of fecal coliform which the water quality criteria are based upon. In addition, DSHS used the fecal coliform in its shellfish tissue tests.

Three unpublished sanitary surveys were conducted that identified a number of specific sources of contamination in the Raymond-South Bend area (DSHS, 1969; Grays Harbor-Pacific Health District, 1973, 1979). Many of those sources have since been eliminated by extension of wastewater collection systems. An unpublished report by the U.S. Environmental Protection Agency suggested that poor water quality occurred during August and September 1972 (Report of Field Studies on the Willapa River, August 29-31, 1972, and September 19-20, 1972).

There have been a number of studies of sediment transport, type, and driving currents in Willapa Bay. Several of these deal with the bay entrance and navigation channels (17.5. Army Corps of Engineers, 1969, 1975; U.S. Army Corps of Engineers and State of Washington Department of Conservation, 1966; Johnson, 1973). Clifton and Phillips (1979) describe bottom sediment types and current distributions based on observed bedforms in the bay and its channels.

Studies of specific industrial discharges are an additional source of background information on Willapa Bay. Smith, Messmer, Phipps, and Schermer (1974) measured temperature, salinity, turbidity, suspended solids, conductivity, pH, and dissolved oxygen in the Willapa River at South Bend. They concluded that the discharge of washwater from a shrimp processing plant did not adversely affect oxygen concentrations in the river. WDOE is critical of some of the conclusions of Smith et al., (1974) (memo from Pat Lee, October 28, 1974, WDOE). Sylvester (1952) earlier had examined water quality in parts of Willapa Bay in relation to possible sites for pulp mills. He concluded that reduced concentrations of dissolved oxygen in the Willapa River at Raymond were caused by decomposing sewage and woodwaste.

STUDY DESIGN

Several major tasks were included in the study design. To identify potential sources of bacterial contamination, a detailed bacterial source sanitary survey was conducted. Bacterial surveys of receiving waters were conducted for a year using helicopter, boat, and shore sampling. A hydrodynamic study using dye and drogues was conducted to determine dilution and current patterns. To estimate bacterial mortality rates, bacterial reduction studies were performed. Data collected were then statistically analyzed, when appropriate, and integrated to provide a detailed assessment of bacterial dynamics in Willapa Bay. A detailed description of each task can be found in the CH2M-Hill report on "Bacteriological Survey of Willapa Bay" 1981. A brief description of each task follows and is outlined in Figure 2:

Figure 2 Objectives and Methods of Studies Conducted Under Phase I, Bacteriological Survey of Willapa Bay

Sanitary and Bacterial Source Survey

Objectives: to identify existing and potential sources of human and animal wastes in bay waters and tributaries.
Methods: house-to-house survey of residences and business along 70 miles of shoreline conducted in April & August, 1980; collected and analyze water samples at suspected sources.

12-Month Monitoring Program

Objectives: to assess ambient concentrations of fecal coliform bacteria in bay waters and tributaries.
Methods: twice monthly samples collected at 30 fixed locations in project area.

Bay Circulation Study

Objectives: to identify the direction and velocity of major water currents in Willapa Bay; to assess dilution and dispersion rates of river water entering the bay.
Methods: tracing of dye patches and wooden floats during ebb tide (June 1980) and flood tide (August 1980) conditions.

Bacteria Reduction Study

Objectives: to determine the rate at which fecal coliform and fecal streptococci bacteria die-off upon exposure to salt water conditions.
Methods: fecal coliform and fecal streptococci bacteria contained in untreated sewage treatment plant influent were exposed to salt water conditions; observations were made for the length of time required for 90% of organisms to die at various salinity concentrations.

Bacterial Source and Sanitary Survey

The bacterial source and sanitary survey was performed to update the inventory of existing pollution sources, review bacterial analyses, and identify new potential pollution sources. A house-to-house survey was carried out over a two-week period, April 14 to April 25, 1980, during which time only negligible precipitation occurred. A follow-up survey was conducted August 21, and 22, 1980, to determine use rates of summer cabins, campgrounds, and North River houseboats. The survey territory was divided into 12 areas to systematically cover a shoreline of about 70 miles.

Bacterial Survey of Receiving Waters

Two types of bacterial surveys were used in this study. The first, useful for setting permanent monitoring stations and assessing the spatial variation in water quality, was the synoptic survey. Because of the large area involved and the extensive shallow zones, a helicopter was used for these surveys. Approximately 60 samples were taken and were analyzed for fecal coliform, fecal streptococci, salinity, and temperature. Bird and livestock counts were also made from the helicopter.

From this first synoptic survey, 30 long-term stations were chosen to monitor water quality at point and nonpoint sources. Station locations are shown as numbers 1 through 30 in Figure 3. These stations were sampled twice a month for a 12-month period (April 1980 through March 1981).

Bacterial Reduction Studies

The mortality rates of both fecal coliform and fecal streptococci were measured. The mortality rates were measured in three different salinities under ambient light and temperature conditions. Nondisinfected wastewater was obtained from the City of Raymond sewage treatment plant. Freshwater was collected from the Middle Nemah River at the Highway 101 bridge, and bay water was collected at Nahcotta from the surface. The river and bay waters were mixed to result in three salinities: 32°/oo, 24°/oo, and 16°/oo. The mixed water was placed in clear 50-liter plastic bags and suspended at the surface in the bay near Nahcotta. Each salinity level was duplicated. Sufficient wastewater was added to each bag to give an initial concentration of fecal coliforms of approximately 1.0×10^5/100 mL.

Samples from each bag were taken three times per day for the duration of the experiment. Both fecal coliforms and fecal streptococci were measured with the membrane filter method. Incident light intensity and water temperature were also monitored.

Hydrodynamic Study

Hydrodynamic information about Willapa Bay was obtained from concurrent tracer dye and drogue releases and subsequent monitoring of the movement of each. Dye and drogues were released at six sites on ebb currents during the week of June 16, 1980, and on flood current on August 12, 1980, at a seventh site.

All of the points were located near the bay mouth itself or in what would be called the near-mouth area for the particular arm of Willapa Bay under consideration.

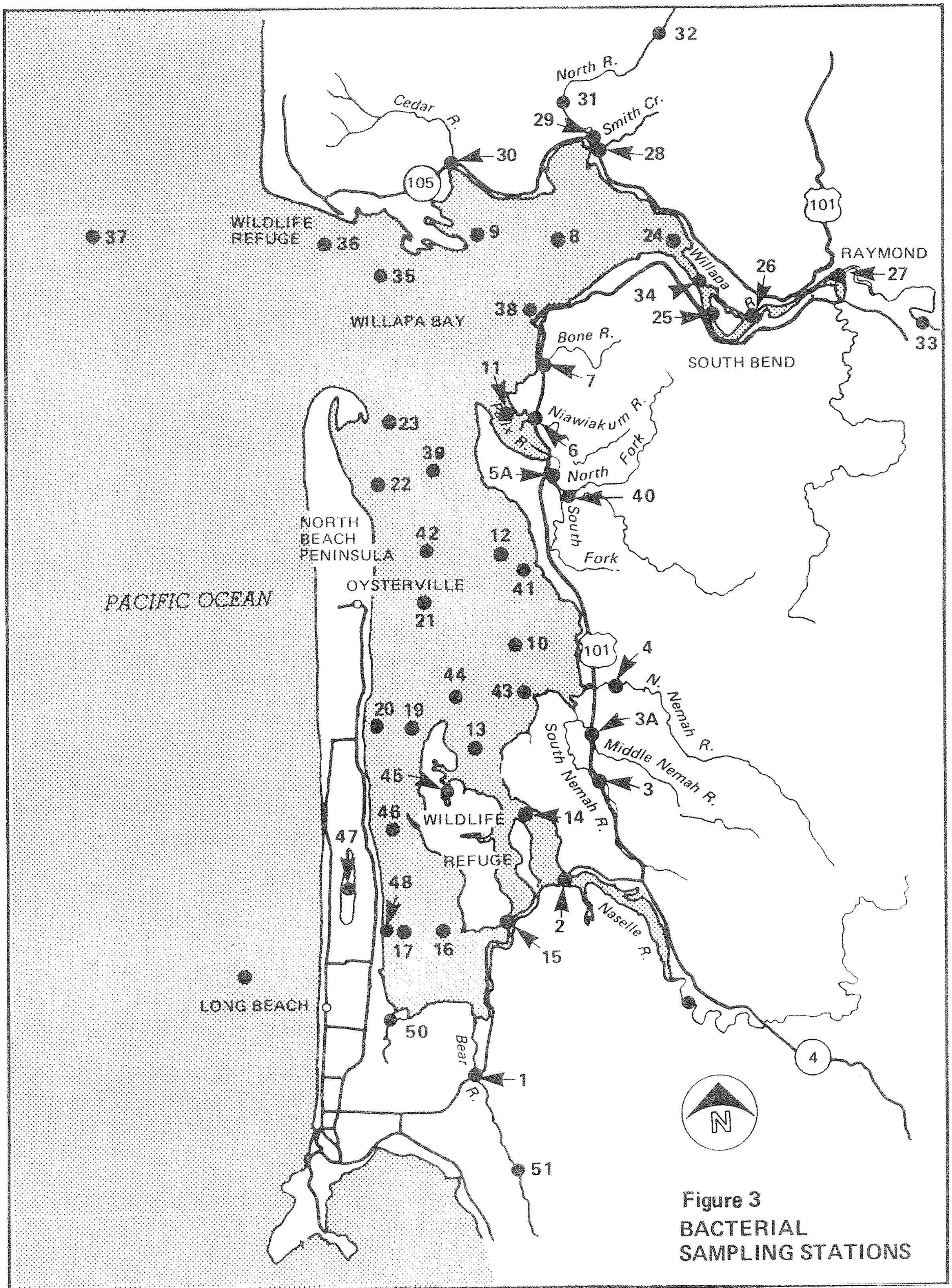

Figure 3
BACTERIAL SAMPLING STATIONS

The movement of both the dye and drogues was monitored by using a Mini-Ranger radar positioning system. This system consists of a readout unit on the tracking vessel that sends out pulses to each of two or more transponders, whose positions on the state plane coordinate grid are known. The position is calculated from the distances from the vessel to the transponders.

Receiving Water Bacterial Survey and Data Analysis

The bacterial survey analysis was analyzed for statistically significant variations between each station, with stratification of the data according to tide height. The data were also analyzed to determine their relation to the applicable water quality criterion.

Various problems in sample collection and data analysis occurred. During field sampling on several dates at four locations, weather conditions made boat sampling impossible In such cases, samples were collected from shore nearby.

Water Quality Study Results

Two sources of information are available to update existing data regarding levels of fecal pollution in Willapa Bay. The first to be considered includes findings from a bacteriological survey conducted in 1980-81 known as Phase I of the Willapa Bay Water Qua7ity Management Program. The second is periodic monitoring data gathered by WDOE as part of its statewide water quality investigations program.

Objectives of the Phase I bacteriological survey were to determine human and animal waste sources, background levels of fecal bacteria (coliform and streptoccoci), and the dilution, dispersion, and bacterial die-off characteristics of Willapa Bay. For a detailed account of study methods and findings see Bacteriological Survey of Willapa Bay, prepared for WDOE by the CH2M-Hill Company, 1981.

MONITORING RESULTS

Willapa Bay

Based upon bacteriological survey and WDOE monitoring results, significant findings relating to this segment may be summarized as follows:

a. Under normal conditions, fecal coliform concentrations in marine waters (salinity greater than 10 parts per thousand) are low and within the Class A water quality criterion (Tables 3 and 4);

b Rivers are major contributors of fecal coliform bacteria to the bay, with the Willapa River being the most significant;

c. Rapid flushing and high rates of dilution of river water appear to be the overriding processes in maintaining low fecal coliform levels in the bay.

Table 3 Concentrations of Fecal Coliform Bacteria at Phase I Regular Sampling Stations - Geometric Means and Percent Exceeding 43 (SW) or 200 (FW) Organisms/100 mLs

Station Number	Basin Segment	Water Type[b]	Geometric Mean[c] (organisms/ 100 mL)	% Samples Exceeding 43 or 200 organisms/ 100 mLs[c]	Number of Samples with Confluent Growth
8	11-24-01	SW	2.8	0	1
9	11-24-01	SW	8.4	0	3
10	11-24-07	SW	1.6	0	0
11	11-24-01	SW	2.8	5	1
12	11-24-01	SW	2.7	5	1
13	11-24-01	SW	1.6	0	0
14	11-24-04	S	1.7	0	0
15	11-24-01	S	4.9	4	1
16	11-24-01	SW	2.0	0	0
17	11-24-01	SW	1.3	0	0
19	11-24-01	SW	1.2	0	0
20	11-24-01	SW	3.6	0	0
21	11-24-01	SW	2.4	5	1
22	11-24-01	SW	1.5	0	0
23	11-24-01	SW	1.2	0	0
24	11-24-01	FW/SW		6	3
25	11-24-02	FW/SW	28.8	10	4
26	11-24-02	FW/SW	26.0	0	2
27	11-24-02	FW/SW	150.7	35	5
1	11-24-04	FW/SW	18.0	23	1
2	11-24-04	FW/SW	18.4	5	3
3	11-24-04	FW	12.5	9	0
3A	11-24-04	FW	15.5	4	0
4	11-24-04	FW	60.4	10	2
5	11-24-04	FW/SW	21.5	9	1
6	11-24-04	FW/SW	17.2	26	
7	11-24-04	FW/SW	11.2	14	
28	11-24-04	FW/SW	19.7	5	
29	11-24-04	FW/SW	14.1		
30	11-24-04	FW/SW	27.3		

[a] Basin segments designated by Washington State Department of Ecology, as follows: 11-24-01, Willapa Bay; 11-24-02, Willapa River from mouth to limit of tidal influence; 11-24-03, Willapa River from limit of tidal influence to headwaters; 11-24-04, other Willapa Bay tributaries; and 11-24-05, Pacific Ocean.

[b] Water salinity varies from salt water (SW) to freshwater (FW) conditions below or above 10 parts per thousand salinity, respectively.

[c] Violations of Class A water quality standards occur when the geometric mean of samples exceed 14 organisms per 100 milliliters (ml) in salt water or 100 organisms per 100 ml in freshwater. Violations also occur if 10% of samples exceed 43 organisms per 100 ml (salt water) or 200 organisms per 100 mo (fresh water),

Table 4 Concentrations of Fecal Coliform Bacteria at. WDOE Sampling Stations - Geometric Means and Percent Exceeding 42 (SW) or 200 (FW) Organisms Per 100 mLs

Station Location	Basin Segment	Water Type[b]	Geometric Mean[c] (Organisms/ 100 mL)	% Samples Exceeding 43 or 200 Organisms/mL[c]	Period of Record
Willapa Bay at Toke Point	11-24-01	SW	1.5	0.0	4/77 to 11/81
Willapa River at Johnson Slough	11-24-01	SW	8.2	6.7	11/76 to 11/81
Willapa River at South Bend	11-24-02	FW/SW	15.1	25.0	11/76 to 5/77
Willapa River at Raymond	11-24-02	FW/SW	60.5	44.8	11/75 to 5/81
Willapa River near Willapa	11-24-02	FW/SW	96.2	28.8	11/75 to 5/81
Willapa River at Lebam	11-24-03	FW	192.2	52.8	10/77 to 2/82
North River near Raymond	11-24-04	FW/SW	10.6	3.6	11/75 to 9/77
North Nemah River at North Nemah	11-24-04	FW/SW	132.1	41.7	10/76 to 9/77
Middle Nemah River near Nemah	11-24-04	FW/SW	28.7	12.5	10/76 to 9/77
South Nemah River near Nemah	11-24-04	FW/SW	177.2	54.5	10/76 to 9/77
Naselle River near Naselle	[illegible]	FW	22.5	7.1	11/25 to 4/80
____________	11-24-04		9.6	0.0	10/76 to 9/77

See Table 3 page 18 for explanation of footnotes.

Fifteen of the bacterial sampling sites were located in Willapa Bay (Figure 3). Geometric means of fecal coliform concentrations ranged between 1.2 and 8.4 organisms per 100 mL (Table 3). The Class A criterion for fecal coliform bacteria for marine waters stipulates that "fecal coliform organisms 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).

WDOE maintained two sampling stations in Willapa Bay: (1) at Toke Point between April 1977 and November 1981; and (2) in the Willapa River at Johnson Slough between November 1976 and November 1981. Geometric means of samples taken monthly at each of these locations were 1.5 and 8.2, respectively (Table 4). Neither station had more than 10 percent of samples exceeding the criterion of 43 organisms/100 mL.

It should be noted that high concentrations of fecal coliform bacteria are frequently observed at the WDOE routine sampling station on the Willapa River at Lebam (Table 4). The 303(e) Water Quality Management Plan (WDOE, 1975) noted that fecal coliform bacteria sources include the Willapa fish hatchery and from septic tank discharges in the communities of Menlo, Lebam, and Frances.

The Phase I sanitary and bacterial source survey resulted in an inventory of existing and potential sources of human and animal wastes. Failing septic systems and sources of animal wastes - such as from pasture lands or waterfowl - were identified and water samples were collected in nearby receiving waters to assess levels of fecal coliform contamination.

Table 5 lists sites sampled during surveys in the spring and summer of 1980. Five sites had fecal coliform bacteria concentrations in excess of Class A criterion when sampled during spring and summer flow conditions. One source (Tarlett Slough) was suspected to be caused by runoff from grazed pasture land. Two other sources (Paul's Lake drainage downstream of Bayside Trailer Park and drainage ditch in front of Chief Charley's Restaurant) produced high fecal coliform counts. The two remaining sources sampled were from landfill site runoff.

High fecal coliform bacteria counts were observed during summer on the east side of North Beach Peninsula. The consultant reports that "summer flows adjacent to Long Beach Peninsula were not thought to be high enough to cause substantial bacterial impact to Willapa Bay. However, lower circulation and salinities in South Bay can increase the threat of pollution to the important oyster production in that area," (CH2M-Hill, 1981, pg. 27).

Long Beach sewage treatment lagoon discharges into segment 11-24-01, Willapa Bay. This treatment facility has a design capacity for serving 4,000 persons and drains via Tinker Lake and East-Main Canal. Analysis of samples taken indicate that the Long Beach treatment plant is not contributing fecal coliform contamination.

Table 5

CONCENTRATION OF FECAL COLIFORMS AND FECAL STREPTOCOCCI AT SUSPECT BACTERIAL SOURCE LOCATIONS AROUND WILLAPA BAY DURING SPRING (4/24/80) AND SUMMER (8/25/80) SURVEYS

Area	Station	Spring Survey		Summer Survey		Comments
		Fecal Coliform	Fecal Streptococci	Fecal Coliform	Fecal Streptococci	
1	G	21[a]	46	28[a]	2	Ditch draining Long Beach treatment plant effluent; no flow 8/25/80
	H	96	51[a]	320	310	Tartlatt Slough (livestock), no flow, closed tide gate 8/25/80
	I	7[a]	40[a]	--	--	Wallacut River tributary enters Columbia River
	CC	--	--	120	46	Paul's Lake drainage upstream of Bayside Tailer Park
	nu	--	--	210	100	Paul's Lake drainage downstream of Bayside Trailer Park
	EE	--	--	100	96	Whiskey Slough at Jo Johns Road
	FY	--	--	40	110	Whiskey Slough at Willapa Bay, flooding tide
	GG	--	--	42	1,000	Big Slough, Oysterville, low flow
2	J	3[a]	2	12[a]	9[a]	Willapa National Wildlife Refuge
3	Za	--	--	29[a]	24[a]	Pond adjacent Naselle Youth Camp STP drainage pipes
	Zb	--	--	60[a]	28[a]	Naselle River adjacent pond (Station Za)
	AA	--	--	120	29[a]	O'Connor Creek, Naselle, low Flow
	BB	--	--	180	620	South Naselle River, Naselle; flooding tide
4	None					
5	K	32[a]	14[a]	21[a]	82[a]	Windy Valley Boys Camp; low flow 6/25/80
	L	16[a]	1,000	82[a]	100	Salmon hatchery, North Nemah River
	Y	--	--	11[a]	57[a]	West end of pond east of aay Center, no flow
7	M	410	220	--	--	Open ditch, Bay Center area, no flow 8/25/80
	N	12[a]	44	--	--	Willaview subdivision, Bay Center
	Oa	--	--	2	12[a]	Pastureland drainage area; no flow, gare closed (station Ob)
	Ob	52	22[a]	29[a]	23[a]	Tidegate, Bay Center (livestock); gate closed 8/25/80
d	None					
9	B	13[a]	7[a]	--	--	Johnson Slough
	C	640[b]/150[c]	590[b]/93[c]	600/ 600[d]	33[a]/700[d]	Lions Club Park, Raymond; low Plow 8/25/80
	D	9[a]	28[a]	--	--	Ludington Avenue, Old Willapa
	E	5[a]	26[a]	--	--	Olive Street, Raymond
	P	110	470	120	1,000	Rrvervrew area, Raymond; low flow 8/25/80
		52	49[a]	--	--	Potter Slough, South Send
	Q	210	63	--	--	Delware Avenue, Hewitt Addition
	R	16[a]	11[a]	--	--	Ground seepage, Riverdale area, Raymond
	S	210	63	--	--	Wilson Creek, Old Wrllapa
	T	16[a]	11[a]	--	--	Upper Smith Creek, north of Raymond
	X	23[e]	240[e]	--	--	East Point Shellfish; shrimp process effluent
	HH[f]	--	--	--	--	Raymond sewage treatment plant
	II[f]	--	--	--	--	Raymond sewage treatment lagoon
13	None					
11	W	--	--	--	--	Drainage behind Willapa Trarler Park, Toie Point, no flow
12	4	440	550	600	C.G.[g]	Ditch near landfill site, North Cove
		--	--	C.G.	1,000	Drainage ditch in front of Chief Charley's Restaurant
		--	--	C.G.	220	Drainage ditch near sanitary landfill

[a]Estimated count due to small numbers of colonies.

[b]Sample lost during original survey April 24, 1980; retaken on June 12, 1980.

[c]Additional sample taken 4/8/81.

[d]Additional sample taken 8/13/80.

[e]Sample taken 4/8/81.

[f]See Table 4.

[g]confluent growth.

Tide stage and rainfall were compared with fecal coliform bacteria concentrations. Average concentrations were higher during low slack tide (Table 6). Rainfall influences the amount of runoff and washing of waste off nonpoint source areas. Fecal coliform bacteria concentrations were highest when more than 0.25 inches of rainfall occurred on the day of sampling. (CH2M-Hill, 1981, pg. 43)

Table 6 Effects of Tidal Changes on Bacterial Concentration Statistics

Tidal Condition	Colonies per 100 mL Number	Colonies per 100 mL Mean	Standard Deviation	Statistical Subgroup[a] 1	2	3
Fecal Coliform						
High Slack	271	19	70.5	X		
Ebb	101	24	70.7		X	
Low Slack	114	69	110.7			X
Flood	60	39	90.4		X	
Fecal Streptococci						
High Slack	227	56	214.8	X		
Ebb	110	70	193.4		X	
Low Slack	117	121	255.2			X
Flood	63	77	137.4		X	

[a]Statistical subgroup based on Duncan's Test (P = .05)

Willapa River

This portion of the Willapa River extends from the Mailboat Slough light buoy and upstream to a point southwest of the community of Willapa.

Three routine sampling stations (Phase I, bacteriological survey) and three WDOE monitoring stations arc located in this segment (Tables 3 and 4). Geometric means of fecal coliform concentrations ranged between 26 0 and 150.7 organisms/100 mL lor Phase I stations, and 15.1 and 96.2 for WDOE stations. Concentrations dropped between Raymond and South Bend, and South Bend and the mouth of the Willapa River, respectively. The reduction in concentrations would indicate that dilution and die-off of fecal coliform bacteria is occurring in the downstream direction.

During the sanitary and bacterial source survey conducted by the consultant in the spring and summer of 1980, 106 sites were identified in this Willapa River segment. Twenty-five were suspected pollution sources, including combined storm sewer overflows, waterfront commercial buildings, industrial discharges, sewage treatment plant effluent, septic systems in housing developments, veterinary clinic effluent, and runoff from livestock pastures. Water sampling at 13 of these sites showed that three areas had fecal coliform concentrations in excess of Class A freshwater criteria (Table 5). Four small creeks flowing through Lions Club Park in Raymond had the highest concentrations. Excessive concentrations were also noted at the time of sampling at Delware Avenue, Hewitt Addition, and Wilson Creek, Old Willapa. There may be significant seasonal sources of bacteria, depending upon streamflow conditions and dispersion and dilution of bacteria after entering Willapa Bay.

Both the South Bend and Raymond sewage treatment facilities are located in the tidal influence segment of the Willapa River. The South Bend treatment lagoon (two treatment ponds that discharge into a common culvert) has a design capacity of 2,350 persons. The Raymond sewage treatment plant and lagoon have a design capacity of 3,500 persons. Both WDOE and Phase 1 surveys indicated that the South Bend and Raymond sewage treatment facilities are, at times, major sources of fecal coliform bacteria to the Willapa River. Specific loading rates were not determined because the sampling frequencies (once monthly or twice monthly) were not sufficient to allow these calculations.

Limitations to these treatment facilities have been noted in the Wastewater Facilities Plan for Raymond-South Bend (1977). Problems listed include deteriorating collection systems and combined storm-sanitary sewers, aggravated by infiltrating ground water, which discharge raw sewage directly into the Willapa River during storm flows.

On December 9, 1981, the Raymond sewage treatment plant and pump station became inoperable, and a raw sewage discharge occurred. A public health emergency was declared by DSHS (see letter from Dr. John Beare to Director Donald Moos, Appendix A). Financial aid to correct this problem was requested at that time.

Willapa Bay Tributaries

This segment includes all surface waters which flow into Willapa Ray except the Willapa River. However, only the lower segments of these tributary rivers are addressed in this plan.

Benefrcial water uses in this segment include domestic, industrial, and agricultural water supply; fish passage, spawning and rearing, stock watering; wildlife habitat; and recreation and related aesthetics such as boating, fishing, swimming, and picnicking.

Willapa Bay tributaries in the planning area are designated by the "State of Washington Water Quality Standards" as Class A (Excellent) waters. In the intertidal reaches of bay tributaries, salinity values vary between marine and freshwater conditions depending upon tide stage and river flow conditions. Monitoring results from such segments must, therefore, be evaluated based upon salinity conditions at the time of sampling.

Naselle River

The geometric mean of fecal coliform concentrations measured over the 1980-81 sampling period for the Naselle River (Station 2, Table 3) was 18.4 organisms per 100 ml which meets the Class A freshwater criterion. Five percent of samples exceeded 43 or 200 organisms per 100 mL, depending upon salinity levels at the time of sampling. WDOE monitoring over the period 11/75 to 4/80 also showed that fecal coliform concentrations met the Class A freshwater criteria (Table 4). Potential pollution sources identified during the sanitary and bacterial source survey included: livestock throughout the Naselle River valley with access to water courses; septic tank effluent; Naselle Youth Camp; O'Connor Creek; and the South Naselle River. CH2M-Hill in its 1980 report (pgs. 27-28) reports that: "In general, some stations . . . in the vicinity of the Town of Naselle, are noted to have above standard counts of fecal coliforms and fecal streptococcis colonies. Additionally, pasture lands lie in the flood zone and tidal zone of the Naselle River. River flows are adequate to introduce substantial amounts of bacteria into Willapa Bay oyster-producing areas."

Samples taken from a pond adjacent to the Naselle Youth Camp indicated that fecal coliform bacteria were present, but within Class A freshwater criteria (Table 3).

Nemah River

Results from routine water sampling showed that, for the period of record, geometric means of fecal coliform concentrations were within Class A freshwater criteria (Station 3, 3A and 4, Table 3). However, 10 percent of samples at station 4 on the North Nemah exceeded the criteria for marine or freshwater, depending upon salinity at the time of sampling. WDOE monitoring for the period 10/76 to 9/77 indicate that above criterion concentrations occur in the North and South Nemah rivers (Table 4).

Nineteen potential pollution sources were identified along all three Nemah rivers during the Phase I, sanitary and bacterial source survey, including: Windy Valley Boys Camp, South Nemah; residential area by New Washington Oyster Company, Middle Nemah; livestock, Middle Nemah; Williams Park Campground, North Nemah; residential area with high water table, North Nemah; and, salmon fish hatchery, North Nemah. Water samples collected downstream from the Windy Valley Boys Camp and the North Nemah fish hatchery indicated that excessive counts of fecal coliform bacteria were not present at the time of sampling (Table 3). Because of the high concentrations observed under WDOE monitoring, additional study of fecal coliform bacteria sources on the Nemah River is recommended.

Palix River

The geometric mean of fecal coliform concentrations measured during the Phase I routine sampling was 21.5 organisms per 100 mL (Station 5, Table 3). No WDOE monitoring stations were located in the Palix River system from the period 1975 to 1981. Potential pollution sources identified during the Phase I sanitary and bacterial source survey include: overflow lines from septic tanks to ditches and down steep embankments; and, livestock pasture drainage to river. One of several sites sampled for fecal coliform bacteria runoff, an open ditch draining pasture land south of Bay Center, had fecal coliform counts in excess of the Class A freshwater criterion (Table 5). Other sites sampled appeared to not be contributing fecal coliform bacteria in excessive amounts at the time of sampling (Table 5).

North River

The geometric mean of samples taken in the North River tor Phase 1, routine samples is 19.7 organisms per 100 mL; for WDOE monitoring it is 10.6 organisms per 100 mL. Both measurements are within the Class A freshwater criterion.

The only potential pollution source identified in the North River area during the Phase I, sanitary and bacterial source survey was the presence of houseboats on the river. CH2M-Hill, 1981, reports that:

> . . . houseboats along the North River were surveyed. No water sample was taken upriver, but the mouth of this river was sampled semi-monthly as part of the regular sampling program. Twenty-eight houseboats were identified. Only two houseboats were occupied during this survey and of these only one is occupied full time. As is required, the permanent dwelling had a chemical toilet, but the other houseboat occupant admitted to discharging wastes directly into the river. According to the permanent dweller, most other houseboats have chemical toilets. The intermittent use of the majority of these houseboats reduces their importance as point sources.

The 303(e) Water Quality Management Plan (WDOE 1975) addresses the presence of houseboats on the North River. It was concluded, based upon DSHS (1969) and Grays Harbor-Pacific County Health District (1973) data, that the North River houseboats pose a potential health hazard - either from consumption of commercially harvested oysters taken near the mouth of the river or from direct water contact by persons in areas downstream from the houseboats. It was recommended that the Grays Harbor-Pacific County Health District take action to reduce the potential for pollution in cooperation with DSHS and WDOE.

DISCUSSION

Data analysis of the routine bacterial surveys showed several patterns. River stations were significantly higher in bacterial loads. Bacterial concentrations increase from high to low slack tides and with higher rainfall. Both of these factors indicate the importance of freshwater inflow into the bay and their linkage to fecal pollution. Bacterial levels were not related to the tourist season. Highest bacterial levels were found in the Willapa River, North Nemah River, North Fork of the Palix River, Palix River, and Cedar River. Ratios of fecal coliform to fecal streptococci (FC:FS) based on average bacterial concentrations indicated a high portion of human waste in only the Bear River and the Willapa River. All rivers except the North Nemah River and the North River did show occasional FC:FS ratios greater than 4.

Two problems emerge from this study. First, during average flow conditions, rivers can supply fecal coliforms to the bay at concentrations above acceptable levels. For bacterial criteria to be met in bay waters, dilution and die-off must reduce each river's input. The second problem is the source of fecal coliform pollution. If it is from humans, it represents a more serious threat to public health than if from animals.

The FC:FS ratios based on average concentrations were biased by two dates with very high concentrations and high ratios in the Willapa and Bear rivers.

Loading rates were estimated by multiplying average bacterial concentrations from this study by average flows from USGS Water Resources Inventory records. The longest period of record available for each river was used. Measured flows were available for the Willapa and Naselle rivers (USGS, 1978); the North and North Nemah rivers (USGS, 1977); and Smith Creek (subwatershed) and Bear River (USGS, 1975). Flows from ungaged streams were calculated from several yields of the closest gaged streams draining a similar watershed. Flows of gaged streams were increased proportionally to surface areas downstream from the gages to account for flows originating below the gages. Average concentrations (numbers per liter) of FC and FS were multiplied by flow (liters per hour) to estimate loading rates (Table 7). Given the wide variability in the bacterial concentrations (CH2M-Hill 1981, pg. 40-41), the loading estimates shown in Table 7 cannot be considered precise.

The Willapa River, with an estimated 210 x 10^9 fecal coliforms per hour, was the largest source, followed by North River with 73 x 10^9 per hour. The Willapa and North rivers were also the largest sources of fecal streptococci (Table 7).

The expected dilution of bacteria from river sources to some point farther down the bay can be calculated from salinities of the two stations and that of the ultimate dilution water from the bay mouth. For example, water at station 27 travels to about South Bend (station 25) on one ebb tide. The salinities are 10.2 and 17.1 ppt (Figure 4). Starting bacterial concentration from station 27 would be diluted to 61 percent by reaching station 25. The average bacterial concentration would be expected to be 985 fecal coliforms per liter, based on dilution by water from the bay mouth. The actual average concentration was 430 per liter. Similarly, fecal coliforms from station 27 would be diluted to an average concentration of 590 per liter at station 24. Actual average concentration at that station was 100 per liter. Average concentrations at bay stations are well below those expected on the basis of dilution calculated from salinities alone. If the mortality rates shown in Table 8 are applied to the original concentrations at station 27, in addition to dilution based on salinity, predicted concentrations at stations 25 and 24 are still too high. The mortality rates observed in Willapa Bay fall well within values reported in the literature (Mancini, 1978: Zison et al., 1978). Fecal streptococci showed much higher mortality rate than fecal coliforms. Other studies have produced similar results (Harris and Williams, 1979).

The mortality rates of fecal streptococci that were observed were higher than those of fecal coliforms, in contradiction to previously published results. The ratio of FC:FS therefore increased with time in the studies Given the questionable quality of this raw data, the interpretation of FC:FS ratios in the bay rs based primarily on results reported in the literature.

Table 8 Estimated Mortality Rates and T_{90} Values Derived from the Bacterial Reduction Study

	Mortality Rates (per hour)		
Salinity (ppt)	32	24	16
Fecal Coliforms	0.060	0.032	0.022
Fecal Streptococci	0.230	0.140	0.190
	T_{90} (hours to 90% reduction in numbers)		
Fecal Coliforms	38	72	104
Fecal Streptococci	10	16	12

As expected, the mortality rate of fecal coliform appears to be strongly related to salinity (Mancini, 1978). No relationship was found between the mortality rate of fecal streptococci and salinity.

The water temperature remained essentially constant (approximately 19°C) through the course of the experiment, so no temperature-caused variations in mortality were observed. Also, there were insufficient differences in daily solar radiation to produce any observable differences in mortality rate.

CH2M-Hill, 1981, could not explain the high variahility that was observed after 1-1/2 days of their study. The methods employed have provided good estimates of bacterial reduction over longer periods of time in previous studies.

A simplified approach by assuming that one tidal cycle would carry water from station 27 to 25 and another from station 25 to *24* was used. Obviously, with mixing, a longer time would be required for bacteria to travel from station 27 to 24. The dilution rates measured in the lower Willapa estuary during the hydrodynamic study *(2* to *3* hours to 90 percent dilution) are, however, more than sufficient to account for the reductions in average bacterial concentrations that occurred in the Willapa River and other sources. It thus appears, based on the limited estimates of bacterial reduction rates, that dilutron through tide and wind-driven mixing is the most important factor in the reduction of bacterial concentrations between the source rivers and the oyster-growing areas of the bay. Times required for 90 percent dilution in the bay downstream from the major source rivers are shown in Table 9 for comparison with loading rates. The relatively short dilution Limes, 30 minutes to **3** hours, in all bay areas are supported by a comparison of the large tidal prism, 393×10^6 m^3 (Johnson, 1973), with an average river input of 5.3×10^6 m^3 per 12 hours (calculated from Table 7). Under average conditions, approximately 1.5 percent of the new water entering the bay on each tidal cycle is from rivers and 98.5 percent From the ocean. Maximum river discharges are about 17 times average discharges in the Willapa basin (USGS flow records). On that basis, even during periods of high river flows, freshwater input is only 20 percent of the total exchange during a tidal cycle.

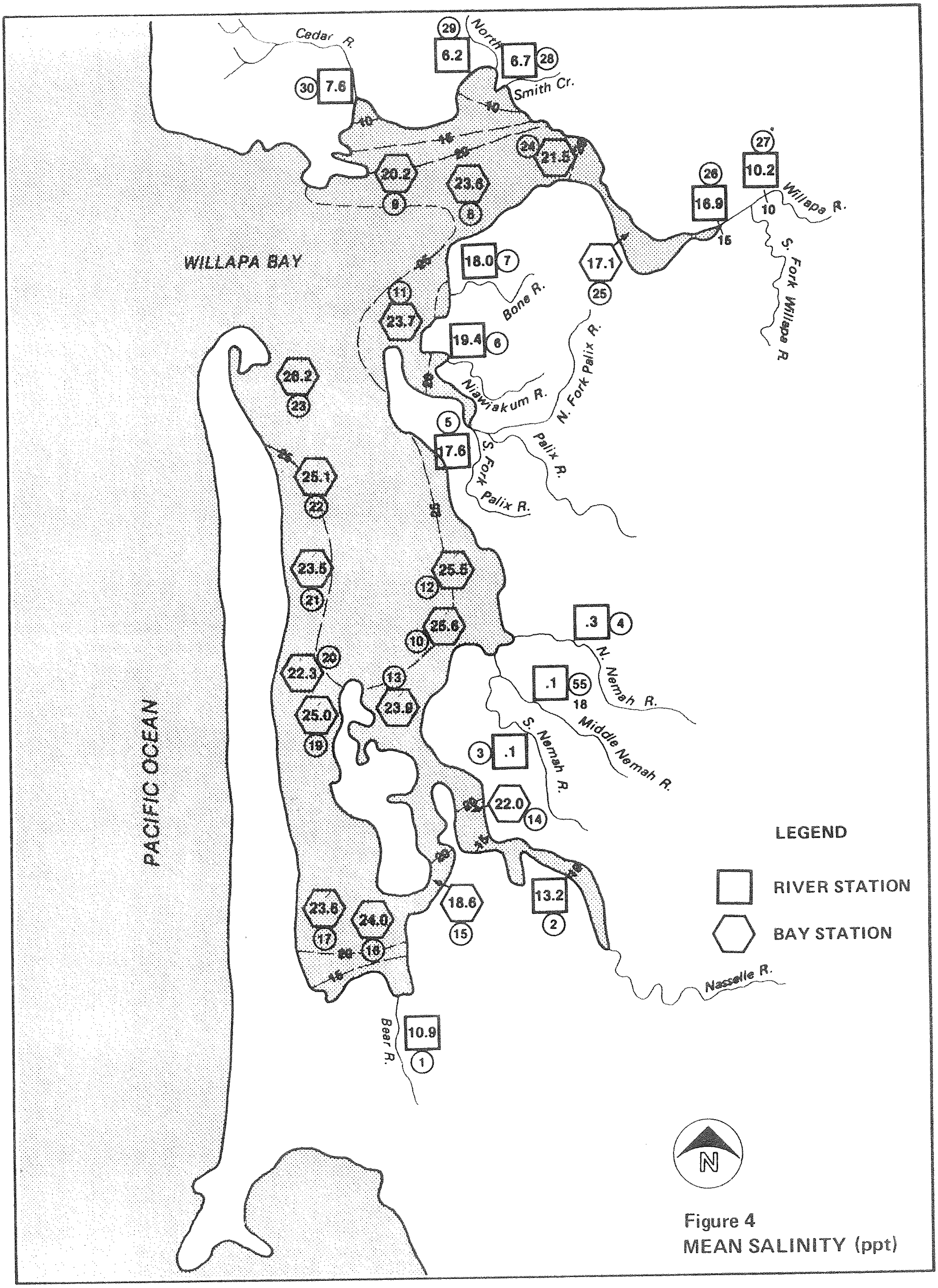

Figure 4
MEAN SALINITY (ppt)

Table 7 Average Bacterial Concentrations, River Flows, Bacterial Loading Rate Estimates, Average Salinities, and Estimated Times to 90 Percent Dilution at Bay Stations Adjacent to River Sources of Bacteria

River		Bacterial Concentrations (N/liter)	Discharge (liters per hour)	Avg. Load (per hour)	Salinity	Time to 90% Dilution at Bay Stations: Dye	Drogue
Cedar R	FC[a]	670		3.8×10^{9}	7.6	56 min	27 min
(30)	FS[b]	1,470	5,666,400	8.3×10^{9}			
North R		510		73×10^{9}	6.2	56 min	27 min
(29)		1,280	143,434,800	18×10^{9}			
Smith Creek		380		15×10^{9}	6.7	56 min	27 min
		820	40,665,600	33×10^{9}			
Willapa R		1,610		210×10^{9}	10.2	3 hr	42 min
(27)		1,340	133,095,600	170×10^{9}			
Bone R		260		$.88 \times 10^{9}$	18.0	40 min	1 hr
(7)		490	3,384,000	1.7×10^{9}			
Niawiakum		870		2.9×10^{9}	19.4	40 min	1 hr
(6)		860	3,384,000	2.9×10^{9}			
Palix II		680		17×10^{9}	17.6	40 min	1 hr
(5)		510	24,894,000	13×10^{9}			
N Nemah		900		11×10^{9}	0.3	10 hr-35 min	
(4)		2,200	12,175,200	27×10^{9}			
M Nemah		370		3.0×10^{9}	0.1	10 hr-35 min	
(18)		920	7,981,200	7.3×10^{9}			
S Nemah		460		3.0×10^{9}	0.1	10 hr-35 min	
(3)		2,350	6,627,600	16×10^{9}			
Naselle		180		17×10^{9}	13.2	30 min	1 hr
(2)		1,340	93,416,400	130×10^{9}			
Bear		350		2.9×10^{9}	10.9	45 min	1.5 hr
(1)		1,590	8,359,200	13×10^{9}			
			483,083,200				

[a] FC = Fecal Coliform Bacteria
[b] FS = Fecal Streptococci Bacteria

Table 9 CALCUWTION OF RELATIONSHIPS FOR ESTUARINE CLASSIFICATIONS

	Beginning (B) End (E)	Surface Salinity (%)	Bottom Salinity (%)	So (%)	$\frac{\delta S}{So}$	Mean Velocity[1] (cm/sec)	Cross-Sectional Area[2] (m^2)	River Discharge (m^3/sec)	Uf ($X10^{-4}$ m/sec)	$\frac{\mu s}{Uf}$
Willapa River	B	19.5	24.0	21.8	.207	25.5	4,315	2.41	5.59	456
	E	23.6	24.2	23.9	.025	25.5	3,850	2.41	6.26	407
Nahcotta Channel	B	23.1	24.1	23.6	,042	26.2	3,950[3]	0.28	0.71	3,690
	E	--	--	--	--	--	--	--	--	--
North River	B	22.4	24.3	23.4	,081	24.3	840	4.33	51.6	47.1
	E	23.6	24.5	24.1	.029	24.3	1,200	4.33	36.1	67.3
Bay Center	B	12.5	23.4	18.0	,607	36.8	1,400[5]	1.13	8.1	454
	E	22.4	24.1	23.3	.073	36.8	1,160[5]	1.13	9.7	379
Nemah River	B	21.7	24.1	22.9	.105	70[4]	400	1.16	29.0	241
	E	21.3	24.1	22.7	.123	--	--	1.16	--	--
Stanley Channel	B	------------No Data-------------				76.9	--	2.83	--	--
	E	------------No Data-------------				76.9	--	2.83	--	--

[1] From August Centroid Velocity, Figure 11.

[2] Using ellipsoid shape: major area = width, minor area = 2 x depth (excludes tide flat area).

[3] No measurement available - estimate from relative stream size.

[4] Estimated - assumed similar to Stanley Channel velocity.

[5] Estimated - assumed similar to Nemah River for this time of year,

While data indicate violations of the water quality criteria occur, these violations are observed at stations with salinity data varying, by definition (10 ppt), from saline to freshwater depending on river flow and tidal cycle. Most violations noted occurred at or slightly above 10 ppt, when the criterion change radically from 100 colonies/100 mL to 14 colonies/100 mL (median concentration) or from 200 colonies/100 mLs to 43 colonies/100 mL (not more than 10 percent of samples to exceed). Strict interpretation of violations under these dynamic conditions is not recommended

Samples of oysters collected by WDOE in April 1981 from the Willapa River near South Bend and from the southern part of the bay had 130 and 230 fecal coliforms per 600 g of tissue (South Bend) and 78 and 45 fecal coliforms per 600 g of tissue (southern bay). As water temperatures were probably still below 15 degrees C in April, the probability of false results (Nussong, Colwell, and Weiner, 1981) was low. Samples collected near station 24 on September 8, 1980, had from less than 20 to 45 fecal coliforms per 100 g of tissue. Limited sampling thus suggests that oysters from the major source area have higher concentrations of fecal toliforms in thrir flesh.

The average salinity contours shown in Figure 4 can be used to determine the area of the bay most subject to river influence. These are two particularly interesting features of the bay salinities. One Is the deep penetration of high salinity water into the southern part of the bay along Nahcotta Channel. The other is the zone of relatively low salinity water on the north side of the bay between Toke Point and the mouth of the Willapa River. A previous study by Weyerhaeuser Company (Smith and Herrmann, 1972), and later additions thereto summarizing salinity and temperature distributions, did not show the low salinity area at the north end of the bay. Two factors probably contribute to the observed distribution of salinity: the relatively high combined flows from the North, Cedar, and Willapa rivers and Smith Creek, and the effects of coriolis forces on estuarine circulation that cause lower salinity waters to follow the right shore (facing downstream). The relatively great influence of freshwater in the north part of the bay, combined with the loading rates from rivers (Table 9), suggests that that area deserves continued attention in future monitoring studies.

At present, sanitary shellfish closures are based either on proximity Lo known sources of contamination or on known deviations from Class "A" water quality criteria. A summary of bacterial sampling (CH2M-Hill, 1981) suggests that much of the area upstream from the present sanitary line in Willapa Bay would be "safe" for the harvest of shellfish under most conditions. Only station 27 at the Highway 101 bridge in Raymond appears to be in strong violation of the Class "A" criteria. The reduced salinities observed along the north shore of the bay (compared to other reports) suggest that continued monitoring should occur there, as well as in the Willapa River estuary.

The average FC:FS ratio of 3.6 from station 27 could indicate human sources of bacteria upstream from Raymond. Given that a starting ratio of 4.2 could decrease to 2.2 in 4 days (Geldrich, et al., 1968), and that the travel time from upstream sources to station 27 is likely to be one to several days, human sources of contamination would be indicated. The results of the bacterial reduction study indicate the opposite, however, i.e., ratios increasing with time. Given the doubtful nature of the results of the study an interpretation based on the Literature is favored. With the exception of the Willapa River, the sources of fecal bacteria to Willapa Bay appear to be mostly of animal origin rather than human.

That suggestion is partly supported by the results of the sanitary survey. While numerous potential sources of human contamination were identified in the Willapa River drainage, examination of Table 3 shows that even at those sources FC:FS ratios seldom approached 4:1. The Bear River, with an average FC:FS ratio in excess of 4:1, had no apparent sources of human contamination, and other streams with apparent sources, such as the North Nemah River, had no instances where the FC:FS ratio exceeded 4:1. Table 10 lists the occurrence of FC:FS ratios in excess of 4:1 at river stations. In most cases, the flows from areas of possible human contamination were very small, with the possible exception of Wilson Creek, the creek flowing through Lions Club Park in Raymond (station C) (Table 3), and the City of Raymond treatment plant and lagoon (Tables 4 and 5). While bacterial concentrations were sometimes high in the treatment plant effluent (Table 4), average flow was always less than 0.5 cfs. Thus, even though the concentration of fecal coliform in the treatment plant discharge is high (average 5,660 per liter), the loading rate is only 9.5×10^5 per hour because of the low average flows (Table 5). Wilson Creek, with a drainage area of about 25 square miles, has a loading rate of 2.7×10^{10} fecal coliforms per hour (based on a single sample, Table 3). The very small creek running through Lions Club Park had a loading rate of 8.0×10^9 fecal coliforms per hour (based on three samples, Table 3). Wilson Creek and the stream in Lions Club Park may thus contribute about 40 percent of the fecal coliform load calculated for the Willapa River.

It appears that reduction or elimination of known sources of bacterial contamination of the Willapa River from Raymond and South Bend and upstream areas would do much toward bringing the Willapa River estuary up to the Class "A" criteria.

Table 10 OCCURRENCES OF FC:FS RATIOS IN EXCESS OF 4:1 AT RIVER STATIONS

Station	No. 4	Date	FC:FS Ratio
1	3	6/11	180
		8/12	8
		3/17	4
2	4	6/11	20
		10/20	4
		12/18	8
		3/17	6
3	2	4/15	4
		6/11	19
18 (55,3A)		4/15	9
		10/6	4
		2/19	8
4	0		
5	2	8/12	5
		1/20	17
6	4	8/12	6
		8/26	8
		12/18	7
		1/2	6
7	3/17	34	
24	7/23	13	
	1/20	4	
26	1	3/17	6
27	2	9/8	4
		2/3	22
28	2	3/3	6
		3/17	4
29	0		
30		4/15	32
		2/3	6

APPENDIX A

LAUREN H. LUCKE, MD, MPH
HEALTH OFFICER

December 7, 1981

RECEIVED
DEC 8 1981
HEALTH SERVICES DIV.

John A. Beare, M.D.
Division Director - DSHS
Health Services Division LJ-18
Olympia, WA 98504

Dear Dr. Beare:

The Pacific wind storm that came into Western Washington and Oregon Saturday, November 14, 1981 was the most damaging storm to hit our Twin Harbors area since the Columbus Day storm of 1962. Of all areas in Grays Harbor and Pacific Counties to sustain damages, the damages suffered by the City of Raymond in Pacific County were the greatest. The flood waters, pushed by high tides, completely inundated the city sewer system, flooding downtown trunk lines and putting four pumping stations out of operation. In addition to the above, the primary treatment plant is out of operation, possibly with two broken shafts on the motors. All sewage is being by-passed to the river.

The City of Raymond is incurring tremendous expenses in overtime and extra employee hours in correcting the existing problems. In addition, the 2½ pumping stations that were back on line by December 3 were inundated again by high tides pushing flood waters in over the weekend of December 5 and 6. Clarifier waste is being discharged to the swampy area adjacent to the south fork of the Willapa River where it will eventually find its way to the river, further creating problems for the citizens of the area by contaminating shellfish beds.

We feel the above series of happenings has created a situation in Raymond that warrants a declaration of emergency from your office to protect the public health of the citizens. Please consider this letter a request for your consideration of this matter.

Sincerely,

Lauren H. Lucke, M.D.
District Health Officer

LHL:ald

cc: Rance Freeman, Mayor, City of Raymond
Joe Krupa, Commissioner, City of Raymond
Howard Steeley, Department of Ecology

ADDRESS REPLY TO:
☒ GRAYS HARBOR COUNTY OFFICE – 2100 SUMNER AVE. – ABERDEEN, WA. – PHONE 532-8631
☐ PACIFIC COUNTY OFFICE – COUNTY COURTHOUSE – SOUTH BEND, WA. – PHONE 875-5584
☐ LONG BEACH OFFICE – 12TH & PACIFIC – LONG BEACH, WA. – PHONE 642-3274

JOHN SPELLMAN
Governor

STATE OF WASHINGTON
DEPARTMENT OF SOCIAL AND HEALTH SERVICES
Olympia Washington 98504

DEC 1_ 9 47 AM '81

December 9, 1981

Mr. Don Moos
Director
Department of Ecology
Mail Stop PV-11
Olympia, Washington 98504

Dear Mr. Moos:

The purpose of this letter is to inform you that I consider the sewage problem in the City of Raymond in Pacific County to be serious enough to warrant the declaration of a "public health emergency" for purposes of funding consideration by the Department of Ecology. This decision is based on an evaluation of a written request submitted by Lauren H. Lucke, M.D., Health Officer for the Grays Harbor-Pacific Health District. A copy of Dr. Lucke's letter is attached for your information.

The situation at Raymond is clearly a serious one. The treatment plant is not operational, most pump stations are not operable, raw sewage is periodically overflowing into streets, and raw sewage is continuously being bypassed to the Willapa River. We hope that this declaration will allow your agency to provide the necessary financial aid to remedy this problem at the earliest possible time.

If you or your staff have questions or wish further information regarding this matter, please contact Kenneth J. Merry in our Water Supply and Waste Section at 753-5953.

Sincerely,

John A. Beare

John A. Beare, M.D., M.P.H.
Director
Division of Health LJ-18

JAB:par

Attachment

cc: Lauren H. Lucke, M.D.
Kenneth Merry

APPENDIX B

WILLAPA BAY STUDY STEERING COMMITTEE MEMBERS

Martin Auseth
Pacific County Health Dept.
Pacific County Courthouse
South Bend, WA 98586
875-6541 Ext. 367

Jack Burkhalter
Rt. 1, Box 242 C
Raymond, WA 98577
942-2703

Marshall Briggs
Port of Willapa Harbor
Raymond, WA 98577
942-3422

Dick Claunch
Twin Harbors Tree Farm
Weyerhaeuser Company
Cosmopolis, WA 98537
532-7110 Ext. 235

Don Heinle
CH2M Hill
1500 114th Avenue
Bellevue, WA 98004
453-5000

Rex Hutchins
Pacific District/Central Area
Department of Natural Resources
P.O. Box 94
South Bend, WA 98586
748-8616

Ken Kimura
Pacific County Planning Dept.
Pacific County Courthouse
South Bend, WA 98586
875-6541 Ext. 378

Jack Lilja
Department of Social and Health Services
LD-11
Olympia, WA 98504
753-5993

Kreg Martinn
City Superintendent
City of Raymond
417 10th
Raymond, WA 98577
942-3452

Jim Sachet
Water Quality Planning
Department of Ecology
PV-11
Olympia, WA 98504
754-1210

Rocky Seaman
City Superintendent
City of South Bend
Box 34
South Bend, WA 98586
875-5571

Gene Tillet
Department of Game
905 E. Heron
Aberdeen, WA 98520
533-9335

Dennis Tufts
Willapa Shellfish Laboratory
Department of Fisheries
P.O. Box 190
Ocean Park, WA 98640
665-4166

Lee Wiegardt
Jolly Roger Seafoods
P.O. Box 309
Ocean Park, WA 98640
665-4111