WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

WILLAPA BAY WATERSHED BACTERIAL EVALUATION AND PRELIMINARY CONTROL STRATEGY

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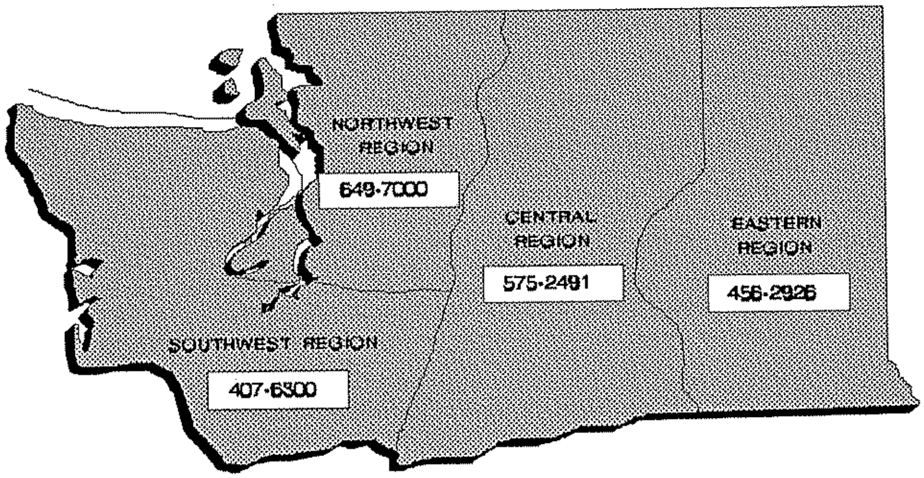

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WILLAPA BAY WATERSHED BACTERIAL EVALUATION AND PRELIMINARY CONTROL STRATEGY

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EXECUTIVE SUMMARY

Introduction

Bacterial pollution from human and animal fecal sources can limit the use of water for domestic water consumption, primary and secondary contact recreation, and shellfish harvesting. Willapa Bay's shellfish areas are an especially important resource in need of protection, producing over 50% of Washington's harvest. Recently, fecal pollution has been responsible for impairment and regulatory reclassification of one hundred acres of commercial shellfish beds in the bay (DOH, 1992b). There is also chronic bacterial contamination in the upper watershed, and sensitive ground water areas in the watershed require close monitoring to prevent bacterial contamination.

The past two statewide 305(b) water quality reports written by the Department of Ecology (Ecology) (1990; 1992) identified Willapa Bay, and the Willapa River below river mile 18.2 as "water quality limited" due to fecal coliform criteria violations (Figure E-1). Water quality-limited is defined in federal regulations as:

> " . . . any (water body) segment where it is known that water quality does not meet applicable water quality standards, and/or is not expected to meet applicable water quality standards, even after the application of the technology-based effluent limitations required by 301(b) and 306 of the (*Clean Water*) Act" (40 CFR 130.2(i)).

The same federal regulations require that Ecology perform a total maximum daily load (TMDL) evaluation, and complete either or both a waste load allocation (WLA) for point sources and a load allocation (LA) for nonpoint sources in water quality-limited areas. The basic goal of the TMDL/WLA procedure is to bring water bodies back into standards compliance by limiting pollutant loading based on the characteristics of the water bodies, rather than by the limits capable from the usual source treatment processes.

The Ecology Water Quality Program is responsible for implementing the TMDL/WLA process which affects point source discharge permits and nonpoint source action plans. However, there have been significant locally initiated actions in recent years to control water quality problems in the Willapa Bay watershed, in part, to keep management of the problems under local control. The organization of a local water quality management structure and locally initiated actions have been supported with resources from local and federal agencies, and from other Ecology programs. The Ecology Water Quality Program needs to either integrate the TMDL process into the local structure, or use the local structure alone to ensure an effective strategy to control bacterial pollution.

The purpose of this report is to evaluate the bacterial problem in the Willapa Bay watershed, and to recommend an effective watershed control strategy. This study was largely funded by a United States Environmental Protection Agency (USEPA) Near Coastal Waters grant. The

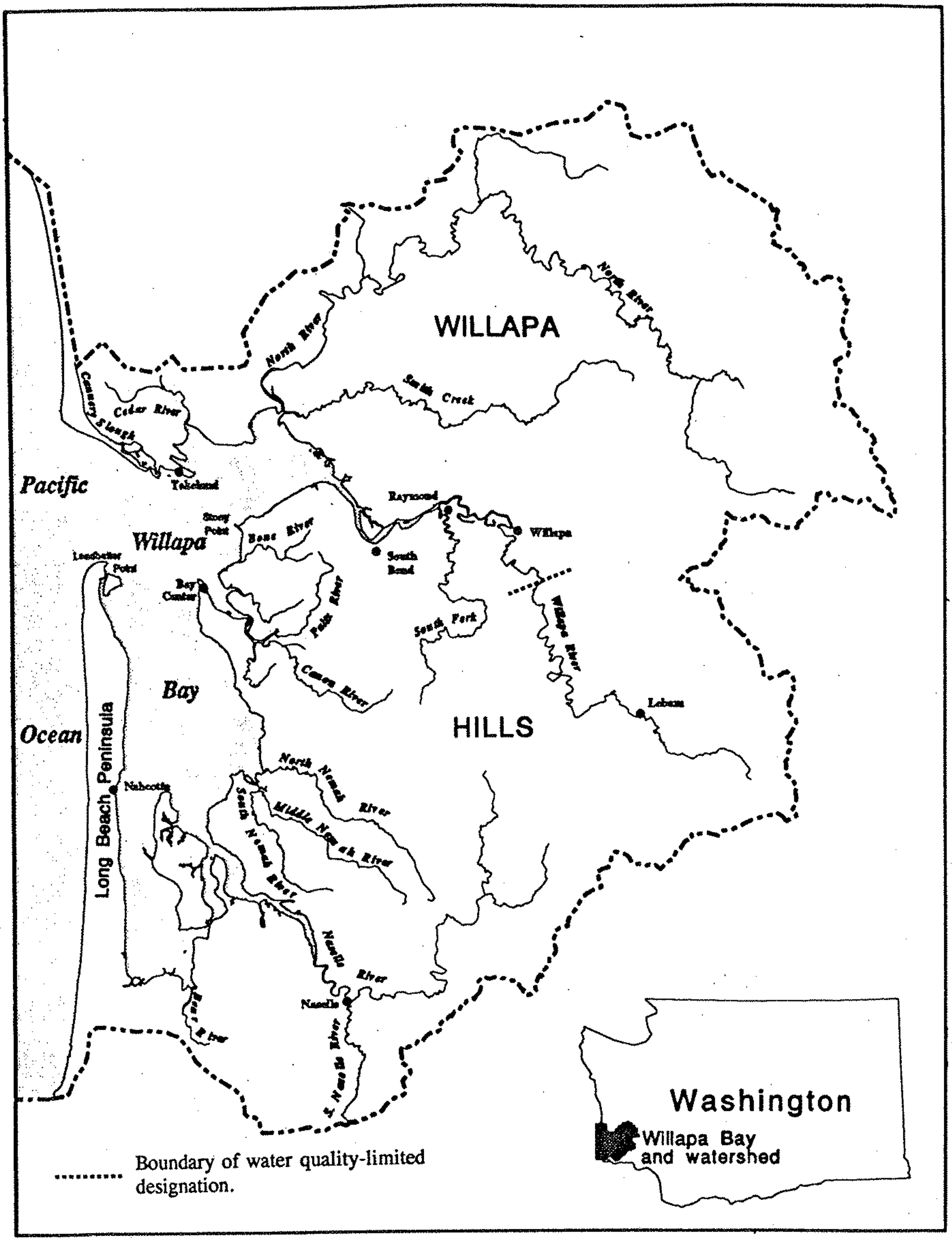


Figure E-1. The Willapa Bay watershed showing major rivers and geographic features. Also noted is the extent of the Lower Willapa River identified as water quality limited (see text) by the Washington State Department of Ecology.

report is divided into two parts. The first part is a compilation of past information and an evaluation of the bacterial problems which include the following:

- a description of the watershed, existing resources, and beneficial uses;
- a review and evaluation of historical fecal coliform sources and problems; and
- a presentation of available fecal coliform bacteria data, and the data's adaptability for loading and modeling calculations.

The second part of the report is an analysis of three major questions concerning a preliminary watershed control strategy for bacterial contamination:

1) How compatible is the Ecology TMDL process with the local water quality management framework operating in the watershed?
2) What are some other strategy options to control bacteria in the watershed?
3) What specific elements are necessary for an effective preliminary watershed fecal coliform control strategy in the Willapa Bay watershed?

Local water quality management initiatives, various Ecology program activities, and successful strategies used in other watersheds are examined. From this analysis, a framework and strategy for the Willapa Bay watershed is outlined and recommended.

The report compiles information from several sources, and is intended as a summary of significant work performed in the Willapa Bay watershed and other watersheds on fecal bacteria issues. The report should provide the Ecology Water Quality Program and interested readers with a summary of the bacterial problems, the historical approaches taken to alleviate those problems, and the current effectiveness of the local water resource management structure. It should also be a resource for inter-program and inter-government cooperation to devise effective control of the bacterial contamination problems in the Willapa Bay watershed.

Evaluation of Bacterial Problems

<u>Willapa Bay Resources</u>

The Willapa Bay watershed encompasses 1,100 square miles (2,850 square kilometers) in southwest Washington State, mostly in Pacific County. Over 20 tributaries drain the managed forest uplands, agricultural holdings, and urban areas located in flood plains and along shorelines of the bay. Pacific County has a resource-based economy with no large industries and supports 19,400 permanent residents.

The Willapa Bay estuary is 92 square miles (238 square kilometers) at mean higher high water, and is comprised of two major arms. Approximately 50% of the estuary is exposed at low tide. Tidal flow in the estuary exceeds cumulative freshwater flow by 5 to 10 times, even during periods of watershed runoff. A low salinity plume from the Columbia River is evident year-round and is carried north into Willapa Bay during the months of October through April. Its presence reduces salinities in the bay by blocking direct ocean currents.

Washington State is the nation's leading shellfish supplier. Ten to 12% of the jobs in Pacific County are tied to the Willapa Bay shellfish industry which produces over 50% of shellfish harvested in the state. Seventy-five percent of the intertidal lands in Willapa Bay are privately held. The remaining intertidal area is in state-owned reserves. Only four percent of Willapa Bay tidelands are Class I and II oysterlands used for shellfish fattening and harvesting. These highly productive oysterlands are located primarily in the northeastern and western areas of the bay. Sixty percent of the oyster harvest takes place from October through December.

Two Washington State agencies have responsibility for protecting shellfish sanitation and general water quality in Willapa Bay: Department of Health (DOH) and Department of Ecology (Ecology), respectively. DOH certifies commercial shellfish harvesting areas through water quality monitoring and bacterial source evaluation. Ecology monitors general water quality to protect beneficial uses of water resources. Fecal coliform bacteria are used by both agencies as an indicator species for human health risk. The fecal coliform criteria used by both agencies for regulatory purposes are similar. However, methods of sampling and data interpretation differ.

Bacterial Sources and Problems

Historical surveys and monitoring data have documented various nonpoint and point sources of bacteria in the watershed. By far, fecal coliform have been the most common data collected for evaluation of bacterial contamination. Most of the bacterial sources are located in urban and agricultural areas along the bayshore and in the river valleys. Although the interior hills comprise most of the watershed land area, only wildlife and recreational land uses would likely generate bacterial loads.

Potential nonpoint bacterial sources identified in various locations in the watershed include: malfunctioning or inadequate on-site septic systems, urban stormwater, livestock, boats, and wildlife. Only on-site systems, urban stormwater, and livestock have been identified as serious threats to water quality. Boats and wildlife have been considered highly localized sources with unquantified contamination potential.

There are 21 point sources in Willapa Bay with National Pollutant Discharge Elimination System (NPDES) permits managed by Ecology. Over 40% of point source wastewater discharged is from three municipal sewage treatment plants (STPs). However, wastewater volumes discharged into the Willapa watershed have high seasonal variability. For example, the heaviest seafood processing season is generally in the fall, which coincides with larger flows from the municipal plants and nonpoint sources if wet weather has set in. Only seven of these 21 permits have fecal coliform limits: the three municipal STPs, a youth camp, and three seafood processing plants. Records for the STPs indicate they are usually able to meet the secondary treatment bacteria limits specified in their wastewater discharge permits.

Fecal coliform bacteria data from local, state, and federal agencies and private institutions were collected and evaluated. A summary of some of the findings from recent data follows:

- Grayland Ditch fecal coliform levels exceed water quality criteria, perhaps from increasing population and land development. Few bacterial problems have occurred in the adjacent open water area.

- The mouths of the Cedar and North Rivers exceed marine fecal coliform criteria after measurable rainfall. The North River has a long history of potential health hazards from inadequate waste disposal systems on houseboats. Livestock access to low-lying pastures may be another source of bacteria.

- The upper segment of Willapa River chronically exceeds fecal coliform criteria. Livestock manure and on-site system failures are thought to be major sources. Preliminary data analysis suggests that fecal coliform bacteria generated in the upper watershed do not necessarily reach shellfish growing areas in the bay, although river beneficial uses are threatened or impaired.

- Long-term monitoring data at three stations in the lower Willapa River show marked reductions in fecal coliform concentrations. Major improvements in the Raymond and South Bend STPs and collection systems completed by 1985 may be responsible for some of the improved water quality.

- Numerous point and nonpoint sources have been documented near the Bruceport/South Bend shellfish growing area. Urban combined sewer overflow (CSO) runoff and livestock sources close to the growing areas may be major sources of bacterial loading during fall, winter, and spring storm events.

- The Stony Point shellfish growing area has no record of fecal coliform water quality criteria violations. However, no monitoring has occurred during major rainfall events when violations are most likely to occur. Also, no samples have been taken at the height of the seal pupping season to evaluate if there is bacterial contamination from the presence of the seals.

- Parts of the Bay Center shellfish growing area were closed by the DOH in 1989 and are under Restricted or Conditional harvesting status now. Bacterial sources had been documented at least nine years previous to the closure.

- Upland and shoreline development in soils poorly suited for on-site septic systems, and grazing pastures and residential areas inundated by high water, cause concern for the shellfish resources along the Long Beach Peninsula and other bayshore areas.

- Historical studies on the Long Beach Peninsula have documented some periodic elevated fecal coliform counts in the drainage ditches. These ditches now may have reduced treatment capability because of increased trenching activities. Major shellfish harvesting and holding areas are located very near potential bacterial sources.

- The Long Beach STP sludge land application site is over-utilized and may be contributing fecal coliform to the back-bay areas.

- The Nemah and Naselle rivers show periodic bacterial contamination above marine water criteria in response to rainfall. On-site septic systems and livestock accesses to waterways were potentially significant sources of bacterial contamination.

- Bay areas in southeast Willapa Bay are subject to lower seasonal salinities which could prolong the mortality rate for bacteria and enhance the possibility of contamination of shellfish.

Modeling and Loading

Few watershed models simulate and predict fecal coliform loads in estuarine conditions. Some of the models available perform simulations of bacterial loading from urban stormwater and field-scale livestock manure run-off for relative comparisons, or rough estimations of sub-basins or reaches. The latter type are usually nonpoint source (NPS) wash-off models using local land use, water quality, and physical feature data. These NPS models could generate useful information for the control strategy. There is a potential for using geographic information system (GIS) coverages in a NPS wash-off model and linking the output with a water quality transport model. The simplest model that will provide the specific information needed should be used.

As a demonstration of modeling approaches to bacterial loading, two simple examples were given. Tributary fecal coliform loads calculated from 1980 data (CH_2M Hill, 1981) were compared to loads calculated from 1985 to 1990 DOH and Ecology data. The Willapa River (above Raymond) load based on 1985 to 1990 data was greatly reduced compared to 1980 data. However, the bias present in both sets of data made comparisons tenuous. The lack of a more complete and compatible data set is a serious obstacle to a long-term watershed assessment.

A second simple, relative comparison of source impacts on shellfish harvest areas in the lower Willapa River was demonstrated using proximity calculations combined with the rational formula to estimate NPS wash-off. The results suggested that when four inches of rain fall over 24 hours, combined sewer overflows (CSOs) and grazed pastures along the bay and sloughs downstream of Raymond are probably major sources of bacteria compared to the treated STP effluents and bacterial loads from the river above Raymond. This basic assessment could be conducted with more sophistication and higher confidence using a model with GIS-based land use and physical feature coverages, and better hydrodynamic functions. However, more specific data from the local area are needed to develop such a model.

Watershed Control Strategies

Pacific County government agencies and citizens have been active in water resource management and planning since 1972 (Shotwell, 1988). A renewed local interest in water quality management in 1988 was the result of three combined events (Willapa Bay Water Quality Organizing Committee, 1990):

1) confirmed water quality problems and shellfish closures in areas thought to be clean, and in areas suspected of having problems,
2) increased involvement in local water quality problems and encroachment on local control by state and federal regulatory agencies, and
3) local support from elected officials and citizens for local policy approaches and involvement in issues.

Because of these events, Pacific County obtained funds from Ecology and USEPA to support a local committee and develop the Willapa Bay Water Resources Management Plan (Willapa Bay Water Quality Organizing Committee, 1990). The plan and ancillary reports outlined past resource planning efforts in the county by various levels of government, identified a broad range of water resource problems, and described the needs and actions necessary to assess and manage water quality in Willapa Bay.

A major outcome of these committee activities was the creation of the Willapa Bay Water Resource Coordinating Council (WBWRCC). The WBWRCC is a 17-member advisory body to the county commission with representatives from agriculture, aquaculture, city government, Native American tribes, commercial fisheries, development, education, industry, forestry, recreation, and the public at large. It is charged with addressing and implementing water resource policy, coordinating multi-agency activities, and providing the citizens with a public forum to discuss and solve local water resource problems.

Another broad-based group, the Willapa Alliance, has also been active in many local issues and is considered another source encouraging the development of local empowerment in Willapa Bay.

Through the WBWRCC, the Pacific Conservation District (PCD) and Pacific County government agencies have been making progress on some water resource and bacterial contamination issues. They have made great efforts to educate and involve those that are immediately affected by water quality control measures and management practices. With the help of state and federal grant funding, they continue to identify sources of bacterial contamination, implement on-site sewage system repairs, and mediate differences of opinion on which activities will best control bacterial problems. However, they have sometimes been slow to act and problems like the closure and down-classification of Bay Center commercial shellfish beds have occurred.

TMDL/WLAs under Ecology's planned basin management approach, Ecology shellfish protection programs, the Coastal Zone Act Reauthorization Amendment activities, the Shellfish

Protection District regulations, the Tillamook Rural Clean Water Project findings, and the Puget Sound Action Plan were briefly discussed as frameworks that hold some elements of interest to make a more effective control strategy for bacterial contamination in the Willapa Bay watershed. There were examples of programs, regulations, and assessment tools that could be drawn from to help control bacterial contamination in the Willapa Bay watershed. The discussion suggested that state and federal regulators and local communities have successfully worked together to solve large water quality problems.

Compatibility of Strategies to the Local Framework

The phased TMDL methodology offers a rational process to focus on specific goals and objectives to control bacterial contamination in the watershed. However, Pacific County citizens would probably look upon a fecal coliform TMDL as another example of heavy-handed state interference in a local issue unless communication and involvement with local groups was started early. Ideally, the TMDL process will mean a planned, internally coordinated, and long-term commitment from Ecology and USEPA. Early and sustained involvement of the DOH, PCD, WBWRCC, and local agencies in the planning, data collection, and subsequent data evaluation is envisioned as an important part of the Ecology basin approach and TMDL process. A cooperative process would likely result in a less redundant effort, and a more complete TMDL. A phased TMDL would also require a long-term monitoring program, something local water resource groups have wanted but have been unable to fund.

On the other hand, fecal coliform bacteria could be a difficult TMDL parameter to establish since counts have a high degree of variability, and annual or seasonal loading estimates may not be useful for comparison to state criteria. Also, Ecology may only be able to address fecal coliform problems in specific areas of the watershed because of current staff and resource limitations. However, if done cooperatively and creatively, Pacific County and Ecology can use the phased TMDL to return critical areas of the watershed to full compliance with standards and protect all beneficial uses.

Locally directed strategies for controlling bacterial contamination in the Willapa Bay watershed also have a good potential for success. Involvement of the WBWRCC, local government, and citizens appears to be high. Locally directed programs with state and federal regulators as advisors rather than initiators continue to receive resources and support in Washington. In Pacific County, the WBWRCC has been effective in getting diverse groups to find solutions and correct some water quality problems. They have also helped coordinate limited monitoring activities at the local level. The locally directed strategy has an advantage of better citizen support, a broader knowledge of bacterial problems compared to other local environmental issues, and a better sense of what control measures will be successful.

There are some factors which hinder the progress of a locally directed strategy. The current structure in the Willapa Bay watershed does not contain many mechanisms to communicate with state and federal regulators, or include their participation as technical advisors and resources. In contrast, the local structure is dependent on state and federal funding, and is chronically short of staff and resources to accomplish its programs. Local organizations can also become splintered as pollution control measures move from voluntary to compulsory. It is also difficult for a group with a broad responsibility to stay focused on an issue after a crisis stage is passed. These factors pose a challenge to the WBWRCC or other local groups working to implement a successful control strategy.

Recommendations

Documents and interviews obtained during the course of this report uncovered an attitude of suspicion and misunderstanding between local groups and state and federal regulators. It is evident that a control strategy for a basin as large and important as Willapa will need the resources and active participation from both groups to be effective. An Ecology fecal coliform TMDL, or a local WBWRCC control strategy would need to open communication, reduce negative attitudes, and include all interested groups in planning and decision-making.

Ecology's Water Quality Program will be addressing water quality problems in the Willapa Bay watershed by 1996 according to its basin management schedule (Wrye, 1993). Before then, several key Ecology programs must come together with an integrated plan of how the department intends to approach basins experiencing bacterial contamination. Meanwhile, the WBWRCC should arrange a series of presentations or meetings with state and federal agencies to decide the best strategy. A lead agency or organization should be identified, and the roles of each participant and the mechanisms for cooperation in the control strategy should be written. The lead agency or organization should emphasize coordination of information and resources. Interagency and intra-agency communication mechanisms need to be established with scheduled meetings and planned agendas. Electronic storage and transfer of data, computer access for all participants, a central information storage area, and a resource directory would be helpful.

The strategy will require clear and concise objectives to fulfill the primary goal of controlling bacterial contamination in the watershed. These objectives need to be important to all members of the strategy structure. Protection of public health should be a primary objective of the strategy. Shellfish harvesting beds, drinking water supplies, and primary contact recreation areas will all require a high level of evaluation and protection, especially in the bay and lower river reaches. Protection of secondary contact recreational uses are important considerations for the chronic bacterial problems in the upper Willapa River reaches.

Education and outreach are important ways a control strategy becomes locally established, so these components need to be included into the strategy plan. Education and outreach programs have been initiated in the watershed and should continue to:

- encourage local citizen participation and support,
- keep citizens and groups aware of control strategy actions and plans,
- encourage voluntary compliance with best management practice (BMP) implementation,

- foster local stewardship and individual awareness, and
- bring necessary political support and funding for the control strategy from outside Pacific County.

A formal re-evaluation cycle conducted by a particular agency, organization, or steering committee should be scheduled on a regular interval. The purpose of the re-evaluation would be to provide feed-back on strategy effectiveness, and to reflect on the strategy direction. Also, evaluation of specific control actions after installation and over the long-term is necessary to ensure proper installation and maintenance, and to test the longevity of individual control techniques.

A long-term monitoring plan for water quality should be established to provide data for setting strategy priorities, and for trend analysis as a way to evaluate the overall effectiveness of actions taken under the bacterial control strategy. The strategy should integrate all available monitoring programs to match informational and statistical objectives of the control strategy and agency programs. Re-establishment of gaging stations on all major tributaries to Willapa Bay should be a priority if bacterial loads are to be calculated. Decisions on whether to collect samples for indicator bacteria species other than fecal coliform should be made early in the process with anticipation of future needs and meeting strategy objectives.

Long-term efforts at documenting and tracking land use and shellfish growing area data should be accelerated. Bay shoreline, river mouth reaches, and likely BMP implementation areas should be high priorities for land use data collection. Geographic information system (GIS) coverages documented by the Willapa Alliance should be made electronically available to participants. Shellfish harvest area production or classification changes should be included as a coverage.

Intensive monitoring studies could assist in a range of control strategy activities. They should be tasks designed to answer data needs for a specific objective. The following studies were suggested:

- re-evaluating bayshore and river sources identified by CH_2M Hill (1981) in their 1980 sanitary survey;
- monitoring bacterial concentrations in the northeast and southwest shellfish growing areas of the bay during the October through December harvest season and during storm events;
- defining fecal coliform die-off rates in specific watersheds, and their relationship to estuarine flushing near shellfish harvest areas;
- completing farm inventories along the entire bayshore, and near-bay river reaches;
- determining the role resuspended sediment plays as a source of bacteria in the water column;
- evaluating bacterial loads from diked grazing land with a focus on predicting tidal gate flows;
- identifying fecal coliform sources in the upper Willapa River;
- clarifying the overall bacterial impact of seasonal seafood processing effluent on shellfish resource areas;

- conducting post-action evaluation of bacterial impacts from Bay Center on-site system upgrades and the Hewitt Addition sewer line installation; and
- investigating bacterial impacts from spring harbor seal pupping areas, elk herd wallows in near tidal meadows, and migratory bird populations.

A basic nonpoint source model linked to a simplified estuarine water quality transport model could be constructed to assess bacterial loading. Simulations would be useful for very general evaluations. Ideally, information from GIS land-based coverages (e.g., soils, topography, land use, hydrography, and source components) would be used to generate bacterial loads. Models should be as simple as necessary, and should be designed to meet specific informational needs.

EVALUATION OF BACTERIAL PROBLEMS

Introduction

In Washington's 1990 and 1992 Statewide 305(b) Water Quality Reports, portions of the Willapa Bay watershed were identified as "water quality-limited" due to bacterial pollution (Ecology 1990; 1992). Fecal bacteria pollution from human and animal sources can impair water uses for domestic water consumption, primary and secondary contact recreation, and shellfish growing and harvesting. Willapa Bay's shellfish growing areas are an especially important resource, producing over 50% of Washington's annual harvest. Fecal coliform bacteria pollution has been responsible for past area closures, and the recent down-classification of one-hundred acres of commercial shellfish beds near Bay Center.

The first part of this report is a detailed assessment of the history, location, and severity of fecal bacteria problems in the Willapa Bay watershed. An understanding of the complexity of the bacterial contamination issue in the region is necessary before a control strategy can be discussed. To summarize the issues, we have included:

- a watershed and estuary description,
- an overview of Willapa Bay's unique shellfish resources,
- a description of the regulations and agency programs directed at monitoring and controlling bacterial pollution, and
- an inventory of specific and general fecal coliform bacteria sources and problems identified in the watershed over the past 20 years.

We have also provided a brief description of water quality modeling, and some demonstrations of using the historical database with some simple fecal coliform loading models. The suitability of the database and potential approaches to using models in the control strategy are discussed.

This document compiles information from many sources, and is intended as a summary of significant work performed on fecal bacteria in the Willapa Bay watershed. Our search was not exhaustive and was fairly biased toward shellfish protection issues. So, we may have missed databases, especially those directed at ground water. However, the background information here should help direct cooperative and effective approaches to controlling bacterial problems in the Willapa Bay watershed.

The Willapa Bay Watershed

The 1,100 square mile (2,850 square kilometer) Willapa Bay watershed is primarily intensively managed forest land located in southwest Washington State (Figure 1). At least 20 rivers and streams drain the Willapa Hills as well as the flood and surge plain areas. The soils of the forested uplands are primarily made up of fine sediments that are prone to slides and slumping during periods of extreme soil saturation. Soils in much of the lowland areas are either poorly or excessively drained (Pacific County Department of Public Works, 1974).

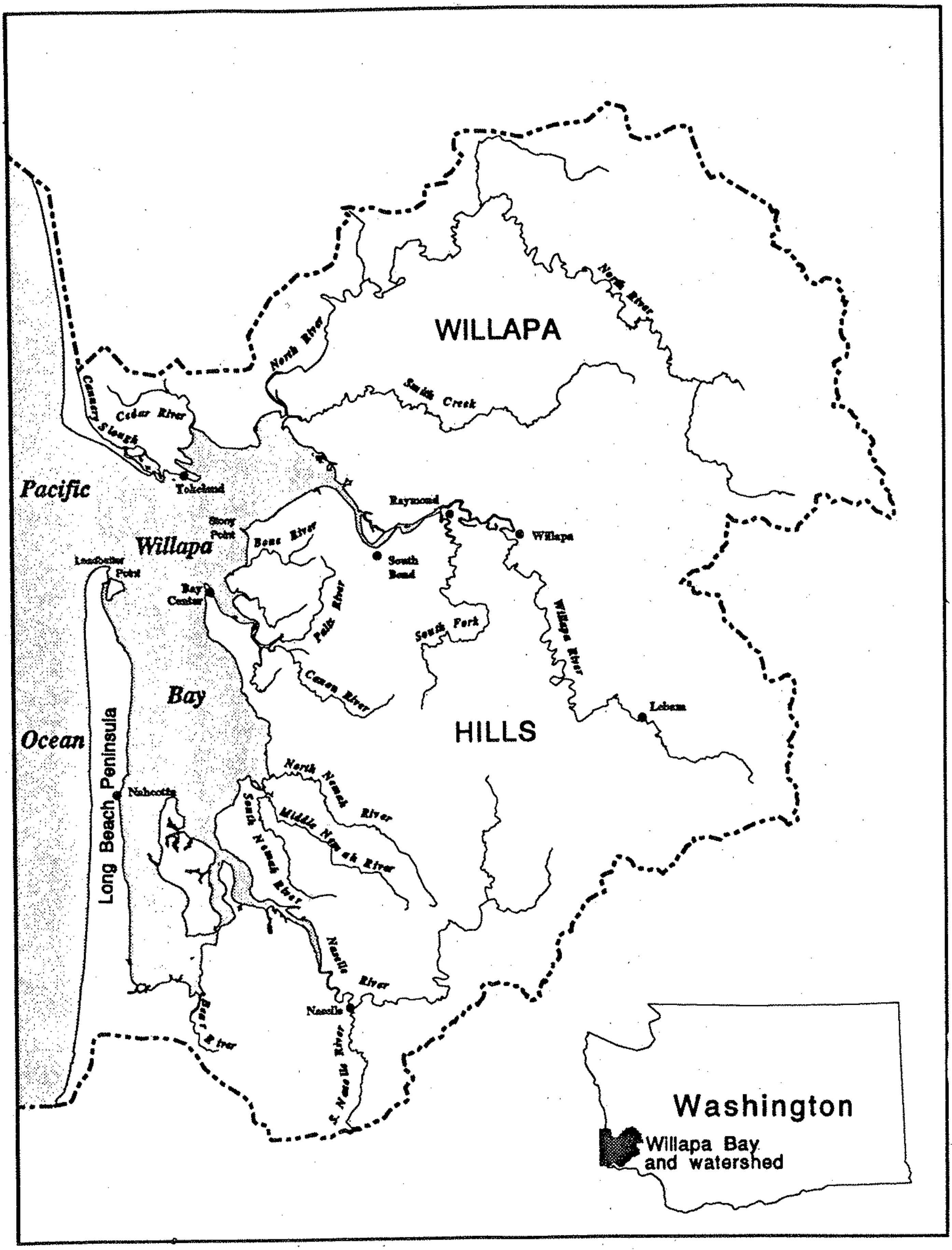


Figure 1. Primary hydrographic features of Willapa Bay and its watershed.

Seventy-five percent of the precipitation in this watershed occurs from October through March, mostly as rain. Rain along the beach areas ranges from 65 to 85 inches, while areas in the Willapa Hills receive 100 inches per year (Hedgpeth *et al.*, 1981). The watershed yields from 73 to 95 inches annually (Collings and Hidaka, 1974).

The principal basins contributing runoff are the North River-Smith Creek, the Willapa River, and the Naselle River. Basins of secondary importance in terms of fresh water discharge rates include the Nemah River, Niawiakum River, Bear River, Bone River, Palix/Canon River, Cedar River, and the Long Beach Peninsula ditch system (Figure 1).

In the lower valley and flood plain areas, the run-off drains through residential, urban, and agricultural areas (Hedgpeth *et al.*, 1981). Areas low in the flood plain have saturated soils from November to March. Many valley and bay areas experience winter floods of short duration (J. Sayce, pers. comm., 1992).

Pacific County has a resource-based economy which supports 19,400 permanent residents with no large industries. Agricultural and populated urban areas are primarily located in flood plains and along shorelines of the bay.

The Willapa Bay Estuary

Several previously published reports have described the Willapa Bay estuary (National Oceanic and Atmospheric Administration, 1990; Shotwell, 1977; U.S. Army Corp of Engineers, 1976). The estuary covers 92 square miles (238 square kilometers) at mean higher high water (MHHW). The estuary is comprised of two major arms (Figure 1). The north-south arm lies east of the Long Beach Peninsula about 18 nautical miles from the mouth of the bay to the mouth of the Bear River. An east-west arm extends about 19 nautical miles from the mouth of the bay up the Willapa River to the head of the tide, which is 2.6 nautical miles upstream of Raymond.

Water quality conditions in the estuary are influenced by its flushing characteristics. In Willapa Bay, tidal volumes are 5 to 10 times watershed freshwater input, even during periods of high river discharge. Diurnal tidal ranges (MHHW-MLLW) are 8.1 to 10.2 feet (2.47 to 3.1 meters) at locations within Willapa Bay. The volume of the bay at MHHW is 56,585,900 ft^3 (1,602,513 m^3); the volume at MLLW is 31,169,000 ft^3 (88,271 m^3). The difference, 25,416,900 ft^3 (719,807 m^3), is the tidal prism (Hedgpeth *et al.*, 1981).

The flushing rate is influenced by coastal and oceanic processes. A low salinity plume out the mouth of the Columbia River is evident year-round and is carried north into Willapa Bay during the months of October through April (Hedgpeth *et al.*, 1981) (Figure 2). Salinity and temperature data collected in Willapa Bay show that the plume lowers salinity and increases water temperatures within the bay in winter relative to open ocean conditions. The intrusion of colder, more saline oceanic waters occurs in summer when plume influences are absent (unpublished Washington State Department of Fisheries [WDF] data). The plume also increases

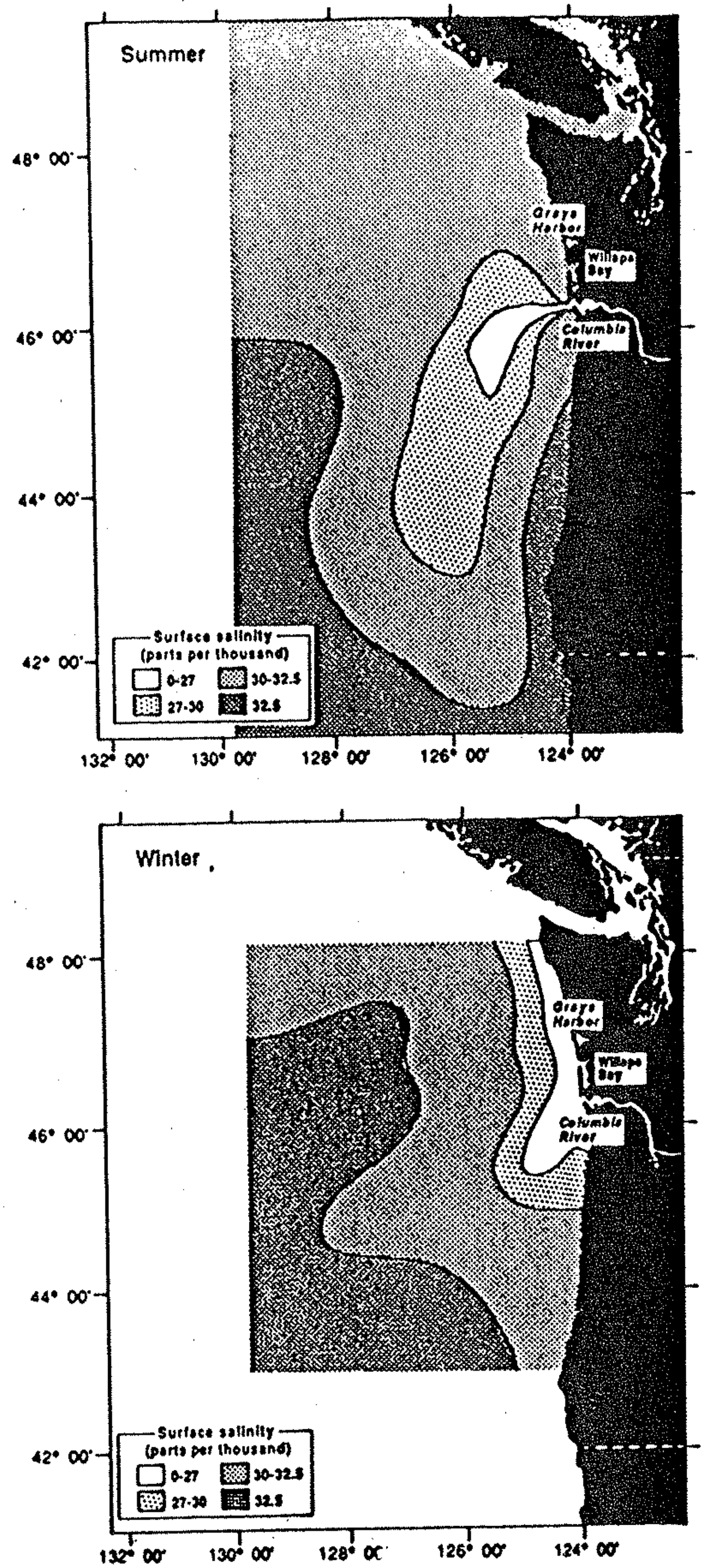


Figure 2. Seasonal influences of the Columbia River plume (Strickland and Chasan, 1989).

oceanic vertical stability, decreases vertical mixing, reduces upwelling, and diverts ocean currents. In this way the plume acts as a discrete water mass to limit oceanic mixing with Willapa Bay, and may reduce the flushing rate of the bay (Strickland and Chasan, 1989).

Willapa Bay Shellfish Resources--An Overview

Commercial Oyster Culture

Oysters were Willapa Bay's first industry after the California Gold Rush Days of the late 1800's, supplying San Francisco with the native oyster, *Ostrea lurida*. Some active oyster farms in Willapa Bay have been operating for 140 years (Strickland and Chasan, 1989). The larger eastern oyster *Crassostrea virginica* was introduced and failed to provide a stable aquaculture. The Pacific oyster, *Crassostrea gigas*, was introduced from Japan in 1928. They were faster growing and marketable within one to two years after planting. The first large oyster set of *C. gigas* from the introduced stock occurred in 1936. As the number of oysters in the bay increased, oyster maturity appeared to slow down to 4-6 years (Hedgpeth *et al.*, 1981). Another result of change in stock which is still influencing oyster production in Willapa Bay is that the areas in the southern bay are no longer capable of fattening oysters for market.

Oyster growers in Willapa Bay have over eight million dollars invested in production. Ten to 12% of the jobs in the county are associated with the oyster industry (Strickland and Chasan, 1989). The industry employs 470 year-round workers and 440 temporary workers, making oyster production the largest or second-largest employer in Pacific County. There were 28 growers from Willapa Bay on the Department of Health's certification list for 1991-1992.

Oyster Cultivation and Oysterland Classification

The distribution of oyster production in Willapa Bay is centered around the intertidal area from 3.5 feet (1.1 meters) above mean lower low (MLLW) water down to 1.5 feet (0.5 meters) below MLLW. Bed culture, where oysters are grown on the bay bottom, is the most common culture method.

Oysterlands vary as much as farmland in their ability to produce a marketable crop and are classified according to their productivity (Table 1). Some tidelands are best for capturing oyster seed, some provide good growth but will not provide marketable oysters, and others provide fattened oysters for market. Oyster seed is planted in the growing areas, and is moved before harvest to the fattening areas, which are located mainly in the northern and western parts of the bay. Three to four years are required on the growing ground, and one or two years more are required on the fattening ground (Hedgpeth *et al.*, 1981). Sixty percent of the oyster harvest takes place from October through December each year (D. Tufts, pers. comm., 1992).

Seventy-five percent of all of the intertidal lands in Willapa Bay are privately held. The rest of the intertidal area is in "Oyster Reserves" consisting of 10,000 acres owned by the State of Washington and administered by the Department of Fisheries.

Table 1. Oysterland production classification descriptions and sensitivities to bacterial contamination.

Class I - Fattening oysterlands are the very best land in the bay. They are best utilized to increase the oyster meat's weight and quality to a marketable standard. They are, in general, closer to the ocean, or are on the edge of bay channels. This suggests that the bulk of the oyster's food supply comes in with the tide (Hiss and Boomer, 1986). Fattening areas are considered sensitive to fecal coliform pollution because these grounds are the last stop before processing and shipping.
Class II - Growing grounds are as valuable as Class I and are best suited for increasing oysters to a marketable size. The lower amount of food available limits the production of "fattened" marketable oysters. Class II grounds are usually closer to the tributaries of the bay (Hiss and Boomer, 1986). This makes them subject to nonpoint and point source bacterial contamination.
Class III - Oyster seed land is used for the catching, holding, or development of oysters. Generally it is located between production land and marginal land.
Class IV - Oyster seed land is much the same as Class III, however, it generally will not support much of a seed crop because the food supply is poorer.
Class V - Marginal land is located between the shoreline and the seed area. It is of little value other than as protection for other bed classes.

Class I and II oysterlands total 2,490 acres (1008 hectares), or four percent of Willapa Bay (Figure 3). Class I and II tidelands are the only oysterlands suitable for producing marketable oysters. Fifty percent of Washington's total shellfish production is harvested from this critical four percent of Willapa Bay.

The oyster condition index is a method that the WDF uses to evaluate oyster fattening. From 1963 to 1986, the highest condition scores in Willapa Bay occurred for oysters collected along the Long Beach Peninsula between Oysterville and Ledbetter Point. Oysters from growing areas near Stony Point, Tokeland, North River, Bruceport, and Bay Center show a lower condition index score.

Commercial Clam Culture

In 1992, there were three certified clam growers in Willapa Bay. Clams have been a minor crop compared to oysters, but production in the bay is increasing. Willapa Bay clams are primarily grown in the southern portions of the bay. As with oysters, summer spawning season lowers the marketability of the clams.

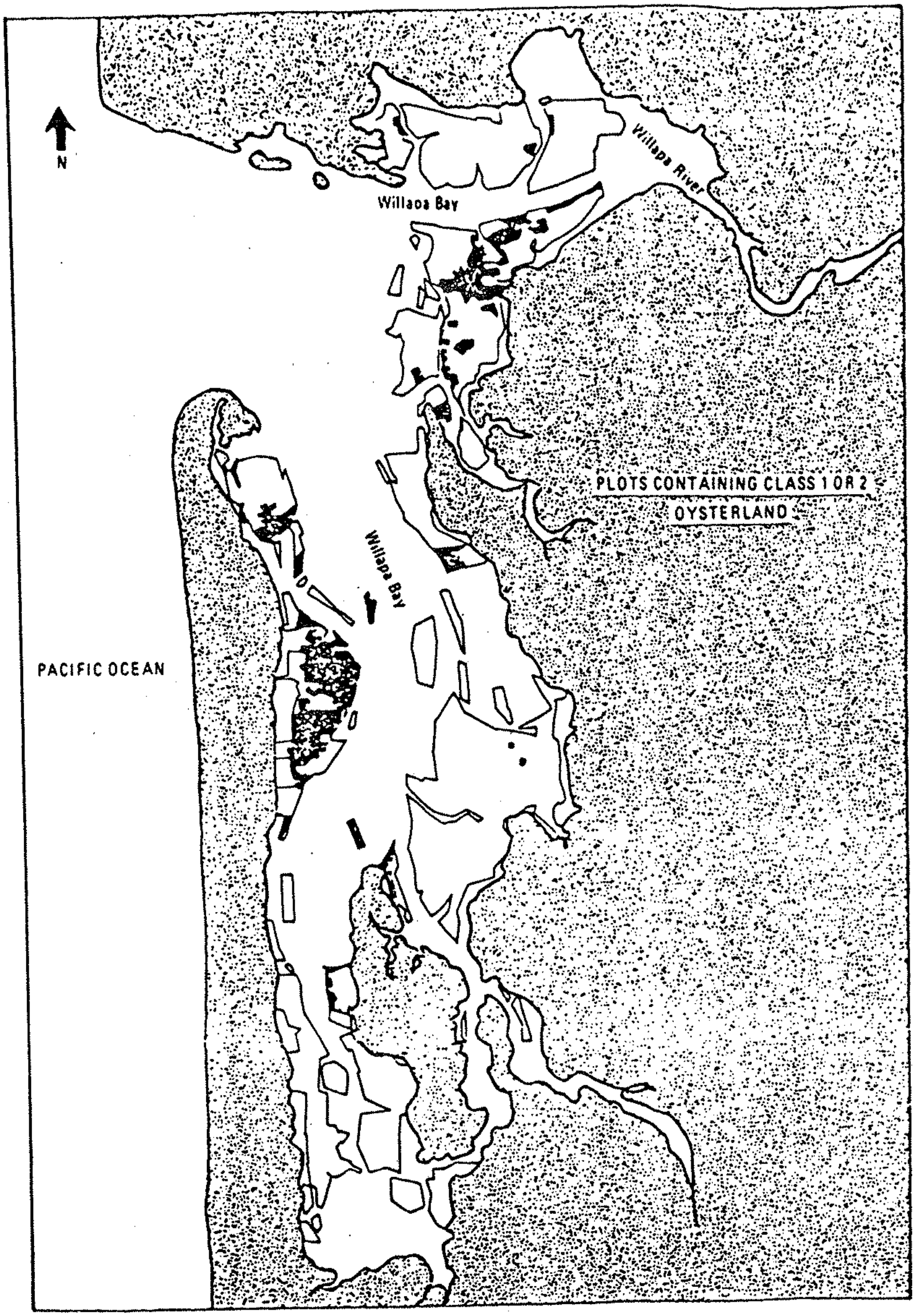


Figure 3. Plots containing Class 1 or 2 Oysterlands, Willapa Bay (Shotwell, 1977).

Recreational Shellfish Harvesting

Willapa Bay has extensive areas open to the public for recreational shellfish collection. These areas are managed by the Washington State Department of Natural Resources. The areas are generally Class V lands, and hold a low commercial value. They are probably not extensively used since they are not designated by signs or advertised, and have limited shore-side access. However, their use is not tracked by any agency.

Water Quality Standards and Classification

Department of Health Shellfish Growing Area--Sanitary Classification

The U.S. Food and Drug Administration's (FDA) National Shellfish Sanitation Program (NSSP) outlines specific methods for the collection, transportation, and examination of samples of shellfish and water from shellfish growing areas (FDA, 1990). Classification of a shellfish growing area is based on the results from samples and surveys (Table 2).

The NSSP guidelines call for a sanitary survey prior to shellfish harvest or to the issuance of a growing area classification (FDA, 1990). A sanitary survey is an evaluation of all actual and potential pollution sources and environmental factors having a bearing on shellfish growing area water quality. A comprehensive map of the survey area and locations of sources is presented with the survey. The survey documents any property or source adversely impacting a growing area with a notation of whether it is a direct or indirect impact.

Bacterial counts in shellfish meats are not used in determining water quality. A regulatory standard for shellfish meats of 230 MPN/100 grams is only applied to interstate shipment of shellfish products already suspected of contamination, and is not used to reflect water quality. The variations in bacterial uptake and retention within the different shellfish species, as well as seasonal biological conditions, are the reasons it is not used as a standard for water quality.

The Washington State Department of Health (DOH) is responsible for protection of public health. The DOH Office of Shellfish Programs ensures the sanitation of shellfish harvested for human consumption in commercial and recreational harvesting areas. They do this by monitoring water quality in shellfish growing areas, as well as by inspecting commercial shellfish harvesting, handling, processing, and shipping practices. They also monitor shellfish for paralytic shellfish poison (PSP) and other toxicants. DOH complies with the NSSP guidelines to establish growing area classifications.

DOH collects several ambient water samples from locations within a shellfish growing area during a one-year period, with some effort towards monitoring critical, worst-case conditions. DOH can declare a station as "failure" when data for the year exceed the Approved criteria (Table 2) regardless of sample salinity or seasonal count distributions.

Table 2. Washington State Department of Health, Commercial Shellfish Growing Area Classification Criteria.

"<u>Approved</u>" areas are designated when the sanitary survey and marine biotoxin data indicate that fecal material, pathogenic microorganisms, or poisonous and deleterious substances are not present in dangerous concentrations. Samples are collected to represent adverse pollution conditions. The APHA, A-1 Modified test (5 tube/3 dilution) laboratory method is used to process fecal coliform water samples. The first of the two-part standard is that the fecal coliform median or geometric mean most probable number (MPN) does not exceed 14 per 100 milliliter (mL). The second part is that not more than 10 percent of the samples exceed an MPN of 43 per 100 mL. Failure of one or both (calculated from a minimum of fifteen samples from each station in the approved area) can be sufficient to reclassify a growing area.
"<u>Conditionally Approved</u>" areas are subject to intermittent and predictable pollution exceeding approved area criteria. Openings and closures of the shellfish areas to harvest are based on performance standards developed from that area's special circumstances (*i.e.*, rainfall, river flow, vessel traffic, sewage bypass, or seasonal land use). Sources of pollution and a sanitary survey must be evaluated to show that the area will meet the approved classification for reasonable periods of time.
"<u>Restricted</u>" areas are designated when a sanitary survey indicates a limited degree of pollution. Under special permit, shellfish may be harvested and relayed from restricted areas to approved areas. This natural biological purification (depuration) in the approved area is controlled, and make the shellfish safe to market.
"<u>Prohibited</u>" areas have no current sanitary survey, or the sanitary survey or other monitoring program data indicate fecal material, pathogenic microorganisms, poisonous or deleterious substances, marine biotoxins, or radionuclides may reach the area in excessive concentrations. The taking of shellfish for any human food purposes from such areas is prohibited.

DOH also monitors shellfish harvest areas under restoration after they have been down-classified. The monitoring determines the management of the area, and the extent of Conditional or Restricted areas. DOH also helps local health districts identify contamination sources.

<u>The Department of Ecology</u>

The Washington State Department of Ecology (Ecology) is responsible for protecting water quality defined under Chapter 173-201A WAC, "Water Quality Standards for Surface Waters of the State of Washington." Willapa Bay and its tributaries are classified as Class A excellent waters which shall meet or exceed the requirement for all or substantially all beneficial water uses. The uses listed include:

- domestic consumption;
- primary and secondary contact recreation;
- fish and shellfish spawning, rearing, and harvesting;
- wildlife habitat;
- stock watering;
- commerce and navigation; and
- aesthetic enjoyment.

Bacterial quality is one measure of a water's ability to provide beneficial uses. In Class A freshwater, fecal coliform organisms 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. Class A marine waters 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. In estuarine conditions, the marine criteria are applicable when ambient water salinity is equal or greater than 10 parts per thousand (ppt) (WAC 173-201A-060(2)).

Potential Fecal Coliform Sources

The following categories represent the major documented or potential land and water uses in Willapa Bay that may contribute to fecal coliform pollution.

<u>Nonpoint Sources</u>

The majority of shellfish growing area closures or harvest restrictions have been occurring in rural areas due to nonpoint source pollution. Nonpoint sources of fecal coliform pollution include:

- on-site septic systems,
- urban stormwater run-off,
- boats and marina areas,
- livestock, and
- wildlife.

These nonpoint sources are diverse and difficult to individually identify and assess for total bacterial loading and impact.

On-Site Sewage Treatment Systems

On-site septic systems are a major concern in the watershed (WBWQOC, 1990). Failing or malfunctioning septic tanks and their drain fields can pose a human health hazard because inadequate disinfection of leachates can lead to water-borne or food-borne diseases.

The Pacific County Health and Human Services Department (PCHHS) conducted sanitary surveys of 419 on-site systems in East Raymond-Willapa-Old Willapa, Eklund Park, the Hewitt

Addition and Bay Center from December 1989 to June 1991 (Table 3). All but Bay Center are located along the Willapa River. The average failure rate for the four areas was approximately 33%, and less than half of all homes inspected had adequately functioning systems.

Water quality in other areas of the Willapa Bay watershed may also be affected by on-site septic systems. Systems built in poor soils with a high water table and saturated conditions may be causing ground water and surface water quality contamination along the Long Beach Peninsula (CH_2M Hill, 1987). Additionally, poorly built or maintained systems along the Naselle River, Nemah River, and Palix River were identified by CH_2M Hill (1981). Houseboats along the lower North River have inadequate sanitary facilities, and have been a documented source of contamination for over 10 years (CH_2M Hill, 1981). In 1989, 34 North River residential sites were inspected and 87% were suspected of septic system failure (DOH, 1989).

Urban Stormwater

Stormwater from urban areas tends to increase peak flows in constructed and natural drainage systems. Urban stormwater can carry a substantial load of pollutants including toxic chemicals, bacteria, and pathogens. In older sewage collection systems, stormwater can get mixed with sanitary wastewater. For instance, stormwater in the Raymond and South Bend areas has caused overloading of the sanitary wastewater systems. Furthermore, during times of prolonged or intense rainfall, mixed stormwater and sanitary wastewater have been discharged into the Willapa River before reaching the treatment plants (Ecology, 1990; Meriwether, 1991a, 1991b). Although Raymond and South Bend have upgraded their collection and treatment systems over the past 15 years, chronic infiltration and inflow (I/I) problems persist at individual connections to the collection systems (J. Anderson, pers. comm., 1992). Intense rainstorms still cause some overload problems for these cities.

Table 3. PCHHS sanitary survey results between December 1989 and June 1991.

Survey	Date	# Homes	Failed	Suspect	Good	To be inspected
East Raymond	Mar-June 1991	233	41	51	34	57
Eklund Park	Jan-Feb 1990	81	24	20	27	0
Hewitt Addition	Mar. 1990	21	14	3	4	0
Bay Center	Dec-Jan. 1990	169	32	30	79	28

Development on the Long Beach Peninsula, as well as wetland drainage and ditch cleaning, may be creating other stormwater pollution problems. The drainage and ditch work may not be allowing enough retention time for fecal coliform bacteria to die off before discharging into Willapa Bay shellfish areas. As the area becomes more developed with homes, the problem could become more serious.

Boats

As filter feeders, shellfish can also accumulate fecal coliform bacteria from boat wastes (Apts and Crecelius, 1989). Sewage discharges from boats are not uniformly distributed in the water, and detection by present day monitoring methods is difficult. Fresh fecal pollution from boat discharges present a greater disease-causing potential than treated municipal sewage sources (Seabloom, 1989).

There are a total of six boating facilities with 249 wet moorage slips available in Willapa Bay. Four major moorage areas are: Bay Center, the Port of Nahcotta, the Port of Willapa, and the Tokeland Marina. All of these moorage slips are occupied during the summer months. There are no data on the number of slips in the city of South Bend Boat Haven. The Port of Nahcotta now has a pump-out facility, and others are planned.

Livestock

Livestock manure can be a major source of bacterial contamination. Good pasturing and manure management practices prevent wastes and wastewater from reaching water courses. Agricultural areas in the Willapa Bay watershed are primarily in the river valleys and along the bay. The greatest concentration of farms is along the Willapa River, from the town of Frances downstream to Old Willapa (Figure 4). There are presently 15 active dairies (Hedt, pers. comm., 1992) containing approximately 4,056 dairy animals along the Willapa River (Geleynse, 1990). The cumulative 95,000 tons of manure produced along the Willapa River per annum is a significant potential source of bacterial pollution (Table 4). Non-dairy farms in the Willapa Valley have about 2,350 animals. There are approximately 170 smaller livestock farms consisting of one or more animals throughout Pacific County. The Naselle River, Nemah River, and Long Beach Peninsula areas are known to have at least five small livestock farms.

Two dairies have registered farm plans with the Soil Conservation District (SCS) and completed installation of best management practice (BMP) systems to reduce bacterial pollution of water courses (Hedt, pers. comm., 1992). BMPs are practices or installations constructed to keep animals out of streams, rainwater off manure, large amounts of manure properly stored and/or reused, or contaminated surface waters from reaching streams or the bay. One other dairy has partially completed their system, and two others are scheduled for 1994.

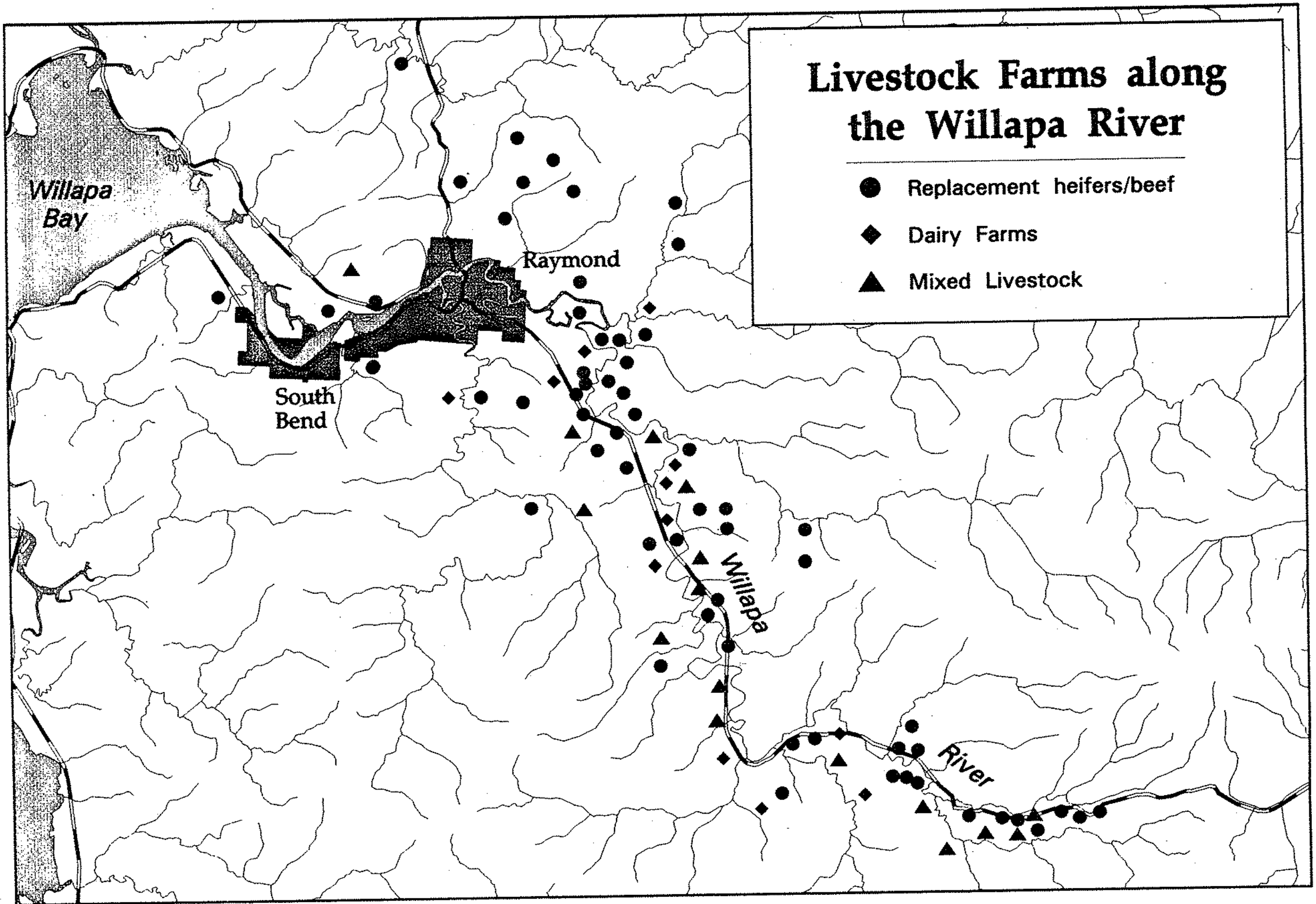


Figure 4. Approximate locations of livestock farms along the Willapa River drainage inventoried October 1988 to February 1989 (Geleynse, 1990).

Table 4. Potential Willapa River valley livestock waste and estimated manure production for animals based on SCS (1978) estimates. Animal count from Gelenyse (1990).

Farm type	Animals	lbs. waste per animal/day	Tons/year animal waste
Dairy	1,906	119	41,393
Dairy Heifer	2,150	85	33,351
Beef	1,753	62	19,835
Total	5,809		94,579

Harbor Seals

Beach *et al.* (1985) observed and documented seal haul-out sites on intertidal sand bars and mud flats in Willapa Bay (Figure 5). There are 32 known seal haul-out sites in five areas of Willapa Bay. The estimated population of harbor seals in Willapa Bay is 4,000 to 6,000 (Jeffries, pers. comm., 1992).

The breeding season from May to August presents the largest gatherings, when over 2,000 seals congregate at the most popular sites. In August, after the end of pupping season, the seals congregate in large haul-out groups on the entrance shoals and along Pine Island Channel. Winter populations may be as high as 1,000 or more at these sites (Beach *et al.*, 1985). The harbor seal population in Willapa Bay had been increasing between 1976 and 1982 at approximately 10 percent annually (Jeffries, 1986).

The high range estimate for fecal coliform production per adult seal per day is 55×10^9 bacteria (Calambokidis, 1989). This implies a potential fecal coliform load from 6,000 seals could be as high as 33×10^{13} colony forming units (cfu) per day.

The increasing seal population may pose a bacteriological loading threat to the water quality of some shellfish areas in Willapa Bay. Dosewallips State Park in Hood Canal is an example where recreational harvesting of shellfish was closed due to fecal contamination by a local harbor seal population (Calambokidis *et al.*, 1991). However, based on water quality data, there is currently no indication that seal fecal material is contaminating shellfish growing areas in Willapa Bay.

Elk and Deer

A census of elk herds was conducted in 1975 (Kuttle, 1975). The herd populations were as follows:

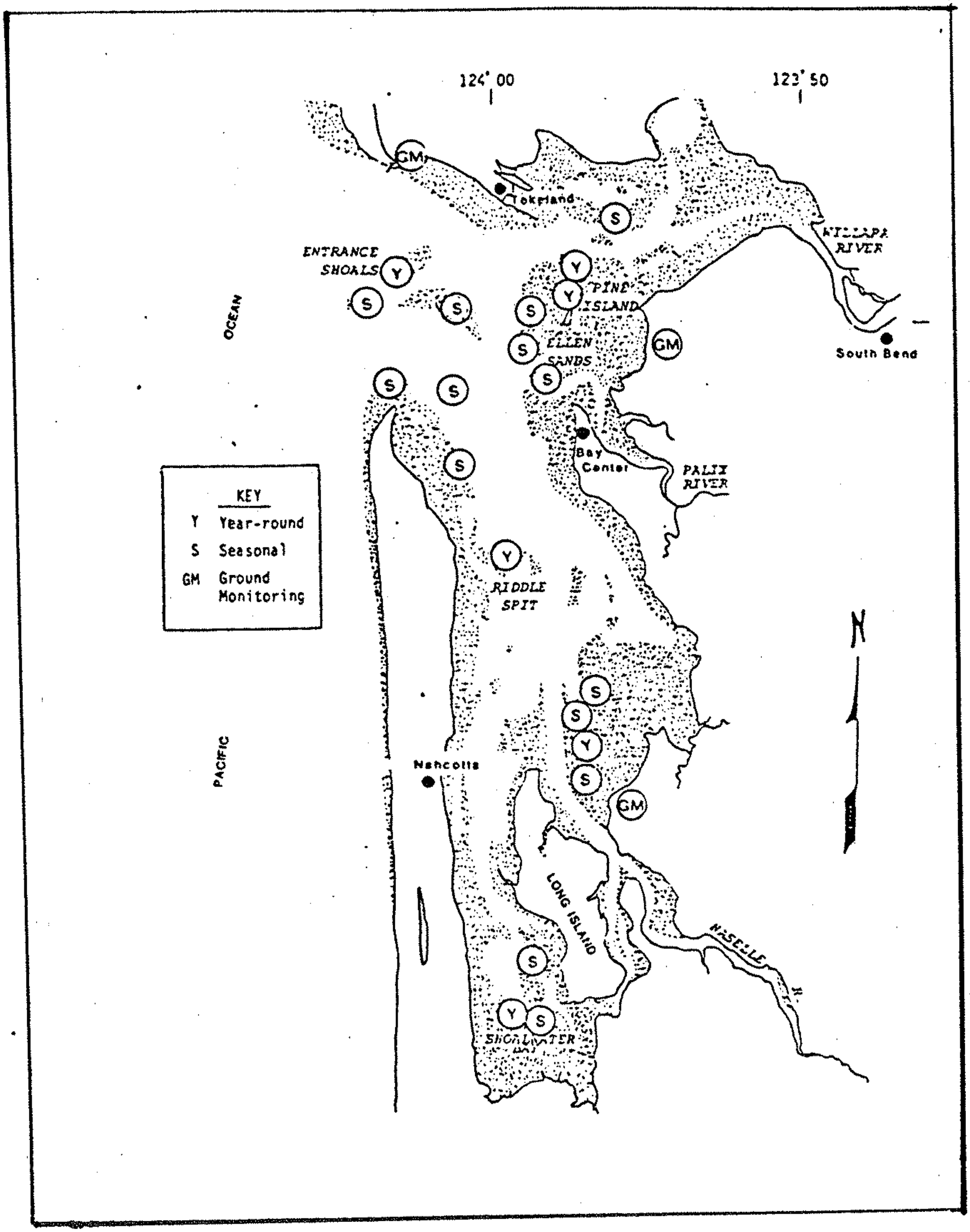


Figure 5. Harbor seal haul-out sites in Willapa Bay, Washington (Beach *et al.*, 1985). Census information from flights over the bay and monitoring from shore stations (GM-ground monitoring).

- Palix, 258;
- Nemah-1, 224; and
- Nemah-2, 76.

There has been an approximate 20 percent decrease in the elk population of the Willapa Hills since Kuttle's study (Zahn, pers. comm., 1991). The carrying capacity of the hills for elk may have decreased since timber clearcuts have been replanted and have grown canopy cover, resulting in fewer open grassy areas that elk prefer for foraging. In addition to elk, Washington State Department of Wildlife biologists estimate that there are 30 to 35 deer per square mile of habitat in the Willapa watershed (Zahn, pers. comm., 1992). Elk and deer have been implicated as sources of elevated bacterial counts in some forested watersheds (Neimi and Neimi, 1991).

Birds

The list of year-round waterfowl in Willapa Bay includes: merganser, teal, wood duck, mallard, bald eagle, great blue heron, gulls, grebes and more. These species do not occur in large populations. The dominant migratory species is the American widgeon. The second largest in migratory numbers is the black brant. A small number of endangered marbled murrelets forage in Willapa Bay and probably nest on Long Island. An average of 1,500 Canada geese occupy the bay from October to May (Major, 1989). The abundance of each species and their seasonal occupance in Willapa Bay have been difficult to census. Gross estimates of seasonal abundances for water birds and shorebirds are estimated using data from within the Willapa Bay National Wildlife Refuge (Strickland and Chasan, 1989). The highest quarterly loadings of fecal coliform from birds occurs in April through June (Table 5). The October through December period has the second highest quarterly loading.

Table 5. Numbers of seabirds and shorebirds (Strickland and Chasan, 1989) with quarterly fecal coliform bacteria loading estimates.

	January-March	April-June	July-September	October-December
Seabirds	19,500	24,000	6,500	108,000
Shorebirds	20,000	165,000	105,000	24,000
Fecal Coliform Loading*	9.875×10^{15}	4.7×10^{16}	2.78×10^{16}	3.3×10^{16}

*Quarterly rate calculated from bird/year coliform production estimate of 10^{12} (CH_2M Hill, 1981).

Point Sources

Industrial Sources and Sewage Treatment Plants

There are 21 permitted point source dischargers in the Willapa Bay watershed (Table 6). They are generally found along the shorelines close to the bay, with the largest density located along the lower Willapa River (Figure 6). The 21 National Pollutant Discharge Elimination System (NPDES) permits for these facilities are managed by Ecology. Only seven of these 21 permits have fecal coliform limits: the three municipal sewage treatment plants (STPs), a youth camp, and three seafood processing plants. The fecal coliform limits on the STPs are based on secondary treatment technology.

Seafood processing plants have no technology-based fecal coliform limits. Joy (1990) collected effluent samples from four seafood processing plants in Pacific County and found elevated levels of fecal coliform (geometric mean of 7 samples was 500 cfu/100 mL). As a result of these findings, more seafood processing plant permits may include fecal coliform limits, or provisions for fecal coliform monitoring, as they come up for renewal.

Wastewater volumes discharged into the Willapa Bay watershed have high seasonal variability. Seafood processing is active all year as different products are harvested, but large wastewater volumes are intermittent. The heaviest processing season is generally in the fall which coincides with larger flows from the municipal plants and nonpoint sources due to wet weather.

Bacterial Data Issues

The Willapa Bay watershed has been the subject of several types of water quality studies over the past 40 years. However, much of that data is not directly applicable to bacterial water quality, or it is in a format which is difficult to retrieve and compile. During the compilation process, several issues were considered concerning bacterial indicators, laboratory methods, and regulatory interpretation of data. This section provides a brief review on those issues, and a presentation of the sources of data used in this report. We have limited our evaluation and search to large fecal coliform databases which were relatively easy to retrieve (e.g., Ecology - STORET and DOH shellfish area monitoring data), or surveys with fecal coliform components which have been conducted since 1980 (e.g., Pacific County, consultant, and state agency special studies).

Indicator Bacteria

Fecal coliform bacteria are common organisms from the intestinal tract of humans and other warm-blooded animals. Some fecal coliform species are human pathogens. However, their presence in water are used as indicators of fecal pollution and possible contamination by more virulent human pathogens. There continues to be disagreement whether indicator bacteria, and specifically fecal coliform, accurately reflect bacterial quality and human health risk in ambient waters (Cabelli, 1983; USEPA, 1986; Tetra Tech and E.V.S., 1986).

Table 6. Willapa Bay watershed point sources with NPDES permits.

Permit #	Name	Design Population	Maximum cfu/100 mL	Maximum Wastewater Discharge Volume
WA-003966-7	Bay Center Fish Company			1,000 gal/day
WA-000218-6	Coast Oyster Company			70,000 gal/day monthly ave. 90,000 gal/day Max
WA-003724-9	Coast Oyster Company			5,000 gal/month
WA-000189-9	East Point Seafood Co. Nahcotta		Geometric mean 200	9,990 gal/day
WA-000110-4	East Point Seafood Co. Willapa River		Geometric mean 200/100 mL	325,000 gal/day
WA-000198-8	Harbor Bell, Inc.			160,000 gal/day
WA-002248-9	Long Beach City STP Population Served: 1,200	4,000	200 monthly 400 weekly	400,000 gal/day 1,200,000 gal/day peak
WA-G131020	Naselle Salmon Hatchery			31,416 gal/month
WA-00023728	Naselle Youth Camp STP	220	200 monthly 400 weekly	35,000 gal/day
WA-000229-1	Nelson Crab Inc.			75,000 gal/day
WA-0040363	Nisbett Oyster Co.			500 gal/day average 850 gal/day maximum
WA-003989-6	Protan Laboratories			30,000 gal/day
WA-002332-9	Raymond, City STP Population Served: 2,890	4,900	200 monthly 400 weekly	430,000 gal/day dry season 670,000 gal/day wet season 3,460,000 gal/day peak
WA-0036879	Raymond Water Treatment Plant			84,000 gal/day
WA-003759-1	South Bend, City STP Population Served: 1,545	3,040	200 monthly 400 weekly	370,000 gal/day dry season 1,450,000 gal/day wet season 1,570,000 gal/day peak
WA-0038946	South Bend Water Treatment Plant			20,000 gal/day
WA-0036889 WA-0039161 WA-0039250	Weyerhaeuser Company			*7,526,000 gal/day 4,999 gal/day
WA-0038806	Weigardt Brothers		200 weekly	9,999 gal/day
WAG-131049	Willapa Salmon Hatchery			14,500 gal/minute
WA-0040096	Willapa Seafoods			
WA-0037532	Willapa Valley Water District			24,000 gal/day

* Permitted capacity, but not currently operating.

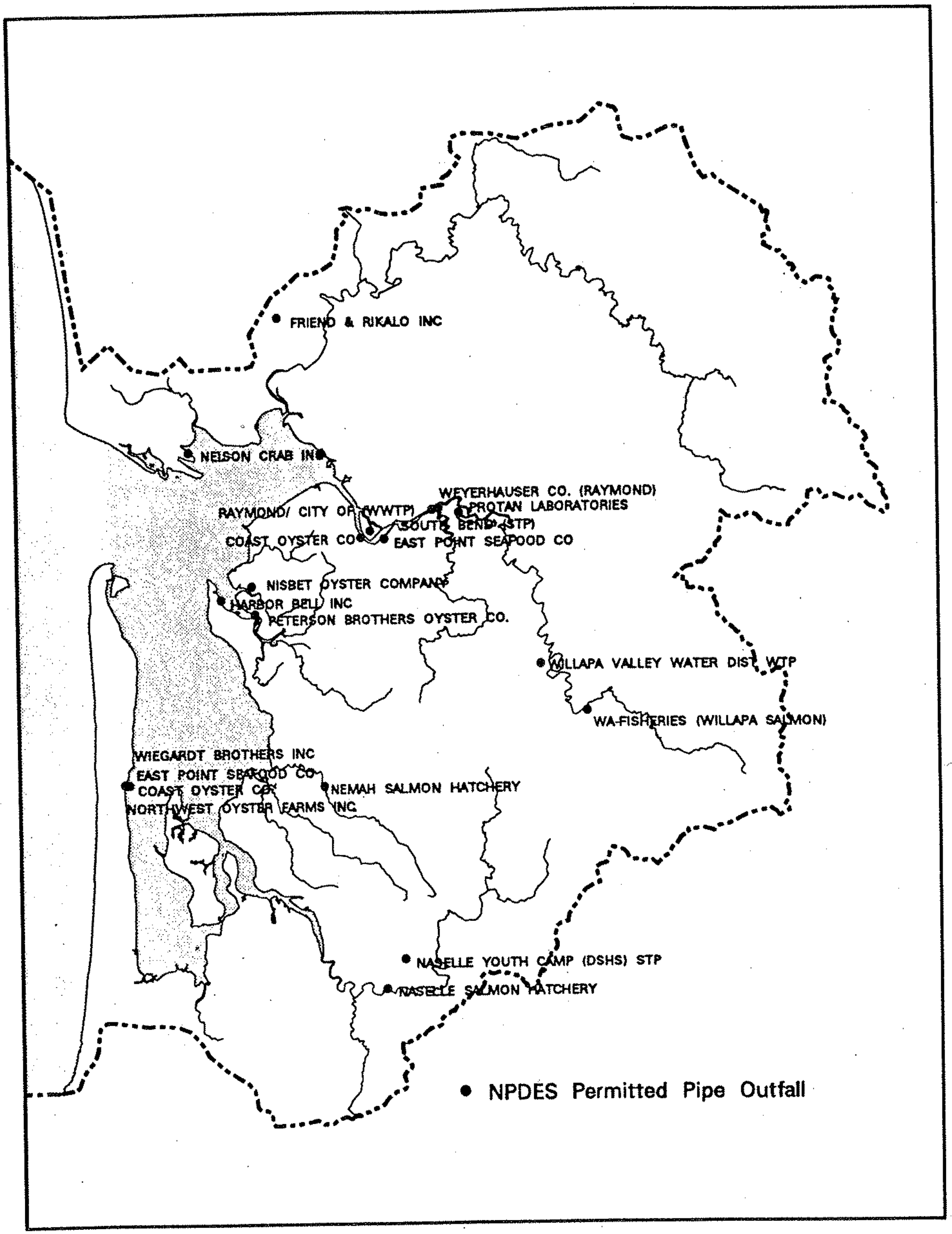


Figure 6. Locations of NPDES permitted point source dischargers in the Willapa Bay watershed.

There is ongoing research on new techniques to detect and culture pathogenic organisms from environmental samples, as well as research on identifying the "model" indicator species (Cabelli, 1983; Dufour, 1984; Pettibone *et al.*, 1987). For example, USEPA (1986) has recommended enterococcus or *E. coli* standards to evaluate waters used for primary contact recreation. Unfortunately, only a few surveys have samples for these bacteria or other disease-causing organisms in Willapa Bay (Kaysner *et al.*, 1989; Wekell, 1984). Since regulatory agencies primarily use fecal coliform to measure water quality and shellfish sanitation, the latter will likely be used for regulatory actions in the foreseeable future.

Laboratory Methods

The scientific community disagrees on the most accurate laboratory methods of fecal coliform bacteria analysis. There are two common and generally acceptable ways fecal coliform bacteria are analyzed: 1) the multiple-tube fermentation, which generates a most probable number (MPN); and 2) the membrane filter (MF) technique (APHA, 1989). The MPN method is recommended and preferred in marine conditions, and is the only method recognized by the FDA and DOH for regulating shellfish harvesting areas (Tetra Tech and E.V.S., 1986; FDA, 1990). The MF technique is preferred by agencies working in freshwater (USEPA, 1990; Ecology, 1992). Generally, the MPN method is thought to yield higher counts than the MF technique because it subjects weakened organisms to less stress, but the MF method is less expensive to run and is considered more precise in replicate testing (APHA, 1989).

Estuarine studies often include both fresh and marine water sampling, so researchers will usually pick one or the other method. Data from the two techniques are not usually mixed in a data analysis, unless statistical comparisons of the two methods were performed. CH_2M Hill (1981) used both MPN and MF results in Willapa Bay and stated their comparative samples showed "no significant difference." None of the other Willapa Bay databases we reviewed mixed the two methods.

Fecal coliform count units have been expressed in several ways (e.g., organisms/100 mL, #/100 mL, colonies/100 mL, and fecal coliforms/100 mL). Results from most probable number analyses are expressed as MPN/100 mL. For this report, we will use colony forming units per 100 milliliters (cfu/100 mL) for MF results, or when the method used is unknown. DOH results and other data known to be multiple-tube fermentation will be expressed as MPN/100 mL. Load, or mass flux, of fecal coliform is calculated by multiplying the bacterial count by discharge volume in cubic feet/second (cfs) by a conversion factor of 283.2 to obtain a fecal coliform load in cfu/second.

Regulatory Interpretation

Ecology and DOH each have specific regulatory areas of authority and may interpret fecal coliform data results differently. Sometimes these two agencies may not have the same opinion about the water quality of a particular location. An agency's opinion of water quality in an area is usually a reflection of:

1) the quality and quantity of data used,
2) the level of uncertainty in data interpretation, and
3) the agency's perception of the political, health, and environmental risk levels.

Different monitoring program designs are used to meet the needs of different agencies. The monitoring design can also affect the interpretation and the ultimate opinion of the agency about the water quality of an area. For example, DOH must collect a regulatory minimum of five samples from each station within a shellfish growing area over one year with some effort towards monitoring worst-case runoff conditions. DOH can declare a station a "failure" when data from the five samples exceed the Approved criteria. Differences in salinity or seasonal count distributions are not considered. On the other hand, Ecology usually depends on auxiliary salinity data to determine water quality criteria compliance during a short-term, intensive survey. Intensive surveys generally have good spatial coverage, but have too few samples at each station in one season to accurately determine the statistical distribution of fecal coliform counts. Therefore, the geometric mean and 10% exceedance fecal coliform counts are vague, and a firm decision on compliance cannot always be made. Ecology long-term monitoring data can give a better sense of sample variability and seasonal distribution to judge water quality standards compliance, but by nature the database takes a longer period of time to accrue and is not focused on critical, worst-case conditions.

Ecology has begun to use all types of monitoring data to help assess statewide water quality, so that there are fewer differences in waterbody status between agencies. The Statewide Water Quality Assessment now incorporates data from DOH, state, federal, and local agencies (Ecology, 1992). These data are used with Ecology data to determine if particular waterbodies are water quality-limited, or support all beneficial uses. For example, data used by DOH to decertify Bay Center (DOH, 1989; 1990) were used by Ecology in the 1992 assessment to list Willapa Bay as water quality-limited, and not supporting all Class A uses (Ecology, 1992). Ecology had no data of its own in the Bay Center area, and would not have been able to make such an assessment without DOH data.

Bacterial Data Sources

Ecology Ambient Monitoring

Ecology has collected water quality data over the past eighteen years from sites within the Willapa Bay watershed. These data are available on STORET, a national water quality database operated by USEPA. Because the database is large and electronically available, it has not been included in the appendices.

There are five active marine ambient monitoring stations in Willapa Bay (Figure 7). Three are long-term stations (1974-1992) located in the northern portion of the bay at Tokeland, the mouth of the Willapa River near Johnson Slough, and at Raymond (WPA004, WPA003, and WPA001, respectively). Two recently established (1991-1992) stations in the southern portion of the Willapa Bay are located north of Long Island (WPA006), and in the Nahcotta Channel on the

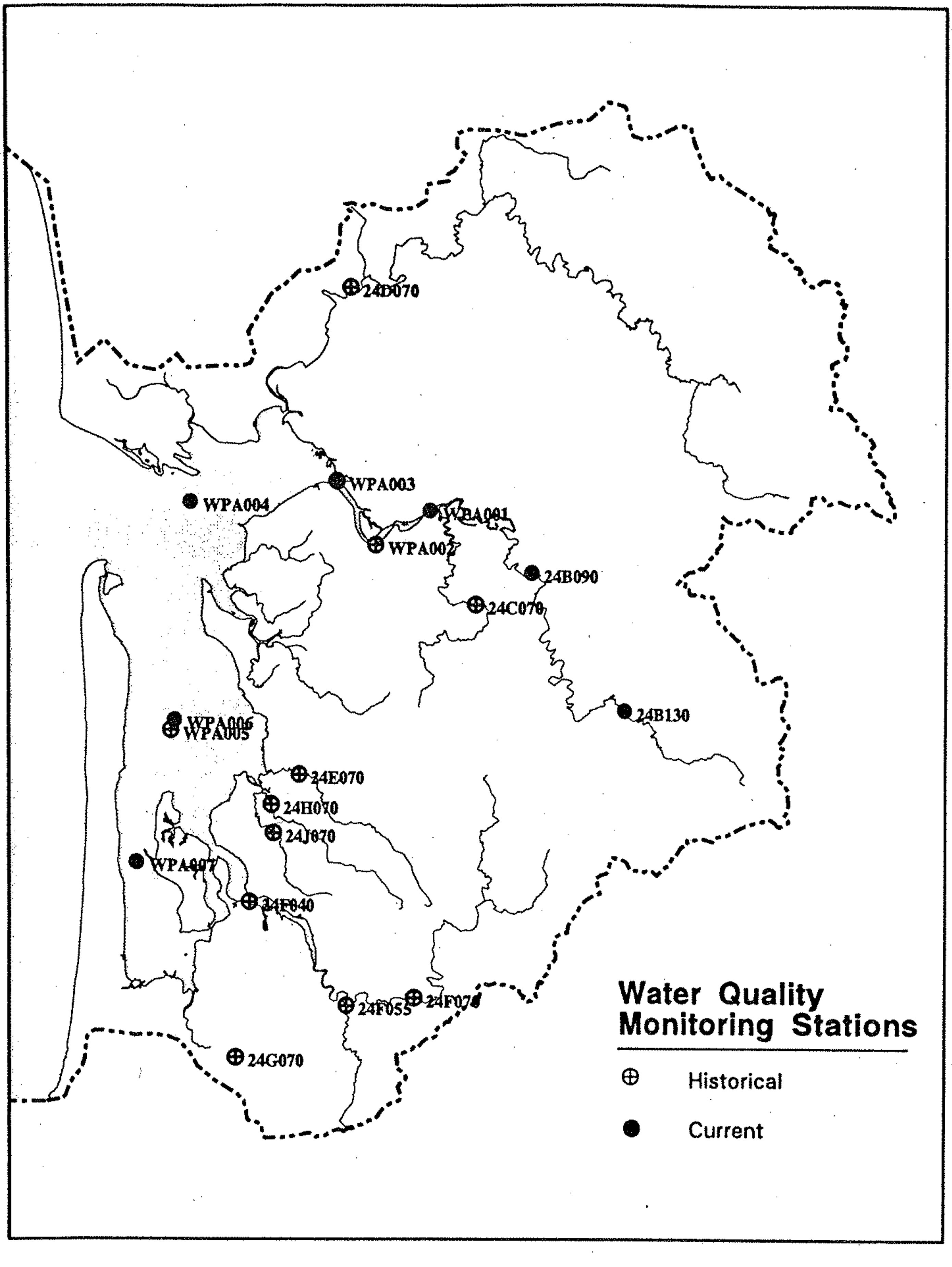


Figure 7. Washington Department of Ecology historical and current water quality monitoring stations in Willapa Bay.

west side of Long Island (WPA007). Two inactive marine stations, sampled during the mid-1970's, were located at South Bend (WPA002) and near Oysterville (WPA005).

Ecology's sampling strategy at these marine stations has changed recently. Samples had been collected by seaplane once a month from April to November. From October 1990 on, year-round monthly sampling began. One fecal coliform sample is collected at the surface at each station, and analyzed using the membrane filter (MF) method.

There are also two active and nine inactive freshwater quality monitoring stations in the watershed (Figure 7). The two active stations are on the Willapa River at Willapa, river mile (RM) 17.7, and the Willapa River at Lebam, RM 34. Inactive stations were located on the South Fork Willapa, North, Nemah, Naselle and Bear Rivers. Freshwater samples have been collected monthly year-round using the MF method of analysis.

DOH Shellfish Ambient Monitoring Program

The DOH Office of Shellfish Programs has ambient water quality data on Willapa Bay available from 1988 to the present (Appendix B, Tables B1-B6). DOH monitors bacterial water quality in eight growing areas in the bay using the MPN laboratory analysis technique (Figure 8). The Department of Health has recently changed their ambient monitoring program design in the Willapa Bay area. Growing areas were sampled three times a year, twice a day over a two or three day period. Surveys were generally timed to record adverse conditions and fulfill a statewide classification requirement of five samples from each station within a shellfish area per year. Since 1991, DOH has used a random stratified method described in the NSSP manual of operations (FDA, 1990). With this method, one sample per station from each shellfish area in the state will be collected every other month. This method provides regularly scheduled long-term monitoring with an opportunity for better seasonal representation.

DOH Shellfish Restoration Program

Bay Center's declassification from Approved to Prohibited transferred Bay Center from the DOH Ambient Monitoring Program to the DOH Shellfish Restoration Program. The Restoration Program's intensive monitoring and analysis of Bay Center's pollution sources has provided data to define a restoration plan for Bay Center. The plan defines the conditions to be met for the upgrade of Bay Center's shellfish area to a Conditional classification status and the resumption of shellfish harvest.

The guidelines of the DOH Shellfish Restoration Program are defined in the Puget Sound Water Quality Management Plan, under Section SF-2 of the Shellfish Protection Program (Puget Sound Water Quality Authority, 1990). The goals are to protect shellfish growing areas from reclassification to more restrictive status, and to reduce contamination sufficiently to allow the removal of harvest restrictions from one commercial or recreational shellfish bed per year.

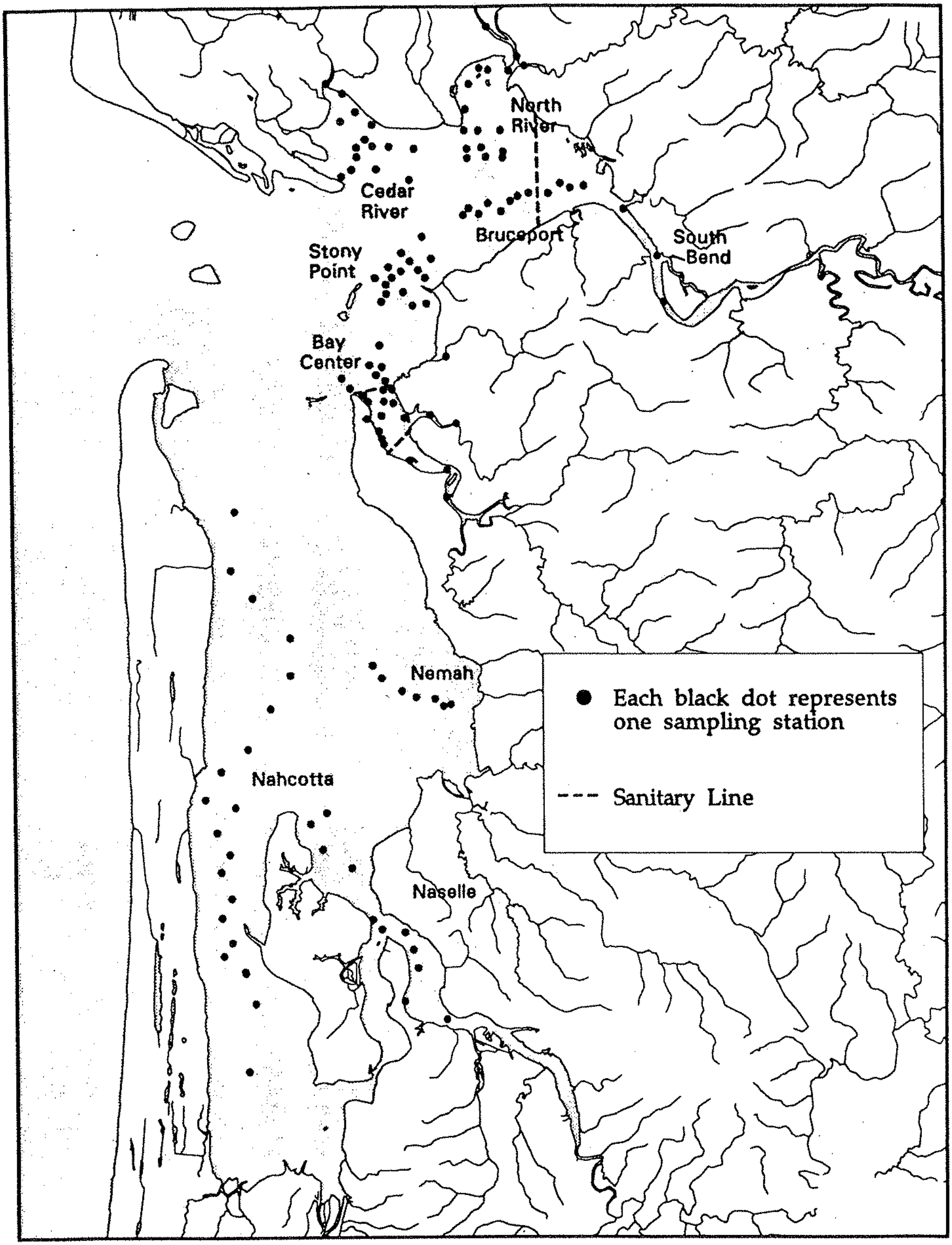


Figure 8. Washington Department of Health Office of Shellfish Programs water quality monitoring stations in Willapa Bay.

The Restoration Program assists local governments in review of land use, ordinances, and programs aimed at preventing contamination of shellfish beds. The program monitors and identifies bacterial source problems. It also provides for the development of a restoration plan and schedule for implementation of corrections. A long-term evaluation process then determines the effectiveness of the restoration plan.

Local Government and Other Studies

Local government agencies within Pacific County have been active in identifying, monitoring, and alleviating sources of fecal bacteria pollution. The Pacific County Health and Human Services (PCHHS) Department and Pacific Conservation District have conducted investigations of nonpoint source pollution. Pacific County planning and water resource departments have been active in various water quality initiatives in the basin. Several of these local studies are briefly described in Appendix A.

Water Quality Zones

We organized the fecal coliform data within Willapa Bay and its watershed into four water quality zones (Figure 9). The zones were delineated after considering the relative distribution of data, the size of river basins, hydrological conditions, shellfish resources, and potential sources of pollution throughout the watershed. Table 7 summarizes some of the attributes of each zone.

Historical fecal coliform bacteria data compiled from Ecology, DOH, and the studies summarized in Appendix A are evaluated and presented for each water quality zone. Many of the graphic displays and various statistical and trend analyses in this section were performed using WQHYDRO computer software (Aroner, 1991).

Zone One

Description

Zone One is the area at the ocean entrance of Willapa Bay (Figure 9). It has shifting sand bars, and is subject to ocean breakers. It is generally not monitored or utilized for oyster production. This zone is dominated by the near-shore Pacific waters. The Shoalwater Tribal lands are located in this area, as are the communities of North Cove, Grayland, and Tokeland. The major drainage of the area is the Grayland Ditch which serves small-scale agriculture and cranberry bogs.

Grayland Ditch

Pacific County Health and Human Services Department collected five samples in 1990 on each of two storm events at river mile (RM) 1.2, at site #119 of the Grayland Ditch (Appendix A,

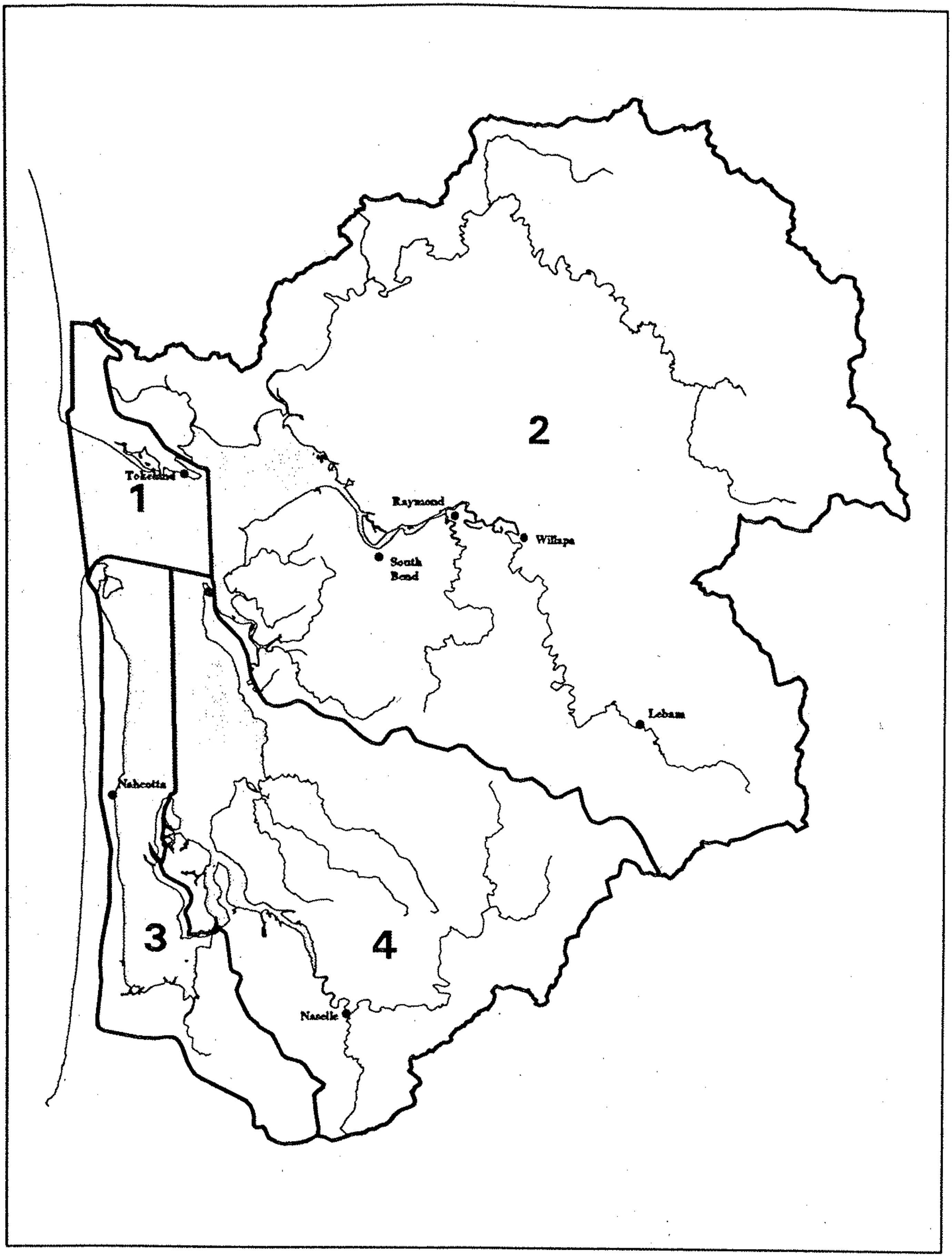


Figure 9. The locations of the four water quality zones designated for Willapa Bay to analyze bacterial data.

Table 7. Description of the four water quality zones used in this report. The term diked wetlands refers to areas behind dikes, undiked fill, road grades, and other structures like tidal gates which effectively remove wetlands from the estuarine system. Missing data designated by (-).

Zone Number	Bay Area (mi^2)	Major Tributaries	Drainage Square Miles	Wetland (Acres) Diked/Undiked	Potential Sources of Fecal Bacteria*
Zone 1	Subtidal = 20.3 Intertidal = 8.0	Grayland Ditch	10.5 Total = 10.7	unknown	S,W
Zone 2	Subtidal = 11.4 Intertidal = 17.7	Cedar River and Kindred Slough North River and Smith Creek Willapa River Bone River Niawiakum River Canon River and Palix River	13 319 258 4 5 37 Total = 660	519/510 420/245 2,017/1,855 -/208 -/295 548/575	W,L L,H,W L,S,STP, US W W L,W
Zone 3	Subtidal = 19.5 Intertidal = 20.1	Long Beach Peninsula Long Island Bear River	(-) (-) 22 Total = 54	158/405 143/318 (-)	S,L,STP W W
Zone 4	Subtidal = 20.5 Intertidal = 18.7	North, Middle, and South Nemah Naselle River Stanley Peninsula	28 133 (-) Total = 215	158/405 532/643 40/10	L,W,S L,W,S,STP W,S

* Key for Potential Source Codes: S=Septic Systems, W=Wildlife, L=Livestock, H=Houseboats, STP=Sewage Treatment Plants, US=Urban Stormwater.

Figure A-2) (Berbells, 1991). The fecal coliform mean counts exceeded 100 cfu/100 mL in both January and July; two samples in winter and one in summer exceeded 200 cfu/100 mL. Fecal coliform loading during January was estimated to be $2x10^6$ cfu/sec. The PCHHS had the following water quality concerns and recommendations for this area (Berbells, 1991):

1) The Grayland area's population is increasing.
2) The fecal coliform results and the increased ammonia concentrations are worse than that of the Willapa River.
3) A sanitary survey of the Grayland area is needed to help identify specific fecal coliform problems sites.

A sanitary survey of the Grayland area, funded by USEPA, is scheduled for 1993 (Harrison, pers. comm., 1993).

Toke Point

Ecology ambient data for Station WPA004 off Toke Point (Figure 7) has shown historically low fecal coliform counts. The median value for the 132 samples collected from 1974-1992 is 1 cfu/100 mL; the maximum detected was 40 cfu/100 mL with 75% of the samples having counts less than 2 cfu/100 mL. Sample salinities have generally been greater than 10 ppt. However, it should be noted that little data have been collected at this station during the months of December through March.

<u>Zone Two</u>

Description

Zone Two contains 970 acres or 39% of all Class 1 and 2 oysterlands in Willapa Bay. Its annual production averages 41% of Willapa Bay's total harvest (Figures 3 and 9).

The largest portion of the Willapa Bay watershed drains to Zone Two (Figure 9). The zone also has the greatest portion of Pacific County's population and the most diverse land uses. In addition, Zone Two has the most diked wetland acreage in Willapa Bay. Data summaries begin in the northeast portion of this zone with the Cedar River and move clockwise within the zone culminating with Bay Center in the Palix River watershed.

Cedar River

PCHHS (Berbells, 1991) collected four samples at Site #120 (Appendix A, Figure A-2), the mouth of the Cedar River, during wet and dry season storm events. Geometric means of 12 cfu/100 mL and 7 cfu/100 mL were measured for the wet and the dry seasons, respectively. The four dry season samples had salinities greater than 10 ppt, and two of the four counts were greater than the Class A marine water fecal coliform bacteria standard of 14 cfu/100 mL.

DOH (1990) collected six samples at the mouth of the Cedar River which had a geometric mean of 18 MPN/100 mL. The mouth of the Cedar River failed both parts of marine water quality standards, although 84 samples taken from the shellfish growing area were within the marine water quality criteria. The geometric mean of six samples taken at the mouth of the river in 1991 was 22 MPN/100 mL. However, no samples were gathered during or immediately following rain events to measure worst-case conditions. Cedar River DOH fecal coliform and rainfall data are summarized in Appendix B, Table B-1.

North River

The sparsely populated North River is the largest freshwater discharge in the entire basin. The general usage of the North River area is forestry. Below RM 25 there are scattered pastures, and rural residential housing. There are three small recreational-based commercial sites near the mouth of the North River.

CH_2M Hill (1981) identified illegally moored and seasonally occupied houseboats on the lower North River as a health hazard to the shellfish growing area because of their inadequate waste disposal systems. In 1989, 34 residential sites, including the houseboats, were part of a sanitary survey, and 87% were suspected of on-site septic failure (DOH, 1989). Pasturage of 20 head of cattle, two horses, and several nonfunctional tidal gates were noted in the survey (DOH, 1989).

The DOH (1988;1989;1990;1991;1992a) has taken 670 fecal coliform water quality samples in the North River and its shellfish growing area on 20 occasions from October 1988 to February 1992 (Appendix B, Table B-2). The amount of rainfall and the number of stations failing water quality criteria appear to be related. The North River stations tend to exceed shellfish area water quality standards for fecal coliform after a rainfall event. The elevated fecal coliform levels sampled during August 27-29, 1991, could reflect a watershed wash-off of accumulated fecal material after an extensive dry period. River stations upstream of the houseboats periodically exceeded 100 MPN/100 mL during rainfall events. The levels of fecal coliform upstream could reflect wildlife sources.

PCHHS (Berbells, 1991) took ten samples from the North River at the USGS gaging station at RM 7.4 (Appendix A, Figure A-2). The station location is upstream of the houseboats, pastures, and diked wetland areas. Fecal coliform was analyzed using the MF laboratory technique. Five samples were taken during the dry season and five samples were taken during the wet season. None of the counts were greater than 100 cfu/100 mL.

Ecology fecal coliform samples were collected monthly for 22 months at RM 10.7 (Station 24D070) in the mid-1970's (Figure 7). The maximum fecal coliform count was 50 cfu/100 mL.

Upper Willapa River

The upper Willapa River section of Zone 2 includes the headwaters and tributaries of the Willapa River and South Fork downstream to their respective heads of tide. The head of the tide on the Willapa River occurs at approximately RM 14. The rivers are entirely freshwater in this area, and surrounding land uses are primarily cropland, pasture, forest, and rural residential housing.

Lebam (RM 34) is the location of the farthest upstream Ecology monitoring station on the Willapa River (Willapa at Lebam, Station 24B130) (Figure 7). The USGS also has an inactive gage site located nearby at RM 33.9 (Station 12011500). From 1979 to 1990, Ecology gathered a fecal coliform sample monthly at Lebam and analyzed it using the MF method. Discharge was measured using a staff reading and a USGS rating curve.

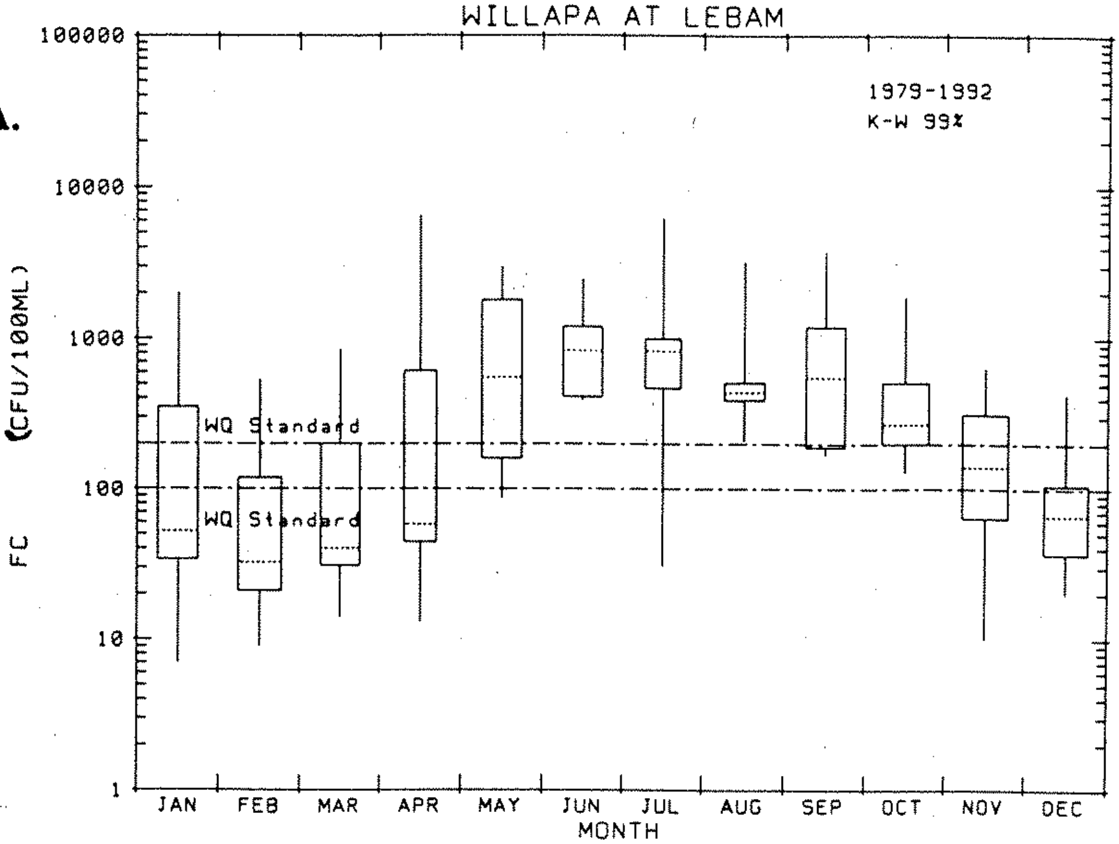
The 11 years of Ecology fecal coliform data collected at the Lebam station are summarized in Figures 10a-10b. Monthly median (which approximates the geometric mean) coliform counts for the period of record exceed both the 100 cfu/100 mL and 200 cfu/100 mL Class A standards in May through October. Counts appear to increase with the lower flows of late summer. Median monthly coliform loads range from $0.8x10^6$ cfu/second in August to $9x10^6$ cfu/second in January. An extreme value of $2.5x10^8$ cfu/second was recorded in November 1984. Seasonal Kendall trend analyses using WQHYDRO (Aroner, 1991) of wet and dry season data suggest there has not been significant change in counts or loads over the period of record ($P<0.8$). The elevated fecal coliform loads indicate that there are nonpoint sources upstream of the station continuously providing fecal coliform to the river. Several residential on-site systems, five dairies, six heifer replacement farms, and wildlife inhabited areas are located upstream from the Lebam station (Geleynse, 1990).

Ecology has a second station (RM 17.7, Willapa at Willapa, Station 24B090) located 16.2 miles downstream of Lebam. Monthly fecal coliform data have been collected from 1975 to 1979, and late 1983 to the present. An active USGS gaging station is located nearby at RM 17.8 (Station 12013500). Ecology fecal coliform data from the Willapa at Willapa station are summarized in Figures 11a-11b. None of the monthly medians exceeded 200 cfu/100 mL, but they were greater than 100 cfu/100 mL in the months of June through November. Median monthly loads range from $1x10^6$ cfu/second in August, to $15x10^6$ cfu/second in March and November. An extreme value of $1.4x10^9$ cfu/second was observed in November 1977.

Fecal coliform counts at the Willapa at Willapa station during the dry season months (May-September) have lower monthly medians compared to the Lebam station; wet season (November-April) monthly medians are similar between stations (Figures 10a & 11a). Median monthly fecal coliform loads at Willapa and Lebam are quite similar.

Seasonal Kendall trend tests on the wet and dry season data from the Willapa at Willapa station indicated no significant linear trend over the period of record ($P<0.8$). However, a significant

A.



B.

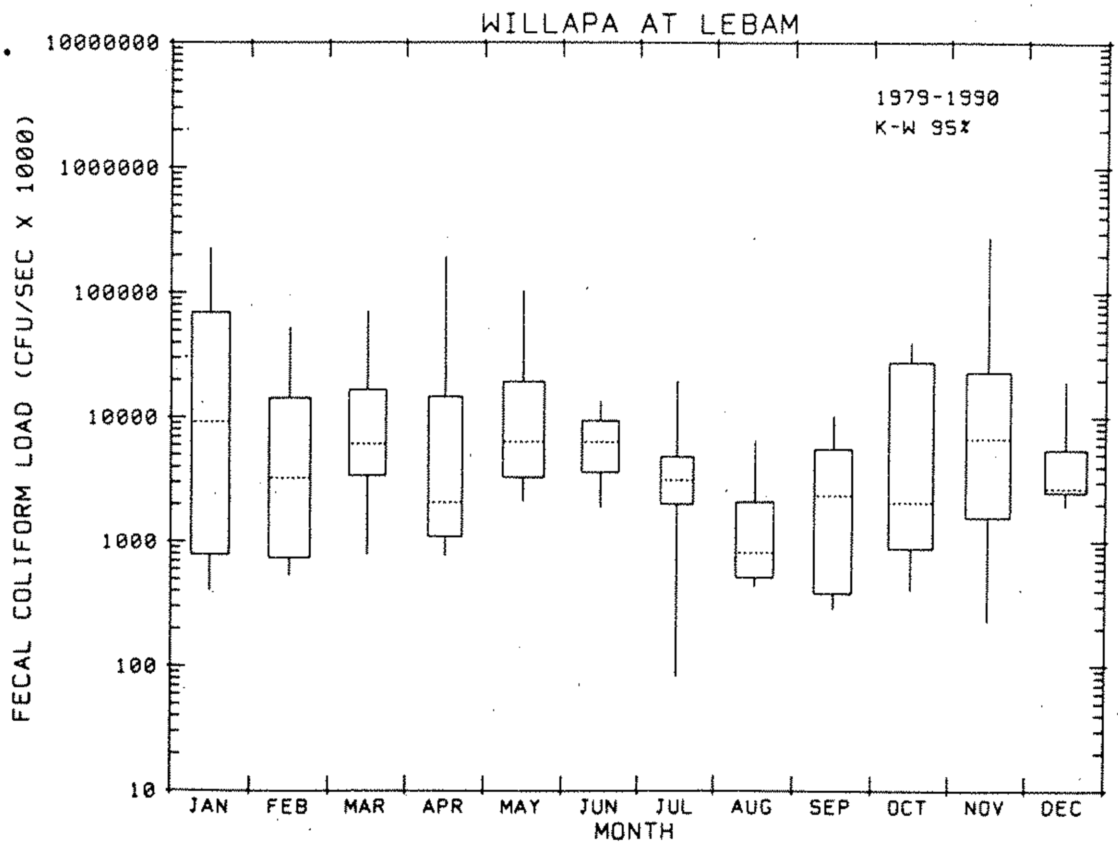
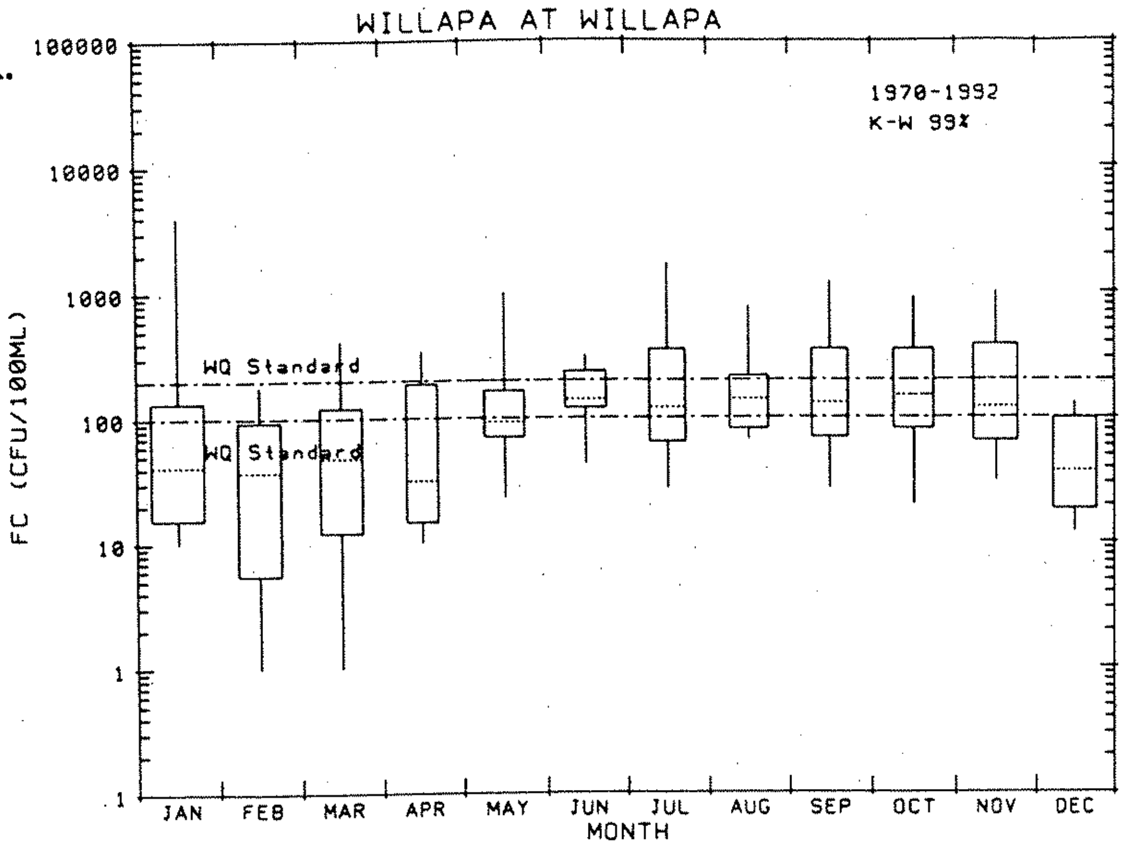


Figure 10. Monthly fecal coliform count (A.) and load (B.) distributions based on data collected by the Department of Ecology from the Willapa River at Lebam (24B130).

A.



B.

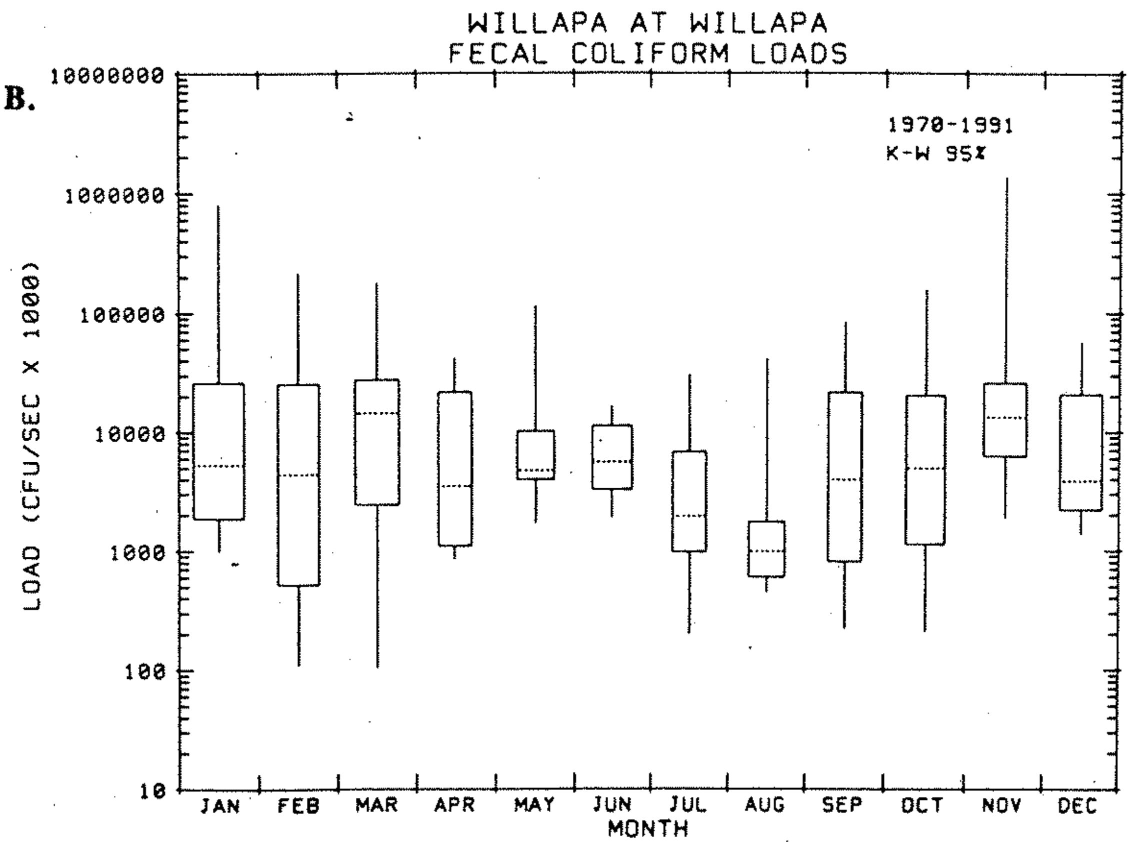


Figure 11. Monthly fecal coliform count (A.) and load (B.) distributions based on data collected by the Department of Ecology from the Willapa River at Willapa (24B090).

difference between data collected before and after 1985 was detected using the Mann-Whitney seasonal step trend analysis (Figure 12a). The year 1985 was based on evaluating data downstream and relates to improvements made at the Raymond and South Bend wastewater treatment plants (see Lower Willapa River). Table 8 summarizes the improvements for the Willapa at Willapa station with respect to fecal coliform criteria. After 1985, there is a shift in 12% of the data from above to below 200 cfu/100 mL. Much of the improvement appears to be occurring during the wet season, but nearly all months have shown improvement. Unfortunately, there is some uncertainty for interpreting the true magnitude of the step-trend. Some of the observed decrease in fecal coliform counts may be an artifact of laboratory changes made in 1985. A smaller, but significant step trend in fecal coliform results was observed for all Ecology monitoring data (Hallock, pers. comm., 1993). However, no step trend was observed in the data collected from the Willapa at Lebam station, which tends to indicate the step-trend was localized, and not basin-wide.

PCHHS (Berbells, 1991) data at a co-located site (Station 126) at RM 17.8 support Ecology long-term data characteristics of higher dry season and lower wet season fecal coliform counts. They collected 15 samples during the wet and dry seasons of 1990 (Appendix A, Figure A-2). The range of counts over each monitoring period was quite pronounced: January - <1 to 80 cfu/100 mL; July - 9 to 274 cfu/100 mL. PCHHS also calculated a wet season sampling load of 6 x 10^6 cfu/second, which is well within the range calculated from the Ecology data.

PCHHS (Berbells, 1991) sampled the South Fork of the Willapa River (Station 127) just off the Menlo-South Fork Road, at RM 9.2 (Appendix A, Figure A-2). The site represents about half of the sub-basin's drainage area of 40.0 square miles. Five wet season and five dry season samples were taken. None of the samples exceeded Class A water quality standards.

Lower Willapa River

The lower Willapa River segment of Zone 2 encompasses the lower 14 miles of the river and portions of the South Fork as well. The waters here are brackish or saline through the estuarine reach of the tidal river channels to the mouth of the Willapa River, just west of Johnson Slough. There are several ditches, urban stormwater systems and a few tributaries contributing to the drainage area. Raymond and South Bend, the most populated areas in Pacific County, are surrounded with rural farmlands along the sloughs and diked tidelands.

Various surveys over the past ten years have identified the Raymond and South Bend sewage collection systems as sources of fecal coliform contamination (CH_2M Hill, 1981; Clark, 1983; Meriwether, 1991a; 1991b; 1991c). Shotwell (1977) shows the city of Raymond superimposed over the original slough drainage pattern (Figure 13). The area's natural drainage situation makes wastewater collection system management difficult.

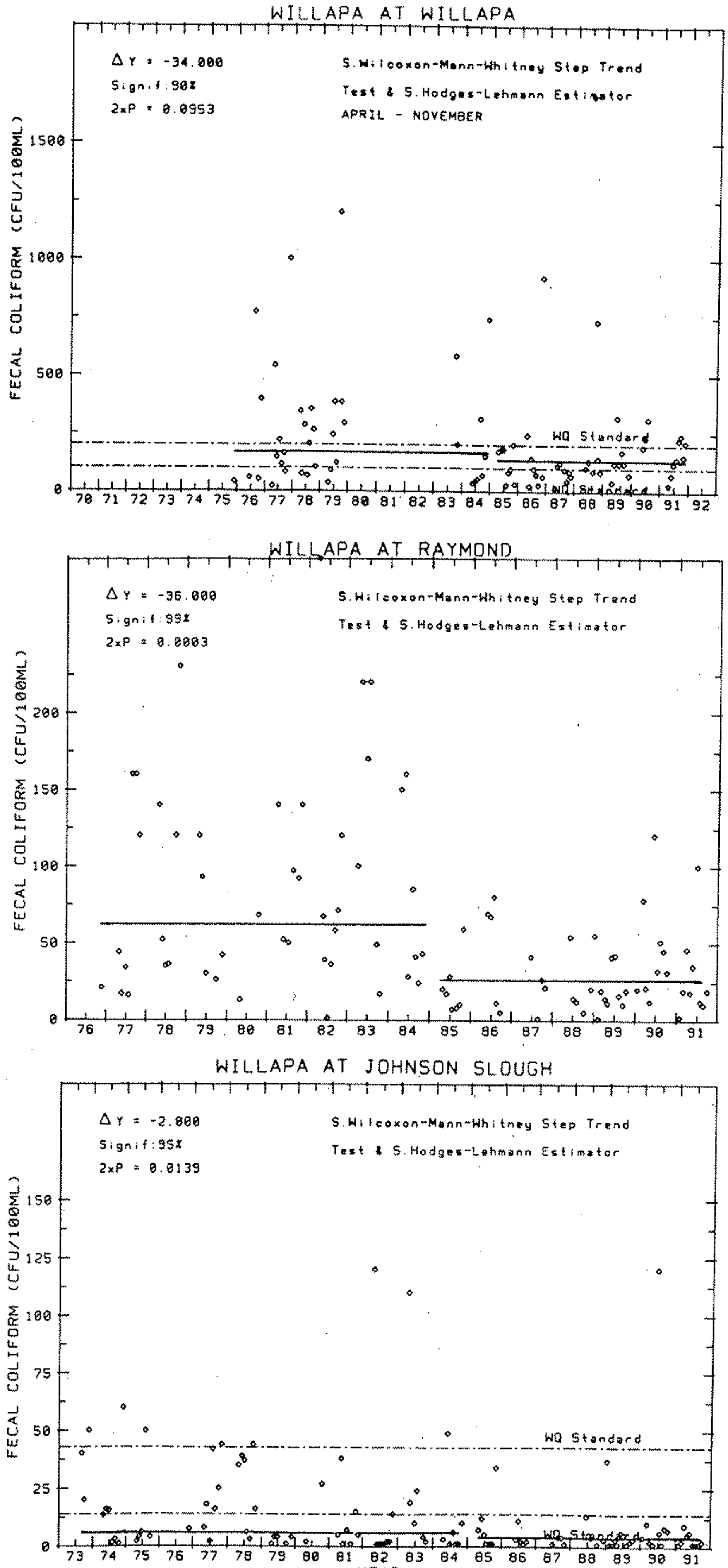


Figure 12. Wilcox-Mann-Whitney step trend analyses of Ecology fecal coliform data from three stations on the Willapa River: 24B090, WPA001, and WPA003. Data from all stations were collected during the months of April through November only.

Table 8. Comparison of fecal coliform count distribution at three Willapa River Stations for Ecology data collected before and after 1985 during the months of April through November.

			Percentage of data exceeding criterion			
Station	Period	# of data	% >200	% >100	% >43	% >14
Willapa at Willapa (24B090)	Before 1985	73	29	51	NA	NA
	After 1985	49	17	41	NA	NA
Willapa at Raymond (WPA001)	Before 1985	50	12	35	61	95
	After 1985	49	<2	2	25	67
Willapa at Johnson Sl. (WPA003)	Before 1985	66	0	4	12	38
	After 1985	49	0	<1	1	6

NA = criteria not applicable to freshwater.

Raymond STP--The city of Raymond has worked toward upgrading its collection and treatment system over the past 15 years. Its three-stage aerated/facultative lagoon system and polishing pond is located on the right bank and discharges into the Willapa River at RM 7 (Figure 6). Wastewater flows are primarily domestic sewage with additions from Rainbow Valley landfill leachate and Protan Industries production waters. Truck loads of 3,000 gallons of leachate from the landfill are delivered at a rate of one per day in summer and 12 to 15 per day during wet weather (Meriwether, 1991a).

The Raymond STP design capacity is regularly exceeded during wet and dry weather (Meriwether, 1991a). Approximately 75% of the main sewer lines have been replaced. The remaining major problem is thought to be continued excessive infiltration and inflow (I/I) at individual services, or improper plant design. However, the problem does not appear to exhibit itself as poor effluent bacterial quality. The wastewater treatment plant discharge monitoring reports (DMRs) record daily effluent volume and weekly fecal coliform counts. The average monthly fecal coliform counts from 1987 to 1990 were used to calculate an overall monthly average. From these records, permit limits of 200 cfu/100 mL and a maximum of 400 cfu/100 mL were being met.

Raymond's NPDES Permit No. WA-002332-9, now includes a requirement under Section S3A intended to protect shellfish areas. Specifically, plant staff are required to report system overflows, plant bypasses, or a failure of the disinfection system to the DOH Shellfish Program at the start of business the next working day.

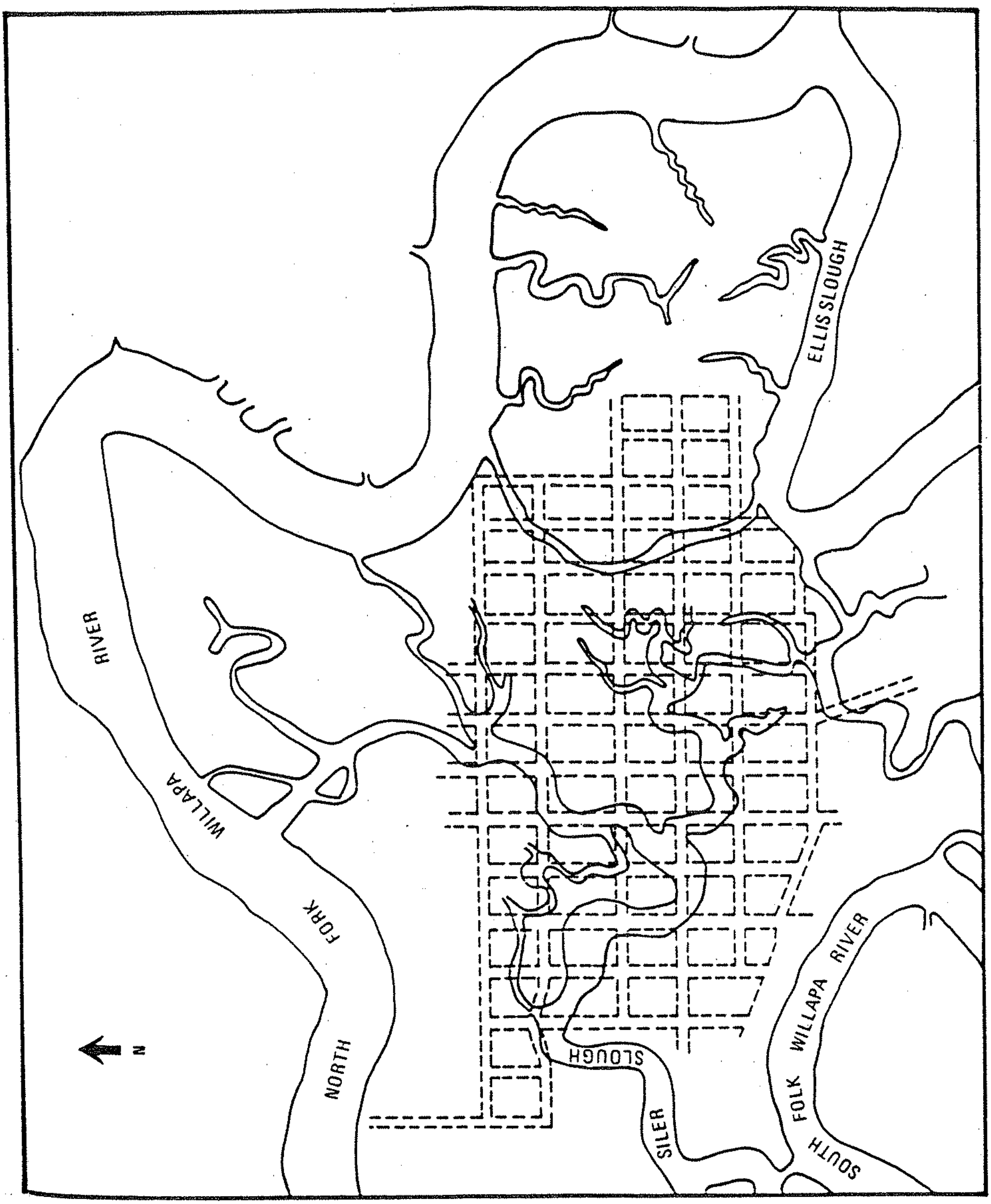


Figure 13. The city of Raymond superimposed over the original slough drainage pattern (Shotwell, 1977).

South Bend STP--The city of South Bend upgraded its wastewater treatment facility and collection system in 1984, 1985, and 1986. Treatment is provided by two aerated lagoons and two stabilization ponds located on the right bank of the Willapa River. Treated sewage is chlorinated and dechlorinated prior to discharging to the Willapa River through an extended outfall at RM 3.86 (Figure 6). Coast Oyster wastewater, domestic wastewater, and eel sliming operations wastewater are included in the design flows. The South Bend STP also regularly exceeds design capacity from November through March due to I/I problems (Meriwether, 1991b). As with Raymond, an analysis of South Bend DMRs from 1987 to 1991 was used to calculate an overall monthly fecal coliform average. Effluent permit limits of 200 cfu/100 mL and a maximum of 400 cfu/100 mL were being met.

Ecology Data--Ecology has maintained two long-term stations in the lower river from 1973 to the present: Willapa at Raymond (Station WPA001, RM 6.4) and Willapa at Johnson Slough (Station WPA003, RM 0.4) (Figure 7). A third station was located near South Bend from 1973 to 1977 (Station WPA002, RM 3.3). Linear and step trend analyses were performed on data from the two current stations. Fecal coliform data from both the Raymond and Johnson Slough stations showed significant declining linear trends using a Seasonal Kendall test ($P=0.99$, $P=0.95$). When data were segregated by tidal stage and tested, only the flood tide data continued to show strong trends at both stations ($P=0.99$, $P=0.95$). As stated earlier, Raymond and South Bend had both completed major upgrades of their wastewater collection and treatment systems by 1985. Using this information, a seasonal Mann-Whitney test was conducted on flood tide data collected before and after 1985 at the Raymond and Johnson Slough stations. Figures 12b and 12c demonstrate there was a statistically significant decrease in long-term fecal coliform concentrations found at Raymond and Johnson Slough ($P=0.99$, $P=0.80$) in those two data blocks. Table 8 summarizes the improvements with respect to fecal coliform criteria; both data sets show significant decreases in the proportion of samples which exceed 43 cfu/100 mL.

The presence of very strong linear and step trends for the flood tide data at the Raymond station is encouraging despite difficulties with the data. As previously mentioned, some of the trend may be the result of laboratory data quality changes. A cautiously optimistic interpretation of these fecal coliform trends would be that they are a cumulative result of changes in practices along the lower river, including improvements in the STP collection systems.

Other Data--Other potential sources of bacterial contamination in the lower Willapa River have also been documented. There are five livestock farms and one dairy downstream of Raymond in low-lying, sometimes diked, areas near the mouth of the Willapa River (Figure 4). The number of livestock reported to be on these farms may produce as much as 7,800 tons of manure per year. The immediate proximity of these farms to the waters adjacent to shellfish areas may present a high potential to degrade water quality.

As previously shown in Table 3, sanitary surveys conducted in East Raymond, Old Willapa at Willapa, Eklund Park, and the Hewitt Addition reported high percentages of failing on-site systems that resulted in direct discharge to the river (PCHHS, 1990). Many of the on-site systems are under repair or being transferred to the municipal sewage collection systems.

The Rainbow Landfill, located near the mouth of the Willapa River, was closed during the summer of 1991 (Figure 6). A summary of water quality data for Rainbow Valley Landfill from 1985 to 1990 found that there were significant increases in all downgradient monitoring wells for five water quality parameters, including fecal coliform.

Bruceport/South Bend DOH Shellfish Growing Area

The significance of fecal coliform sources in the lower segment of the Willapa River are their proximity to Class 1 and 2 shellfish growing grounds near Bruceport (Figure 8). The Bruceport area is also affected by the North River, and ditches draining agricultural areas near Range Point to the south. The Bruceport/South Bend shellfish area is west of the DOH sanitary line just beyond the mouth of the Willapa River (Figure 8). No shellfish can be commercially harvested east of the sanitary line because of historical water quality problems and a high risk of contamination from bacterial sources.

The Bruceport/South Bend DOH monitoring stations cover the transition from the river channel to the shellfish growing area. The DOH has fecal coliform data available from a total of nine days of monitoring from three separate surveys conducted between November 1989 and June 1991. Table B-3 in Appendix B categorizes stations that failed one or both parts of the water quality criteria for shellfish growing waters during each of the nine days. The table also includes: the amount of rainfall on the sampling day, the previous 48 hours rainfall, and the cumulative rainfall total for the five previous days.

Most violations occurred at stations east of the sanitary line (Stations 1 through 7). However, several stations in the growing area had fecal coliform counts greater than 14 MPN/100 mL during the June 1990 and 1991 surveys. There may be some relationship between the onset of low levels of rainfall and decreased fecal coliform counts in the growing area. Further analysis of this data later in the report also indicates there may be an impact from nonpoint sources west of the sanitary line.

Stony Point DOH Shellfish Growing Area

The Stony Point area is unique in that it is not in immediate proximity of a river (Figure 8). It has a higher average salinity than any adjacent shellfish sampling area (CH_2M Hill, 1981). DOH collected and analyzed a total of six water quality samples at each of 18 stations in each of three sampling surveys from 1990 to 1992. Table B-4 in Appendix B summarizes Stony Point fecal coliform data. Only one nearshore station had an elevated fecal coliform count of 17 MPN/100 mL. The DOH data on Stony Point generally show good water quality.

There are two large harbor seal haul-out and pupping sites within Zone Two near the Stony Point shellfish area. The largest groups of seals gather near the Pine Island Channel during May through August. Samples collected in early May 1990, and early June 1991 showed no increased coliform counts in response to the presence of seals, but more sampling during the active pupping season and during critical tidal phases should be conducted.

Bay Center Shellfish Growing Area

Water quality in the Bay Center shellfish area is influenced by the Niawiakum and the Palix/Canon Rivers, and drainage from the Bay Center peninsula (Figure 8). The upper watershed usage is limited to forestry. Light residential and agricultural uses appear in the lower watersheds and along the peninsula. Bay Center is a small community centered on the shellfish and fish industries with some new residential development planned on Wilson Point. The area has been the subject of several water quality studies over the past 15 years.

A shoreline sanitary survey of Bay Center was conducted in 1980 (CH_2M Hill, 1981). Fecal coliform samples taken from ditches draining Bay Center east into the Palix River were greater than 200 cfu/100 mL. Livestock were pastured in the area with direct access to water courses. Monitoring of the rivers showed both the Palix and Niawiakum Rivers periodically exceeded standards for fecal coliform. Periods with elevated counts appeared to be related to rainfall events.

A shoreline sanitary survey of residential sites was conducted by DOH in 1987 (Schlorff, 1987). Samples of the Niawiakum River and the drainage creek from the central portion of Bay Center exceeded fresh water quality standards. Six of 17 inspected on-site sewage systems were failing or potentially failing. The survey and samples resulted in a recommendation against any type of wet storage of oysters in the Niawiakum and Palix rivers (Schlorff, 1987).

In a June 1989 survey, DOH found 13 out of 75 fecal coliform samples exceeded shellfish growing area water quality standards. In August and October of 1989, DOH intensive water quality studies reported five of 15 stations exceeding a geometric mean value of 14 MPN/100 mL. Twelve of the 15 stations had more than 10% exceeding 43 MPN/100 mL. In November 1989, the DOH Office of Shellfish Programs enclosed a portion of the growing area with a sanitary line and reclassified it as Prohibited (Figure 8). This classification was given because there was no current sanitary survey nor any intensive monitoring program data that could accurately identify the sources or health risk of the bacterial contamination (DOH, 1989).

In 1991, DOH restoration studies of Bay Center listed the upper Palix and Canon River watersheds as the primary sources of fecal coliform (Melvin, 1991). Community and individual on-site system failures in Bay Center, agricultural runoff, as well as seasonal commercial live-aboard boats were contributing to the problem. The lack of sufficient onshore sanitary facilities at the marina was also reported as a factor in fecal coliform pollution in Bay Center (Melvin, 1991).

A survey of seafood processing plants in southwest Washington was conducted in 1988 (Joy, 1990). A grab sample taken of unscreened wastewater at one plant in Bay Center had an estimated fecal coliform count of 8,300 cfu/100 mL. However, the effluent volume was relatively low at 500 gallons per day.

As previously mentioned, the PCHHS began a sanitary survey of Bay Center in December 1989 and completed it January 10, 1990 (Table 3). Approximately 44 percent of the 141 homes inspected had failing or suspect on-site sewage systems (PCHHS, 1990a). The process of implementing repairs to failing on-site sewage systems is predicted to be completed by late 1992. Several farm sources were also identified. Farm plans are being written with Soil Conservation Service staff to improve manure waste management practices in the area.

In September 1992, the restricted harvesting areas were reclassified Conditionally Approved by the Department of Health (DOH, 1992). The harvest area management plan calls for a five-day closure after any rainfall event of one inch or more over 24 hours. The reclassification came after all on-site sewage system repairs were completed.

In 1991, PCHHS (Berbells, 1991) sampled Station 128 on the Niawiakum River for fecal coliform during the wet and dry season (Appendix A, Figure A-2). All ten samples were well below the Class A water quality standard for freshwater (Berbells, 1991).

Zone Three

Description

Zone Three is located in the southwestern section of the bay along the Long Beach Peninsula and includes Long Island and the Willapa Bay National Wildlife Refuge (Figure 9). It contains 1,349 acres or 54% of all Class 1 and 2 oysterlands, and produces an average of 49% of Willapa Bay's annual oyster harvest. This zone also contains approximately 75 acres of commercial clam beds which are harvested year-round.

The Bear River is the only major river drainage in the zone (Figure 1). The Long Beach Peninsula has a network of lakes and ditches that drain from west to east.

Long Beach Peninsula

The main industries of the Long Beach Peninsula are the commercial oyster business, small-scale agriculture and cranberry farming, and seasonal tourist and fishing facilities. The intensity of the seasonal recreational industry can be inferred by the numbers of visitors to the State Parks. In 1988, 2.6 million people visited the parks located on the Long Beach Peninsula. From 1988 to 1991 an average of 1.7 million people visited the parks each year. These numbers only reflect park visitors, and do not include the seasonal usage of commercial lodgings.

The town of Long Beach has a NPDES permitted activated sludge and aeration STP. Effluent discharges via a drainage ditch to Tinker Lake, and then into southwest Willapa Bay. The sludge is applied to local forested land. Inspectors have noted that the application area needs more time to assimilate the sludge and recover from accumulated solids loading (Ecology, 1991b).

The DOH Shellfish Program has collected approximately 17 fecal coliform water samples at each of 21 stations in the Nahcotta monitoring area (Figure 8). Samples were collected during four surveys conducted between September 1989 and February 1992. One sample near Nahcotta Harbor exceeded the water quality standard of 43 cfu/100 mL.

The CH_2M Hill (1981) report stated that the tourist season had no bacterial impact on water quality in the peninsula area. However, impacts from livestock were evident. Samples taken within livestock pasture areas behind a closed tide gate had measured counts that exceeded fresh water criteria.

A major concern in the Long Beach Peninsula is that residential and commercial growth will result in substantial nonpoint bacterial loading to the adjacent oysterlands and to ground water (CH_2M Hill, 1987). Sanitary surveys of surface waters have found elevated levels of fecal coliform. In response, only moderate levels of development were recommended for the area (CH_2M Hill, 1987). The soils in many areas of the Long Beach Peninsula have qualities adverse to on-site septic treatment, including areas with high water tables and other areas with excessively draining soils. The surface and subsurface drainage patterns could lead contaminants from the eastern shoreline into shellfish growing areas.

The PCHHS (Berbells, 1991) sampled four stations on the peninsula (Appendix A, Figure A-2). Ten percent of the samples collected during the dry season at station 140D in Pauls Slough, and 140B in East Main exceeded the 200 cfu/100 mL water quality criterion. Of the 15 samples taken during the low flow dry season in East Main, four exceeded 100 cfu/100 mL.

Bear River Watershed

Bear River has no apparent sources of human contamination, and has only had minimal sampling. Three survey efforts have been undertaken in the Bear River since 1976.

Ecology's Ambient Monitoring Section collected samples twice a month from October 1976 to September 1977 at RM 5.8. Only two samples out of 24 had counts greater than 100 cfu/100 mL.

The Bear River had an average of 35 cfu/100 mL from a total of 23 samples collected in 1980 by CH_2M Hill (1981).

PCHHS (Berbells, 1991) collected 10 samples from the wet and dry season in 1990. All were less than 50 cfu/100 mL.

Zone Four

Description

Zone Four is located on the southeastern side of Willapa Bay (Figure 9). It contains 171 acres of Class 1 and 2 oysterlands and produces approximately nine percent of Willapa's oyster harvest. There are 10 acres of certified clam harvest beds on the South Fork of the Nemah River Channel. The Nemah River, the Naselle River, and several smaller watersheds drain to this zone. The town of Naselle is located in the upper area of the zone. Southern portions of Zone Four have a lower than average salinity. Lower salinities may reduce bacteria mortality rates and make shellfish in these areas more vulnerable to contamination (Mancini, 1978).

Nemah River

The various branches of the Nemah River have had minimal fecal coliform monitoring. The monitoring has generally been sporadic and isolated to two or three sites in the watershed upstream of salt water influence.

Ecology sampled the North, Middle, and South Nemah Rivers twice a month (24 samples each) from October 1976 to September 1977. Stations 24E070, 24H070, and 24J070 on the North, Middle, and South branch, respectively are shown in Figure 7. The results from this monitoring effort are summarized below:

- The North Nemah River fecal coliform data had a geometric mean of 145 cfu/100 mL with 13 of the 24 samples exceeding the 100 cfu/100 mL criterion, and 42% of the samples exceeding the 200 cfu/100 mL criterion.

- The Middle Nemah River fecal coliform data had a geometric mean of 29 cfu/100 mL with six of the samples exceeding 100 cfu/100 mL, and three (12.5%) of the samples exceeding 200 cfu/100 mL.

- The South Nemah River fecal coliform data had a geometric mean of 20 cfu/100 mL with three of the samples exceeding 100 cfu/100 mL, and one (4%) of the samples exceeding 200 cfu/100 mL.

Most of the higher counts on the North Nemah River occurred in the months of September through December. Middle Nemah River high counts occurred in April through August. CH_2M Hill (1981) data and Ecology data from the three forks of the Nemah River gave similar results. Their mean count of the North Nemah was 90 cfu/100 mL, and the Middle and South Nemah mean counts were 37 cfu/100 mL, and 46 cfu/100 mL, respectively. About 10% of the samples from the North and South Nemah exceeded 200 cfu/100 mL. CH_2M Hill (1981) identified livestock, residential areas with on-site septic systems, a youth camp, a fish hatchery, and a campground as potential sources of fecal bacteria.

Pacific County Health and Human Services (Berbells, 1991) sampled the North Nemah River Station just below the state salmon hatchery at RM 4, and the Middle Nemah River (Station 130) at RM 0.9 (Appendix A, Figure A-2). None of the ten samples taken at each station during the wet and dry seasons exceeded the Class A freshwater criterion of 100 cfu/100 mL.

The DOH Shellfish Program has stations in the shellfish growing area along the tidal reaches of the Nemah River system channel (Figure 8). Twelve samples per station were gathered in October 1990 and May 1991. Fecal coliform results and rainfall data on each sampling date are summarized in Appendix B, Table B-5. The DOH data indicate that there are a greater number of stations failing fecal coliform criteria during rain events than dry periods. Also, in contrast to the Pacific County Health survey work in the rivers (Berbells, 1991), the fecal coliform counts from the watersheds sometimes exceed 100 MPN/100 mL.

Naselle River

Ecology monitored the Naselle River near Naselle (Station 24F070) twice monthly from October 1976 to September 1977 (Figure 7). The USGS collected 15 additional samples from the site between 1978 and 1980. Monthly monitoring was resumed by Ecology at the site in October 1991. The geometric mean count of the 45 fecal coliform samples analyzed at station 24F070 was 24 cfu/100 mL. Eight of the counts exceeded 100 cfu/100 mL, and one exceeded 200 cfu/100 mL. The other two historical Ecology monitoring stations (Station 24F040 and 24F055) have no fecal coliform data. They were sampled in the early 1960's and 1970's when only total coliform bacteria were analyzed.

Several potential sources of bacterial pollution were identified in the CH_2M Hill 1980 sanitary survey (CH_2M Hill, 1981). These included:

1) livestock with access to watercourses and pasturelands in the flood and tide zones,
2) failing septic tank effluent,
3) the Naselle River Camp,
4) O'Connor Creek,
5) the South Naselle River, and
6) the area around Naselle.

The CH_2M Hill monitoring site was located at the mouth of the Naselle River in the estuarine zone. The median fecal coliform count for the 22 samples collected at the station was 9 cfu/100 mL. Five samples (23%) had counts greater than 200 cfu/100 mL or 43 cfu/100 mL, whichever criterion was most applicable based on concurrent salinity concentrations.

The Washington State Department of Social and Health Services Naselle Youth Camp, located at RM 3 near Naselle, has a STP system that discharges to the Naselle River. An inspection by Ecology's Southwest Regional Office in October 1990 found problems with infiltration and inflow (I/I) in the winter. Previous upgrade work at the plant had reduced I/I by 20%.

Pacific County Health and Human Services (Berbells, 1991) monitored a site (Station 135) on the Naselle River at RM 16.3 in 1991 (Appendix A, Figure A-2). As with the Nemah River data, the Naselle River fecal coliform data showed very low counts. None of the samples collected in the wet or dry season exceeded the 100 cfu/100 mL criterion.

The DOH Shellfish Program collected 12 water quality samples at each of 11 stations in the Naselle shellfish growing area during October 1990 and May 1991 (Figure 8). Fecal coliform and rainfall data for this period are summarized in Appendix B, Table B-6. In October 1990, five stations failed both portions of shellfish growing area water quality standards. Three river samples, apart from the ambient monitoring network, were also gathered during this monitoring survey. All three had fecal coliform counts that were greater than 100 cfu/100 mL.

Fecal Coliform Loading and Modeling

The historical monitoring data presented above provide a general overview of bacterial water quality conditions and/or potential conditions for each of the Water Quality Zones. This section briefly discusses factors controlling bacterial loading, and reviews mathematical modeling concepts. Approaches for evaluating bacterial loading in Willapa Bay will be demonstrated, and data needs to successfully complete those approaches will be identified.

Controlling Factors

The Willapa Bay watershed exhibits a wide diversity of bacterial sources and intensities. The impact of these on shellfish beds and water quality depends on watershed features that affect bacterial loading, transport, and die-off rates. Several of the following source to water delivery factors need to be quantified to assess sub-basin bacterial loading and their water quality impacts:

- the type of source;
- the relative magnitude or bacterial intensity of the source;
- the distance and transport process from the source to the nearest receiving water;
- the bacterial die-off, settling, or growth rate from the source to the nearest receiving water; and
- the frequency of discharge from the source to the water transport channel.

The next set of factors are related to instream transport of the bacterial load from the source to the area of interest or beneficial use area (e.g., a shellfish growing area or public swimming beach). These include:

- the instream distance between the nearest receiving water and the beneficial use area;
- dilution and dispersion during transport; and
- the effects of physical, chemical, and biological conditions on bacterial populations (*i.e.*, the instream settling, resuspension, or die-off rate).

Finally, if the area of interest or beneficial use is shellfish growing and harvesting, there are a few other factors to be considered:

- the duration of exposure of the shellfish to contaminated water or sediment;
- the type of bacteria or virus and its virulence;
- the type of substrate; and
- the type and size of shellfish exposed (*i.e.*, their bioconcentration and depuration rates).

Once sources are identified, their loading and impact on beneficial use areas are influenced by:

- climate;
- the physical features of the sub-basins and the bay; and
- the physical, chemical, and biological characteristics of the marine, estuarine, and freshwaters (e.g., the instream suspended sediment, light, heat, salinity, predation, and other decay or growth mechanisms affecting bacterial populations).

The climatic influences and transport and die-off processes are quite complex, site-specific, and not well understood for specific types of bacteria.

All of these factors are important for understanding, evaluating, and controlling bacterial loading, and creating a management strategy for the Willapa Bay watershed. Mathematical modeling of these factors can be helpful during the planning stage as a decision-making tool, or to evaluate best management practice (BMP) alternatives.

Modeling

Mathematical or conceptual models help interpret controlling factors and processes, and estimate the relative impact of point and nonpoint sources on target waterbodies or organisms. Models have varying degrees of complexity and data requirements from simple equations to detailed computer simulations. Bacterial load modeling can involve components describing the three sets of controlling factors listed earlier. These are generalized into the following:

1) a land use component to simulate bacterial delivery from sources to local receiving waters,
2) a tributary and estuary/bay component to describe water and bacterial transport and transformation through the waterbody, and
3) a biological component to characterize bacterial uptake by shellfish or other organisms.

Few general water quality models are available with more than one of these components. Modeling point and nonpoint source bacterial impacts under estuarine conditions is an especially challenging problem. Estuary systems tend to be more difficult to model than other waterbodies. Tidal motion, water density effects, and currents complicate hydrodynamic modeling. The mixing of fresh and salt waters makes pollutant modeling more complicated too. Assumptions can be simplified in some cases which make the estuarine models less data intensive, but still useful for describing the process and system. The assumptions usually involve setting spatial and/or temporal boundaries.

Bacterial source, transport, and die-off factors have large, site-specific variabilities which make generalization for modeling difficult. For example, some nonpoint sources are very spatially and temporally unpredictable (e.g., wildlife or livestock herds fouling streams; combined sewer overflow response to localized thundershowers). Unfortunately, bacterial concentrations and loads often lack consistent controlling factors or correlations with more easily modeled variables like discharge volume, suspended sediment load, rainfall intensity, or cumulative precipitation. Good correlations with these variables would tend to simplify some of the modeling processes and make simulations more accurate and universally applicable. Bacterial regrowth, resuspension from sediment, and microlayer phase separation can also challenge modelers of bacterial transport and die-off.

There are two main time frames used for models: dynamic and steady state. Dynamic models are used to simulate short-term rainstorm or flow events on time scales of hours or days. They help evaluate changes in loading at sites within the waterbody over the course of an event. Steady state models usually predict critical period, seasonal, or annual average loading and use data averaged over time scales of days to years. The information gained from both types of models can be used to compare basins or sub-basins, or to evaluate changes in loading as a result of changes in land use practices.

Models may differ in their conceptual approach of pollutant delivery and transport. Donigan and Huber (1990) placed nonpoint source (NPS) models into four conceptual categories:

1) unit concentration or load,
2) statistical or probabilistic,
3) regression or rating curve, and
4) mechanistic.

These NPS model types vary in complexity, and are suitable for a wide variety of informational goals.

Unit concentration models assign various land uses or sources with constant pollutant runoff concentrations. The cumulative load from each land use or source is then simply the concentration multiplied by the land area and the unit runoff volume. Spreadsheet software has been used to automate calculations for unit concentration models and allowed more complex watershed evaluations. Horner *et al.*, (1986) and Horner and Brenner (1989) developed nonpoint model spreadsheets for Ecology using this approach, coupled with basic mechanistic factors. Similarly, the National Oceanic and Atmospheric Administration (NOAA) used this approach to model sediment loading in the Willapa Bay watershed for its National Coastal Pollutant Discharge Inventory (Singer *et al.*, 1988). Some geographic information system (GIS)-

based models are the next level of sophistication beyond the spreadsheet approach. San Luis Obispo Creek was modeled using a GIS-based land use component for evaluating wash-off from nonpoint sources (LTI, 1992).

Statistical or probabilistic modeling approaches use concentration and flow frequency distributions (usually lognormal) to calculate concentrations and loads. The total load of a pollutant during a storm event, divided by the total runoff volume during the storm is termed the event mean concentration (EMC). When a lognormal distribution of EMCs is coupled with a distribution of runoff volumes, and then a distribution of stream discharge volumes, an instream pollutant distribution is calculated. The approach was pioneered by the USEPA National Urban Runoff Program (NURP) from studies conducted throughout the United States. It is very data intensive and has been used primarily in urban runoff applications.

Regression or rating curve models use a correlation of local pollutant concentrations or loads as dependent variables to independent variables such as land use type, rainfall volume, or other watershed factors. From this relationship, other concentrations or loads can be predicted for changes in the independent variable. Health agencies use such models to predict rainstorm intensities or discharge levels likely to result in water quality or shellfish tissue bacteria violations. An intensity or level is then designated as a trigger to close a shellfish growing area for a predetermined period of time, or initiate more frequent and intense monitoring. These models are usually very specific to the original data set.

Mechanistic models attempt to characterize the physical processes of pollutant accumulation, removal, transport, and transformation in a step-by-step progression. The most typical are very complex models that require a great deal of detailed information. For example, HSPF (Johanson *et al.*, 1984) and SWMM (Huber and Dickenson, 1988) provide continuous simulation of water budgets, and pollutant accumulation, transformation, and transport. Algorithms and mathematical functions are used to mimic processes, and any absence of site-specific information reduces the simulation accuracy. GIS coverages are now being linked to these types of models (Vieux, 1991).

Nonpoint source and watershed models are available for a wide range of applications (Giorgini, *et al.*, 1986; Donigan and Huber, 1990; Dillaha and Gale, 1992). However, few of these models simulate and predict fecal coliform loads in receiving waters (Horner and Brenner, 1989; Dillaha and Gale, 1992). Fewer yet look at the effects of estuarine conditions on bacterial loads. Of the models available, researchers appear to have modeled urban stormwater fecal coliform loads (e.g., SWMM simulations) more than agricultural, on-site septic, or mixed land use contributions. Field scale, mechanistic models such as MWASTE (Moore, *et al.*, 1988) and COLI (Walker, *et al.*, 1990) have been used to estimate bacterial runoff to a receiving water from deposited livestock manure. Some screening models also calculate rough estimates of bacterial loads for relative comparisons of sub-basins or reaches (Horner and Brenner, 1989; Mills, *et al.*, 1985).

Modeling could be a valuable tool for the Willapa Bay watershed bacterial control strategy despite the limitations discussed. Local land use, water quality, and physical feature data collected by local, state, and federal agencies could be used in applications ranging from basic stream reach equations to complex GIS-based basin models. There are possibilities of linking NPS wash-off model output with a watershed/estuarine transport model. Models with both point and nonpoint source coverage may provide better interpretations of the data, and lead to better decision-making. The choice of a model will depend on the specific question(s) being asked. The simplest model that will answer the question should be used.

Assessing Fecal Coliform Loading to Willapa Bay

An accurate basin-wide assessment of fecal coliform loading in the Willapa Bay watershed would be difficult at this time. Most of the water quality monitoring has been very site-specific and there has not been a comprehensive monitoring plan designed to monitor the watershed as a whole. The data that are available can be used to make rough loading estimates, but not without a number of qualifications. The following examples demonstrate some of the difficulties and limits to the current fecal coliform database.

CH_2M Hill (1981) estimated annual sub-basin fecal coliform loads using data they collected in 1980 (Table 9). The results showed the Willapa River (above Raymond) accounted for nearly 60% of the average annual tributary fecal coliform loading to the bay. The same sort of analysis with a second set of more recently collected data under DOH and Ecology monitoring programs showed the North River accounts for nearly 60% of the load, and the Willapa River load is greatly reduced (Table 9). Although improvements may have occurred in the lower Willapa River, bias in both data sets influences the results and makes interbasin and temporal comparisons tenuous. For example, both data sets neglect the Willapa River from Raymond to the mouth, a section with several documented bacterial sources. Also, CH_2M Hill (1981) monitored twice a month by helicopter and boat, but few samples were collected during rainfall and runoff events. The DOH and Ecology data were collected over multiple years, but at varying frequencies. These differences within and between data sets in sampling frequency and analytical technique can seriously bias the data analyses.

This sub-basin comparison does not adequately address the question of bacterial impact on shellfish harvest areas, or the distribution of bacterial problems in the watershed. Sample collection frequencies, station locations, and analytical methods need to be planned with these specific informational needs in mind. However, the water quality data reviewed earlier in this report can provide direction for asking more specific questions and designing more appropriate monitoring programs. For example, fecal coliform monitoring data and regulatory actions indicate that areas like the upper and lower Willapa River, North River, Long Beach Peninsula, and Bay Center have had bacterial problems. Combined sewer overflows (CSOs), on-site septic systems, livestock, and wildlife have been bacterial sources documented as problems for shellfish growing areas, shallow ground water areas, and recreational uses along river courses (Ecology, 1992). Sources in the Willapa Bay have relatively short (less than four days) waterborne transport times to shellfish resource areas. This information is useful for locating monitoring

Table 9. A comparison of loading estimates based on data collected by CH_2M Hill (1981) in 1980 to data from various sources collected since 1985.

River	FC/liter	Flow L/Hr	Avg. Load/Hr.	Avg. Salinity
Cedar River CH_2M Hill	670 23 samples	5,666,400	$3.8x10^9$	7.6
Cedar River DOH 1989-91	400 11 samples	5,666,400	$2.26x10^9$	20.8
North River CH_2M Hill	510 23 samples	143,434,800	$7.3x10^{10}$	6.2
North River DOH 88-91	1,275 38 samples fall	143,434,800	$1.8x10^{11}$	9.5
Smith Creek CH_2M Hill	380 22 samples	40,665,600	$1.5x10^{10}$	6.7
Smith Creek DOH Data	1450 37 samples fall	40,665,600	$5.9x10^{10}$	7.5
Willapa River CH_2M Hill	1610 17 samples	133,095,600	$2.1x10^{11}$	10.2
Willapa River Ecology WPA001	300 49 samples 1985-1991	133,095,600	$4.0x10^{10}$	16
Palix River CH_2M Hill	680 22 samples	24,894,000	$1.7x10^{10}$	17.6
Palix River DOH Data	1120 18 samples	24,894,000	$2.7x10^{10}$	14.1
Naselle River CH_2M Hill	180 22 samples	93,416,400	$1.7x10^{10}$	13.2
Naselle River DOH	90 7 samples	93,416,400	$8.4x10^9$	22.5

All flow values from CH_2M Hill (1981) calculations.

stations. CH_2M Hill (1981), Ecology, PCHHS, and DOH data also show seasonal differences in fecal coliform loads, or increases in tributary and bay bacterial concentrations collected at some locations after rainstorms. This information would help determine when and how often sampling should occur.

Land use and nonpoint source data have not been collected for large portions of the watershed since CH_2M Hill's (1981) work in 1980. An evaluation of average sediment contributions from generalized land uses in the Willapa Bay watershed was conducted by the NOAA for its National Coastal Pollutant Discharge Inventory (Singer *et al.*, 1988). Thomann and Mueller (1987) and Mills *et al.* (1985) proposed that a useful approach for basin assessment is a comparison of continuous point source to intermittent nonpoint source loads over a range of rainstorm events. Willapa Bay data and experiences from other nonpoint source affected areas (e.g. Tillamook Bay, Puget Sound watersheds, Chesapeake Bay) suggest proximity comparisons of intermittent nonpoint sources would be an important load analysis to conduct to select priority problem areas. Both of these analyses would require land use data.

Phillips (1991) outlined a simple method for a quick relative comparison of source impacts using basic proximity calculations and delivery ratios. Phillip's method was combined with the basic rational formula to estimate nonpoint source wash-off and evaluate the potential bacterial impact of several sources on water quality in the Bruceport/South Bend shellfish harvest area during a wet season rain storm. The procedure is outlined in Appendix C and relies on 1980 land use data from CH_2M Hill (1981), recent DOH and Ecology monitoring data, and coefficients obtained from technical literature. The results of the method are shown in Table 10. The results suggest that when four inches of rain fall over 24 hours, CSOs and grazed pastures along the bay and sloughs downstream of Raymond could be more important sources of bacteria than the STP outfalls and upper watershed inputs above Raymond.

This basic assessment could be conducted with more sophistication and higher confidence by applying a model with GIS-based land use and physical feature coverages, and better hydrodynamic functions. However, the exercise also indicates what kinds of data are needed to answer specific questions about basic nonpoint and point source loading comparisons (e.g., livestock populations and grazing areas, CSO runoff bacterial concentrations, and reach-specific die-off rates). Once the specific question has been formulated, the monitoring design and analytical models can be conceptualized. The data can then be gathered and the evaluation can be completed. The control strategy description in the last section of the report will explore some of the questions and data needs, especially for total maximum daily load (TMDL) analyses and targeting of BMPs.

Fecal Coliform Problem Summary

The bacterial water quality problems identified in each of our management zones during the data evaluation are summarized in this section. Also, the *Spartina alterniflora* problem and its possible relationship to bacterial water quality in Willapa Bay are discussed. Finally, the potential for future shellfish growing area closures in Willapa Bay is explored.

Table 10. Relative contribution of various bacterial loads generated by sources along the Willapa River during an idealized wet season rainstorm of four inches in 24 hours. Source impacts compared to a theoretical Range Point livestock source at river mile 0.

Source Location along Willapa River	Distance from impact area (mi)	Proportional* Impact	Calculated fecal coliform load (cfu/cfs)	Source type	Relative load**	Relative load contribution ***
Range Point	0	1	2.2×10^4	Livestock	1	1
Mailboat Slough	3.5	0.25	8.1×10^4	Livestock	3.7	0.93
South Bend	5	0.143	1.0×10^3	Treatment plant	0.045	0.006
			7.9×10^6	Combined sewer overflow	360	51
Raymond	8	0.042	1.6×10^3	Treatment Plant	0.073	0.003
			1.6×10^7	Combined sewer overflow	730	31
USGS gage	19	0.00054	3.5×10^5	Mixed Unknown	16	0.009

* The impact of a similar strength bacterial source located away from impact area with an instream fecal coliform decay rate of 0.396/river mile: $PI = (e^{0.396 \times distance})^{-1}$.

** Load at location compared to mile 0 load.

*** Load impact after proportional impact factor is applied (*i.e.*, proportional impact x relative load). Values of one or greater indicate bacterial load will have greater impact on Range Point area than local sources.

Problems in Zone One

Grayland Ditch bacterial levels exceed water quality criteria. This demonstrates a need for a sanitary survey in the area of increasing population and land development. Few bacterial problems have occurred in the open water area of the zone. Zone One has no known commercial or recreational shellfish areas at the present time, but water quality could affect adjacent Zone Two shellfish growing areas.

Problems in Zone Two

Zone Two has been the most intensively monitored area of the Willapa Bay watershed. It contains the largest land area and population. It also contains 39% of the Class 1 and 2 growing areas in Willapa Bay. Several problems were identified in the zone:

1) The mouth of the Cedar River exceeds marine fecal coliform criteria after measurable rainfall. A major rainfall and runoff event in fall and winter, coupled with low salinities in the bay, may adversely impact the shellfish growing area's water quality.

2) The North River has a long history of a potential health hazards from inadequate waste disposal systems on houseboats. Livestock access to low-lying pastures may be another source of bacteria. Data have shown extraordinarily high levels of fecal coliform which may represent seasonal nonpoint wash-off. DOH marine stations fail fecal bacteria standards at an increased rate after rainfalls of less than 0.5 inch.

3) The upper segment of the Willapa River chronically exceeds fecal coliform criteria. Livestock manure, on-site septic system failures, and wildlife manure are thought to be potential contributors. Preliminary data analysis suggests that fecal coliform generated in the upper watershed do not necessarily reach shellfish growing areas in the bay. However, threats and impairments to other Willapa River beneficial uses are implied by the high bacterial counts.

4) Long-term monitoring data at three stations in the lower Willapa River show marked reductions in fecal coliform concentrations. Major improvements in the Raymond and South Bend STPs and collection systems completed by 1985 may be responsible for some of the improved water quality. There are indications that the Willapa River above Raymond may also be contributing lower bacterial loads as well.

5) Numerous point and nonpoint sources have been documented near the Bruceport/South Bend shellfish growing area. Although local agencies are working to control on-site septic and municipal system failures, fecal coliform criteria may be exceeded in the shellfish areas during the major harvest season of October to December when bay salinities are low and runoff is great. Urban CSO runoff and livestock sources close to the growing areas may be major sources of bacterial loading during wet weather storm events. DOH monitoring during these periods has been infrequent in the past, but will be more frequent in the future.

6) The DOH Stony Point shellfish growing area has no record of fecal coliform criteria violations, although no monitoring has occurred during major rainfall events. From May to August, about 1,000 harbor seals occupy five pupping sites at Pine Island Channels. No samples have been taken at the height of the pupping season to evaluate if there is bacterial contamination from the presence of the seals.

7) Parts of the Bay Center shellfish growing area were closed by the DOH in 1989 and have been under Conditionally Approved status since September 1992. Bacterial sources had been documented at least nine years previous to the closure.

Problems in Zone Three

The Long Beach Peninsula has 54% of Class 1 and 2 shellfish production areas in Willapa Bay. Some upland and shoreline developments have soils which are poorly suited for on-site septic systems. Furthermore, inundation of grazing pastures and residential areas by high water raises concern for the shellfish resources in this area. Historical studies have documented periodic elevated fecal coliform counts in the drainage ditches. Increased clearing of the ditches to improve drainage may have reduced their treatment capability for runoff waters. The close proximity of the potential sources to the shellfish growing, harvesting, and holding areas is a concern that requires attention. Additional seasonal water quality data needs to be collected to better understand the severity of the problem. The Long Beach STP's sludge application site is over-utilized and may be contributing fecal coliform to back-bay areas.

Problems in Zone Four

The Naselle and Nemah River areas are scheduled for sanitary surveys in the Fall of 1992. The rivers show periodic contamination above standards levels for marine waters in response to rainfall. On-site septic systems and livestock access to waterways were potentially major sources of bacterial contamination. This zone contains a limited number of Class 1 and 2 shellfish areas and clam harvest areas. The southern-most portions of this zone are subject to lower seasonal salinities which could prolong the survival rate for bacteria and thus enhance the possibility of shellfish contamination.

Spartina

Spartina alterniflora is an introduced and invasive cordgrass that grows in intertidal areas of Willapa Bay. In 1988, it was estimated to inhabit 600 to 800 acres. *Spartina* has the potential to colonize 30,000 out of the 36,000 acres of total intertidal sand and mud flats. *Spartina* coverage of oyster grounds in these areas would be a devastating blow to the oyster industry in Willapa Bay. *Spartina* invasion of intertidal areas can also rapidly change ground elevations and water movement, which may result in extensive flooding in urban areas adjacent to the bay and along the river valleys. Flooding and increased soil saturation would promote additional fecal coliform loading into Willapa Bay.

Willapa Bay's Potential For Future Downgrades

Our review of historical data suggests long-standing bacterial problems in some areas of the Willapa Bay watershed. Many of the sources of bacterial contamination in these areas are known and have been documented by past efforts. The Bay Center shellfish growing area closure and down-classification in 1989 is an example of how these problems have been managed in Willapa Bay.

The Bay Center closure was not the result of recent degradation or the appearance of new bacterial sources. Many of the sources of fecal coliform were identified as much as 10 years earlier. Both the elevated fecal coliform levels in the rivers near Bay Center, and the close relationship between antecedent rainfall and elevated fecal levels were shown in the CH_2M Hill (1981) study. A DOH sanitary survey (Schlorff, 1987) conducted seven years later confirmed the location of suspected bacterial sources documented by CH_2M Hill (1981). Two years later, in November 1989, DOH sampled during a "worst case" rainfall event and recorded levels of fecal coliform that exceeded shellfish growing area water quality standards. In turn, this led to the harvest area closure. Further sampling by DOH (Melvin, 1991) confirmed other nonpoint sources first identified in 1980 and 1987.

This process of monitoring, water quality problem identification, source discovery, and shellfish area closure in Bay Center could easily be repeated in other areas of Willapa Bay. Data from shellfish growing areas in Zone Two near the mouths of the Cedar, North, and Willapa Rivers, and in Zone Three along the Long Beach Peninsula appear to have many characteristics in common with the pre-closure Bay Center condition (e.g., documented sources of bacterial contamination, and documented seasonal water quality problems). Since large portions of Willapa Bay Class 1 and 2 growing areas are located in these zones, the economic impact of a full or partial closure would be great.

Physical characteristics and chemical conditions may be preventing severe bacterial contamination problems in Zones Two and Three. For example, the Bay Center shellfish growing areas are enclosed and closer to the river sources than growing areas are to the Cedar River, North River, and Bruceport/South Bend sources. Average salinities are higher along the Long Beach Peninsula than in Bay Center, which may increase bacterial die-off rates. And most importantly, local Pacific County agencies and others have been actively working on remediation of several of the identified sources, such as municipal STP collection system upgrades, on-site system inspections and repairs, and outreach programs designed to educate landowners of their responsibility to protect water quality.

On the other hand, the lower average salinity at the mouths of the North and Willapa Rivers presents a greater possibility of prolonged bacterial contamination (Carelli, 1983). Few data have been gathered in Zone Two and Zone Three growing areas during worst case conditions, especially during high run-off periods after a long dry periods. The paucity of data during these periods may mask the presence of several nonpoint bacterial sources, and prevent an accurate view of the current problem. Many of the issues related to protection of growing areas in Zone

Three are land use and growth management related. Pacific County has suffered great economic hardship in recent years, and it will be a challenge to local officials to balance economic growth with land use management.

The prevention of future shellfish harvest area downgrades and closures will depend on the ability of local and state agencies to work together quickly on specific monitoring objectives, data sharing, education, and enforcement issues. If land use and water quality data being collected by all groups in the Willapa Bay watershed are shared and evaluated with some common goals in mind, then problems can be more efficiently identified and corrective actions more swiftly taken. Mathematical models which interpret bacterial loading processes from land use and water quality data may be helpful for directing monitoring, source evaluation, and correction activities.

Beyond data sharing, modeling, and cooperative monitoring, a new cooperative strategy is needed in the Willapa Bay watershed to control and correct bacterial contamination problems. There are several recent developments at the local and state level to encourage a cooperative relationship and approach. There are also strategies used in other areas of the state and nation that can be studied, borrowed, and built upon. The second part of our report presents these developments, model strategies, and approaches suitable for Willapa Bay.

PRELIMINARY WATERSHED BACTERIAL CONTROL STRATEGY

Introduction

The ultimate goal of this water quality assessment is to propose a preliminary fecal coliform bacterial control strategy for the Willapa Bay watershed. The Ecology Water Quality Program (WQP) is required to address the fecal coliform problem because portions of the watershed have been listed as water quality-limited. The total maximum daily load (TMDL) process is one approach Ecology's WQP can take to control bacteria in the watershed. Other Ecology programs have invested resources into supporting local water quality management organizations and locally directed initiatives, especially to identify and control nonpoint sources of pollution.

The first part of this report provided background information on the history and scope of the bacterial problem in the watershed. The second part of this report is an analysis of three major questions concerning a preliminary watershed control strategy for bacteria:

1) How compatible is the Ecology TMDL process with the local water quality management framework currently operating in the watershed?

2) What are some other strategy options to control bacterial contamination in the watershed?

3) What specific elements are necessary for an effective preliminary fecal coliform control strategy in the Willapa Bay watershed?

Local water quality management initiatives, various Ecology program activities, and successful strategies used in other watersheds will be examined to answer these questions. From this analysis, the most effective framework and strategy for Ecology and others to pursue in the Willapa Bay watershed will be outlined and recommended.

Local Water Quality Management Initiatives

Pacific County government agencies and citizens have undertaken water resource planning and management activities since 1972 (Shotwell, 1988). The past five years have seen the most sustained activity. This renewed local interest in water quality management was the result of three combined events (Willapa Bay Water Quality Organizing Committee, 1990):

1) "The appearance of real water quality problems in areas previously thought to be pristine and the confirmation of water quality problems in areas suspected of being contaminated;

2) Increased involvement of outside state and federal regulatory agencies and the threat of further involvement and loss of local control; and

3) Support by local officials and citizens for policy development to address real concerns requiring a proactive response. Local government also recognized that lack of response would lead to a lessening of local participation in finding solutions."

Because of these events, Pacific County has obtained funds from USEPA and Ecology to assess and plan water quality control options and create a local water quality management organization. The following documents have detailed some of the directions and framework desired by Pacific County to manage water quality.

Willapa Bay Actions and Programs--1988

In 1988, an Ecology Coastal Zone Management grant was used by the Pacific County Planning Department and the County Commission to draft a report: "Willapa Bay-Actions and Programs Required to Insure Its Continued Value as a Major Resource" (Shotwell, 1988). The report reviewed past efforts in the county by various levels of government, and outlined the current needs and actions necessary to assess and manage water quality in Willapa Bay.

The report had three primary targets for recommendations: Pacific County Commission actions, grants, and long-term programs. The report urged the commissioners to:

1) adequately staff county programs involved in the enforcement of water quality-related laws and regulations;
2) support USGS flow monitoring;
3) establish a body to oversee implementation and coordination of water quality programs; and
4) cease county pest control in sensitive areas, and urge other agencies to follow suit.

Second, the report recommended that grants be limited to short-term intensive studies on specific problems in Willapa Bay, or be used to cover initial costs in establishing long-term programs. Finally, the report suggested that long-term programs should be established for monitoring, habitat enhancement or restoration, and a local laboratory/research facility.

The report stressed that the long-term water quality plan and programs should be the focus of a permanent local oversight group. The group would also be responsible for the following:

- be a clearing house for grants in cooperation with regional planning;
- maintain records and a long-term database;
- initiate new programs in response to monitoring information, public input, or new laws and regulations; and
- stay attuned to the significance of monitoring and other work performed by enforcement agencies.

Willapa Bay Water Resource Management Plan--1990

In response to the Shotwell (1988) report and public comments during a series of public meetings in 1988, the Pacific County Commissioners established a Willapa Bay Water Quality Organizing Committee (Willapa Bay Water Quality Organizing Committee, 1990). Ecology Coastal Zone Management funds were obtained for the Planning Department to staff and administratively support the committee. The committee wrote the "Willapa Bay Water Resource Management Plan." The plan contained problem identification and recommendation statements on the following topics: on-site sewage disposal, aquaculture, agriculture, timber/forest, upland shoreline development, public education, recreation, and wildlife. Implementation goals were centered on long-term information gathering, community education and involvement, and methods to sustain local involvement. The committee also recommended that a Willapa Bay Water Resource Coordinating Council be created.

Willapa Bay Water Resource Coordinating Council (WBWRCC)

The WBWRCC was created by the Pacific County Commission in 1990. It is a 17-member advisory body with representatives from agriculture, aquaculture, city government, Native American tribes, commercial fisheries, development, education, industry, forestry, recreation, and the public at large. It has the responsibilities outlined by Shotwell (1988), and the organizing committee plan (WBWRCC, 1990) contained in the following four directives:

1) "continuously address water resource policy;
2) implementation (oversight) of water resource policy;
3) coordinating existing multi-agency jurisdiction; and
4) serve as a public forum to collectively discuss and find shared solutions to water resource problems."

Since the council is advisory, final decision authority still lies with the county commission (Willapa Bay Water Quality Organizing Committee, 1990). The council has obtained Centennial Clean Water Act funds through Ecology to continue and expand their efforts.

The Willapa Alliance

Ecotrust and The Nature Conservancy have formed a broad-based group called the Willapa Alliance. The group is "committed to sustaining the diversity and health of Willapa's unique environment, the local economy, and the people who live there." The Willapa Alliance has been active in many local issues and is considered another source encouraging the development of local empowerment in Willapa Bay.

The Willapa Alliance has been concentrating on gaining local support, identifying sources of information, working to establish a local center or institution for education and research, and gathering baseline information for an ecosystem assessment of the Willapa region. They are actively cataloging Willapa Bay geographic information system (GIS) coverages held by various agencies and organizations. They are also undertaking a salmon stock assessment and restoration potential study, and developing local interest in more environmentally compatible economic projects.

Pacific Conservation District and Pacific County Health and Human Services

The Pacific Conservation District is a cooperative but separately administered partnership between staff from the U.S. Department of Agriculture Soil Conservation Service (SCS), and staff from the Pacific Conservation District (PCD), a governmental subdivision of Washington State. These state and federal staff have been active in water quality issues with the Willapa Bay watershed agricultural community for many years.

The SCS, PCD, and Ecology have joined in agreements that define roles and responsibilities for several water resource issues. The SCS provides technical assistance to implement best management practice (BMP) systems on individual farms through their agreement with PCD and Ecology. A compliance agreement between the Conservation District and Ecology allows referral of most confirmed water quality complaints to the CD for farm plan remedial action before Ecology takes enforcement action. By offering the option to a landowner of working on a problem with the CD first, the CD acts as an intermediary between the landowner and the enforcement arm of Ecology.

The Willapa River farm inventory and attitude questionnaire by Geleynse (1990) is an example of how the PCD is trying to prioritize agricultural impacts on water quality (Appendix A). The PCD has also obtained State Revolving Funds (SRF) and other grants to help landowners with the cost of implementing BMPs. Through this type of work and their daily contact with the agricultural community, PCD and SCS staff perform an important role in education and alleviation of water quality problems in the watershed.

Pacific County Health and Human Services (PCHHS) has also been very active in responding to water quality problems in the Willapa Bay watershed. PCHHS has been working with a very limited local funding base. They used USEPA and Ecology grant funds to perform some of the following projects which are detailed in Appendix A:

- on-site septic system inspections in Bay Center and in areas along the Lower Willapa River
- a cooperative Long Beach Peninsula ground water study with USGS
- a year-long water quality study of major tributaries to Willapa Bay (Berbells, 1991)
- sanitary surveys and fecal coliform sampling in several watersheds
- marina and boat waste surveys

PCHHS works closely with DOH, Pacific County Planning, and the WBWRCC on problems as they arise in the county. They also perform an important function of educating the public about water quality and sanitation issues.

Coordination of Actions

The WBWRCC, SCS, and Pacific County government have been working together and developing the essential dialogue between the new and extensive county regulatory efforts and the local regulated population. They have made great efforts to educate and involve those that are immediately affected by water quality control measures and management practices. They continue to identify sources of contamination, implement on-site septic system repairs, mediate differences of opinion on effective control actions, and pursue nonpoint issue funding (e.g., CCWF, CZM, and shellfish district grants).

Nearly all of the recent reports from these local groups have recommended creating a comprehensive or long-term water quality monitoring network, and establishing a method of prioritizing and implementing nonpoint source problems in the watershed. These are important objectives of any strategy. The mechanism and organizational structure under which they are accomplished can vary. The bacterial contamination problems threatening resources in the Willapa Bay watershed are the result of point and nonpoint sources. The USEPA and others have been strong advocates of using a basin-wide TMDL approach for controlling water quality from mixed sources. Federal, state, regional, and local governments have used other watershed strategies, especially to control nonpoint source pollution. We will briefly examine TMDLs and some of these other efforts as instructive approaches.

The Total Maximum Daily Load Management Strategy

TMDL and WLA Descriptions

Section 303(d) of the federal Clean Water Act requires states to identify water bodies that are water quality-limited (*i.e.* water bodies that do not meet, or are not expected to meet applicable water quality standards after sources have undergone technology-based controls). Other federal regulations have defined source-specific best available technologies (BAT) and best conventional technologies (BCT) as technology-based controls for point sources. Legally enforceable best management practices (BMPs) are considered technology-based controls for nonpoint sources (USEPA, 1991b). Section 303(d) also instructs states to give water quality-limited water bodies a priority ranking based on the severity of the problem and the value of the resource being protected. These water bodies are then primary candidates for total maximum daily load (TMDL) evaluations.

The TMDL is a mechanism for establishing water quality-based controls on all point and nonpoint sources of that pollutant within a water quality-limited basin, sub-basin, or hydrographic segment. Water quality-based controls are source pollutant reductions beyond BAT and BCT controls. The TMDL evaluation uses monitoring data and water quality models to estimate the pollutant load that a water body can receive and continue to meet water quality standards. The portion of the pollutant load attributable to all point and nonpoint sources is also determined. Other portions of the TMDL are assigned to uncontrollable background sources, and to a safety margin that incorporates anti-degradation, future growth options, or data and modeling uncertainty. The pollution reductions required to meet the TMDL can also be quantified. TMDLs can be established on annual, seasonal, quarterly, or monthly periods. The final TMDL determination is then presented in a public hearing, and subject to comment and revisions.

The next part of the process is the waste load allocation (WLA) for point sources, and a load allocation (LA) for nonpoint sources. During the WLA/LA process, decisions are made locally about the division of the TMDL and load reductions allocated among the identified pollution sources. There are several proposed schemes for achieving an equitable WLA/LA among dischargers (Ecology, 1991a). A schedule for implementation and monitoring of compliance and control actions is agreed to by all parties in the WLA/LA. The implementation can involve modification of point discharge (e.g., NPDES) permits, installation of special treatment processes, local adoption of land use management regulations, or the submittal of farm management plans and BMP installation. The final TMDL and WLA/LA are submitted to USEPA for approval (Ecology, 1991a).

States are required to develop TMDLs and WLA/LAs that account for both point and nonpoint sources within a target water body. However, water bodies with nonpoint sources often have inadequate information for accurately quantifying nonpoint source contributions, and the effectiveness of additional source controls (*i.e.*, additional BMPs). Therefore, basins or water bodies with a large nonpoint source contribution are given special consideration and a "phased TMDL" approach is recommended (USEPA, 1991b).

The "phased approach" of TMDL development is used to establish load reductions based on estimates of load allocations where there is impairment due to nonpoint sources, or when there is a lack of data or modelling available. Its aim is to allow pollution reduction to proceed while data gaps are filled, especially to evaluate the effectiveness of the nonpoint source controls. Nonpoint load reductions include the implementation of control mechanisms, monitoring, and the assessment of standards attainment. If nonpoint source controls are less effective than initially estimated in the first WLA decision, point and nonpoint source allocations may have to be adjusted or other nonpoint management techniques explored.

A TMDL does not necessarily have to be conducted by Ecology alone. Although Ecology has not yet submitted it to USEPA as such, the DOH restoration studies and conditional area management plan for shellfish harvesting near Bay Center may be an example of a TMDL performed with only peripheral Ecology involvement. The closure action, monitoring, and evaluation of the problem by DOH closely parallels the TMDL process. DOH set a fecal coliform bacteria TMDL based on bacteria loading under critical rainfall and runoff conditions. Background and nonpoint source loads were identified. Local decision and effort to control nonpoint loads from on-site septic systems and farms were required before DOH could reopen the beds to harvesting. The remaining bacterial load was allocated to background conditions, and is part of the conditional area management plan. These actions are exactly what a load allocation requires.

The Ecology Water Quality Program (WQP) is responsible for managing the TMDL process in Washington State while final approval for a completed TMDL is given by USEPA. Recently, the Ecology WQP has restructured some of its activities using a basin approach, in part to address over 135 TMDLs needed statewide (Wrye, 1993). The process involves scheduling permit review, TMDL, and monitoring actions over a five-year repetitive cycle within a given geographic area. The cumulative result of these efforts will yield a comprehensive basin water quality strategy which includes the TMDL action for that year.

The Willapa Bay watershed has been placed with the Grays, Elochoman, Cowlitz, and Coweeman River watersheds as the Lower Columbia basin unit of the Ecology Southwest Regional Office (Figure 14). It is scheduled to receive focused attention for discharge permits and other actions in 1996 (Wrye, 1993). The Lower Columbia basin has eight water quality-limited waterbody segments, three of which are located in the Willapa Bay watershed:

- Willapa Bay based on Bay Center fecal coliform standard violations,
- Willapa River to river mile 6.4 based on fecal coliform standard violations, and
- Willapa River from river mile 6.4 to 18.2 based on dissolved oxygen, fecal coliform, and temperature standard violations.

<u>Ecology Shellfish Protection Programs</u>

Shellfish Protection Strategy--1984

The Ecology Shellfish Protection Strategy (Saunders, 1984) was developed by the Ecology Shorelands Division. The strategy was formed in cooperation with the Shellfish Advisory Committee, a group of 22 technically knowledgeable and involved people representing state and local agencies, and the shellfish industry. The purpose of the strategy was to educate interested parties about the causes and consequences of bacterial pollution in commercial shellfish areas, and to guide Ecology's responses to the problem.

Four major elements of policy and program efforts were identified to prevent further decertification of shellfish growing areas, and to restore degraded areas:

1) Ecology will promote and develop assistance for local governments to voluntarily implement basin planning. Plans will focus on watershed management to control bacterial contamination. Ecology will review results of the voluntary approach.

2) Ecology will direct intensive surveys in selected areas. Shellfish productivity, the degree of bacterial threat, and local support for corrective programs will be considered in selecting areas.

3) Ecology will initiate an intensive permit review policy requiring all staff reviewing any permit to consult shellfish resource maps to assess whether impacts to growing areas are likely.

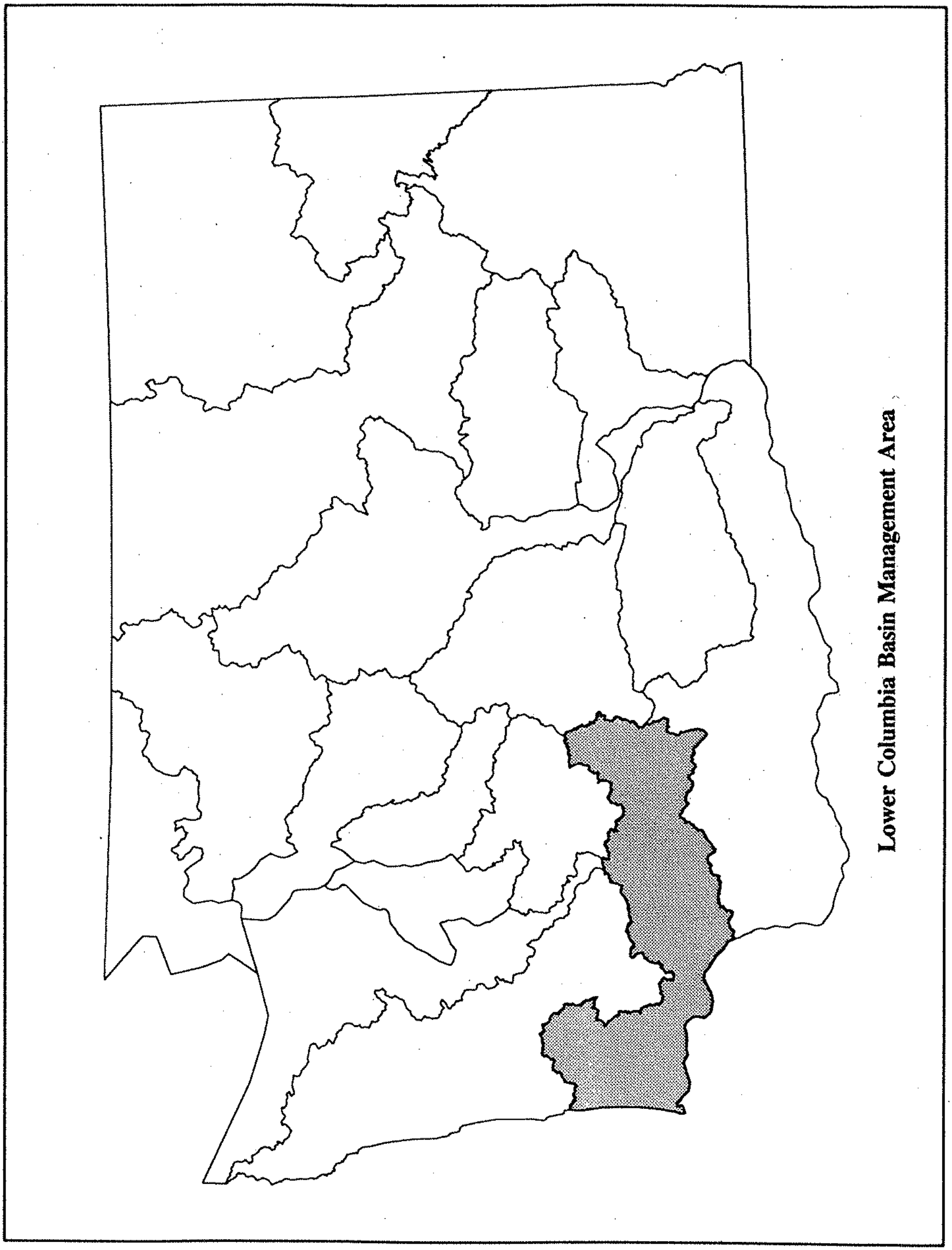


Figure 14. Department of Ecology Water Quality Program Lower Columbia Basin unit and planning area that includes the Willapa Bay watershed (Wrye, 1993).

4) Ecology and DOH will coordinate a point source discharge policy to evaluate reliability factors of STPs. Separate efforts by Ecology will evaluate the feasibility of developing regulations to preclude any additional point discharges in the unique areas.

The strategy identified three areas in Willapa Bay as unique growing areas of exceptionally high production. They were among six areas statewide designated to receive additional protective measures by Ecology (Saunders, 1984). The three areas were the Long Beach Peninsula, and the eastern/central and northern shorelines of Willapa Bay.

Shellfish Protection through Land Use Management--1992

The Ecology Shorelands and Coastal Zone Management Program has recently drafted a new document for shellfish protection. <u>Shellfish Protection Through Land Use Management</u> (Campbell, 1992) is a document to help local governments develop their land use management guidelines in areas effecting shellfish harvesting. Some county governments were required to do this under the state's Growth Management Act (GMA) of 1990.

The document shows how local jurisdictions can use the Shoreline Management Act and GMA to manage shorelines with water-related and water-dependent activities near shellfish growing areas. The guidance provides detailed descriptions of management and regulatory approaches on:

- residential density,
- agricultural and industrial uses,
- development rights,
- buffer zones, and
- set-backs.

It also makes specific BMP recommendations for all land uses adjacent to shellfish areas, and along water corridors (*i.e.*, uses within 1,000 feet of ordinary high water).

Coastal Zone Act Reauthorization Amendment Compliance

Ecology is now revising its Shellfish Protection Strategy to help bring Washington into closer compliance with new federal requirements from the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). The CZARA requires states to establish coastal nonpoint management programs for approval by both the USEPA and NOAA by 1995. The USEPA and NOAA have written guidance outlining minimum management measures (*i.e.*, systems of BMPs to reduce total impacts) for nonpoint source categories, and descriptions of representative BMPs (USEPA, 1991a). States failing to submit adequate coastal nonpoint management plans for approval will face cuts in federal nonpoint and coastal zone management funds.

Plans submitted by the states are required to address specific elements for approval (USEPA, 1991a). Briefly, these elements must accomplish the following:

- describe the coordination of the plan with existing state and local water quality plans and programs;
- provide documentation for implementation of management measures equal to or exceeding those outlined in the USEPA and NOAA guidance document;
- identify the type of nonpoint sources contributing and not contributing to problems in coastal areas, and programs and measures used to assess and control them;
- identify and prioritize coastal areas not meeting standards or threatened waters that require additional management measures;
- contain provisions for technical and other assistance to local government and the public to implement management measures;
- provide ways for public participation throughout the program;
- establish mechanisms for coordination between all agencies at all levels of state and local government with responsibilities for land use, water quality, habitat protection, public health, and safety; and
- propose modifications to state coastal zone boundaries to implement NOAA boundary recommendations.

The overall goal of the CZARA is to improve the success of state and local land use management, water quality, and coastal habitat programs by strengthening cooperative and coordinated efforts at all levels of government.

Ecology Shellfish Protection Initiative and Shellfish Protection Districts

The Shellfish Protection Initiative administered by Ecology's Shorelands Program was endowed with $3 million to supplement local shellfish protection efforts in Puget Sound and coastal areas. Through a competitive application process in 1992, five project areas were selected. The funded projects will identify problems, initiate enforcement actions, and provide cost-sharing for agricultural BMP activities. The Shellfish Protection Initiative's purpose was to find smaller basins for a focused bacterial control effort. The basins selected had strong potentials for measurable improvements and success. Counties that received this one-time disbursement of funds must also develop long-term funding strategies to ensure that water quality improvements are maintained after the state-funded projects end.

Another piece of related legislation has a potential to greatly affect the way Pacific County responds to commercial shellfish area downgrades. In 1992, the state legislature amended Chapter 90.72 RCW regulating Shellfish Protection Districts. Counties with shellfish tidelands are now required to create a shellfish protection district within 180 days of a commercial shellfish harvest area downgrade by DOH. The county council or commission must establish a program to control nonpoint sources of pollution and protect water quality within the district. The county can raise tax revenues, and charge inspection or installation fees to finance the protection program. Counties with shellfish protection districts are also given high priority for obtaining state water quality loans and grants. County legislative authorities can also voluntarily create these districts to generate funds for bacterial control projects.

Pacific County did not complete an application for the Shellfish Protection Initiative. If funding is reallocated in the future for this program, or a similar one, perhaps Pacific County could apply. A major difficulty faced by Pacific County for voluntarily creating a shellfish protection district is a low population base for generating fees. If compelled to create a district under RCW 90.72 regulations, creative funding solutions would need to be explored or state grants would have to be pursued.

Tillamook Rural Clean Water Project

The Tillamook Rural Clean Water Project (RCWP) demonstrates a cooperative and successful effort by the Tillamook Soil and Water Conservation District (SWCD) to bring together dairy farmers and shellfish growers in the Tillamook Bay watershed to improve water quality without creating major economic hardships. Advisory and evaluation committees of federal, state, local agencies and local organizations were created to help the SWCD with the process. The Tillamook Bay Water Quality Committee, with members from major interests affected by nonpoint source control actions, advised and assisted the SWCD with writing a nonpoint source abatement plan. The project has been funded by RCWP grants and other sources.

The ten year progress report (Tillamook SWCD, 1991) offers some excellent guidance for controlling agricultural nonpoint source pollution in rural watersheds while improving water quality in shellfish growing areas. The assessment of bacterial sources and installation of BMPs appear to be reducing bacterial levels in the bay, although the reductions will remain statistically inconclusive until more years of data are collected. Many lessons were learned throughout the project about what would and would not work in meeting rooms and out on farm sites.

The report details how an initial inventory of farms was conducted, and how each dairy and farm was given a placement on a priority ratings list. Some of the criteria used to establish top priority farms were:

1) farm operations adjacent to open waterways and characterized by poorly drained soils,
2) farm operations on estuarine shorelines and tidal areas,
3) farms located in river sub-basins having shellfish growing waters, and
4) farms on flood plains.

Highest priority for BMP education and implementation was given to farms or grazing lands located in all the first reaches of rivers, and along the bay shoreline.

The Tillamook report provided many implementation, institutional, and monitoring recommendations and conclusions. Several pertinent to the Willapa Bay watershed include the following:

1) A manure management system is more effective in controlling problems than a single BMP, and must be considered when developing realistic average costs of control actions.

2) The BMP implementation process must have low interest loan programs available.

3) Roofing of manure accumulation areas in a high annual rainfall area is more cost effective than collecting and storing contaminated rainwater.

4) Identifying the flood frequency of an area is important to estimate bacteria removal effectiveness of BMPs.

5) BMPs must be developed at the local level by selecting successful installations from working farms rather than small scale experimental or demonstration projects.

6) Agencies responsible for various program elements should have compatible computer networking capabilities.

7) Sufficient (more than two years) baseline water quality data are needed prior to project implementation.

8) Establish a minimum monitoring program with regular sampling intervals and consistent methods of data analysis early in the project. Adhere to the strategy throughout the project unless periodic evaluation indicates otherwise.

9) Education of the public about the benefits of BMPs should be initiated and continued. The enhancement of water quality and protection of shellfish resources and other beneficial uses of the estuary should be stressed as links to the future economic stability of the watershed.

10) Intensive studies need to be performed to establish baseline data on dairy and livestock bacterial source locations and loading.

11) Ensure that long-term monitoring continues after implementation of BMPs so future reductions in loading can be quantified, and BMP effectiveness can be evaluated.

<u>Puget Sound Action Plan</u>

Another management model that may be useful to the Willapa Bay watershed control strategy is the Puget Sound Action Plan (PSWQA, 1990). For the past five years, citizens in over 20 Puget Sound watersheds have successfully formed watershed management committees and have formulated, or are in the process of formulating, action plans to locally manage nonpoint sources. Several of the watershed committees have been specifically formed to protect shellfish resources. These activities have been made possible under a Washington State regulation (Chapter 400-12 WAC, commonly called the Nonpoint Rule), and through grants from the Centennial Clean Water Fund.

Each Puget Sound watershed management committee has representatives from groups with interests in controlling and managing nonpoint source pollution (e.g. shellfish growers, forest industries, local government, Native American tribes, development interests, citizen representatives, etc.). Puget Sound committees stress public education, coordination of efforts, prioritization of work, and comprehensive approaches to water quality problems. They have access to local staff for clerical and research support, but must seek outside funding sources for their activities. They also have access to limited help from state and federal agencies through the management plan process.

The management (or action) plans put together by Puget Sound watershed management committees contain watershed characterizations; problem identification; goals and objectives; and recommendations for voluntary, regulatory or educational control strategies. The action plans also have a monitoring strategy component, a plan review and revision process, and statements of concurrence from all planning and implementing agencies mentioned in the plan. The statements of concurrence bind the local entities to implementation of the completed and approved plan. Failure by any of the local entities to fulfill its responsibilities under the plan brings regulatory action by the Puget Sound Water Quality Authority and Ecology.

Compatibility to the Local Framework

Pacific County groups and individuals appear to seriously distrust state- and federally-led initiatives in Pacific County. A recurrent theme which appeared in the documents and during our research interviews was that state and federal agencies are inconsistent in their interest in Willapa Bay. The agencies have a perceived history of forcing generic water quality management programs on the area without asking for local involvement. The agencies then apply an incomplete and transient program without long-term commitment or support for local groups to follow through.

On the other hand, there is a perception among some state and federal agencies that little cooperation and coordination is present in Pacific County. Local politics and divided self-interests are blamed as being too strong to effectively attack bacterial contamination problems in Willapa Bay. Agency staff are frustrated that some long-standing and documented sources of contamination have not been controlled in a more timely manner.

This state of suspicion and misunderstanding between local interests and state and federal agencies is not conducive for solving the bacterial problems of the watershed and bay. It is evident that any strategy attempted will need to have close and balanced involvement by both groups to be successfully adopted. The strategy models presented earlier are reviewed here in the light of their compatibility with this political atmosphere.

<u>TMDLs in the Willapa Watershed</u>

It is likely that Pacific County would initially look upon fecal coliform TMDLs from Ecology and the USEPA as a heavy-handed approach from outside. Ecology will need to be internally committed to the TMDL process, and be willing to heavily involve others at the state and local level to successfully undertake a phased TMDL in Willapa Bay. The Ecology Water Quality Program (WQP) will need to clearly state the reasoning behind its TMDL priorities, and the geographic scope of the TMDL work.

A consistent internal commitment from Ecology and USEPA will be essential. Programs within both agencies will have to make Willapa a priority for regional and statewide resources. Ecology's WQP will need to integrate TMDL activities with Ecology's Shorelands and Coastal Zone Program and Water Resources Program actions in the watershed. A phased TMDL and WLA/LA integrated with other Ecology and USEPA program support would allow Ecology and local government to concentrate grant funds and staff resources on priority areas. Grant funds within Ecology should be more readily available to local governments for activities documented in a TMDL/WLA/LA agreement (Ecology, 1991); as should federal grant funds (e.g., Clean Water Act 319(h) and Coastal Zone Management Act funds).

DOH will need to be consulted early to help define TMDL conditions in shellfish growing areas. As stated earlier, some DOH and local actions may be equivalent to TMDLs when restoration studies are conducted and a conditional area management plan is written. In such cases, Ecology may be able to avoid making a redundant assessment.

The phased TMDL process will mean a long-term commitment and presence from Ecology and USEPA in cooperation with other agencies and the local community. Ecology and USEPA will need to establish a dialogue with local residents early in the TMDL process. Local and interagency involvement are envisioned as important parts of the WQP basin approach and the TMDL process (Wrye, 1993; Ecology, 1991). Due to the scheduling constraints imposed by the 5-year basin approach cycle, Ecology will be able to initiate and complete a fecal coliform TMDL for Willapa Bay prior to 1996, when WQP staff are slated to concentrate water quality management efforts in the Lower Columbia basin. However, the importance of the Willapa Bay shellfish resource to the state, the relatively high density of discharge permits, the history of local actions, and the presence of the WBWRCC should bring Willapa Bay and its tributaries to a high priority for TMDL consideration at the start of the next cycle in 1997.

The WBWRCC should be the local focus for Ecology and USEPA to introduce and coordinate both the WQP basin approach and any phased TMDL evaluation. Many elements of the phased TMDL strategy would be highly beneficial to the WBWRCC and other local agencies and groups. Decision-making roles during the planning and execution of TMDLs will be a major area for negotiation between agencies and the local community. Early involvement of the WBWRCC, PCHHS, PCD, and local groups with planning, data collection, and the subsequent evaluation process would probably make a better TMDL product. Local groups should be well aware of the TMDL process through the WBWRCC by the time Ecology ultimately presents the concept for public review.

The phased TMDL methodology offers a rational process to quantify present bacterial loading conditions and to make projections of possible actions to accomplish needed reductions. In this way, firm goals and objectives for specific areas of the Willapa Bay watershed can be formed by the WBWRCC or others. The methodology can also help identify realistic treatment options that would likely meet reduction objectives. Re-evaluation of the TMDL is also built into the process. In the phased-TMDL approach, a regular cycle of progress review is made. The Ecology WQP basin approach also ensures a review of the basin strategy and TMDLs on a regular cycle of five years.

The quantitative analysis and the specific load identification described in the phased TMDL process could be cooperatively conducted by Ecology, DOH, PCD, PCHHS, and other local groups in Pacific County. The monitoring data would be shared among all groups to guide implementation actions and evaluate their effectiveness. Long-term monitoring commitments to support a phased TMDL could provide a database able to profile the watershed for trend analysis, quantification and assessment of land use changes, or effectiveness of BMPs. Such a data set would have a broader application for a variety of regulatory mandates and control strategies. The database would also help in designing intensive studies. These additional studies, performed with interagency cooperation and shared data results, could serve to guide watershed management actions directed by the WBWRCC.

TMDL implementation can look very enforcement-oriented with NPDES permit modifications, BMP farm plan requirements, and noncompliance enforcement actions. Implementation in the Willapa Bay watershed will require local cooperation and innovative approaches for compliance. The WBWRCC, PCHHS, and PCD may know better than Ecology and USEPA which local solutions and approaches work best with identified sources to abate contamination. An agreed time frame for implementation would need to be negotiated between Ecology and the local groups. Ecology enforcement options would always be available for the local authority to use under current memorandums of agreement, or newly negotiated ones if local solutions failed to meet expectations.

There may be some technical problems with the phased TMDL approach for the Willapa Bay area. The first problem is that fecal coliform is a difficult parameter to establish as a TMDL. The fecal coliform criteria have no established limit in terms of duration (e.g., 1-hour, 4-day average, maximum not to exceed). Understanding conditions in upper watershed areas would require PCHHS and PCD input. Modeling fecal coliform loading has a high degree of uncertainty, and annual or seasonal loading estimates are not useful for comparison to criteria. New techniques for establishing an actual load in a fairly new regulatory framework could decrease credibility and acceptance by several key players. The effectiveness of various BMPs on fecal coliform load reduction is not well documented, and several iterations of implementation may be necessary to meet target loads. This could be frustrating to all parties involved in the process.

The second problem is that TMDLs developed through the WQP basin approach will not necessarily address the entire Willapa Bay watershed. Only three specific water body segments in the watershed have been identified as water quality-limited, and as high priorities for TMDLs. The limited resources of Ecology WQP and Environmental Investigations and Laboratory

Services (EILS) Program would probably focus TMDL work in these water quality-limited portions of the Willapa River and Willapa Bay. In fact, the focus may only be on the river segments if the Bay Center conditional area management plan is accepted as a TMDL by USEPA. Ecology would probably continue to rely on DOH and local data to identify other areas of the watershed not meeting water quality standards and in need of TMDLs. The Ecology EILS Ambient Monitoring Section could also establish short-term monitoring stations to characterize other areas of the watershed if the Ecology WQP requested it as part of the basin approach process.

In all, the phased TMDL strategy could become a piece of an overall Willapa Bay framework. The process will take a high level of commitment and resources from Ecology and USEPA. The TMDLs would likely only affect parts of the watershed, so the coverage is not as comprehensive as a watershed bacterial control strategy could be. The local community will probably not accept a TMDL until it understands the process and is given a role in planning, design, evaluation, and implementation. The strategy has much to offer both the local community and regulatory agencies for controlling bacterial contamination if a cooperative and interactive approach can be followed.

Locally Directed Strategies for Willapa Bay

The Ecology shellfish protection strategies, the Puget Sound watershed plans, and the Tillamook RCWP strategy all rely on local initiative and direction more than the TMDL approach. State and federal agencies play important advisory and resource roles in these strategies, but the regulatory power is directed by a high level of local involvement and structure. The ability of the local group to achieve its goal of improved water quality depends on staying focused getting diverse groups to work cooperatively on common goals, and generating adequate funding.

The WBWRCC would be the most likely local group to plan and direct a watershed control strategy for bacterial contamination. The determination of Pacific County to control its destiny led to creation of the WBWRCC, and it appears to be committed to its purpose of finding local solutions for evaluation and remediation of water quality problems. They have been successful in coordinating, planning, and implementing activities with PCHHS, PCD, and other local agencies and interests. Water quality issues related to bacterial contamination control appear to be a high priority with the WBWRCC. Ecology's Shorelands and Coastal Zone Program and Water Quality Financial Assistance Program, and USEPA's Near Coastal Waters Program, have strongly encouraged and funded WBWRCC water quality activities.

The WBWRCC's advisory relationship to the Pacific County Commission is much like the Tillamook Bay Water Quality Committee's relationship to the Tillamook Soil and Water Conservation Commission. This organizational structure appears to be currently effective. If the WBWRCC needed to broaden their influence beyond the county commission for implementing a control strategy, they could consider becoming more like a Puget Sound management committee. This could come about by gaining concurrent agreements from local, state, and federal agencies and local user groups on implementing elements of the 1990 Water

Resource Management Plan. The county would remain the lead agency, but responsibility for implementing plan elements would be clearly distributed among signatories to the plan with WBWRCC oversight.

The WBWRCC provides a forum for a clear exchange of information on actions taken by several levels of government working in the Willapa Bay watershed. Local government can have direct communication access to state and federal water resource agencies through the WBWRCC. For example, when the Ecology WQP needs to perform a TMDL as a legal requirement, it would present the problem to the WBWRCC for local perspective. If the WBWRCC decided to take the lead role, Ecology WQP would then work closely with the WBWRCC and other Ecology programs to integrate the TMDL into the local control strategy. Ecology WQP could assist the WBWRCC with technical resources, and perhaps Ecology could also help coordinate funding. The WBWRCC control strategy implementation would be expected to bring the water quality-limited segments into compliance with water quality standards within a specified time period. According to USEPA guidance on TMDLs, bringing a waterbody into standards compliance through a nonpoint control program would remove it from the water quality-limited list (USEPA, 1991b).

The WBWRCC does not contain a mechanism, committee, or other structure for outreach to state or federal government representatives except through a staff person from Ecology Shorelands Program's Shellfish Protection Unit. One of the WBWRCC's directives is to coordinate existing multi-agency jurisdictions, and it may remain isolated until there are formal links to regulatory agencies involved in the Willapa Bay watershed. Some Puget Sound watershed committees and the auxiliary Tillamook Evaluation Committee included state or regional agencies with local regulatory authority as full members of the committee. An auxiliary board of agency staff as advisory members is another option. Stronger links could be beneficial for scientific and regulatory information, cooperative work agreements, and filling-in areas where local expertise is lacking. For example, a multi-agency meeting under the direction of the WBWRCC could begin creating a comprehensive or long-term water quality monitoring network, or establishing a method of prioritizing and implementing nonpoint source problems in the watershed.

The WBWRCC has been given the role of addressing many water-related resource and quality issues with limited resources. WBWRCC sub-committees with specific problem-solving tasks rely on a limited number of county planning and health services staff for technical assistance. Competitive short-term state and federal grants fund WBWRCC operations, and similar grants are used to implement programs. As with many organizations, the issues which are assigned staff, funding, and volunteer resources are those which are immediate "crisis" problems, or those which can be more readily resolved. Implementing a control strategy for problems before they become critical, and dealing with chronic problems that require involvement beyond educational outreach and volunteer cooperation can be serious challenges to a largely volunteer organization. Organizations can lose focus and momentum, experience volunteer burn-out, and suffer serious internal political breaks under the pressure of limited resources and broad responsibilities.

A locally directed strategy for controlling bacterial contamination in the Willapa Bay watershed can be successful. The WBWRCC, or some other local group, can achieve water quality improvements required under the TMDL process if they:

- maintain local interest and commitment at a high level,
- continue to receive grants or create alternative funding strategies,
- address difficult bacterial loading problems that require more than voluntary compliance,
- establish specific goals and procedures for monitoring and action, and
- develop cooperative agreements with state and federal agencies with jurisdiction in the Willapa watershed.

Organizational Model Summary

Pressure for agencies to organize and control bacterial problems in the Willapa Bay watershed is coming from several directions. DOH is building a database through its new monitoring program which, in the near future, could show bacterial problems in more areas of the bay. Ecology WQP is reorganizing to address TMDLs in the watershed through a comprehensive management approach. Ecology must address the new CZARA requirements to show progress in controlling nonpoint sources in coastal watersheds. USEPA's Near Coastal Waters Program, Ecology's Shorelands and Coastal Zone Program, and Ecology's Water Quality Financial Assistance Program have responded to local citizens and groups with support of action through WBWRCC and local agencies.

Recent local initiatives in Pacific County appear to be effective in getting citizens and local agencies to work on bacterial source controls. However, more resources are needed to address the bacterial problems within the basin, and ensure protection of water quality and all beneficial uses. A phased TMDL strategy directed by Ecology with an emphasis on local cooperation and interaction has many similarities to a comprehensive nonpoint source strategy directed by a local group like the WBWRCC. Both strategies appear to be capable of success, but the local initiative would probably have a broader geographic focus than the TMDLs. The TMDLs could be complementary components of the local control strategy, providing technical resources and direction to specific areas in the watershed.

A bonding of local, state, federal, and private efforts and resources has been successful in areas like Puget Sound and Tillamook Bay, and could enhance the Willapa Bay watershed effort as well. Government agencies at all levels, local groups, and non-government organizations with active interests or authority in Willapa Bay watershed bacterial issues should come together and choose a primary framework around which to organize a control strategy. The WBWRCC could arrange a series of meetings or presentations on the issue. USEPA had one meeting in 1992 which could be built on. The proposed Ecology WQP basin approach may provide a scheduled opportunity before 1996 for Ecology to present such a choice to the Willapa Bay watershed community. It is an essential part of the basin management process for the different Ecology program interests to discuss an integrated agency approach before they meet with locals and other agencies.

An effective strategy to control bacterial contamination in the Willapa Bay watershed will come only when local and outside groups are working together under a common set of goals and agreed upon priorities. This usually will not occur until a lead agency or organization is recognized, and an organizational structure is defined. Implementing a control strategy will require resources beyond the capabilities of one agency or group. Only through pooling resources can a comprehensive effort be achieved.

Recommended Elements for a Preliminary Watershed Control Strategy

Once the structure and framework are decided, there are major elements that need to be addressed in a bacterial control strategy for the Willapa Bay watershed. These include:

- coordination of information and resources,
- setting priorities,
- education and outreach,
- periodic re-evaluation of goals and priorities, and
- long-term and special project monitoring.

We have seen in this report that several documents have listed important elements for action in the Willapa Bay watershed (CH_2M Hill, 1981; Carelli, 1983; Shotwell, 1988; Willapa Bay Water Quality Organizing Committee, 1990). Other studies and projects also have very insightful recommendations that should be considered for a strategy (Tillamook SWCD, 1991; Phillips, 1991; Campbell, 1992). This section does not include an exhaustive list, but some select elements are drawn from the sources listed above, and the data covered in the main body of this report.

<u>Coordination of Information and Resources</u>

The previous section explored the possible organizational structures available to conduct a bacterial control strategy. Whichever structure is chosen, a lead agency or organization should be identified, and it should be the center of communication channels through which the strategy operates (USEPA, 1987). The roles of all groups involved in the strategy, and mechanisms to ensure effective coordination of work, should be clearly established in writing. The structure should be kept to as minimum a size as possible to focus interested groups on the strategy.

Pacific County agencies and organizations, and state and federal offices need to devise a way to coordinate information and resources for the Willapa Bay watershed. Effective actions to control bacteria in the watershed can only proceed if all parties work together. Unfortunately, Pacific County and state and federal agencies that have regulatory responsibilities concerning shellfish and water quality issues are not well coordinated at present. Participation and information exchange might be encouraged in several ways:

- well-planned meetings that include representatives of all agencies and interest groups;

- identification of state, federal, and local technical resource staff with an invitation for their participation;
- scheduled quarterly or biannual meetings similar to the USEPA Near Coastal Waters-sponsored meeting in 1992; and
- invitation to local representatives to participate in the Ecology WQP approach or TMDL strategy teams.

Communication is hindered in another way. Local, state, and federal agencies often have multiple programs within each agency that are involved in Willapa Bay water quality issues. For example, the Department of Ecology has local involvement through at least five programs and a regional office: Shorelands and Coastal Zone, Water Quality, Water Resources, Environmental Investigations, and Water Quality Financial Assistance Programs; and the Southwest Regional Office. Only the Shorelands Program has a staff person that regularly attends WBWRCC meetings. Each agency has internal coordination problems that exacerbate the problem of communication between agencies, between levels of government, and between agencies and local citizens. Although Ecology is beginning to integrate programs through a basin approach, a challenge for the lead agency or organization will be to either contact all programs involved in Willapa water quality issues, or convince each agency to organize communication for its programs around an internal primary contact. The latter approach has been advocated by local governments around the state for several years.

All parties need to have access to information, and be aware of resources available to them to participate in a control strategy. The current effort of the Willapa Alliance to gather GIS coverages and environmental data into one database is a good start. Information exchange could expand to memorandums of agreement on roles, responsibilities, and funding in response to shellfish harvest closures, water quality standards violations, or other water quality concerns. Computer access to the database by all parties would be highly desirable as well. A resource center in Pacific County also is appealing. Another alternative would be a resource directory. The groups that use the data need to know what others are doing to foster coordination. A newsletter or other communication forum sponsored by the lead organizing group would be helpful so that groups within the strategy could regularly share information of interest.

Setting Priorities

Conducting a successful bacterial control strategy requires clear and concise goals and objectives. When goals and objectives are established, monitoring can be directed and data evaluated to establish priorities for effective control actions. Setting priorities is especially important when time and money are limited--as it is for Willapa Bay.

Past water quality work, especially bacteria-related studies, in the Willapa area has been conducted by various groups pursuing different sets of goals and objectives. Most work appears to come under one or more of three major goals:

1) investigations of general surface or ground water quality with respect to standards and criteria,
2) protection of water quality in shellfish harvesting areas, and
3) response to public health complaints.

Several study objectives have been used by groups to evaluate data and meet their major goal(s):

- locate bacterial sources to prioritize problem areas and target control activities;
- measure impacts from one or several sources over an event, a season, or a year;
- compare sub-basin bacterial contributions;
- evaluate changes in water quality over time;
- compare seasonal differences in bacterial concentrations or loads;
- compare indicator species concentrations;
- measure differences between analytical methods; and
- meet regulatory or program requirements.

These goals and objectives would probably become adopted into an overall control strategy for the Willapa Bay watershed. It would be the responsibility of the organizing group to prioritize interests under the control strategy. For example, protection of public health should become a major objective. Evaluation and protection of shellfish harvesting waters, groundwater investigations, and bacterial concerns in primary contact recreation areas have close connections to public health concerns. In addition, protecting shellfish harvest areas provides a powerful economic incentive for controlling bacterial contamination. As was found in the Tillamook project discussed earlier, the link between economic stability and water quality protection is clear when jobs are at stake. When harvest closures or restrictions are threatened or occur, activity and interest by all government and non-government parties increase. A similar connection might be made between the need to protect groundwater and shellfish resources through careful management of land development in environmentally sensitive areas.

Bacterial sources that are public health threats may emphasize bay or lower watershed problems at the expense of upper watershed problems. Few primary contact uses appear to be present in the upper watershed (e.g., swimming beaches and surface water drinking supplies). However, bacterial data from the upper watershed indicates poor water quality, which could impair some secondary contact recreational uses like fishing and boating. In addition, bacterial contamination is often accompanied by sedimentation and eutrophication which can impact fish rearing and spawning habitat. Parameters other than bacteria may also need to be considered in the control strategy.

Prioritizing human health protection may also emphasize human sources of bacteria. Higher potential risks to human health would be more likely to come from disease organisms found in human fecal wastes. Therefore, identification and control of on-site septic system failures and combined sewer overflows (CSO) should become a priority over livestock, wildlife, and industrial sources. Much of the recent work performed in the Willapa Bay watershed by local government agencies has been directed this way. However, there is some evidence that non-human sources of bacteria that can cause human illness can reach shellfish areas with a potential for transmission (Stelma and McCabe, unpublished paper). Except by individual source investigation, there is yet no practical way of differentiating bacteria from human and non-human sources. The National Indicator Study being conducted by the Food and Drug Administration and several other agencies may eventually develop methods for source identification, but until then all sources will need to be controlled because of unknown health risks and current regulatory policies.

Education and Outreach

Education and outreach are important ways a control strategy becomes locally established. Whether pursuing a TMDL approach or a locally-based initiative, the citizens, government agencies, and non-government organizations need to be informed about what actions are taking place, and how they can (or should) be involved. Locally, education creates a sense of interest and accomplishment. A vigorous outreach program often leads to voluntary compliance, or less resistance to BMP implementation. Outside Pacific County, education elements of the control strategy can help bring necessary political support and funding.

Education and outreach can take several forms. Successful educational programs in other areas of the country have effectively used radio, newspaper and TV media, landowner meetings, field days, demonstration farms, youth activities, organization newsletters, and county fair exhibits. Two impressive local examples of education are underway. The aquaculture lab at the South Bend High School Aquaculture Center has a high-quality experimental curriculum where students have hands-on experience with culturing plants and animals, water quality testing, business management, marketing, financing, and permitting. The students helped build and maintain a substantial laboratory. The second is the construction of a 250 square foot information center at the Washington State Department of Fisheries, Willapa Shellfish Laboratory. The center will feature an aquarium and interpretive displays of local estuarine ecology.

Information exchange and links to groups outside of Pacific County are important. A copy of the video "Understanding and Maintaining On-Site Sewage and Disposal Systems" produced by Mason County and funded by Ecology was sent to PCHHS for their educational outreach programs. Sharing of informational and educational materials helps to reduce costs of education programs. The WBWRCC invitational tour of the bay held in summer 1992 was another good approach to familiarize both local and outside groups with the problems of the bay. Both of these actions helped establish ties for working on common goals, and informed others about ongoing Willapa bacterial control efforts.

Re-evaluation Cycle

Once control strategy goals are established and various programs are operating, a formal re-evaluation cycle should be scheduled. The cycle could be scheduled on a regular interval, perhaps in coordination with Ecology's WQP five-year basin cycle. The purpose of the re-evaluation would be to provide feed-back on the effectiveness of the entire control strategy, and to reflect on the strategy's direction. The re-evaluation report should evaluate progress on:

1) meeting the overall strategy goal and objectives,
2) assessing bacterial water quality in the watershed through the monitoring program,
3) identifying and targeting bacterial sources for control actions,
4) updating priority issues, long-range management goals and management strategies, and
5) implementing control actions.

In addition to the large scale effort, re-evaluation of specific control actions must be built into the system. This requires detailed tracking of implemented controls, and monitoring their effectiveness. Often controls (e.g., BMPs, on-site system repairs, or land use plans) are incompletely implemented, so improper conclusions are drawn from the resulting receiving water data. Only through adequate tracking, inspection, post-treatment evaluation, and monitoring can cause and effect be shown. Periodic visits to control action sites need to occur over the long-term to ensure maintenance and test control action longevity.

<u>Monitoring Networks</u>

Monitoring of water quality and land use are essential for achieving the control strategy goals. An integrated and coordinated long-term monitoring effort for both water quality and land use could create databases indispensable for making bacterial control evaluations and management decisions. Intensive surveys based on specific objectives are also necessary components of a monitoring network plan.

Long-term Monitoring

Long-term water quality monitoring at established stations provides data on bacteria for trend analysis, and a way to evaluate the overall effectiveness of actions taken under the bacterial control strategy. The stations established by Pacific County, USGS, Ecology and DOH provide an excellent foundation from which to build an effective monitoring network. They provide a good spatial and temporal coverage of many of the critical resource areas of the bay and watershed. Data collected by WDF, universities, and private groups need to be considered in planning a network. For example, WDF salinity and temperature data collected at the Willapa Shellfish Laboratory may be important for estimating bacterial die-off or interpreting bacterial data. Unpublished data collected by groups like Weigardt and Sons Oyster Company may be helpful in local problem assessment.

Changes in the monitoring design resulting from a integrated effort should be well thought-out and match informational and statistical objectives of the control strategy and agency programs. For example, a seasonally stratified monitoring design for the bay areas could be used to concentrate on critical shellfish harvest and nonpoint runoff periods (e.g., increased monitoring November through January, and decreased monitoring July through September). What would be lost in annual coverage could be gained in more intense seasonal or spatial coverage. In another example, both DOH and Ecology have recently changed their ambient monitoring program schedules in Willapa Bay. The changes to more frequent, scheduled monitoring should provide better representation of seasonal water quality differences and allow more opportunities for inter-agency coordination. Pacific County monitoring stations along the tributaries with reactivated USGS flow monitoring stations should be included in a coordinated effort as well.

Agreements on sampling protocols and the collection of additional physical and chemical parameters would be needed to integrate the long-term monitoring network. Resolving fecal coliform and additional analytical issues would require further discussion and research. The usefulness of historical data should be considered, but should not dictate monitoring station locations and procedures. Decisions on whether to collect samples for other indicator bacteria species (e.g., National Indicator Study recommendations) should be made as early as possible with anticipation of future needs and meeting strategy objectives.

Long-term efforts at documenting and tracking land use and shellfish growing area data should be accelerated. Farm inventory work performed by Pacific County SCS, and on-site septic system work being performed by PCHHS, should be made electronically available.

Detailed tracking of changes in land and commercial shellfish area uses may be necessary to make meaningful data evaluations and control decisions. In keeping with the primary goals of the bacterial control strategy, bay shoreline and river mouth reaches should be a high priority. Candidate BMP implementation areas, like the mid and upper Willapa River agriculture-rural zone, may need detailed data as well. Tracking shellfish harvest area production or classification changes would ensure the monitoring network is applied to the goal of resource protection.

Intensive Monitoring

Intensive monitoring surveys for source and problem identification should be included in the control strategy to better direct water quality management decisions (Ward, *et al.*, 1986). Intensive studies could assist in a range of activities, from developing estuarine models to clarifying specific source problems in shellfish areas. They should be tasks designed to answer data needs for a specific objective. For example, many intensive rain events were monitored in the Bay Center area over several days by the DOH Restoration Program. Indicator bacteria and rainfall data from the study were used to determine Conditional area shellfish harvest closure and reopening criteria. These criteria use the relationship between rainfall and fecal coliform levels as a trigger to open and close harvesting in that shellfish area. This type of intensive information gathering could also assist in developing wash-off loading functions for NPS models. The following are general descriptions of other intensive monitoring surveys that would further characterize bacterial water quality for human health and shellfish protection in the Willapa Bay watershed:

1) Storm runoff monitoring in Water Quality Zones 2 and 3 (*i.e.*, the mouth of the Willapa and North Rivers, and the east shore of the Long Beach Peninsula) is needed during the major shellfish harvest season of October through December. Data are needed to assess

the impact of point and nonpoint bacterial sources on water quality in Class 1 and 2 shellfish growing areas during major loading events. Sampling of marine waters, shellfish, major rivers and sloughs, and of sources or runoff sites is needed over extended rainfall events. Areas of suspected on-site septic system failures and combined sewer overflows should be sources with the highest monitoring priority. Data should provide a profile of peak bacterial runoff concentrations from sources, response time from sources to harvest areas, die-off rates, and shellfish exposure duration and resultant tissue concentration.

2) Diked grazing pastures with tidal gate mechanisms need to be monitored to understand their bacterial impact on adjacent shellfish growing areas. Calculating an instantaneous or total flow through tide gates to assess loading has been a problem. Tidal gate operations and their relationships to tidal heights, upstream water height, and flow exchange need to be integrated into predictive models. Then perhaps a simplified monitoring procedure using staff gages may be applied. In this way the relative impact of these numerous sources can be evaluated, and BMPs for each site can be designed if necessary.

3) Fecal coliform die-off rates in specific watersheds, and their relationship to estuarine flushing near harvest areas, need further definition. Data are especially needed to determine seasonal variability in die-off rates and the impact of controlling factors such as salinity, temperature, and sedimentation.

4) The role of resuspended sediments as a reservoir of fecal coliform and subsequent contamination of overlying water is of particular concern to shellfish growers in Willapa Bay. The role resuspension plays in determining fecal coliform transport and fate needs to be better understood. Findings could have important implications for the potential impact of upper watershed sources.

5) The upper Willapa River fecal coliform sources need to be identified.

6) Bayshore and river sources identified by CH_2M Hill (1981) in their 1980 sanitary survey need to be re-evaluated. The North River, Cedar River, Grayland Ditch, Nemah River, Naselle River, and Palix River all need detailed fecal coliform source surveys. Priority should be given to areas nearest Class 1 and 2 shellfish growing areas, especially in Water Quality Zones 2 and 3.

7) Seafood processors along the lower Willapa River and near Bay Center may be a seasonal source for bacterial loads. The source of fecal coliform bacteria within the plants is still a major question. The overall bacterial impact of these plants on shellfish resource areas needs clarification.

8) The impact on local bacterial water quality from Bay Center on-site system upgrades and the Hewitt Addition sewer line installation need post-action evaluation.

9) Farm inventories along the entire bayshore need to be completed. River reaches near the bay should also be included. Inventory data should be entered into a geographical database. Farms with a high risk of creating bacterial contamination problems in shellfish harvesting areas should be notified. A vigorous effort should then be made to educate farm owners and achieve voluntary BMP installations.

10) Bacterial impacts and seasonal bacterial loads from wildlife in the Willapa Bay watershed need more investigation. Potential problems include: spring harbor seal pupping areas, elk herd wallows in near tidal meadows, and migratory bird populations.

Special Projects

1) An accurate estimate or calculation of seasonal flushing rates for the four Water Quality Zones and the whole bay would be useful in evaluating fecal coliform loading. A more complete definition of general estuarine circulation, and transport of water through channels and sloughs and over flats, is needed.

2) A basic nonpoint model for the Willapa Bay watershed needs to be constructed to evaluate fecal coliform loading. Ideally, geographic information system (GIS) coverages would be incorporated into a unit load/mechanistic model structure. This would then be linked to a transport and estuary model constructed from data gathered in item 1.

3) Fecal coliform trapping and resuspension in river and bay sediments need further investigation. Underestimation of the contribution from resuspended bacteria could lead to poor bacterial control decisions.

4) The efficacy of monitoring other indicator or pathogenic bacteria/virus species needs more research. Fecal coliform is not an ideal indicator, and could be abandoned in the next 20 years. The control strategy should be prepared to switch, or have a potential "back-up" indicator already in place. The progress of the National Indicator Study should be followed closely, and critically examined.

SUMMARY AND CONCLUSIONS

Several potential and documented sources of bacterial contamination are present throughout the Willapa Bay watershed. Point sources probably pose less of a contamination threat than nonpoint sources. Malfunctioning on-site systems, combined sewer overflows, and livestock manure are nonpoint sources with the greatest risk to human health through ground water and shellfish sanitation. Less is known about the impact from wildlife (seals, elk, and birds) on shellfish growing waters. Generally, sources along the bayshore and downstream river reaches have a greater potential impact on shellfish areas than upper watershed sources.

The largest portion of Class 1 and 2 shellfish growing areas are in Water Quality Zones 2 and 3 of Willapa Bay. Zone 2 (lower Willapa and North Rivers) shellfish growing areas are the most threatened by point and nonpoint fecal coliform sources. Zone 3 shellfish areas and ground water supplies also have a high potential for bacterial contamination problems if population growth pressure persists along the Long Beach Peninsula. Major fecal coliform problems also occur in the upper Willapa River watershed, but they probably do not seriously affect shellfish growing areas.

Analysis of Ecology long-term monitoring data indicates fecal coliform counts may have decreased in the lower Willapa River during high tidal stages in response to completion of sewage collection system improvements in the cities of Raymond and South Bend around 1985. Although there are some problems with the data, the trend appears to be present in the lower river and at the station located just upstream of Raymond.

Several historical studies and monitoring programs have documented a variety of bacterial problems and sources in the Willapa Bay watershed. Delayed action on the part of regulatory authorities to control documented sources in the Bay Center shellfish harvest area led to restrictions, closure, and then reclassification by DOH. Other areas in Willapa Bay have similar potential for restriction or closure conditions which could prove economically devastating for the area.

Water quality and land use databases are not complete or compatible enough to perform more than simple evaluations of bacterial loading. The influence of Willapa Bay estuarine circulation and flushing mechanisms on bacterial populations are complex and not well studied. The lack of important source and transport data hinder accurate appraisals of bacterial loading problems, and will need to be remedied before a TMDL analysis of large portions of the bay can be performed.

Plans and strategies for water quality improvement in Willapa Bay have a long history. Through local initiative and some outside financial support, locally coordinated actions have been directed at water quality problems. Local government and non-government organizations, and state and federal agencies currently have a high level of interest in water quality in the Willapa Bay watershed, but cooperation has been hampered by mutual suspicion and distrust.

The phased TMDL approach offers a systematic process for controlling bacteria in portions of the Willapa Bay watershed. The TMDL/WLA/LA process has a defined structure that requires local, state, and federal cooperation. Ecology programs are working to integrate the TMDL process into existing basin activities through a basin approach strategy. However, it is not easy to establish a bacteria TMDL, especially because of the high degree of variability in fecal coliform numbers. TMDL actions might also be limited to the three identified water quality-limited portions of the Willapa Bay watershed because of limited staff resources. The TMDL and Ecology basin strategies should include mechanisms to negotiate direction and decision-making authority with local groups early on and throughout the process.

Initiatives to improve and protect water quality in the Willapa Bay watershed were revived by local governments and citizens in the late 1980's. They have been aggressively working to act on water quality issues in a comprehensive and proactive manner, especially through the Willapa Bay Water Resources Coordinating Council (WBWRCC). The WBWRCC has enjoyed local, state, and federal encouragement, cooperation, and support, but the WBWRCC has limited ties to state and federal regulatory agencies. Effective implementation of nonpoint source controls requires sustained commitment and resources from the WBWRCC. A mechanism to include outside regulatory and resource agencies could be helpful, especially to take advantage of technical resources and funding opportunities, and to become informed about planned regulatory actions.

Recent local initiatives in Pacific County appear to be effective in getting citizens and local agencies to work together on bacterial source controls. However, more resources are needed to address the bacterial problems within the basin, and ensure protection of water quality and all beneficial uses. A strategy of phased TMDLs directed by Ecology with an emphasis on local cooperation and interaction has many similarities to a comprehensive nonpoint source strategy directed by a local group like the WBWRCC. Both strategies appear to be capable of success, but the local initiative would probably have a broader geographic focus than the TMDLs. The TMDLs could be complementary components of the local control strategy, providing technical resources and direction to specific problem areas of the watershed. Integration of the Ecology WQP basin approach with other Ecology program activities, especially the Shorelands and Coastal Zone Program, could also help the WBWRCC with long-term water quality monitoring and problem identification.

RECOMMENDATIONS

Government agencies, non-government organizations, and local groups with active interests or authority in Willapa Bay watershed bacterial issues should meet and decide the primary mechanism for conducting a control strategy. The Ecology WQP will be focusing permit issuance and other actions in the Lower Columbia basin management unit by 1996. Progress on a comprehensive and cooperative control strategy should be made earlier by Ecology programs, USEPA, or WBWRCC. The meeting should result in the identification of a lead agency or organization, with written descriptions of the role of each participant and the mechanisms for cooperation in the strategy.

Whichever structure is chosen, local, state, and federal interests need to balance decision-making authority. Local empowerment should be actively cultivated by federal and state agencies. In turn, local groups should acknowledge the regulatory responsibilities of state and federal agencies. The attitude of suspicion and mistrust should be eliminated, and one of common purpose and cooperation should be fostered.

Ecology programs, DOH, and USEPA should continue to support the work of the WBWRCC, PCHHS, PCD, and other local agencies and groups while a more comprehensive structure evolves. The participation of the Ecology Shorelands Program staff at WBWRCC meetings should be encouraged, and staff from other Ecology programs should become involved.

The DOH management plan for Conditionally Approved shellfish harvest areas near Bay Center should be considered for submittal to USEPA as a TMDL and LA. The closure action, remedial activities, monitoring, and evaluation of the problem parallels the TMDL process closely.

Protection of public health should be among the highest priorities for the strategy. Protection of shellfish harvesting beds and groundwater in response to public health concerns may emphasize control of human sources of bacteria at locations near the bay. This may de-emphasize bacterial problems in the upper watershed or from non-human bacterial sources. However, all sources need to be addressed since it is neither practical nor within the regulatory framework to distinguish between bacterial sources when water quality is threatened or degraded.

The lead agency or organization should emphasize coordination of information and resources. Interagency and intra-agency communication mechanisms need to be established, perhaps to the point of memorandums of agreement. Electronic accessibility to data would be helpful. The current effort by the Willapa Alliance to obtain or catalog geographic information system (GIS) coverages of the watershed generated by various agencies and organizations should be encouraged and expanded.

Once the control strategy goals are established and various programs are operating, a formal, routine re-evaluation cycle should be scheduled. It could be conducted by a particular agency, organization, or over-sight committee. The purpose of the re-evaluation would be to provide feedback on strategy effectiveness, and to reflect on strategy direction. Also, evaluation of specific control actions after their installation and over the long-term is necessary to ensure proper installation and maintenance, and to test the effectiveness and longevity of the action.

Education and outreach are important ways a control strategy becomes locally established, so these components need to be included into the strategy plan. Education and outreach programs should accomplish the following:

- encourage local citizen participation and support,
- keep citizens and groups aware of control strategy actions and plans,
- encourage voluntary compliance with BMP implementations,

- foster local stewardship and awareness, and
- bring necessary political support and funding for the control strategy from the outside.

A long-term monitoring plan for water quality should be established under the direction of the organizational structure to provide data for trend analysis, and a way to evaluate the overall effectiveness of the strategy to reduce bacterial contamination in the watershed. To the degree possible, the stations established by various agencies should be integrated into a monitoring network to match informational and statistical objectives of the control strategy. Agreements on sampling protocols, such as MPN versus MF, and the collection of additional physical and chemical parameters will be needed to integrate the long-term monitoring data. Re-establishment of USGS gaging stations on all major tributaries to Willapa Bay should be a priority if bacterial loading data are needed. The usefulness of historical data should be considered, but should not dictate monitoring station locations and procedures. Decisions on whether to collect samples for other indicator bacteria should be made early in the process with anticipation of future needs and meeting strategy objectives. Local involvement in data collection should be encouraged.

Long-term efforts at documenting and tracking land use and shellfish growing area data should be accelerated. Work performed by various agencies and GIS coverages documented by the Willapa Alliance should be made electronically available. Bay shoreline and river mouth reaches, and likely BMP implementation areas, should be high priorities for basic land use data collection. Shellfish harvest area production or classification changes should be included as a GIS coverage.

Intensive monitoring studies could assist in a range of control strategy activities, from developing estuarine models to clarifying specific source problems in shellfish areas. They should be tasks designed to answer data needs for a specific objective. The following studies were suggested:

- monitoring bacterial concentrations in Zones 2 and 3 growing areas during the October through December harvest season;

- investigating bacterial loading response to rainfall for all the rivers, especially in Zone 2;

- evaluating bacterial impacts from diked grazing land with a focus on predicting tidal gate flows and loading;

- defining fecal coliform die-off rates in specific watersheds, and their relationship to estuarine flushing near harvest areas;

- investigating sediment resuspension and its effect on fecal coliform bacteria loads;

- identifying fecal coliform sources in the upper Willapa River;

- re-evaluating bayshore and river sources identified by CH_2M Hill (1981) in their 1980 sanitary survey;

- clarifying the overall bacterial impact of seasonal seafood processing effluent on shellfish resource areas;

- conducting post-action evaluation bacterial impacts from Bay Center on-site system upgrades and the Hewitt Addition sewer line installation;

- completing farm inventories along the entire bayshore, and near-bay river reaches; and

- investigating bacterial impacts from spring harbor seal pupping areas, elk herd wallows in near tidal meadows, and migratory bird populations.

A basic nonpoint source model linked to an estuarine water quality transport model could be constructed to assess bacterial loading. Simulations would be useful for very general evaluations. Ideally, information from GIS land-based coverages (e.g., soils, topography, land use, hydrography, and source components) would be used to generate bacterial loads. Models should be as simple as necessary, and should be designed to meet specific informational needs.

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APPENDIX A. HISTORICAL FECAL COLIFORM DATA

CH_2M Hill 1981

In 1980 CH_2M Hill, under contract with Ecology, analyzed bacteria and water quality in Willapa Bay to identify sources of fecal pollution and measure rates of dilution and dispersion. Their conclusion was that Willapa Bay was in relatively good condition with no major bacterial threat to the oyster industry. The sanitary survey sampled a total of 37 suspected bacterial sources at locations around Willapa Bay during spring and summer (Figure A-1). Thirty routine receiving water sites were sampled approximately twice a month for one year. The general findings of this study were:

1) Bacterial concentrations increase from high to low slack tides and with higher rainfall.

2) The relative increase was greatest in proportion with daily rainfall.

3) Rivers supply fecal coliform to the bay at concentrations above acceptable levels.

4) Average concentrations of fecal coliform at bay stations were well below those expected on the basis of dilution calculated from salinity alone.

5) Bacteria levels were not related to the tourist season.

Willapa Bay Water Quality Management Plan - Ecology 1983

The following recommendations were made to protect or enhance water quality in Willapa Bay and its tributary streams:

1) Seek construction grants to upgrade South Bend and Raymond STP.

2) Implement management practices for nonpoint source pollution control.

3) Establish long term monitoring in Willapa Bay.

4) Focus on Willapa River for full implementation of nonpoint control management practices.

5) Conduct additional coliform study on the following areas: Nemah River, Wilson Creek, Lion Club Park, Tarlatt Slough, and along the eastern shore of the Long Beach Peninsula where circulation and salinity are low.

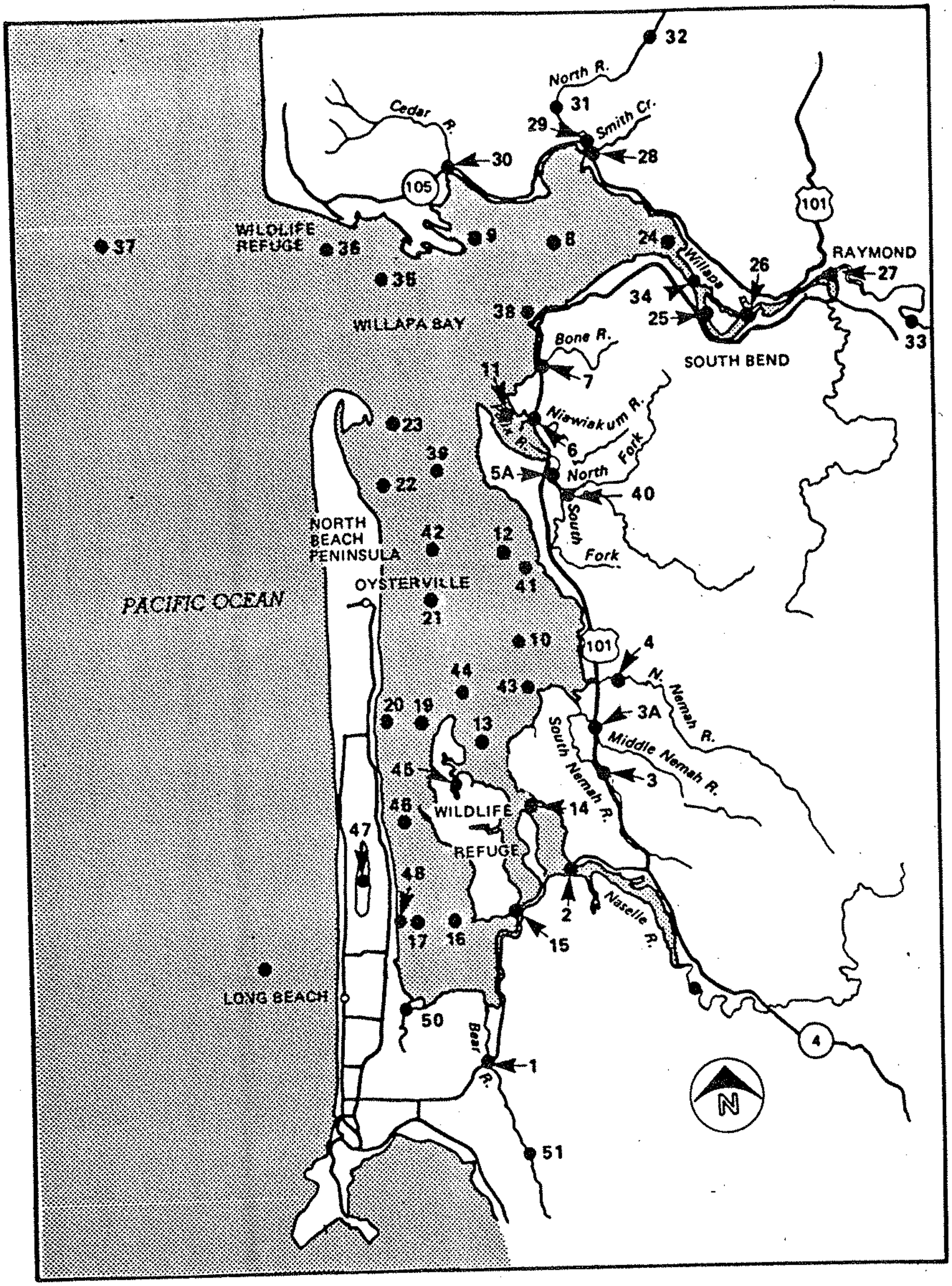

Figure A-1. CH$_2$M Hill Sampling Stations (CH$_2$M Hill, 1981).

CH_2M Hill 1987

A sanitary survey and a study of surface water quality involved sampling along the eastern side of the Long Beach Peninsula. Seventeen stations were monitored to provide baseline information on possible bacterial loading to the nearby oyster growing grounds. The overall conclusion was that fecal coliform concentrations in the drainages occasionally exceeded state criteria. Development in Oysterville, Nahcotta, and selected areas south of Nahcotta were of concern. Development could result in substantial nonpoint bacterial loading to the local oysterlands which produce over 50% of Willapa Bay's harvest.

The recommendations of the 1987 Long Beach Peninsula study by CH_2M Hill:

1) Leadbetter Point to Nahcotta Harbor has the largest Class I and II oysterlands along the Peninsula. The dense development and fecal coliform results in the community drainage system of the Oysterville and Nahcotta area indicate that a community treatment plant should be investigated.

2) Septic systems should not be placed in shoreline sites frequently inundated by tides.

3) Housing densities should be kept at a moderate level as defined by the PCHHS Department.

4) Ground water in the Oysterville area should be monitored for potential bacterial impacts from septic systems.

5) Cattle need to be kept from direct access to waters that drain directly to the bay.

6) The 1987 improvements in the drainage of wetland systems may be responsible for high bacterial counts by not providing adequate retention or filtration of waters.

7) Re-evaluate the Long Beach treatment plant's bacterial degradation effectiveness, including an analysis of effluent particulates and residence time of Tinker Lake.

8) Evaluate possible impacts of land application of sewage sludge.

9) Change the major west to east drainage patterns which discharge into the bay.

DOH Bay Center Sanitary Survey 1987

A shoreline survey of Bay Center was conducted by DOH in 1987. Ten out of 28 sites were listed as potential sources of fecal contamination (Schlorff, 1987). Pastured animals were identified as having direct access to waters that drain into the Palix River. Nine water quality samples were taken. A recommendation against wet storage of oysters along the Palix and Niawiakum Rivers was made because of the high fecal content in river samples.

Ecology 1987 and 1988

Between June 1987 and February 1988, ground water samples from 36 wells on the Long Beach Peninsula were sampled for nutrients, chloride, bacteria, and selected metals (Carey and Yake, 1990). Data gathered indicated moderate degradation. Thirty samples were analyzed for fecal coliform and total coliform content; two samples taken near Ocean Park had coliform above the specified quantification limit of 1 cfu/100 mL; neither involved fecal coliform.

DOH Bay Center 1989

In June 1989, the DOH Shellfish Program ambient monitoring of the Approved shellfish area in Bay Center had 13 out of 75 samples which exceeded the water quality criterion of 43 cfu/100 mL. Intensive water quality studies conducted during August and October, indicated that the shellfish growing areas near the mouths of the Palix and Niawiakum Rivers did not meet Approved water quality criteria for shellfish growing areas. A sanitary line was established at the mouth of the bay and all the enclosed growing area was classified as Prohibited.

Ecology Long Beach Peninsula Lake Samples 1990

The Department of Ecology's EILS Program sampled Peninsula Lake and Loomis Lake for fecal coliform on June 12 and September 13, 1990, as part of a statewide lake survey. The sample results were 1 cfu/100 mL on June 12, and 3 cfu/100 mL on September 11 (Coots, 1991).

Pacific County Surveys and Studies

Pacific County Health and Human Services (PCHHS) conducted sanitary surveys of 419 on-site systems in East Raymond, Willapa, Old Willapa, Eklund Park, the Hewitt Addition, and Bay Center from December 1989 to June 1991. The overall average failure rate was approximately 26.5%. The Hewitt Addition was identified as a severe public health hazard by DOH (Gebbie, 1991). The soils in Eklund Park and Hewitt Addition were considered poor for on-site treatment, with seasonally high water tables, and many of the failing septic systems had no repair options. PCHHS believed the best solution for Eklund Park and the Hewitt Addition was to extend the sewer systems to these areas. The survey identified public education on septic system function and maintenance as a need. In September 1992, repairs to Bay Center's failed on-site systems were completed and the adjacent shellfish area was reclassified to Conditionally Approved.

The Willapa Bay Watershed Study

PCHHS conducted a study of the Willapa Bay watershed in 1990 (Berbells, 1991). The study was funded by a Centennial Clean Water Fund (CCWF) grant to analyze the surface water quality of major drainages within the watershed. For the purpose of the study, three watershed zones were identified; four to five sampling sites were selected in each zone; and each zone was sampled during two seasons (wet and dry) (Figure A-2). One zone was sampled at a time, but

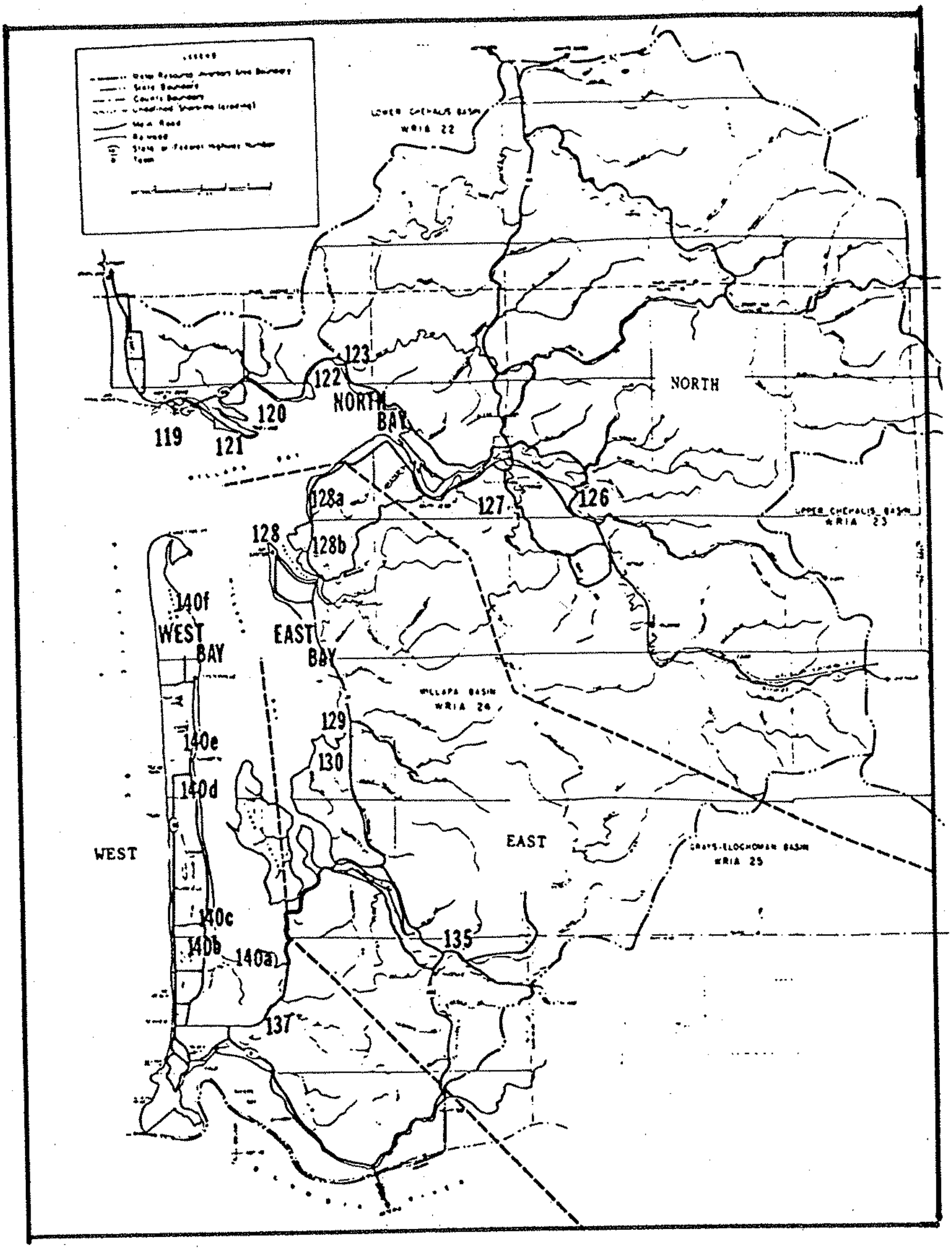

Figure A-2. Monitoring Stations from the Draft Willapa Bay watershed: A surface water study (Berbells, 1991).

it was tied to a primary sampling station from each of the other zones. Sampling was done at 12-hour intervals for a 48-hour period. The study found that water quality within the watershed was generally good. Recommendations included:

1) Correlate water quality results and remedial action efforts.

2) Develop a long term water quality monitoring plan.

3) Conduct a study to correlate rainfall within a zone to flow of the major drainages.

4) Continue sanitary surveys, with emphasis on the Willapa River, Grayland Ditch, and the Long Beach Peninsula.

PCHHS is presently conducting a Remedial Action Program to identify sources of fecal coliform pollution and to prepare/implement remedial action strategies. The program funded by a CCWF grant includes the following:

1) Sanitary surveys of Willapa, North, and Naselle Rivers, to be completed by June 1992.

2) Fecal coliform sampling of the Willapa, North, and Naselle rivers, as well as Long Beach Peninsula's sloughs and drainages.

3) A survey of marina waste practices and development of a remedial management strategy for marina and boat waste.

4) Develop a tracking database to manage data on septic systems, river surveys, and marinas.

5) Education and coordination with the Willapa Bay Water Resources Coordination Council (WBWRCC).

<u>The Willapa Bay Water Quality Enhancement Project of 1990</u>

This project was initiated by Pacific Conservation District in 1988, and focused on fecal coliform in the Willapa River watershed (Geleynse, 1990). An opinion survey of farmers, loggers, urban residents, and others along the Willapa River was undertaken to identify and help solve problems contributing to water quality. A farm and animal count was also conducted in the Willapa River drainage from October 1988 to February 1989 (Figure 5). The majority of the 118 farmers worked small, non-commercial livestock farms (Table A-1). There were 21 large commercial livestock operations at the time of the survey, including two beef farms, one hog farm, and 18 dairies.

Table A-1. Summary of animal and farm inventory data collected in the Willapa River Valley in 1989 (Geleynse, 1990).

Animal Inventory		Farm Inventory	
Dairy Cows	1,906	Farms with less than 10 animals	26 Farms
Dairy Heifers	2,150	Farms with 10-20 animals	48 Farms
Beef/Young Stock	1,753	Farms with more than 30 animals	44 Farms
Horses/Mules	128	Total Farms	118 Farms
Swine	271		
Sheep	98		
Total Animals	7,306		

The conclusions and recommendations of the project were:

1) the public was largely unaware of water quality problems;

2) poor management practices contributed to declining water quality;

3) a comprehensive water quality monitoring study is needed to document water quality problems in Willapa Bay and Willapa River; and

4) more effort and financial aid are needed to institute best management practices (BMPs) on farms and in forests.

<u>The Long Beach Ground Water Characterization Study</u>

The Long Beach Ground Water Characterization is a study of the principle aquifer of the Long Beach/North Beach Peninsula. The study is being conducted by PCHHS in cooperation with USGS with CCWF grant funding. The study seeks to describe the aquifers boundaries, and recharge areas, and define potential sources of contamination. The study will assist Pacific County in developing ground water protection policies, ground water management areas, wellhead protection areas, aquifer protection districts, sewage districts, and water districts.

A Near Coastal Waters Initiative was recently funded by the EPA to allow Pacific county to make the transition from nonpoint problems to comprehensive solutions in unincorporated areas. Fourteen surface water sites, 24 new resource protection wells, and 16 domestic wells will be sampled for fecal coliform. Samples taken in February and July 1993 will represent wet and dry seasons. A ground water management database system will be developed. This project is due to be completed in September 1994. Comprehensive solutions can be achieved through the adoption of the legislative authority to:

1) Create sewer and water utility ordinances.

2) Identify engineering designs and costs for sewer services in the Eklund Park and Hewitt Addition.

3) Establish nonpoint priority areas.

DOH Raymond and South Bend STP Evaluations

The DOH Office of Shellfish Programs conducted a set of surveys of the Raymond and South Bend sewage treatment plants (STPs) (Meriwether, 1991a;1991b; 1991c). The STPs were visited, the operators interviewed, and the records reviewed. Findings at Raymond were:

1) Wet weather flows approached or exceeded design capacity indicating an inappropriate design or sources of inflow and infiltration (I/I) throughout the year.

2) Two manhole locations upstream from pump station #11 overflow into ditches at least twice a year. The overflows occur when four inches of rain fall in 24 hours or when six inches of rain fall over 36 hours.

3) Some sections of the sewer line are 30 years old and a major source of the infiltration is at individual house connections.

Meriwether (1991b) made the following recommendations to protect nearby shellfish resources:

1) If reduction of excessive I/I cannot be quickly accomplished, the pumping capacity of lift station #11 should be expanded.

2) The pipeline carrying raw sewage under the Willapa River from lift station #11 should be evaluated and cleaned.

South Bend STP records from 11/88 to 5/90 indicated excessive I/I, and effluent flows exceeded 85% of design capacity from November through March (Meriwether, 1991a). Sewage overflow problems in the collection system usually occur two to three times a month during the winter season when rainfall exceeds 2.0 to 2.5 inches in 24 hours. Meriwether (1991a) made the following recommendations concerning the South Bend STP:

1) The locations of stormwater flows into the collection system should be identified and the frequent exceedances of design capacity (85%) eliminated.

2) Records should be kept for maintenance and repairs done to the collection system.

3) Alarm systems should be maintained and checked at the time that pump station wet wells are inspected.

4) The integrity of the line that runs under the river should be tested, and methods to clean the line should be investigated.

5) The emergency generator should be tested and maintained at the plant.

6) The NPDES permit requirement of "no detectable amount" of residual chlorine should be modified, especially during wet weather conditions.

In February 1991, a hydrographic study was conducted by representatives of the FDA and the DOH Shellfish Program (Meriwether, 1991c). The study was conducted during "worst case" field conditions of high flows from the South Bend STP on an ebbing tide. The CORMIX1 computer model was used as a predictive tool. The computer simulation worked fairly well at predicting dye concentration in the Willapa River that originated from the South Bend STP outfall. The simulation was found incapable of modeling river bends and constrictions, or the changing tidal influences. The simulation was considered "conservative" in predicting dilution and dispersion of the dye plume traveling 9,500 yards downstream to the DOH sanitary closure line.

DOH Bay Center Shellfish Restoration Project

Restoration work performed by DOH after the closure of parts of the Bay Center shellfish area were summarized in the "October 1991 Willapa Bay, Bay Center Commercial Shellfish Growing Area Restoration Project Report" (Melvin, 1991). The Bay Center shellfish growing area classification was downgraded from Approved to Restricted in November 1989 based on results of water quality studies conducted in June, August, and October of 1989. Source identification work was performed by local and state health agencies. The major findings of the investigations were:

1) Watershed runoff from the Bone River, Niawiakum River, and Palix River was identified as the primary source of fecal coliform impacting the Bay Center shellfish growing area. All three rivers failed both parts of NSSP growing area water quality standards during the December 1989 intensive storm study. The Palix River study of November 1990 detected high fecal coliform bacterial counts in the upper watershed with resultant high levels in marine waters.

2) Failing commercial and residential on-site sewage systems were also identified as sources from the Bay Center peninsula. Community ditches from Bay Center frequently had high levels of fecal coliform.

3) Agricultural runoff from Bay Center peninsula pasture lands adjacent to the shellfish beds also contributed to the problem.

4) Other potential sources identified were: 1) sewage discharged from the seasonal commercial live-aboard fleet moored at the Bay Center boat basin, and 2) a seafood processing plant on the lower Palix River Channel.

DOH Shellfish has evaluated all water quality data collected during periods which meet the conditions defined by the current proposed Conditional area closure criteria. Based on that evaluation, DOH Shellfish has expanded the boundaries of the original proposed Conditionally Approved harvest area (Guichard, 1992).

The final on-site treatment system repairs and upgrades were completed in Bay Center in September 1992. The DOH Shellfish program has upgraded the Bay Center shellfish area to Conditionally Approved status and will initiate a monthly monitoring routine. Rainfall is related to fecal coliform contamination within the area. Forty-eight hours are required for fecal coliform contamination to reach the shellfish growing area following a storm event. The Conditional area closure criterion is rainfall of one-inch within a 24 hour period. Harvest may resume five days after a storm event of one-inch or more.

Ecology and the City of Raymond

The Ecology Coastal Zone Management Program provided a grant to the city of Raymond to develop Shoreline Master Program Amendments and identify issues for a Comprehensive Flood Hazard Management Plan (CFHMP). The products will be: 1) a summary of issues and strategy of plan development; 2) a plan to identify and develop alternative approaches to issues within the broad context of the Shoreline Master Program, Flood Hazard Management, Growth Management and Economic Development; 3) document the specific minimum requirements of a comprehensive flood control management plan according to WAC 173-145-040; and 4) include a strategy for implementation and adoption by city of Raymond following public hearings.

APPENDIX B. DOH WILLAPA BAY MONITORING STATION FECAL COLIFORM AND RAIN DATA

Table B-1. DOH Cedar River fecal coliform MPN data and rain data collected from 1990-1991. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling.

	Cumulative Rain (in.)			Stations Exceeding Criteria		
Date	Day	2 Day	5 Day	>100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
8/14/90	0	0	0			8,9
8/15/90	0	0	0	9		7,9
8/16/90	0	0	0	9		7,8
7/24/91	0	0	0	16		6,9,10
7/28/91	0	0	0		16	6,7,8,9

Table B-2. DOH North River fecal coliform MPN data and rain data collected from 1988-1992. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling. Underlined numbers denote stations located in shellfish harvest areas. Numbers in parentheses indicate multiple samples from the station exceeded criterion.

	Cumulative Rain (in.)			Stations Exceeding Criteria		
Date	Day	2 Day	5 Day	>100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
10/11/88	0.05	0.05	0.05		13, 9	11, 12(2), 5, 8, 9, 10, 13
10/12/88	0.0	0.05	0.05		12, 13	12, 14(2), 13
10/13/88	0.23	0.23	0.23	14	12, 3, 14(2), 9(2)	1, 10(2), 11, 12, 13(2), 5, 6, 7, 8, 3
10/25/88	0.0	0.0	0.12	8	8	10, 12, 14(2), 18, 6, 7, 9
10/26/88	0.0	0.0	0.12			10(2), 12, 14, 3, 5, 7 9(2)
10/27/88	0.0	0.0	0.0			10(2), 12, 14, 3, 5, 7 9(2)
11/14/88	0.0	0.07	1.41		10, 7, 8, 9	1 10, 12, 13(2), 15, 17 19(2), 3(2) 6, 7, 8, 9
11/15/88	0.31	0.0	1.35		9	1, 3, 12(2), 10(2) 13(2)
12/20/89	0.02	0.05	0.07		9	10, 18, 19 9
12/21/89	0.0	0.02	0.07			10, 12, 6
4/17/90	0.19	0.0	0.93		11, 9, 12, 7,	10(2), 11, 12, 13(2) 3, 5, 7, 8, 9
4/18/90	0.03	0.19	0.92		13	12, 13, 3, 5, 8,
4/19/90	0.02	0.03	0.24			10

Table B-2. Continued.

	Cumulative Rain (in.)			Stations Exceeding Criteria		
Date	Day	2 Day	5 Day	>100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
8/27/91	0.23	0.99	0.99	4(2), 8, 9(2), 10, 11, 12(2), 13(2), 14,	18, 8, 10, 11	1, 14, 16, 17, 18, 5, 6, 7,
8/28/91	0.23	0.99	0.99	3, 11(2), 4(2), 12(2), 5, 6, 13(2), 7, 8(2), 14(2), 9	3, 5, 6, 7, 9, 10(2),	1, 15, 16, 17, 18, 19,
8/29/91	1.3	1.53	2.29	1, 10(2),3, 4(2), 5(2) 6(2) 7(2), 8(2), 9(2) 11(2), 12(2), 13(2) 15 14(2), 16, 17 18, 19	1, 3, 10(2), 15 16, 17, 18, 19	
10/29/91	0.44	0.46	0.90	13(2),	8, 7, 12	10(2), 11(2), 12, 14 18, 4(2), 6, 7(2), 8, 9
10/30/91	0.0	0.44	0.66	13	5, 6, 4, 7, 16 10, 12(2), 13	10, 11(2), 14(2), 16, 3, 4, 5, 6, 7, 8, 9(2)
10/31/91	0.0	0.0	0.56		5, 13, 6	10(2), 11, 12, 13, 14, 3, 4, 5, 8, 9(2)

Table B-3. DOH Bruceport/South Bend fecal coliform MPN data and rain data collected from 1989-1991. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling. Underlined numbers denote stations located in shellfish harvest areas.

	Cumulative Rain (in.)			Stations Exceeding Criteria	
Date	Day	2 Day	5 Day	>43 MPN/100 mL	>14 MPN/100 mL
11/27/89	0.07	0.39	2.26	1, 4,1,2,2,3,	3, 6, 4, 5, 5, 6, 8 , 9 , 13
11/28/89	0	0.07	1.71	1,1,	2, 3, 3, 4, 2, 7, 8
11/29/89	0	0	1.09	1	1, 2, 4, 5, 9, 14
6/12/90	0.24	0.23	1.42	1, 3, 5	1, 2, 2, 3, 4, 4, 5, 6, 7, 8, 8, 9, 10, 13, 15
6/13/90	0.18	0.24	1.27	1 2, 3, 5, 5, 7, 8, 9,	1, 2, 3, 4, 4, 6, 7, 9, 10 10, 11, 11, 14, 14,8
6/14/90	0	0.18	1.18	1	1, 2, 2, 4, 6, 8, 8, 9, 11, 11, 12, 12, 14
6/11/91	0	0	0.18	1	2, 4, 6,
6/12/91	0.28	0	0.39	1, 3,	3, 4, 5, 6, 6, 7, 8, 10, 11
6/13/91	0.15	0.28	0.43	1, 2, 5,	1, 2, 3, 4, 6, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

Table B-4. DOH Stony Point fecal coliform MPN data and rain data collected from 1990 to 1991. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling. Underlined numbers denote stations located in shellfish harvest areas. Numbers in parentheses indicate multiple samples from the station exceeded criterion.

Cumulative Rainfall (in.)				Stations Exceeding Water Quality Criteria		
Date	Day	2 Day	5 Day	>100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
5/8/90	0.06	0.06	0.23			17 (@) 17
5/9/90	0	0.06	0.23			
5/10/90	0	0	0.23			
2/26/91	0	0	0			
2/27/91	0	0	0			

Table B-5. DOH Nemah River fecal coliform MPN data and rain data collected from 1990 to 1991. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling. Numbers in parentheses indicate multiple samples from the station exceeded criterion.

Cumulative Rainfall (in.)				Stations Exceeding Criteria		
Date	Day	2 Day	5 Day	> 100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
10/15/90	2.60	0.18	4.04		21	7, 21, 22(2)
10/16/90	0.47	2.60	4.50		22	16 21(2), 22
10/17/90	0.06	0.47	3.26			16, 21(2), 22(2)
5/28/91	0.0	0.0	0.0			
5/29/91	0.0	0.0	0.0			
5/30/91	0.83	0.0	0.0	22		16, 22, 21

Table B-6. DOH Naselle fecal coliform MPN data and rain data collected from 1990-1991. Station numbers where fecal counts exceeded freshwater or marine criteria are categorized. Rain data are cumulative for the day of sampling, and two and five days prior to sampling. Numbers in parentheses indicate multiple samples from the station exceeded criterion.

	Cumulative Rainfall (in.)			Stations Exceeding Criteria		
Date	Day	2 Day	5 Day	>100 MPN/100 mL	>43 MPN/100 mL	>14 MPN/100 mL
10/15/90	2.60	0.18	4.04		14	7
10/16/90	0.47	2.60	4.50	14	12, 15(2)	3, 7, 12
10/17/90	0.06	0.47	3.26		12(2) 14, 15	6(2), 14
5/28/91	0	0	0			
5/29/91	0	0	0			
5/30/91	0.83	0	0		11,	3, 4, 14, 12(2)

APPENDIX C. PROXIMITY AND RATIONAL FORMULA CALCULATIONS FOR THE LOWER WILLAPA RIVER

Appendix C - Proximity and Rational Formula Calculations for the Lower Willapa River

The bacterial delivery ratios to shellfish harvesting areas of the bay are dependent on die-off rates through the freshwater and estuarine reaches. Gross wet and dry season mean die-off rates (includes salinity, dispersion, dilution, etc.) in the Bruceport/South Bend shellfish harvest area were calculated using the DOH monitoring ebb tide data (Table C-1). Several other areas (e.g., North River and Bay Center) had similar rates. Rates were calculated on geometric mean counts after graphic inspection (Figure C-1).

For simplicity, the single rate calculated from stations downstream of South Bend was used for all sources contributing to the lower Willapa River. This could be a large source of error in the method since salinity greatly affects bacterial die-off rates. Freshwater portions of the river would probably have lower die-off rates, so multiple rates would need to be used for a more accurate analysis.

The rational formula is a basic equation used to calculate runoff volumes from various land coverages during different rainstorm intensities:

$$Q = C I A$$

where, Q = discharge (cfs)
C = coefficient of runoff (0.1 to 0.9) for various land covers and slopes
I = rainfall intensity (inches/hour)
A = land area (acres)

A rainstorm intensity of 4 inches over 24 hours (*i.e.*, an average of 0.17 in./hr.) was used. Livestock and grazing pasture use areas were estimated from data collected by CH_2M Hill (1981) as follows: Bruceport to Range Point, 480 acres; Range Point to South Bend, 512 acres; and Johnson Slough and Mailboat Slough, 1280 acres. Pasture areas were highly generalized and given a coefficient of 0.25. Data for combined sewer overflow (CSO) collection areas were estimated from sewer plan maps: Raymond, 1280 acres; and South Bend 640 acres. A coefficient of 0.6 was used in these mixed urban areas. The watershed upstream of the Willapa River at the USGS gage (RM 18.2) is 130 square miles (83,200 acres), and was given a forested land coefficient of 0.1.

Once a runoff volume was calculated, it was multiplied by a characteristic fecal coliform concentration to yield a load. Characteristic runoff fecal coliform concentrations were taken from various sources:

- livestock grazing area runoff of 1.1×10^3 cfu/100mL for data reported from western Washington (Crane *et al.*, 1983),
- CSO fecal coliform lower range concentrations, 1.2×10^5 cfu/100mL, estimated from Thomann and Mueller (1987),
- the 90th percentile Willapa River fecal coliform count, 250 cfu/100mL, from data collected by Ecology at RM 18.2 since 1985.

Table C-1. Calculated fecal coliform decay rates based on MPN data collected by the Washington State Department of Health in shellfish growing areas. Data are seasonally stratified and collected on ebb tide only. Rates are natural log relationships of station mean counts or geometric mean counts to distance (river mile).

Area	Season	Mean rate	r^2	Geometric Mean rate	r^2
South Bend/ Bruceport	wet	0.3848	0.821	0.3958	0.825
	dry	0.3732	0.603	0.3525	0.620
North River*	wet	0.3404	0.623	0.27092	0.567
	dry	0.5555	0.843	0.5340	0.843
Palix River	wet	0.7237	0.863	0.68114	0.871
	dry	0.6725	0.429	0.5559	0.563
Niawiakum River	wet	1.620	0.927	1.2266	0.970
	dry	1.1427	0.806	1.1753	0.863

* North River Regression excludes two most upstream stations.

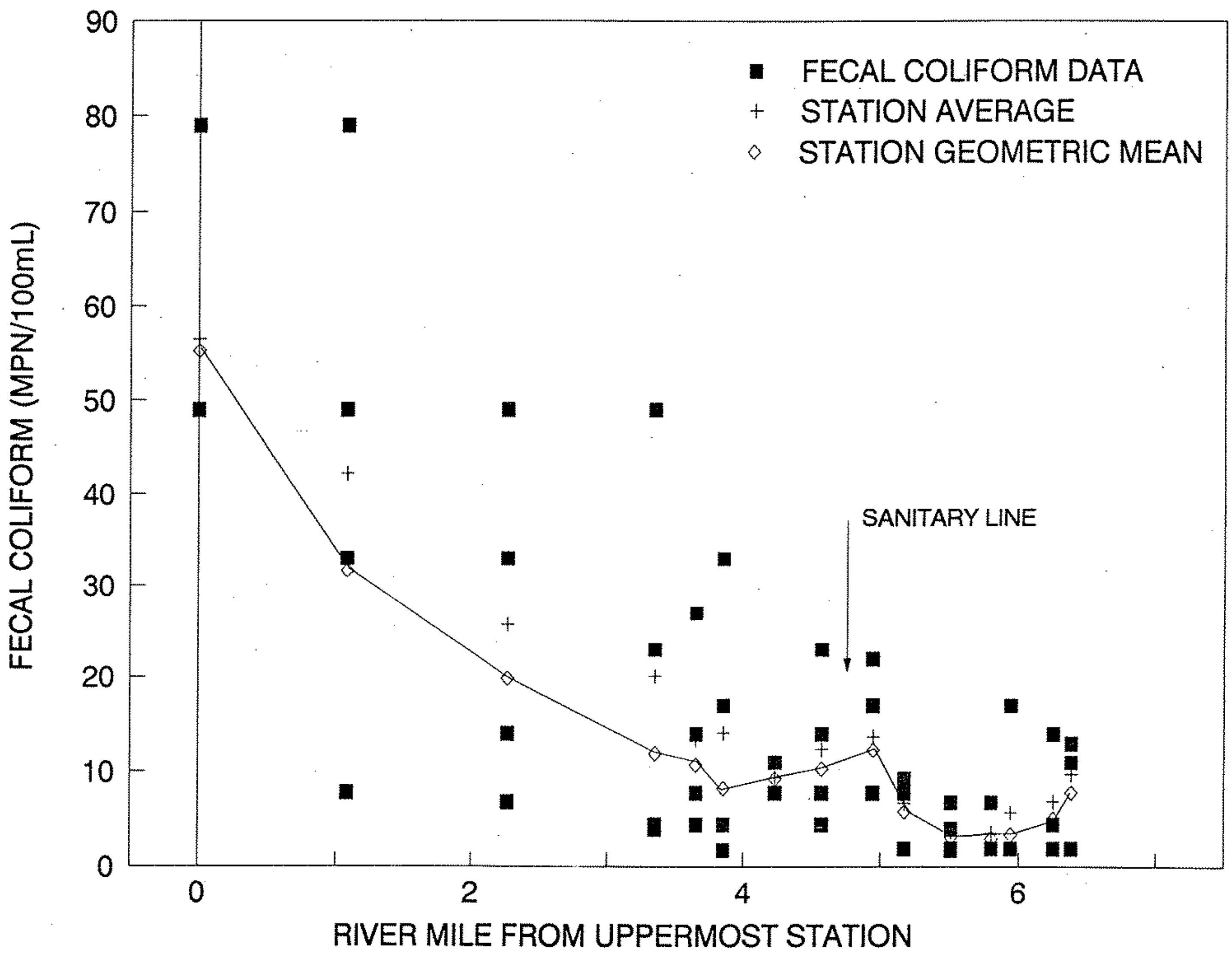

Figure C-1. Washington Department of Health Shellfish Program fecal coliform data collected from the Willapa River at the Bruceport/South Bend growing area during ebb tides (November through May only). The coliform die-off rate of 0.396 /river mile (log e) was calculated using station geometric mean values.