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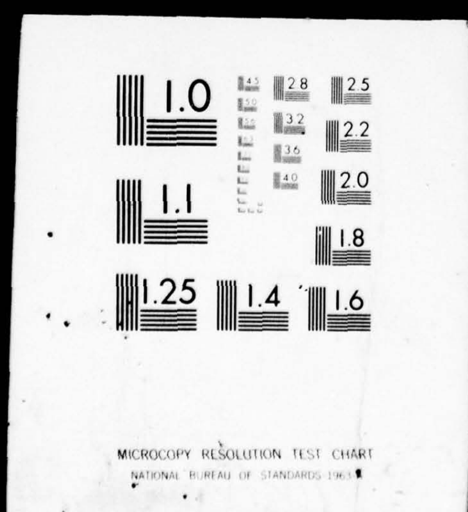

Comprehensive Study of Water
and Related Land Resources

Puget Sound and Adjacent Waters

State of Washington

Appendix XIII
Water Quality Control

Puget Sound Task Force—Pacific Northwest River Basins Commission

March 1970

PARTICIPATION

STATE OF WASHINGTON

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Department of Commerce & Economic Development
    Office of Nuclear Development
Department of Fisheries
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Department of Highways
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Department of Water Resources
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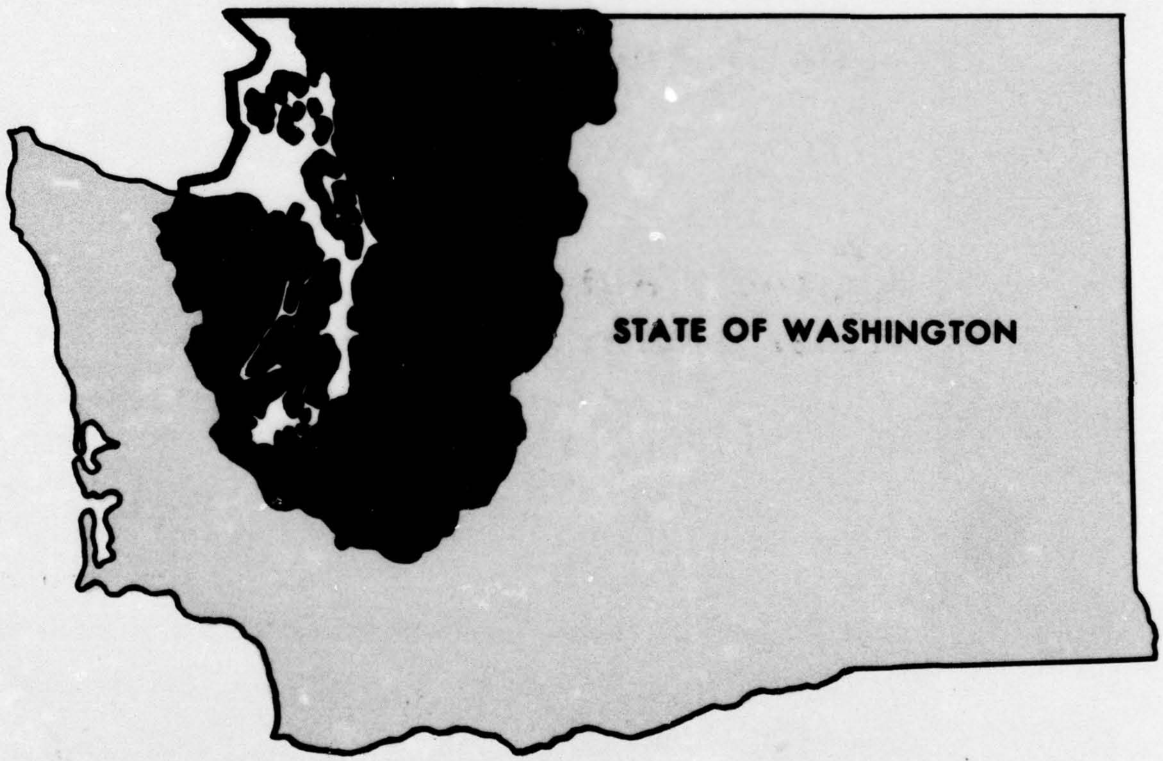

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Comprehensive Study of Water and Related Land Resources.

Puget Sound and Adjacent Waters.

APPENDIX XIII.

WATER QUALITY CONTROL,

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Alfred T. Neale, Sidney Steinborn,
Lewis F. Kehne, Ernest E. Allen
Francis L. Nelson

11 Mar 70

12 289p.

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

Municipal and Industrial Water Supply and Water Quality Control Technical Committee

PUGET SOUND TASK FORCE of the PACIFIC NORTHWEST RIVER BASINS COMMISSION

1970

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FOREWORD

Appendix XIII, Water Quality Control, contains a detailed report of one component of the Comprehensive Water Resource Study of Puget Sound and Adjacent Waters. It is one of the technical appendices providing supporting data for the overall water resource study.

The Summary Report is supplemented by 15 appendices. Appendix I contains a Digest of Public Hearings. Appendices II through IV contain environmental studies. Appendices V through XIV each contain an inventory of present status, present and future needs, and the means to satisfy the needs, based upon a single use or control of water. Appendix XV contains comprehensive plans for the Puget Sound Area and its individual basins and describes the development of these multiple-purpose plans including the trade-offs of single-purpose solutions contained in Appendices V through XIV, to achieve multiple planning objectives.

River-basin planning in the Pacific Northwest was started under the guidance of the Columbia Basin Inter-Agency Committee (CBIAC) and completed under the aegis of the Pacific Northwest River Basins Commission. A Task Force for Puget Sound and Adjacent Waters was established in 1964 by the CBIAC for the purpose of making a water resource study of the Puget Sound Area based upon guidelines set forth in Senate Document 97, 87th Congress, Second Session.

The Puget Sound Task Force consists of ten members, each representing a major State or Federal agency. All State and Federal agencies having some authority over, or interest in, the use of water resources are included in the organized planning effort.

The published report is contained in the following volumes.

SUMMARY REPORT

APPENDICES

I. *Digest of Public Hearings*
II. Political and Legislative Environment
III. Hydrology and Natural Environment
IV. Economic Environment
V. Water-Related Land Resources
   a. Agriculture
   b. Forests
   c. Minerals
   d. Intensive Land Use
   e. Future Land Use
VI. Municipal and Industrial Water Supply
VII. Irrigation
VIII. Navigation
IX. Power
X. Recreation
XI. Fish and Wildlife
XII. Flood Control
XIII. Water Quality Control
XIV. Watershed Management
XV. Plan Formulation

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WATER QUALITY CONTROL

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SKAGIT-SAMISH BASINS

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INTRODUCTION

The Puget Sound Area is rich in water resources. Large rivers like the Skagit, outstanding lakes such as Lake Washington, many estuaries, and the main body of Puget Sound, are the range of these resources. Enhancement and preservation of the quality of these resources is a goal of the highest priority consistent with existing and future needs. Much of the present economy and most of this Area's future development is based upon the availability of good quality water.

This Appendix presents an evaluation of existing water quality problems in the Puget Sound Area and outlines the actions necessary for their solution. Also presented are projections of waste sources and their impacts on water quality and a plan to preserve and enhance water quality now and in the future.

This is the first study in this Area which included an extensive economic base analysis tied to projections and evaluations of the whole range of water and land resources and uses. This study has allowed the beginning of an appraisal of possible future interactions upon which plans could be based to achieve the goal of water quality preservation.

PURPOSE

The goal of water quality control is to insure that water of suitable quality is available for all beneficial purposes such as public health and enjoyment, propagation and protection of aquatic life, and economic development. This goal is only partially realized today, and in future years it will become more difficult to attain as the Puget Sound Area grows in population and industry and as a changing technology creates new problems.

This study analyzes the various adverse forces acting on water quality today and the threats they pose in the future and develops an action plan to enhance and preserve the water quality in the face of these forces. The plan will be integrated into the comprehensive water resources plan being developed through the Puget Sound and Adjacent Waters Task Force.

The many water uses planned for in this report all demand waters of certain quality characteristics. These uses, together with the several land and water development and management activities, have had their impact on water quality. In many instances, this impact had an adverse effect. For this reason, it is critical that all water resource plans consider water quality both as an impact and as a requirement. This appendix serves that function.

SCOPE

The study was based upon information available as of the summer of 1967. Data collection programs were not established to define areas where inadequacies existed. Reliance was placed upon published and unpublished reports, waste surveys, and data from ongoing programs.

All aspects of water quality were considered. In areas lacking adequate definition, consideration was broad and general. In other areas, more depth and specifics could be developed. All studies were of necessity broad; sufficient detail is not, therefore, presented to identify, for instance, specific sizes or locations of waste treatment facilities. Some emphasis was given to establishing waste treatment and/or freshwater flow requirements and in evaluating the water quality requirements of other functions in the plans.

In keeping with the methodology employed in the comprehensive study of Puget Sound and Adjacent Waters, the findings on water quality are based upon a single purpose use of water resource for development of the Comprehensive Plan. (See Appendix XV Plan Formulation).

PROCEDURE

The Municipal and Industrial Water Supply and Water Quality Control Technical Committee was formed at the outset of the Task Force Study. This Committee was composed of the following member agencies:

State of Washington
- Water Pollution Control Comm., Co-Chairman
- Department of Water Resources
- Dept. of Commerce & Economic Development
- Department of Health

Federal Government
Department of the Interior
Federal Water Pollution Control Administration, Co-Chairman
Bureau of Reclamation
Geological Survey

Department of Agriculture
Forest Service
Economic Research Service

Department of Health, Education & Welfare
Public Health Service

Department of Transportation
Coast Guard

The Committee served as the major vehicle to facilitate coordination and information exchange between agencies having an interest in the committee functions. Committee members contributed all pertinent information available to them and reviewed all appendix drafts.

SUMMARY

Over the years, the transition from limited to the intense use of the resources of the Puget Sound Area has been accompanied by changes in water quality, the occurrence of water quality problems in both fresh and marine waters, and an active policy for the prevention, control, and abatement of water pollution in a period of improving public understanding and support.

The major water quality problems existing today are largely the result of municipal and industrial waste discharges generated by the rapidly growing population and economic environment. Problems are not confined in location although they are generally found in the vicinity of the major population and industrial service centers located adjacent to the marine waters. Four marine water areas have experienced more severe water quality degradation due to the discharge of wastes primarily from the paper and allied industry. While this industry discharges wastes which are the equivalent to that of a population more than six times the present population of the Puget Sound Area, wastes from food processing industries have also played a significant role in the water quality picture in fresh waters. Legislation, standards, and a plan of implemented action on discharges will remove these problem areas in a period of six years or less.

Problems of lake eutrophication also exist, and the potential is there for these to increase in significance and number in the years ahead. In the 1950's, Lake Washington was undergoing eutrophication which prompted the establishment of METRO, a municipal authority to divert treated sewerage from the lake. Today Metro has eliminated treated waste discharges to the lake, and the lake now is well on its way to water quality recovery. Other smaller lakes, however, are in early stages of eutrophication and as the population expands and urban areas reach out to encompass more land, lake eutrophication and nuisance algae growths will become more significant from man's activities on the environment. Special studies will be essential to assist in prescribing the facilities that will be needed to adequately protect the numerous lakes in intensively developed areas for most uses.

Adequate streamflows are available now, and should be present in the future, to assimilate residual waste discharges in most of the rivers in the Area.

In addition, Seattle's increasing diversion of the Cedar River flow for municipal water supply will further deplete inflow to Lakes Washington and Union required to maintain lake level, provide lockage, control salinity intrusion and maintain adequate water quality. Nutrient enrichment and salinity intrusion from the increasing Hiram Chittenden Lock's operation, are the two major impacts on quality.

Additional problems that will require ever increasing attention include solid waste disposal, water and land management effects, waste disposal from vessels and recreational craft, the separation of storm and sanitary sewers and the dissipation of heat from thermal power installations. A trend should be toward increased water re-use and an effective environmental quality agency.

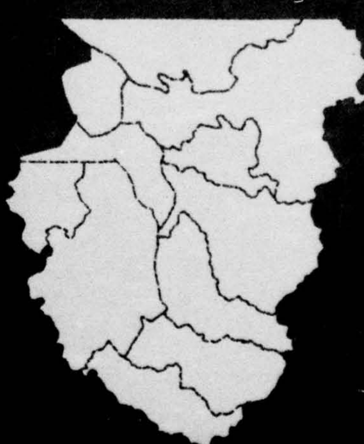
It was the consensus of the Municipal and Industrial Water Supply and Water Quality Control Technical Committee that these problems must be attacked on a regional or drainage basin basis; and it was noted that several of the larger municipalities were either activating or were in the process of preparing plans to provide for regional and metropolitan systems for the collection, treatment and disposal of both solid and liquid wastes. It was also emphasized that the degree of waste treatment must be increased in accordance with present and future water quality needs.

A number of years ago, it would have been quite difficult to envision many of the water-related problems that are facing us today, because social and technological advances have emerged so rapidly. What new developments lie ahead are again difficult to foresee, but it is certain that new industrial pursuits and significant use of advanced waste treatment will evolve. Their potential affects on the environment are also difficult to forecast, but these, too, will also evolve and should be handled through research and programs of management and development in effect now and expanded in the future.

The social and economic development of the Study Area has been followed by water quality control programs based upon an expanded understanding of ecological facts and processes, marine research and technology, reduction of nutrients, particularly phosphorous, and improved Federal-State-local enforcement and regulation procedures.

Costs and expenditures are expected to increase as population, industry, and recreation leisure increase. By the year 2020, a total investment of more than two billion dollars will be needed for water quality control.

Puget Sound Area



THE PUGET SOUND AREA

HISTORY

The beginning of a pollution control program in Washington and the Area was a fact finding program based on interagency cooperation between the Departments of Health, Fisheries, and Game, from 1925 to 1937.

In 1935, a small appropriation was granted the Washington State Department of Health for the purpose of conducting a stream pollution study of the Yakima River. Publication of this study aroused a gradual public awareness that the State's waters were becoming polluted.

The industrial expansion of the State around this time included significant increases in the production of pulp and paper and in the rapid expansion of the chemical industry. The wastes discharged by these industries soon attracted much public attention because of their influence on the commercial and sports fisheries resources of the State.

An initial budget of $14,500 for an executive Pollution Control Commission consisting of the Directors of the State Departments of Health, Fisheries, Game, and Conservation, in 1937, commenced the first activities in determining the status of water quality and building a broad foundation for municipal and industrial waste treatment. This was the modest beginning of a concerted effort to bring together all of the State agencies having a major interest in water quality. Most agency efforts at this time were directed toward investigating biological effects of sulfite waste liquor[1] and evaluation of water quality conditions in the vicinity of sulfite pulp mills.

Pollution control bills were introduced in both the 1941 and 1943 Legislatures, but neither passed. An act creating the present Water Pollution Control Commission was passed by the Legislature and approved by the Governor in 1945. The Commission, basically a policy-making body, was composed of the four Directors of the State departments mentioned previously and, in addition, the Director of the State Department of Agriculture. The act directed the Commission to maintain the highest possible standards of water quality consistent with the various water uses and vested the Commission with full powers to promulgate rules and regulations, determine the condition of water of the State and to issue orders.

The new Commission, concerned with fresh, tidal and salt water, established water standards on October 8, 1945, to protect the health and recreation and the conservation of natural resources.

By 1945, the problems of industrial waste treatment and control had grown in both magnitude and complexity since pre-war days. The Puget Sound in particular, with its abundance of fresh and salt water for waste disposal purposes, experienced a considerable growth. The impact of this pollution load evoked increasing alarm and consideration from many groups. In addition to public health aspects, the important oyster growing industry was deeply concerned. Commercial and sports fishing interests and recreation enthusiasts such as swimmers, water skiers, and pleasure boat operators, and civic-minded citizens in general, deplored the increasing impact of industrial wastes on Washington waters. As a result, many pollution abatement programs were instituted in 1945 and 1946 by a broad educational program for the public and industry on the needs for pollution abatement.

PHOTO 1-1. Waste discharges from expanding industry aroused attention to the need for water pollution control.[2]

[1] See Glossary for definition of technical terms.

[2] See Photo Credits at back.

The first Federal Water Pollution Control Act (PL 845, 80th Congress) became law on June 30, 1948, to be administered by the U.S. Public Health Service. This Act declares that the states have primary rights and responsibilities for taking action to abate and control pollution. The Federal responsibility in the field of water pollution control applies to interstate and navigable waters, whether the matter causing or contributing to pollution is discharged directly into such waters or reaches such waters after discharge into a tributary, which endangers the health or welfare of any person. Provisions of this Act resulted in Federal-State cooperation on a number of projects, programs, and enforcement actions. It also greatly speeded up programs, notably in municipal sewage treatment plant construction and in authorizing grants for the improvement and expansion of the State's pollution control program. The law provided for construction grants to municipalities, but no monies were appropriated.

Definite progress was secured in the subsequent ten years, but the most workable tool for water quality control was provided by the State Legislature in 1955 when they enacted a waste discharge permit law which materially strengthened the basic law of 1945. This permit law requires that all industrial operations involving solid or liquid waste discharge to State waters must secure a permit every five years from the Water Pollution Control Commission. The permit could be permanent (five years) or temporary. Conditions to prevent water quality deterioration and maintain standards of the 1945 Statutes were stated. By June 1957, 70 percent of the industries had obtained permanent permits; in 1958, 80 percent, and in 1963, 93 percent. This law assisted greatly in obtaining corrective and preventive pollution control for industries. Major industries with problems in removing solids, improving outfalls to get maximum diffusion, reduction in strength of sulfite waste liquor, and aquatic life mortality or toxicity continued their operations under temporary and special permits while investigations of significant water quality impact and development of in-plant controls were determined.

After 1956, newer developments in Washington's pollution control program started to occur from utilization of Public Law 660, the Federal Water Pollution Control Act. Special studies concerning pollution in Puget Sound were continued and new ones undertaken. The incentive of additional grants increased the construction of waste treatment facilities by municipalities.

Of particular interest is the Municipality of Metropolitan Seattle (METRO) program. By 1956, a total of 41 towns and sewer districts representing separate taxing units were contiguous to Lake Washington and Puget Sound. As a result, serious water pollution was not only a threat but a reality. The State Legislature in 1957 passed a metropolitan municipal corporation law which made it possible for cities, towns, and sewer districts in any area to jointly and collectively solve their sewage disposal problems. As a result of this enabling legislation, the Municipality of Metropolitan Seattle (METRO) embarked upon a ten-year program in 1961 which was designed to remove all sewage treatment plant effluent from the Lake Washington drainage area and to provide adequate sewage treatment for the entire area.

In 1958, the Washington Water Pollution Control Commission retained two scientific consultants (Gunter and McKee) to prepare a report on the effects of sulfite waste liquor (SWL) on oysters. It was hoped that this report would permit the establishment of sulfite waste liquor concentration standards. The report, however, was unacceptable to the Commission due to the lack of field data and related research studies and because it was concerned only with oyster mortalities due to SWL from investigations by others conducted in other parts of the country.

In 1960, therefore, the Commission issued new and more stringent waste control standards which resulted in the issuance in 1961 of temporary permits to pulp and paper mills which lacked adequate waste control facilities. These temporary permits required recovery of 85 percent of the SWL and reductions in fiber losses and suspended solids in process effluents. Prior to and after this time, from 1958 to 1962, 20 special committee sessions concerning pulping wastes were held to cooperatively improve these inadequate waste control measures taken by the pulp industry.

The Pacific Oyster Growers Association appealed to the Commission to revoke the permit issued to the Puget Sound Pulp and Timber Company of Bellingham, charging that it was inadequate since it did not require the removal of sulfite waste liquor. A Federal Enforcement Conference as provided for in Public Law 660, was held on January 16 and 17, 1962, in Olympia as requested by the Governor in a letter dated November 22, 1961. As a result of this conference, a special five-year Federal-State study was initiated to gather scientific and legal proof of pollution in Puget Sound with particular emphasis given to the pollutional impact of pulp and paper mill wastes upon the fish and shellfish resources of the Puget Sound.

PHYSICAL ENVIRONMENT

DESCRIPTION

Contrasts in the physical make-up of the Area give it a striking character. Landscapes vary from streams to marine waterways, islands to peninsulas, lowlands to mountains, and pastoral to wilderness. These physical features cover 13,200 square miles, all blending into a natural environment whose beauty is claimed to be second to none in the world. These same physical characteristics are largely responsible for the present pattern of population and for marking the Puget Sound Area as an economic unit.

Geography

The blue-green sea of Puget Sound which covers about 2,500 square miles is the focal point of the Area. A number of islands lie in this inland sea. They vary from Whidbey Island, second largest in the contiguous United States, to the picturesque San Juans, an archipelago of 172 islands in the northern part of the Area.

The Sound has two main arms; between the two arms is the Kitsap Peninsula. The western arm–Hood Canal–is a 50-mile-long, narrow inlet which extends southward between the Olympic Mountains and the Kitsap Peninsula. The eastern arm is the main basin of the Sound, which extends southward from Admiralty Inlet and ends near Olympia in a series of inlets and connecting channels. Between the two arms is the Kitsap Peninsula.

Eastward from the Sound, elevations range from sea-level to Mt. Rainier's lofty 14,410-foot summit in the Cascade Range. The lowlands are composed of moraines and outwash plains of gravels, sands, and clays. Numberous rivers and streams discharge into Puget Sound. These streams have built up deltas and flood plains over the older gravelly plains. Large tidal estuaries are formed where they meet the sea.

Beyond the plains and deltas are alluviated river valleys, separated by gently rolling surfaces. Terraces, lakes, marshes, and reservoirs diversify the terrain. These lowland valleys, with their mountain-valley extensions, contain most of the population, industry, and agriculture.

The Cascade Range, which reaches altitudes of about 8,000 feet in the north and 5,000 feet in the south, forms the eastern boundary of the Area. Rising prominently above the ridges are the volcanic cones of Mount Baker (10,778 feet) and Mount Rainier.

Westward from the Sound, the Olympics rise abruptly from the shores of Hood Canal. This portion of the Area is a complex system of deep valleys and canyons, separated by sharp ridges and peaks that commonly attain altitudes of 6,000 feet; through them cascade numerous streams. Beyond these contoured gorges is a great arc of snowcapped peaks (the Baily Range). Towering above are the crags, the snowdome, and the glaciers of Mount Olympus (7,965 feet). To the north, the landscape tumbles off abruptly to a narrow plain lying between the steep foothills and the Strait of Juan de Fuca.

The Puget Sound Area was divided into 11 basins for planning purposes. These basins are shown and named on the Study Area map (Figure 1-1). Information and plans are developed individually for each basin and presented as the concluding section of this Appendix. This initial area section develops the broader region-wide information and presents the methodology and assumptions used in arriving at the basin plans.

Land Use

The present pattern of land use ranges from areas with intense residential, commercial, and industrial concentrations to undeveloped cut over lands and areas of second-growth timber. Land use is shown on the map (Figure 1-2) and in Table 1-1.

Forest land predominates and accounts for 75 percent of the total land use. The area contains 6.4 million acres of forest, 5 million acres of which are classified as commercial forest land. Approximately

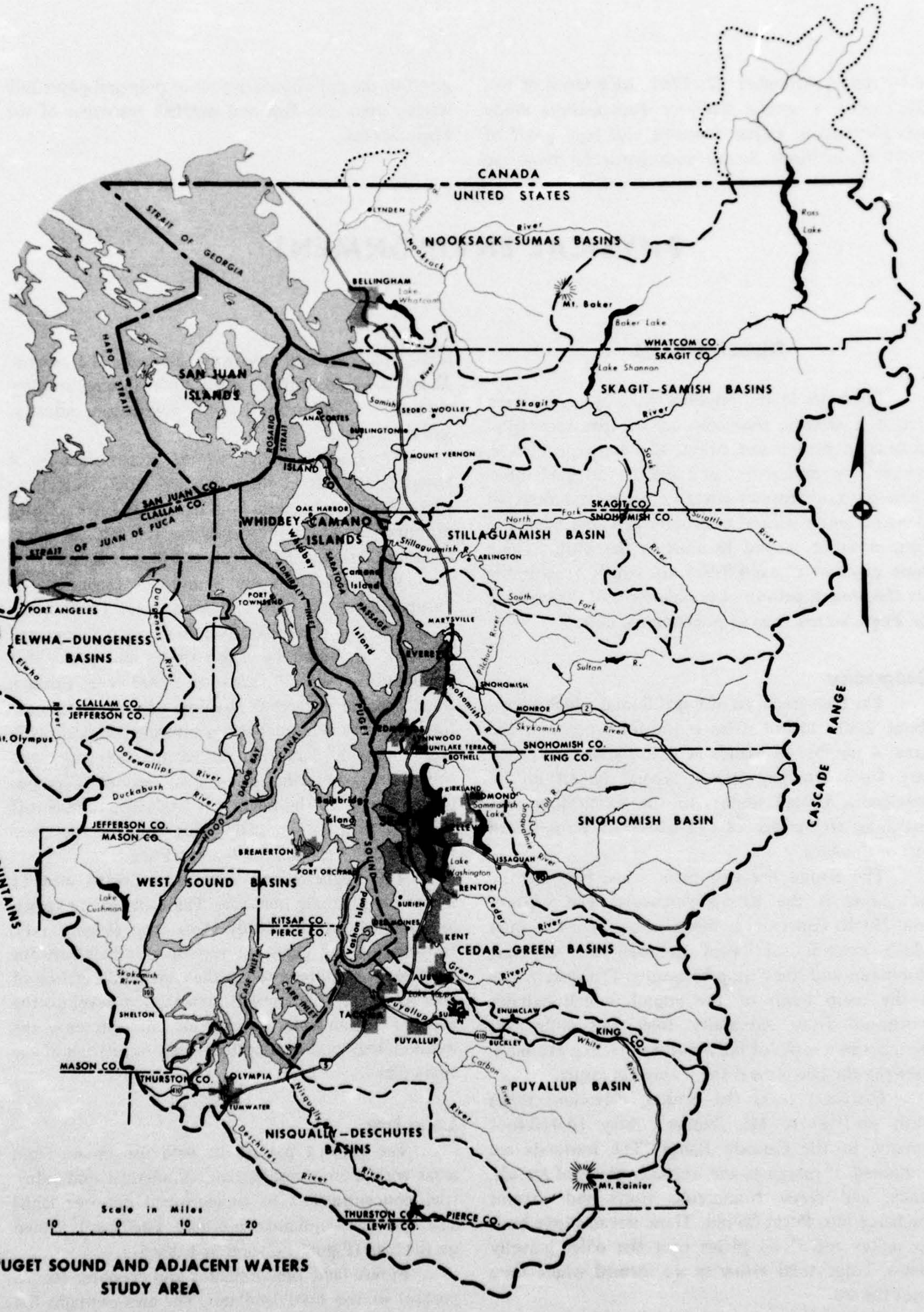


FIGURE 1-1. Basins in the Puget Sound Area.

TABLE 1-1. Present land use and ownership Puget Sound Area

		LAND OWNERSHIP[1] (Thousands of Acres)					LAND USE[2] (Thousands of Acres)						
Basins		Federal	State	County & City	Private	Total	Crop-land	Range Land	Forest	Rural Non-Farm	Urban Build-Up	Fresh Water	Total
Nooksack-Sumas	Acres	277	87	7	437	808	137	12	610	13	21	12	804
	% Area	3.2	1.0	0.1	5.1	9.4	1.6	0.1	7.1	0.1	0.2	0.1	9.4
Skagit-Samish	Acres	1,378	107	8	433	1,936	100	20	1,753	20	19	35	1,948
	% Area	16.1	1.2	0.1	5.2	22.5	1.2	0.2	20.5	0.2	0.2	0.4	22.7
Stillaguamish	Acres	178	72	2	190	442	35	1	385	6	7	5	438
	% Area	2.1	0.8	0.0	2.2	5.2	0.4	0.0	4.5	0.1	0.1	0.1	5.1
Whidbey-Camano Islands	Acres	8	6	1	119	134	23	2	84	12	11	1	134
	% Area	0.1	0.1	0.0	1.4	1.6	0.3	0.0	1.0	0.1	0.1	0.0	1.6
Snohomish	Acres	430	142	56	588	1,216	72	2	1,055	29	36	24	1,218
	% Area	5.0	1.7	0.7	6.9	14.2	0.8	0.0	12.3	0.3	0.4	0.3	14.2
Cedar-Green	Acres	76	24	116	520	736	53	3	447	34	166	39	743
	% Area	0.9	0.3	1.4	6.1	8.6	0.6	0.0	5.2	0.4	1.9	0.5	8.7
Puyallup	Acres	307	19	13	439	779	37	6	593	26	97	11	770
	% Area	3.5	0.2	0.2	5.1	9.1	0.4	0.1	6.9	0.3	1.1	0.1	9.0
Nisqually-Deschutes	Acres	135	64	5	447	650	46	43	507	20	20	10	646
	% Area	1.6	0.7	0.1	5.2	7.6	0.5	0.5	5.9	0.2	0.2	0.1	7.5
West Sound	Acres	368	122	20	782	1,291	46	5	1,124	64	42	13	1,294
	% Area	4.3	1.4	0.2	9.2	15.1	0.5	0.1	13.1	0.8	0.5	0.1	15.1
Elwha-Dungeness	Acres	332	27	2	80	442	24	2	409	5	6	2	448
	% Area	3.9	0.3	0.0	0.9	5.2	0.3	0.0	4.7	0.1	0.1	0.0	5.2
San Juan Islands	Acres	1	9	1	101	113	19	9	72	9	3	1	113
	% Area	0.0	0.1	0.0	1.2	1.3	0.2	0.1	0.8	0.1	0.0	0.0	1.3
Total	Acres	3,490	679	232	4,147	8,547	592	106	7,039[3]	239	428	152	8,557
	% Area	40.8	8.0	2.7	48.4	100.0	6.9	1.2	92.2	2.8	5.0	1.8	100.0

1 Figures obtained from Forest Work Group.

2 Figures obtained from Land Usage and Development Technical Committee.

3 Includes open lands normally associated with forest areas.

44 percent of the forest land is in Federal ownership and 11 percent in other public holdings. The remaining 45 percent is held by private owners.

There are about 591,000 acres of cropland in the Puget Sound Area which is about seven percent of the total land use. Agricultural operations are confined largely to the wide, fertile lowlands which are utilized for fruit, berry, and vegetable growing and also for dairying and poultry raising operations. Cropland is well established in the river valleys of the Nooksack, Puyallup, Green and Sammamish, Skagit, and Elwha-Dungeness basins. Crop and pasture lands are not extensive in the area, but the resulting production from them is very important to the general economy.

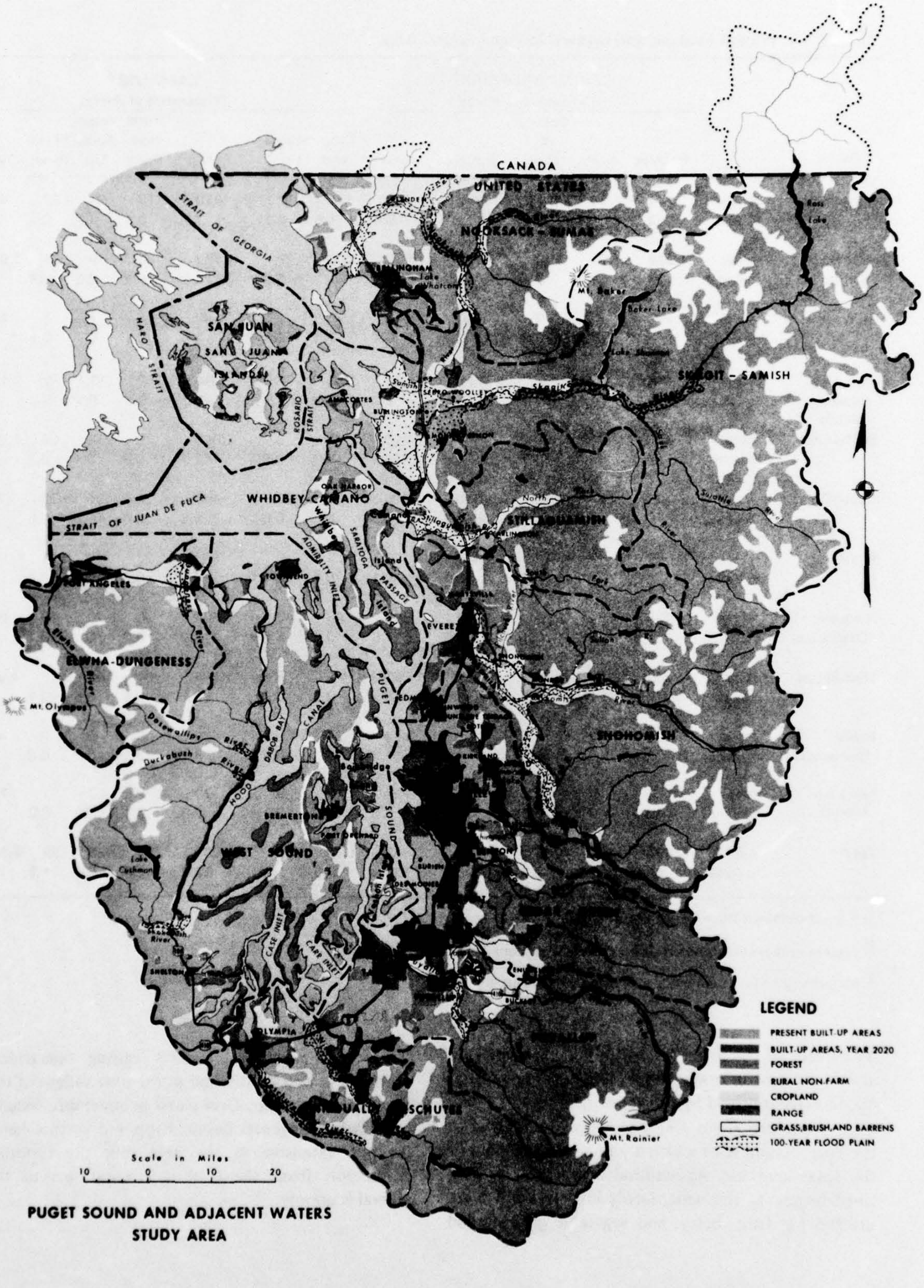


FIGURE 1-2. Generalized land use in the Puget Sound Area.

PHOTO 1-2. Marine waterways cover about 2,500 square miles, giving a maritime air to the Puget Sound Area.

Urban build-up accounts for five percent of the Area's total land use. Most urban development to date is found adjacent to the shores of Puget Sound and in the lowlands. Heavy industry is concentrated along the shores of Commencement Bay and Elliott Bay, on the tideflats near the mouth of the Puyallup River, and in the lower Duwamish River area. Developed lands are concentrated in the central part where the Seattle-Tacoma-Everett metropolitan and industrial complex and numerous small cities and suburban residential areas comprise approximately two-thirds of the area's total urban land use.

Inland waters–streams and lakes–make up about two percent of the total land use. The fresh waters are utilized for outdoor recreation, fish and wildlife habitat, irrigation, various types of industrial operations, and domestic water supply.

The present pattern of land ownership in the area is 41 percent Federal, 11 percent State and local, and 48 percent private. Most of the Federally-owned lands lie in the National Forests and National Parks.

Soils and Cover

The broad lowland of Puget Sound is often described as a trough or valley, lying between the Olympics and the Cascades. The entire area has been glaciated and occupied by the sea. Geologists believe that the last continental glacier receded about 12,000 to 14,000 years ago, leaving an infertile plain of moraines and outwash gravels, sands, and clays.

There is a great diversity of soils in the Puget Sound Area due to the heterogenous character of rocks in the mountains, glacial materials, and stream alluvial deposits. Soil development is influenced by a range of climatic factors, topographic features, biologic activity, and the length of time the materials have been exposed to the soil-forming elements.

The mountainous areas generally consist of shallow, stony, and rocky loams and silt loams, ranging in depth from less than six inches to more than 36 inches, overlying bedrock. The soils of some mountain areas are influenced by local glaciers and volcanic materials. Glacial soils are formed on cemented basal till, clay till, outwash or recessional moraines, and lacustrine or glacial lake materials. Those soils on glacial basal till consist of sands, gravelly sands, and gravelly sandy loams 20 to 36 inches deep over slowly permeable cemented sandy or clay till. Those soils on outwash materials consist of sands, gravelly sands, and gravelly sandy loams ranging between six and 30 inches deep over rapidly permeable gravel and sands. Those soils on lacustrine materials consist of silt loams, silty clay loams, and clay loams from 24 to more than 60 inches deep overlying either stratified sands and silts or slowly permeable, firm, platy, silty lakebed materials. Those soils on stream alluvium consist of rapidly permeable sands in the upper reaches and successively grade to more slowly permeable fine sandy loams, silt loams, loams, clay loams, silty clay loams, and clays in the lower reaches.

PHOTO 1-3. Mount Rainier, 14,410 feet. Mountains and ranges comprise much of the western and eastern parts of the area.

Dense conifer forests dominate the Area's native land cover. Douglas fir dominates, although hemlock, true firs, western red cedar, bigleaf maple, and willow are found throughout the conifer woodlands. Several varieties of small trees, shrubs, and vines form a dense understory cover in all forested areas. Ferns and mosses dominate the ground cover in shaded areas.

Scattered through the lowlands are several prairie areas. Grasses are the main cover, with scattered stands of fir, lodgepole pine, and Oregon white oak. Scotch broom has invaded some parts of the prairie areas.

The soil mantle and vegetative ground cover are of special significance since they directly affect the runoff pattern and also have an impact on the water quality. Forested areas tend to slow melting of snow and retard the outflow of rainfall whereas logged-over areas yield larger quantities of runoff and have larger snowmelt flood peaks sooner in the spring. Woodlands converted to farm land, and rural areas converted to urban land, also increase the amounts of runoff as well as the size of flood peaks. The condition of cover, as well as the soil types and topography, is significant in considering soil erosion and the resulting fluvial sediment and debris loads. Considerable precipitation first passes through the soil profile, leaching out the more soluble fractions of the mineral constituents in the soil. When the ground water emerges as streamflow, it has a chemical composition that reflects the soil characteristics.

Climate

The Cascade Mountains shield the Area from cold air masses traveling southward across Canada in the winter. The Olympic Range is effective in protecting it from the more intense winter storms reaching the coast. As a result, the Puget Sound Area is typified by a climate with cool, dry summers, and mild, wet winters.

The average annual precipitation varies generally from 20 to 50 inches in the lowland areas surrounding the Sound, to over 200 inches in the higher elevations. The driest area receives from 18 to 30 inches of precipitation annually. This area, often referred to as the "rainshadow" of the Olympic Mountains, extends eastward from Port Angeles to near Everett and northward into the San Juan Islands.

The Area has a marked seasonal distribution of precipitation. Autumn, winter, and early spring are rainy with persistent cloudiness and high relative humidity, while rainfall is scant during May through August. About two-thirds of all precipitation occurs during the six-month period of October through March.

Most of the winter precipitation falls as snow in the higher elevations. For example, the annual snowfall at Snoqualmie Pass (altitude 3,000 feet) is about 400 inches. Glaciers and permanent snowfields blanket much of the high country.

Average summer temperatures vary from the mid-70's (24°C) in Seattle, to about 68°F (20°C) on the coast. Average winter lows vary from about 28°F to 36°F (-2° to 2°C). Temperatures below 0°F (-18°C) in the lowlands are rare, and maximum temperatures very seldom exceed 100°F (38°C).

Population

The population of the Puget Sound Study Area is approaching 2,000,000. Almost two-thirds of the State's total populace live within the Puget Sound Area.

Almost 90 percent of the people live in the eastern portion of the Area, concentrated largely in the Everett, Seattle, and Tacoma service areas. The Snohomish, Cedar-Green, and Puyallup Basins alone contain about 80 percent of the total population. They also constitute the fastest growing area, having more than doubled in population since 1940. The river deltas and glacial drift plains support a fairly well-distributed rural population. The northern and western portions stand out as sparsely populated areas. The Nisqually-Deschutes, West Sound, and Elwha-Dungeness Basins together account for only 11 percent of the area's population. Less than ten percent of the population is located in the Nooksack-Sumas, Skagit-Samish Basins, San Juan Islands and Whidbey-Camano Islands.

The major population cluster is located in the Cedar-Green Basins in the Seattle metropolitan area. Over half of the Area's people live in this Basin. Census data estimates for 1967 include 6 cities with populations greater than 10,000.

Economy

Geographical characteristics and its natural resource base are responsible for marking the Puget Sound Area as an economic unit. Geographically, the

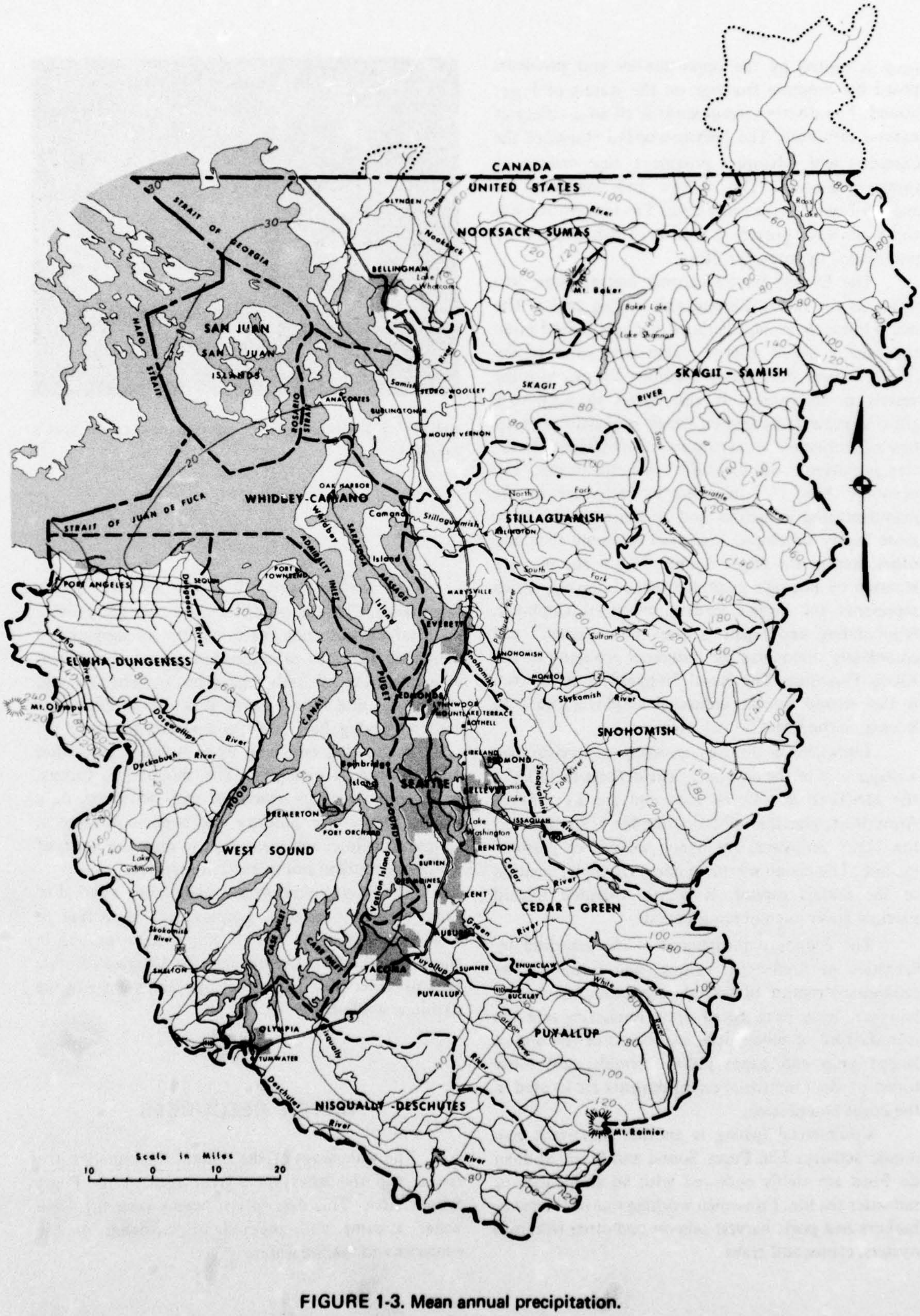


FIGURE 1-3. Mean annual precipitation.

Area is united by the opportunities and problems posed by common frontage on the waters of Puget Sound. The diverse terrain lends itself to a variety of natural resources. The heavily-wooded slopes of the Cascades and Olympics provide a rich reserve of timber resources. The valleys and lowlands are endowed with fertile farm lands. The numerous rivers and waterways provide a wealth of fish and sea life plus several hydropower sites.

The Everett-Seattle-Tacoma metropolitan area serves as the major shipping and trading center. The many inlets, bays, and harbors of Puget Sound make this area a major seaport region with some of the finest natural deep-water facilities for ocean-going vessels in the world. It also serves to support a growing industrial complex which is heavily oriented toward activities in aerospace, shipbuilding, trade, transportation, and diversified manufacturing. The economy here is dominated by activities in the manufacturing industries and is characterized by a more highly developed industrial economy than any other area in the Puget Sound. This is the primary location of Boeing's giant aerospace industry, which represents the Area's leading industrial employer. Shipbuilding and repair is also "big business" and completely dominates the industrial economy of the Kitsap Peninsula. The Naval Shipyard at Bremerton is the second largest industrial employer, next to Boeing, in the Puget Sound Area.

Elsewhere in the area, government services play a major role in the economy. The defense facilities at the McChord Air Force Base and the Fort Lewis Army Post, plus the military complex of the Bremerton Naval Shipyard, are major sources of personal income. The economy surrounding Olympia, location of the State's capitol, is heavily oriented toward meeting governmental requirements.

The economy throughout is characterized by activities in lumbering, fishing, and farming. The economic structure of several areas within the region, however, have been based upon lumbering and the manufacture of wood products. Some of the State's largest pulp and paper mills, sawmills, and other forest product industrial establishments are located in the Puget Sound Area.

Commercial fishing is another important economic activity. The Puget Sound and Strait of Juan de Fuca are richly endowed with an abundance of saltwater sea life. Fishermen working out of the many harbors and ports harvest salmon and other fish, plus oysters, clams, and crabs.

PHOTO 1-4. Forest land comprises most of the area's land use.

The lowlands and valleys contain many fertile farm lands. Climatic conditions and rich soil provide an ideal environment for a number of agricultural activities. The area produces and processes considerable quantities of fresh vegetables, strawberries, and caneberries and flower bulbs. It is also an important area in dairying, beef cattle, and poultry farming.

A growing emphasis upon outdoor recreation and tourism is emerging. The mountains, forests, lakes, and rivers are resources easy to reach. As a result, the service industry has been expanding in terms of facilities and manpower to meet the needs of a growing tourism and recreation industry.

The Puget Sound Area is undergoing a period of rapid economic growth. Employment is soaring to new heights and the rate of employment growth in the Seattle-Tacoma-Everett area for 1966 was double that of other West Coast metropolitan areas and the nation as a whole.

WATER RESOURCES

The waterways of the Sound, the estuaries, the rivers, and the lakes are a great asset of the Puget Sound Area. This description begins with the fresh water streams and proceeds downstream to the estuaries and marine waters.

Fresh Water

The rivers of the Puget Sound Area vary from a few miles to 135 miles in length. Glaciers, located in the higher elevations in the Cascades and Olympics, are the sources for many of these streams. In the lowlands, rivers like the Skagit and Stillaguamish exhibit meandering courses across the floodplains. The principal rivers of the area are the Nooksack, Skagit, Stillaguamish, Snohomish, Cedar, Green, Puyallup, Nisqually, Deschutes, Skokomish, Elwha, and Dungeness Rivers. Discharge figures for various stations on these rivers are shown in Table 1-2. Together, these twelve rivers account for over three-fourths of the total runoff.

Nearly three-fourths of the available surface water flows from forested watersheds. These areas are geologically young and typified by steep topography with fast-flowing streams. The climate and topography result in a heavy winter and spring runoff with several flood peaks. However, the major floods usually result from warm rainstorms occurring in the winter.

Minimum streamflows for most rivers here occur between July and November. The magnitude and duration of low flows are significantly affected by ground and surface storage. Melt water from glaciers and snowfields sustain flows in many streams. The timing and quantities of low flows are significant for water quality considerations since warm water has a lower capacity for absorbing waste loadings. In addition, wasteloads to a stream oftentimes are at a maximum during the low-flow period.

Most of the ground-water supplies in the Puget Sound Area are contained in sedimentary deposits of Quaternary age. These deposits occupy most of the lowlands and the mountain-valley extensions of the numerous rivers. The uplands do not support large-yielding wells. The Quaternary units, generally, contain the most dependable aquifers in the area.

TABLE 1-2. Principal rivers Puget Sound Area

Basin	River	Drainage Area Sq. Miles	Discharge (cfs) Min. Daily	Max. Daily	Average Annual
Nooksack-Sumas	Nooksack River nr. Lynden	648	595	46,200	3,699
Skagit-Samish	Skagit River nr. Mt. Vernon	3,093	2,740	144,000	16,490
Stillaguamish	South Fork, Stillaguamish River nr. Granite Falls	119	55	32,400	1,064
Snohomish	Snohomish River nr. Snohomish	1,714	--[1]	136,000	9,500[2]
Cedar-Green	Cedar River at Renton	186	56	6,640	711
Cedar-Green	Green River at Tukwila	440	195	12,100	1,462
Puyallup	Puyallup River at Puyallup	948	306	57,000	3,364
Nisqually-Deschutes	Nisqually at McKenna	517	20	25,700	1,415
Nisqually-Deschutes	Deschutes River nr. Rainier	90	16	5,620	263
West Sound	Skokomish River nr. Potlatch	227	125	27,000	1,188
Elwha-Dungeness	Elwha River nr. Port Angeles	269	10	41,600	1,487
Elwha-Dungeness	Dungeness River nr. Sequim	156	77	8,400	373

1 Discharge below 10,000 cfs not generally computed due to large tidal fluctuations.

2 Accurate continuous streamflow records in the Snohomish River have not been possible because river stages are affected by tidal fluctuations. Projection of upstream records, however, suggests that the mean annual discharge of the entire Snohomish River system is probably about 9,500 cfs.

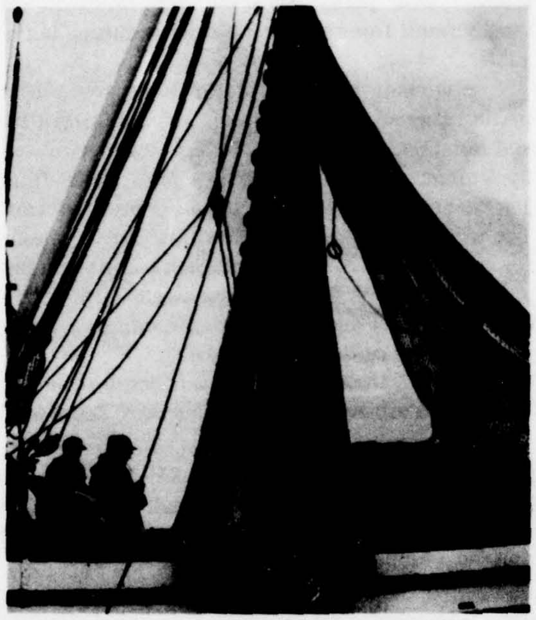


PHOTO 1-5. Fishermen find a way of life, harvesting salmon and other fish from Puget Sound waters.

The more favorable areas for ground-water supplies are found south of Seattle where zones of water-bearing coarse sand and gravel in both recessional outwash and subtill strata are relatively abundant in comparison to northern areas. In the areas south of Seattle, groundwater is used for municipal and industrial purposes to a greater degree than elsewhere where the principal use of ground water is for irrigation.

Lakes and reservoirs comprise a resource of growing importance to the Area. Many of the lakes were formed by glacial scour that deepened and widened pre-existing troughs. There are over 2,800 lakes and reservoirs occupying a water surface area of about 175 square miles. Of these there are 24 major reservoirs having a total surface area of about 70 square miles. Ross Reservoir on the Skagit River is the largest, with a total capacity of about 1.4 million acre-feet. The two largest lakes are Lake Washington (22,138 surface acres) which forms the eastern city limits of Seattle and Lake Sammamish (4,897 surface acres), approximately five miles directly east of Lake Washington. Many of the other lakes are small and are located in mountainous country above 2,500 feet in elevation. Most of these are high alpine lakes of exceptional beauty, lying in a wilderness of scenic grandeur.

Estuaries

Estuaries occur in the tidal zone where rivers meet the Sound. There, the fresh surface runoff joins and dilutes the marine waters. It creates a unique and delicate environmental system which includes salt marshes, bays, channels, and inshore waters. Here also is where the rivers deposit their sediment loads, filling and modifying the lower channels and building deltas.

The estuary is of extreme importance for fish as it is the doorway for juvenile salmon and searun trout on their trip to the ocean, as well as adult salmon returning to their spawning grounds. It is through this zone that the young fishes must adjust to the new marine environment. This adjustment is a critical period, and good quality water is a requirement to provide this transition. In addition, both shellfish and bottomfish have a great economic value in these estuaries.

Actually, estuaries support an extremely rich and varied ecosystem of aquatic, mud flat, and marsh habitats. They also support extensive wildfowl populations. They are a unique outdoor laboratory for study and research of the complex interactions of living organisms.

Few of the principal estuaries in Puget Sound are unspoiled. The Skagit and Nisqually remain essentially untouched. Others, like the Duwamish, Snohomish, and Puyallup have been seriously encroached upon by the expansion of cities and the growth of industries. Examples of man's activities can be seen in the continual dredging, port building, and waste discharges. These activities have caused great concern over their future preservation.

PHOTO 1-6. Numerous rivers and streams flow from the higher elevations.

Marine Waters

The following discussion of the marine waters of Puget Sound is the only such writeup in the Appendices to the Puget Sound and Adjacent Waters Study. Accordingly, more detail has been included here than would normally be warranted.

Most of the Puget Sound oceanographic description has been presented in this section. Only brief oceanographic discussions have been presented in the basin chapters.

The waters confined within the boundaries of Puget Sound are actually a small portion of a larger complex that includes the Strait of Georgia and the Strait of Juan de Fuca. The entire system is composed of many inter-connected inlets, bays, and channels with sea water entering from the west and fresh water entering at many points along the system. This large complex may be divided into nine major oceanographic areas which are interrelated one to the other: Strait of Juan de Fuca, Admiralty Inlet, Puget Sound Basin, Southern Puget Sound, Hood Canal, Possession Sound, Bellingham Bay, San Juan Archipelago, and Georgia Strait.

Basically, the Puget Sound-Georgia Strait-Juan de Fuca Strait complex is a two-layer system with fresher water moving seaward in a surface layer that overrides a more saline layer of inflowing oceanic water. The surface layer contains fresh water added locally from direct precipitation, river runoff, and other land drainage. The deeper, more saline layer has its origin in the Pacific Ocean off Cape Flattery and has a net flow landward in response to the pressure forces associated with the difference in density between fresh water and sea water. The boundary between these two layers is most distinct near the freshwater source or on either side of a constriction having strong tidal currents. This boundary becomes more diffuse as the freshwater layer moves seaward as a result of vertical mixing by winds and the entrainment of deeper, more saline water into the surface layer. The processes that govern the mixing and transporting of waters from one part of the complex to another are complicated and are related to meteorological conditions and to tidal action.

As one travels eastward from the entrance of the Strait of Juan de Fuca off Cape Flattery to the head of either Georgia Strait or Puget Sound, a series of sills are encountered that separate the deeper basins. These sills are often mixing zones where the fresher surface water and the more saline deeper water are mixed by tidal action to form a new water type that becomes the deep water for the next landward basin. As a result, the waters of each basin become fresher as one proceeds landward. Also, the temperature range from winter to summer becomes greater and the tidal range increases.

The Strait of Juan de Fuca is the main channel connecting the waters of Puget Sound and Georgia Strait with the Pacific Ocean. Oceanic-type water enters the Strait of Juan de Fuca below the surface at the western end off Cape Flattery and travels landward (to the east) without significant modification until it reaches the Victoria-Green Point sill near Port Angeles. At this point, most of the oceanic water is stopped, but a portion of it is mixed with the fresher surface water to form a water type that becomes the deep water source for both Puget Sound and Georgia Strait. The eastern end of the Strait of Juan de Fuca is essentially the mixing area and the region where the water splits with a portion going south into Puget Sound and the largest part going into Georgia Strait via Haro and Rosario Straits. Under proper conditions, some oceanic water may penetrate into the San Juan Islands in late summer.

The importance of the increased density in late summer by the oceanic water intruding into the Strait and then being mixed in the eastern end of the Strait cannot be over-emphasized. Because of this more dense water entering in the early fall, most parts of the Puget Sound-Georgia Strait complex are flushed once a year by a replacement of the less dense water with the more dense water. The maximum density water does not occur simultaneously in all parts of the complex, but depends upon the distance from the Strait and upon local mixing areas.

Admiralty Inlet—are those waters separating the Strait of Juan de Fuca from the Puget Sound Basin. Most of the water entering and leaving Puget Sound must flow through Admiralty Inlet. Only a small portion of water flows through Deception Pass at the northern end of Whidbey Island. Tidal currents are strong in Admiralty Inlet with speeds frequently over three miles per hour on both ebb and flood with a maximum of nearly six miles per hour during periods of large tidal range. Because of these strong currents, Admiralty Inlet is a large mixing zone for the deeper waters of the Strait of Juan de Fuca with the fresher surface waters from Puget Sound. The mixed water is more dense than the surface water and less dense than the Strait water and flows back into Puget Sound on a flood tide. The depths at which this mixed water

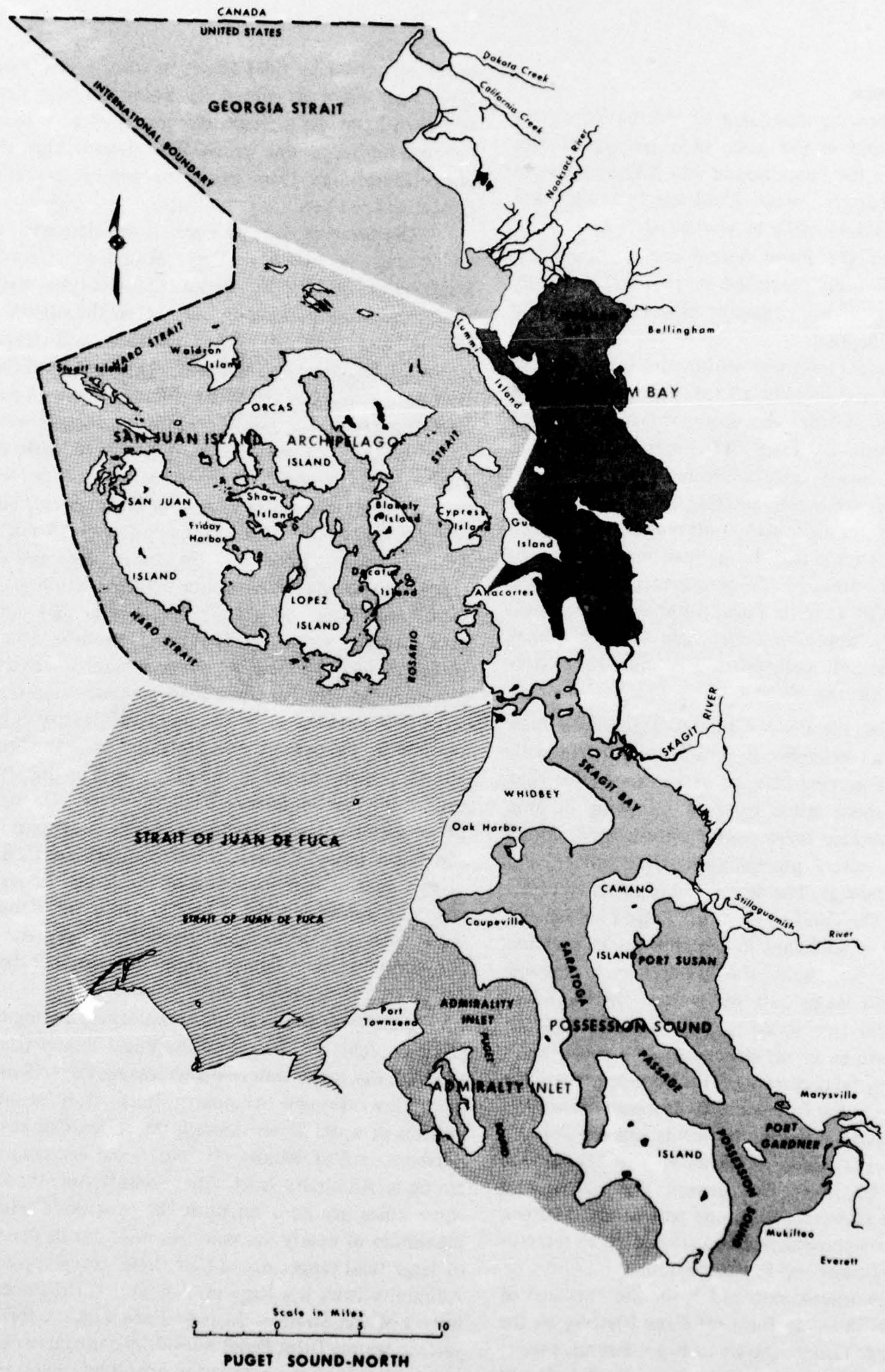


FIGURE 1-4. Puget Sound North Oceanographic Areas

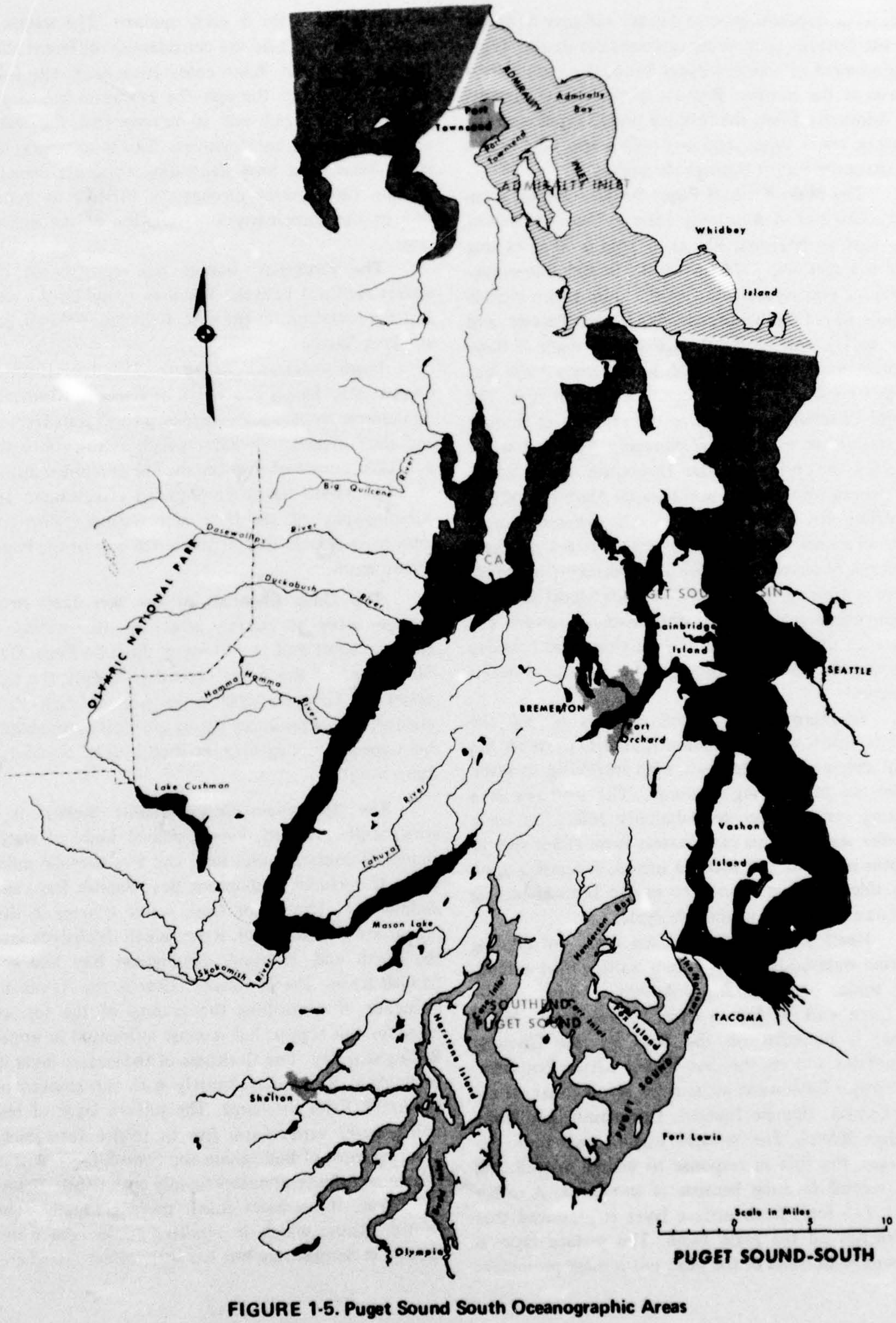


FIGURE 1-5. Puget Sound South Oceanographic Areas

will settle depends upon its density and may be either at the bottom or at some intermediate depth. Thus, replacement of water in Puget Sound does not always occur at the bottom. Because of the strong currents in Admiralty Inlet, the flushing time is rapid with the various water types requiring only a few tidal cycles to make the transit through the region.

The Main Basin of Puget Sound–extends from the south end of Admiralty Inlet to the north end of the Tacoma Narrows. The main basin is 50 miles long and averages five miles in width. Several sub-oceanographic regions are found in the basin which include Elliott Bay, Commencement Bay, Colvas Passage, and the waters west of Bainbridge Island. Each of these subregions is closely related to the main basin but with somewhat different surface characteristics. The major differences are due to the source and amount of fresh water entering the subregion. The fresh water sources are primarily the Duwamish River which discharges into Elliott Bay (Seattle Harbor) and the Puyallup River which empties into Commencement Bay (Tacoma Harbor). The major effect of these rivers is observed near their mouths where a surface layer is formed that dominates both Elliott Bay and Commencement Bay. As one proceeds toward the entrance of either of the bays, a sharp line between the muddy surface layer and the outside water is observed.

Southern Puget Sound–consists of all the waters south of the Tacoma Narrows. Currents are very strong in the Narrows, with speeds up to seven miles an hour being common. The Narrows is a mixing zone similar to Admiralty Inlet, but on a smaller scale. In this case, waters from either side to depths of about 160 feet are mixed, depending upon the tide direction. Complete top to bottom mixing occurs during most of the tide cycle.

Hood Canal–is one of the most outstanding marine waterbodies. It is a long, narrow inlet extending some 70 miles from Admiralty Inlet on its northern end to Lynch Cove to the south. Hood Canal is bounded on the west by the Olympic Mountains and on the east by the Kitsap Peninsula. The major fresh water sources for Hood Canal are the Skokomish, Hamma Hamma, Duckabush, and Dosewallips Rivers. The streams exhibit two peak discharges, the first in response to winter rainfall, and the second in June because of snowmelt. A rather thick (15 feet) fresh surface layer is produced that dominates all the main basin. The surface layer is present at all times of the year, but is most prominent in winter and again in early summer. The waters at depth in Hood Canal are considerably different than the surface waters. Water enters from Admiralty Inlet and travels south through the entrance arm. Some mixing occurs, but not so intense that the water column becomes homogeneous. This water enters the main basin at a level depending upon its density, making the flushing mechanism difficult to define due to the complexity and variation of the mixing zone.

The Possession Sound–area consists of the waters confined between Whidbey Island on the west and the mainland on the east. It includes Skagit Bay and Port Susan.

Fresh water sources are: the Skagit River which empties into Skagit Bay north of Camano Island, the Snohomish River which empties into Everett Harbor, and the Stillaguamish River which empties into the northeast corner of Port Susan. The combined inflow of these rivers has a pronounced effect upon the oceanography of the Possession Sound region and frequently affects that of the north end of the Puget Sound Basin.

The Deep Channels of the San Juan Archipelago–serve as mixing areas for the waters of Georgia Strait and the Strait of Juan de Fuca. Over 90 percent of the water needed to supply the tidal prism of Georgia Strait must pass through these channels. This produces strong currents accompanied by vigorous mixing even in such a deep channel as Haro Strait.

The Bellingham Oceanographic System–is a north-south oriented, kidney-shaped body of water about 19 nautical miles long and five nautical miles wide. It includes Bellingham Bay, Samish Bay, and Padilla Bay. The major fresh water sources in this region are the Nooksack River which discharges into the north end of upper Bellingham Bay and the Samish River. The Nooksack River is the dominant influence in controlling the salinity of the surface layer for this region, but is most influential in upper Bellingham Bay. The thickness of the surface layer in Bellingham Bay varies directly with the amount of Nooksack River discharge. The surface layer of less saline water varies from five to twelve feet thick, covering most of Bellingham and Samish Bays. Within this layer, salinity increases rapidly with depth. Below this layer, it increases much more gradually. The Samish River, which is smaller, dilutes the water locally in Samish Bay but has little effect elsewhere.

Density stratification associated with the surface layer retards vertical mixing, maintaining the surface layer as a relatively stable and distinct body of water. Stability decreases with distance from the fresh water sources, since the fresh water forming this layer must flow to sea. As it flows, slight vertical mixing gradually entrains underlying salt water, reducing density stratification and increasing salinities. The effect of winds upon this area is to move the surface water from one part of the system to another with a deep compensating counterflow being established. This counterflow is often cooler and more saline than the original water and may appear at unexpected locations within the region.

The Strait of Georgia is one of the largest marine waterways on the west coast of North America. It is about 140 miles long, with an average width of 20 miles. Only the lower portion is in the Puget Sound and Adjacent Waters Study Area. The volume of Georgia Strait is six times that of the Puget Sound system. It may be classified as a fjord with an excess of precipitation over evaporation. The major source of fresh water is the Fraser River which discharges near Vancouver, B.C. This river, plus other small rivers and land drainage, contributes over 90 percent of all the fresh water flowing into the Puget Sound-Georgia Strait system. Hence, what happens in Georgia Strait has a very significant effect upon the waters of Puget Sound but the reverse is not true. This large quantity of fresh water produces a surface flow that is southward into the Strait of Juan de Fuca. In order to replenish the loss of salt being transported seaward, a net flow of deep Juan de Fuca water must flow landward from the Strait of Juan de Fuca and through the San Juan Channels. Intensive tidal action, aided by winds, mixes the brackish surface water with the deep saline water in these channels. Homogeneity extends across most of the marine waters, although some stratification occurs from local coastal drainage. The circulation pattern in Georgia Strait is generally counter-clockwise as a result of tides, runoff, and winds. The volume of Fraser River water dispersed in Georgia Strait averages the equivalent of 1.3 years of average Fraser River discharge. This amount increases to about 1.6 years of average Fraser River discharge in the summer.

WATER USES

The streams, lakes, and marine waterways of the Puget Sound Area are used for municipal and industrial water supply, fish and wildlife, outdoor recreation, irrigation, navigation, power generation, and log storage and rafting. Each of the beneficial uses of water has a quality requirements. The following examination of these uses, both present and projected, and their quality requirements, forms the basis for planning a sound water quality management program to serve the present and future needs of the residents in the Area. The data presented in the discussion of water uses were obtained from other appendices.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Present municipal and industrial water use within the Puget Sound Area averages about 650 million gallons per day. More than two million persons and numerous industries are being served. Water used for these purposes in the Area for 1965 is shown in Table 1-3. The distribution of this use by basin shows that it is concentrated in the central part of the Area, namely in the Cedar-Green, Snohomish, and Puyallup Basins where two-thirds of the total use occurs.

Although both surface and ground water are used to meet needs, the surface sources furnish more than 85 percent of the total. Major sources include the Skagit, Nooksack, Tolt, Cedar, and Green Rivers. Although surface water supplies the major municipal and industrial users in the Area, ground water is readily available and an important source in some basins.

Water used primarily for municipal purposes accounts for about one-third of the total water use in the Area. The overall average per capita water use in municipalities for the entire Area is about 120 gpd. Municipal water use is concentrated in the Cedar-Green Basins. About one million metropolitan dwellers are using over 100 million gallons daily. The city of Seattle ranks as the largest municipal water user.

TABLE 1-3. Summary of municipal and industrial water use, Puget Sound Area (1965)

Basin and use	Estimated population served	Surface water usage (mgd)		Estimated population served	Ground water usage (mgd)		Estimated population served	Total usage (mgd)	
		Average daily	Maximum monthly		Average daily	Maximum monthly		Average daily	Maximum monthly
NOOKSACK-SUMAS									
Municipal	42,600	9.0	13.0	16,800	1.9	2.6	59,400	10.9	16.0
Rural-Individual	1,500	0.1	0.2	16,500	0.9	1.8	18,300	1.0	2.0
Industrial	---	60.0	65.0	---	0.6	1.2	---	60.6	66.0
Total	44,400	69.0	78.0	33,300	3.4	5.6	77,700	72.4	84.0
SKAGIT-SAMISH									
Municipal	34,400	3.5	4.2	5,800	0.8	1.1	40,200	4.3	5.0
Rural-Individual	1,550	0.1	0.2	13,750	0.8	1.6	15,300	0.9	2.0
Industrial	---	23.0	27.0	---	---	---	---	23.0	27.0
Total	35,950	27.0	31.0	19,545	1.6	2.7	55,500	29.0	34.0
STILLAGUAMISH									
Municipal	665	0.1	0.1	6,135	0.9	1.5	6,800	1.0	2.0
Rural-Individual	1,200	0.1	0.1	10,900	0.6	0.9	12,100	0.7	1.0
Industrial	---	---	---	---	0.6	4.0	---	0.6	4.0
Total	1,865	0.2	0.2	17,035	2.1	6.4	18,900	2.2	7.0
SNOHOMISH									
Municipal	147,930	23.0	28.0	6,530	0.6	1.2	154,760	24.0	29.0
Rural-Individual	3,540	0.2	0.3	32,400	1.8	2.5	35,940	2.0	3.0
Industrial	---	138.0	144.0	---	0.4	0.7	---	138.0	145.0
Total	151,470	161.0	172.0	39,230	2.8	4.4	190,700	164.0	177.0
CEDAR-GREEN									
Municipal	899,420	94.0	133.0	125,800	14.0	21.0	1,025,220	108.0	154.0
Rural-Individual	1,500	0.1	0.1	13,500	0.8	1.0	15,000	1.0	1.0
Industrial	---	54.0	61.0	---	2.3	2.7	---	56.0	64.0
Total	900,920	148.0	194.0	139,300	17.0	25.0	1,040,220	165.0	219.0
PUYALLUP									
Municipal	151,200	22.0	29.0	193,255	22.0	98.0	344,455	44.0	127.0
Rural-Individual	75	---		670	0.1	0.1	745	0.1	0.1
Industrial	---	41.0	49.0	---	15.0	16.0	---	56.0	65.0
Total	151,275	63.0	78.0	193,925	37.0	115.0	345,200	100.0	193.0
NISQUALLY-DESCHUTES									
Municipal	11,680	0.6	1.3	35,209	4.8	8.7	46,389	5.0	10.0
Rural-Individual	2,300	0.1	0.2	20,600	1.1	1.6	22,900	1.2	1.8
Industrial	---	0.2	0.2	---	2.0	2.4	---	2.2	2.7
Total	13,980	1.0	2.0	55,809	8.0	13.0	69,300	9.0	14.0
WEST SOUND									
Municipal	44,555	7.3	11.6	64,695	7.1	14.6	109,250	14.0	26.0
Rural-Individual	1,250	0.1	0.1	11,400	0.9	1.3	12,650	1.0	1.4
Industrial	---	30.6	42.5	---	3.2	3.8	---	34.0	46.0
Total	45,850	38.0	54.0	76,095	11.0	19	121,900	48.0	73
ELWHA-DUNGENESS									
Municipal	17,672	4.6	8.2	323	---	--	18,000	4.6	8.2
Rural-Individual	1,200	0.1	0.1	10,800	0.5	0.7	12,000	0.6	0.8
Industrial	---	59.2	64.9	---	---	---	---	59.0	65.0
Total	18,872	64.0	73.0	11,123	1.0	1.0	30,000	65.0	74.0
SAN JUAN									
Municipal	1,642	0.4	0.9	746	0.2	0.3	2,388	0.6	1.2
Rural-Individual	---	---	---	212		---	212	---	---
Industrial	---	---	---	---	---	---	---	---	---
Total	1,642	0.4	0.9	958	0.2	0.3	2,600	0.6	1.2
WHIDBEY-CAMANO									
Municipal	4,800	1.0	1.4	11,385	1.1	2.2	16,185	2.1	3.6
Rural-Individual	---	---	---	4,015	0.2	0.4	4,015	0.2	0.4
Industrial	---	1.5	1.8	---	---	---	---	1.5	1.8
Total	4,800	2.5	3.2	15,400	1.3	2.6	20,200	3.8	5.8
TOTALS[a]									
Municipal	1,356,550	165	231	467,000	53	151	1,823,550	219	382
Rural-Individual	14,450	1	1	134,700	8	12	149,150	9	13
Industrial	---	408	455	---	24	31	---	432	486
Total	1,371,000	575	687	601,700	85	194	1,972,700	660	881

a/ Figures are rounded

Industries are using about 420 million gallons per day, or two-thirds of the total municipal and industrial water demand in the Area.

Most of the industrial water use in the Area centers in the Snohomish Basin where one-third of the total use occurs. Major water using industry elsewhere is heavily concentrated along the shores of Commencement Bay, Bellingham Bay, and near Anacortes and Port Angeles.

In light of projected growth, the Area may, by 2020, require 1,511 million gallons of water per day for municipal purposes, as shown in Figure 1-6. This is seven times present requirements. This projection is based on an average per capita municipal water demand of 190 gallons per day by 1980 and 230 gallons per day by 2020.

The growth of industry has been rapid in recent years. This growth is expected to continue to account for a major portion of all water use. The primary water using industries are expected to be the pulp and paper mills, food processing plants, aluminum reduction, and chemical plants—all requiring varying degrees of clean water.

In the Puget Sound Area, industrial water withdrawal constitutes the greatest single water diversion. It represents the water industries' use for a power source, a coolant, a transporting device, an ingredient, a processing agent, and an air conditioner. Industries such as pulp and paper manufacturing use water in large amounts.

Because of protected watersheds, most municipally-supplied water in the Area receives minimal treatment. A substantial portion of the total population served by municipal surface water supplies receives water treated only by chlorination.

Eight major watersheds, comprising about 500 square miles are used as the source of municipal and industrial water supplies (Figure 1-7). The cities manage these watersheds for the purpose of protecting water quality. Access control is exercised by Seattle on the Cedar and Tolt, by Tacoma on the Green, and by Bremerton on the Gorst, through ownership of all or portions of these watersheds.

Forests are carefully managed to preserve the water quality. Through this careful control and management, the water is of sufficiently high quality to require only disinfection prior to distribution to consumers.

It is held by the municipal suppliers that opening the watersheds to recreation use would allow bacterial and viral contamination of the water supplies, necessitating more extensive and expensive treatment.

Appendix VI, Municipal and Industrial Water Supply of the Task Force adds considerable information on the public health aspects of alternative watershed management operation.

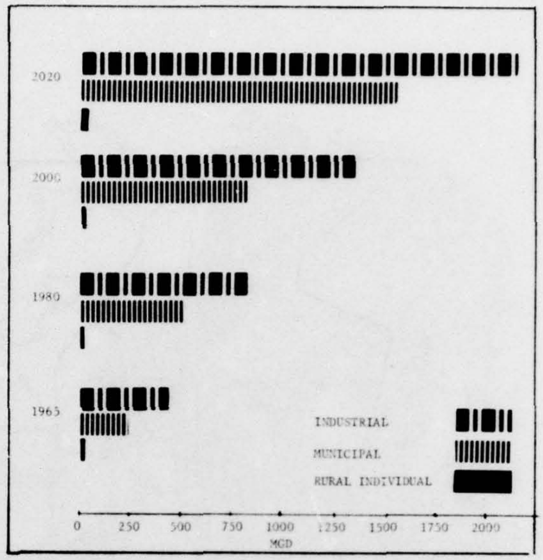


FIGURE 1-6. Projected water requirements for the Puget Sound Area.

PHOTO 1-7. Many of the lakes are small and located in mountainous terrain.

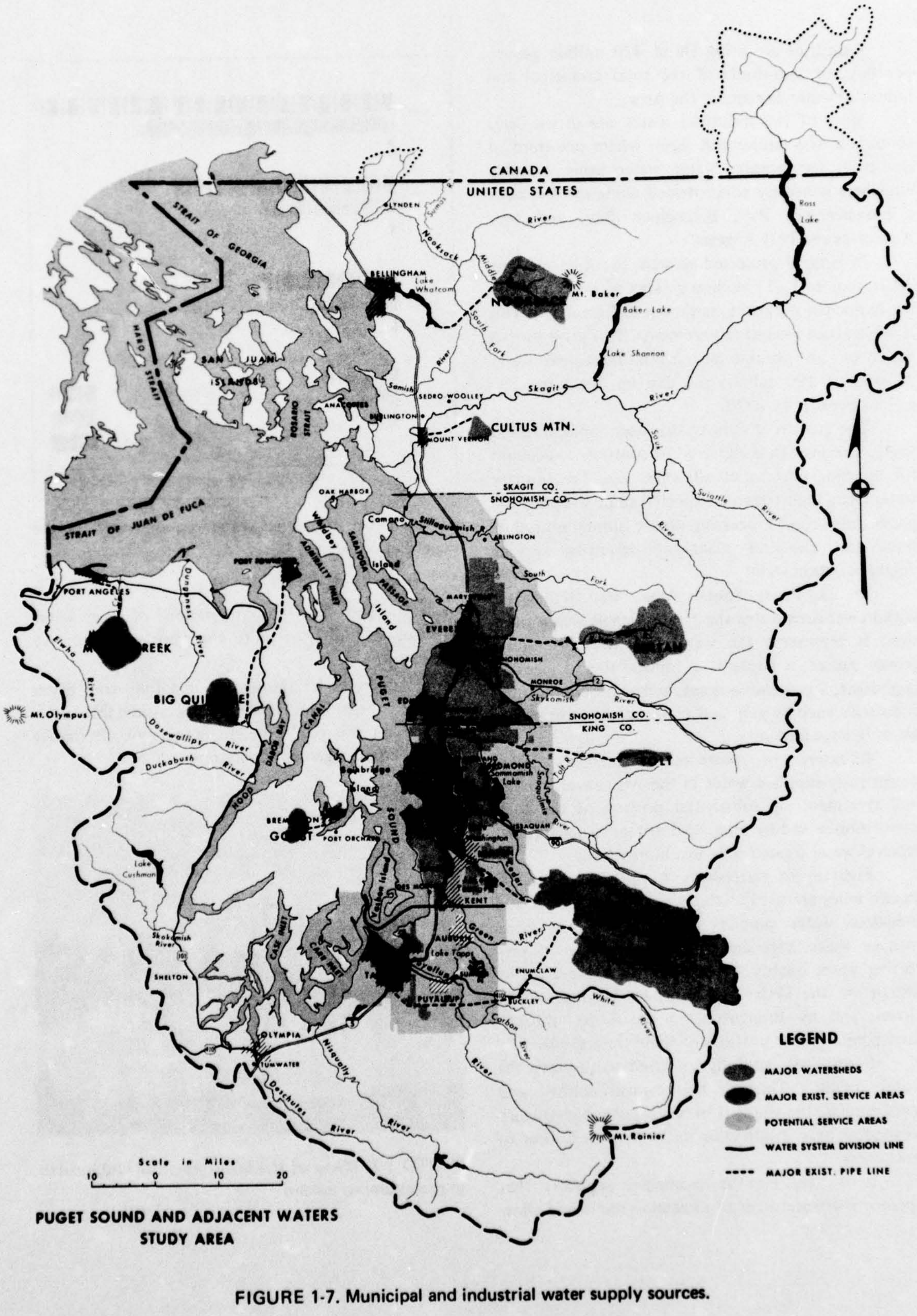


FIGURE 1-7. Municipal and industrial water supply sources.

FISHERIES

Puget Sound is the only inland sea on the Pacific Coast. Its waters are extremely rich in marine life and its environment widely varied. These factors combine to produce a wide variety of marine fish and shellfish species. The varied environment is a limiting factor on distribution of many species and is, in part, responsible for their diversity. The ecology of Puget Sound has been studied in only a few areas, and total population estimates of marine fish and shellfish are lacking.

The important shellfish inhabiting the Sound are oysters, crabs, hard-shelled clams, octopus, squid, shrimp, and scallops. Oysters are commercially cultivated in many areas of the Sound, including Samish Bay in the Bellingham study area and Padilla and Fidalgo Bays in the Anacortes area, as well as many places in the south and west Sound.

Many of the fish and shellfish that reside or migrate through Puget Sound waters are of significant value to commercial and sports fishermen. The 1961-1965 average annual commercial harvest of all fish and shellfish in the Sound amounted to over 98 million pounds, and the average annual wholesale value of the Puget Sound commercial harvest of fish and shellfish for 1961-1965 amounted to over $13,800,000. An estimated 300,000 sportsmen fish Puget Sound waters and its tributaries for chinook and coho salmon, steelhead trout, and other saltwater fishes. Crabs and clams are also taken by sport and commercial fishermen. It is estimated that on Puget Sound $50 to $60 million per year is spent for bait, tackle, boats, and other fishing expenses.

Annual harvest ranges from three to four million pounds. The other shellfish, particularly crabs and clams, are harvested by both commercial and sport fishermen. Total commercial shellfish harvest for 1961-1965 averaged 6,500,000 pounds annually.

The anadromous fishery of the Sound includes the chinook, coho, sockeye, pink, and chum species of salmon and the steelhead, searun cutthroat, and searun Dolly Varden species of trout. All of these fish spend their adult life in the saltwaters of Puget Sound and the Pacific Ocean before migrating to tributary streams to spawn. The juveniles of these fish spend varying amounts of time in the waters of the Sound before moving to sea. Salmon are a valuable commercial as well as an important sport fish. In 1965, commercial fishermen took nearly 4,000,000 salmon, while sportsmen caught about 940,000.

The saltwater fishery of the Sound includes rockfish, sole, founder, lingcod, blackcod, Pacific cod, sharks, rays, skates, ratfish, perch, anchovy, candlefish, hake, herring, pilchard, smelt, turbot, and greenling. All of these fish are commercially harvested, either for their value as food fish or for their incorporation into such products as fertilizer, vitamins, mink food, fish food, and pet foods. The 1965 annual commercial harvest of these fish was about 48 million pounds. Several of these species are also taken by the sports fishermen.

Puget Sound also provides an appropriate environment for all those animals and organisms of the food chain below those fish already listed. Such life includes the smaller fishes, zooplankton, phytoplankton, and numerous types of invertebrates.

The potential for production of marine fish and shellfish has not been fully evaluated. Ultimate realization of the potential, however, is dependent upon correction of a number of man-made pollution problems. Oyster production potential has been estimated at six billion pounds per year—equal to the present total U.S. oyster production of all species.

Resident fresh water species found in the lakes and streams include trout, char, spiny ray, kokanee, plus numerous other fish. The anadromous trout and char species and significant populations of other fresh water game fish play a leading role in the Area's recreation, being sought after by many local sportsmen, other State residents, and non-residents.

The most intensive steelhead fisheries in the Area are located in Green, Skykomish, Puyallup, and Skagit Rivers. The Green and Puyallup are in the most heavily populated areas and are readily accessible by road. The range and average of natural salmon production in the Puget Sound Area for the period 1956 to 1965 is presented in Table 1-4.

An estimated 2,820 miles of stream are utilized for salmon spawning and rearing throughout the Puget Sound Area. Most accessible streams are utilized by steelhead and searun cutthroat trout.

Salmon escapements to spawning grounds in Puget Sound rivers for the period 1956 to 1965 have averaged 106,040 chinook, 423,870 coho, 1,346,400 pink,[1] 381,850 chum and 98,640 sockeye.[2] In addition to natural production, the Washington Department of Fisheries operates eleven hatcheries propagating this type of fish. As many as 115,500 adult salmon were handled annually at these facilities during this time period.

The sport fishery for steelhead trout is considered to be the most important fresh water sport

[1] Odd years only.

[2] For period 1964-1967.

TABLE 1-4. Range and average of natural salmon production in Puget Sound Area (harvest and escapement) for the period 1956-1965

Basin	Chinook Range	Chinook Average	Coho Range	Coho Average	Pink[1] Range	Pink[1] Average	Chum Range	Chum Average	Sockeye[2] Range	Sockeye[2] Average
Nooksack-Sumas	2,940-16,730	8,820	9,250-74,100	37,050	37,500-450,000	219,390	28,530-290,760	109,720		
Skagit-Samish	72,520-284,830	134,330	36,950-852,700	246,450	450,000-3,570,000	1,455,000	37,000-475,340	231,870	1,670-30,530	8,640
Stillaguamish	1,120-76,160	34,580	33,900-312,700	106,000	375,000-1,920,000	806,250	11,080-25,860	16,970		
Whidbey-Camano										
Snohomish	9,960-126,840	53,760	56,500-404,500	182,200	150,000-825,000	446,250	18,060-65,980	42,290		
Cedar-Green	7,350-54,670	24,430	56,900-296,900	162,400			7,440-86,410	33,360	48,000-190,000	90,000
Puyallup	1,050-25,550	14,210	4,150-143,850	37,850	30,000-75,000	44,250	9,900-114,980	44,390		
Nisqually-Deschutes	7,600-69,200	26,950	5,200-60,750	24,450	10,950-18,000	13,530	8,070-37,770	21,460		
West Sound	5,460-67,060	26,320	191,500-872,700	372,300	99,150-1,539,000	561,030	110,920-475,990	258,670		
Elwha-Dungeness	700-23,940	7,980	4,950-33,900	12,700	150,000-1,320,000	493,500	3,790-7,110	5,120		
San Juan										
Puget Sound Region[3]		330,788		1,181,400		4,039,200		763,850		98,640

1 Odd years only, 1959-1965.

2 Because of recent increase in run size, figures taken for period 1964-1967.

3 Only averages are additive since highs or lows do not necessarily occur in all basins in the same year.

fishery. In 1966, 190,700 steelhead punchcards were issued and over 158,700 fish were taken. The steelhead catch has increased more than fourteen times from 1948 to 1966. A conservative estimate suggests that the steelhead fishery of Puget Sound generates an expenditure of four million dollars per year. Based on 1966 survey data, almost 2,557,000 man-days were spent fishing in lakes, ponds, and reservoirs within the Puget Sound Area, which resulted in a catch of 8,484,000 trout and 2,547,000 other game fish species. About 953,000 man-days were spent fishing in streams of the Area which resulted in a catch of about 3,110,000 trout. The most significant production of game fish comes from the Cedar-Green, Nisqually-Deschutes, Puyallup, Snohomish, Skagit and West Sound Basins.

OUTDOOR RECREATION

Outstanding physical features of the Puget Sound Area–great mountain ranges and forests, wilderness areas, streams, lakes, and marine waterways–make it an important recreation area. The outdoor recreation activities which Puget Sounders enjoy take many diverse forms including hiking and swimming, fishing, hunting, playing outdoor games, bicycling, sightseeing, picnicking, and camping.

The total use of recreation resources in the Area was estimated to be 58 million recreation days in 1960. Almost 45 percent of this total participation was for water-related activities. By the year 2020, public participation in the major forms of outdoor recreation activities will be six times greater than it was in 1960. In water-related activities alone, a seven-fold increase is expected.

The total demand for water-related activities in the Area was 25 million recreation days in 1960. As shown in Figure 1-8, more than half of this recreational water use is concentrated in four basins–Snohomish, Cedar-Green, West Sound, and Puyallup.

Swimming has emerged as the most popular water-related activity. It appears destined to remain number one through 2020. As the rivers and marine waters are generally too cool for this recreational activity, most swimming occurs at lakes and pools. Scuba diving has enjoyed a large increase in popularity in the last decade.

Camping and picnicking together account for one-third of the activity occasions in water-related sports. They are the most common by-products of the other recreational pursuits and park visits. Camping is expected to be one of the fastest-growing outdoor recreational activities through 2020.

Numerous varieties of fresh and saltwater game fish make sport fishing an important recreational activity. Anglers consider the steelhead trout king of the fresh water game fish.

POWER GENERATION

The rivers in the Puget Sound Area have been a source of power since the earliest days of settlement. Today, 1.26 million kilowatts are installed here. There are 22 developed waterpower sites located in eight of the basins. The Stillaguamish, San Juan, and Whidbey-Camano Basins have no existing waterpower plants.

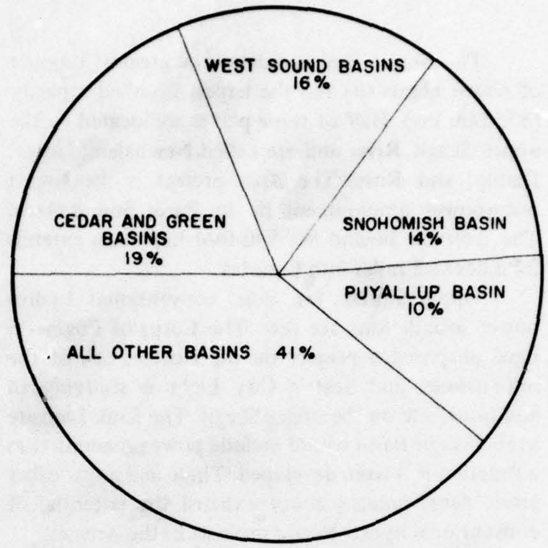


FIGURE 1-8. Concentration of recreational water use, Puget Sound Area.

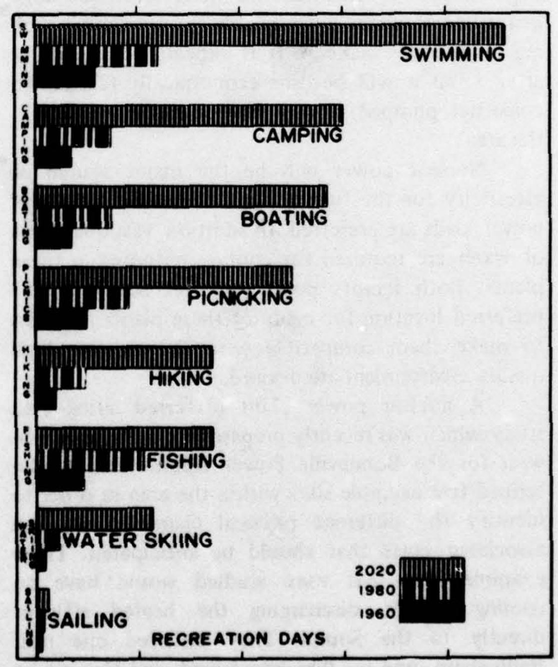


FIGURE 1-9. Relative growth of outdoor recreation related activities in the Puget Sound Area.

The Skagit Basin contains the greatest number of power plants (8) and the largest installed capacity (825,000 kw). Half of these plants are located on the upper Skagit River and are called Newhalem, Gorge, Diablo, and Ross. The Ross project is the largest waterpower development in the Puget Sound Area. The reservoir behind the 540-foot high dam extends 24 miles (1.5 miles into Canada).

Opportunities for new conventional hydropower installations are few. The Corps of Engineers have proposed a project on the North Fork of the Snoqualmie, and Seattle City Light is studying an additional site on the upper Skagit. The Sauk Damsite in the Skagit Basin would include power generation as a function if it were developed. These and a few other lesser developments about exhaust the potential of conventional hydroelectric projects in the Area.

There are five thermal-electric and two diesel-electric plants in the Puget Sound Area having a total installed capacity of about 202,000 kw. The five steam-electric plants, with a total installation of 200,000 kw, are located on Lake Union, Lake Washington, the Duwamish River, and directly on the Puget Sound or channels. At these locations, large quantities of water are available for condenser cooling, and boiler makeup. It is expected that shortly after 1990 it will become economically feasible to construct pumped storage hydroelectric projects in the area.

Nuclear power will be the major source of electricity for the future. Plant sites near the major power loads are preferred. In addition, vast quantities of water are required for cooling purposes in these plants. Both factors point to Puget Sound as the preferred location for many of these plants if means to make them compatible with the existing high quality environment are devised.

A nuclear power plant preferred siting area study which was recently prepared by Battelle Northwest for the Bonneville Power Administration, described five example sites within the area in order to identify the different physical characteristics and associated costs that should be anticipated. Three example sites that were studied would have no cooling towers, discharging the heated effluent directly to the Sound. They included one near Bellingham, one on Whidbey Island, and the last on the Strait of Juan de Fuca. Two example sites were located on fresh waters—one on the lower Skagit River and one on Alder Reservoir on the Nisqually River. These latter two included cooling towers. It is most likely, however, that future thermal plants will be sited along the Sound. There are many physically suitable sites which could be utilized to meet future growth.

An indication of the number of 1,000 MWe nuclear-filled, steam-electric plants which might be constructed has been derived by the Power Technical Committee. According to their projections, no plants would be installed by 1980, 12 by 2000, and 40 more by 2020.

NAVIGATION

The natural deep water channels of Puget Sound provide the waterways for ships. This, plus the strategic location of the Sound with respect to Alaska and the Orient, has made navigation of major importance here. Waterborne commerce in forest products, fish products, oil, aluminum, chemicals, and aerospace industries has been showing a steady increase. Foreign and domestic coastwise traffic showed a 50 percent increase to 16 million tons from 1952 to 1963. Annual local and internal traffic increased 20 percent to 24.7 million tons during the same period.

Major ports are located in Seattle, Tacoma, Everett, Bellingham, and Anacortes harbors. Bremerton's port facilities are used almost exclusively by military vessels. In the past few years, the port authorities have been substantially improving and expanding their facilities.

More and more deep draft transports are being constructed to move raw materials to suitable processing sites and manufactured materials to major world markets. Puget Sound is one of the few natural areas in the United States which has the depth and port potential suitable to handle these super-ships. It is expected that traffic in waterborne commerce will show increasing growth in the near future.

IRRIGATION

About 91,700 acres are presently irrigated in the Puget Sound Area. The Nooksack-Sumas Basins contain the most irrigated lands—more than 38,000 acres. The Dungeness Basin is second with 15,900 acres and the Snohomish Basin is third with 12,800. Irrigated areas between 1,200 and 6,200 acres are found in the remaining basins. These lands tend to be in small, isolated areas, interspersed with larger areas of unirrigated agricultural lands and almost entirely developed by private rather than project means.

Irrigation is generally supplemental to natural precipitation and is applied mostly by sprinklers during extended dry periods in the summer. If the summer is wetter than average, many farmers do not irrigate at all that season. The only exception is the Sequim area in the Elwha-Dungeness Basins where rainfall is so sparse that the area is classified semi-arid. An irrigation development there diverts from the Dungeness River and distributes the water through a canal system for surface irrigation throughout the entire growing season.

The amount of water used for irrigating the 91,700 acres is estimated to be only about 180,000 acre-feet annually, less than 0.5 percent of the runoff in the Area. Irrigation expansion in the future is projected to be relatively modest. The location and extent of suitable land is the primary limiting factor. Projected acreages are 138,000 acres by 1980 increasing to 223,000 acres by 2020.

WATER QUALITY OBJECTIVES

The water quality objectives discussed in this section represent the levels of water quality required to fully support water uses. In managing the Area's water, the primary purpose is to protect or enhance the quality and value of the water resources and to establish regional programs for the prevention, control, and abatement of water pollution to allow maximum use of the resource for all beneficial purposes. The main issue, in the future, is water quality–controlling pollution so that water can be used again and again to meet increasing demands.

Under the Water Quality Act of 1965, quality standards for interstate and coastal waters and a plan[1] for implementation and enforcement of such standards were established by the State of Washington and approved by the Secretary of Interior. The primary objective of establishing water quality standards is to protect the water quality for the uses of any given watercourse. These levels of protection or criteria are summarized in Table 1-5.

Each stream is classified as to its intended use–including agricultural, municipal, industrial, recreational, fish and wildlife and the water quality standards to support each use–including not only the criteria or levels of quality necessary, but plans to implement and achieve these levels of quality. The standards apply only to interstate and coastal waters at the present time.

Dissolved Oxygen–is a valuable indicator of overall water quality. Low dissolved oxygen concentrations may indicate the presence of excessive quantities of wastes having a high biochemical of chemical oxygen demand or may indicate the occurrence of natural processes such as the upwelling of deep sea waters during the fall. Dissolved oxygen levels outside the range of 75 to 100 percent of saturation denote a more undesirable raw water quality.

Dissolved oxygen standards for fresh waters range from 5.0 mg/l or 50% saturation, whichever is greater, for Class C waters, to 9.5 mg/l for Class AA waters. For marine waters, DO standards range from 4.0 mg/l or 50% saturation, whichever is greater, to 7.0 mg/l for Class AA waters. Under the standards, no sewage or industrial waste shall be discharged into any waters of the Area that will cause the reduction of the dissolved oxygen concentration to less than 5.0 mg/l for fresh waters or 4.0 mg/l for marine waters. At dissolved oxygen values below 5.0 mg/l, ecological changes occur which start to limit the passage of fish, production of fish food, and other useful aquatic life.

Dissolved oxygen needs in the Area have been geared to salmonid fishes due to their physiological intolerance, migratory uniqueness, and economic importance. The production of salmonid species of fish is a major use of the rivers, streams and estuaries in the Puget Sound Area, and oxygen objectives have been assigned accordingly. As a result, dissolved oxygen guidelines are set at nearly 100 percent saturation in locations vital to the spawning, hatching, and early rearing of salmonid fishes.

Total Coliform Organisms–common to the intestinal tract of warm-blooded animals, are commonly used to measure bacterial contamination and to indicate the probable presence of disease causing organisms. Natural waters, uncontaminated by human activity, will normally have an average Most Probable Number (MPN) of coliform organisms per 100 milliliter (ml) of less than 50. The criterion of 240

[1] **Implementation and Enforcement Plan for Interstate and Coastal Waters, State of Washington, December 1967.**

coliforms with less than 20 percent of the samples exceeding 1,000 when associated with a fecal source is considered to be the upper limit for waters to be safely used as source of domestic water supply receiving filtration and chlorination. Coliform concentrations in water used for contact recreation should not exceed 1,000 MPN.

The standard test for the measurement of total coliform is the multiple tube dilution technique to determine the "Most Probable Number" (MPN) of coliform bacteria per 100 milliliters. During recent years the trend has developed towards the use of membrane filters to measure total coliform. Both the tube dilution and membrane filter methods are used with differential media and proper temperatures to measure "fecal coliform" in water samples. The fecal coliform groups appear to have more sanitary significance in the environment than do the total coliforms, and are being considered as the indicator organisms to replace the present MPN standard.

Temperature–not exceeding 50°F (9.9°C) is usually satisfactory, with 65°F (18.2°C) representing the upper temperature limit for acceptable Puget Sound Area water supplies. Water with temperatures greater than 65°F is likely to support excessive bilogical and bacterial growth. It has a flat, unpleasant taste, and is generally unappealing as a source of domestic water supply.

The temperature of water also affects its dissolved oxygen concentration. At 50°F (9.9°C), distilled water at sea level has a DO saturation value of 11.2 mg/1, whereas at 65°F (18.2°C), it has a DO saturation value of 9.5 mg/1.

Water temperatures are critical to salmonoid fish, especially as they apply to the spawning of adult fish, development of embryos and young, and disease control. Migration of anadromous fish requires an optimum temperature range of 45°F to 68°F (7.2° to 19.8°C). Rearing of both trout and salmon occurs in a somewhat narrower ideal temperature range–50°F to 65°F (9.9° to 18.2°C)–and spawning requirements are very narrow, with temperatures beyond the range of 45°F to 55°F (7.2° to 12.6°C) destroying fish production if sustained beyond a very limited period of time.

Temperature, as a water quality parameter for shellfish, cannot be prescribed within definite limits; it must be related to time and species. In general, the water temperature for shellfish propagation must vary from 65°F to 68°F (17.6° to 19.8°C). For edible body condition, the temperature should be in the range of 45°F to 50°F (7.2° to 9.9°C).

TABLE 1-5. Water quality classification and criteria Puget Sound Area

Water Quality Standards	Class AA Extraordinary		Class A Excellent		Class B Good		Class C Fair	
	Fresh	Marine	Fresh	Marine	Fresh	Marine	Fresh	Marine
Coliform	50 MPN	70 MPN	240 MPN	70 MPN	1,000 MPN	1,000 MPN	1,000 MPN	1,000 MPN
Dissolved Oxygen	9.5 mg/1	7.0 mg/1	8.0 mg/1	6.0 mg/1	6.5 mg/1	5.0 mg/1	5.0 mg/1	4.0 mg/1
Temperature[1]	60°F	55°F	65°F	61°F	70°F	66°F	75°F	72°F
pH	6.5-8.5	7.8-8.5	6.5-8.5	7.8-8.5	6.5-8.5	7.8-8.5	6.0-9.0	7.0-9.0
Turbidity	5 JTU	5 JTU	5 JTU	5 JTU	10 JTU	10 JTU	10 JTU	10 JTU
Toxicity[2]	Shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.							
Aesthetic Values	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.							

[1] For all classes, the permissible increase in temperature over natural conditions is less than 1.8°F.

[2] Exact definitions of toxicity can be found in the Water Quality Standards.

Turbidity—in water is due to suspensions of clay, silt, finely divided organic matter, and similar substances. Large quantities of turbidity-causing materials impose heavy loadings on water treatment facilities and can impart dissolved impurities to the water with resultant deterioration of quality.

Public health considerations also apply to turbidity. Water must be clear enough to be effectively disinfected when it is used for domestic water supply. This is generally considered to be a level below 5 Jackson Turbidity Units (JTU). Turbidities exceeding 25 JTU are not desirable for recreation uses because of aesthetic reasons.

The most critical period in the life cycle of fish, as it concerns turbidity, is during the incubation period of the eggs which occupy the interstitial spaces within the gravel. Otherwise suitable spawning gravel will not produce fish when silted over. Eggs become smothered and production is impossible.

The quality objective has been expressed that concentrations of toxic materials should be below those which adversely affect public health, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect characteristic water uses. Therefore, it is general practice to prohibit discharge of these wastes to public waters. Toxic materials cover a wide range, from naturally occurring heavy metals to radioactive materials and complex insecticidal and herbicidal compounds. Such materials are generally objectionable as it is not always possible to depend on water treatment to lower the concentrations to acceptable levels.

Aesthetic Values—are impaired when the presence of materials or their effects offend the senses of sight, smell, touch, or taste. Anything that is offensive to these senses is not acceptable in a water supply. People shy away from any area which has floating solids, scum, excessive aquatic growths, or other evidences of pollution. For most uses of water, it is necessary to exclude these unsightly, objectionable, and potentially harmful materials.

Nutrients—are required to support a well-balanced biota. However, when water bodies are excessively enriched, aquatic plants and other growths may become dense and interfere with other water or of the aquatic habitat. These growths interfere with fishing by fouling lines, clogging nets, and generally creating unsightly conditions in the infested area. Their decomposition imposes a high Biochemical Oxygen Demand (BOD) load on the stream and can severely deplete the dissolved oxygen. The more important compounds contributing to nutrient enrichment are those of nitrates and phosphates.

Nitrate is usually present in relatively small quantities in unpolluted surface waters. However, the nitrate content may be increased in streams by waste from industrial, domestic, and agricultural sources. Nitrate is considered the final oxidation product of nitrogenous material. Thus, the oxidation of this material may eventually increase the nitrate concentration in the stream. Quantities of nitrate present in surface waters usually amount to less than 5 mg/1.

The phosphate content of natural surface waters is normally quite low, often less than 0.1 mg/1. However, the occurrence of phosphate is quite important, and the phosphorous concentration in the water may often have a direct bearing on the aquatic life and excessive algal growths. Unfortunately, the phosphorous values given in this study do not usually give a true picture of phosphorous regime in the Area's water. The values given as soluble phosphorus are the amounts in solution at time of analysis and are not those in the stream at time of sampling. Based on a limited amount of work which has been done, soluble phosphorus will be reduced to less than 0.05 mg/1, regardless of the source of phosphorus, as soon as warming waters and increased sunlight cause algal blooms. All indications are that phosphorus is the principal limiting nutrient in our rivers and streams. Naturally occurring phosphorus is the major contribution to the streams of the Puget Sound Area.

In order to limit nuisance growths, the disposal of all organic wastes such as sewage, food processing, cannery, and industrial wastes containing nutrients, vitamins, trace elements, and growth stimulants must be carefully controlled. The naturally occurring ratios and amounts of nitrogen to total phosphorus should not be radically changed by the addition of waste materials. Where streams enter lakes or reservoirs, total phosphorous concentrations exceeding 0.1 mg/l in flowing streams or 0.05 mg/l where streams enter lakes or reservoirs may create conditions leading to algal growths.

Hydrogen Ion Concentrations—can affect water uses. The pH measures the log of the hydrogen ion concentration. A good source of drinking water should have a pH between 6.5 and 8.5. Water with low pH may be corrosive and is often associated with disagreeable tastes and odors. High pH waters are generally hard, deposit-forming, and stimulate growth of algae and water weeds which interfere with water intake mechanisms and affect taste.

In general, no public health problems may be expected from water contact with pH values in the range of 6.5 to 8.5.

Salmon do not thrive under pH conditions much beyond the range of 6.5 to 8.5, though some resident species can flourish outside of that range. Proper pH in waters for shellfish production appears to be more critical than previously thought by growers and researchers. Recent studies on oyster larvae demonstrate that larvae do not "lay down" calcareous shell material in waters with a pH below 7.5. Therefore, a pH of 7.8 was set as the lower level of acceptance. Marine waters of the Puget Sound are commonly within the range of pH 8.3 to 8.4.

Wherever existing receiving waters of a classified area are of higher quality than the criteria assigned for that area, the existing higher water quality should be maintained.

These water quality objectives, as outlined in the standards and implementation plan, are necessary in order to effectively control water pollution and quality. They describe the quality of water needed for each use. They relate quantitatively the relationships of substances in water to their effect on uses of the water, and they quantitatively measure the quality to be provided. Their primary purpose is to protect high quality waters in the Area and upgrade polluted ones. They also provide additonal tools for making objective and clear public policy statements on the orderly development and improvement of the Area's water resources.

The concept incorporated in the standards and implementation plan is that minimizing the generation of waste at the source is more desirable than treatment of the watercourse to allow for additional use of the resource. In exploring this concept, a three-step policy is unfolding to (1) minimize withdrawals of water from the watercourses; (2) maximize use of withdrawn water; and (3) minimize discharge of polluting effluents back into the waterways.

All levels of government, as well as industry and the private sector, face a special challenge and responsibility to implement and enforce the standards which have been set. There will be a continued need, over the years, to examine, revise, and improve these standards in light of new knowledge and activities which affect land and water use and waste output in the Puget Sound Area.

PRESENT STATUS

WATER QUALITY

Fresh Water

Systematic measurement of fresh water quality characteristics began on Puget Sound tributary streams in June, 1959. At this time a Water Quality Basic Data Program was put into operation as a joint effort of the Washington Water Pollution Control Commission, the State Department of Water Resources, and the U.S. Geological Survey. Station locations are given in Table 1-6 and shown in Figure 1-10. At the present time (1968), approximately 49 water quality monitoring stations are operating in the Puget Sound Area.

All of the data collected is designed to establish and maintain a continuing inventory of the basic quality of the State's water resources, to provide the basis for study of specific water quality problems, to serve as a planning guide for resource and industrial development, and to detect changes in quality in time to initiate control and preventive programs before pollution problems become acute.

Samples are now collected on a monthly, bimonthly, or quarterly basis and are analyzed for most chemical constituents by the U.S. Geological Survey soon after being collected. The Water Pollution Control Commission analyzes for physical constituents and bacterial concentrations.

Sediment data have also been periodically gathered in the past, but are not part of this program and are not systematically collected.

Most rivers in the Sound emerge from heavily forested watersheds which through the years have been depleted of much of the soluble material in the soil mantle. The resulting river runoff is a calcium-bicarbonate type of water, low in hardness, dissolved solids, and bacterial contamination. The major reaches of the rivers contain this high quality water suitable for almost all uses.

In the lower reaches near the Sound, however, urban and industrial development has had a measurable effect on the water quality. Dissolved solids and bacterial counts are significantly higher and dissolved oxygen levels are lower.

Since most rivers are of good quality, the following discussion is intended to summarize quality characteristics with some emphasis on those few areas where quality has been degraded. A more detailed discussion of water quality of specific streams is contained in the respective basin sections of this Appendix.

The chemical characteristics of the rivers are very uniform throughout the area. Iron occurs in all surface waters in concentrations up to a maximum recorded value of 7.7 mg/1. Most measurements, however, show concentrations below 0.5 mg/1. The reported values are total iron in the sample.

Most streams here contain moderate amounts of bicarbonate, usually below 50 mg/1. Sulfate concentrations are low in most streams.

Nitrate concentrations are low in most streams. The Samish River, however, carries significantly higher concentrations than any other stream in the Skagit Basin. Boise Creek near Buckley, and Chambers, Clover, Flett, and Leach Creeks are others carrying higher nitrate concentrations.

The phosphate content is normally quite low and often occurs in concentrations of less than 0.1 mg/1.

Streams with the highest dissolved solids concentrations per unit flow are Leach, Flett and Chambers Creeks near Tacoma; Chico Creek near Bremerton; and Issaquah Creek near Issaquah. Rivers with the lowest concentrations are the largest rivers—the Skagit, Snohomish, Skykomish, and Snoqualmie. The change in dissolved solids with flow is relatively consistent between all streams, regardless of levels of concentration. For all streams, however, dissolved solids concentrations are generally low (usually within the range 20 mg/1-120 mg/1.

Dissolved oxygen levels are at or near saturation in nearly all the streams. A few river reaches are called upon to assimilate sizeable quantities of partially treated or untreated wastes, with depressed oxygen levels being one of the resulting effects. In South Tacoma, Flett Creek has exhibited dissolved oxygen concentrations as low as 4.5 mg/1 during the fall. Bottom dissolved oxygen levels near 0.0 mg/1 in Lake Union result from solids deposited during past heavy industrial waste loadings and from conditions of stratification. The estuarial reach of the Duwamish River has low dissolved oxygen levels during the late summer and early fall. Bottom oxygen concentrations have ranged between 3 and 4 mg/1, with the minimum dropping below 2 mg/1. Surface concentrations during this period varied between 5 and 6 mg/1. During this low-flow period, tides are the predominant factor affecting changes in dissolved oxygen due to the low DO of the intruding seawater and the low oxygen capacity of the higher temperature river water. Therefore, increases in fresh water flows have little influence on oxygen levels through the lower reach.

Bacteriological quality, although variable, generally reflects the density of urban, industrial, or agricultural buildup. High densities of total coliform organisms generally occur in the same areas as low dissolved oxygen. Outside of the developed lowlands along eastern Puget Sound, the streams receive little waste and are of excellent bacteriological quality. High coliform densities periodically occur in the Nooksack River near Ferndale; the Skagit River near Mount Vernon; the Snohomish River near Everett; and Sammamish River, Issaquah Creek, and the Duwamish River near Seattle; Boise Creek near Buckley; and the Puyallup River, Flett Creek, and Leach Creek near Tacoma. Most results from domestic wastes, often as either untreated or inadequately treated municipal treatment plants effluents. In some rural areas, occasional high coliform densities occur from runoff due to dairy farms and feed lots.

Streams draining the Olympic Peninsula, the upper Puyallup, and upper Skagit Rivers have maximum recorded temperatures below 61°F (16°C) and mean temperatures of about 48°F (9°C). Maximum temperatures over 68°F (20°C) have been recorded on the Deschutes, Nisqually, lower Green and Cedar, Sammamish, Sultan, Tolt, and the creeks around Lake Steilacoom. Their average temperatures are above 50°F (10°C).

Several streams originate in glaciers, notably the North and Middle Forks of the Nooksack, the Sauk River, Puyallup, and Nisqually Rivers. Turbidity of these streams at times is significantly higher than the streams not affected by glacial melt. These periods of high turbidity usually occur when a major portion of the streamflow is coming from glacial melt carrying suspended glacial flour. Turbidity also occurs periodically as a result of erosion caused by intense rainstorms.

TABLE 1-6. Water quality sampling stations in the Puget Sound Area

Map No.	Frequency	USGS No.	Station
1	M	12213100	Nooksack River at Ferndale
2	Q	12210500	Nooksack River at Lawrence
3	M	12202500	Whatcom Lake
4	M	12201500	Samish River near Burlington
5	M	12200500	Skagit River near Mt. Vernon
6	Q	12219350	Baker River near Concrete
7	Q	12186000	Sauk River near Darrington
8	Q	12181000	Skagit River at Marblemount
9	M	12167700	Stillaguamish River near Silvana
10	Q	12167000	No. Fork Stillaguamish River near Arlington
11	Q	12161000	Stillaguamish River near Granite Falls
12	M	12155500	Snohomish River at Snohomish
13	Q	12148500	Tolt River at Carnation
14	Q	12144400	Snoqualmie River at Snoqualmie
15	Q	12138200	Sultan River at Sultan
16	Q	12134500	Skykomish River near Gold Bar
17	M	12128100	Lake Washington Ship Canal
18	M	12126500	Sammamish River at Bothell
19	M	12121600	Issaquah Creek near Issaquah
20	M	12119000	Cedar River at Renton
21	Q	12117500	Cedar River at Landsburg
22	M	12113350	Duwamish River at Tukwila
23	M	12113000	Green River in Auburn
24	M	12112600	Big Soos Creek near Auburn
25	Q	12106500	Green River at Palmer
26	M	12101500	Puyallup River at Puyallup
27	Q	12100500	White River at Sumner
28	Q	12099600	Boise Creek near Buckley
29	Q	12099300	Boise Creek near Enumclaw
30	Q	12094000	Carbon River near Orting
31	Q	12093500	Puyallup River near Orting
32	Q	12091500	Chambers Creek near Steilacoom
33	M	12091300	Leach Creek near Steilacoom
34	M	12091100	Flett Creek at Tacoma
35	M	12091000	Chambers Creek below Steilacoom Lake
36	M	12090600	Clover Creek above Steilacoom Lake
37	M	12090300	Clover Creek near Parkland
38	M	12089500	Nisqually River at McKenna
39	M	12080000	Deschutes River in Tumwater
40	Q	12079000	Deschutes River near Rainier
41	SA	12077000	Goldsborough Creek at Shelton
42	M	12072000	Chico Creek near Bremerton
43	SA	12061500	Skokomish River near Potlatch
44	SA	12055000	Hamma Hamma River near Eldon
45	SA	12054100	Duckabush River near Brinnon
46	SA	12053500	Dosewallips River at Brinnon
47	SA	12052300	Big Quilcene River near Quilcene
48	SA	12048000	Dungeness River near Sequim
49	SA	12045500	Elwha River near Port Angeles

Frequency: SA–Semi-Annual; M–Monthly; Q–Quarterly.

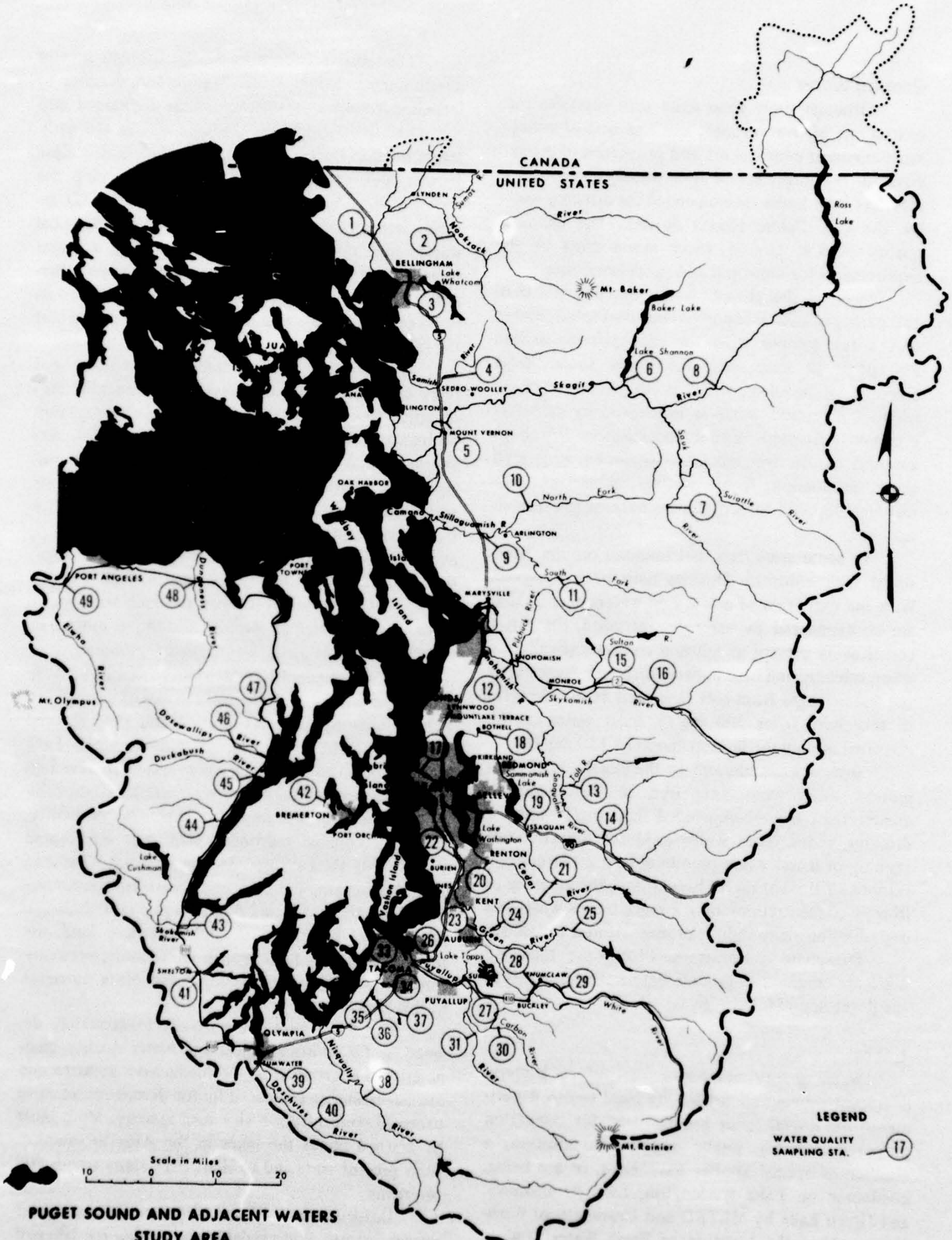


FIGURE 1-10. Water quality sampling stations.

Ground Water

Although some areas exist with excessive concentrations of iron, nitrate, and hardness of water—most chemical constituents and properties of ground water in the Puget Sound Area usually are considerably less than limits recommended for drinking water by the U.S. Public Health Service. The chemical quality of the ground water meets most of the requirements for industrial and agricultural uses.

Most of the ground water contains less than 150 parts per million (ppm) of dissolved solids, and in only a few samples does the concentration exceed 250 ppm. In areas near the Puget Sound, large amounts of dissolved solids occur in a few places where the ground water is influenced by saltwater intrusion. Isolated inland occurrences of large amounts of dissolved solids are attributed to ground water production from aquifers in marine sedimentary deposits of early Quaternary or pre-Quaternary age.

In some areas near metropolitan centers, occasional high coliform densities have been observed. With the exception of a few well waters in areas that are contaminated by saltwater intrusion, the major constituents present in solution characteristically are silica, calcium, and bicarbonate. Although hardness of the water ranges from soft (less than 50 to 75 mg/1) to very hard (over 200 mg/1), most water can be classified as only moderately hard (75-150 mg/1).

Several areas adjacent to the Puget Sound yield ground water containing iron in concentrations greater than the recommended 0.30 mg/1 limit for drinking water. Such water produces objectionable staining of laundry and plumbing fixtures at concentrations of 0.5-1.0 mg/1. In addition, the presence of iron in concentrations of 1-2 mg/1 makes water less desirable for many industrial uses without treatment.

Phosphate concentrations of more than 0.5 mg/1 are common in ground waters of a large part of the Puget Sound lowlands.

Lakes

Water quality monitoring for coliform bacteria is currently being conducted by local health departments on several lakes heavily used for recreation purposes and for public supply. In addition, a number of special studies have been, or are being, conducted on Lake Washington, Lake Sammamish, and Green Lake by METRO and University of Washington. Also, the Institute of Fresh Water Studies, Western Washington State College has studied Lake Whatcom.

The postwar boom in Seattle brought greater developments around Lake Washington, leading to increased volumes of treated sewage discharged into the lake. By the 1950's, the lake was in the early stages of nutrient enrichment, with undesirable algae growth and excessive weed growths reducing the water quality for outdoor recreation. METRO recently completed the task of diverting all municipal wastes out of the Basin, thus eliminating a major source of bacterial and nutrient contamination. Presently, only stormwater and combined sewer overflows enter the lake. As a result, there is evidence that the lake's quality is improving.

Green Lake, heavily used for recreation and lying completely within a developed residential area of north Seattle, had a long history of water quality problems resulting from extensive drainage of streets and lawns and natural springs. Increased algal blooms, swimming restrictions due to high coliform counts and "swimmer's itch," turbidity and loss of clarity from dead algal cells, semi-domesticated waterfowl, and storm overflows, led to a program of investigation and rehabilitation by the Seattle Park Department. Seattle presently flushes the lake with water from their municipal supply system, resulting in reduction of most of the water quality problem.

Lake Sammamish, which discharges directly to Lake Washington, is in the early stages of eutrophication. Studies by METRO in 1964 and 1965 showed that its condition corresponds to that of Lake Washington in the 1950's prior to extensive sewerage system construction. However, recent studies by METRO show drastic improvements in water quality, since a municipal treatment plant was intercepted into the METRO system. Studies of Lake Whatcom, near Bellingham, indicate high bacterial contamination along the north end due to septic tank drainage. Residential developments and intensive land use around American Lake, south of Tacoma, presently contribute excessive phosphorus and other nutrients to this lake.

The lakes here are generally inadequately defined as far as limnological and water quality characteristics are concerned. Problems have occurred and are occurring, as evidenced by the described excessive bacterial concentration and algal activity. More must be learned about the lakes in the Area to establish their present state and to chart the quality trends and problems.

Unfortunately, there is only minimal water quality information available concerning the lakes of Washington. As a result, a concentrated lake sampling program was initiated in 1968.

The following discussion is based on a study conducted during 1968 by the Washington Water Pollution Control Commission.

Nooksack-Sumas Basins:

Terrell Lake–is a very shallow, eutrophic lake and appears to be in an advanced stage of senescence. At the time the lake was sampled it was found to be isothermal, with a uniform dissolved oxygen concentration from surface to bottom of approximately 9.5 mg/1. A heavy algal bloom was present. Terrell Lake is essentially undeveloped. Coniferous trees and farm lands border the lake.

Whatcom Lake–is one of the largest and deepest lakes in the State. The water below the thermocline was essentially devoid of oxygen while that above was near 10 mg/1. Small amounts of suspended algae were observed but not enough to constitute bloom.

Skagit-Samish Basins:

Cavanaugh Lake–is essentially oligotrophic. A bottom sample contained gravel and silty material and was unlike the gelatinous mud usually found on the bottom of lakes which are more eutrophic. Summer cabins encircle 75% to 85% of the lake's shoreline.

Big Lake–a shallow eutrophic lake, was found to be nearly isothermal from surface to bottom. The dissolved oxygen concentration ranged from 10.2 mg/1 at the surface to 9.9 mg/1 at the bottom. Aggregated clumps of algae were prevalent over the entire surface of the lake. The lake was approximately 90% developed, the majority of homes being resident dwellings.

Campbell Lake–was found to be isothermal with a high dissolved oxygen concentration from top to bottom. A secchi disc reading of 1.5 feet was recorded and a dense suspended algal bloom was observed, which adversely affected the aesthetic quality of the lake. Numerous fish kills have been reported and although the causes are unknown, it is suspected that they occurred as a result of algae die-off and resulting deoxygenation of the water.

Samish Lake–represented a good example of a thermally stratified lake. Aesthetically, the water quality of Samish Lake was good. Very little suspended algae was present and the water was clear.

Clear Lake–was found to be thermally stratified and stable. The secchi disc reading was 12.5 feet, with very little suspended algae.

Snohomish Basin:

Goodwin Lake–was thermally stratified with deoxygenated water below the thermocline. The water was clear and relatively free of suspended algae.

Stevens Lake–was found to be thermally stratified with a vertical distribution of dissolved oxygen that suggests eutrophication.

Cedar-Green Basins:

Meridian Lake–had developed a stable thermocline with well-oxygenated water above and deoxygenated water below the metalimnion. A suspension of "bird-shot-like" algae was present in this lake. Otherwise, the water was clear and transparent. Meridian Lake is almost completely developed with residential homes surrounding its shores.

Green Lake–(Data taken from Shepherd, 1968). The aesthetic quality of Green Lake's water as measured with a secchi disc changed drastically in 1967, relative to previous recorded years. In June of 1965 and 1966 the transparency was approximately 10.5 feet, whereas in June of 1967 the secchi disc reading increased to 21 feet. Green Lake's water temperature for 1967 varied from a summer high of 23.5°C to a winter low of 4°C, with a general lack of thermal stratification in the lake. The lake is mixed enough to maintain dissolved oxygen, in the upper twelve feet of water, between 83.4% and 131.3% saturation. There has been a gradual reduction of available nutrients in the lake since 1959. Source: Shepherd, Thomas A., 1968–Dilution effects on algal standing crop in a eutrophic lake. M.S. Thesis, University of Washington, Seattle. 109 pp.

Puyallup Basin:

American Lake–a slightly eutrophic lake, had a well-established thermocline (stable) at a depth of approximately 40 feet. The dissolved oxygen concentration above the thermocline was high, but rapidly decreased to below 1 mg/1 at, and below, the thermocline. A slight suspension of algae was present.

Nisqually-Deschutes Basins:

Clear Lake–was found to be a shallow isothermal lake with clear water. For some unexplainable reason, the dissolved oxygen concentration was very low. A maximum dissolved oxygen concentration of 4.5 mg/1 at the surface dwindled to about 1 mg/1 at a depth of 12 feet, and remained low to the bottom of the lake. If the lake had only recently turned over, the mixing of deoxygenated water from the hypolimnion with oxygenated water from the epilimnion would result in a reduced overall dissolved oxygen concentration below the air-saturation level. In order to obtain the low dissolved oxygen values measured in this lake, the volume of deoxygenated water would have had to be much greater than the volume of oxygenated water, unless the oxygenated water had a low oxygen content initially.

Long Lake—is a shallow eutrophic lake which usually has a heavy annual algal bloom. The surface waters were alkaline (pH 9.0-9.1), but water near the bottom was nearly neutral (pH 7.3). A low secchi disc transparency of 4 feet indicated the denseness of the algal bloom present.

Black Lake—the pH of the water was near neutrality from surface to bottom. Black Lake is not deep and algal blooms occur annually. Fortunately, the lake, flushed by incoming water from springs and subsurface seepage, supports two outlet streams which enable it to rid itself of unpleasant algae. In coves and other sheltered areas, however, algal blooms are often very dense and stagnation occurs.

Patterson Lake—is a shallow, moderately eutrophic lake which supports algal blooms from midsummer to early fall. Like Long Lake, the surface waters were alkaline, with pH values near neutrality at the bottom. Water temperatures decreased steadily from 17.8°C at the surface to 15.4°C at the bottom. The dissolved oxygen concentration profile remained high, between 10-11 mg/l to a depth of 8 feet and then decreased sharply. The apparent decrease in dissolved oxygen below 8 feet probably resulted from decomposition of dead algal material settling out from the surface waters.

Summit Lake—a stable thermocline existed at Summit Lake at a depth of approximately 45 feet. As would be expected, the dissolved oxygen concentration dropped sharply at and below the thermocline. The water in Summit Lake was clear with only small amounts of suspended algae present.

West Sound Basin

Mason Lake—for all practical purposes, the waters of Mason Lake were found to be similar to those discussed above for Summit Lake.

Estuaries

The water characteristics of most of the estuaries are not well defined. A few special studies have been carried out in the past on areas influenced by pulp mill discharges. An extensive investigation is currently underway conducted by the U.S. Geological Survey and METRO, to define the characteristics of the Duwamish River estuary.

PHOTO 1-8. The Cedar River watershed is protected to preserve the high water quality for municipal use.

The principal estuaries are being degraded by man's activities and waste discharges from cities and industries. The primary effects in some areas have been periodic low dissolved oxygen levels, high bacterial concentrations, and high levels of toxic sulfite waste liquor.

Marine Waters

Marine waters have had water characteristics measured systematically by the University of Washington, Department of Oceanography, since 1948. Temperature, salinity, dissolved oxygen, and phosphates have been the primary constituents which were measured; and the stations have been widespread throughout the major regions of the Sound. The bays and harbors have been generally left either to special studies or not covered. The recent coopera-

PHOTO 1-9. Lake Washington . . . some evidence of improvement after elimination of waste discharges by METRO.

tive Puget Sound Study has resulted in an intensive study of Bellingham Bay, Everett Harbor, and Port Angeles Bay. Elliott Bay and Commencement Bay were also the subject of some previous Washington Pollution Control Commission studies.

The U.S. Geological Survey and Metro have conducted an intensive monitoring program in Puget Sound between Point Wells and Point Pulley since 1963. This reach of the Sound encompasses the entire Seattle metropolitan area and the program effectively covers Puget Sound waters adjacent to the Cedar-Green Basins.

Generally speaking, however, the water quality characteristics are inadequately defined for Puget Sound marine waters. The long-term effect of the wastes discharged into the Sound is now well known except for the outfall areas of the major waste sources.

Puget Sound water characteristics are dependent upon the oceanographic and meteorologic conditions described in the previous section on Marine Waters. Throughout the Sound a surface layer of less saline water overlies more dense sea water. Near the mouths of major streams, this layer is quite pronounced and stable. The boundary becomes more diffuse as the fresh water layer moves seaward as a result of vertical mixing, but the surface layer is never completely destroyed. The waters of each oceanographic area tend to be fresher as one proceeds landward, and the temperature range from winter to summer becomes greater.

Selected measured water characteristics are shown in Table 1-7. These partially illustrate, in a general way, the variance in water characteristics of the Sound. Since they represent such a small group of measurements, however, they do not indicate the actual maximum or minimum levels, nor the extent of spatial variance. In addition, these few parameters give only an incomplete definition of the quality.

The surface waters of some areas of Puget Sound also contain dilute concentrations of sulfite waste liquors. These originate primarily from the sulfite pulp mills at Bellingham, Anacortes, Everett, and Port Angeles. Concentrations diminish as distance from these sites increases. Concentrations greater than 10 ppm can be found throughout most of Bellingham Bay, Port Gardner Bay and Possession Sound, and Port Angeles Harbor.

The water quality surveillance stations which have recently been established by the Washington Pollution Control Commission for the marine waters of the Area, are listed in Table 1-8.

The present status of watercourses covered by the existing Interstate and Coastal Water Standards and by the proposed Intrastate Standards is given in Table 1-9.

TABLE 1-7. Water quality of marine waters, Puget Sound Area

	Strait of Juan de Fuca		Admiralty Inlet		Puget Sound Basin		Southern Puget Sound[1]		Hood Canal[1]		San Juan Island[1]		Bellingham Bay[1]		Georgia Strait[1]	
	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer	Fall Winter	Spring Summer
Temperature °C																		
Surface																		
Mean	7.6	11.3	8.0	10.5	3.5	12.0			6.0	20.0								
Maximum	11.5	11.8	9.2	12.7	12.7	15.2		16.0				12.0		12.2		15.0		
Minimum	6.3	7.8	6.4	9.6	7.3	8.1	7.0				6.8		6.0		6.5			
Depth																		
Mean	8.1	6.5	8.1	9.6	8.6	8.8												
Maximum	9.0	7.0	8.9	11.1	10.9	11.2		14.0		12.0	9.4		10.5		9.0			
Minimum	6.6	6.3	6.4	7.0	6.5	7.6			8.0	10.0	7.2			7.9	6.5			
Salinity o/oo																		
Surface																		
Mean	30.85	31.0	30.5	30.0	24.3	28.0		29.5										
Maximum	31.4	31.8	32.1	30.9	30.7	30.2			28.0		31.1			30.5	30.2			
Minimum	29.8	30.6	28.5	29.0	26.9	22.8	28.0		24.0			27.6		12.0		24.0		
Depth																		
Mean	33.55	34.0	30.8	31.0	30.3	30.0		29.5										
Maximum	33.8	34.1	32.4	31.8	31.0	31.1				30.8		32.5	30.5		31.0			
Minimum	32.2	33.8	28.8	29.6	29.6	29.0	28.0		29.0	30.0				29.5		30.4		
Dissolved Oxygen mg/1																		
Surface																		
Mean	8.2	7.1	8.0	6.8	9.6	9.6												
Maximum	9.0	9.5	8.6	9.1	12.2	20.1		9.6		20.0		10.0		13.0		10.0		
Minimum	5.1	6.6	3.8	3.8	6.4	7.0	5.6			5.0	5.6			7.0	7.0			
Depth																		
Mean	3.6	2.9	6.8	6.4	7.2	6.7												
Maximum	8.0	3.5	8.3	8.3	9.9	8.4					6.0		11.0		5.0			
Minimum	3.2	2.4	2.8	2.4	5.4	4.3					4.8			5.0		7.1		
Phosphate mg/1																		
Surface																		
Mean	0.06	0.06	0.05	0.04	0.07	0.03												
Maximum	0.07	0.07	0.06	0.06	0.08	0.06	0.08	0.08	0.08									
Minimum	0.03	0.05	0.02	0.02	0.02	0.02	0.05	0.05		0.00								
Depth																		
Mean	0.07	0.08	0.06	0.06	0.07	0.06								0.06				
Maximum	0.12	0.09	0.10	0.10	0.08	0.08												
Minimum	0.06	0.08	0.02	0.02	0.05	0.05				0.06								

[1] Generalized presentation of data.

TABLE 1-8. Water quality surveillance stations on Puget Sound

Name & Code	No.	Location
Admiralty Inlet		
ADM	001	Whatcom Waterway
	002	Standard Oil Dock
	003	Southend of East Pier
	004	Yacht Basin Light No. 2
	005	Middle of Inner Bay
	006	Nun Buoy No. 4
	007	Cannery Ship Yard
	008	Past Point Buoy No. 2
	009	Point Francis Buoy No. 2
	010	Eliza Rock Bell
Budd Inlet		
BUD	001	Yacht Basin
	002	Port Dock Buoy No. 18
	003	Spar Buoy No. 10
	004	Red Light Buoy No. 6
	005	Olympia Shoals
Commencement Bay		
CMB	001	Tacoma Yacht Club
	002	Browns Point
	003	Mid Bay
	004	Old Tacoma
	005	City Waterway
	006	Mouth of City Waterway
	007	City Waterway S.W. of the R.R. Bridge
	008	Mouth of the St. Paul Waterway
	009	Puyallup Waterway, 500 yds. N.W.
	010	Puyallup Waterway, midstream at mouth
	011	Puyallup Waterway, midstream at the 11th St. Bridge
	012	Puyallup River under Hwy 99 Bridge
	013	Port Industrial Waterway
	014	400 yds. from the mouth of the Port Industrial Waterway
	015	Mouth of the Hylebos Waterway
	016	Hylebos Waterway beneath the 11th St. Bridge
	017	Hylebos Waterway near Lincoln Ave.
Carr Inlet		
CRR	001	Mid Channel Carr Inlet
Case Inlet		
CSE	001	S.W. of Heron Island
Drayton Harbor		
DRA	001	Drayton Harbor
Dyes Inlet		
DYE	001	Elwood Point
	002	Windy Point
	003	Washington Narrows
Elliott Bay		
ELB	001	East of Pier 91
	002	50 yds. off Pier 66
	003	100 yds. off Pier 51
	004	North of Harbor Island
	005	100 yds. off Pier 15
	006	200 yds. off Pier 13
	007	100 yds. N.E. of Seacrest Marina
	008	Duwamish Head
	009	Beneath the Spokane St. Bridge

TABLE 1-8. Water quality surveillance stations on Puget Sound (Continued)

Name & Code	No.	Location
	010	Beneath the 16th St. Bridge
	011	Beneath the Ox Bow St. Bridge
	012	Beneath the East Marginal St. Bridge
	013	Tukwila, behind Village Green Apts.
	014	Bridge on Hwy 181
Eld Inlet		
ELD	001	Flapjack Point
Strait of Georgia		
GRG	001	Birch Bay, Whitehorn Point
Hammersley Inlet		
HAM	001	Libbey Point
Hood Canal Basin		
HCB	001	South Point
	002	Pulali Point
	003	Eldon Chinom Point
	004	Sisters Point
	005	Point Julia
Holmes Harbor		
HLM	001	Honeymoon Bay
Haro Strait		
HRO	001	Skipjack Island
Strait of Juan de Fuca		
JDF	004	Off the end of Ediz Hook
	005	Pit Ship Point, Sequim Bay
	006	Carr Point, Port Discovery Bay
Tacoma Narrows		
NRR	001	Point Defiance
Nisqually Reach		
NSQ	001	Nisqually Reach
Oakland Bay		
OAK	001	Eagle Point
	002	Center North Bay
	003	Yacht Basin
	004	Mid Bay, Eagle Point
Port Angeles Harbor		
PAH	001	East of Ediz Hook
	002	Pilot Station
	003	Head of Ediz Hook
	004	Fiberboard Mill
	005	Ferry Landing
	006	Rayonier Mill
	007	Rayonier Mill Pier, 200 yds. out
	008	Mouth of Morse Creek
Padilla Bay		
PAD	001	South of Hat Island
	002	Fidalgo Bay
Pickering Passage		
PCK	001	Mid Channel off Graham Point
Port Orchard		
POD	001	Point White
	002	Battle Point

TABLE 1-8. Water quality surveillance stations on Puget Sound (Continued)

Name & Code	No.	Location
	003	Auto Bridge at Agate Passage
	004	Northend of Liberty Bay
Puget Sound		
PSB	001	Point Robinson
	002	Between Alki and Restoration Points
	003	West Point
	004	North of Edmonds at Ferry Slip
Possession Sound		
PSS	001	Camano Head
	002	Tulalip Bay
	003	S.E. tip Gedney Island
	004	Mukilteo Point
	005	Weyerhaueser Dock
	006	Port Gardner Pier No. 1
	007	Port Gardner Pier No. 2
	008	Port Gardner Pier No. 3
	009	Scott Paper Dock
	010	Naval Reserve Dock
	011	East Waterway, westend
	012	Snohomish River at Light No. 5
	013	American Pile Driving Pier
	014	Preston Point
	015	Snohomish River beneath Hwy 99 Bridge
	016	South tip Smith Island
	017	Snohomish River beneath Hwy No. 2 Bridge
	018	Snohomish River above Lowell
Port Townsend		
PTH	001	Kala Point
	002	Crown Zellerbach Mill
	003	Yacht Basin
	004	Point Hudson
Rosario Strait		
RSR	001	Guemes Channel
	002	Borrows Island
	003	Deception Pass
	004	Lawrence Point
Sammish Bay		
SAM	001	East of Williams Point
	002	Williams Point
Saratoga Passage		
SAR	001	Forbes Point
Sinclair Inlet		
SIN	001	Navy Yard Dry Dock
	002	West Sinclair Inlet
San Juan Islands		
SJI	001	Reid Rock
Skagit Bay		
SKE	001	Hope Island
	002	Strawberry Point
Pt. Susan		
SUS	001	Kayak Point
Totten Inlet		
TOT	001	Windy Point

FIGURE 1-11. Water quality surveillance stations, Puget Sound North.

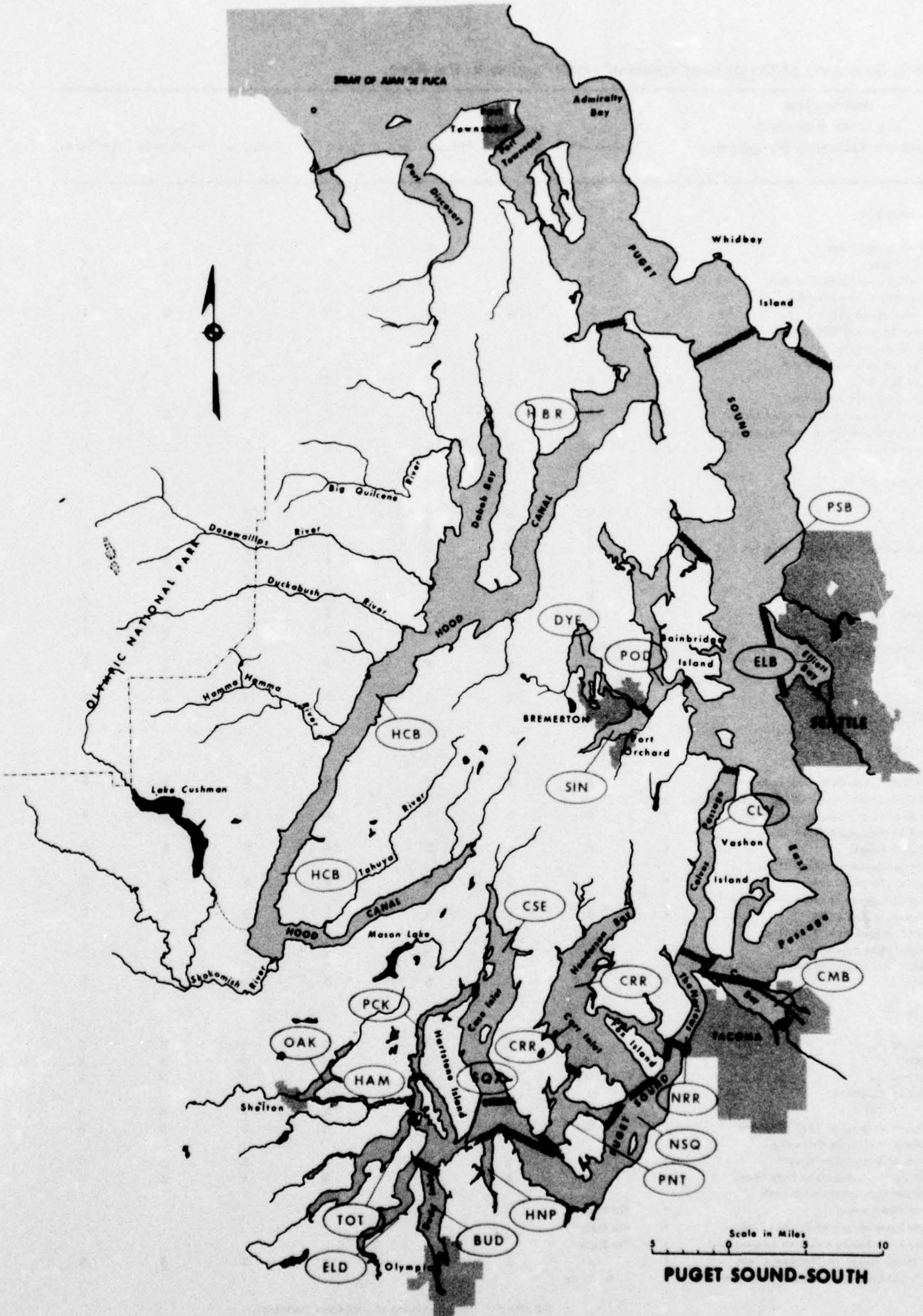


FIGURE 1-12. Water quality surveillance stations, Puget Sound South.

TABLE 1-9. Summary of the present status of water quality in the Area.

Watercourse • Interstate Standards † Intrastate Standards (Proposed)		Total Coliform	Dissolved Oxygen	Temperature	pH	Turbidity	Toxic or Deleterious	Aesthetics
Nooksack-Sumas Basins								
Samish and Bellingham Bays	•	X	X	S	S	X	X	X
Inner Bellingham Bay	•	X	X	S	X	X	X	X
Nooksack River, mouth to river mile 4	•	X	X	S	S	S	X	X
Nooksack River from river mile 4 to confluence with Maple Creek	†	X	X	S	S	S	X	X
Nooksack River from confluence with Maple Creek to the headwater	†	S	S	S	S	S	S	S
Maple Creek to the headwater Middle Fork of Nooksack River	†	S	S	S	S	S	S	S
South Fork of Nooksack River from mouth to confluence with Skookum Creek	†	S	S	S	S	S	S	S
South Fork of Nooksack River from Skookum Creek to the headwater	†	S	S	S	S	S	S	S
Skagit-Samish Basins								
Skagit River	•	X	S	S	S	S	X	
Skagit River	•	X	S	S	S	S	S	S
Guemes Channel, Padilla, and Samish Bays		S	X	S	S	S	X	S
Skagit Bay		S	S	S	S	S	S	S
Skagit River	•	X	S	S	S	S	X	
Skagit River	•	X	S	S	S	S	S	S
Guemes Channel, Padilla Bay	•	S	X	S	S	S	X	S
Samish River	†	X	S	S	S	S	S	S
Friday Creek from mouth to Samish Lake	†	No Data						
Baker River	†	S	S	S	S	S	S	S
Cascade River	†	No Data						
Sauk River	†	S	S	S	S	S	S	S
Suiattle River	†	No Data						
Stillaguamish Basin								
Stillaguamish River, mouth to river mile 7	•	S	X	S	X	S	S	S
Stillaguamish River from river mile 7 to confluence with North and South Fork Stillaguamish	†	S	S	S	S	S	S	S
North Fork of Stillaguamish River to mouth of Squire Creek	†	S	S	S	S	S	S	S
North Fork of Stillaguamish River from Squire Creek to the headwater	†	S	S	S	S	S	S	S
South Fork of Stillaguamish River from mouth to Canyon Creek	†	S	S	S	S	S	S	S
South Fork of Stillaguamish River from Canyon Creek to the headwater	†	S	S	S	S	S	S	S
Pilchuck Creek from mouth to Cavanaugh Lake	†	No Data						
Port Susan Bay	•	S	S	S	S	S	S	S
Snohomish Basin								
Possession Sound	•	S	S	S	S	S	S	S
Everett Harbor	•	S	X	S	S	X	X	X
Inner Everett Harbor	•	X	X	X	X	X	X	X
Snohomish River mouth to Latitude 47 56' 30"	•	X	S	X	S	X	X	X
Snohomish River to limit of tidal influence	•	X	S	S	S	X	S	S
Snohomish River from tidal influence to confluence of Skykomish River	†	X	S	S	S	S	S	S
Skykomish River from mouth to May Creek	†	S	S	S	S	S	S	S
Skykomish River from confluence with May Creek to headwaters	†	No Data						
Pilchuck River from mouth to Purdy Creek	†	No Data						
Pilchuck River from Purdy Creek to headwaters	†	No Data						
Sultan River from mouth to Chaplain Creek	†	S	S	S	S	S	S	S
Sultan River from Chaplain Creek to headwaters	†	No Data						

S - Satisfactory, meets existing or proposed standards.
X - Unsatisfactory, does not meet existing or proposed standards.

TABLE 1-9. Summary of the present status of Water Quality in the Area (Continued)

Watercourse •– Interstate Standards †– Intrastate Standards (Proposed)		Total Coliform	Dissolved Oxygen	Temperature	pH	Turbidity	Toxic or Deleterious	Aesthetics
Snohomish Basins (Continued)								
Snoqualmie River from mouth to confluence with North Fork of Snoqualmie River	†	X	S	S	S	S	S	S
Tolt River from mouth to headwaters	†	S	S	S	S	S	S	S
North Fork of Snoqualmie River from mouth to headwaters	†	No Data						
Middle Fork of Snoqualmie River from mouth to headwaters	†	No Data						
South Fork of Snoqualmie River from mouth to headwaters	†	No Data						
Cedar-Green Basins								
Elliott Bay	•	X	X	S	S	S	X	X
Duwamish River mouth to Black River junction	•	X	X	S	S	X	X	X
Duwamish River upstream from Black River junction to limit of tidal influence	•	X	X	S	S	X	X	X
Duwamish River to Green River	†	X	X	S	S	S	X	X
Green River from beginning to intersection of river with east boundary of Section 10 R. 7E., T.21N.	†	X	X	S	S	S	X	X
Green River from intersection of river with east boundary of Section 10 R. 7E., T.21N. to headwaters	†	S	S	S	S	S	S	S
Cedar River from Lake Washington to Issaquah-Ravensdale watershed boundary		S	S	S	S	S	S	S
Cedar River from watershed boundary to headwaters		No Data						
Sammamish River from Lake Washington to Lake Sammamish		X	S	S	S	S	S	S
Issaquah Creek		X	S	S	S	S	S	S
Puyallup Basin								
Commencement Bay	•	X	X	S	S	X	X	X
Inner Commencement Bay	•	X	X	S	S	X	X	X
Port-Industrial and City Waterways	•	X	X	S	S	X	X	X
Puyallup River mouth to river mile 1	•	X	S	S	S	X	X	X
Puyallup River–river mile 1 to limit of tidal influence	•	X	S	S	S	S	S	S
Chambers Creek mouth to the limit of tidal influence	•	S	S	S	S	S	S	S
Puyallup River from tidal influence to confluence with Fisk Creek	†	X	S	S	S	S	S	S
Puyallup River from Fisk Creek to headwaters and tributaries	†	S	S	S	S	S	S	S
Carbon River from mouth to confluence of South Prairie Creek	†	S	S	S	S	S	S	S
Carbon River from South Prairie Creek to headwaters	†	No Data						
White River from mouth to Mud Mountain Dam	†	X	S	S	S	S	S	S
White River from Mud Mountain Dam to headwaters and tributaries	†	No Data						
Nisqually-Deschutes Basins								
Budd Inlet	•	X	X	S	S	X	X	X
South Puget Sound, West of Brisco Point and northern tip of Hartstene Island	•	X	S	S	S	S	S	S
Nisqually River mouth to river mile 9	•	S	S	S	S	S	S	S
Nisqually River from river mile 9 (tidal influence) to Alder Dam	†	S	S	S	S	S	S	S
Nisqually River from Alder Dam to headwaters and tributaries	†	No Data						

S-Satisfactory, meets existing or proposed standards.
X–Unsatisfactory, does not meet existing or proposed standards.

TABLE 1-9. Summary of the present status of Water Quality in the Area (Continued)

Watercourse * – Interstate Standards † – Intrastate Standards (Proposed)		Total Coliform	Dissolved Oxygen	Temperature	pH	Turbidity	Toxic or Deleterious	Aesthetics
Nisqually-Deschutes Basins (Continued)								
Deschutes River from tidal influence to Lawrence Creek	†	S	S	S	S	S	S	S
Deschutes River from Lawrence Creek headwaters and tributaries	†	No Data						
West Sound Basins		West Sound Basins						
Oakland Bay	*	No Data						
Union River	†	S	S	S	S	S	S	S
Tahuya River	†	S	S	S	S	S	S	S
Skokomish River and tributaries	†	S	S	S	S	S	S	S
Hamma Hamma River and tributaries	†	S	S	S	S	S	S	S
Duckabush River and tributaries	†	S	S	S	S	S	S	S
Dosewallips River and tributaries	†	S	S	S	S	S	S	S
Big Quilcene River and tributaries	†	S	S	S	S	S	S	S
Little Quilcene River	†	No Data						
Dungeness River from mouth to Canyon Creek	†	SS	S	S	S	S	S	S
Dungeness River and tributaries from Canyon Creek to headwaters	†	S	S	S	S	S	S	S
Elwha-Dungeness Basins								
Port Angeles	*	X	X	S	X	X	X	X
Sequim Bay	*	S	S	S	S	S	S	S
Port Townsend	*	X	S	S	S	S	X	S
Elwha River and tributaries	†	S	S	S	S	S	S	S
All Basins								
Strait of Juan de Fuca and Puget Sound	*	S	S	S	S	S	S	S

S-Satisfactory, meets existing or proposed standards.
X–Unsatisfactory, does not meet existing or proposed standards.

SOURCES OF WASTES

As shown in Table 1-10, the average daily municipal and industrial organic wasteload generated in the Puget Sound Area approximates 16 million population equivalents, of which only 9 percent is presently removed by waste treatment.

The peak season daily wasteload discharged to the marine and fresh waters of the Area is equivalent to the amount of wastes produced by about 14.9 million people.

Basins receiving the largest quantities of wastes as shown in Figure 1-13, include the Snohomish, Elwha-Dungeness, and Nooksack-Sumas. About 84 percent of the Area's total organic waste discharges occur in these three basins. The sources of wastes to both fresh and marine waters are summarized for each of the eleven basins in Table 1-10.

Ninety-three percent of the daily wasteload is discharged solely to marine waters. Cities and industries located near marine waters are generating daily about 14.4 million population equivalents (PE) in peak season.

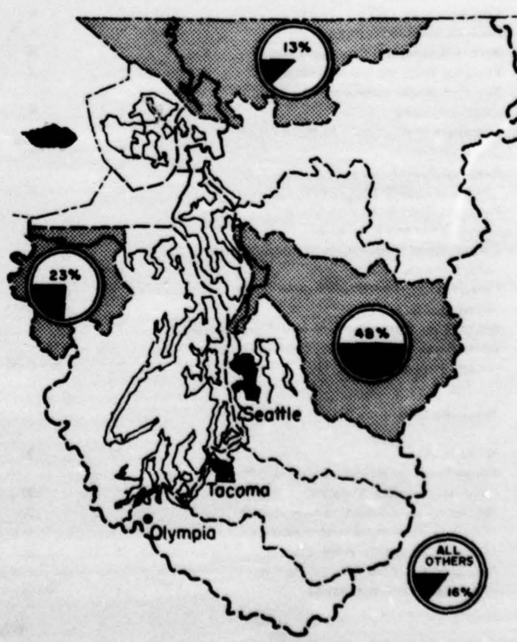


FIGURE 1-13. Distribution of waste discharges in the Puget Sound Area.

About one percent of this total wasteload receives secondary treatment; about 5 percent receives primary treatment; 4 percent is treated by lagoon; and 90 percent is released into the marine waters untreated. As a result, the waste from an equivalent population of 13,710,000 people is being discharged to marine waters.

The principal waste sources are located in Bellingham, Anacortes, Everett, and Port Angeles. Other sources of wastes include treated and untreated sanitary wastes from several municipalities and food processing wastes discharged from numerous seafood canning and freezing plants.

Certain water-related outdoor recreation activities contribute wastes to the marine waters. Boating is especially significant. Pleasure craft concregating in the bays, harbors, and channels impose a load of untreated wastes on the waters they use. Disposal of wastes by commercial vessels–such as sanitary wastes, oil, litter, bilge and ballast water–are other sources of pollution to marine waters.

Sources of waste located on fresh waters produce about 952,000 PE of raw organic wastes daily. This is only six percent of the total waste generated daily in the Puget Sound Area. During the food processing season, an additional 723,000 PE are produced every day. The generation of wastes from sources along fresh water reaches 1,675,000 PE daily in peak season.

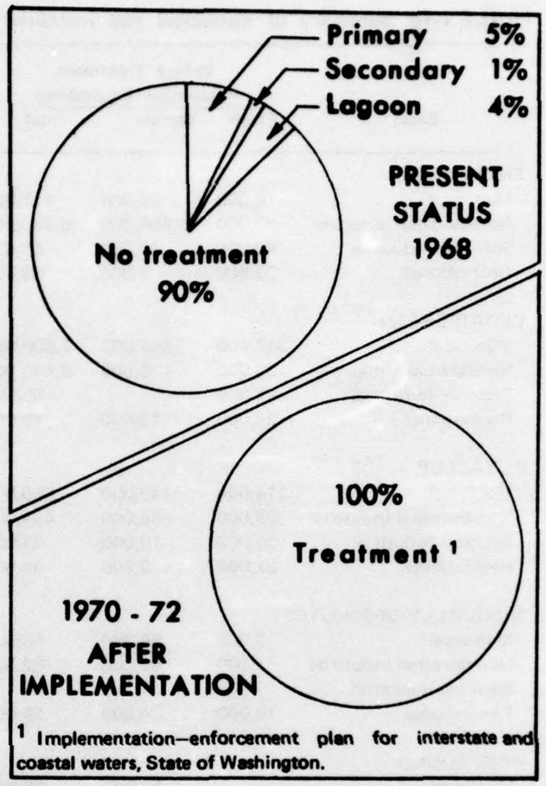


FIGURE 1-14. Treatment of wastes discharged into marine waters in the Puget Sound Area.

TABLE 1-10. Summary of municipal and industrial wastes Puget Sound Area

Basin	Before Treatment Population Equivalents			Discharged Wastes Population Equivalents			Treatment Efficiency (Percent)		
	Fresh	Marine	Total	Fresh	Marine	Total	Fresh	Marine	Total
NOOKSACK-SUMAS									
Municipal	5,400	55,000	60,000	2,000	34,000	36,000	63	38	40
Non-Seasonal Industrial	25,600	1,745,000	1,770,000	20,000	1,745,000	1,765,000	22	None	None
Seasonal Industrial	116,200	77,500	189,000	46,000	59,000	105,000	60	24	44
Recreational	15,000	5,000	20,000	3,700	1,200	5,000	75	76	75
SKAGIT-SAMISH									
Municipal	23,000	8,000	31,000	14,300	5,000	19,300	38	37	38
Non-Seasonal Industrial	25,000	789,000	814,000	25,000	785,000	810,000	None	None	None
Seasonal Industrial	116,000	78,000	194,000	116,000	78,000	194,000	None	None	None
Recreational	14,000	5,000	19,000	3,600	1,200	5,000	74	76	74
STILLAGUAMISH									
Municipal	5,600	–	5,600	2,200	–	2,200	61	–	61
Non-Seasonal Industrial	–	–	–	–	–	–	–	–	–
Seasonal Industrial	335,000	–	335,000	221,000	–	221,000	34	–	34
Recreational	6,500	1,200	8,000	1,600	300	2,000	75	75	75

TABLE 1-10. Summary of municipal and industrial wastes Puget Sound Area (Continued)

Basin	Before Treatment Population Equivalents			Discharged Wastes Population Equivalents			Treatment Efficiency (Percent)		
	Fresh	Marine	Total	Fresh	Marine	Total	Fresh	Marine	Total
SNOHOMISH									
Municipal	16,000	95,000	111,000	9,000	33,200	42,200	44	65	62
Non-Seasonal Industrial	77,000	6,906,000	6,983,000	61,000	6,644,000	6,705,000	21	3.8	4.0
Seasonal Industrial	48,000	10,000	58,000	38,800	3,400	42,200	19	66	27
Recreational	22,000	7,000	29,000	5,500	1,800	7,000	75	74	76
CEDAR-GREEN									
Municipal	347,000	653,000	1,000,000	52,000	424,000	476,000	85	35	52
Non-Seasonal Industrial	108,000	136,500	2,445,000	83,300	136,500	219,800	23	None	10
Seasonal Industrial	55,000	--	55,000	29,000	--	29,000	47	--	47
Recreational	37,000	12,000	49,000	9,000	3,000	12,000	76	75	76
PUYALLUP									
Municipal	214,000	142,000	356,000	140,000	95,000	226,000	35	33	37
Non-Seasonal Industrial	88,000	346,000	434,000	64,000	346,000	410,000	27	None	5
Seasonal Industrial	39,000	10,000	49,000	32,000	10,000	42,000	18	None	14
Recreational	21,600	3,800	25,000	5,400	1,000	6,400	75	74	74
NISQUALLY-DESCHUTES									
Municipal	3,000	55,300	58,300	100	40,000	40,100	97	28	31
Non-Seasonal Industrial	200	62,300	62,500	200	57,300	57,500	None	8	8
Seasonal Industrial	--	--	--	--	--	--	--	--	--
Recreational	14,000	4,000	18,000	3,600	900	4,500	74	78	75
WEST SOUND									
Municipal	--	75,000	75,000	--	52,800	52,800	--	30	30
Non-Seasonal Industrial	--	126,000	126,000	--	119,000	119,000	--	6	6
Seasonal Industrial	--	2,000	2,000	--	2,000	2,000	--	None	None
Recreational	16,700	16,600	33,300	4,000	4,000	8,000	76	76	76
ELWHA-DUNGENESS									
Municipal	--	24,600	24,600	--	23,200	23,200	--	6	6
Non-Seasonal Industrial	--	3,234,000	3,234,000	--	3,234,000	3,234,000	--	None	None
Seasonal Industrial	--	--	--	--	--	--	--	--	--
Recreational	4,600	1,500	6,000	1,100	400	1,500	76	73	75
SAN JUAN ISLANDS									
Municipal	--	800	800	--	800	800	--	None	None
Non-Seasonal Industrial	--	--	--	--	--	--			
Seasonal Industrial	--	2,800	2,800	--	2,800	2,800	--	None	None
Recreational	--	7,000	7,000	--	1,700	1,700	--	76	76
WHIDBEY-CAMANO ISLANDS									
Municipal	--	11,500	11,500	--	7,400	7,400	--	36	36
Non-Seasonal Industrial	--	--	--	--	--	--	--		
Seasonal Industrial	--	--	--	--	--	--	--		
Recreational	600	11,300	12,000	200	2,800	3,000	67	75	75
TOTALS									
Municipal	614,000	1,121,000	1,735,000	220,000	715,000	935,000	64	36	46
Non-Seasonal Industrial	324,000	13,345,000	13,669,000	254,000	13,067,000	13,321,000	20	2	2
Seasonal Industrial	709,000	180,000	889,000	483,000	155,000	638,000	33	4	28
Recreational	152,000	74,000	226,000	38,000	18,000	56,000	75	76	75

All figures are rounded.

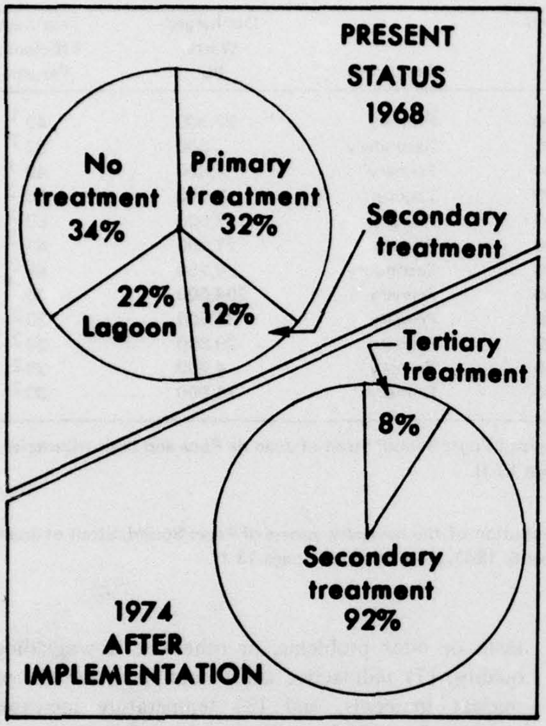


FIGURE 1-15. Treatment of wastes discharged into fresh waters in the Puget Sound Area.

These wastes are given varying degrees of treatment. Twelve percent receives secondary treatment; 32 percent receives primary treatment; 22 percent of the wastes are treated by lagoon; and 34 percent is discharged into the fresh waters untreated. After treatment, more than a million PE are discharged daily into the rivers by cities and industries during the peak season. Most of these discharged wastes (73 percent) are generated by industry. After 1972, implementation of the Interstate Standards will reduce the million PE to an estimated 302,000.

Significant waste sources to fresh waters in the Puget Sound Area are concentrated in four basins: the Puyallup, Stillaguamish, Cedar-Green, and Skagit-Samish Basins. They account for over three-fourths of the Area's waste discharge to fresh waters.

Municipal

More than 1.3 million PE are collected by municipal sewer systems throughout the Puget Sound Area at the present time (Table 1-10). Two-thirds of this waste production occurs adjacent to marine waters of the area, indicating the population and industrial concentration near marine waters. More than 80 percent of these municipal wastes are produced within the Snohomish, and Cedar-Green Basins alone. The Cedar-Green Basins account for 45 percent of the total municipal waste in the Area.

About 1,370,000 people or 75 percent of the municipal population of 1,818,000, are served by municipal sewage collection systems and the remainder by septic tanks and drain fields. All municipal sewer systems are also served by waste treatment facilites. Waste treatment facilities for handling municipal wastes include primary plants, lagoons, and secondary waste treatment plants. An estimated 30 municipalities of over 500 population provide primary treatment, seven provide secondary treatment by lagoon, and eight provide treatment by secondary sewage treatment plants.

About 875,000 people are considered to have adequate waste treatment facilities.

After treatment, 694,000 PE are discharged to the Area's fresh and marine waters. Nearly 70 percent of these are discharged to the marine waters. More than 90 percent of the municipal wastes discharged to fresh waters and 65 percent of the municipal wastes discharged to marine waters are centered in the Snohomish, Cedar-Green, and Puyallup Basins.

Waste treatment efficiencies of the major municipalities within the Puget Sound Area are shown in Table 1-11. The overall treatment efficiency for municipal wastes presently stands at 47 percent.

PHOTO 1-10. Green Lake . . . once a eutrophic body of water plagued by heavy blooms of bluegreen algae during the summer.

TABLE 1-11. Municipal treatment efficiencies Puget Sound Area

City	Untreated Waste PE	Treatment	Discharged Waste PE	Treatment Efficiency Percent
Bellingham	47,000	Primary	27,300	42 [1]
Lynden	2,700	Secondary	500	82 [2]
Anacortes	8,000	Primary	4,800	40 [1]
Everett	45,000	Lagoon	18,000	60 [3]
Seattle (West Point STP)[4]	228,000	Primary	113,000	50 [3]
Seattle (Alki Point STP)[4]	37,000	Primary	21,000	43 [3]
Seattle (Renton STP)	93,000	Secondary	4,250	95 [3]
Tacoma	266,000	Primary	204,000	30 [2]
Olympia	49,000	Primary	34,500	30 [2]
Bremerton	42,500	Primary	29,800	30 [2]
Port Townsend	6,000	Primary	4,200	30 [2]
Port Angeles	22,800	Primary	15,900	30 [2]

[1] Conference on the matter of pollution of the navigable waters of Puget Sound, Strait of Juan de Fuca and their tributaries, Seattle, September 6-7 and October 6, 1967 (this Appendix, page 13-1).

[2] Based on design.

[3] Treatment plant records and conference on the matter of pollution of the navigable waters of Puget Sound, Strait of Juan de Fuca and their tributaries, Seattle, September 6-7 and October 6, 1967, (this Appendix, page 13-1).

[4] Sewage treatment plant.

Industrial

As shown in Table 1-10, 13.7 million PE are produced by annual non-seasonal industries. These wastes represent about 91 percent of the combined peak municipal and industrial wastes. The paper and allied industries are responsible for 95 percent of the annual non-seasonal wastes. The pulp and paper operations of the Area are presented in Table 1-12.

Of the total annual non-seasonal waste production, more than 98 percent occurs adjacent to marine waters, and more than 50 percent is produced within the Snohomish Basin alone.

Seasonal wastes, generated primarily by food processing plants, represent only about six percent (885,000 PE) of the total industrial wastes.

TYPES OF WASTES

Wastes can be classified into eight general categories: (1) oxygen demanding organic wastes contributed by domestic and industrial sources; (2) infectious agents contributed by domestic sewage and animal wastes which may transmit diseases; (3) sediments resulting from man's activity such as gravel washing; (4) plant nutrients which promote the growth of algae; (5) synthetic organic chemicals such as pesticides, which are toxic to aquatic life; (6) inorganic chemicals and mineral substances, acids, or industrial waste either toxic to aquatic life, causing taste or odor problems, or otherwise downgrading quality; (7) radioactive substances from the use of nuclear materials; and (8) temperature increases resulting from the use of water for cooling purposes.

Municipal

Municipal wastes are composed primarily of unstable oxygen demanding matter containing large concentrations of microbial agents (bacteria or viral) which may be pathogenic. They are colored and odorous and impart these characteristics to receiving waters if discharged in the untreated state. Wastes making up the municipal category include those from domestic sources, smaller industrial and commercial establishments connected to the municipal system, and storm water runoff. Domestic wastes—those generated primarily by households (sanitary, laundry, garbage disposals, etc.) usually account for a major portion of the organic material contained in municipal wastes and are the primary source of infectious agents. Industrial and commercial operations such as smaller food processing plants, laundries, and restaurants, also contribute to the organic load with wastes similar to domestic wastes. Storm runoff from streets and other urban areas contributes sediment, oil washed from streets, and chemicals such as fertilizers and pesticides utilized by homeowners.

Unusually large water-using industries have large waste discharges and, therefore, are not connected to the municipal system of most cities in the

TABLE 1-12. Summary of wastes from paper and allied industries Puget Sound Area

Basin	Industrial Plant	Average Production Tons/Day	Untreated Waste PE	Treatment Facilities	Discharged Waste PE	Treatment Efficiency
Nooksack-Sumas	Georgia-Pacific	730	1,687,000	None	1,687,000	None
Skagit-Samish	Scott Paper Co.	140	778,000	None	778,000	None
Snohomish	Simpson Lee Paper Co.	270	75,000	Pond	60,000	20%
	Scott Paper Co.	1,400	4,481,000	Solids Removal	4,481,000	None
	Weyerhaeuser Co.	300	1,910,000	Solids Removal	1,910,000	None
	Weyerhaeuser Co.	420	--	Holding Lagoon	238,000	*1
Puyallup	St. Regis Paper Co.	1,500*2	294,000	None	294,000	None
	West Tacoma Newsprint	430*2	31,200	None	31,000	None
West Sound	Crown Zellerbach	400*2	96,000	None	96,000	None
	Simpson Timber Co.		30,000	Pond	23,000	
Elwha-Dungeness	Fiberboard Corp.	190	264,000	None	264,000	None
	Rayonier, Inc.	470	2,820,000	None	2,820,000	None
	Crown Zellerbach	880	145,000	None	145,000	None

*1 Treatment efficiency of lagoon has not been determined. Effluent is discharged into Steamboat Slough over a five-hour period on each ebbing tide.

*2 Capacity.

Puget Sound Area. In evaluating the strength of these organic industrial wastes that are discharged to the municipal systems, a value of 0.17 pounds of biochemical oxygen demand (BOD_5) is normally equated to one population equivalent (PE). This is the average amount of BOD_5 exerted by the organic waste from one individual.

Municipal wasteloads presented here are based primarily on the inventory of municipal and industrial wastes developed for the Puget Sound Task Force by the Water Quality Control Technical Committee. This inventory presents the sources and locations of the wastes generated within the Area along with the number of people served by the sewage collection system, the quantity of waste produced, the type of treatment provided, and the quantity of wastes discharged after treatment. Generally speaking, the inventory is based on 1965 data although many entries reflect the use of more recent data. Because the installation of new waste treatment facilities is an ongoing program, a number of cities, towns and industries may have upgraded their treatment facilities which may not be shown on the Sources of Waste Summary Tables in each basin chapter. Information regarding municipal wastes was, in most cases, obtained by personal communication with officials of cities and towns although considerable information was also obtained from engineering reports, State Health Department reports, and the State Water Pollution Control Commission. Information regarding industrial waste discharges was obtained primarily from the State industrial waste discharge permits and from a number of industrial waste surveys.

Industrial

Wastes from industrial operations such as pulp and paper mills; milk products plants; fruit, vegetable, fish, and shellfish canneries; meat processing plants; chemical plants; sawmills; and aggregate production areas are the primary sources of pollution in the Puget Sound Area. Over 90 percent of the total organic wasteload generated in the Area is attributed to industry.

Industrial wastes discharged into the fresh, estuarial, and marine waters of the Area affect these waters in several ways. Organic solids may settle to the bottom to form sludge beds. These solids decompose, producing odors and destroying aquatic life. Another adverse effect of these waters has been the depression of dissolved oxygen levels which has occurred in some harbors as well as in the lower reaches of the Duwamish River as previously mentioned. Some wastes contain compounds that are toxic to fish and other aquatic life. Such compounds as acids, alkalies, cyanides, metals, or phenols are the usual toxicants.

Certain industrial wastes cause damage to the waters by physical actions such as wastes from lumbering and mining operations which contribute large amounts of sawdust and silt; cooling water discharges which raise the temperature of the waters; and oil wastes which contribute floating oils, color, and sludge.

Many industrial effluents contain substances which produce disagreeable tastes and odors to water supplies. Other highly acidic or basic wastes are corrosive and seriously damage piping systems.

Some of the industrial wastes produced in the area which possess significant biochemical oxygen demand include waste liquors from sulfite pulp mills, food processing plant wastes, meat packing wastes, and milk processing wastes.

The findings of the joint Federal-State Washington State Enforcement Project were published in a report entitled "Polutional Effects of Pulp and Paper Mill Wastes in Puget Sound," March 1967, and are reproduced more fully in the last section of this appendix. Bioassay studies conducted by the Project showed that sulfite waste liquor concentrations in excess of ten parts per million were damaging to oyster larvae and English sole eggs and, in some cases, caused adult and juvenile oyster mortality. Sulfite waste liquor was also shown to produce conditions toxic to juvenile salmon.

Also, detrimental to water quality are industrial wastes which have a direct lethal effect on biological life forms. Included in this category are spent metal plating solutions containing heavy metals, cyanide, cleaners and strippers; acid wastes from pickling operations, chemical manufacture, primary aluminum reduction, organic phenols and petro-chemical wastes.

Waste treatment for industries include the use of screening, primary treatment plants, lagoons, secondary treatment plants, neutralization, chemical treatment, oil separation, and in-plant controls. Very few industries have no waste treatment facilities while others utilize municipal facilities. Pulp mill wastes, however, cannot be adequately treated by municipal facilities due to the large quantities and high strength of the wastes. Of the total industrial wastes produced, 92 percent receive no treatment; about 1.7 percent receive primary treatment and about 6 percent receive secondary treatment.

After treatment, 13,970,000 PE (seasonal and non-seasonal wastes) are discharged to the Area's fresh and marine waters, reflecting the large quantity of pulp and paper wastes which are discharged without treatment.

Some plants in the pulp and paper industry have improved their waste-handling methods. For example, Georgia-Pacific Corporation has instituted their alcohol by-product recovery program; the Everett sulfite mills have constructed a deep water outfall; the Everett Kraft plant has built settling lagoons; West Tacoma Newsprint has installed flotation units for fiber recovery; Sampson Lee Paper Company in Everett discharges to a settling lagoon prior to release to the Snohomish River on favorable tides; and the Anacortes mill has relocated their outfall to Guemes Channel for better dispersion of wastes.

A number of mills have been operating barker clarifiers and Scott Paper Company at Everett has constructed a complete clarification system.

The paper and allied products industry generally provides treatment for suspended solids (fiber) removal at present and all plants are required to provide collection treatment and control equipment of a type such as is described here:

In the operation of the hydraulic barker for logs, the bark removed is discharged with the water on a drag conveyor with a perforated bottom. The water passing through these perforations contains fine bark particles as well as sand and other material. This water flows through a fabricated flume and is distributed to vibrating screens. The water passes through the bark screens into the main pit and is then discharged to a clarifier. The solids retained on the screen fall into a drag chain conveyor and are delivered to one of the refuse conveyors. Water fed to the clarifier is retained in the clarifier tank for approximately 1½ hours, then flows to the main mill sewer. Suspended solids settle to the tank bottom during the 1½ hour holding period and form a sludge layer. Clarifier rake arms move the collected sludge to a circular sump where it is pumped out for further processing. Any scum which floats to the surface of the clarifier water is collected by a rotating rake and piped back to the vibrating screens for reprocessing. Water from plant floor drains and bark press liquor is collected in a small sump and pumped to the clarifier for clarification. The solids are ultimately burned in boilers after mixing with the hog fuel.

Mill systems are subject to continuous maintenance, metering and sampling; and deep water outfalls are used to gain adequate and required dispersion as follows:

Effluents from pulp mill chlorination washers are combined with the clarified effluent flow entering a deaerating tank just ahead of the diffuser system. This tank is equipped with showers, mechanical foam breakers and level controls to maintain a full discharge line.

Fresh water inputs to the mill and the main mill effluent are measured, integrated, and recorded. This metering equipment provides a check of input vs. effluent for the mill, indicates any abnormal effluent conditions and provides data requested by the industrial waste permits.

Dredging

Dredging normally is carried out in the estuarine areas where sediment and waste products build up to block navigable waters. In areas where new port facilities are being constructed, dredging is usually a prerequisite.

Dredging introduces quantities of suspended material to the local water prism. In those bottom areas where debris and sludge beds have built up from industrial waste discharges, dredging frees large quantities of oxygen-demanding organics in the water and may release toxic products of decomposition. In Puget Sound, dredging is an important activity. The primary effect on water quality has been high turbidity.

PHOTO 1-11. Dredging in Elliott Bay.

Agriculture

Constituents carried in the water draining from this Area's agricultural land could result in significant water quality degradation. The urban dwellers as well as the farmers of the Area use large amounts of petroleum products, fertilizing minerals, and toxic substances such as organic and inorganic insecticides and herbicides. If too high a concentration of these compounds reaches the watercourses, either by direct application, rainfall runoff, or irrigation runoff, a significant deterioration of water quality will occur. Careless handling or excessive applications may result in some of these materials being sprayed onto or dumped directly into streams, lakes, ponds, or underground water sources. No large-scale problems have occurred from the use of these materials in the Puget Sound Area. Most of the pesticides and fertilizers now applied have been classed as permissible and have been recommended by county, State, or Federal agricultural agencies.

Evidently some of Puget Sound's croplands receive fertilizers at rates much heavier than those normally used in other parts of the State. This is illustrated by the fact that the 3.1 percent of the State's farm land which is in the Puget Sound Area received 12 percent of the total fertilizer reportedly used in Washington in 1964. Even with such large amounts of fertilizer elements being applied, however, little is leached or washed away in the surface waters. The conditions peculiar to the Puget Sound Area tend to minimize the loss of fertilizer elements. The region's mild climate permits live, viable roots to abound in the soil even during winter. This tends to utilize all the available nitrogen and to prevent its being leached out of the soil. Additionally, little, if any, phosphorus or potash is leached out because Puget Sound's soils have a high iron content that tends to complex phosphorus and potash into insoluble compounds. Special phosphorus and potash fertilizers must be used to minimize this binding and to make usable forms of these elements available to plants.

Excessive irrigation can impair water quality by leaching minerals from the soil and flushing them into surface or ground waters. This seldom, if ever, occurs in Puget Sound, however. Here the amount of water applied per acre amounts to 35 percent, or less, of the 35 to 50 inches of average annual precipitation that falls on most of the lowlands. This means that the relatively easily dissolved constituents have already been removed. Sprinkler irrigation is the usual means of applying water here, and it rarely, if ever, results in surface wash or even in measurable leaching of the soil.

Farm animals, whether fed in concentrated lots or grazed loosely on pastures or ranges, produce large amounts of waste. It has been estimated that the waste produced by one cow is equivalent to that produced by about 6.4 persons. Most of this waste produced in Puget Sound remains on the land, but rain and irrigation waters flush part of it into streams and ponds. Dairies, feedlots, and other animal concentrations along streams cause accelerated erosion as well as intensifying the potential coliform bacteria, nutrients and biochemical oxygen demand in the water.

Navigation

Commercial vessels are a major source of unquantified pollution in marine waters. While at dock, these ships discharge raw domestic waste directly into the harbor waters. For a naval vessel at Bremerton, this may amount to a wasteload equivalent to a town of 3,000 people. Other waste from ships are the accidental oil spills and bilge waters pumped while in transit which contain oil and other petroleum products. These create the oil slicks on the Sound which ultimately gather on the beaches.

Forests

More than three-quarters of the fresh-water runoff in Puget Sound originates in forested watersheds. Thus, any activity in these forests will influence, to some extent, the quality of these surface waters.

Timber harvesting is the primary activity in the forests, along with its road construction requirement. The Area clear-cut per year averages about 900 square miles. Forest management practices at the present time range from total land clearing through careful, intensive, sustained-yield management to a closed, no-cut policy on sensitive areas or those set aside for certain specified uses.

Major effects on water quality of clear-cut timber harvesting may be accelerated erosion with consequent siltation and sediment transport and increased summer stream temperatures. A tenuous balance exists between the vegetative cover and the soil of this geologically young, steep, well-watered forest area. The "normal" or geologic rate of erosion can be greatly accelerated by upsetting the vegetation-soil balance. Acceleration of the erosion rate increases the amount of soil lost, the turbidity of the transporting water, and the amount of sedimentation in stream, pond, or ocean.

There is no specific data which describes the effects of past or present logging practices. Logging has increased sediment to some unquantified extent. Well-controlled logging can be conducted with a minimum damage, but careless operations can result in increased sediment loading. Studies indicate minimal siltation in those areas where proper road construction and logging practices are followed. Test watersheds recently established by the Forest Service have, as one of their objectives, the measurement of water quality resulting from various forest practices.

Sometimes intensive forest management may call for the application of pesticides or fertilizers on either the publicly or privately-owned forest land. This introduces the potential for dangerous pollutants to enter the rivers and streams. However, little, if any, pesticides have been applied to the forests in the Area. Recent research shows that many economic chemicals introduced into the forest environment have little or no adverse effect on water quality if they are carefully applied.[1]

A growing activity in the forests is recreation, which is discussed in the recreation section.

Mining

Uncontrolled mining, gravel washing, and ore processing can render a stream unfit for most water uses. The pollutional substances which are likely to enter streams from these operations are: silt, color, minerals, acids, and other chemicals.

At the present time, the mining of heavy metals is limited in the Puget Sound Area. Economic conditions have caused most of the existing mines to be closed. There are several areas where limestone is mined for use in pulp mills or in the manufacture of cement, but no water quality problems have arisen from this activity. Coal is being mined to a limited extent in two locations in the Puget Sound Area. Many other large deposits exist, but the market does not justify the mining of these deposits. Although there has been some water pollution in the past from coal mining operations, these have been eliminated.

[1] Forest Service.

Water pollution can result intermittently from incorrect mining practices by the sand and gravel industry. There are some 55 separate locations under permit from the Washington Water Pollution Control Commission. In addition to these permanent locations, there are 31 other operators who are under special permit for portable operations. These portable plants may be set up almost anywhere in the Area for a day or a month. No data are available as to their operations except that they are required to notify the WWPCC any time they set up a wet operation.

Recreation

Recreation is rapidly expanding in ever-increasing forms. The dimensions of this growth are sketched in the following chapter on water uses.

Recreation is also growing into a major waste source. Increasing numbers of recreationists are participating in outdoor activities at National Parks and Forests, at saltwater beaches, and along the lakes and streams. The major impact of these recreational activities is bacterial contamination of both the fresh and saltwater areas. In mountain streams and lakes, recreational activities can introduce nutrients into the waters. Organic oxygen demand is another secondary factor here. Pleasure boats spill oil and gas as well as discharge human wastes. In some areas, accumulation of rubbish and garbage in streams, lakes, and bays creates both maintenance and pollution problems.

Water quality problems caused by recreation activities are isolated and scattered throughout the Area. Several recreation home developments around small lakes in the West Sound Basins have been halted because of inadequate waste handling facilities. Wastes from boaters periodically concentrate in bays in the San Juan Islands and West Sound.

Impoundments

The impoundment of a free flowing stream modifies the physical and chemical properties of the water. These changes may be either beneficial or detrimental to the water quality in the reservoir, and reservoir releases may similarly have either beneficial or detrimental effects on downstream water quality.

Beneficial effects include the entrapment of sediment where it is settled out and retained in the reservoir. Thermal stratification in larger reservoirs provides storage of cool waters at depth. Multi-level outlets then allow the release of selected cooler waters during the summer to reduce natural stream temperature.

Adverse effects include the depletion of dissolved oxygen concentrations in the bottom layers. Releases of this water to the streams depress the oxygen levels. If the sediment trapped during the flood runoff season is sluiced out by reservoir operation procedures in the fall, this creates excessively high sediment loads in the downstream reaches. Stimulation of algal growth is another problem that often occurs in reservoirs. This results in nuisance taste and odor conditions and affects dissolved oxygen concentrations.

Few effects on water quality have been documented for the 24 major reservoirs in the Area. Ross Dam has little effect on the temperature regime of the downstream reaches of the Skagit River. Probably the most significant adverse effect has been on the White River tributary to the Puyallup. Mud Mountain Dam is operated as a single-purpose flood control structure, storing the winter and spring floods which carry substantial suspended material from upstream glaciers. To prevent a build-up of this material in the reservoir, it is flushed out each fall. This introduces a large slug of sediment to the White River during the lowflow period, seriously degrading the water quality. This operation procedure is undergoing review to find a means which will achieve the same results without the severe impact to water quality.

Lake Whatcom receives inflows diverted from the Middle Fork of the Nooksack River which contain large sediment loads of glacial origin. There has been no noticeable effect upon the lake from suspended material, but study is continuing to discern any adverse trend that may develop.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Water quality problems in the Puget Sound Area are most critical in the bays, harbors, and estuaries. These waters are located near the major population and industrial centers and are the most susceptible to man-caused pollution.

Degradation of water quality is related to the volumes of municipal and industrial wastes produced in these areas, as well as the wastes produced from

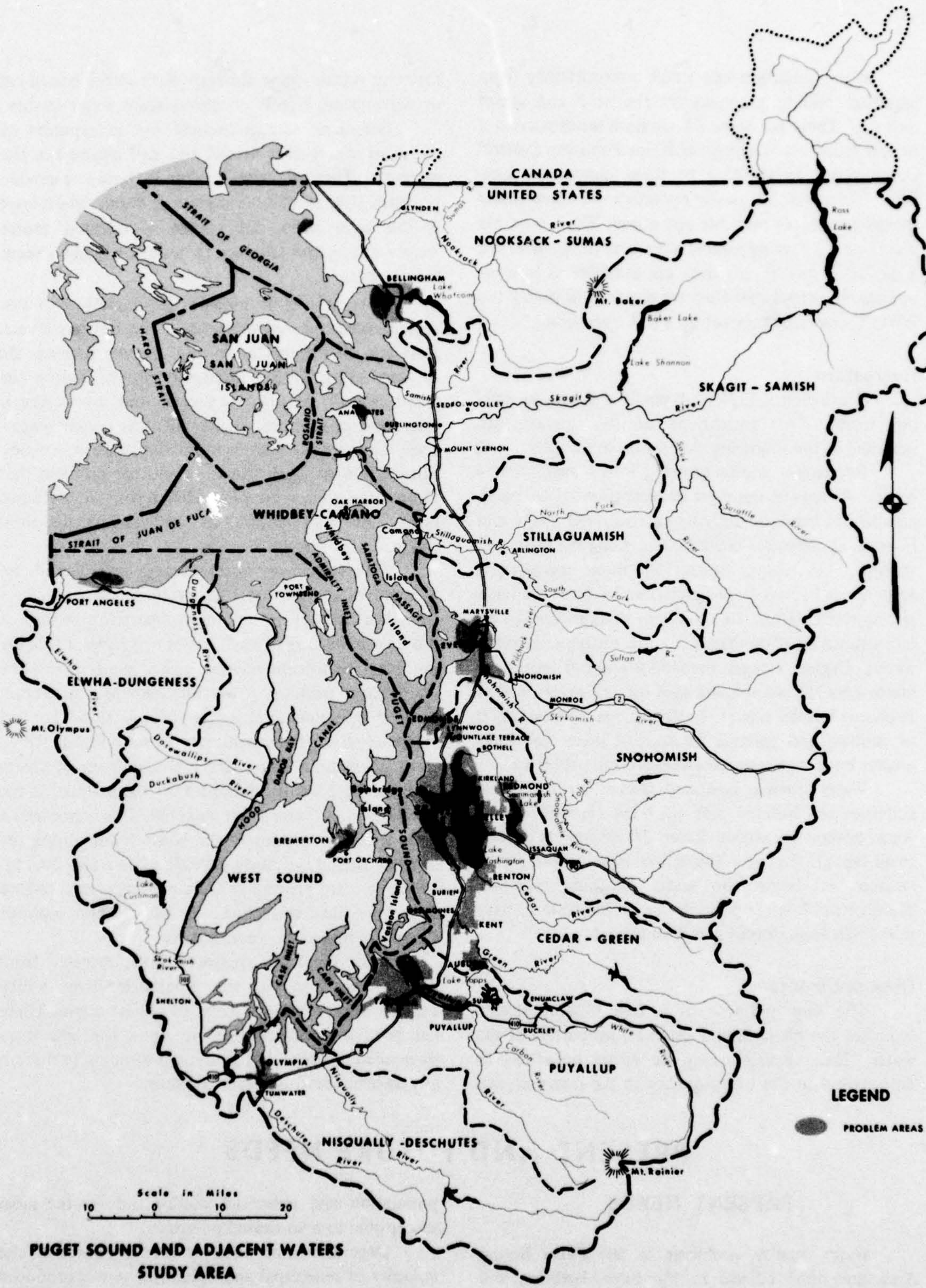


FIGURE 1-16. Major water quality problem areas.

such other sources as agricultural activities, navigation (including oil spills), recreation, and sand and gravel.

While not as clearly defined as the point source loads from the major pulp and paper and food processing plants, wastes contributed by recreation activities also contribute to water quality degradation. Wastes produced by watercraft are presently discharged without treatment. While certain areas are not affected to a great degree, other locations known for recreational boating opportunities, such as the San Juan Islands, are threatened to a greater degree.

Oil pollution caused by accidental spills and illegal discharges to both fresh and marine waters is a significant problem. Since December of 1966, more than 30 oil spills have been documented within the Puget Sound Area. Lack of shore facilities for collection of oil-containing wastes and adequate disposal methods has contributed to the problem.

Untreated or inadequately treated municipal and industrial wastes have created substandard water quality conditions primarily in four bays in Puget Sound. These are Bellingham, Port Gardner, Commencement, and Port Angeles Bays. The effects of these waste discharges are high bacterial concentrations, low dissolved oxygen, toxic levels of SWL in some areas, extensive sludge beds, and low aesthetic levels. These conditions have limited recreation uses and damaged immature forms of indigenous fish and shellfish.

Waste discharges from unintercepted municipal and industrial outfalls have created conditions of substandard water quality in Elliott Bay. Most water quality standards–those for bacteria, dissolved oxygen, toxic substances, and aesthetics–are not being met in these waters.

In addition to the above-mentioned locations, needs for improved water quality also exist on several river reaches in the Area. Most of these reaches are in downstream locations near the urban concentrations. Water quality problems exist on the lower Snohomish, Duwamish, and Puyallup Rivers and on Chambers Creek. The needs on the lower Snohomish River and Chambers Creek stem largely from the discharged wastes of pulp and paper operations. The Duwamish River, lined with industrial establishments–slaughter houses to ship yards–receives considerable amounts of wastes and presently does not meet the established water quality standards. Municipal discharges are the primary cause of degraded water quality on the Puyallup River.

Needs for water quality control may also be found on several lakes of the Area. Most prominent are Lake Washington, Lake Sammamish and Lake Whatcom. High nutrient concentrations have been responsible for considerable algal activity in Lake Washington which has contributed to water quality degradation. Since the establishment of METRO, water quality of the lake has improved. All municipal waste discharges, with the exception of storm overflows, have now been removed from the lake. Storm water runoff, however, is a factor in the control of the lake's water quality. In addition, wastes produced on board watercraft presently do not receive treatment prior to discharge to lake waters.

Green Lake and Lake Sammamish also exhibit signs of the eutrophication or aging process. Green Lake has to be flushed with considerable amounts of fresh water from the city supply to control water quality. Lake Sammamish is in the early stages of eutrophication. Residential build-up along the shores coupled with upstream waste discharges have resulted in conditions similar to those found in Lake Washington in the early 1950's. METRO has since intercepted the upstream waste discharges. Other lakes of the Area, such as American Lake, Lake Steilacoom, Lake Tapps, and Lake Whatcom near where substantial residential growth is now taking place, are also threatened with eutrophication.

FUTURE NEEDS

Future water quality in the Puget Sound Area will be affected by several economic factors–population growth, industrial expansion, agricultural production, and outdoor recreation. As this growth occurs, the production of wastes will likewise increase. Looking ahead to 1980 and beyond to 2000 and 2020, these factors provide the primary source for: (1) projecting the quantity and location of wastes, and (2) determining the means to preserve water quality and to protect the water uses of any given watercourse. The following discussion regarding the economics of the Area is based upon information contained in Appendix IV, Economic Environment:

A period of extraordinary growth lies ahead for the Puget Sound Area. This growth will be driven along by the aerospace industry, but the economic base is far broader (see Table 1-14).

Figure 1-17 shows the population growth trend for the Area. Population in the Puget Sound Area is projected to be 2.7 million persons by 1980, exploding to 6.8 million by the year 2020. It is expected that population growth in the Seattle-Tacoma-Everett area will run far ahead of other areas, accounting for 1.6 million persons by 1980, or 58 percent of the Area's total population. Table 1-13 shows the population projection for the Area and for the basins.

It is easy to see from Table 1-13 that the greatest growth will occur in the central part, namely in the Cedar-Green, Puyallup, Snohomish, and West Sound Basins. By 1980, these four basins will be home for some 2.4 million people and will account for 88 percent of the Area's total populace. Present trends point to a continued concentration of population in these areas. The Seattle-Tacoma-Everett complex will grow into a Pugetopolis by 2020, with over five million people and a solid development of intensive land use from north of Everett to south of Tacoma.

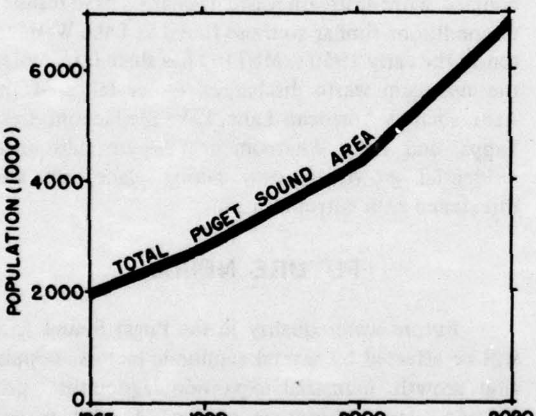


FIGURE 1-17. Projected population growth for the Puget Sound Area.

Future economic growth to 1980 includes a number of highlights. Employment will approach one million jobs as shown on Table 1-14. Gross Regional Product will almost double to 11.4 billion expressed in 1963 dollars. Gross Regional Product per person will be up some 34 percent over the 17-year period.

Even a casual inspection of Figure 1-18 which summarizes the value added by the large water-using industries to the Gross Regional Product indicates a substantial growth in those industries expected to have a major impact on water quality in the region. Production growth for the major water-using industries is expected to realize an 82 percent increase from 1965 to 1980 in terms of value added. Food and kindred products, paper and allied products, and primary metals are projected to lead this growth. Relatively large increases are also projected for chemicals and petroleum industries. On the declining growth side is the lumber and wood products industry.

TABLE 1-13. Population projections by river basins (in thousands), Puget Sound Area

Basins	1963	1980	2000	2020
Nooksack-Sumas	74.6	91.6	123.5	168.7
Skagit-Samish	53.8	64.2	86.5	118.2
Stillaguamish	17.6	30.2	48.5	77.8
Snohomish	178.2	302.7	485.8	780.3
Cedar-Green	976.9	1,479.0	2,375.7	3,816.3
Puyallup	324.5	449.8	721.0	1,157.7
Nisqually-Deschutes	69.6	74.9	104.5	146.5
West Sound	124.2	175.0	274.1	432.7
Elwha-Dungeness	28.3	29.8	41.0	56.6
Whidbey-Camano Islands	19.9	26.9	36.2	49.5
San Juan Islands	2.6	2.8	3.7	5.1
Regional Totals	1,870.0	2,726.9	4,300.5	6,809.4

Source: Appendix IV.

Recreation and tourism will become very important economic activities. By 1980, over 109 million recreation days are forecast for Puget Sound—almost double the 1960 estimate. Water-related activities are expected to account for over 45 percent of this total outdoor recreation demand in 1980. Intense recreation is expected to occur in the Cedar-Green, Snohomish, West Sound, and Puyallup Basins. These four basins will account for about 63 percent of the total outdoor recreation demand estimated for 1980.

Significant changes are predicted for the Area's agricultural economy. Farm land is expected to decrease 23 percent between 1963 and 1980, and to decrease 56 percent by 2020. The number of farms will also be reduced 40 percent by 1980 and 66 percent by 2020. Future declines in the amount of farm land will be associated with urban-population growth and industrial expansion. Agriculture will have its greatest decline in the central part of the Area where over 30,000 acres are expected to be converted to urban uses by the year 2020. The northern part will contain the major share of farm land.

TABLE 1-14. Present and projected output, value added, and employment by industry, Puget Sound Area

Industry	1963 Output[1]	1963 Value Added[2]	1963 Employment	1980 Output[1]	1980 Value Added[2]	1980 Employment	2000 Output[1]	2000 Value Added[2]	2000 Employment	2020 Output[2]	2020 Value Added[2]	2020 Employment
Agriculture, fish, forests, mining	196.7	99.5	23,700	261.1	139.0	18,200	360.0	190.0	13,500	[illegible]	268.0	11,000
Food and kindred products	698.5	223.3	15,900	1,240.9	405.3	19,500	2,333.4	900.2	22,900	4,088.7	1,906.6	25,600
Lumber and wood products[3]	413.7	174.6	19,700	371.3	154.6	17,000	305.5	146.0	14,700	234.2	136.0	12,600
Paper and allied products	349.2	168.1	9,400	683.1	334.9	10,300	1,009.4	561.0	10,900	1,101.5	705.1	9,300
Chemicals	70.4	33.9	2,300	138.6	68.4	1,900	287.0	170.4	1,400	553.7	420.2	1,000
Petroleum refining	255.9	61.5	1,200	511.8	123.0	1,300	1,080.2	301.4	1,400	2,124.7	729.1	1,300
Stone, clay, glass	92.4	37.9	3,800	172.5	71.1	5,000	337.1	161.2	6,500	614.0	361.1	8,000
Primary metals	118.8	53.6	4,100	518.6	216.7	7,300	885.3	392.1	8,700	1,408.5	699.8	9,900
Other non-durable manufacturers	168.7	92.0	15,100	344.3	187.6	19,700	740.8	468.6	25,200	1,485.6	1,555.8	30,900
Other durable manufacturers	1,815.9	959.6	86,200	5,460.7	2,408.6	175,700	18,707.1	7,707.4	380,700	58,086.5	24,349.1	787,400
Transportation	615.6	461.1	40,200	1,192.8	894.6	36,200	2,422.7	1,990.8	29,700	4,585.6	4,373.5	23,300
Wholesale and retail trade	1,250.3	1,011.3	140,000	2,269.4	1,835.4	202,600	4,267.4	4,006.3	292,300	7,477.7	8,634.1	402,400
Services	1,149.5	842.2	144,000	2,185.9	1,604.5	230,100	4,356.0	3,711.8	388,800	8,088.8	8,477.0	627,300
Construction	673.8	277.0	41,200	1,359.7	558.8	54,500	2,869.9	1,395.9	70,500	5,644.7	3,442.6	87,200
Government	--	734.0	115,800	--	1,565.1	178,100	--	4,140.9	275,100	--	10,816.5	405,800
Consumption	--	600.8	--	--	790.8	--	--	1,191.6	--	--	1,773.0	--
TOTAL	7,869.4	5,830.4	662,600	16,710.7	11,358.4	977,400	39,961.8	27,435.6	1,542,300	96,010.2	68,247.5	2,443,100

1 Output: Except for those industries where "margin" entries are used, this is equivalent to sales. Expressed in millions of dollars.

2 Value Added: A firm's sales less the purchase of goods and services from other firms. It is equivalent to the firm's contributions to gross regional product. Expressed in millions of dollars.

3 Includes employment generated by exports.

Note: Figures may not add to totals due to rounding.

Source: Appendix IV—employment data for lumber and wood products and paper and allied products obtained from U.S. Forest Service.

The proportion of farm land used either for crops or for pasture will increase substantially. A few major commodities account for most of farm output. Projections of the major farm products to 1980 show the following changes: production of vegetables will increase 80 percent; berries, 52 percent; boilers, 47 percent; eggs, 40 percent; and milk, 27 percent. Total value of crop and livestock production is projected to increase from $128 million in 1963 to $165 million in 1980 and to $274 million by 2020.

In terms of percentages, the northern part of the Area is projected to show the largest increase in economic activity through 1980. Aluminum, petroleum refining, and university and research facilities will lead the way, especially in the Nooksack Basin and the Skagit Basin. The pulp and paper industry and the wood products industry will also expand. Since most of these industries require water access, development of additional deep-water port facilities is expected. Subdividing the San Juan Islands and the Whidbey-Camano Islands into summer houses and recreation lots will continue to be the main activity there. Recreation and tourism will provide the economic lift to these two island areas.

The present economic upsurge in the central part of the region is expected to continue, with the aerospace industry providing the explosive force in the future. The big growth "industries"–in the Cedar-Green, Snohomish, and Puyallup Basins–will be transportation equipment, construction, machinery trade, finance, insurance, real estate, and services. Noticeable declines in economic activities will be felt in lumber and wood products and in agriculture where the land will be converted to urban uses.

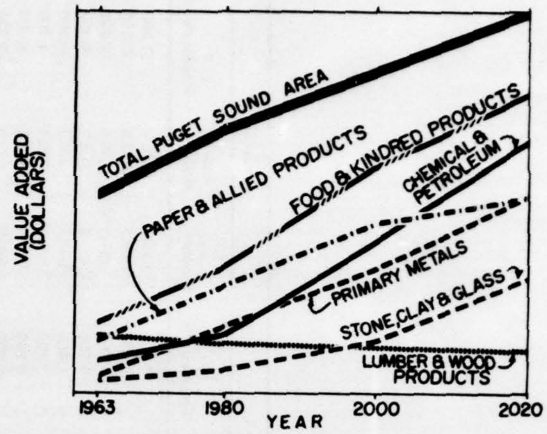


FIGURE 1-18. Relative growth for major water using industries in the Puget Sound Area.

Major growth strength in the western part of the region will be drawn from the pulp and paper products component of the forest products industry. But there will be a decline in the wood products-lumber industry. In both areas–West Sound Basins and the Elwha-Dungeness Basins–tourism and recreation will continue to expand.

Future population and economic growth will be greatest in and adjacent to the existing cities and towns of each of the basins. The extent of this growth through 1980 will shift, spill over, and vary from basin to basin. The greatest changes will occur

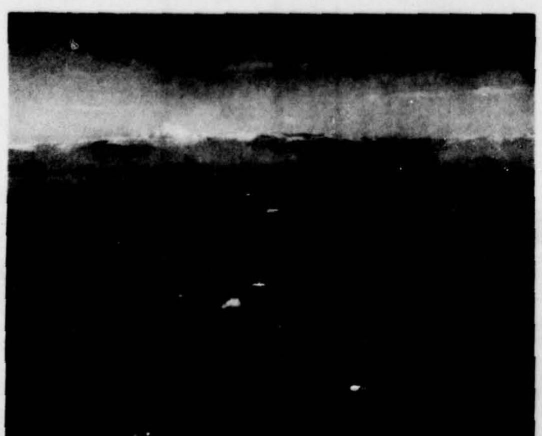


PHOTO 1-12. Future economic growth in the north is expected to come from increases in petroleum refining, aluminum, and education.

PHOTO 1-13. The aerospace industry is expected to continue to lead the economic "boom" in the central portion of the area.

in the Snohomish, Cedar-Green, and Puyallup River Basins.

In the northwest and southwest sectors of the Cedar-Green Basins a large amount of industrial activity is expected to take place. A major industrial corridor is expected to occupy the Green River Valley area between the city of Seattle and the King-Pierce county line. This industrial development will replace a large amount of agricultural land.

The boom period of growth in the Snohomish Basin will continue as a suburban area for the Seattle-Everett metropolitan area due to the development of the Boeing complex at Paine Field. Future development of industry is expected to occur in and around the Edmonds-Everett-Marysville area.

Present trends show that the Puyallup River Valley is destined to develop intensively from the mouth of the Puyallup River to the city of Puyallup. There is also a good possibility that the fertile agriculture lands between the cities of Puyallup and Orting may be developed intensively. Large spill overs of population from the Cedar-Green Basins will continue into the future.

In the Nooksack-Sumas and Skagit-Samish Basins, future development—both industrial and residential—is expected to take place along the shore of Puget Sound. Other new growth is expected along various locations bordering Interstate Highway 5.

The Stillaguamish Basin may become a distant suburb to the fast-growing Seattle-Tacoma-Everett area. There is a good possibility that this basin may receive a large spill over of population and intensive land uses from the developing Pugetopolis to the south.

Growth within the West Sound Basins is expected to continue in and around the various communities—principally Bremerton, Port Townsend, Shelton, and Port Orchard. If a cross-Sound bridge is constructed connecting the Seattle metropolitan area with Bainbridge Island and the Peninsula mainland, growth will be accelerated. This would serve to make the Peninsula area a suburb of Seattle.

New growth in the Elwha-Dungeness Basins through 1980 will occur primarily in and around Port Angeles and Sequim, with some small scatterings along the Strait of Juan de Fuca.

The outer perimeter of the San Juan Islands will continue to be subdivided into summer homes and recreation lots. A good percentage of the part-time residential development on Whidbey and Camano Islands will become permanent residents. This will be the result of residential spill over from the Seattle-Everett metropolitan area. The construction of a bridge from Whidbey to the mainland is expected to accelerate the residential development of these islands.

Generally speaking, the waste projections presented graphically in Figure 1-19 are a result of the close relationship between unit wasteloads and the projected economic conditions. These waste projections—indeed, all projections—are limited by the criteria used in their derivation but are, nevertheless, a necessary tool in future planning. The specific projections for each basin may prove to be in error due to the narrowing of the geographical area studied in relation to the broader, Area-wide outlook; the projection of all industrial growth in present locations; and lack of projections of new waste producing industries. The summary of Area-wide totals, however, can be expected to minimize this error and to provide generally usable figures for future planning.

The present municipal, industrial, and recreational raw waste production of 16.4 million population equivalents (PE) is projected to grow to 28.2 million PE by the year 2020. Most of the increase will occur in the central area. By 2020, 57 percent of the total waste production is expected to be concentrated in the Everett-Seattle-Tacoma urban-industrial complex. Generally speaking, the bulk of the future waste production is expected to occur near marine waters since these areas are most heavily populated and industrialized at the present time. By 2020, about two-thirds of the total waste production will be located in the vicinity of marine waters.

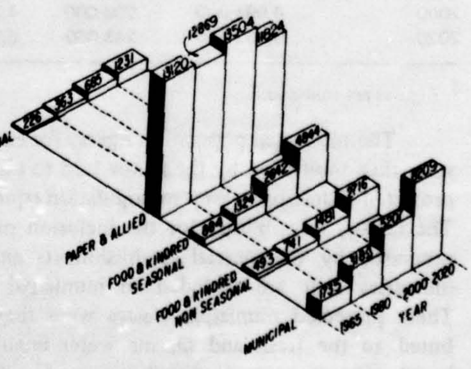


FIGURE 1-19. Projected municipal and industrial wastes for the Puget Sound Area (thousands of PE).

The overall future profile of the wastes will be somewhat different from the existing mix due to population, technological, and economic growth shifts. For instance, municipal wastes which presently account for about 8 percent of the total waste production will, by 2020, represent about 38 percent of the total. Likewise, industrial wastes, presently accounting for 90 percent of the total wastes, will then account for 57 percent. More specifically, the paper and allied industry which presently produces 80 percent of the total wastes is expected to diminish to 41 percent of the total by 2020. A more detailed discussion of municipal, industrial, and recreational wastes follows.

Municipal

Projected total basin populations as provided by the PS&AW Task Force were broken down into municipal and rural segments based on consideration of the present distribution for each basin. A basic assumption here was that the municipal portion of the population would account for an increasingly greater share of the total basin population–i.e., most future growth would occur in the already populated areas, leaving the rural segment with a declining rate of growth. The projected municipal populations were also assumed to be served completely by municipal sewerage systems by 1980. Table 1-15 presents the regional summary of this population breakdown.

TABLE 1-15. Projected population,[1] Puget Sound Area

	Municipal	Rural	Total
1980	2,547,000	181,000	2,728,000
2000	4,094,000	206,000	4,300,000
2020	6,567,000	243,000	6,810,000

[1] Figures are rounded.

The municipal population figures for each basin were then multiplied by the factor 1.25 to obtain the projected municipal wastes in population equivalents. The factor, 1.25, allows for the inclusion of wastes generated by commercial establishments and small industries that are included in municipal wastes. These projected municipal wastes were then distributed to the fresh and marine water environment based upon the present distribution and also on the expected future growth pattern for each basin. The projected municipal raw wastes summarized for the Area are presented in Table 1-16.

TABLE 1-16. Projected municipal wastes, Puget Sound Area

Year	Population Equivalents		
	Fresh	Marine	Total
1980	396,000	2,787,000	3,183,000
2000	601,000	4,606,000	5,207,000
2020	815,000	7,391,000	8,206,000

Municipal raw wastes are projected to increase greatly from 1965 to the year 2020. More than 70 percent of these wastes will be generated in the Everett, Seattle, and Tacoma area. Of the total projected municipal wastes, 90 percent are expected to be generated in the vicinity of marine waters.

As seen in Figure 1-19, the amount of municipal wastes to be dealt with in the Puget Sound Area is expected to double by 1980 and increase more than six-fold by 2020. Proper controls must be implemented to insure that the impact of these organic wasteloads will not intensify the problem areas or create new problem areas. Without adequate controls low dissolved oxygen conditions could occur in marine waters and in some streams and many areas could become bacterially contaminated for water-contact use.

Although the rural population projected for the Area is significant, this waste source is not considered to have any adverse water quality impact due to the extensive utilization of sub-surface waste disposal methods by rural households.

Industrial

Industrial organic wastes are projected to decline slightly from present levels and are projected to account for 57 percent of the total municipal and industrial waste production by the year 2020. About 38 percent of these industrial wastes will be generated in the Everett-Seattle-Tacoma service area. About 55 percent of the industrial wastes will be generated near marine waters.

Paper and Allied Products–Based upon the projected figures of value added for this industry, as presented in the Economic Appendix, growth factors were determined for the periods present to 1980, 1980 to 2000, and 2000 to 2020. From these, the future production levels for the Area's pulp and paper operations were projected. It was assumed that all additional pulp production over present levels would be of the sulfate (kraft) process. Based on projected product mix profiles as provided by the Northwest

Pulp and Paper Association, the total projected production was distributed accordingly. The present and projected pulp and paper production levels, based on value-added figures developed by the Puget Sound Task Force, are presented in Table 1-17.

TABLE 1-17. Present and projected production levels paper and allied products, Puget Sound Area

	Production–Tons/Day			
	Pulp			
Year	Sulfite	Kraft	Paper & Groundwood	Total[1]
1965	2,322	1,825	3,722	7,870
1980	2,480	4,985	9,020	16,500
2000	2,305	9,580	16,190	28,100
2020	1,740	12,520	21,020	35,300

[1] Figures are rounded.

Unit wasteloads established for the production processes were derived from Gaudy's 1957 work in Publication 17, California State Water Pollution Control Board. The projected raw unit wasteloads for the sulfite and kraft processes are shown in Table 1-18.

TABLE 1-18. Projected unit wasteloads, lbs. BOD/ton, Puget Sound Area

	Process		
Year	Sulfite	Kraft	Paper & Groundwood
1980	750	30	15
2000	750	25	15
2020	750	20	15

These unit wasteloads were then applied to the projected production levels to obtain the projected raw wasteloads as presented in Table 1-19.

TABLE 1-19. Projected raw wastes[1] paper and allied products, Puget Sound Area

Year	Sulfite	Kraft	Paper & Groundwood	Total
1980	11,160,000	896,000	813,000	12,868,000
2000	10,373,000	1,438,000	1,458,000	12,270,000
2020	7,830,000	1,503,000	1,891,000	11,224,000

[1] Expressed in population equivalents.

The paper and allied industry, located almost entirely on marine waters, will continue to be the major producer of organic waste. The amount of paper and allied wastes produced, as shown in Figure 1-19, will remain at about present levels through 2020. These wasteloads adequately handled, will maintain water quality standards conditions.

Food and Kindred Products–Food processing will also be a major source of organic wastes in future years. Wastes produced by this industry will amount to about 40 percent of the total industrial waste production by 2020, increasing to 7.6 million PE or nearly 5.5 times present levels of waste production.

Unless properly treated, these wastes could contribute further to the degradation of streams and marine waterways. Wastes from most food processing industries are strong in terms of BOD and suspended solids.

Food processing wastes produced by seasonal operations will be about twice as great as those produced in non-seasonal operations. Approximately 18 percent of the seasonal wastes and 55 percent of the non-seasonal wastes are projected to be produced near the marine waters of the Area by 2020.

Utilizing growth index figures obtained from the food processing industry, projected levels of value added for production are 175 percent, 365 percent, and 775 percent of present levels by the years 1980, 2000, and 2020, respectively. To allow for expected increased processing efficiencies and greater utilization of the input materials, future waste production has been projected as 150 percent, 300 percent, and 550 percent of present levels by the years 1980, 2000, and 2020, respectively. Projected wastes were then distributed to seasonal and non-seasonal categories and to production in the vicinity of fresh waters and marine waters using currently existing ratios. The projected food and kindred products wastes are summarized in Table 1-20.

Other Industries–The lumber and wood products industries are contributors of sludge, organics, and heat. Sand and gravel operations may impart heavy turbidities to the receiving waters. The chemical and petroleum industries produce primarily synthetic, organic, and inorganic chemical wastes toxic to aquatic life. These will require special treatment facilities and handling in order to maintain water quality.

Potential contributors of oil pollution in the Puget Sound Area will be all facilities engaged in the production, transportation, handling, and use of

TABLE 1-20. Summary of projected wastes[1] food and kindred products, Puget Sound Area

Year	Non-Seasonal		Seasonal		Total	
	Fresh	Marine	Fresh	Marine	Fresh	Marine
1980	331,000	410,000	1,084,000	240,000	1,415,000	650,000
2000	662,000	790,000	2,169,000	474,000	2,831,000	1,264,000
2020	1,214,000	1,502,000	3,976,000	868,000	5,190,000	2,370,000

[1] Population equivalents.

oil–ships, oil-loading points, refineries, garages, and industries. The primary source of oil pollution is the discharge from vessels of oil-contaminated ballast and bilge. Accidental oil spills are also of importance. These discharges can damage beaches and wildlife; foul boats, fishing gear, quays; create fire hazards in harbors and other enclosed areas; and damage marine flora and fauna.

The ship repair activities at the Bremerton Naval Shipyard are expected to increase at a steady rate. The number of nuclear powered ships will expand substantially, introducing the potential problem of radioactive waste disposal to that area. This, plus increases in metal processing wastes and ship domestic and bilge wastes, will be the future wasteloads to be handled.

Control of waste heat produced by thermal nuclear power plants will be important in the maintenance of adequate water quality. For the potential sites located on marine waters, it is presumed that waste heat may be dissipated directly to Puget Sound. For all proposed power plant locations, however, special studies will be required to determine treatment or controls necessary for protection of temperature in receiving waters. The future development of nuclear power plants represents a considerable growth, creating a great potential threat to water quality–particularly to the ecological balance of Puget Sound waters. Sites located on fresh waters will require adequate facilities for proper control of waste heat discharges for prevention of adverse quality and ecological effects on the rivers.

Recreation

Wastes generated by recreational activities are projected to increase to 1,230,000 PE by 2020–more than six times present levels. These wastes, however, will account for only 5.7 percent of the total wastes in the Area. About 70 percent of these wastes are projected to be generated on fresh waters and the remaining 30 percent on marine waters.

Wastes generated by recreation activities were based primarily on projections of water-related and non-water-related recreation days. Consideration was given to their seasonal distribution, the percentages of both the water-related and non-water-related recreation days requiring treatment facilities, and natural features of each basin affecting the location potential for the assumed facilities. In the determination of wastes, one recreation day was assumed to equal one population equivalent. The projected raw wastes summarized for the Area are shown in Table 1-21.

TABLE 1-21. Summary of projected recreation wastes[1], Puget Sound Area

Year	Recreation Wastes, PE		
	Fresh	Marine	Total
1980	244,000	119,000	363,000
2000	461,000	225,000	686,000
2020	842,000	388,000	1,230,000

[1] Figures are rounded.

Agriculture

Livestock handling poses a future threat to water quality. The potential of this problem may be glimpsed from the fact that the cattle and calves in the Puget Sound Area have been estimated to number nearly one-half million, which would be equated to over three million PE generated daily. A study now being established on the dairy herd located on Washington State's honor farm near Monroe, Washington, should provide considerable specific information on the dairy cattle waste problem and means of control.

Runoff from feedlots and stockyards would pose a health problem, as well as a possible depletion of oxygen in receiving waters. Since these wastes are very high in nitrogen and phosphorus, they would also cause heavy nuisance algal growths if not properly diluted or adequately treated.

MEANS TO SATISFY NEEDS

Most of the present and future needs in Puget Sound will be met if adequate waste treatment facilities required in the present and proposed quality standards are installed at all municipal, industrial, and recreational areas. This will reduce the amount of residual wastes entering fresh and marine waters to levels within their assimilative capability. It will also require substantial new waste treatment construction in the near future, especially by the pulp and paper industry. Ports will need to provide hookup facilities for commercial vessels, and recreation sites will have to have adequate facilities for people and recreation watercraft.

It is possible that streamflow will be inadequate in future years in the Cedar and Green Rivers. A potential conflict exists on the Cedar River between future municipal water supply diversions and the need for flushing inflows to Lake Washington. A detailed study and development of information systems including computer models, however, should be undertaken to determine flows required for this purpose and potential sources of supply. Increased future diversions from the Green River by the city of Tacoma may also conflict with required flows for water quality control in the Green-Duwamish River.

Surveillance of water quality is a critical action for the estuaries and marine waters. A framework of recommended elements of this program is outlined and cost elements developed.

Ultimately, the achievement and preservation of good water quality is based upon people operating within the context of a political, social, and economic system. The attainment of adequate water quality in Puget Sound will require an efficient, adequately staffed and funded water quality management system geared for attacking the water pollution problem.

These broad elements and costs of the water quality plan are described in more detail below. Plans specific to each basin are presented in the basin chapters.

The water quality control system in Puget Sound is based upon two broad principles. These are: (1) control of wastes at the source, provision of the required waste treatment facilities before discharging effluent to a watercourse and (2) attack of problems that remain after installation of adequate treatment effectively and efficiently. The system of waste collection and treatment facilities required for presently-known and projected discrete waste sources was first established. The costs of acquiring these facilities were also estimated. Then the treated waste discharges to the watercourses were estimated to determine flow requirements for assimilation of these residual waste loadings. Finally, the general support requirements needed to measure and solve the remaining problems were outlined. These include the water quality monitoring system, management system, and research.

The plans presented here are generally for recommendations which apply to several or all basins. The plans involve recommendations for construction of new facilities as well as increased programs for management agencies. They are intended to provide a guide for further study or action. For example, a general outline of immediately required municipal treatment facilities is given for each basin, but the reader must go to the Washington State Water Quality Standards Implementation Plan for the specific list under each watercourse. Wherever possible, the agency responsible or best suited to carry out the recommendations is identified.

Water control and management must be implemented by a systems approach so as to relate agencies and their requirements to needs. A close, formal interrelationship is needed between all levels of government in the area tied in with a good communication system which would facilitate rapid and unified decision-making on serious problems as they evolve.

As established in the previous chapter, the marine waters are and will be the most important water quality problem area. The Task Force emphasis, however, has been on the fresh-water resources. The net result is that only a portion of these plans is effectively integrated into the Puget Sound Water Resources Plan. It is unfortunate that the overall study does not extend broadly enough, but it was necessary to emphasize marine waters here to bring the future of water quality in the Sound into perspective, since so many of the uses developed—such as fisheries, recreation, and future power generation—are basic to these waters.

One of the main inputs to the formulated plans of the Task Force is the projected flow requirements for various major streams needed to maintain adequate quality for all legitimate present and future stream uses. It must be remembered, however, that these have been determined for conditions of adequate waste treatment facilities and operation which should prevail through implementation of the water quality standards.

To provide a base for the planned waste handling facilities systems, as detailed in the basin chapters of this appendix, certain basic assumptions were made, such as—all wastes would be diverted out of the lake basins or advanced waste treatment for nutrient removal to prevent excessive algal growths along with the concomitant water deterioration.

The general approach was to assume that water quality levels and controls acceptable and achievable today, under the Interstate and Coastal Waters Standards, would persist into the future.

WASTE TREATMENT

Adequate waste collection and treatment facilities are the primary means for achieving desired water quality objectives in the Puget Sound Area. Although other elements are also necessary, installation of adequate waste treatment facilities is considered a prerequisite. The approved State-Federal Water Quality Standards have set the levels of waste treatment upgrading, modification or expansion and other controls for municipalities and industries located on interstate and estuarial waters. The purpose of the Implementation and Enforcement Plan is the achievement of the water quality criteria and classification objectives. All activities which discharge wastes into the waters or affect water quality must provide all known available and reasonable methods of treatment and control. For these locations, referred to in the implementation plan, in the Puget Sound Area the general policy regarding waste treatment was that the proposed Interstate and Coastal Waters Standards would require secondary treatment unless it could be shown that a lesser degree of treatment could be utilized without violation of the standards. With approval of the Interstate and Coastal Waters Standards by the Secretary, Department of the Interior, exceptions have been made to allow primary treatment with adequate outfalls and disposal area evaluations for plants at several cities, including these major cities of Seattle, Tacoma, Port Angeles, and Anacortes, with the provision that additional treatment would be required if water quality standards were violated.

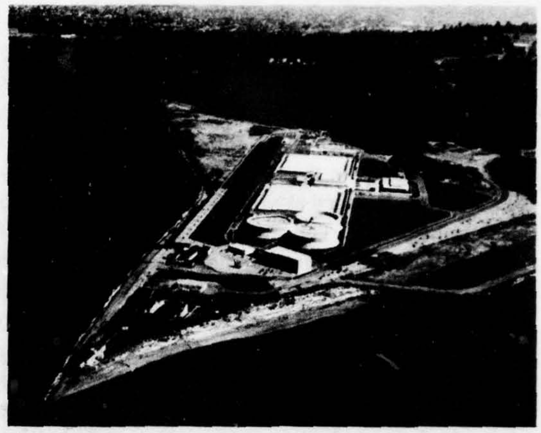


PHOTO 1-14. The key to attaining desired water quality in the future is adequate waste collection and treatment facilities.

Municipalities or industries planning to construct a new outfall on a watercourse will be required to conduct adequate outfall and dispersion studies to ascertain if their waste discharge will be able to meet the existing Water Quality Standards as set forth in the Implementation and Enforcement Plan, for Interstate, 1967, and Intrastate Waters, (Proposed) 1969, of the State of Washington. This study will also reflect the type and extent of treatment necessary to protect the existing water quality. The Plan calls for secondary treatment for all waste discharges. However, if the receiving watercourse is marine water and the outfall and dispersion studies indicate primary treatment, an adequate deep-water outfall will protect the water quality, and secondary treatment will not be required by the Commission.

In order to maintain a healthful environment and to provide adequate disinfection commensurate with legitimate water uses and established water quality criteria, the (proposed) policy to be used in the design, operation, and control of disinfection facilities is that all liquid wastes which are, or may be associated with the spread of waterborne disease, shall be disinfected with chlorine or by other approved methods.

Efficiency of Disinfection—In general, investigations by State agencies have found that the effluent coliform counts are influenced most by chlorine dosage rate and contact time. Field investigations have indicated that the coliform count in chlorinated sewage effluent was much higher than previously suspected. Substantial numbers of coliform organisms may be present with chlorine residuals as high as 2.0 mg/1, which could result in pathogenic organisms entering the receiving stream. The presence of such organisms in chlorinated sewage effluent constitutes a potential health hazard.

Adequate disinfection proposes a treated effluent with a median value of total coliform organisms of 1000/100 ml or less, with no more than 10% of the samples exceeding 2400/100 ml for secondary treatment, or a median value of 2400/100 ml or less, with no more than 10% of the samples exceeding 10,000/100 ml for primary treatment. In no case shall the disinfected effluent cause the degradation of the receiving water quality below the criteria established for the waterway.

New facilities should have sufficient capacity to maintain 15 minutes of chlorine contact time at peak hourly flow or maximum rate of pumping in chambers, basins and outfalls. Existing plants whose disinfection facilities do not meet the above criteria should be upgraded.

The required waste collection and treatment facilities, described in the basin chapters from the standards, will be the major tool in attainment of adequate water quality (to desired levels). They do not, however, guarantee water quality improvement, but represent only the initial needed requirements. If additional requirements and actions become necessary to attain desired quality levels, the standards and implementation plan will have to be revised accordingly. In addition to these standards for marine and estuarial waters, the establishment of Interstate and Coastal Water Quality Standards for the fresh waters of the Area now being formulated will aid in quality attainment in these locations.

The separation of storm and sanitary sewers will become an increasingly important factor in reaching water quality goals. Antiquated combined systems, a definite source of wastes, will need separation. This is a costly, long-term program but one which will substantially aid in the sustained achievement of firm water quality levels. Seattle is presently embarking on such a program but these efforts will need to be extended throughout the Area.

The Bellingham, Everett, Seattle, and Tacoma service areas all have high priority requirements for waste collection and treatment facilities. Most of the requirements are geared to problems which are primarily concentrated in estuarial and bay areas. These locations have the greatest need in terms of present and potential water quality.

The Basin and Area plans were developed according to the following criteria which are:

1. After sufficient treatment, wastes would be conveyed and discharged to Puget Sound through adequate outfalls, wherever feasible.

2. Secondary treatment facilities would be required for waste sources discharging to fresh waters, based on the proposed Intrastate Water Quality Standards.

3. Primary treatment facilities would be adequate for most waste sources discharging to marine waters. This conforms with recent actions in regard to the water quality standards where adequate dispersion has been accepted as the basis for allowing exceptions to the requirement for secondary treatment throughout the State.

4. Industrial wastes suitably located and acceptable to a system were assumed to be intercepted by municipal treatment facilities. Lagoons were assumed as treatment for seasonal food processing wastes.

5. Municipal populations were projected to be completely sewered by 1980.

6. Secondary treatment and adequate outfalls would be required at all recreation areas.[1]

Treatment costs were estimated for present, 1980, 2000, and 2020 waste conditions. Waste treatment facilities were assumed to have an effective life of fifty years.

Waste treatment costs were divided into three categories: municipal, industrial, and recreational. Under the industrial treatment category, petroleum, food processing, pulp and paper, chemcial and aluminum refining treatment processes were each separately derived.

Present treatment construction costs were determined from information in the State Implementation Plan of the Water Quality Standards, and the State priority list from the Annual State Plan. These sources gave costs for many of the required facilities. Costs for facilities not estimated from these sources were estimated from curves derived by the Federal Water Pollution Control Administration (FWPCA). Municipal waste treatment facility cost curves were established from "A Compilation of Cost Information for Conventional and Advanced Wastewater Treat-

[1] The proposed Interstate and Coastal Water Quality Standards may require tertiary waste treatment facilities at lakes and their feeder streams and on all surface waters in the Olympic and Cascade Mountains above certain elevations.

ment Plants and Processes." Industrial waste treatment costs were derived primarily from the Industrial Waste Profiles, Volume III, "The Cost of Clean Water," U.S. Department of the Interior. Although organic waste projections were not determined for the chemical and petroleum industry, treatment costs were based on future growth projections for this industry and assumed facilities which included an API separator, an activated sludge unit, a sludge filtration and incinerating unit and outfall facilities.

Food and kindred products waste treatment costs were based on provision of a screening and lagoon system.

Pulp and paper waste treatment costs were based on a paper developed by the FWPCA for the Puget Sound Enforcement Project; the greater cost of which involve a recovery plant to destroy, by burning, the major part of the waste stream produced during the manufacture of sulfite pulp–spent sulfite liquor. The basic process (for a sodium base recovery plant) is as follows:

Spent sulfite liquor is pretreated by steam stripping to remove dissolved sulfur dioxide, neutralized with recycled sodium carbonate, a second steam stripping to remove carbon dioxide, and filtration. The pretreated liquor is then concentrated in a six effect evaporator and a direct contact cyclone evaporator. The concentrated liquor is then burned in a Kraft-type recovery furnace. Over 95 percent of the entering biological oxygen demand is destroyed. A Kraft-type smelt (a mixture of molten sodium sulfide and sodium carbonate) is removed from the bottom of the recovery furnace. This smelt is dissolved, clarified, treated with carbon dioxide to remove the sulfide fraction, and filtered. A blower furnishes stack gas to the carbon dioxide plant. The resulting sodium carbonate solution is used in part for manufacture of cooking acid and in part for the neutralization step previously mentioned. Carbon dioxide is obtained by absorbing recovery furnace stack gas.

The sulfide removed from the dissolved smelt is released in the form of hydrogen sulfide. The hydrogen sulfide is treated in a hydrogen sulfide reduction unit to release elemental sulfur which is returned to the pulp mill for cooking acid manufacture.

It was presumed that future technology would result in decreased treatment costs per unit of waste treated. This influence of technology on treatment costs was approximated by using the costs from the Industrial Waste Profiles of "The Cost of Clean Water" report, U.S. Department of Interior. For the three industries of petroleum, vegetable and fruit processing, and dairies, costs for biological treatment processing for the three levels of technology (1950, 1963, and 1967) presented in the report were plotted. A logarithmic decreasing unit treatment cost rate was then applied to the present costs of both municipal and industrial treatment. To derive approximate treatment costs for the year 2000, these reduced costs were then plotted to attain a modified treatment versus plan size cost curve for derivation of future treatment costs.

Costs and efficiencies of advanced waste treatment, processes, were not applied in the plans derivation although they will probably be utilized within the next thirty years.

Sewer construction costs were based upon cost curves developed in 1964 and indexed to October 1967 cost levels.

Residual wastes following treatment were computed using secondary treatment efficiencies of 85 percent for 1980 and 2000 and 90 percent for 2020. Primary treatment efficiencies were assumed to be 35 percent for 1980 and 2000, and 40 percent for 2020, to reflect more advanced equipment and processes.

The required investment for municipal, industrial, and recreational sewerage facilities in the Puget Sound Area is enormous. About $2,190,000,000[1] will need to be invested by 2020. Of this vast sum, about 80 percent will be spent for municipal facilities, 15 percent for industrial treatment, and the remaining 5 percent for waste treatment facilities for recreational wastes. The present and projected investment requirements for the Puget Sound Area are shown on Figure 1-20 and Table 1-22.

FIGURE 1-20. Required rates of waste treatment investment[1] for the Puget Sound Area to meet the standards for interstate waters.

Investment for municipal treatment and sewers[1] will total $176,000,000 by 1980, with an

[1] Costs are not amortized.

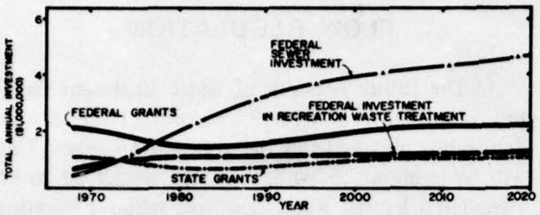


FIGURE 1-21. **Government investment requirements[1] for waste collection and treatment in the Puget Sound Area.**

additional $366,000,000 needed by 2000 and another $400,000,000 needed by 2020. About 75 percent of this money is projected to be needed for sewer construction.

Waste treatment for the paper and allied products industry accounts for about 80 percent of the present total investment required for industry.[1] By the year 2020 it will account for 70 percent of the total industrial investment requirement. Industries will need to spend $43,000,000 by 1980, an additional $43,000,000 by 2000, and another $80,000,000 by the year 2020.

An investment[1] of $13,000,000 is needed by 1980 for waste treatment facilities for recreational areas. An additional $52,000,000 is needed by 2020.

Sources of funding for treatment facilities are shown in Figure 1-21. The Federal Construction Grants program will need to provide a total of $21,000,000 by 1980 and an additional $34,000,000 by 2000, with another $40,000,000 by 2020. State funding requirements are projected to total $10,500,000 by 1980, $27,500,000 by 2000 and $47,500,000 by 2020. The Federal investment in sewer construction will total nearly $17,000,000 by 1980. An additional $67,000,000 will be needed by 2000 and another $84,000,000 by 2020. The Federal investment in recreation is expected to be $8,500,000 by 1980 with an additional $20,000,000 needed by 2000 and another $20,000,000 needed by 2020.

In addition to the requirements of collection and treatment of conventional waste sources, achievement and maintenance of adequate water quality in future years will involve dealing with other waste types not now playing a significant role in the impact on water quality.

Considerable future development of thermal power plants is expected for the Puget Sound Area. With this development, large amounts of waste heat will be generated which could cause serious water quality degradation without the application of adequate waste heat control methods. What to do with this waste heat is of primary concern to those charged with the maintenance and control of water quality. With the potential for thermal power plants being located on both the fresh and marine waters of the Puget Sound Area, control of waste heat may be accomplished by different means.

TABLE 1-22. Total amortized capital and operational costs—Puget Sound Area

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	88.9	40.2	33.9
Municipal treatment	99.5	99.9	44.4
Municipal sewers	483.4	512.6	217.1
Recreation	23.4	24.9	11.2
Advanced waste treatment	31.7	48.4	72.1
Sub-Total	726.9	726.0	358.7
Water quality engineering management and evaluation	13.0	12.8	14.9
Operation and maintenance	51.7	314.7	287.7
Total	791.6	1053.5	661.3

For those plants to be located on marine waters once-through cooling may be utilized with waste heat discharged directly to Puget Sound waters. However, this must be based on detailed studies for each proposed installation. It is difficult to predict the effects of this waste source on the marine waters. It is expected that effects on marine life in the immediate vicinity of the plants may be more pronounced. An adequate surveillance system tied in with oceanographic research will be an important key to the protection of the marine waters.

For those thermal power sites located on the fresh water streams of the Area, once-through cooling—direct discharge of waste heat to the stream—will not be possible in the control of water quality. Cooling towers or possibly lagoons will need to be employed to adequately reduce the amounts of waste heat discharged without violation of the established water quality standards.

A study designed to analyze all existing and

[1] Costs are not amortized.

potential thermal power sites which would present locational guidelines and requirements, and recommend those areas most suitable for development from the standpoint of water quality preservation.

A study is presently underway to determine if waste heat could be utilized for beneficial purposes, such as establishing and maintaining marine life not now suited to the cold waters of Puget Sound.

The control of oil pollution is now important to water quality and is expected to become even more important in the future. Control of the widespread pollutional source will involve finding an adequate, legal method of disposal coupled with an effective preventive-oriented oil pollution control program. Collection systems aboard ships and onshore collection and disposal facilities must be provided if the occurrence of oil pollution is to be prevented. Further control involves implementation of an efficient system for reporting and collecting accidental spills.

A plan should be developed for combating massive oil contamination in the event of a tanker accident in Puget Sound. It should be aimed at coping with accidents such as that of the Torrey Canyon off the British Coast. Such a disaster in Puget Sound could cause a serious economic and environmental loss to the Area. A task force should be formed to study operating procedures and all other information that would be needed to combat a major disaster of this nature.

Disposal of watercraft wastes–trash, garbage, debris, sewage, oil, and gasoline–directly to the waters without treatment, is presently a common practice. The control of such wastes will largely depend on legislation prohibiting the discharge of raw sewage, garbage, and trash or debris, by requiring these wastes to be retained in holding tanks for disposal on-shore or on the high seas. In addition to enabling legislation, more cooperation between governmental agencies, ship owners, boat designers, port authorities, private and public marina operators, and other responsible groups should be effected to expedite the required collection and treatment facilities or methods for servicing watercraft. Increased consideration should also be given to proposals for grants and contracts for studies in the Area of watercraft waste collection and disposal.

FLOW REGULATION

The future network of waste treatment facilities will remove at least 85 percent of the oxygen demanding wastes from the raw waste stream. This will leave about 15 percent of the wasteload to be assimilated by the water resources without lowering the level of water quality below standards. In addition, land drainage will contribute some wasteloads. Therefore, virtually all streams near the Sound require some flow to absorb the wastes expected to be discharged to them. In the future, with the heavy development of recreation in the headwaters of the basins creating residual wasteloads there, it will even be necessary to maintain adequate levels of flows in those presently remote areas.

Present streamflows during the summer low-flow period exceed flow requirements for waste assimilation in most rivers. The Green-Duwamish River, however, is completely regulated during summer months, and flow releases of 110 cfs for fish requirements are being made. Substantial quantities of effluent are expected from METRO's Renton secondary sewage treatment plant (projected to be 180 cfs by 2000, and 234 cfs by 2020). A study has been made by METRO of diverting the Renton plant effluent directly to Puget Sound. Cost estimates were prepared and METRO is committed to diversion of the treatment plant effluent if water quality conditions in the Duwamish River so dictate.

Lake Washington will continue to receive increasing loads of nutrients as urban build-up continues. The nutrients introduced from this source may provide the potential for increasing algal growth. In addition, lockages between Lake Washington and the Sound are projected to increase substantially. This will mean more chance of salinity intrusion into the lake. To handle both problems will require fresh water inflows to the lake. The Cedar River presently accounts for a major amount of low nutrient inflows. The city of Seattle projects increasing diversions from the Cedar River to meet municipal and industrial demands. Before any more diversions are made, an in-depth study of the entire Lake Washington system must be undertaken to establish flow requirements in combination with other elements of a comprehensive plan to preserve the lake's quality.

It should be noted that the flow requirements are ultimately based upon a presumed settlement pattern and assumed industrial development locations. These, as previously noted, were primarily extensions of the present patterns and would result in the minimum impact on the streams and rivers. Should extensive urban shifts to inland areas occur, such as along the Snoqualmie or Stillaguamish Rivers, the flow requirements would be markedly increased. Again, these contingencies were not investigated nor built into the plans. The recommended minimum flow requirements do present a reasonable approximation to maintain adequate future water quality in the face of the projected growth, presuming the planned waste treatment facilities are constructed.

MONITORING

A monitoring network for the estuaries and marine waters of Puget Sound has been developed as specified in the implementation plan. Adequate decisions concerning waste management and water quality requires a basic knowledge of the water characteristics. While a number of Federal, State and local agencies and universities are actively involved in the monitoring of water quality in certain locations of the Puget Sound Area, overall the water quality characteristics of the marine waters are not adequately defined.

A basic network exists for fresh water areas. It requires some expansion now and will undergo readjustments in the future as the conformation of waste sources changes. Similarly, the parameters measured will be adapted to the needs. A basic network needs to be established for ground water. Ground water monitoring will be more actively pursued in the future.

An area-wide network of water quality stations in Puget Sound, with measurements taken at sufficiently close intervals to adequately define the marine environment, is a must. The Washington Water Pollution Control Commission began an operating system in 1967. It includes a sizeable number of stations with measurements taken monthly or quarterly. The U.S. Geological Survey and METRO also have a number of stations located on the marine waters in the vicinity of the Cedar-Green Basins. In addition, the University of Washington has some stations located on marine waters. These programs form a good basis from which to begin.

The next step is to bring into this system design elements. Selection of the sampling interval and spatial location of stations in marine waters is a highly complex problem. If data are collected in excess of needs, the result is an expensive overload of processing facilities. Similarly, data collected too infrequently will have limited value.

The first step in system design is to elucidate the goals of the monitoring program. A very important goal is to measure the long-term trend in productivity in the Sound. The past occasional measurements that have been made indicate Puget Sound is one of the most productive marine areas in the world. The continued future growth of waste discharges to the Sound will result in an ever increasing load of nutrients. These effects must be traced to prevent over-enrichment of the marine environment. The primary goal for which the present system is operated is to monitor for Standards compliance. Another goal should be the development of an information system to assist in a precise definition, over a long-term period, of the eco-system of the Sound. In addition, consideration should be given to the public health aspects of water quality, especially in those areas utilized for shellfish growing and water contact recreation. The network should be a framework, expandable in the future to meet projected needs, of which the ongoing data collection would also be usable in the context of the future programs. To meet these types of goals will require several types of sampling programs. Some will define long-term changes, some short-term changes, and some will give in-depth definition of rather limited areas.

Long-term changes should be observed by a systematic sampling program at key locations. The parameters measured at each station should include temperature, salinity, dissolved oxygen, coliform organisms, dissolved organic phosphate, total phosphate, nitrate, silicate, pH, alkalinity, and sulfite waste liquor. A systematic biological and ecological program should be carried out at the same time to determine both the phyto and zoo-plankton populations at the same locations. Other supporting data should include (1) river runoff data of all rivers and creeks that feed into Puget Sound, and (2) meteorological observations of winds, rainfall, air temperatures, and insolation at sufficient locations to adequately define these parameters for the Puget Sound Area.

MANAGEMENT SYSTEM

Authority to manage or affect water quality in the Puget Sound Area today is dispersed among private concern and numerous local, State, and Federal agencies.

Coordination and cooperation are necessary at the various levels of government. Adequate definition of a water quality control program for the Puget Sound Area, utilizing a task force composed of Federal, State, and local agencies is needed to put pollution control on an effective, continuing basis. This could be a formal development of present informal interagency cooperation.

Area-wide approaches such as metropolitan municipal corporations, or county area services, should be emphasized as a way to strengthen institutional arrangements at the local level. Important problem areas for municipalities include the fragmentation of waste treatment among multiple units, city-suburban relationships, and the urban fringe; sewer controls and controls over privately-owned septic tanks and package treatment plants; and regulation and development of land use in relationships to waste disposal and protection of water quality.

At the present time, the State occupies a strategic position in water quality management. It is the focal point and has the primary responsibility for water pollution control. The ability of the pertinent State agencies to discharge their responsibilities must be strengthened in order to enhance the effectiveness of their roles in water quality management by engineering and planning developments. There are six areas of need for grants, appropriations, direct funds, and new approaches to deal with: (1) local and State projects to demonstrate new or improved treatment and disposal technology, (2) implement area-wide management systems to end fragmentation of responsibility among small communities beyond the single Seattle-METRO at present, (3) State surveys of needs using an up-to-date information system, (4) research to establish the basis for new approaches to treatment effectivenes, potential severity of discharge, degree of compliance, effect or enhancement on water quality by waste discharges, cause and effect of resource damage, effectiveness of industrial inplant control, (5) training programs to alleviate shortages of trainee personnel, and (6) technical assistance to local entities from State and Federal Governments in special techniques. As an example, the State Water Pollution Control Commission, has utilized gas chromatography in quality management programs and the abatement of water pollution; this instrument has been used to analyse for DDT and its isomers in water, fish, shellfish, and residues from other various hosts. Analyses were made for pantachlorophenol, ethylene dichloride (used indirectly to determine concentrations of gasoline in clams), diesel oil, and numerous pesticides, using the electron capture detector and hydrogen flame ionization detector. These instruments are scarce and expensive, but extremely efficient and results obtained are very satisfying. The atomic absorption unit technique is an excellent accessory, and lends itself very well to a monitoring program. This technique can determine the trace concentrations of a metallic element in solution. Generally, the level of detection is in the parts per billion range. A few of the elements that are easily applied are: aluminum, iron, lead, silica, silver, tin, chromium, nickel, potassium, and sodium. These ions are suspected to be involved in algae growths as trace elements and in chronic (low level) toxicities to aquatic life.

The private sector should be explored in this study of new institutional arrangements. Today, industry must work toward a position of asserting proudly and positively its contribution to a better environment through involvement in outside pollution control matters. Strict programs of good housekeeping and preventive maintenance should also be implemented for in-plant pollution control. Industry must adopt new standards, perform in new ways, show new concern for the quality of the environment of the Puget Sound Area it serves.

The use of planning grants to develop permanent arrangements in the Puget Sound Area for regional water quality management is encouraged. Under Section 3(c) of the Federal Water Pollution Control Act, planning grants are available to State-designed agencies seeking to develop an action program to control pollution. Such grants can also be used to support the preparation of a regional plan for the provision of programs and facilities through which the communities and industries of a metropolitan or multi-community area can most effectively and economically control and abate pollution.

Serious consideration should be given to tying 660 grant funds to comprehensive county planning and regional planning. This should include separation of storm and sanitary sewers and inclusion of large trunks as being eligible.

Stronger land use controls and other associated controls must be developed that: (1) give significant attention to the physical capabilities of the fresh and marine waters and (2) give protection to the various uses of water. This will require a combination of actions, including the regulation of urban and industrial development, maintenance of control over densities, and narrowing of the range of permitted uses to be compatible with and complementary to water quality and primary water use objectives.

Zoning can be a useful tool to preserve water quality and to protect the uses of water, provided that such regulations are prepared in conjunction with a carefully-worked-out policy of comprehensive planning and that their application bears a substantial relationship to the health, safety, or general welfare of the public.

Conflicting uses of water are likely to increase in future years along with the increases in water use activities which have been forecast. In recreation activities alone, the water skier conflicts with the fisherman in his boat, the power boater with the scuba diver, the beach swimmer with the shore fisherman. Specialized recreation waters will have to be designated in the future in order to keep such conflicts at a minimum. Restrictions on some activities will probably be required wherever they tend to "overuse" areas and degrade the water quality.

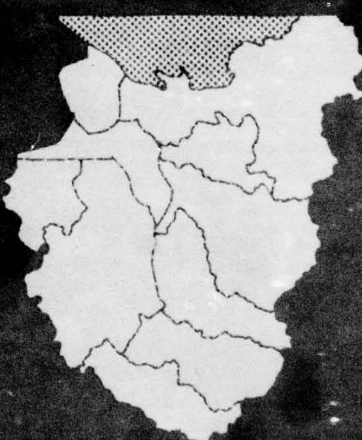
The poor flushing and dispersion characteristics of marine water in some areas indicate that the location of new industry must be constrained so as to minimize its adverse effect on water quality. Transport characteristics of marine waterways in South Puget Sound and Hood Canal are weak and poorly defined. Such bays as Port Susan, Skagit, Samish, and Padilla exhibit poor flushing. Other local areas have limited waste dispersion capabilities, suggesting that future wasteloads must be kept to a minimum in these areas. By the same token, areas of good water movement and replacement, air movements, and other attributes should be indicated as good industrial sites and the way paved for their development as such.

Rivers and lakes must also be zoned in the future. The boom in outdoor recreational activities will make this necessary in order to protect the high quality of water needed for these activities and to prevent the conflict of uses. Sections of rivers and all lakes will have to be set aside for certain uses and kept free of industrial and municipal development.

A master plan of land use zoning should be established to protect the water resources from pollution, over-development, and conflicting uses. The Puget Sound Area should be divided into several water quality and land use zones in which development of industry, housing, recreation, and other future development can be regulated.

The industrial waste discharge permit system employed by the Washington State Water Pollution Control Commission could be a useful tool in implementing a zoning program. New sources of industrial wastes are permitted to locate where water quality conditions are less critical and where waste treatment requirements and their associated costs will be least to industry.

Nooksack-Sumas Basins



NOOKSACK - SUMAS BASINS

INTRODUCTION

The physical features of the Nooksack-Sumas Basins vary from relatively low, flat farmlands and fertile valleys characteristic of the western portion of the Area, to the rugged, heavily forested, and mountainous terrain of the northern Cascades.

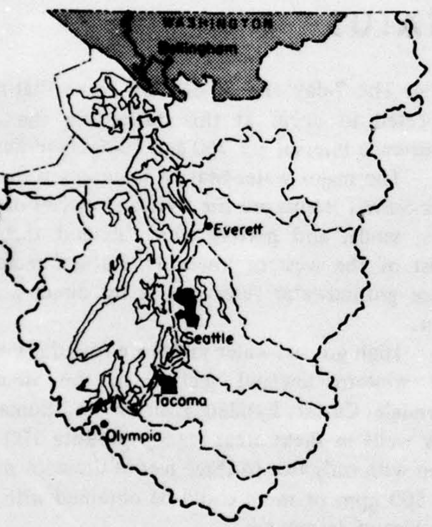


FIGURE 2-1. Location of the Nooksack-Sumas Basins

West of the mountainous foothills, at elevations generally below 2000 feet, lies a glacial plain which is dissected by the Nooksack River, Sumas River, and coastal streams.

The Nooksack River merges from the glaciers on the western slopes of Mount Baker and flows westerly more than 70 miles to Bellingham Bay. The Middle and South Forks, the major tributaries, emerge from the southern glaciers of Mount Baker and flow westerly to their confluence with the Nooksack River near Deming.

The Sumas River, which originates on Sumas Mountain, meanders through a broad, fertile valley and crosses the border into Canada at the city of Sumas, draining about 56 square miles in the United States.

The major marine water bodies of the area are Bellingham, Lummi, Chuckanut and Birch Bays, Drayton Harbor, and portions of the Strait of Georgia. Lummi is the largest offshore island, located west of Bellingham Bay.

Land and inland waters of the Nooksack-Sumas Basins total 1,256 square miles. Forest land accounts for 75 percent of this area and crop land 17 percent. Inland waters comprise 1.5 percent of the area. Land ownership is divided about equally between public and private. About 80 percent of the public land is held in Federal ownership.

An estimated 77,300 people reside in the Nooksack-Sumas Basins, based on 1967 Seattle Area Industrial Council figures. More than half of this population is urban and concentrated largely in the city of Bellingham. Bellingham, with an estimated 1967 population of 36,500, accounts for nearly 47 percent of the total basin population. Another 9 percent are concentrated in the cities of Lynden, Blaine, Ferndale, and Sumas, having populations in the range of 600 to 3,000.

In past years, the basins' economy relied almost entirely on the lumber and wood products industry and agriculture. These industries are still important aspects of the economy, but industrial diversification is having a strong effect on population growth and

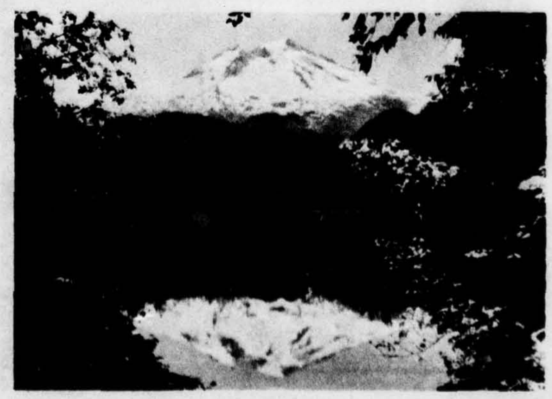


PHOTO 2-1. MAJESTIC MOUNT BAKER is charistic of the rugged eastern portion of the basins.

economic expansion. Important industries in the area include a pulp and paper plant located on Bellingham Bay, and an oil refinery and an aluminum reduction plant located along Georgia Strait west of Ferndale. A site at Bellingham is being developed for industrial use by the reclamation of tidelands.

Major commercial fishing areas for salmon, marine fish, and shellfish are located in the marine waters of the basins. Purse seiners, gill net and reef-net fishermen, fish near Lummi Island, Point Roberts, and Bellingham Bay. A variety of marine fish are harvested in the waters of Bellingham, Birch, and Boundary Bays, as well as in the lower Gulf of Georgia area. Shellfish, principally crabs, are harvested in good numbers in the Boundary Bay-Point Roberts vicinity.

The Nooksack-Sumas Basins are also experiencing an increasing tourist trade. This scenically endowed area is catering to the outdoor enthusiast on a year-round basis. Its natural resources and recreation facilities offer opportunities for both summer and winter sports.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The Nooksack River has two high runoff periods each year: one in the fall or winter, coinciding with the time of maximum precipitation; and one in the spring, during the melt-off of snowpack in the higher elevations. The average annual discharge (1944-1965) for the Nooksack River near Lynden (drainage area 826 square miles) is 3,700 cfs. The maximum discharge of 46,200 cfs was recorded at this station on February 10, 1951, and the minimum flow of 595 cfs was recorded on November 30, 1952.

A low-flow frequency analysis was made by the USGS for the Lynden gaging station based on the 18-year period extending from April 1946 to March 1964. The 7-day and 30-day low flows that may be expected to occur at this station for the 10-year recurrence interval are 760 and 1000 cfs respectively.

PHOTO 2-2. The NOOKSACK RIVER is the primary water resource of the basins.

The major water-bearing materials in the Nooksack-Sumas Basins are the river and glacier-deposited silts, sands, and gravels which extend throughout most of the western lowlands. Natural recharge to these groundwater reservoirs is by direct precipitation.

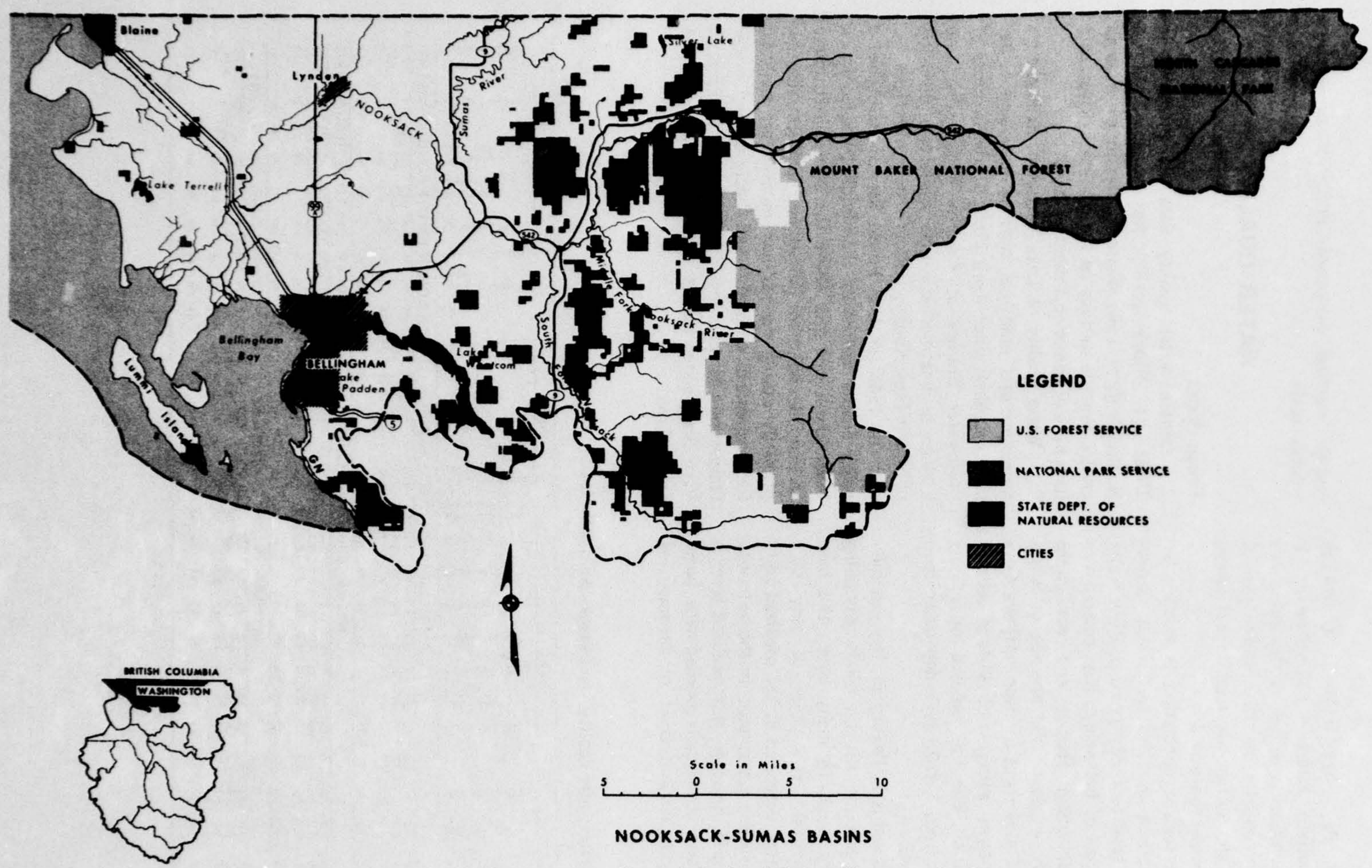
High ground-water yields are found primarily in the western lowland section in the vicinity of Ferndale, Custer, Lynden, Everson, and Sumas. Shallow wells in these areas readily produce 100 to 200 gpm with only two to three feet of drawdown. Yields of 500 gpm or more could be obtained with five to ten feet of drawdown.

Areas of moderate yield include the delta lowland of the Nooksack and Lummi Rivers south of Ferndale, the area west of Custer to Blaine, the lower Custer trough, the lower fringes of the upland areas west of Ferndale, and the lower portions of the North, Middle and South Fork valleys of the Nooksack River.

Marine Water

Marine waters of the Nooksack-Sumas Basins encompass a total surface area of 234,200 acres.

Strait of Georgia. The Strait of Georgia is classified as a deep basin estuary. Substantial quantities of fresh-water inflow create a brackish surface layer, mixing with sea water in its movement to the Pacific Ocean. This oceanward movement of brackish water is replaced by a deep flow of sea water from the ocean through the San Juan channels.



NOOKSACK-SUMAS BASINS

Figure 2-2 Land Ownership

Bellingham Bay. Net transport (long-term movement) of surface waters in Bellingham Bay is seaward. This transport is driven by the inflows of fresh water. Consequently, in the northern part of Bellingham Bay, net surface-water movement carries Nooksack River water southward.

Short-term surface circulation is variable because of the actions of tides and winds. Strong southerly winds tend to hold Nooksack River water in the northern part of Bellingham Bay, cuasing it to spread into Bellingham Harbor and contiguous waters. Northerly winds or the absence of winds allows southward movement of river outflows. Consequently, short-term patterns of surface salinity show much variation. The time required for flushing of the bay varies from 3 to 78 days, depending upon fresh-water inflow.

Natural sediments in Bellingham Bay generally consist of homogeneous, silt-clay muds containing about 10 percent sand. In many cases, this base formation is covered by a layer of very fine, flocculated material, described as the oxidized layer because of its brownish appearance. In the waterway adjacent to the mill, however, this oxidized layer is absent, and the base formation is overlaid with sludge deposit—an oxygen-deficient layer of decomposing organic material composed, primarily, of settled, volatile solids.

WATER QUALITY

Fresh Water

Surface-water quality data are presented in Table 2-1. Water quality was measured on the Nooksack River, Lake Whatcom, and numerous small creeks. For the stations on the Nooksack River, data have been obtained on a monthly basis.

Water quality of Lake Whatcom, Bellingham's municipal and industrial water supply source, has been measured since April 1962, by the Institute of Freshwater Studies at Western Washington State College, to determine the quality effects of diversion of Middle Fork Nooksack River water on the lake.

In 1965 the U.S. Forest Service established a water quality station on the Middle Fork Nooksack River about one mile above the diversion structure that supplies water for Bellingham. Samples collected, primarily during the summer months, are analyzed for suspended sediment and bacteria and water temperature is measured at the time of collection. Very little water quality data are available for the Sumas River.

TABLE 2-1. Surface water quality, Nooksack—Sumas Basins

			MG/L											MG/L									MG/L		MG/L		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
											WHATCOM LAKE NEAR BELLINGHAM								OCTOBER 1961 THROUGH PRESENT								
Maximum	...	52	7.2	1.9	6.0	0.8	24	0	8.8	5.8	0.2	1.1	61	0.03	...	6.7	0.16	0.02	7.1	10	15	21.4	13.0	122	22	4	930
Mean	...	32	5.3	1.5	3.3	0.5	22	0	5.1	2.6	0.1	0.6	56	0.01	...	1.9	0.07	0.02	...	...	...	12.3	10.7	102	19	2	184
Minimum	...	28	4.8	0.7	2.9	0.2	17	0	4.4	1.5	0.0	0.1	54	0.00	...	0.6	0.02	0.01	6.6	0	0	3.5	8.6	90	18	0	0
Number	...	25	25	25	25	25	25	24	25	25	24	25	24	12	...	25	12	4	24	24	12	27	27	27	25	24	27
											NOOKSACK RIVER AT DEMING								DECEMBER 1965 TO SEPTEMBER 1966								
Maximum	9,130	68	12.0	3.5	2.8	0.9	46	0	14.0	1.5	0.2	1.0	103	0.21	...	9.8	7.70	0.06	7.8	50	330	16.4	13.4	137	44	10	24,000
Mean	...	49	8.9	2.3	1.6	0.5	32	0	8.0	0.7	0.1	0.4	73	0.02	...	7.4	1.09	0.01	...	...	...	9.3	11.2	100	32	5	727
Minimum	3,800	35	6.0	1.2	0.9	0.1	22	0	4.2	0.0	0.0	0.0	49	0.00	...	4.7	0.01	0.00	6.9	0	5	2.4	9.8	88	22	2	0
Number	11	40	40	40	40	40	40	14	40	40	40	40	40	37	...	40	37	9	40	40	20	40	41	40	40	40	41
											NOOKSACK RIVER AT FERNDALE								JULY 1959 THROUGH PRESENT								
Maximum	...	77	13.0	4.9	4.2	1.0	53	0	15.0	4.2	0.3	2.5	128	0.05	...	11.0	7.50	0.02	7.7	25	700	17.5	13.6	121	53	10	24,000
Mean	...	56	9.5	2.9	2.4	0.6	36	0	9.2	1.9	0.1	0.8	85	0.02	...	8.1	1.16	0.01	...	...	...	9.1	11.1	99	36	6	2,488
Minimum	...	32	5.0	1.4	1.2	0.2	22	0	5.4	0.2	0.0	0.1	51	0.00	...	5.1	0.08	0.00	6.8	5	5	2.0	5.1	45	22	2	36
Number	...	57	57	57	57	57	57	33	57	57	57	57	57	46	...	57	43	7	57	61	46	60	60	59	57	57	60

Chemical. The chemical quality of surface waters in the Nooksack-Sumas Basins is generally excellent. Total dissolved solids concentrations for the surface waters of the basins rarely exceed 100 mg/1. Samples collected monthly from the Nooksack River at Ferndale during a five-year period had a maximum dissolved solids content of 77 mg/1. (See Table 2-1.) Data for small tributary streams around Lynden and Ferndale show about twice the dissolved solids concentrations of the Nooksack River.

The water in all streams is generally soft, normally having hardness values of 60 mg/1 or less. Hardness of more than 100 mg/1 is unusual.

Nutrient concentrations in the Nooksack River are relatively low. Most phosphate values are below 0.05 mg/1 for both the upstream station at Lawrence and the downstream station at Ferndale. Nitrate concentrations for the Nooksack River at Lawrence average 0.1 mg/1, with a maximum value of 0.2 mg/1. Concentrations for the river at Ferndale are higher, averaging 0.2 mg/1 with maximum values of 0.6 mg/1.

The ground waters are relatively low in dissolved solids, although they are more highly mineralized than the surface waters. They are generally of good chemical quality.

Ground waters may be generally classed as being soft to slightly hard. In many ground-waters, hardness is but 60-80 mg/1, while in others it is as high as 175 mg/1, with the average hardness being about 150 mg/1.

Iron, in concentrations greater than 0.3 mg/1, is a common objectionable constituent of ground-water in the basins, occurring mainly throughout the Nooksack and Sumas River lowlands.

Bacteriological. The bacteriological quality of the Nooksack River is, for the most part, satisfactory but a general trend of decreasing quality from the headwaters to the mouth is apparent from the data. The higher concentrations of coliform bacteria usually occur during the summer months in stream reaches below the more populated areas. The most probable number of coliform organisms per 100 ml (MPN) has reached a high of 24,000 at Lawrence, but is normally in the range of 36 to 91 MPN. These relatively low MPN figures are typical of streams draining remote mountain areas. At Ferndale, the MPN has ranged from a low of 36 to a maximum value of 24,000. The normal range for the MPN for this station is from about 230 to 4,600. In the Middle Fork of the Nooksack River, bacterial levels were normally found in the range of less than 3 to 105 MPN. A summary of bacteriological data is presented in Table 2-2.

TABLE 2-2. Summary of coliform concentrations Nooksack-Sumas Basins

	MPN/100 mls							
	Less Than 240		240-1,000		1,000-2,400		Greater Than 2,400	
Watercourse	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.
Nooksack River (Lawrence)	40	91	1	2	2	5	1	2
Nooksack River (Ferndale)	19	29	26	39	5	8	16	24
Whatcom Lake (Bellingham)	29	88	4	12	0	0	0	0

Source: Washington Water Pollution Control Commission.

Physical. The Nooksack River and its major tributaries are relatively fast-moving watercourses. Dissolved oxygen concentrations throughout the river's length are normally near saturation. At Ferndale, on the lower Nooksack River, DO concentrations ranged from a minimum of 5.1 mg/l to a maximum of 13.6 mg/l, based on the period of record from October 1961 to May 1966. Except for the minimum value of 5.1 mg/1, DO concentrations were in the range of 9.4 mg/l to 13.6 mg/1. Further upstream at Lawrence, DO concentrations ranged from a minimum value of 9.8 mg/1 to 12.9 mg/1.

The Nooksack River has cooler stream temperatures than the other major streams in the Puget

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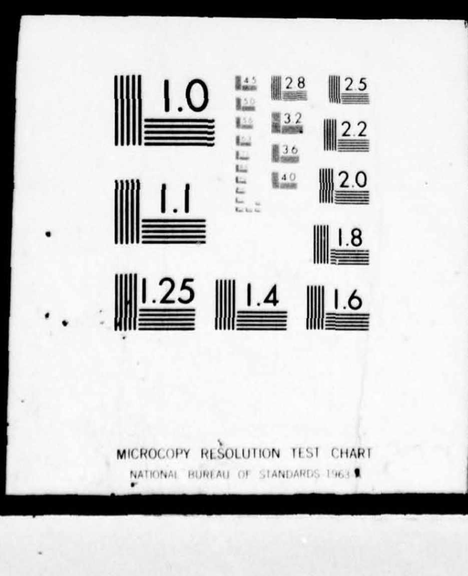


Sound Area. The maximum temperature on the South Fork is the highest recorded in the Nooksack–Sumas Basins. Temperatures on the main stem of the Nooksack River at Deming are about the same as those near Lynden. During the summer of 1965, temperatures on the Middle Fork ranged between 46°F (7.8°C) and 56°F (13.3°C). Maximum and minimum monthly stream temperatures obtained from spot observations at three sites in the Nooksack-Sumas Basin are shown in Table 2-3.

The turbidity of the Nooksack River is high compared to other streams on the east side of Puget Sound, due to substantial quantities of the glacial melt water. Turbidity of the Nooksack River at Ferndale has averaged 69 Jackson Turbidity units, with a maximum of 700 JTU being recorded.

During high streamflows some bank sloughing and bed movement are evident in the three major tributaries of the Nooksack River. Most of the headwater streams are almost sediment-free, and rarely have concentrations greater than 20 mg/1. In contrast, glacier-fed streams that originate on the slopes of Mount Baker and Mount Shuksan have a milky appearance and are particularly turbid and sediment-laden during periods of high runoff.

Analyses of samples obtained from the Nooksack River near Lynden during 1965 and 1966 show that large sediment loads are transported during high-water periods. An annual load of about one million tons of suspended sediment can be expected during a year of normal runoff. The daily load is probably about 300,000 tons when the daily river discharge averages about 30,000 cfs. During the winter, sediment concentrations of the Nooksack River near Lynden range from 50 to 3,000 mg/1. During the low-flow period (July through October), sediment concentration is low, ranging from about 20 to 50 mg/1.

Lake Whatcom samples have been collected weekly for the years 1963 through 1966 at four stations on the lake and analyzed for dissolved oxygen (DO), pH, and coliform bacteria, in addition to measuring water temperature at the time of collection. The maximum monthly mean surface-water temperature was 68.4°F (20.2°C) for August of 1963. Mean surface dissolved oxygen concentrations for the period 1963 to 1966 were a maximum of 11.8 mg/1 for April 1965 and a minimum of 8.1 mg/1 for August 1965. Bottom DO concentrations were considerably lower, particularly in the extreme western section of the lake. Monthly mean bottom DO concentrations of 0.0 mg/1 were found during August, September, and October of 1966. Both surface and bottom concentrations of coliform bacteria were found to be highest in the western parts of the lake. During 1966, mean surface concentrations in this area ranged from 1 to 49 coliform bacteria per 100 ml, while bottom concentrations ranged from 0 to 61 coliform per 100 ml.

A definite trend of water quality change, due to the Middle Fork diversion entering Lake Whatcom, has not been established. Although the Nooksack River water entering the lake is more turbid, it moves to the lower level of the lake shortly after entering and is mixed and diluted.

The bacteriological quality of Lake Whatcom water has also been studied by the city of Bellingham and the Washington Water Pollution Control Commission. High coliform concentrations during the winter months were found by both agencies. City data for the period 1961 through 1963 showed maximum values up to 700 MPN for all three winters. WWPCC data for 1964 through 1966 showed 930 MPN for February and October 1965.

Marine Waters

The waters of the Strait of Georgia within the Study Area are usually well-mixed. Salinities range from 28.0 parts per thousand (o/oo) in the fall to 30.0 o/oo in the spring, with little variation over

TABLE 2-3. Water temperatures, Nooksack-Sumas Basins

Station	Period of Record	Maximum Temperature	Minimum Temperature
South Fork Nooksack River near Wickersham	October 1944-June 1965	70°F (Aug.)	32°F (Dec.-Jan.)
Nooksack River near Deming	October 1944-July 1965	65°F (Aug.)	32°F (December)
Nooksack River near Lynden	January 1945-August 1966	66°F (Aug.)	32°F (January)

Source: Appendix III Hydrology and Natural Environment depth or tide. Some stratification occurs at places near shore due to local surface inflow, occasionally resulting in lower salinities in the upper zone (2.0 o/oo generally across the overall area).

Temperature has the same uniform characteristics as salinity. Temperature in the upper zone (60 feet) ranges from 44°F (6.7°C) to 52°F (11.1°C) during the year.

Dissolved oxygen concentrations near the surface range from 9 to 10 mg/l in the summer; minimums of 7 mg/l occur in the fall. Concentrations decrease to about 5 mg/l at about the 300-foot depth, and remain at this concentration at depths below 300 feet.

Surface pH ranges from 7.8 to 8.5. The usual pH range is between 7.9 and 8.0 at most depths. Variations of pH conform closely to that of dissolved oxygen concentrations.

Surface salinities in Bellingham Bay are affected by fresh-water inflows from the Nooksack River. For the period 1959 to 1962, average surface salinity varied uniformly from 20.0 o/oo at the head of the bay near the Nooksack River to 29.0 o/oo southeast of Lummi Island. Below a depth of about ten feet, salinity is nearly uniform, with concentrations in the range of 29.0 to 30.0 o/oo.

Waters of Bellingham Bay are usually of better quality than those in and around Bellingham Harbor. Surface dissolved oxygen (DO) varies from about 7 mg/l near the city of Bellingham to about 13 mg/l in the outer bay. Dissolved oxygen varies with depth from about 8 to 12 mg/l at 15 feet to about 5 to 8 mg/l at 60 feet. The pH ranged from 7.6 in the inner harbor to 8.3 in the outer bay. The pH is uniform with depth.

Sulfite waste liquor concentrations are highest near Bellingham and in the surface ten-foot layer of water. Concentrations decrease rapidly to insignificant levels (less than 5 ppm) with increasing depth.

Water quality in and around Bellingham Harbor is variable, being influenced by the actions of winds and tides. During a four-day period in May 1964, DO varied from 0.35 to 9.30 mg/l at one station and from 6.46 to 9.47 mg/l at another. For ten stations, the minimum DO concentrations ranged from 0.35 to 7.2 mg/l, while maximums were from 9.25 to 10.47 mg/l. Similarly, pH ranged from a minimum of 5.6 to a maximum of 7.9. Sulfite waste liquor concentrations varied from minimums of 34 to 87 ppm to maximums of 129 to 6,230 ppm.

MPN concentrations within Bellingham Harbor have ranged from 500 to 22,500 coliform organisms per 100 ml, while concentrations in Bellingham Bay have ranged from 20 to 830 coliform organisms per 100 ml.

SOURCES OF WASTE

The peak municipal and industrial waste load generated in the Nooksack-Sumas Basins approximates over two million population equivalents, of which six percent are presently removed by treatment before being discharged to fresh and marine waters. Almost 90 percent of the total raw waste load is produced in the Bellingham Service Area on Bellingham Bay. About eight percent is produced in areas along the Nooksack River.

The quantities and general location of waste production and discharge are shown on Figure 2-3. A summary of the present status of municipal and industrial waste sources for the basins is presented in Table 2-4. After compliance with the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, these waste quantities and strengths should be substantially reduced.

Fresh Water

Municipalities and industries located along the Nooksack and Sumas Rivers produce about 25,500 PE of organic wastes each day. During the food-processing season, an additional 130,000 PE are produced daily along these waters. These wastes are given varying degrees of treatment. Of 156,000 PE peak waste production, about five percent receives secondary treatment, 65 percent is treated by lagoon, about one percent receives primary treatment, and 29 percent receives no treatment. After treatment, a total of 67,000 PE is discharged to fresh waters during the peak waste production period. Over 99 percent of these wastes are discharged to the Nooksack River. Of the total waste load discharged to fresh water, 96 percent is contributed by industrial sources, and the remaining four percent is contributed by cities and towns.

About six percent of the total waste load discharged to the Nooksack River during the peak waste production period is released at Ferndale, 67 percent at Lynden, and 27 percent at Everson. The Sumas River receives 200 PE daily from the town of Sumas.

TABLE 2-4. Summary of municipal and industrial wastes, Nooksack-Sumas Basins, 1965

Watercourse	1965 Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Boundary Bay						
Food and Kindred	--	2,800	600	None	2,800	600
Drayton Harbor						
Blaine	1,700	2,200	--	Primary	2,200	--
Food and Kindred	--	1,450	--	None	1,450	--
Blaine A.F.B.	350	350	--	Secondary	50	--
Birch Bay						
Birch Bay State Park	--	1,000	--	Primary, Individual	--	--
Georgia Strait						
Oil Refining	--	1,000	--	Secondary	600	--
Bellingham Bay						
Bellingham-Harris St. Outfall	1,600	2,000	--	None	2,000	--
Food and Kindred	--	50,000	58,600	None	50,000	58,600
Paper and Allied	--	1,687,000	--	None	1,687,000	--
Whatcom Creek						
Bellingham	30,000	47,000	--	Primary	27,300	--
Food and Kindred	--	5,500	--	City	3,200	--
Squalicum Creek						
Fairhaven Outfall	2,600	2,600		None	2,600	--
Nooksack River						
Lynden	2,700	2,700	--	Secondary	500	--
Food and Kindred	--	--	4,500	Secondary		700
Food and Kindred	--	19,000	25,000	None	19,000	25,000
Everson	300	300	--	Primary, Individual	--	--
Food and Kindred	--	--	70,500	Lagoon	--	17,000
Food and Kindred	--	1,100	--	None	1,100	--
Ferndale	1,450	1,500	--	Primary	1,200	--
Food and Kindred	--	--	30,000	Lagoon	--	3,000
Hospital	--	350	--	Secondary	100	--
Sumas River						
Sumas	500	600	--	Primary	200	--
TOTAL[1,2]	41,200	1,830,000	189,000	--	1,800,000	105,000
Municipal	41,200	60,000	--	--	36,000	--
Industrial	--	1,770,000	189,000	--	1,765,000	105,000

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

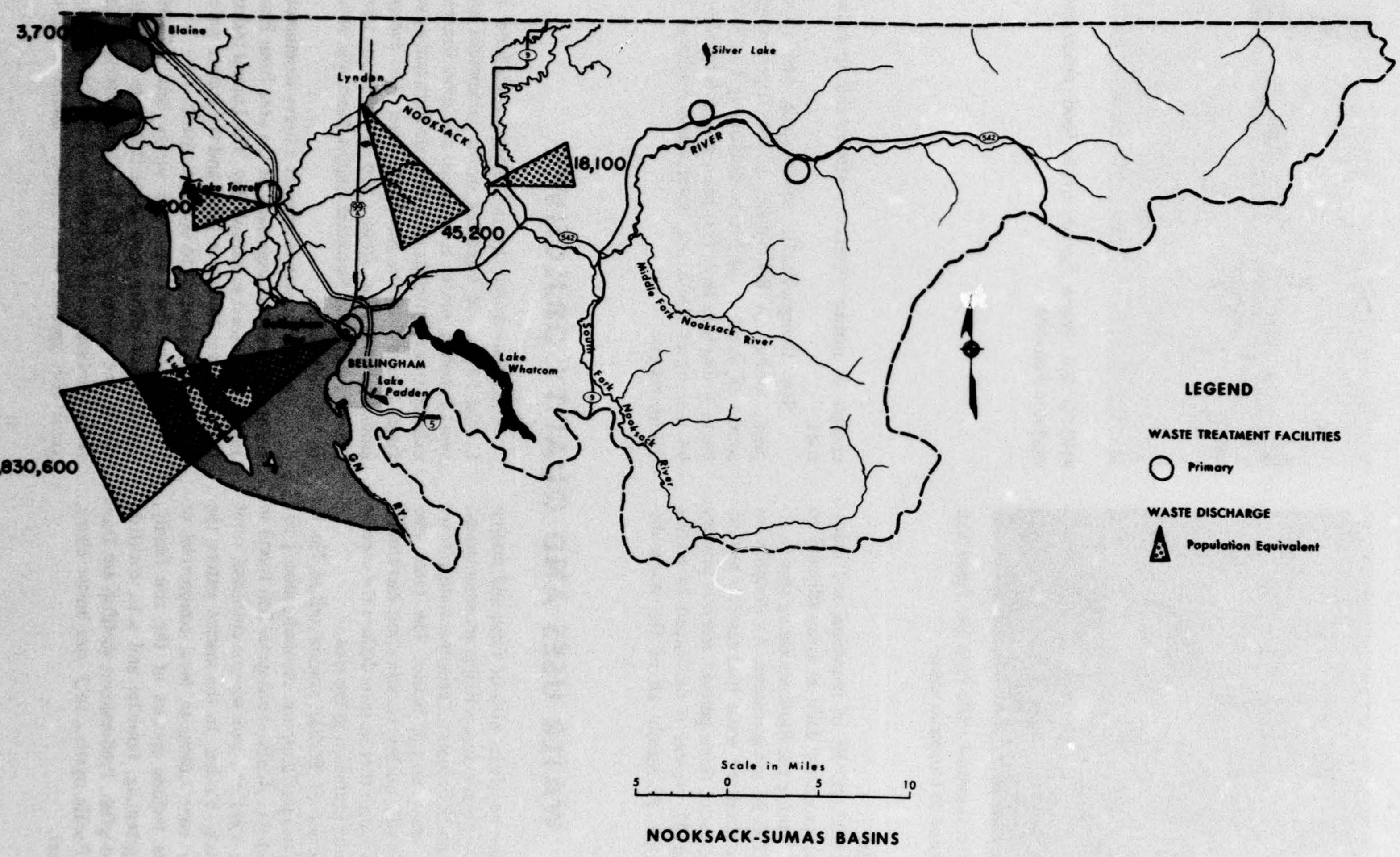


FIGURE 2-3. Location of major waste discharges

PHOTO 2-3. The Georgia-Pacific Pulp and Paper Mill is the major source of industrial wastes.

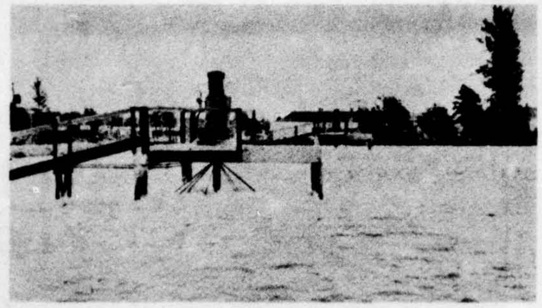


PHOTO 2-4. Waste lagoon treats food processing wastes in Ferndale.

Marine Waters

About 1,803,000 PE of municipal and industrial wastes are produced daily in areas adjacent to marine waters. During the food-processing season, an additional 59,200 PE are generated. An insignificant amount of the total raw waste load receives secondary treatment; about three percent receives primary treatment; and 97 percent is discharged to marine waters untreated. Practically all of the waste discharges to marine waters are attributable to industries.

The Georgia-Pacific sulfite pulp and paper plant, located in Bellingham, is the largest single source of waste in the basins, discharging 1,687,000 PE to Bellingham Bay. This plant accounts for about 94 percent of the basins' total waste discharge to marine waters.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the Nooksack-Sumas Basins are summarized in Table 2-5, which focuses on principal watercourses and problem areas in the basins. The table also indicates the water quality classification established for each watercourse that in turn defines the type of water usage to be protected in the area.

Five species of Pacific salmon utilize Nooksack-Sumas drainages. They are: chinook, coho, pink, chum, and sockeye. Anadromous game fish found in the basins are steelhead and sea-run cutthroat trout and searun Dolly Varden. In the marine waters, the fish presently contributing to local commercial or sport interests include species of the cod family, lingcod and greenling, flounder and sole, rockfish, herring, and dogfish. Predominant shellfish are Dungeness crab, Pacific oysters, rock and butter clams, and blue mussel.

Salmon reared in the basins contribute to United States and Canadian ocean commercial and sport fisheries, and to commercial and sport fisheries existing through the Strait of Juan de Fuca and upper Puget Sound into the Nooksack River. The average annual contribution from 1956 to 1965 to these fisheries from the Nooksack-Sumas Basin amounted to 180,980 salmon.

The marine waters support a heavy commercial fishery for salmon, especially in the area from Point Roberts southeast to Samish Bay. The Lummi Indians fish the lower Nooksack River and the marine waters immediately adjacent to the river mouth.

On the basis of 1966 survey data, 126,800 man-days of effort were spent fishing in the lakes, ponds, and reservoirs of the Nooksack-Sumas Basins; and a total harvest of 450,600 trout and 83,600 other game fish species was realized. Similarly, 61,500 man-days of effort were spent fishing for game fish other than steelhead in the streams, and 190,600 fish were harvested. About 31,100 man-days of effort were spent fishing for steelhead and searun cutthroat trout, and 2,860 steelhead and 10,100 cutthroat trout were harvested.

Commercial and sport harvest of shellfish is considered moderate to heavy with principal emphasis on crabs and oysters.

The Nooksack-Sumas Basins have the seventh largest recreational water use in the Puget Sound Area. Except for Inner Bellingham Bay, all of the surface waters in this region are presently being employed for outdoor recreation activities.

One of the most popular recreation sites is Mt. Baker, where skiing and other winter sports are enjoyed by thousands of enthusiasts. Three State parks–Birch Bay, Larrabee, and Peace Arch– are located in the basins. Outstanding natural areas include Church Mountain Fossil Bed, Mt. Shuksan, Galena Falls, Wells Creek Falls, and the North Cascades, which are often referred to as the American Alps. A North Cascades National Park has been established recently. A portion of the Park is within

TABLE 2-5. Water uses and quality objectives, Nooksack-Sumas Basins

Use Intensity
L - Light
M - Medium
H - Heavy

Watercourse	Assigned Class[2]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Nooksack River, Mouth to River Mile 4	A			H	H	L				L	H†		L		L	M	M			L		L		
Sumas River, Border to Headwaters	A			M	L	L		L					M		L	M	L				M			
Lake Whatcom	A[1]							M	M						H	H	H		H	H				
Strait of Juan de Fuca and Puget Sound	A			H	H				M	H	H	H	L		L	H	H			M		H	M	
Drayton Harbor, South of Entrance	A			L	L							M	L			M	M					L	L	
Outer Bellingham Bay	A			H	H					H	H	H	H		H	H	H					H	H	
Bellingham Bay	B			M	M								L				M			L		M	H	
Inner Bellingham Bay	C			L	L												L			L		M	H	
Nooksack River from river mile 4 to confluence with Maple creek	A[3]			H	H	H							H		L	H	H		M	M	M			
Nooksack River from confluence with Maple Creek to headwaters	AA[3]			H	H	H							H		L	H	H		M	L	L			L
Middle Fork of Nooksack River	AA[3]			H	H	H							H		L	H	H		M	M	L			
South Fork of Nooksack River from mouth to confluence with Skookum Creek	A[3]			H	H	H							H		L	H	H		L	L	L			
South Fork of Nooksack River from Skookum Creek to the headwaters	AA[3]			H	H	H							H		L	H	H		L	L	L			

†Indian Fishery

1 Not presently classified. Equal to existing quality.

2 See Table 1-5.

3 Tentative Assigned Class, Information Bulletin on intrastate water quality standards, Washington Water Pollution Control Commission, 1969.

the Nooksack-Sumas Basins and should greatly increase the recreation activity in this area.

The Middle Fork of the Nooksack River is the major source of water for the basins. Water from the Middle Fork is diverted through a ten-mile pipeline into Mirror Lake; flows thence down Anderson Creek into Lake Whatcom where the city of Bellingham draws an average of 59.6 mgd for municipal and industrial use.

Navigation is heavy on Bellingham Bay, the population center for the basins. In 1963, the foreign and domestic coastwise traffic was nearly 990,000 tons. The 1963 domestic internal traffic in the Bay was over 440,000 tons.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, for most watercourses in the Nooksack-Sumas Basins, and because even greater importance is expected to be given to these uses in future years, the water quality class in the basins is either excellent (A) or extraordinary (AA), with the exception of Inner Bellingham Bay. This body of water (Class C) does not receive any high-quality uses, due to the intense, waste-producing pulp and paper manufacturing along the shore.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs are concentrated primarily in marine waters, where fish processing, pulping, and municipal waste discharges create unsatisfactory water quality conditions. The water quality objectives for dissolved oxygen, bacteria, temperature, turbidity, aesthetics, and toxic substances, are not being met in Bellingham Bay.

The Georgia-Pacific pulp and paper mill located in the city of Bellingham is the principal source of wastes now discharged to Bellingham Harbor. The Bellingham–Samish Bay system is too shallow, and the flushing characteristics are too weak to afford adequate dispersion of the mill's large volume of untreated wastes. These wastes, discharged into near-surface waters, and largely confined to the surface-layer waters, produce sulfite waste liquor concentrations from values less than 100 ppm to values greater than 6,000 ppm in the harbor. These high concentrations are injurious to marine life and adversely affect water quality for most uses. In addition, sludge deposits have been created in Whatcom Waterway adjacent to the mill. This material has a strong hydrogen-sulfide odor, is high in volatile solids, contains wood fragements, exerts a high biochemical oxygen demand, and produces generally toxic and turbid conditions when disturbed. Disposal of this material to the deep waters of the bay would violate the water quality standards.

Other major sources are municipal and food-processing wastes. Food processing wastes contribute significant amounts of oxygen-demanding settleable solids to these marine waters.

Water quality standards on the lower-Nooksack River are not being met. High concentrations of coliform organisms in the lower reaches of the river are most probably due to waste discharges from the Ferndale, Lynden, and Everson areas. The lower Nooksack River flood plain, however, is used extensively for dairying, and the wastes produced by livestock may be significant in contributing to the coliform concentrations in the river.

Adequate water quality data for the Sumas River are not available and, therefore, it is not known whether the water quality meets established standards. However, municipal wastes from the city of Sumas (population 674) are collected in septic tanks and then discharged directly to the Sumas River.

Lake Whatcom, an integral part of Bellingham's water supply system, is recognized as a most important resource. The continuing water quality study by Western Washington State College, Institute of Freshwater Studies, has demonstrated the persisting excellent quality of the lake in all respects, except bacterial. High coliform concentrations occur near the outlet of the lake. These are believed to originate from septic tank effluents of lakeshore residents.

No known man-caused water quality problems exist for ground-water in the basins.

FUTURE NEEDS

The principal factors determining future waste loads in the Nooksack-Sumas Basins will be population and industrial growth–including increases in agricultural production and in the recreational use of the basins' water resources. As this growth occurs, the production of wastes will also increase. Forecasts of the amount and location of wastes set the basis for determining the means to preserve water quality and to protect the water uses of any given watercourse.

The 1967 population of 77,300 persons in the Nooksack-Sumas Basins is projected to increase about 18 percent by 1980, 59 percent by 2999, and 117 percent by 2020. Figure 2-4 shows the present and projected basin population.

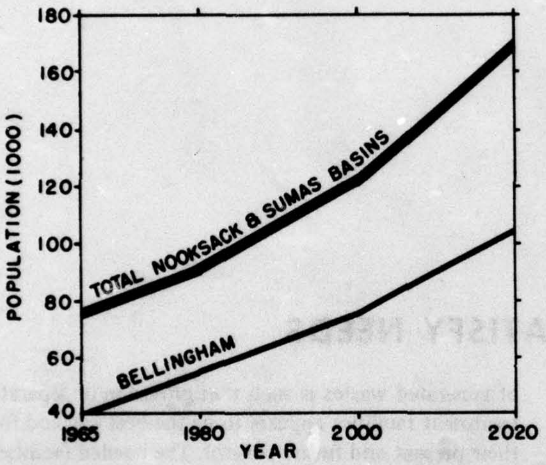


FIGURE 2-4. Projected population growth 1965-2020.

As shown in Figure 2-5, production growth for the major water-using and waste-producing industries in the Nooksack-Sumas Basins is expected to realize a four-fold increase between 1980 and 2020, in terms of value added.

Primary metals–chemicals, and petroleum–are forecasted to play a relatively large role in the basins' economy. By 2020, these two industries will account for two-thirds of the total added value produced by the major water-using industries. These industries, however, are not expected to be major waste producers.

Paper and allied products, and food and kindred products, are projected to increase but at a slower rate. By 2020, these industries will account for about 22 percent of the total value added by the major water-using industries.

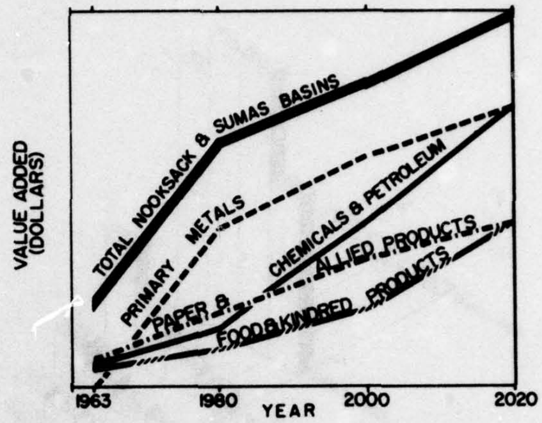


FIGURE 2-5. Relative growth for major water-using industries.

Future population and economic growth are expected to concentrate primarily in the Bellingham service area, although substantial industrial development is expected for the Ferndale industrial park area. A large, new oil refinery is to be constructed in this area by Richfield Oil Company.

Growth of recreation in the Nooksack-Sumas Basins will be substantial. By 1980, the number of water-oriented recreation days is expected to top four million–double that of 1960. Intense recreation is expected for both the upper Nooksack River area with the establishment of a North Cascades National Park, and the marine waters of the basins.

As shown in Figure 2-6, raw waste loads generated in the basins are projected to equal 3,100,000 PE by 1980. The pulp and paper, and food and kindred industries, will remain the largest sources of waste in the basins, accounting for over 96 percent of the basins' total raw waste production by 1980.

By 1980, the basins' municipal waste production, primarily from the Bellingham service area, is projected to increase to 92,000 PE from the present level of 60,000 PE. By 2020, municipal waste production is projected to be about 300 percent of the 1965 production.

Raw wastes generated from recreational activities are projected to increase to 31,000 PE by 1980. By 2020, this raw waste production is expected to be more than five times present levels.

At the present time, 38,000 acres are under irrigation in the Nooksack-Sumas Basins. By 1980, 58,000 acres and by 2020, 78,000 acres are expected to be under irrigation.

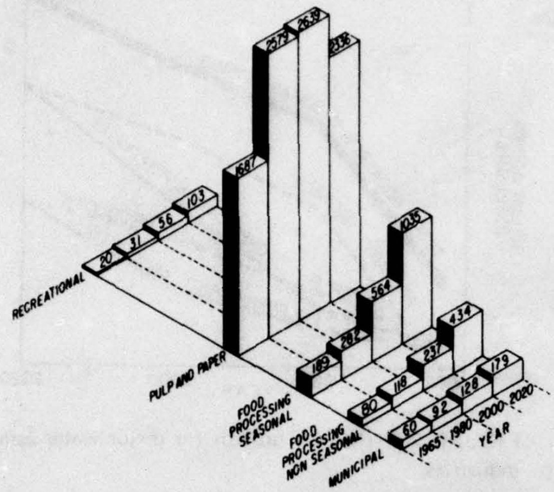


FIGURE 2-6. Projected untreated municipal and industrial wastes (thousands of PE)

In summary, by 1980 more than 2,500,000 PE will be produced by the pulp and paper industry, 400,000 PE by food processing, and about 90,000 PE by municipalities. There will also be other types of wastes produced which will need special handling methods. The future needs are to manage these large projected waste loads so as to enhance and preserve the water quality environment. The demand for high quality water will increase as population and recreation increase. The plans required for protection of water quality are presented in the Means to Satisfy Needs section.

MEANS TO SATISFY NEEDS

The principal aspect of the plan for attainment of adequate water quality in the basin is the provision of adequate waste collection and treatment facilities. Other elements have been integrated into the plan to insure the effectiveness of the needed waste collection and treatment facilities. Water quality management required in support of the treatment construction includes water quality surveillance stations on Bellingham Bay, Lake Whatcom, Birch Bay, Drayton Harbor, and the lower Nooksack River. Present management procedures for control of pesticides in agricultural and forest operations should meet future water quality protection requirements. With proper controls, no significant detrimental water quality impact is expected through the application of toxic substances and fertilizers in the future. Control and treatment of dairy wastes by lagoons or land application will be required in the near future.

WASTE COLLECTION AND TREATMENT

Present needs can be met largely through the construction and proper operation of waste collection and treatment facilities. For these basins, the location of generated wastes is such that provision of separate treatment facilities appears to be the best method for their present and future control. The needed facilities as outlined in the implementation plan are:

Nooksack-Sumas Rivers

1. **City of Ferndale**—secondary treatment and disinfection.
2. **Cities of Everson, Nooksack, and Sumas**—sewerage systems, secondary treatment, and disinfection.
3. **Food-processing plants in Lynden**—secondary treatment and disinfection.

Lake Whatcom

Interception of septic tank effluent by a municipal system is needed to control high coliform concentrations in the west end of the lake and to reduce the nutrient load to retard or eliminate eutrophication of the lake.

Bellingham Bay

1. **Georgia-Pacific Corporation**—primary treatment, including adequate

means for the disposal of recovered solids or sludge; facilities which will remove 80 percent of the sulfite waste liquor from mill effluents or limit sulfite waste liquor discharges to 3,600,000 pounds per day, based on 10 percent solids by weight; a submarine outfall with diffuser; and removal of existing sludge deposits in Whatcom Waterway adjacent to the Georgia-Pacific mill to land disposal.

2. **City of Bellingham**—adequate collection and treatment of unintercepted waste discharges; submarine outfall and an engineering study to determine whether a higher degree of treatment than primary will be necessary in order to meet water quality standards.

Birch Bay

Secondary treatment with disinfection should be provided for all municipal and domestic wastes generated in this area prior to discharge to Birch Bay to insure adequate water quality for the expected water-contact recreational activities in this area.

A large number of waste treatment plants will be needed to handle the expected recreational growth. Intense recreational activities are expected in the mountainous areas near Mt. Baker and Mt. Shuksan, especially with the establishment of a North Cascades National Park; on nearby Lake Whatcom; and on the marine waters, particularly in the vicinity of Birch Bay.

Considerable investment will be required to meet the present and future waste collection and treatment requirements.

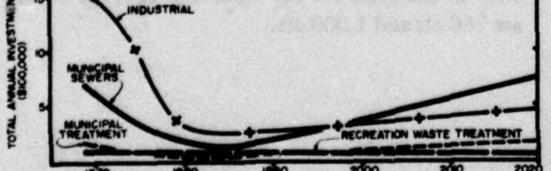


FIGURE 2-7. Relative required rates of waste treatment investment for Nooksack-Sumas Basins.

The estimated present and projected municipal, industrial, and recreational waste treatment investment requirements are presented in Table 2-6, Table 2-7 and Figure 2-7. Present investment requirements are large, reflecting the costs associated in compliance with the State Implementation Plans.

Following the higher initial investment, costs reflect the investment required to keep pace with urban and industrial growth and replacement of facilities.

Industrial costs[1] will total $10,258,000 by 1980 with additional sums of $6,951,000 by 2000 and $9,000,000 by 2020.

Sewer construction[1] will amount to about 75 percent of the total municipal cost, which is expected to be $4,038,000 by 1980, $10,080,000 by 2000, and $26,080,000 by 2020.

The cost[1] of waste treatment facilities for recreation areas will total $1,500,000 by 1980 with an additional $2,000,000 by 2000 and an additional $2,000,000 by 2020.

Sources of funding are shown in Figure 2-8. The Federal Construction Grants program will need to invest $445,000 by 1980, an additional $618,000 by 2000, and $1,800,000 more by 2020. For the same periods the State will need to invest $220,000, $310,000 and $800,000, respectively. Federal investment in sewers will amount to $350,000 by 1980 with an additional $1,260,000 by 2000 and an additional $2,600,000 by 2020. Federal investment in waste treatment facilities for recreation areas will total $960,000 by 1980, $1,650,000 from 1980-2000, and $1,800,000 from 2000-2020.

FLOW REQUIREMENTS

With the installation of adequate treatment facilities in conformance with State standards and

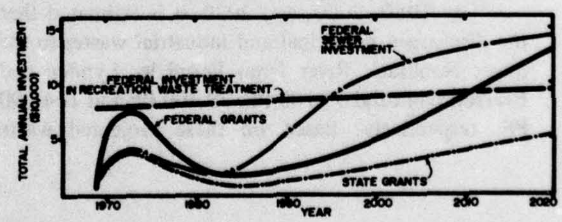


FIGURE 2-8. Government investment requirements[1] for waste collection and treatment in the Nooksack-Sumas Basins.

[1] Costs are not amortized.

TABLE 2-6. **Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Nooksack-Sumas Basins**

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$207	$149	$115
Disinfection	31	18	15
Outfalls	167	69	65
Interception and sewer system			
a. Municipal	124	85	75
b. Industrial	31	18	15
Combined sewage infiltration and overflow correction	64	25	15
Advanced waste treatment in recreation, lakes, areas, etc.	61	87	79
Sub-Total	$685	$451	$379
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 9	$ 9	$ 11
Evaluations—dispersion areas, ecological, productivity	47	6	7
Information system, quality control, plant operation improvement, operation research	28	9	9
Sub-Total	$ 84	$ 24	$ 27
OPERATION AND MAINTENANCE[2]	$ 234	$ 609	$ 617
TOTALS	$1,003	$1,084	$1,023

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest)

in-plant waste controls, future waste discharges to the waters of the Nooksack-Sumas Basins will be considerably less than they are at the present time.

By 1980, 2000, and 2020, it is estimated that the discharged municipal and industrial wastes to the lower Nooksack River from Ferndale, Lynden and Everson will total 39,100 PE, 78,400 PE and 164,000 PE, respectively. Based on these projected waste discharges, the minimum flows required in the lower Nooksack River for the maintenance of adequate water quality, assuming a single-point waste loading at Lynden, have been determined to be 180 cfs by 1980, 350 cfs by 2000 and 725 cfs by the year 2020. The 7-day and 30-day lowflows expected to occur once in ten years for the Nooksack River at Lynden are 760 cfs and 1,000 cfs.

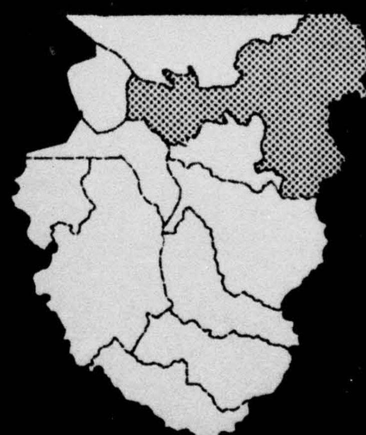
TABLE 2-7. Total amortized capital and operational costs—Nooksack-Sumas Basins

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	20.3	6.7	3.7
Municipal treatment	2.0	2.4	2.7
Municipal sewers	12.0	14.5	15.4
Recreation	3.0	1.9	0.8
Advanced waste treatment	3.1	4.4	4.0
Sub-Total	40.4	29.9	27.1
Water quality engineering management and evaluation	1.0	0.5	0.6
Operation and maintenance	2.3	12.2	12.3
Total	43.7	42.6	40.0

OTHER MEASURES

Adequate water quality monitoring is an essential element for the water quality program in this area. The existing State water quality surveillance program for fresh waters should be continued, and new stations should be established, as industrial discharge and/or population increases place additional pressures on the receiving watercourse. The existing station locations, characteristics measured, and sampling frequency are described in the Regional section and are shown in Figures 1-10 and 1-14. In addition, stations to monitor lakes and ground-water should also be established.

Skagit-Samish Basins



SKAGIT - SAMISH BASINS

INTRODUCTION

The physical features of the Skagit-Samish basins are varied as they comprise marine islands, reclaimed tidal lands, and mountains. The eastern part of this area lies mostly in Mount Baker National Forest which includes an extensive alpine area of high ridges and peaks of the Cascades. The western section of the basins consists largely of the Skagit-Samish lowlands. This lowland area encompasses the tideflats, delta plains, and valley bottomlands of the Skagit and Samish Rivers. The Skagit-Samish Basins contain approximately 3,044 square miles of land and inland waters.

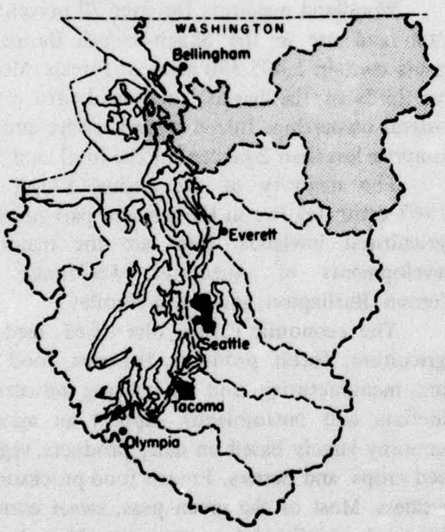


FIGURE 3-1. Location of the Skagit–Samish Basins in the Puget Sound Area.

The basins are rich in water resources which include the Skagit River, Samish River, several small streams, and over 150 square miles of marine waters. The Skagit River, originating in a network of narrow, precipitous canyons in Canada, is the largest river in the Puget Sound Area. The Skagit River leaves its mountainous catchment area near Marblemount, where it is joined by the Cascade River. Below Marblemount it flows through flood and glacial outwash plains in the vicinity of Sedro Woolley. About eight miles from Puget Sound it branches into two major distributaries that flow into Skagit Bay. The Cascade, Sauk, and Baker Rivers are its largest tributaries. The Suiattle River is a large and important tributary of the Sauk River.

An important aspect of the Skagit is the three power dams of Seattle City Light. The uppermost is Ross Dam, which forms a reservoir 24 miles long extending into Canada. The reservoir has more than 1,434,000 acre-feet of total storage. It is estimated that Ross Dam controls one-third of the annual runoff from the upper Skagit. South of Ross lies Diablo Dam, which forms another reservoir that extends up to Ross Dam. Farther downstream is the Gorge Dam, backing up a deep, narrow pool of water. Two other dams, the Upper and Lower Baker, are on the Baker River. The lower dam forms 8-mile long Lake Shannon, and the upper forms Baker Lake. They are used for both power and flood control purposes.

The Samish River heads in rough upland terrain south of Bellingham and drains unregulated into Samish Bay. Friday Creek, the outlet of Samish Lake, is its main tributary.

The marine waters include a number of offshore islands and bays. Fidalgo, Cypress, and Guemes are the three largest islands. The major marine inlets

PHOTO 3-1. Tideflats and bottomlands comprise the western part of the basin.

PHOTO 3-2. Glacier Peak area is characteristic of the basins' rugged, eastern portion.

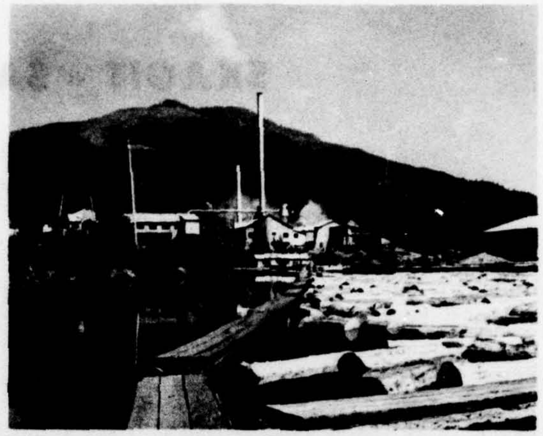


PHOTO 3-4. The timber industry is one of the mainstays of the economy.

of the area are Samish Bay, Padilla Bay, Fidalgo Bay, and Skagit Bay.

Soils of the extensive deltas are made up of alluvial materials. They consist of silty clay, sandy silt, and silty fine sand laid down by the Skagit and Samish Rivers. Natural drainage of the sandy soils is generally good, while that of the clay soil is poor. The upland soils, lying between the flood plain and the

PHOTO 3-3. Diablo Dam on the Skagit River.

valley walls, consist of a gravelly, sandy silt derived from the weathering of glacial drift.

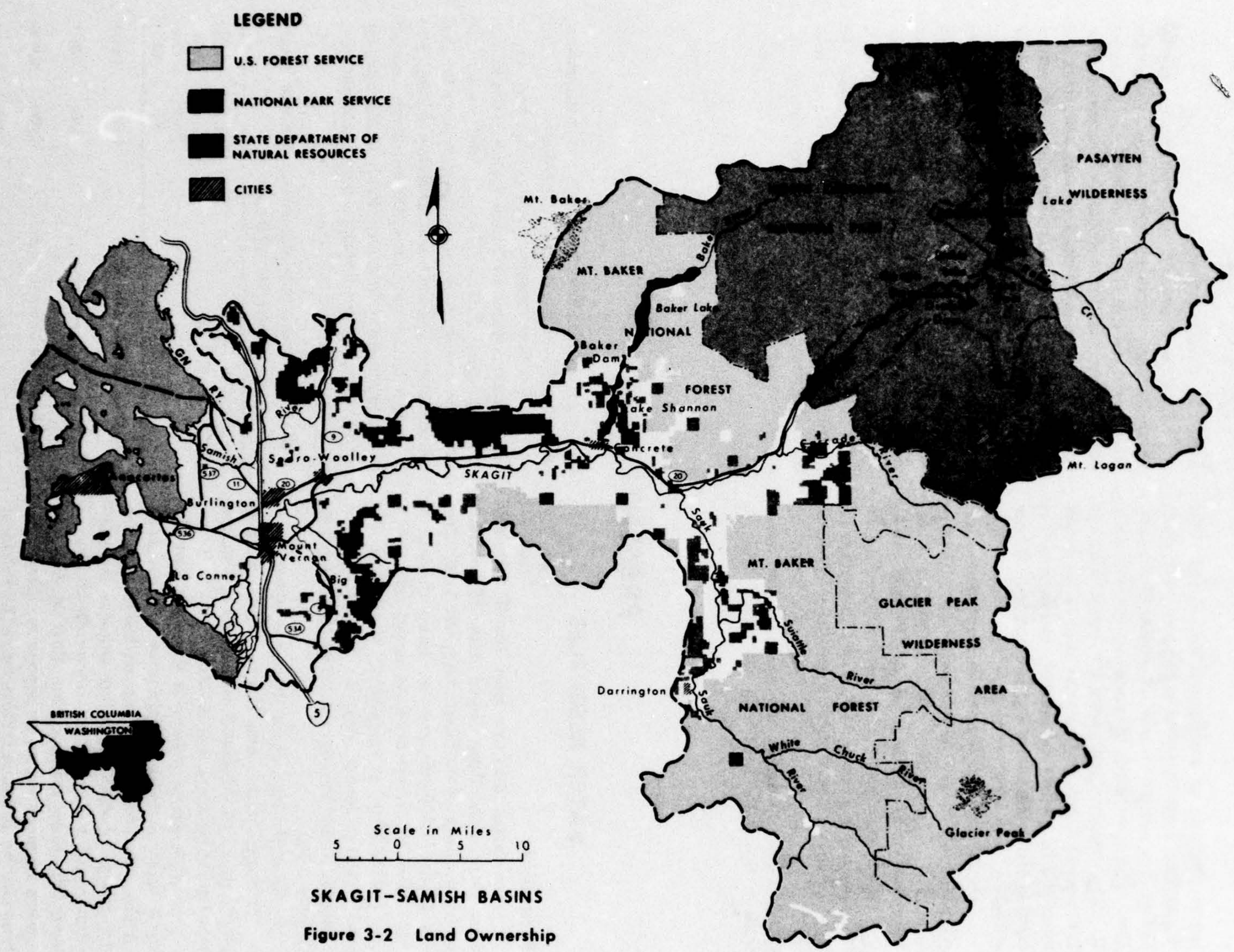
Woodland accounts for over 70 percent of the total land use in the Skagit-Samish Basins. These basins contain 1,405,330 acres of forests. More than two-thirds of the basins' total land area is held in Federal ownership. Inland waters–rivers and lakes–comprise less than 2 percent of the total land area.

The majority of the basins' 57,000 people (1967 estimate) live in the western part on the rich, agricultural lowlands. Here are the major urban developments of Anacortes, LaConner, Mount Vernon, Burlington, and Sedro Woolley.

The economic base is diversified, made up of agriculture, forest products, fisheries, food processing, manufacturing, and oil refining industries. The tideflats and bottomlands support an agricultural economy largely based on dairy products, vegetables, feed crops, and berries. Frozen food processing is big business. Most of the green peas, sweet corn, cauliflower, broccoli, and carrots are shipped to local processors in Mount Vernon, Burlington, and LaConner.

Since the earliest settlement, lumbering has been one of the most important elements of the economy. The timber industry today primarily consists of log output, most of which is trucked to pulp and lumber mills in Everett and Bellingham. Short-fiber pulp from hardwood is produced in the basins at the Scott Paper Mill in Anacortes.

The large migratory runs of salmon and steelhead in the Sakgit River provide a significant sports and commercial fish resource. The Skagit River is the



SKAGIT–SAMISH BASINS

Figure 3-2 Land Ownership

largest producer of anadromous fish in the Puget Sound Area. Large runs of pink, chinook, coho, chum and sockeye salmon occur in all months of the year. The largest sport catch of winter steelhead trout in the State usually comes from the Skagit. Plants in LaConner and Anacortes process most of the Skagit River and Skagit Bay commercial catches as well as some of the catches from Puget Sound and offshore waters.

Oil refining is important on March Point near Anacortes where two refineries—Texaco and Shell—operate. The Skagit Steel and Iron Works at Sedro Woolley, founded in 1902, plays a dominant role in the basins' manufacturing. Other industries include two chemical plants and several meat-packing companies. Water-transport oriented industries depend on the port facilities at Anacortes. Petroleum, forest and fish products, chemicals, and sand-and-gravel move through this port. Traffic on the Skagit River is mainly confined to rafting logs.

Outdoor recreation and tourism are rapidly increasing their economic importance. Recreation resources in the basins are exceptional, and unlimited opportunities exist for most outdoor recreation activities. The area is especially endowed with fresh and saltwater areas that are recreation and scenic attractions which North Cascades National Park, Ross Lake National Recreation Area, Pasayten Wilderness Area, and additions to the Glacier Peak Wilderness Area have been authorized through passage of Public Law 90-544. Public Law 90-542 designates a portion of the Skagit River and its tributaries as a potential addition to the National and Scenic Rivers System with studies to be expeditiously undertaken to determine suitability. State highway 20, North Cross-State Highway, which is under construction, will provide access to much of this area.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The Skagit produces more runoff than any other river in the Puget Sound Area. The average annual discharge of the Skagit River into Skagit Bay was about 11,800,000 acre-feet during the period 1931-1960. Its average discharge ranges from 4,418 cfs (1931-1960) at Newhalen to 16,250 cfs (1931-1960) at Mount Vernon. The minimum discharge at Mount Vernon was 2,740 cfs recorded in October, 1942.

Above the Whitechuck River, the 30-year average discharge of the Sauk River is 1,144 cfs. For practically all of the Sauk-Suiattle River system, the mean annual discharge is 4,387 cfs.

The numerous glaciers in the basins have the effect of supplementing streamflows and practically eliminate the occurrence of extreme low flows during dry summer months. At higher altitudes the minimum runoff occurs in February or March, but at lower elevations the minimum flow in tributary streams normally occurs in September. Streamflow from October to March is characterized by a series of sharp rises superimposed on an increasing base flow which is highest in December. As temperatures begin to rise in April, snowmelt causes a rise in streamflow which usually reaches a peak by mid-June.

A low-flow frequency analysis has been made for 25 stations within the Skagit-Samish Basins by the U.S. Geological Survey. The 7-day and 30-day low flows for a recurrence interval of ten years for five selected stations in the basins are shown in Table 3-1.

Ground water occurs at shallow depths over all of the Skagit River delta area. Fairly large yields, up to 600 gpm, can be developed from the major sand and gravel aquifers in this area.

TABLE 3-1. Low flow frequency: Ten-year recurrency interval Skagit-Samish Basins

Station	7-Day Low Flow cfs	30-Day Low Flow cfs
Skagit River at Newhalem, Wash.	1,200	1,600
Sauk River near Sauk, Wash.	860	1,050
Skagit River near Concrete, Wash.	4,700	5,500
Skagit River near Mt. Vernon, Wash.	5,100	5,800
Samish River near Burlington, Wash.	19.5	21

Recharge to aquifers in the delta area comes primarily from local precipitation. In the upper areas of the Skagit Valley where the alluvium is much coarser than the fine-grained alluvium of the lower delta, recharge may come directly from the Skagit River. Aquifers in the low-lands are conservatively estimated to receive about 50,000 acre-feet of recharge annually.

The discharge of ground water is mostly into the Skagit and Samish Rivers and their tributaries. The amount discharged to marine waters is unknown.

Samish Island is a water-short area. Most of the local precipitation runs off because of a thick cover of relatively impermeable glacial till. Some water does percolate through fractures or permeable zones in the till to recharge aquifers below that have small area and varied permeability. These strata have been tapped by several wells that supply sufficient water for domestic use.

Marine Water

Samish Bay forms the southern portion of the Bellingham-Samish Bay system, and has a relatively stable surface layer of low salinity, weak and variable circulation and protracted flushing. This system has a relatively low capability for assimilating large waste influent flows.

Padilla and Fidalgo Bays are shallow, with most depths less than 60 feet. The deeper waters of Padilla Bay occupy a channel along the east side of Guemes Island which joins Bellingham-Samish Bays to the north and Guemes Channel to the east.

Guemes Channel, a narrow, moderately deep channel, carries large tidal flows between Padilla-Fidalgo Bays and Rosario Strait. It has been estimated that from two to three times the volume of water that is contained in the Fidalgo-Padilla Bay tidal prism normally passes through the channel on ebb tide. The large volume of additional water carried out into Rosario Strait comes from the water masses to the north, since the inflow from Swinomish Channel is neglible. Thus, significant portions of the Bellingham-Samish Bay waters are carried out through this system. On flood tide, inflowing water to the bays about equals the intertidal volume being filled. The large water exchange results in strong prevailing tidal currents in Guemes Channel. The large flows and associated turbulence cause rapid dispersion and transport of inflows into the channel.

Skagit Bay receives the flows of the Skagit River, which exerts a significant effect on this system. The Swinomish Channel connects Skagit Bay with Padilla Bay. There is little exchange of waters between the two bays through the channel.

WATER QUALITY

Fresh Water

Water quality of the Skagit-Samish Rivers has been measured on a routine basis since July, 1959.

TABLE 3-2. Surface water quality Skagit–Samish Basins

Item	Discharge (cfs)	Dissolved solids (mg/l)	mg/l: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	mg/l: Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2) (mg/l)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	mg/l: Dissolved oxygen	Oxygen saturation (%)	Hardness: Total	Hardness: Noncarbonate	Coliform (MPN)
SKAGIT RIVER AT MARBLEMOUNT — JULY 1959 THROUGH 1966																											
Maximum	11,700	44	10.0	1.4	1.2	0.9	36	0	5.2	0.5	0.2	1.1	70	0.08	---	6.5	0.23	0.04	8.0	5	5	15.2	13.3	131	30	2	230
Mean	---	32	7.5	0.8	0.8	0.5	26	0	3.7	0.1	0.1	0.3	51	0.01	---	5.1	0.07	0.01	---	---	---	8.3	11.7	103	22	1	40
Minimum	4,120	18	4.0	0.1	0.6	0.2	15	0	2.2	0.0	0.0	0.0	30	0.00	---	3.0	0.01	0.00	6.8	0	0	3.8	9.7	89	12	0	0
Number	29	36	36	36	36	36	36	23	36	36	36	36	36	33	---	36	33	11	36	36	15	37	37	37	36	36	37
SAUK RIVER ABOVE WHITECHUCK RIVER NEAR DARRINGTON — JULY 1959 THROUGH 1961																											
Maximum	2,500	52	7.0	1.7	2.8	0.9	29	0	7.0	1.8	0.2	0.9	66	0.08	---	13.0	0.28	0.02	7.9	15	40	13.0	13.7	106	24	2	2,400
Mean	---	32	5.1	1.0	1.3	0.5	20	0	3.7	0.7	0.1	0.2	44	0.02	---	8.0	0.09	0.01	---	---	---	7.4	11.8	101	17	0	153
Minimum	201	18	3.0	0.2	0.7	0.3	13	0	0.9	0.0	0.0	0.0	28	0.00	---	5.2	0.01	0.00	5.7	0	0	2.0	10.2	91	11	0	0
Number	17	17	17	17	17	17	17	4	17	17	17	17	17	17	---	17	17	2	17	16	15	17	17	17	17	17	17
BAKER RIVER AT CONCRETE — NOVEMBER THROUGH AUGUST 1965																											
Maximum	5,770	56	11.0	1.8	2.4	0.8	37	0	9.8	1.0	0.1	0.6	81	0.03	---	8.4	0.81	0.04	7.5	15	40	16.7	13.8	114	35	6	930
Mean	---	37	6.7	1.0	1.6	0.6	21	0	7.2	0.5	0.1	0.3	52	0.01	---	6.8	0.25	0.02	---	---	---	9.4	11.3	101	21	4	72
Minimum	332	24	4.5	0.5	1.1	0.3	15	0	5.0	0.2	0.0	0.1	38	0.00	---	4.7	0.09	0.00	6.9	0	0	4.0	9.6	90	14	1	0
Number	12	16	16	16	16	16	16	16	16	16	16	16	16	16	---	16	15	8	16	---	---	16	16	16	16	16	15
SKAGIT RIVER NEAR MOUNT VERNON — JULY 1959 TO PRESENT																											
Maximum	50,800	52	10.0	2.2	2.0	1.0	38	0	8.6	1.5	0.2	1.6	76	0.07	---	9.0	2.00	0.06	8.1	20	380	17.8	13.7	127	32	7	24,000
Mean	---	36	7.0	1.2	1.2	0.6	26	0	4.2	0.4	0.1	0.4	53	0.02	---	6.4	0.32	0.02	---	---	---	9.3	11.2	100	22	1	1,849
Minimum	6,380	0	4.5	0.3	0.7	0.2	16	0	2.0	0.0	0.0	0.0	36	0.00	---	4.7	0.01	0.00	6.3	0	0	4.0	9.3	80	13	0	0
Number	84	86	86	86	84	84	86	33	86	86	84	86	86	73	---	86	73	11	84	84	44	87	88	87	86	86	87
SAMISH RIVER NEAR BURLINGTON — JULY 1959 TO PRESENT																											
Maximum	764	71	12.0	4.3	4.2	1.4	52	0	7.1	4.0	0.6	4.7	108	0.08	---	12.0	1.80	0.04	7.6	40	90	19.0	13.0	105	44	6	11,000
Mean	---	40	7.4	2.2	2.8	0.7	30	0	4.8	2.2	0.1	2.2	71	0.03	---	7.9	0.40	0.01	---	---	---	9.7	10.8	97	27	3	1,003
Minimum	27	34	4.8	1.1	1.7	0.2	19	0	3.8	0.2	0.0	0.7	50	0.00	---	4.6	0.07	0.00	6.6	5	0	3.8	7.0	63	17	0	0
Number	29	36	36	36	36	36	36	23	36	32	36	36	36	33	---	36	32	11	36	36	16	39	39	39	36	36	39

The following discussion is based on this data which was gathered from five monitoring stations as presented in Table 3-2.

Chemical Dissolved solids concentrations in the Skagit River at Marblemount have ranged from 23 to 44 milligrams per liter, and values of hardness have ranged from 14 to 30 mg/1. Mineralization of Skagit River water increases only slightly downstream. Near Mount Vernon the dissolved solids concentration ranged from 22 to 52 mg/1, and hardness ranged from 15 to 32 mg/1. Water in the Samish River is slightly more mineralized than water in the Skagit River. Maximum dissolved solids concentrations and values of hardness for this river are 71 and 44 mg/1, respectively.

Phosphate values are very low. Six years of water quality data have not indicated concentrations over 0.10 mg/1. Nitrate values are also low, the maximum recorded value being 0.34 mg/1. The Samish River, however, carries moderately high nitrates with a mean concentration of 0.51 mg/1 for the period of record.

High iron concentrations are common, especially in the vicinity of the Skagit River. Ground-water increases in salinity towards the bay areas, and fresh water cannot be obtained in some places along the shoreline. Significant encroachment of saline water has not been observed, however.

Bacteriological The bacteriological water quality data for the Skagit River show a general trend of decreasing quality downstream from Marblemount. The most probably number of coliform organisms per 100 ml (MPN) ranged from a low of 0 to a high of 230 at Marblemount, but is usually less than 50/100 ml. This low average is typical of streams draining remote mountain areas. At Mount Vernon the MPN has ranged from a low of 0 to a maximum value of 24,000. The normal range for the MPN for this station is from about 91 to 4,600. Bacteriological water quality of the Sauk and Baker Rivers generally indicates better quality than the Skagit River. The maximum recorded MPN values obtained on the Sauk River and Baker River are 2,400 and 930 coliforms per 100 ml, respectively. The MPN values obtained for Samish River near Burlington indicate a range from 0 to 11,000 coliforms per 100 ml. Table 3-3 gives a summary of coliform concentrations taken from basic data sampling.

Physical. The Skagit River and its major tributaries are relatively fastmoving water courses. Dissolved oxygen concentrations throughout the length of the Skagit River are near saturation. At Mount Vernon, on the lower Skagit River, DO concentrations have ranged from a low recorded value of 9.3 mg/1 to a high of 13.7 mg/1. The recorded low DO concentrations on the Sauk and Baker Rivers were 10.2 and 9.7 mg/1. Dissolved oxygen concentrations in the Samish River Basin have ranged from 7.0 mg/1 to 13.0 mg/1.

Generally cool stream temperatures occur in

TABLE 3-3. Summary of coliform concentrations, Skagit-Samish Basins

	MPN/100 mls							
	Less Than 240		240-1,000		1,000-2,400		Greater Than 2,400	
Watercourse	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.
Skagit River (Marblemount)	40	100	0	0	0	0	0	0
Sauk River (Nr. Darrington)	16	94	0	0	0	0	1	6
Baker River (Concrete)	14	93	1	7	0	0	0	0
Skagit River (Mount Vernon)	45	48	24	26	2	2	22	24
Samish River (Burlington)	13	29	24	53	1	2	7	16

Source: Washington Water Pollution Control Commission.

the Skagit River. The temperature of the Skagit River at Mount Vernon has reached a maximum recorded value of 64°F (15.2°C) recorded for the Skagit River at Marblemount, 55.4°F (13.0°C) for the Sauk River near Darrington, 62°F (16.7°C) for the Baker River at Concrete. Maximum temperatures of the Samish River near Burlington are higher than the Skagit River. A maximum of 66.2°F (19.0°C) was recorded.

Fluvial sediment in the upper Skagit Basin is of glacial origin. Non-glacial streams normally transport little sediment except during periods of high runoff. Analysis of data obtained in 1965 and 1966 indicates that the Sakgit River can be expected to transport a sediment load of ten million tons during a year of normal streamflow. Observed concentrations of suspended sediments in the Skagit River near Mount Vernon ranged from 19 to 654 mg/l during 1965 to 1966.

PHOTO 3-5. Streams in the basins transport large amounts of sediment during periods of high runoff.

The Samish River, heading in low mountains south of Bellingham, may transport a total sediment load of 10,000 tons during a year of normal streamflow. When the flow of the Samish River near Burlington is 5,000 cfs, a daily sediment load of about 4,000 tons can be expected. Observed concentrations of suspended sediment ranged from 6 to 60 mg/l during 1965 and 1966.

Marine Waters

The Samish River dilutes the marine waters locally in Samish Bay, but has little effect elsewhere. The surface layer in Padilla Bay is affected mostly by local drainage. Thus, the surface salinity of these bays varies only from about 27 to 30 o/oo over the period of a year.

Measurements of dissolved oxygen, pH, water transparency, sulfite waste liquor (SWL) and phenols in the bays show water quality properties approaching those of ambient sea water in most areas. The oxygen content of the surface layer will vary from 7 to 13 mg/l and is somewhat dependent upon biological activity. Samples in Guemes Channel just off Anacortes showed high concentrations of SWL and occasional dissolved oxygen levels near zero. These were localized and did not appear to persist throughout the channel. Maximum SWL values observed in past surveys showed levels ranging from 20 to 40 ppm in northern Padilla Bay and 4 to 14 ppm throughout the remaining areas except at Anacortes in Guemes Channel. The higher levels in northern Padilla Bay result from inflows of Bellingham Bay waters carrying higher concentrations of dispersed SWL.

In the Skagit Flat area, the fresh water layer was frequently observed nearly to the bottom, and extended from the mouth of the Skagit River north to Deception Pass and south into Saratoga Pass. Surface temperatures varied from an average low of 42.8°F (6°C) in winter to about 62.6°F (17°C) in summer. The oxygen content of this water was above 6 mg/l and completely saturated most of the time. The phosphate concentrations varied from a low of 0.05 mg/l to over 0.27 mg/l with the fresher water usually being deficient in phosphate while being high in oxygen.

SOURCES OF WASTE

The raw municipal and industrial wasteload generated in the Sakgit-Samish Basins approximates over one million population equivalents, of which less than two percent is presently removed by waste treatment before being discharged to fresh and marine waters. The waters receiving the largest quantities of wastes in relation to the total basin area are Guemes Channel (80 percent) and the lower Skagit River (15 percent).

The quantities and general location of waste production and discharges in the basins are shown in Figure 3-3. Sources of wastes contributing to the degradation of fresh and marine waters are summarized in Table 3-4. Compliance with the Implementation and Enforcement Plan will substantially reduce the quantities and strength of discharged wastes.

TABLE 3-4. Summary of municipal and industrial wastes, Skagit-Samish Basins

Watercourse	Estimated Population Served	Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Normal Waste Discharge PE	Seasonal Waste Discharge PE
Skagit River						
Diablo	265	265	--	Primary	190	--
Newhalem	225	225	--	Primary	180	
Sedro Woolley	3,500	6,000	--	Primary	4,200	--
Metals	--	75	--	Oil, separ.	50	--
Food processing	--	800	--	None	800	--
Burlington	3,000	3,600	--	Secondary	800	--
Food processing	--	5,700	--	None	5,700	
Food processing	--	--	40,200	None	--	40,200
Mt. Vernon	8,000	13,000	--	Primary	9,000	--
Food processing	--	8,300	66,000	None	8,300	66,000
Avon						
Food processing	--	8,200	10,000	None	8,200	10,000
Samish River						
Edison						
Food processing	--	1,900	--	None	1,900	--
Guemes Channel						
Anacortes	7,000	8,000	--	Primary	4,800	--
Food processing	--	800	39,820	None	800	39,820
Paper & allied	--	778,000	--	None	778,000	--
Oil refining	--	2,000	--	Secondary	500	--
Fidalgo Bay						
Lumber & wood	--	6,000	--	None	6,000	--
Oil refining	--	2,000	--	Secondary	600	--
Padilla Bay						
Chemicals	--	--	--	Neutralization	--	--
Skagit Bay						
Skagit Co. SD No.1	--	250	--	Primary	150	--
Swinomish Slough						
LaConner						
Food processing	--	--	37,700	None	--	37,700
TOTAL[1]	21,990	845,000	4,000	--	829,300	194,000
Municipal	--	31,000	--	--	19,100	--
Industrial	--	814,000	4,000	--	810,000	194,000

1 Figures are rounded.

2 PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

Fresh Water

Municipalities and industries along the Skagit and Samish Rivers produce about 48,000 PE of raw organic wastes daily. During the food processing season, an additional 116,000 PE are produced each day. The production of wastes exceeds 164,000 PE during the peak season.

These wastes are given varying degrees of treatment. Two percent of this total wasteload receives secondary treatment; 12 percent receives

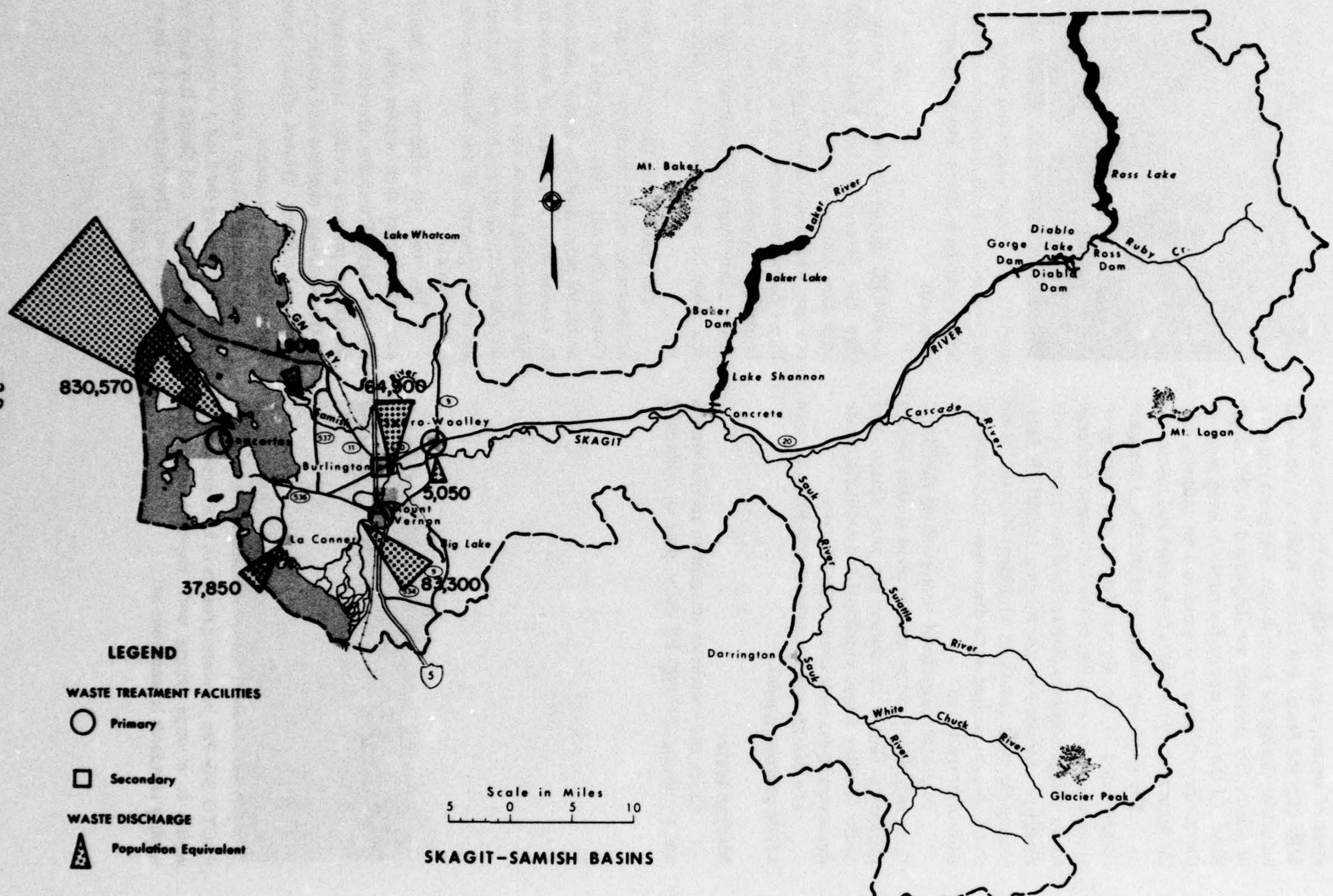


FIGURE 3-3. Location of major waste discharges

primary treatment; and 85 percent of the total wastes are dumped into the streams untreated. After treatment of wastes, a total of 155,500 PE are discharged daily into the Skagit and Samish Rivers by cities and industries during the peak season. The great majority of wastes (99 percent) are discharged to the Skagit River. Of the total wastes discharged to fresh water in the basins, 90 percent is generated by industry and the remaining 10 percent is from cities and towns.

The major waste sources to the Skagit River are concentrated in the Mount Vernon and Burlington areas, where three-fourths of the total waste discharge to the Skagit originate. Several food processing plants discharge untreated wastes totaling 14,000 PE daily. During the peak season an additional 100,000 PE are discharged. Municipal waste discharges total 9,800 PE daily after treatment.

Two other significant sources along the Skagit River include a food processing plant at Avon, which discharges 18,000 PE during the peak season, and Sedro Woolley where municipal and industrial waste discharges to the river total 5,000 PE daily.

The Samish River receives 1,900 PE daily from a food processing plant.

Marine Water

Cities and industries adjacent to marine waters are producing 797,000 PE daily, plus an additional 77,500 PE during the food processing season. Less than one percent of this total wasteload receives secondary treatment; less than one percent receives primary treatment; and 98 percent is released into Puget Sound untreated. As a result, wastes from an equivalent population of 868,400 are being discharged into Puget Sound. Practically all of the waste discharges to marine waters are generated by industry.

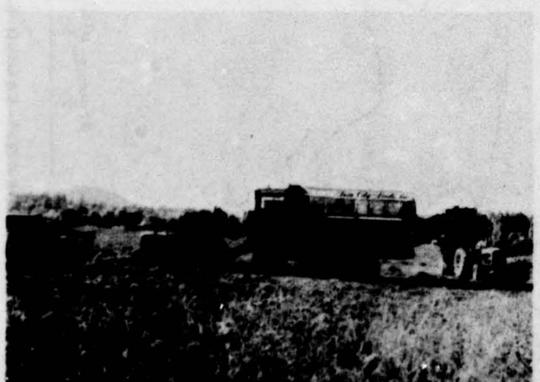


PHOTO 3-6. Pea harvesting results in food processing wastes to a water course until implementation of quality standards is accomplished.

PHOTO 3-7. Food processing wastes are discharged to Swinomish Slough, a popular recreation waterway, before implementation and enforcement of quality standards.

The major waste source is the Scott Paper mill at Anacortes which discharges 778,000 PE daily to Guemes Channel. This pulp mill is responsible for about 90 percent of the basins' total waste discharge to marine waters. The city of Anacortes and several fish processing plants also discharge wastes totaling 45,900 PE to Guemes Channel. This channel receives about 95 percent of the basins wasteload going to marine waters.

The two oil refineries on March Point both adequately treat their wastes prior to discharge to Fidalgo Bay. Treatment includes oil collection and separation, primary clarifier, and biological treatment of the combined clarified oily wastes and septic tank (sanitary) effluent. Treated effluent meets the Washington State requirements.

Swinomish Slough receives wastes equivalent to 37,700 PE during the food processing season. Fidalgo Bay, Padilla Bay, and Skagit Bay also receive wastes from industries. The discharges to these three marine areas total 6,800 PE.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the Skagit-Samish Basins are summarized in Table 3-5, which focuses on principal watercourses and problem areas in the basins. The table also indicates the water quality classification established by the State for each watercourse that, in turn, defines the type of water usage to be protected in the area.

As shown in Table 3-5, most surface waters are used for fish passage and rearing. An enormous variety of ecological environments exists in the area and all of them are used by certain anadromous or resident fishes. All but a few of the total number of the species recorded in the entire Puget Sound Area exist somewhere in the Skagit system. The Samish River system also supports abundant fish stocks. The tidelands of Skagit, Padilla, and Samish Bays; the island beach areas; and the mainland shorelines support extensive shellfish stocks.

All five of the Pacific salmon species utilize the Skagit-Samish Basins' drainages. These include spring, summer, and fall runs of chinook, coho, pink, chum, and sockeye salmon. In addition, there are summer and winter runs of steelhead, searun cutthroat trout and searun Dolly Varden.

The marine waters of the basins are generally restricted to the more shallow expanses of Skagit and Samish Bays and Rosario Strait. Principal marine fish found in these waters include members of the cod family, lingcod, flounder, surf perch, rockfish, herring, dogfish, shark, and ratfish. The two most prevalent species of shellfish are Dungeness crab and softshell clam.

Salmon produced or reared in the Skagit-Samish Basins contribute to United States and

TABLE 3-5. Water uses and Quality objectives, Skagit-Samish Basins

Use Intensity
L—Light
M—Medium
H—Heavy

Watercourse	Assigned Class[2]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Skagit River, Mouth to River Mile 17	A			H	H					L	L[1]		L			H	H					L	L	
Skagit River, River Mile 17 to Canadian Border	AA			H	H	H							M		L	H	H		L	M				H
Padilla, Samish Bays; Guemes Channel	A			H	H					H	H	H	H		H	H	H					H	M	
Possession Sound, Port Susan Saratoga Passage, & Skagit Bay	A			H	H					H	H	H	H		H	H	H					H	M	
Samish River, mouth to headwaters	A[3]			H	H	H							M		H	H	H		L	L	L			
Baker River	AA[3]			H	H	H							H		L	H	H		L	L	L			H
Sauk River	AA[3]			H	H	H							M		L	M	H		L	L	M			M
Friday Creek from mouth to Samish Lake	A[3]			H	H	H							H		H	H	H		L	L	M			
Cascade River	AA[3]			H	H	H							H		L	H	H		L					
Suiattle River	AA[3]			H	H	H							H		L	M	H		L	L	L			

[1] Indian Fishery.

[2] See Table 1-5.

[3] Tentative assigned class, information bulletin on intrastate water quality standards. Washington Water Pollution Control Com. 1969.

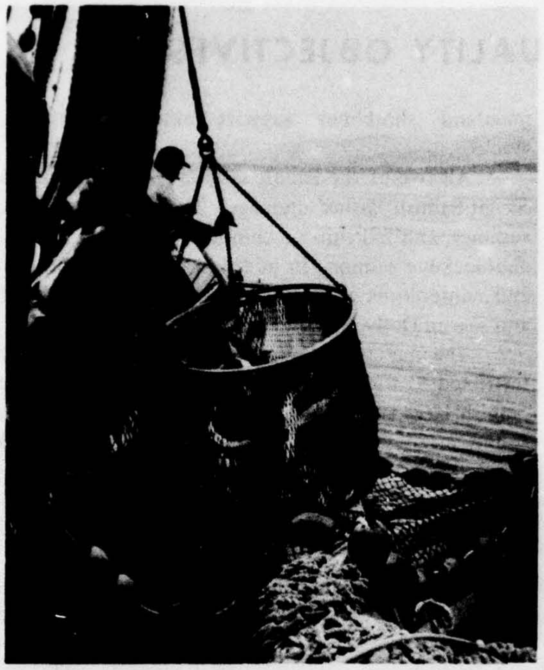


PHOTO 3-8. Salmon produced in the basins contribute to commercial fisheries and to the economy.

Canadian Pacific Ocean sport and commercial fisheries and to fisheries existing through the Strait of Juan de Fuca and upper Puget Sound. The estimated average annual contribution to these fisheries from 1956 to 1965 from the Skagit-Samish Basin amounted to 1,008,820 salmon.

Surveys estimate that 180,000 man-days were spent in catching 36,000 steelhead. Searun cutthroat data shows 50,000 man-days spent in catching 30,200 fish.

Resident fish supported 363,200 man-days of effort for a total harvest of 1,413,300 trout and 169,000 other game fish from lakes, ponds, and reservoirs. Similarly, 153,500 man-days of effort were spent fishing for game fish other than steelhead in streams; and 508,300 were harvested.

Marine fish species in the basin receive moderate to heavy sport and commercial fishing effort. Commercial harvest is conducted principally by otter trawl vessels.

Commercial and sport harvest of shellfish species is considered moderate for the basins' waters.

The Skagit-Samish Basins rank fifth in the Puget Sound in recreational water uses. In 1960, the number of water-related recreation days was 2,200,000. By 1980 this will increase to 4,300,000. At the present time, fishing is the most popular outdoor recreational activity. All of the principal watercourses in the area are utilized by fishermen. Camping and boating are two other pastimes enjoyed by large numbers of people. It is estimated that by 2020 there will be a ninefold increase in camping activity, making it by far the most popular of the outdoor recreations.

The area has long been famous for its mountains, wilderness, streams, lakes and saltwater, islands, and shorelines. The Skagit River is the largest river in the Puget Sound Study Area and the most significant for recreation. The Baker, Diablo, and Ross Reservoirs are popular recreation attractions. In 1964, there were 126 publicly-administered outdoor recreation areas within the basin.

Outstanding natural areas included: Little Mountain Park in Mt. Vernon; Baker Hot Springs Geological Area; Rainbow Falls Scenic Area; and North Fork Falls Scenic Area. The North Cascade Mountains are immensely valuable in recreation resources. Much of the area is characterized by spectacular mountain scenery unsurpassed in the United States. The North Cascades National Park, which encompasses the Picket Range country and the Eldorado Peaks vicinity, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area were authorized by Public Law 90-544 which also designates the Pasayten Wilderness Area.

The only significant diversion of water from the Skagit River for municipal and industrial purposes is an indirect one by Anacortes along the lower reach near Mount Vernon. Anacortes obtains its supply from two Ranney Wells, which are infiltration galleries supplied primarily by the Skagit River. The average daily requirements met from the source amount to about 24 cfs.

Navigation on the waters surrounding Anacortes is extremely heavy. The 1963 foreign and domestic coastwise traffic of 4,411,232 tons was second only to Seattle's traffic. In 1963, the domestic internal traffic was over 2,000,000 tons.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, for most watercourses in the Skagit-Samish Basins, the water quality class is either excellent (A), or extraordinary (AA), with the objectives being to meet or exceed the quality requirements for all uses.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs occur primarily in marine waters, where fish processing, pulping, and municipal waste discharges create unsatisfactory water quality conditions. The State-Federal water quality standards for dissolved oxygen and toxic or deleterious concentrations of pulp mill wastes are not being met in Guemes Channel and Padilla and Samish Bays.

The Scott Paper Company pulp mill located in Anacortes is the major source of wastes now discharged to Guemes Channel. Tidal currents in the channel provide conditions suitable for assimilating residual waste discharges. However, pulping wastes discharged by the Scott Paper Company will produce sulfite waste liquor concentrations of 10-10,000 ppm SWL in the vicinity of the outfall. These concentrations are injurious to marine life and adversely affect water quality for most uses. Further, they produce a surface patch of highly colored, aesthetically displeasing wastewater over the outfall and under the docks fronting the city of Anacortes.

Food processing wastes containing significant quantities of settleable solids are discharged into the marine waters on a seasonal basis by several fish packing plants.

Possession Sound, Port Susan, Saratoga Passage and Skagit Bay receive wastes from small settlements and several fish canneries. Swinomish Slough, in particular, receives a large load of untreated food processing wastes during the summer which impairs the aesthetic, boating, and recreational uses of this popular watercourse.

Bacterial standards on the lower Skagit River are not being met. High concentrations of coliform organisms in the lower reaches of the river are most probably due to the domestic and industrial waste discharges from the Mount Vernon and Burlington areas. Wastes produced by livestock may also be significant in contributing to the total bacterial count in the river. At times, silt from private gravel washing operations has been destructive to fish and deleterious to other water uses. No water quality needs exist for ground-water in the basins.

FUTURE NEEDS

The principal factors expected to affect future fresh and marine water quality in the Skagit-Samish Basins will be the growth in population, industry, agricultural production and recreation. As this growth occurs, the production of wastes and water quality problems will likewise increase. Forecasts on the quantities and location of wastes are the basis for the means to preserve water quality and to protect the water uses of any given watercourse.

The 1967 population of 57,000 persons in the Skagit-Samish Basins is projected to increase about 16 percent by 1980, 56 percent by 2000, and 113 percent by 2020. It is expected that the Mount Vernon-Burlington-Sedro Woolley Service Area s are expected to grow at the same rate.

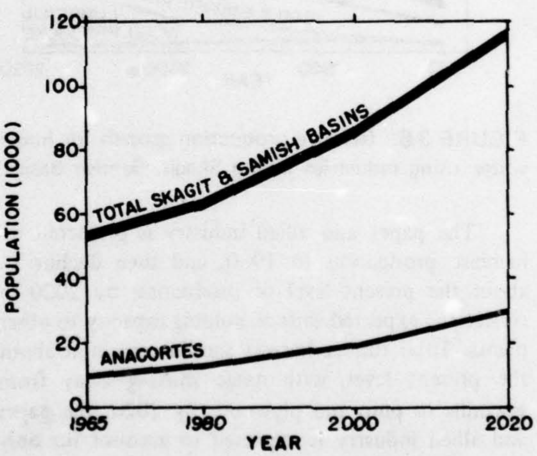


FIGURE 3-4. Projected population for Skagit–Samish Basins.

Production growth for the major water using industries in the Skagit and Samish Basins is expected to realize a 2.7-fold increase between 1980 and 2020 in terms of value added.

The petroleum and food and kindred industries have been rapidly increasing and are forecasted to loom relatively large in the basins by the year 2020.

By 2020, the chemicals and petroleum and the food and kindred products industries will account for 95 percent of the total value added by the major water using industries. (See Figure 3-5). Two oil refineries are currently located on March Point, and several large food processing plants are located in the Burlington, Mount Vernon, and other communities. As potentials for increased agriculture exist, greater volumes of fruit and vegetable processing and dairy production are expected.

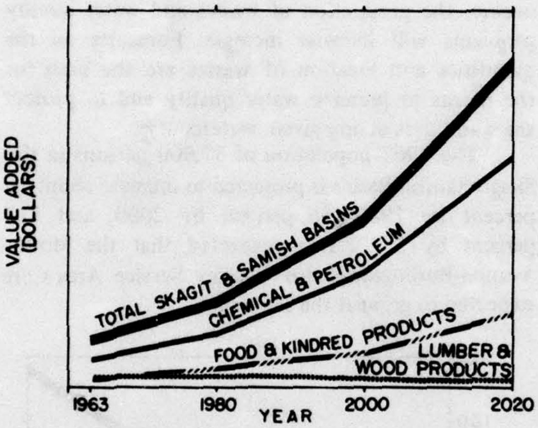


FIGURE 3-5. Relative production growth for major water using industries in the Skagit–Samish Basins.

The paper and allied industry is projected to increase production to 1980, and then decline to about the present level of production by 2020 to reflect the expected shift of pulping capacity to other plants. Total timber harvest should remain at about the present level, with usage shifting away from sawmills to pulp and plywood. By 2020, the paper and allied industry is expected to account for only 0.5 percent of the basins' total value added by the major industries.

Future population and economic growth is expected to concentrate in two areas–the Mount Vernon-Burlington-Sedro Woolley Service Area and the Anacortes-March Point Service Area.

By 1980, almost eight million recreation days are forecast for the basins–double the 1960 level. Intense recreation is expected to occur in the upper Skagit River area, with completion of State Highway 20, North Cross-State Highway and establishment of the North Cascades National Park and Ross Lake National Recreation Area, and the designation of the Pasayten Wilderness by Public Law 90-544. In addition, portions of the Skagit River and its tributaries have been designated for potential addition to the National Wild and Scenic Rivers System established by public Law 90-542.

As shown in Figure 3-6, the total raw wasteload is projected to equal 1,880,500 PE by 1980. The major waste producers will be the pulp and paper and food and kindred industries. These two industries are expected to account for 98 percent of the total raw waste production in 1980. Municipal waste production, primarily from the Sedro Woolley -Burlington-Mount Vernon Service Area and Anacortes, is expected to double, increasing from 30,000 PE in 1965 to 60,000 PE in 1980. Raw wastes from recreational activities are projected to increase about 52 percent by 1980. By 2020, this raw waste production is expected to be about five times the present level.

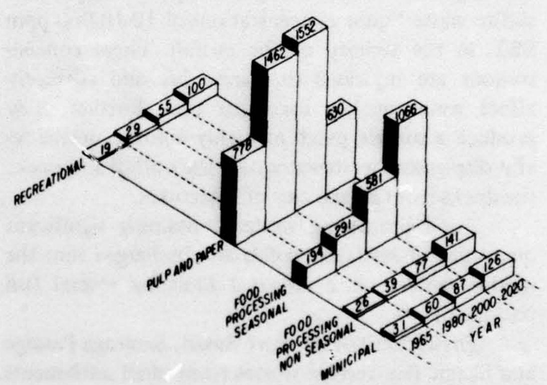


FIGURE 3-6. Projected untreated municipal and industrial wastes for the Skagit-Samish Basins (thousands of PE)

Livestock handling poses the most serious, future agricultural threat to the quality of water flowing in the streams of the Skagit-Samish Basins. In 1964, these basins had a cattle plus calf population of 73,780–about 0.74 per acre of cropland. The total number was second highest of Puget Sound's 11 subregions, but the intensity ranked eighth. During heavy winter rains some of this waste material washes into streams. The magnitude of the threat of pollution from this source will increase in the future, not only as a result of an increase in the number of cattle

but also because they are likely to be concentrated onto smaller areas.

The Skagit-Samish Basins produce large amounts of green peas for the canning market. In 1964, Skagit County had 22,500 acres in peas. This is about 22 percent of the total cropland acreage of the Skagit-Samish Basins. If peavine waste is ensiled in stacks, the liquor produced from such stacks is extremely high strength. A BOD of 35,000 to 78,000 mg/l is common. Such liquors should not be allowed to enter streams untreated.

Although excessive irrigation can impair water quality by leaching or washing sediment and minerals into surface or ground waters, this is not now, nor is it expected to be, a future problem in the Skagit-Samish Basins. The present irrigated acreage of 6,200 acres is expected to increase slowly to 38,200 acres by 1980 and to 95,000 acres by 2020. However, most of the irrigation here will be of the sprinkler type and will rarely, if ever, result in surface wash or in measurable leaching of the soil.

Pesticides have become an almost indispensable land management tool of the farmer and forester. The exact amount of these chemicals that have been used by farmers in the Skagit-Samish Basins is not known, but it is believed that little, if any, has yet been used on the forest land. It is expected that future applications of these toxic substances or of fertilizers will be only of recommended kinds and amounts.

By 1980, more than 1,460,000 PE will be produced by the pulp and paper industry; 330,000 PE by food processors; and about 60,000 PE by municipalities. Greater wasteloads are predicted through 2020. Adequate management of these wastes by all levels of government and private industry will be a "must," in order to protect the various uses of water and to preserve the environment.

MEANS TO SATISFY NEEDS

Several elements compose the water quality means for the Skagit-Samish Basins. The central and paramount element is adequate waste collection and treatment. Most wastes are and will continue to be organic, generated primarily around Anacortes and Mount Vernon-Burlington-Sedro Woolley. Collection and treatment facilities will provide waste discharges amenable to acceptance by the water resources. The flow requirements to assimilate the residual wastes, both now and in the future, are small compared with present minimun flows.

Water quality management measures required to support the treatment construction includes water quality stations on each of Skagit and Padilla Bays. Present management procedures for control of pesticides in agricultural and forest operations will meet future quality protection requirements. Control and treatment of dairy wastes in lagoons or by other treatment will be required in the near future. The majority of treated wastes should be disposed of in the vicinity of Guemes Channel for optimum dispersion.

The major aspects of the water quality control means are discussed in more detail below.

WASTE COLLECTION AND TREATMENT

The large waste loads now discharged require a collection and treatment complex composed of several new facilities and replacement and expansion of most existing plants. The actions required to meet these requirements are outlined in the Washington State Water Quality Standards and Implementation Plan, December, 1967. They are separate actions and are summarized as follows:

Skagit River

1. **Cities of Mount Vernon, Sedro Woolley**, the town of **Concrete**, and the facilities of **Seattle City Light**—secondary treatment with disinfection. **City of Burlington**—expand or modify domestic system and disinfection. This will reduce bacterial concentrations reaching the river to allow the levels to drop to standard requirements.

2. **Food processors**—adequate secondary treatment or interception by a municipal system.

Guemes Channel, Padilla and Samish Bays

1. Scott Paper Company at Anacortes—primary treatment facilities to remove all settleable solids from mill effluents; adequate facilities for the disposal of recovered solids or sludge; and a submarine outfall with diffuser. This will reduce SWL concentrations in Guemes Channel to acceptable levels.

2. The fish canneries and wood products industries—adequate treatment or intercepted by a municipal system.

Possession Sound, Port Susan, Saratoga Pas-sage, and Skagit Bay

1. Town of LaConner—the nearby **Swinomish Indian settlement**, and the **Skagit County Sanitary District No. 1**—secondary treatment, disinfection, and adequate outfall.

2. Several seafood canneries—interception of wastes by a municipal system.

Future wastes can, in most cases, be treated by the above complex of municipal and industrial treatment facilities with adequate expansion and replacement. An exception is the Mount Vernon-Burlington-Sedro Woolley group. These towns should coordinate their waste system planning. As the urban areas expand to meet each other in the future, and as replacement of treatment facilities becomes necessary, interceptors leading to a central treatment facility will allow increased efficiency of operation at lower cost.

Substantial waste treatment facilities will be required to support recreation growth in the upper Skagit Basin. Several large recreation complexes and many small developments for more specialized recreation pursuits are indicated. Since most of the recreation potential exists on Federal lands, the Federal Government will be required to provide or insure provision of most of these facilities.

A substantial continuing investment will be required to meet present and future waste collection and treatment requirements.

Projected municipal waste collection and treatment investment requirements are shown in Tables 3-6, 3-7 and Figure 3-7. Treatment requirements are initially high to meet the State Implementation Plan. Following this, a steady investment rate is required to keep pace with urban growth and facilities replacement. A significant finding is the large near-future investment requirements for sewers. This high initial rate anticipates significant expansion of sewers to serve all urban concentrations.

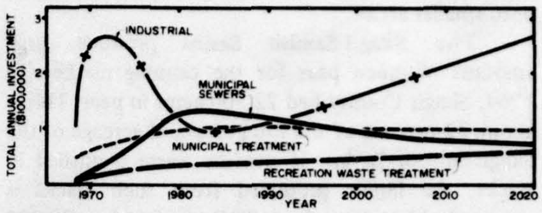


FIGURE 3-7. Municipal and industrial investment requirements for waste collection and treatment in the Skagit-Samish Basins.[1]

The relative investment rates for the municipal, industrial, and recreational sectors are shown in Figure 3-7 also. The industrial sector shows an immediate rise in investment to provide needed new facilities. Once this initial large investment has been made, the rate drops substantially where enlargement and replacement takes place. The pulp and paper and food processing industries' requirements dominate the industry curve. The rise and decline of the municipal sector reflect the impact of sewer construction. Recreation investment shows a steady growth.

Municipal costs[1] will total over $2,000,000 by 1980 with an additional $4,500,000 by 2000 and an additional $3,700,000 by 2020.

Industrial costs[1] will total $2,400,000 by 1980 with additional amounts of $2,650,000 needed for the period 1980-2000 and $4,200,000 from 2000 to 2020.

Sources of funding are shown in Figure 3-8. The Federal Construction Grants program will need to invest $530,000 by 1980, an additional $1,088,000 by 2000, and another $1,020,000 by 2020. State grants for these time periods will be $265,000, $544,000 and $474,000, respectively. Federal investment for sewers will total $128,000 by 1980, $500,000 from 1980-2000, and $540,000 from 2000-2020. Federal investment in waste treatment facilities for recreation areas will total $480,000 by 1980, an additional $900,000 by 2000 and another $1,000,000 by 2020.

[1] Costs are not amortized.

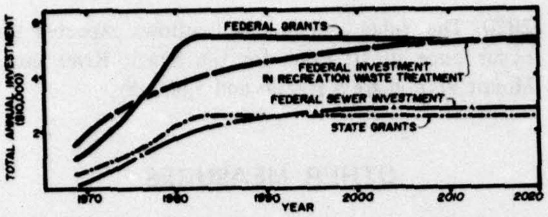


FIGURE 3-8. Government investment requirements[1] for waste colleciton and treatment for the Skagit-Samish Basins.

[1] Costs are not amortized.

FLOW REQUIREMENTS

With the installation of secondary treatment in conformance with State standards and in-plant waste controls, future waste loadings to surface waters will be reduced to 125,000 PE less than exists at the present time.

The major demand on the Skagit River for assimilating residual waste discharges is now, and will be, centered in the Burlington-Mount Vernon area.

By 1980, 2000, and 2020 it is estimated that the discharged municipal and industrial wastes to the lower Skagit River from Mount Vernon, Burlington and Sedro Woolley will total 42,100 PE, 78,900 PE, and 93,900 PE, respectively. Based on these projected waste discharges, the minimum flows required in the lower Skagit River for the maintenance of adequate water quality, assuming a single-point waste loading at Mount Vernon, have been determined to be 240 cfs by 1980, 435 cfs by 2000 and 650 cfs by the year

TABLE 3-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Skagit-Samish Basins

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 73	$ 57	$ 22
Disinfection	10	8	4
Outfalls	58	47	22
Interception and sewer system			
a. Municipal	29	23	11
b. Industrial	10	8	4
Combined sewage infiltration and overflow correction	14	13	11
Advanced waste treatment in recreation areas	61	82	113
Sub-Total	$255	$238	$187
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER[2]			
Monitoring—ground water, automatic equipment, etc.	$ 7	$ 6	$ 7
Evaluations—dispersion areas, ecological, productivity	22	5	7
Information system, quality control, plant operation improvement, operation research	18	7	7
Sub-Total	$ 47	$ 18	$ 21
OPERATION AND MAINTENANCE[2]	$ 58	$193	$152
TOTALS	$360	$449	$360

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

TABLE 3-7. Total amortized capital and operational costs—Skagit-Samish Basins

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	4.8	2.6	1.7
Municipal treatment	1.6	1.8	0.6
Municipal sewers	4.7	5.2	1.8
Recreation	1.0	0.9	0.4
Advanced waste treatment	3.1	4.1	5.7
Sub-Total	15.2	14.6	10.2
Water quality engineering management and evaluation	0.5	0.4	0.4
Operation and maintenance	0.6	3.9	3.0
Total	16.3	18.9	13.6

2020. The 7-day and 30-day lowflows expected to occur once in 10 years for the Skagit River near Mount Vernon are 5,100 cfs and 5,800 cfs.

OTHER MEASURES

The present State water quality surveillance program for fresh waters is adequate and should be continued. Marine stations will need to be expanded as industry and population density increases. In addition, more lakes and ground-water sampling stations should be established.

Stillaguamish Basin

STILLAGUAMISH BASIN

INTRODUCTION

The Stillaguamish Basin encompasses an area of 690 square miles, including six square miles of salt water. It lies in the northwestern part of the State in Snohomish and Skagit Counties. The greater portion (about 75 percent) is in Snohomish County. Elevations range from the tideflats and deltas of the Stillaguamish River at sea level to the 6,819-foot summit of Mt. Bullon. Between these two extremes lies a topography made up of river bottoms, gently rolling foothills, level benchlands, narrow canyons, and numerous mountain spurs of varying height and extent.

FIGURE 4-1. Location of the Stillaguamish Basin within the Puget Sound Area.

Alluvial flats, an extensive delta plain, and low glacial outwash plans comprise the western part of the basin.

The eastern sector is mountainous and lies mostly within the boundary of the Mt. Baker National Forest. This is steep, rugged terrain, mostly forest-covered except for high-elevation alpine barrens. Logging has occurred at scattered points throughout the basin, but the major part of the area remains in the natural, undeveloped state.

The Stillaguamish River drains the entire area into Puget Sound. The three principal drainage areas of the Stillaguamish River are: the North Fork, with a drainage area of about 286 square miles; the South Fork, with an area of about 257 square miles; and the downstream coastal area of 147 square miles.

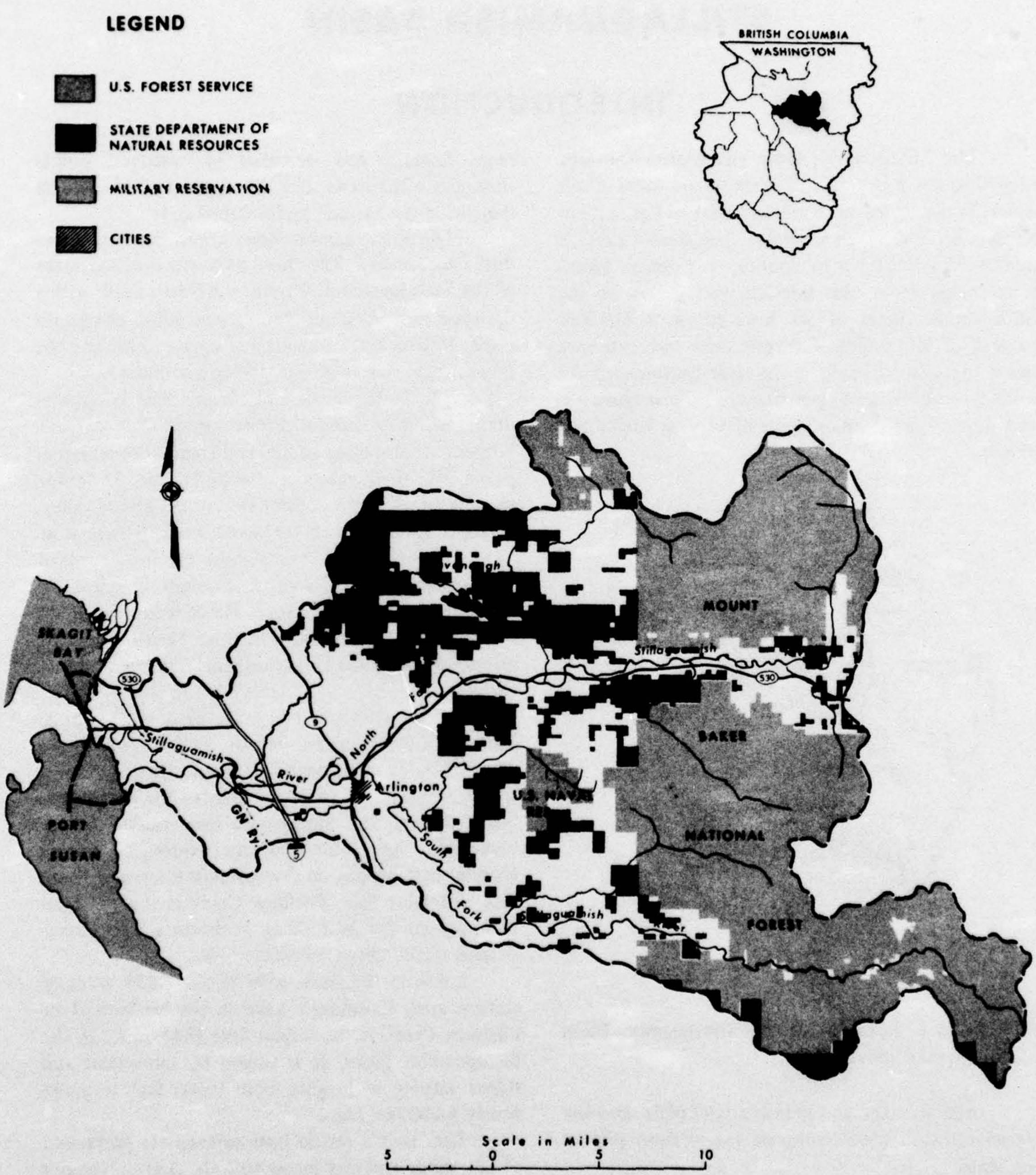
The North Fork and its principal tributaries drain the area around Finney Peak (5,090 feet), Whitehorse Mountain (6,820 feet), and other adjacent peaks. It then meanders westerly for 31 miles, flowing through a comparatively broad glacial valley, to its confluence with the South Fork at Arlington.

The South Fork heads above the ghost town of Silverton and falls swiftly through a gradually widening valley. This stream flows westerly for 41 miles to its confluence with the North Fork. Its principal tributaries are Boardman, Canyon, and Jim Creeks.

Below Arlington the main stem of the Stillaguamish River meanders slowly over a broad flood plain 23 miles to tidewater. It makes three entrances to Puget Sound. Most of the river's flow enters Port Susan through Hat Slough, the main outlet. During high river stages, some flow enters through a smaller channel that divides into two outlets known as South Pass and West Pass. Pilchuck Creek is the principal tributary to the main stem. It drains a long gourd-shaped area of about 74 square miles.

Lakes in the basin total about 1,937 acres of surface area. Cavanaugh Lake in the headwaters of Pilchuck Creek is the largest lake (844 acres) in the Stillaguamish Basin. It is ringed by mountains and ridges varying in heights from 2,500 feet to peaks nearly 4,000 feet high.

The basin's fertile bottomlands are composed of silt, sandy and clay loams with the coarser textures in the upper reaches and becoming progressively finer textured towards the mouths of the rivers. Peat and muck soils are scattered throughout both river bottoms and uplands in patches of 10 to 12 acres. Most



STILLAGUAMISH BASIN

Figure 4-2 Land Ownership

soils in the basin which are used for agriculture have been formed from some type of glacial material. Except for the younger alluvial soils, they are highly leached and acid in character. Soils of gravelly and sandy loams cover most of the western half. These include the uplands, terraces, and hilly areas above the river flood level.

Forest-covered lands account for more than 85 percent of the total acreage in the basin. About 34,500 acres are utilized for cropland, which represents six percent of the 441,600 total acres in the basin. Most of this land is confined to the alluvial lands of the flood plain. More than 55 percent of the basin's total land area is held in public ownership.

About 18,300 people live in the Stillaguamish Basin (1967 estimated figures). The two principal population centers are Arlington (2,195 persons) and Stanwood (1,240 persons). With the main occupations being agriculture and lumbering, most settlement has occurred in the rural areas. The eastern part of the basin is sparsely populated due to the rugged terrain.

In the last century, the basin has grown from a few pioneer clearings to an important area in agriculture and forest products. Agriculture and its associated industries has become the most important, and accounts for more than half of the basin's income. Dairy farming is the main agricultural enterprise. As a result, most of the cropland here is used for hay and silage to support the livestock industry. Pastures dotted with cattle and fields of hay on the valley flats and plains are common sights. There is now a trend toward the growing of peas, sweet corn and other field crops to meet the demands of a growing freezing industry and to satisfy the need for more fresh vegetables in the expanding Seattle-Tacoma metropolitan area.

Lumbering from the more than 377,000 acres of forest lands in the eastern part is the second mainstay of the basin's economy. Future increases in timber production are expected with the development of access roads to remote areas. Five sawmills at Arlington and two at Stanwood attest to the importance of the timber industry.

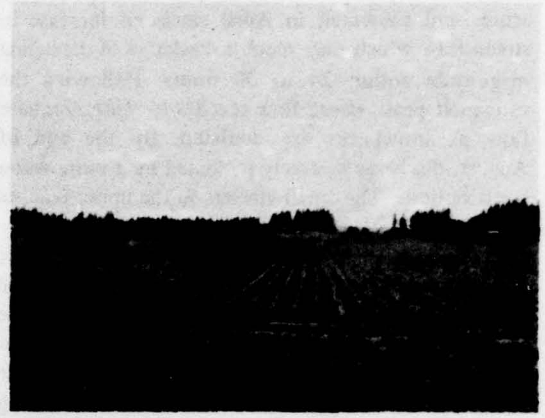


PHOTO 4-1. Many different raw crops grow in the basin (U.S. Bureau of Reclamation Photo).

The eastern half of the basin is being used extensively for sports, fishing, hunting, and other outdoor recreation. River shorelands are rapidly being developed for recreation homes.

The basin is located away from large employment centers and has been unable to generate any significant employment itself. But for all its rural atmosphere and open spaciousness, the Stillaguamish Basin is being encroached upon by progress taking place beyond its borders. Suburbia has no respect for boundaries, and even now some farmlands are being plowed under and replaced with subdivisions. The countryside is being consumed a bit here, a piece there. More croplands may be removed from agriculture in the future with the development of new industry in nearby Everett.

PRESENT STATUS

WATER RESOURCES

Fresh Water

Two stream gaging stations—one on the South Fork near Granite Falls and the other on the North Fork near Arlington—measure runoff from approximately 55 percent of the basin. Flow in the mainstem of the Stillaguamish (3,500 cfs average annual) is estimated from the two forks. During the period of record (1931-1960), streamflow averaged 1,850 cfs on the North Fork and 1,085 cfs on the South Fork. Variations in annual discharges during this same period included lows of 1,120 cfs on the North Fork and 711 cfs on the South Fork and highs of 2,615 cfs on the North Fork and 1,466 cfs on the South Fork.

The flow of the Stillaguamish River and its tributaries begins to increase in September or October from the summer base flow. During the October-March period, a series of closely spaced storms cause frequent sharp rises in river flow. Increasing temperatures and snowmelt in April cause an increase in streamflow which may reach a discharge of damaging magnitude within 24 to 30 hours. Following the snowmelt peak, streamflow recedes to minimum base flow as snowpacks are depleted. By the end of August, discharge is largely sustained by ground-water contributions. The small glaciers in the upper reaches of the basin contribute little to summer low flows.

In general, little variation in annual low flows are found to occur on the Stillaguamish River. The only exception is Pilchuck Creek which has a large variation in low flow–as much as twice that of other streams in the Puget Sound Area. Low flows are due to the absence of appreciable glacial meltwater during critical summer months.

A low-flow frequency analysis has been made by the U.S. Geological Survey for the two gaging stations in the basin, based on a 36-year period (1929-1964) for the North Fork and on a 21-year period (1937-1957) for the South Fork. These discharges were adjusted to a base period April 1, 1946 to March 31, 1964. The 7-day and 30-day low flows that may be expected to occur at these gaging stations for a recurrence interval of ten years is shown in Table 4-1.

TABLE 4-1. Low flow frequency 10-year recurrence interval Stillaguamish Basin

Station	7-Day Low Flow cfs	30-Day Low Flow cfs
North Fork near Arlington	200	240
South Fork near Granite Falls	94	112
South Fork near Arlington	130	163

Source: Appendix III: Hydrology & Natural Environment.

There are no dams or reservoirs on the Stillaguamish River; it flows freely, unchecked and unharnessed by man. The surface area of lakes and glaciers in the basin provides at least a comparative indication of the amount of water that is stored. The total lake surface area here is about 2.8 square miles, most of which is accounted for by Lake Cavanaugh. The total surface area of glaciers in the basin is only about one-half of a square mile.

The important aquifers in the lowlands are found in the coarse sedimentary zones of Quaternary deposits, which are rather continuous over sediments exposed at the surface. The plateaus are covered with till, which is not an important aquifer, because it is composed largely of fine materials. In some places, the till plateaus, terraces, and flood plains are covered with recessional outwash that contain little water. Deposits of alluvium–consisting mostly of sand, silt, clay and peat, with minor amounts of gravel–occur in the flood plain and delta of the Stillaguamish River.

Practically all recharge to the lowland aquifers is by infiltration of precipitation. These aquifers are estimated to receive about 40,000 acre-feet of recharge annually on the average. However, not all of this recharge can be captured by wells. The natural discharge of ground water is mostly into the river and its tributaries, and into Port Susan through submarine springs.

Marine Water

The basin's marine water area consists of Port Susan which is connected to Possession Sound at its southern end. Port Susan has an entrance sill with a controlling depth of 318 feet east of Camano Head, but deepens to an average basin depth of 378 feet. Because of the entrance sill, some of the water below 328 feet is trapped and will remain in the inner basin for several months. Flushing of this water occurs in the fall and again in February or March of each year. Winds will affect the surface layer and in turn move the deeper water.

WATER QUALITY

Fresh Water

The following discussion is based on an analysis of water samples collected monthly from the main stem of the Stillaguamish River near Silvana and at Granite Falls and from a station located on the North Fork near Arlington.

Chemical–A review of several water quality indicators shows that the water is soft and low in dissolved solids. Low dissolved oxygen content and generally poor water quality conditions are prevalent in Hat Slough near Stanwood during peak season waste production.

TABLE 4-2. Surface water quality, Stillaguamish Basin

		mg/l												mg/l									mg/l		mg/l		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (μmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
STILLAGUAMISH RIVER NEAR GRANITE FALLS — JULY 1959 THROUGH 1966																											
Maximum	4,850	42	8.0	2.1	2.0	0.9	34	0	4.0	1.5	0.5	0.7	64	0.11	---	7.8	4.30	0.03	7.4	30	150	17.7	13.8	123	29	2	4,600
Mean	---	27	4.7	0.9	1.1	0.3	18	0	2.4	0.7	0.1	0.3	38	0.02	---	4.9	0.80	0.01	---	---	---	8.8	11.7	102	15	0	182
Minimum	153	15	2.5	0.1	0.6	0.0	11	0	1.2	0.0	0.0	0.0	22	0.00	---	2.8	0.03	0.00	6.1	5	0	1.0	8.9	93	9	0	0
Number	29	36	36	36	36	36	36	23	36	36	36	36	36	33	---	36	32	11	36	36	15	37	36	36	36	36	37
STILLAGUAMISH RIVER NEAR ARLINGTON — NOVEMBER 1961 THROUGH 1966																											
Maximum	5,070	55	10.0	2.8	2.9	0.9	44	0	3.6	2.5	0.2	1.0	80	0.04	---	9.1	2.80	0.02	7.6	30	135	17.6	13.8	141	34	1	930
Mean	---	36	5.9	1.6	1.7	0.5	26	0	2.7	1.2	0.1	0.6	51	0.02	---	6.2	0.53	0.01	---	---	---	9.2	11.6	103	21	0	182
Minimum	400	22	3.0	0.9	1.0	0.2	14	0	1.6	0.5	0.0	0.1	29	0.00	---	3.5	0.10	0.00	6.7	0	5	2.3	9.3	91	12	0	0
Number	11	18	18	18	18	18	18	18	18	18	18	18	18	15	---	18	15	8	18	18	14	19	19	19	18	18	19
STILLAGUAMISH RIVER NEAR SILVANA — JULY 1954 THROUGH 1966																											
Maximum	---	58	10.0	3.5	3.3	1.1	48	0	4.4	2.8	0.3	2.0	96	0.10	---	11.0	5.20	0.03	7.6	45	400	22.8	14.3	127	39	4	1,500
Mean	---	37	6.0	1.6	1.7	0.5	26	0	3.0	1.3	0.1	0.6	53	0.02	---	6.6	0.80	0.01	---	---	---	9.9	11.1	100	22	1	204
Minimum	---	17	3.0	0.5	0.8	0.0	13	0	0.9	0.0	0.0	0.0	26	0.00	---	3.2	0.05	0.00	5.9	0	0	1.8	4.8	40	11	0	0
Number	---	83	83	83	83	83	83	33	83	83	82	83	83	72	---	83	72	12	83	83	44	87	87	87	83	83	87

Ground-water is generally low in dissolved solids–usually less than 200 mg/l and rarely more than 300 mg/l. Water hardness normally ranges from 60 to 120 mg/l, and silica concentration is usually between 200 and 40 mg/l.

Bacteriological–The bacteriological measurements of the waters show high coliform values occasionally occurring below points of waste disposal. Maximum MPN values ranged from 930 on the North Fork to 4,600 on the South Fork at Granite Falls. On the main stem near Silvana, the maximum MPN observed was 1,500. Table 4-3 gives a summary of coliform concentrations taken from basin data sampling.

Physical–Average DO concentrations range from 11.1 mg/l to 11.7 mg/l on the main stem. Evidence of oxygen depression in the basin is on the main stem near Silvana where a minimum DO of 4.8 mg/l was recorded and in Hat Slough near Stanwood.

Maximum stream temperatures on the North Fork are relatively low, less than 63.7°F (17.6°C) during the warmest months. Past Arlington the Stillaguamish River warms up on its way to Puget Sound. Temperatures on the main stem near Silvana have reached a maximum recorded value of 73°F (22.8°C).

Throughout its length and tributaries, the Stillaguamish River runs decidedly turbid. The average turbidity is 50 JTU on the main stem below Arlington, 42 JTU on the North Fork, and 44 JTU on the South Fork at Granite Falls. Maximum turbidities on the entire system have ranged from 135 to 400 JTU. Color values are also high, ranging from 0 to 45 units on the main stem and 0 to 30 units on the North Fork.

Stream-borne sediment in the basin is minimal. Precipitation in the high country is excessive, but a heavy cover of vegetation normally retards erosion. The well-drained glacial till and outwash materials are also not easily eroded. At times, however, sediment from clay slides has been particularly destructive to spawning salmon. During low flow, most streams in the upper drainages are nearly sediment-free. In the lowlands, heavy vegetation normally prevents excessive erosion on steep slopes.

Marine Waters

Temperatures of the marine waters will vary from a winter low of 44.6°F (7°C) to a summer high of 51.8°F (11°C). Salinities will vary from about 29 o/oo in winter to slightly over 31 o/oo in late summer. The oxygen content will vary from 5 to 8 mg/1 and the phosphate content from .06 to .09 mg/1. The oxygen content of the trapped water (below 328 feet) in Port Susan will decrease with time, becoming less than 1.5 mg/1 while the phosphate content will increase to over 0.36 mg/1.

SOURCES OF WASTE

The raw municipal and industrial wasteload generated in the Stillaguamish Basin approximates 350,000 population equivalents. Of this amount, 35% is presently removed by treatment before being discharged. The results of the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan will reduce the discharged PE's to 15 percent of the present raw wasteload.

TABLE 4-3. Summary of coliform concentrations, Stillaguamish Basin MPN/100 mls

Watercourse	Less Than 240		240-1,000		1,000-2,400		Greater Than 2,400	
	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.	No. of Samples	Percent of Total No.
Stillaguamish (at Granite Falls)	34	94	1	3	0	0	1	3
North Fork Stillaguamish (nr. Arlington)	16	73	6	27	0	0	0	0
Stillaguamish (nr. Silvana)	72	79	16	18	2	2	1	1

Source: Washington Water Pollution Control Commission.

Quantities and general location of waste production and discharges in the basin are shown on Figure 4-3. The sources of waste are listed in Table 4-4.

Fresh Water

The principal sources of wastes to fresh water in the basin are outlined in Table 4-4. Cities and industries are daily discharging wastes into the Stillaguamish River equivalent to those from a population of 2,200 persons, with an additional 221,000 PE daily during the food processing season.

The municipal and industrial wastes produced in the Stanwood area account for virtually all of the total raw wasteload generated in the basin. During the peak food processing season, two food processing plants produce 335,000 PE daily. The town provides waste stabilization ponds to treat both municipal and flood processing wastes from the two local industries. After treatment, the normal waste discharge is 800 PE daily from the town and 221,000 PE daily in season from the two industries.

Arlington discharges 1,400 PE daily after providing primary treatment to some 2,000 PE. Other towns in the basin rely primarily upon individual septic tanks.

Marine Water

There are no direct discharges of wastes to marine waters in the basin.

TABLE 4-4. Summary of municipal and industrial wastes, Stillaguamish Basin

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Stillaguamish River						
Arlington	2,000	2,000	--	Primary	1,400	--
Stanwood	1,100	3,600	--	Lagoon	800	--
Food Processing	--	--	150,000	Stanwood	--	36,000
Food processing	--	--	185,000	None	--	185,000
TOTAL	3,100	5,600	335,000		2,200	221,000

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after completion of implementation and enforcement plan for interstate and intrastate waters—1970-1972.

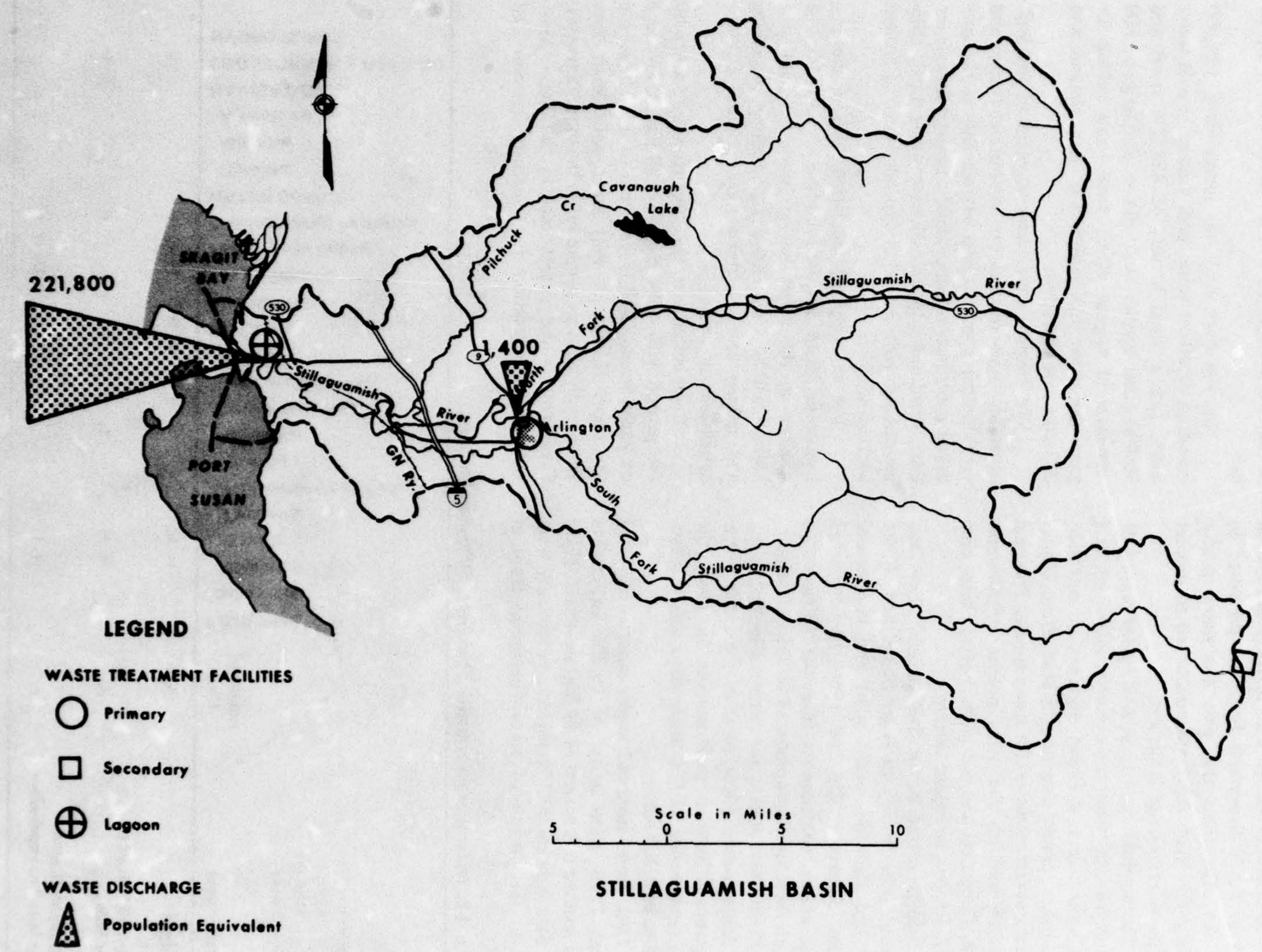


FIGURE 4-3. Location of major waste discharges

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the Stillaguamish Basin are presented in Table 4-5. The table also gives the water quality classification which the State established to protect the type of water usage in the area.

The anadromous fish inhabiting the waters of the Stillaguamish system are chinook, coho, pink, and chum salmon and steelhead and searun cutthroat trout. Lakes, ponds, and sloughs also afford important natural rearing waters for many species. Principal species of shellfish and other marine invertebrates include Dungeness and red crabs, butter clams, blue mussel, octopus, and ghost shrimp.

Salmon reared in the Stillaguamish River system contribute heavily to Puget Sound and United States and Canadian ocean sport and commercial fisheries. Between 1956 and 1965, the estimated average annual contribution from the Stillaguamish Basin to these fisheries amounted to 396,110 salmon.

Fresh-water angling for salmon is limited to the main Stillaguamish River. Most of the catch in the Stillaguamish River is pink salmon. In 1965, the catch, representing 18,800 angler-days use, was estimated to be 4,700 salmon.

Data from steelhead angler surveys, adjusted through 1966, show a use of 99,200 angler-days which resulted in a harvest of 19,830 steelhead. These same data indicate 50,300 angler-days annually were spent in the pursuit of searun cutthroat trout in saltwater environments with a total harvest of 30,200 fish.

On the basis of 1966 survey data, 124,000 man-days of effort were spent fishing in cold water lakes, and a total harvest of 433,000 trout and 30,800 other species was realized. Similarly, 63,800 man-days of angling effort were spent fishing for game fish other than steelhead in basin streams, and 215,800 were harvested.

The small marine water segment of the Stillaguamish Basin receives no commercial fishing and very limited sport fishing. Marine fish stocks produced contribute to commercial and sport fisheries of Port Susan and adjacent saltwater areas. Little commercial or sport fishing is expended on the limited shellfish stocks.

The water-related recreation days in the Stillaguamish Basin in 1960 numbered 830,000, the smallest in the Puget Sound Area. By 1980, the number will be 1,600,000 days. Camping, picnicking and fishing are the three most popular outdoor activities in the basin.

Water based recreation opportunities are few by comparison with other Puget Sound Basins. Frontage on Puget Sound itself is restricted to tideflat areas in the upper reaches of Port Susan and Skagit Bay. While small lakes are numerous in the mountain areas, Cavanaugh is the largest lake in the basin. Most water-based recreation is, therefore, concentrated

TABLE 4-5. Water uses and quality objectives, Stillaguamish Basin

Use Intensity
L – Light
M – Medium
H – Heavy

Watercourse	Assigned[1] Class	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environmental Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Port Susan	A			H	H					H	H	M	H		H	H	H						L	
Stillaguamish River to River Mile 7	A			H	H				L				L			H	H						L	
Stillaguamish River—River Mile 7 to Headwaters	A			H	H	H							H		M	H	H							

[1] See Table 1-5.

along the streams and rivers, of which the South Fork of the Stillaguamish is the most used. Other recreational attractions include the high mountain area in the eastern half of the basin. The area includes some 25,000 acres of alpine or subalpine terrain and supports a large ski development on Mt. Pilchuck. There are outstanding natural areas to be found in the Mt. Baker National Forest. In 1964, there were 37 publicly-administered outdoor recreation areas within the basin.

The Stillaguamish River is not presently being used as a source of water supply for municipal or industrial purposes. Ground-water is expected to fulfill these needs in the future. The rural population likewise obtains most of its water supply from wells.

Navigation on the Stillaguamish River is not possible except on the lower reaches at high tide. There are no significant water terminals or water-transport oriented industries in this basin. With dredging and filling, several thousand acres of water-front industrial property at the head of Port Susan could be developed, but there is no knowledge of such a development having been investigated.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, for most watercourses in the Stillaguamish Basin, the water quality class is excellent (A) with the objectives being to meet or exceed the quality requirements for all uses.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

There are few water quality problems in the basin. The most significant deficiency exists on the lower Stillaguamish River below Stanwood. The large industrial organic wasteloads discharged to the stream at Stanwood seriously deplete the oxygen content, sending dissolved oxygen levels far below water quality standards requirements.

Mud and clay slides, one on each fork of the river, cause excessive water discoloration and heavy siltation of the downstream reaches. Another adverse natural condition is the high temperature levels reached periodically throughout the lower reaches.

An estimated 62.4 miles of the Stillaguamish River banks and channels are subject to bank cutting and braiding. Another 60 to 90 miles of bank cutting and braiding is estimated to occur on tributary streams.

FUTURE NEEDS

The food processing industry, population, and recreation growth are the significant projected future waste sources. The forecast of the quantity and location of these waste sources forms the basis for deriving the means to achieve and maintain water adequate in quality for the established uses.

The 1967 population of 18,300 persons in the Stillagauamish Basin is projected to increase about 60 percent by 1980, 157 percent by 2000 and 310 percent by 2020. Stanwood and Arlington are expected to be population centers in this agriculturally-oriented basin. The basin is connected to nearby Everett by the Interstate 5 Freeway. Continued growth in Everett would very likely generate extensive suburban developments in this basin. Such an occurrence would make the adopted projections significantly low and would modify the assumed population distribution.

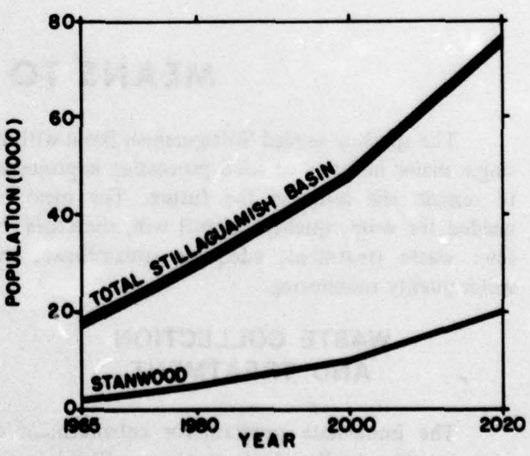


FIGURE 4-4. Population growth projected for the Stillaguamish Basin.

Industrial growth is expected to be from food and kindred industries. These industries' production is projected to be 3.7 times as great in 2020 as in 1980. Stanwood was assumed to remain the major food processing center.

In 1980, about 3.7 million recreation days are expected–1.8 times the 1960 amount. Major recreational activities will be camping, picnicking, and fishing along the North and South Forks of the Stillaguamish River.

Figure 4-5 shows the breakdown of the 530,000 raw PE expected to be produced by 1980. The 500,000 PE contributed by food and kindred industries accounts for 95 percent of the raw waste produced. Municipalities should produce about 170 percent more raw wastes in 1980 than in 1965. Raw wastes from recreation activities are projected to increase 56 percent–from about 7,700 PE in 1965 to 12,000 PE in 1980.

The area in cropland (now about 35,000 acres) will increase only slightly in the future. The major shift will be loss of some better agricultural lands to other uses and improvements of some less desirable lands. The number of cattle and calves is relatively low. The small amount of present irrigation (2,500 acres) is projected to double by 1980 and double again to 10,000 acres by 2000, remaining at about that level thereafter. Agricultural impacts on stream water quality should remain rather insignificant.

The major future waste source in this basin is expected to be the food processing industry. Municipalities and recreation developments will be the other two significant waste sources. The primary future need, then, will be to adequately control and manage the wastes from these sources so as to maintain the water quality standards in the basin. Increased efficiency in forest management will be a supporting need.

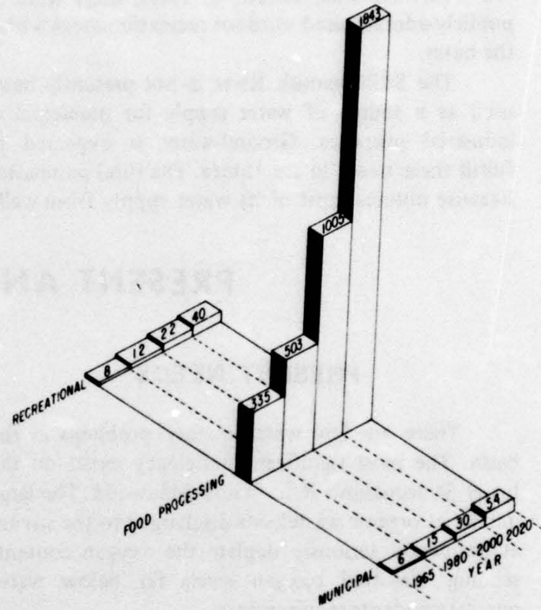


FIGURE 4-5. Projected municipal and industrial wastes for the Stillaguamish Basin (thousands of PE).

MEANS TO SATISFY NEEDS

The sparsely settled Stillaguamish Basin with its single major industry of food processing is projected to remain the same in the future. The measures needed for water quality control will, therefore, be few: waste treatment, adequate streamflows, and water quality monitoring.

WASTE COLLECTION AND TREATMENT

The immediate program for enhancement of water quality to Standards level is outlined in the Washington State Water Quality Standards and Implementation Plan of December, 1967. The separate needed actions are summarized below.

1. **Stanwood**–enlargement of treatment facilities to a size capable of handling existing and future wasteloads and adequate disinfection. The food processing industry should make arangements to have their wastes intercepted and treated by Stanwood or provide other adequate treatment; and lagooning of waste sludge.
2. **Arlington**–secondary treatment.

These treatment improvements will make it possible to reduce the wasteload discharged to the Stillaguamish River and, thus, allow dissolved oxygen concentrations and pH to return to required levels and also reduce bacterial concentrations.

Future wasteloads are projected to be essentially of the same nature and located in the same places. Under this premise, future treatment requirements can largely be met through expansion and replacement of the network established to meet immediate needs and continuation of the land disposal of the food processing industry treated effluent. Small communities that grow beyond several hundred population will also have to meet their waste handling needs with adequate treatment facilities.

Recreation growth will spawn resorts with population concentrations in the upper basin. Treatment facilities to handle the concentrated loads have been forecast.

Cabins along the streams also pose a potential water quality threat here. The projections of increasing numbers of cabin developments, coupled with present sub-surface waste disposal methods would be expected to lead to bacterial contamination of the streams. A waste collection and treatment scheme designed for this situation will be a likely solution in the future. State and Federal assistance, in the form of research and funding, will be required.

The investment requirements for waste collection and treatment facilities are shown in Figure 4-6 and Tables 4-6 and 4-7. Municipal treatment costs show a steady rise to meet future population growth. Industrial investment will be high initially. Expansion and replacement will proceed at a lower, although ascending rate, in the future.

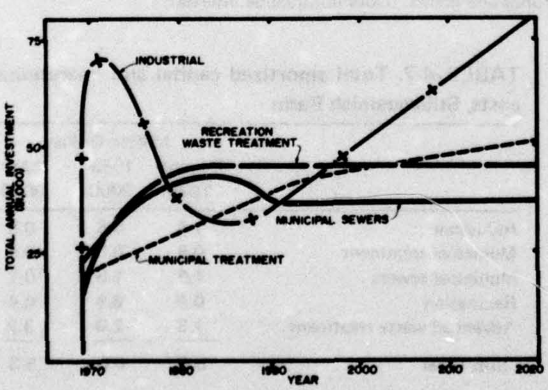


FIGURE 4-6. Relative required rates of investment for waste collection and treatment in the Stillaguamish Basin.

The total investment[1] for municipal sewers and treatment is projected to be $740,000 by 1980, with an additional $1,544,000 by 2000, and an additional $1,680,000 by 2020.

Industrial investment[1] will total $670,000 by 1980; an additional $830,000 by 2000; and an additional $1,380,000 required by 2020.

Treatment of wastes resulting from recreational activities is estimated to cost[1] $450,000 by 1980, $920,000 from 1980 to 2000 and an additional $920,000 by 2020.

Figure 4-7 shows the sources of funding to construct the required treatment facilities. Federal grants will total $160,000 by 1980; $380,000 for the time period 1980-2000 and $520,000 for the period 2000-2020. Federal investment in sewers is expected to total $51,000 by 1980 with additional amounts of $170,000 for the years 1980-2000 and $240,000 for 2000-2020. State grants are expected to total $80,000 by 1980, $190,000 from 1980-2000 and $220,000 from 2000 until 2020. Federal investment in treatment facilities for recreational areas is estimated to total $320,000 by 1980, with an additional $860,000 needed for 1980-2000, and $900,000 for 2000-2020.

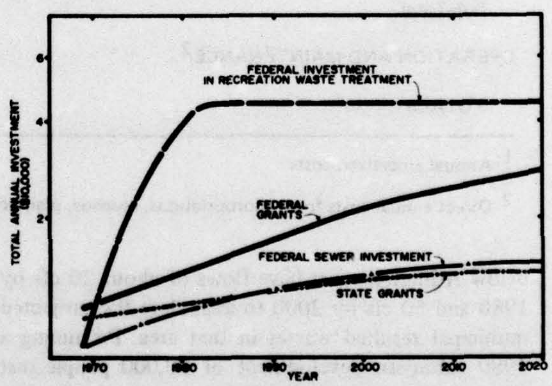


FIGURE 4-7. Government investment requirements[1] for waste collection and treatment in the Stillaguamish Basin.

FLOW REQUIREMENTS

The largest concentrations of point waste discharges to the river system are projected to be at Arlington and Stanwood. The Stillaguamish River

[1] Costs are not amortized.

TABLE 4-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Stillaguamish Basin

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 23	$ 19	$ 7
Disinfection	4	3	2
Outfalls	23	19	10
Interception and sewer system			
a. Municipal	11	10	5
b. Industrial	4	3	2
Combined sewage infiltration and overflow correction	11	10	5
Advanced waste treatment in recreation areas	25	39	63
Sub-Total	$101	$103	$ 94
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 5	$ 6	$ 6
Evaluations—dispersion areas, ecological, productivity	5	6	6
Information system, quality control, plant operation improvement, operation research	6	3	5
Sub-Total	$ 16	$ 15	$ 17
OPERATION AND MAINTENANCE[2]	$ 24	$ 69	$ 61
TOTALS	$141	$187	$172

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

below Arlington must have flows of about 20 cfs by 1980 and 50 cfs by 2000 to assimilate the projected municipal residual wastes in that area. Presuming a 1980 suburban development of 20,000 people just below Arlington, resulting from expansion in Everett, about 70 cfs would be needed in this area following adequate treatment. Present 7-day lowflows expected on a 10-year recurrence interval exceed 170 cfs through this reach.

The lower Stillaguamish River at Stanwood is influenced by tidal fluctuations.

Based on the projected municipal and industrial residual waste discharges in the vicinity of Stanwood, minimum streamflow requirements for the mainstream of water quality were determined to be 140 cfs by 1980, 270 cfs by 2000 and 415 cfs by the year 2020. With the combined one in ten year 7-day

TABLE 4-7. Total amortized capital and operational costs, Stillaguamish Basin

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	1.4	0.8	0.6
Municipal treatment	0.8	0.8	0.4
Municipal sewers	1.5	1.5	0.7
Recreation	0.9	0.9	0.4
Advanced waste treatment	1.3	2.0	3.2
Sub-Total	5.9	6.0	5.3
Water quality engineering management and evaluation	0.2	0.3	0.3
Operation and maintenance	0.3	1.4	1.2
Total	6.4	7.7	6.8

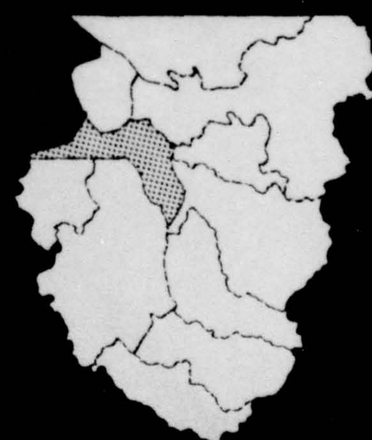
lowflows of the North and South Forks of the Stillaguamish River near Arlington amounting to 330 cfs, additional flow would be required under these waste discharge circumstances to adequately protect water quality. Unless additional flow could be made available for waste assimilation purposes, it is recommended that the industrial waste discharges from Stanwood be applied to suitable nearby land for disposal. With this waste discharge scheme, the minimum flows required in the Stillaguamish River to handle Stanwood's municipal waste discharges are estimated to be 20 cfs for 1980, 30 cfs for 2000 and 40 cfs for the year 2020.

OTHER MEASURES

Preservation of water quality will require a surveillance system designed to measure the impacts of future developments not only on streams and marine water, but on lakes and ground-water as well. The lower Stillaguamish River below Stanwood should continue to be monitored to measure the return of water quality to standards level. In the near future, the impact on streams due to recreation activities in the upper basin will need to be measured.

The Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, sets out classiciation of watercourses and treatment facilities necessary to maintain and/or improve existing water quality.

Whidbey-Camano Islands



WHIDBEY - CAMANO ISLANDS

INTRODUCTION

The Whidbey-Camano Islands cover about 209 square miles in the northern end of Puget Sound and comprise five islands. Whidbey Island is the largest; it is about 40 miles in length and from one to ten miles in width. Camano is the second largest island and is about 15 miles long and from one to seven miles wide. Three smaller islands—Ben Ure, Strawberry, and Samith—are included in the group.

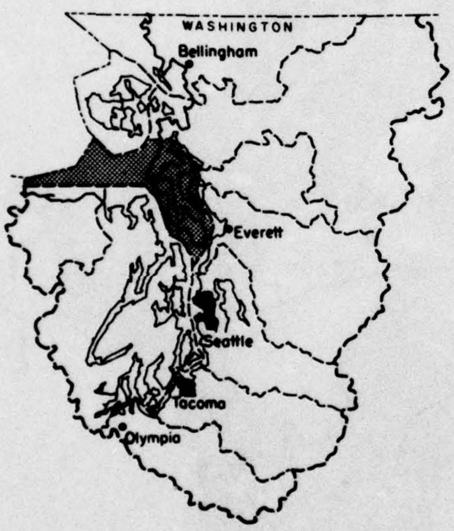


FIGURE 5-1. Location of the Whidbey—Camano Islands within the Puget Sound Area.

The Islands are composed primarily of glacial drift consisting of unassorted glacial tills, sands, gravel, and clays.

There are no major rivers on the Islands, only short coastal streams that empty into Puget Sound. There are more than 40 fresh water lakes in the Area, but most are smaller than 15 acres in size.

The marine waters include parts of Admiralty Inlet, Skagit Bay, Port Susan, and Possession Sound. Whidbey Island contains several harbors and bays.

Land use is predominantly woodlands (63 percent). Cropland accounts for about 17 percent. The Whidbey-Camano Islands contain 522,154 acres, and about 25 percent of this area is made up of land and fresh water. The majority of the area (60 percent) is composed of marine waters. Almost 90 percent of the Islands' total land area is held in private ownership.

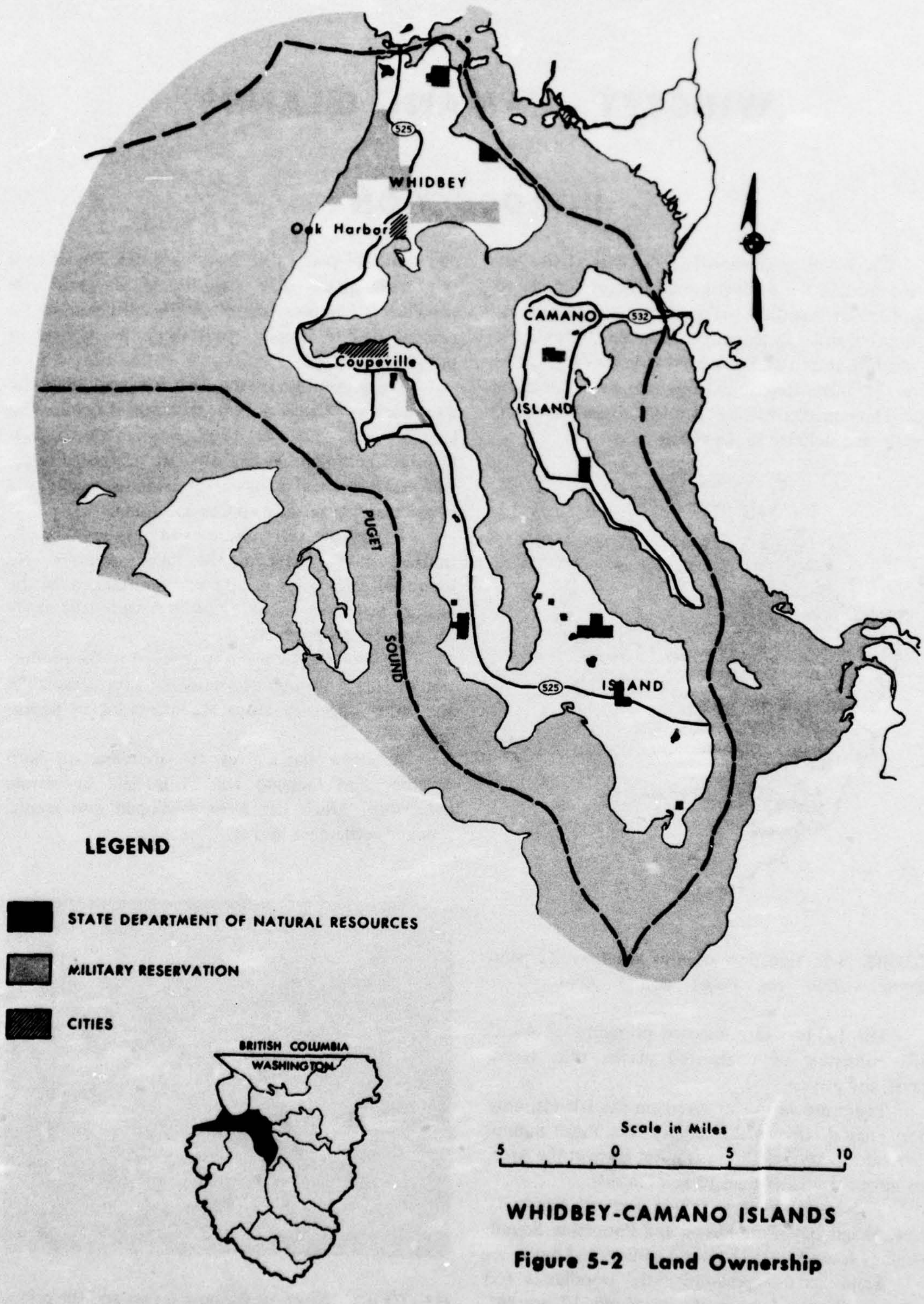
The population of the Area is spread along the shorelines of Camano and Whidbey Islands. The Islands' population in 1967 was about 22,400. Principal communities include Oak Harbor, Coupeville, Langley, and Clinton on Whidbey Island and Camano and Utsaladdy on Camano Island.

Lumbering, agriculture, and military installations form the base of the local economy. No industrial enterprises of any size are located on the Islands, and most of the timber is used locally as are the agricultural products.

Most of the cropland is devoted to the production of forage to support a dairy industry. Vegetables and other specialty crops are increasing in importance.

A major portion of the shoreline on both Whidbey and Camano Islands is held in private ownership, which has been developed into recreation and retirement homes.

PHOTO 5-1. South of Deception Pass and the bridge extends Whidbey, the largest of the islands.



WHIDBEY-CAMANO ISLANDS

Figure 5-2 Land Ownership

Rapid growth of the Islands is beginning as a result of The Boeing Company extension in nearby Everett. Considerable land speculation is occurring due to the likelihood of a bridge linking Whidbey Island and Everett.

PRESENT STATUS

WATER RESOURCES

Fresh Water

There are no major streams on either island. Surface drainage is to marine waters through several small, mostly intermittent, streams.

Average annual runoff from the area has been estimated to be about 168,000 acre-feet, or 68 percent of the average annual precipitation. Of the 168,000 acre-feet, Whidbey Island discharges about 136,000 acre-feet and Camano about 32,000 acre-feet. The low annual runoff expected to occur once in 50 years has been estimated to be 72,000 acre-feet. Precipitation is the only source of recharge to ground water. Although about 10,000 acre-feet of recharge is available to the aquifers above sea level, it is estimated that only about 60 to 70 percent of this is actually absorbed.

Marine Water

Admiralty Inlet is about 19.2 miles long, with an average width of 3.4 miles and an average depth of about 361 feet. Most of the water entering and leaving lower Puget Sound must flow through Admiralty Inlet; only a small portion of water flows through Deception Pass at the northern end of Whidbey Island.

Tidal currents are strong in Admiralty Inlet with speeds frequently over 3.5 miles per hour (mph) and a maximum of nearly 5.7 mph during periods of large tidal range. Because of these strong currents, the inlet is a large mixing zone for the deeper waters of the Strait of Juan de Fuca with the fresher surface waters from Puget Sound. The flushing time is rapid, with the various water types requiring only a few tidal cycles to make the transit through the area.

The distance from Possession Point to Deception Pass via Saratoga Passage and Skagit Bay is 46 miles and the width varies from 2 miles to 6.2 miles. Port Susan is a large bay east of Camano Island it is 17.4 miles long and has an average width of 2.3 miles. Holmes Harbor is a small bay on the southeast side of Whidbey Island and is 6.5 miles long and 1.1 miles wide.

The depths of these marine waters vary from 723 feet off Possession Point to extensive mud flats east of Skagit Bay. Fresh water sources for this area come from three major rivers, namely the Skagit, Snohomish, and Stillaguamish. This large amount of fresh water has a pronounced effect upon the oceanography of the marine waters in the Islands.

WATER QUALITY

Fresh Water

Little information is available concerning the surface water quality on either Whidbey or Camano Islands, as surface water quality measurements have not been made. Dissolved solids content in ground waters usually varies between 100 and 300 mg/1, but values above 300 mg/1 occur in some well waters. Objectionable concentrations of iron have been reported in both shallow and deep wells in scattered locations on Whidbey Island. Some saltwater intrusion of the ground water has been reported in some areas.

Marine Water

The salinity throughout Possession Sound and Saratoga Passage varies from less than 5 o/oo off the river mouths to about 28 o/oo in more distant parts such as near Deception Pass or off Possession Point. Surface temperatures will vary from an average low of 42.8°F (6°C) in winter to about 62.6°F (17°C) in summer. The oxygen content of these marine waters is usually above 6 mg/1 and is usually completely saturated, but may vary from as low as 4 mg/1 to over 15 mg/1. The phosphate concentration may vary from a low of 0.05 mg/1 to over 0.27 mg/1.

In Holmes Harbor, temperatures observed below 66 feet vary from 44.6°F (7°C) to 53.6°F (12°C), the salinities from 27.5 o/oo to 30.5 o/oo, the oxygen content from 3 mg/1 to 8 mg/1, and the phosphates from 0.09 mg/1 to 0.32 mg/1.

SOURCES OF WASTE

The raw wasteload generated in the Islands approximates 11,500 PE, of which about 35 percent is presently removed by waste treatment before being discharged to marine waters. The areas receiving the largest quantities of wastes in relation to the total basin include Oak Harbor (34 percent), Crescent Bay Seaplane Base (28 percent), and Ault Field (28 percent).

The quantities and general location of waste production and discharges in the Islands are shown in Figure 5-3. Sources of waste are summarized in Table 5-1. The completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans will substantially reduce the strength of these wastes in relation to the present untreated wastes.

Over 90 percent receives primary treatment and less than 10 percent of the total generated wasteload receives secondary treatment. After treatment of wastes, a total of 7,400 PE are discharged daily into marine waters.

Whidbey and Camano Islands, being residential in nature, have primarily domestic wastes to treat. The major exception is the **Naval Air Base complex at Ault Field and Oak Harbor.** Wastes from these installations also include such items as residue from airplane washings and petroleum products from field runoff.

The towns of Oak Harbor, Coupeville, and Langeley all have waste collection and treatment systems. Treatment consists of primary plants and disinfection followed by discharge to the Sound. Estimated population served by these systems is 4,300.

Deception Pass and Camano State Parks provide septic tanks for waste treatment.

The Naval Air Base installations have primary treatment plants with disinfection prior to disposal to the Sound. These systems serve about 4,800 people.

The remaining 13,000 people on the islands utilize individual septic tanks for waste disposal.

TABLE 5-1. Summary of municipal and industrial wastes, Whidbey-Camano Islands

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Puget Sound						
Oak Harbor	3,500	3,500	--	Primary	2,550	--
Crescent Bay Seaplane Base	2,500	3,000	--	Primary	2,100	--
Crescent Bay Capehart Housing	800	1,000	--	Secondary	150	--
Coupeville	600	750	--	Primary	520	--
Langley	200	250	--	Primary	--	--
Ault Field	2,500	3,000	--	Primary	2,100	--
TOTAL[1]	10,100	11,500	--		7,400	--
Municipal	--	11,500	--		7,400	--
Industrial	--	--	--		--	--

[1] Figures are rounded.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of marine water in the Whidbey and Camano Islands are summarized in the following table. The table indicates the water quality classification established by the State for each watercourse, which in turn indicates the type of water usage to be protected in the area.

As there are no perennial streams on the islands, there are only small numbers of anadromous

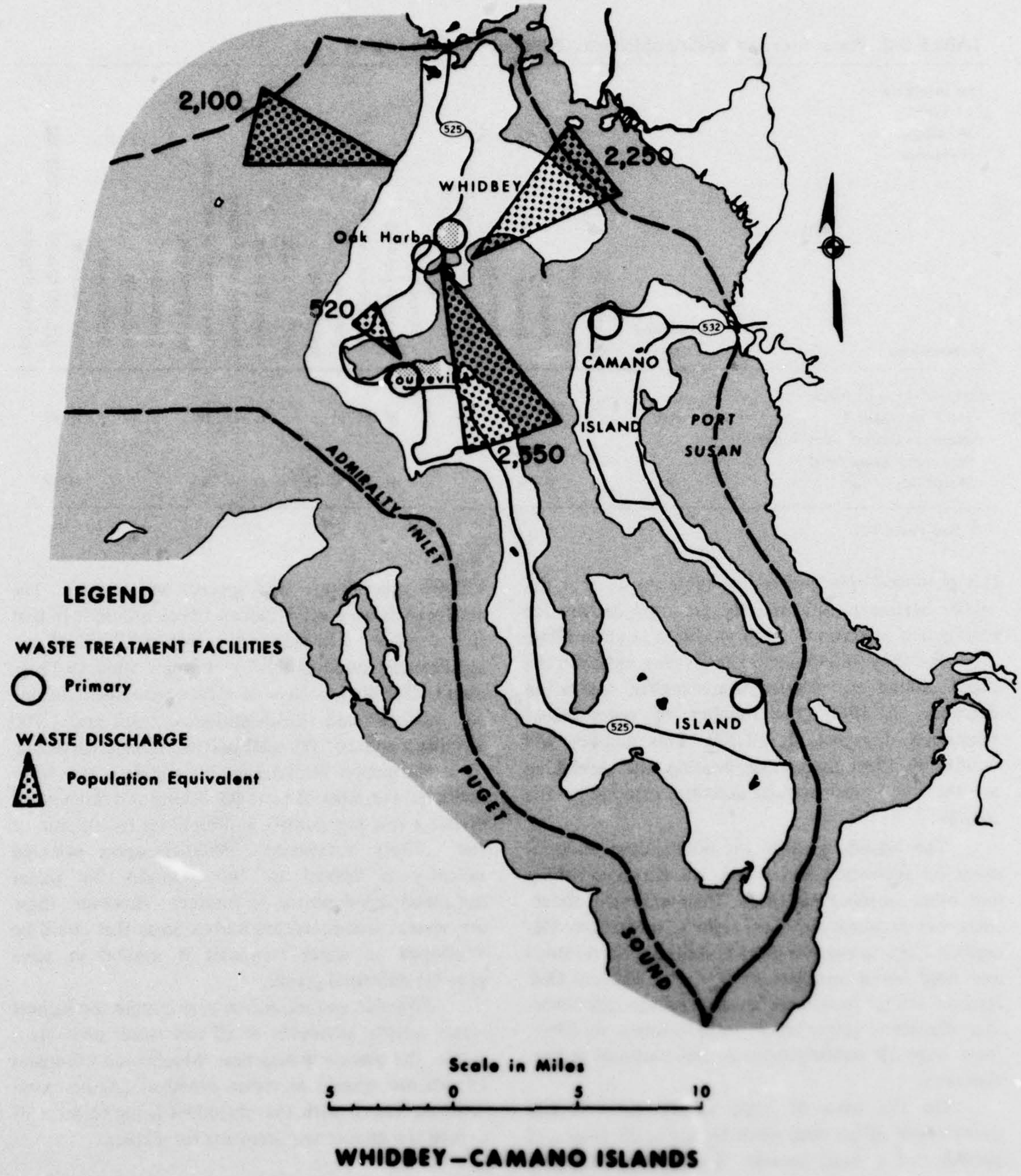


FIGURE 5-3. Location of major waste discharges

TABLE 5-2. Water uses and quality objectives, Whidbey-Camano Islands

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[1]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environmental Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Strait of Juan de Fuca and Puget Sound	AA			H	H					H	H	H	L		L	H	H			M		H	M	
Possession Sound, Port Susan, Saratoga Passage, and Skagit Bay	A			H	H					H	H	H	H		H	H	H					H	M	

[1] See Table 1-5.

fish produced. The preceeding table shows that the marine waters in this vicinity are used heavily for rearing and migration of fish produced in other areas.

Whidbey and Camano Islands rank eighth in the Puget Sound in outdoor water-related recreation demand. In 1960, the number of water-related recreation days was 1,500,000. This number will double by 1980. Swimming, boating, and picnicking are the three most popular activities enjoyed on the islands.

The Islands provide an outstanding environment for recreation and a base for saltwater fishing and other outdoor activities. Their extensive shorelines and excellent beaches, resorts, spectacular Deception Pass, towns and older buildings, historic sites, and large Naval installations at Ault Field and Oak Harbor, attract many visitors. In addition, the favorable climate is attractive to recreationists. In 1964, there were 19 publicly-administered outdoor recreation areas.

On the basis of 1966 survey data, 44,100 man-days of effort were spent fishing in the lakes and ponds; and a total harvest of 214,400 trout and 22,000 other game fish species was realized. The steelhead fishery off Whidbey Island is unique in that it is the only saltwater fishery for steelhead of any significance found in the Puget Sound Area. In 1966, about 25,100 man-days of effort were spent fishing for steelhead and searun cutthroat trout and 1,700 steelhead and 10,100 cutthroat trout were harvested.

Navigation terminal facilities include two ferry landings, a number of piers for fishing and other small boats, a few log dumps, and facilities for the use of the military installations. Water-transport oriented industry is limited to two sawmills. No major industrial development is foreseen. However, there are several well-protected harbor areas that could be developed as water terminals if needed to serve possible industrial plants.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, the marine waters near Whidbey and Camano Islands are classed as either excellent (A) or extraordinary (AA), with the objectives being to meet or exceed the quality requirements for all uses.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

The population density in many areas of the islands is reaching a point where community sewage disposal facilities are required. The situation is aggravated by widespread soil conditions not well-suited to on-site sewage disposal through septic tanks. About 70 percent of the land area is unsuited for septic

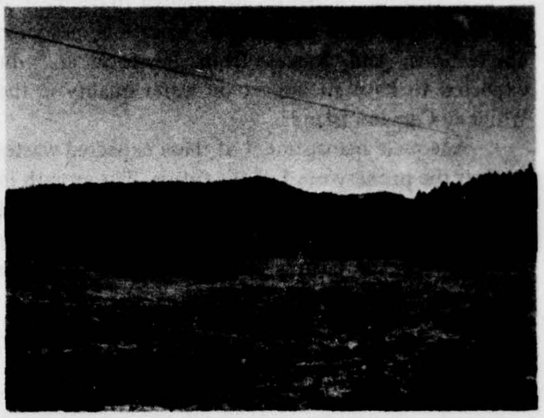


PHOTO 5-2. Many small farms are giving way to recreation and retirement home sites (U.S. Bureau of Reclamation Photo).

tanks. The soil mantle in many areas is shallow and is not sufficiently permeable to adequately receive septic tank drainage.

With the exception of Penn Cove Park, the entire rural population relies on septic tanks or other individual means for sewage disposal. Septic tanks have been established as the minimum for sewage disposal in the area. A few of the older homes still rely on cesspools and, there are isolated instances ρf pit privies in use.

The spread of population along the shorelines of Whidbey and Camano Islands makes the installation of proper facilities difficult and costly.

Both Whidbey and Camano are oriented toward water recreation, yet adequate public sewage disposal facilities are not being provided at parks, boat marinas, beaches, etc. Sewage disposal from pleasure craft is another concern.

FUTURE NEEDS

Population and recreation growth will be responsible for the increase of wastes in the Whidbey-Camano Islands. Establishment of large water-using industries is not expected because of fresh water limitations.

The 1967 population for the Islands was about 22,400. Figure 5-4 shows the 33 percent increase in 1980, the 79 percent increase in 2000, and the 145 percent increase in 2020 that is expected for the two Islands.

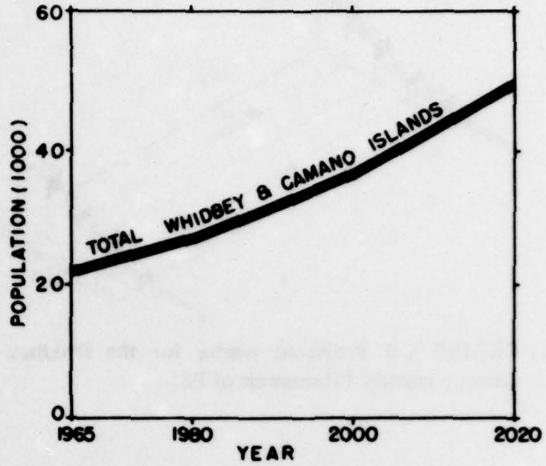


FIGURE 5-4. Projected population growth for the Whidbey–Camano Islands.

By 1980, the production of municipal wastes is expected to reach 29,000 PE.

Major municipal areas in order of raw waste production are Crescent Harbor, Oak Harbor, Naval Air Station (Ault Field), and Coupeville. Residential developments along the shoreline and near freshwater lakes are expected to substantially increase.

Raw wastes generated by recreation is expected to be 40 percent of the total raw wastes for 1980. Recreation wastes for 1980 will amount to 19,200 PE.

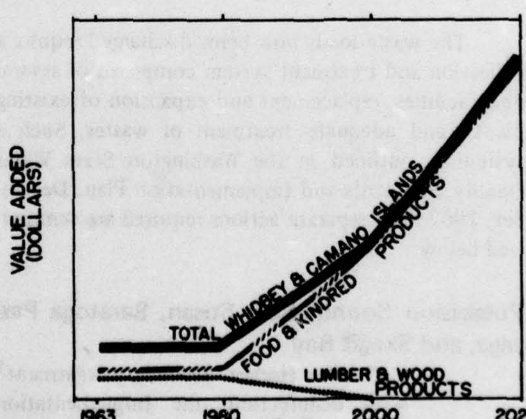


FIGURE 5-5. Relative growth for major water using industries.

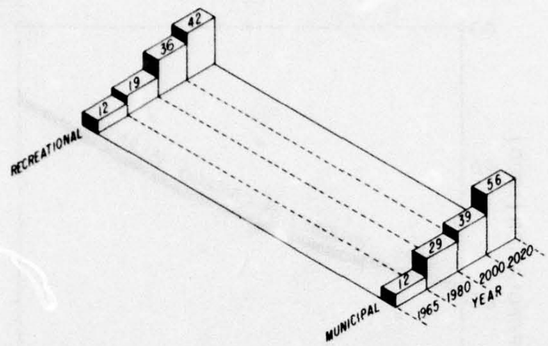


FIGURE 5-6. Projected wastes for the Whidbey–Camano Islands. (Thousands of PE)

Agricultural activities are forecast to decrease in the future, so such practices as irrigation, pesticide applications, and wastes from livestock are not expected to have an impact on water quality in the Whidbey-Camano Islands.

Adequate management of these expected waste-loads is the primary need of the future. The growth in population and water-oriented recreation will demand it. The means to prevent, control, and abate water pollution in the Islands to 1980 and beyond are presented in the succeeding section.

MEANS TO SATISFY NEEDS

Several elements comprise the overall plan for insuring water quality in the Whidbey-Camano Islands. The major aspect of this plan is adequate waste collection and treatment facilities. Most wastes will continue to be organic, being generated primarily from Oak Harbor, the Naval installations, and other areas along the shoreline. Collection and treatment facilities will provide waste discharges amenable to acceptance by the water resources.

The major aspects of the water quality control means are discussed in more detail below.

WASTE COLLECTION AND TREATMENT

The waste loads now being discharged require a collection and treatment system composed of several new facilities, replacement and expansion of existing plants, and adequate treatment of wastes. Such a system is outlined in the Washington State Water Quality Standards and Implementation Plan, December, 1967. The separate actions required are summarized below:

Possession Sound, Port Susan, Saratoga Passage, and Skagit Bay

1. **Oak Harbor**—secondary treatment[1] with disinfection; the Implementation Plan singles out the septic tank used to treat sewage from a portion of Oak Harbor and calls for this sewage to be intercepted and directed to the city's treatment facilities; an adequate outfall.

2. **Towns of Coupeville, Langley, and the Penn Cove Sewer District**—secondary treatment[1] and disinfection facilities with adequate outfall.

3. **Seaplane Base**—secondary treatment[1] and disinfection facilities; adequate outfalls at both the Seaplane Base and Capehart Housing.

Future wastes could, in most cases, be handled by a similar system of municipal treatment facilities with adequate expansion and replacement. The majority of treated wastes should be disposed of in Admiralty Inlet for rapid and optimum dispersion.

A large number of waste treatment facilities will be required to handle the expected growth in outdoor recreation.

Considerable investment will be required to meet the present and future waste collection and treatment requirements.

Tables 5-3, 5-4 and Figure 5-7 show estimates of projected waste collection and treatment investment requirements. Treatment costs will be high initially in order to comply with the State Implemen-

[1] Secondary treatment required unless a lesser degree of treatment will provide for protection of present and future water uses and the preservation or enhancement of existing quality

TABLE 5-3. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Whidbey-Camano Islands

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 29	$ 17	$ 8
Disinfection	5	3	1
Outfalls	29	17	8
Interception and sewer system			
a. Municipal	14	9	4
b. Industrial	5	3	1
Combined sewage infiltration and overflow correction	14	9	4
Advanced waste treatment in recreation areas	--	--	--
Sub-Total	$ 96	$ 58	$26
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 5	$ 3	$ 4
Evaluations—dispersion areas, ecological, productivity	10	4	4
Information system, quality control, plant operation improvement, operation research	10	3	4
Sub-Total	$ 25	$ 10	$12
OPERATION AND MAINTENANCE[2]	$ 27	$ 73	$55
TOTALS	$148	$141	$93

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

tation Plan. A steady annual investment will be required after 1975 to keep pace with population and recreation growth. After 1990, municipal investment is expected to increase, which anticipates the expansion and replacement of sewer facilities.

Municipal costs[1] are expected to total $2,000,000 by 1980 with additional amounts of $2,000,000 in the intervals 1980-2000 and 2000-2020.

The investment[1] for recreation is expected to be $430,000 by 1980 with an additional $1,000,000 needed by 2000, and an additional $1,000,000 by 2020.

Sources of funding for treatment facilities are shown in Figure 5-8. Local entities must pay for a

[1]Costs are not amortized.

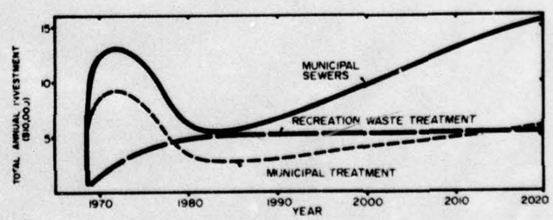


FIGURE 5-7. Relative required rates of investment for waste collection and treatment.

sizeable portion to meet waste treatment needs as they develop.

Federal grants will total $385,000 by 1980, $710,000 by 2000, and $1,170,000 by 2020. State grants will total $190,000 by 1980, $350,000 by

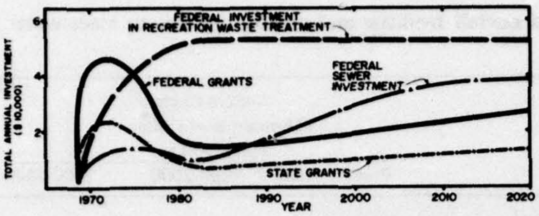


FIGURE 5-8. Government investment requirements[1] for waste collection and treatment in the Whidbey-Camano Islands to meet Interstate Quality Standards and secondary treatment in fresh water.

TABLE 5-4. Total amortized capital and operational costs, Whidbey-Camano Islands

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	--	--	--
Municipal treatment	1.4	0.7	0.3
Municipal sewers	5.1	2.5	1.1
Recreation	0.9	1.0	0.4
Advanced waste treatment	--	--	--
Sub-Total	7.4	4.2	1.8
Water quality engineering management and evaluation	0.3	0.2	0.2
Operation and maintenance	0.3	1.5	1.1
Total	8.0	5.9	3.1

2000 and $550,000 by 2020. Federal investment in sewers will total $131,000 by 1980. Additional amounts of $368,000 and $750,000 will be needed in the periods 1980-2000 and 2000-2020, respectively. The Federal investment in waste treatment facilities for recreation areas will total $410,000 by 1980; $1,000,000 from 1980-2000; and another $1,000,000 from 2000 to 2020.

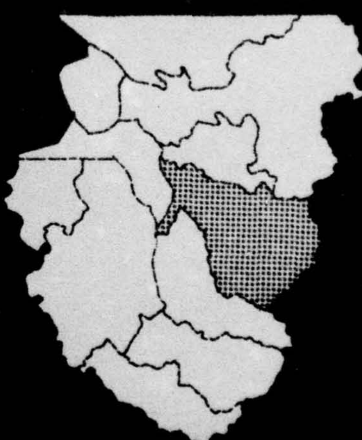
At least for the present, the economics of sewer system construction and the intermittent population concentrations along the shorelines of Whidbey-Camano Islands favor the formation of a number of sewer districts or county service areas to meet sewage disposal needs. In the near future, a coordinated approach to pollution problems must be made by the county, communities, and special districts, in order to decrease the burden of financing treatment and disposal facilities and to develop an adequate revenue base throughout the Islands.

OTHER MEASURES

A water quality surveillance program for the marine water and ground-water is an essential element. Stations have been established on Camano Head, Port Susan (Kayak Point), Gedney Island, Holmes Harbor, Crescent Harbor, Strawberry Point, and Skagit Island, to regularly measure the marine water characteristics. Additional stations, however, are necessary to achieve adequate checks of lakes and ground-water in the Islands.

The Implementation and Enforcement Plans for interstate and intrastate waters sets out classification of watercourses and upgraded treatment facilities necessary to maintain and/or improve existing water quality.

Snohomish Basin



SNOHOMISH BASIN

INTRODUCTION

The Snohomish Basin is the third largest (1,978 square miles) in the Puget Sound Area. The eastern portion is heavily forested and includes an extensive scenic area of numerous mountain spurs. Westward, the varied topography is composed of rolling foothills and the tideflats and deltas of the Snohomish River.

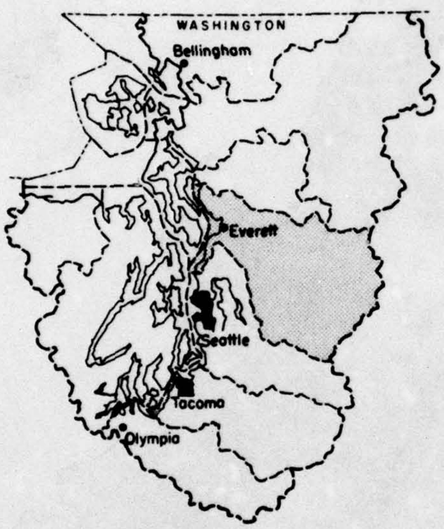


FIGURE 6-1. Location of the Snohomish Basin within the Puget Sound Area.

The entire basin drains into Puget Sound by way of the Snohomish River which enters through Port Gardner and Possession Sound in the vicinity of the city of Everett. Two major river systems–the Skykomish and Snoqualmie Rivers–unite in the lower part of the basin to form the Snohomish River. The Skykomish is the largest tributary (844 square miles) and drains the northeastern part of the basin, while the Snoqualmie River drains 693 square miles in the southern part. The Tolt River, a tributary of the Snoqualmie, has storage facilities on its south fork for the city of Seattle water supply.

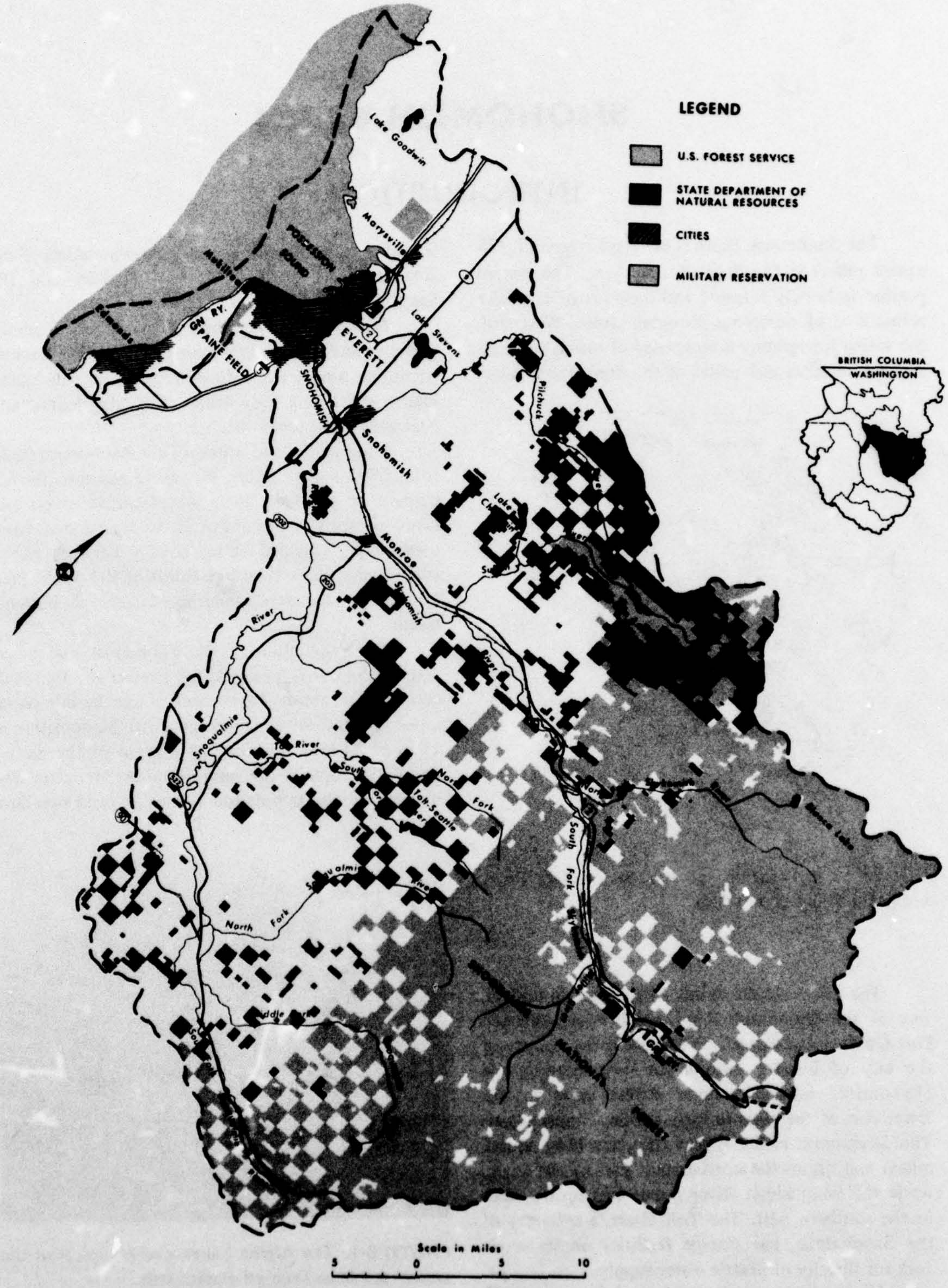
Marine waters in the Snohomish Basin cover 78 square miles and encompass parts of Possession Sound and Port Susan. The major marine inlets of the area are Port Gardner, Everett Harbor, and the Snohomish River estuary.

Soils of the river flood plains consist of sands, gravelly sands, and sandy loams in the upper reaches, becoming progressively finer textured to fine sandy loams, silt loams, clay loams, silty clay loams, and peat soils in the lower reaches.

Land and inland waters of the Snohomish Basin total 1,903 square miles. Woodland accounts for 85 percent of the land area. Inland waters–rivers and lakes–comprise 2 percent of the total land area. Land ownership is divided about equally between public and private. More than two-thirds of the public land is held in Federal ownership–largely in national forest.

The population of the Snohomish Basin was 201,300 in 1967. The cities of Everett and Edmonds account for about 30 percent of the basin's population. Everett is the largest city with a population in 1966 of 51,000. Another 20 percent of the basin's population lives in the rural inland communities. The balance of the population is mostly rural non-farm

PHOTO 6-1. The Alpine Lakes area is typical of the basins' scenic and rugged eastern part.



SNOHOMISH BASIN

Figure 6-2 Land Ownership

PHOTO 6-2. The forest products industry continues to buttress the economy.

(45 percent) clustered around Everett and Edmonds and rural (about 5 percent).

In the last 100 years, the Snohomish Basin has grown from a few pioneer clearings to an area important in forest products and agriculture. Forest products–lumber, wood products, pulp, and paper–continue to be one of the most important mainstays of the economy. The wood and paper products industries are responsible for a large share of the basin's work force–about 30 percent. The number of pulp and paper mills, lumber mills, and wood product plants also attest to its importance.

The Snohomish River valley–which has become an important food supplier for Puget Sound residents–produces dairy products, forage crops, vegetables, berries, and poultry products. Numerous frozen food companies, canneries, and packing plants provide ready markets for these farm products.

The Snohomish River, with its feeder streams, is one of the important fish spawning watersheds in Puget Sound. Both salmon and steelhead utilize these fresh waters. Commercial fishermen in the area rely directly on these salmon runs for their livelihood. Sport fishermen are coming in increasing numbers each year to catch salmon and steelhead.

The proximity of deep salt water is an important factor in the basin's economy. Everett Harbor is capable of handling both shallow and deep-draft facilities.

In late 1966, the Boeing Company purchased several hundred acres in the Paine Field area and began construction of a plant to assemble the Boeing 747. As a result, prompt and significant increases in employment and population in the Snohomish Basin are forecast.

The waterways, forests, and mountains attract a large number of people who are pursuing outdoor recreation activities. The basin is experiencing an ever-increasing rate of use of its public lands for hunting, fishing, camping, hiking, and other recreation activities.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The 22 miles of the Snohomish River begin at the confluence of the Skykomish and Snoqualmie Rivers. Tidal fluctuations in the lower 18 miles of the Snohomish make it impractical to compute flows below 10,000 cfs. However, projections from upstream tributary flow records indicate a mean annual discharge of about 9,500 cfs for the entire basin for the years 1931 to 1960. Climatic conditions entailing heavy precipitation in the late fall and winter months and melting snow in the late spring usually cause two annual periods of high water. A maximum discharge of 71,600 cfs for the year was computed from readings taken in January, 1965 at the gaging station at the town of Snohomish.

The North, Middle, and South Forks of the Snoqualmie River meet near the town of North Bend. Four miles below the confluence the river drops 268 feet at Snoqualmie Falls, then flows northwesterly about 36 miles to join the Skykomish River. The average annual discharge of the North, South, and Middle Forks (as measured at the gaging station at the town of Snoqualmie) is about 2,636 cfs for the period 1931 to 1960.

The Tolt River, major downstream tributary of the Snoqualmie River, drains about 81 square miles of foothills and mountains. The city of Seattle operates water supply storage facilities on the South

Fork of the Tolt River. The Tolt Reservoir has a storage capacity of about 68,000 acre-feet, supplying Seattle with upwards of 30 cfs. Records for the period 1928 through 1958 taken at the gaging station located on the Snoqualmie River near Carnation show an average discharge of 3,777 cfs for the combined Tolt and Snoqualmie Rivers.

PHOTO 6-3. The Snoqualmie River drops 268 feet at the falls, then flows northwesterly to join the Skykomish River.

PHOTO 6-4. Water supply storage facilities on the South Fork of the Tolt River are operated by the Seattle Water Department. The water is diverted to the Cedar-Green Basins.

The Skykomish River and its tributaries drain over 40 percent (844 square miles) of the Snohomish River Basin–all in the northeastern portion of that area. The headwaters of the Skykomish River are in the high Cascades, with the North and South Forks rising in the mountains around Stevens Pass. The South Fork is the largest contributor to the Skykomish main stem. Discharge from this area is effectively measured at a gaging station near Gold Bar; records for the period 1930 to 1960 reflect a mean annual flow of 3,976 cfs.

The Sultan River, tributary to the Skykomish River main stem, drains a relatively limited area of 74.5 square miles. The discharge from this stream is correspondingly small at 813 cfs (30-year mean annual yield). The city of Everett has constructed water supply storage facilities on the Sultan River to supplement the existing supply from Lake Chaplain; the two reservoirs together supply the communities of western Snohomish Basin with approximately 260 cfs (170 mgd) from storage of about 36,000 acre-feet capacity.

The Pilchuck River empties into the Snohomish River main stem and is the only major tributary downstream from the confluence of the Skykomish and Snoqualmie Rivers. This stream drains 54.5 square miles in the northern central basin which is comprised mostly of foothills of the Cascade Mountain Range.

Periods of low river flow in the Snohomish Basin occur in the months of August and September and are significant in evaluating problems of water quality. The 7- and 30-day low flows for a recurrence interval of ten years are given in Table 6-1.

TABLE 6-1. Low flow frequency 10–year recurrence interval, Snohomish Basin

Station	7–Day Low Flow cfs	30–Day Low Flow cfs
Snoqualmie River at Carnation	450	510
Skykomish River near Gold Bar	490	580
Sultan River near Startup	64	80

Source: Appendix III. Hydrology and Natural Environment.

Marine Water

Reaching from the community of Warm Beach in the north, to the city of Edmonds in the south, the salt waters of the Snohomish River Basin include parts of Port Susan, Possession Sound, and Puget Sound. Major features of the area are Port Gardner, including Everett Harbor, and Gedney Island, the only offshore land in the basin's marine waters.

Port Susan is a narrow inlet to the north of Everett bounded by Camano Island and the mainland and open only at its southern end. Shallows occur over the Stillaguamish River delta at its northern end and the Snohomish River delta at the southern end. Otherwise, it is steepsided with depths up to 360 feet.

Port Susan tends to act apart from the rest of the marine waters in the area. The Stillaguamish River inflows are not large and are greatest in the winter rather than spring or summer. Because of the entrance sill, the Port is not afforded continuous tidal flushing such as that which occurs in the more open waters of Port Gardner Bay. Some of the waters below 300 feet will remain trapped for several months. Net circulation consists of inflowing saline water from Port Gardner entering at mid-depth and moving very slowly northward and outflowing less saline surface water (from Stillaguamish River). Net current velocities are low and flushing is a long term situation.

Port Gardner is the northeastern arm of Possession Sound, lying west of Everett. Depths in most of the Port are from 200 to 600 feet with shallow areas found around Everett Harbor and north along the sill to Port Susan Bay.

The Snohomish River and, to a lesser extent, the Skagit and Stillaguamish Rivers, produce a fairly stable surface layer of less saline water. This density stratification inhibits vertical mixing of surface water with underlying saline water. Tidal currents are weak and variable with no strong circulation patterns. Generally, flood tide currents move northward and ebb tide currents move southward.

WATER QUALITY

Fresh Water

The Snohomish River system has had water quality measured on a routine basis at the stations shown on Table 6-2.

Chemical. The waters of the Snohomish Basin are low in dissolved solids. The average dissolved solids are about 25 mg/l for all streams measured.

The chemical characteristics are quite similar for all the major tributaries. In general, the average composition is 15 percent magnesium, 65 percent calcium, and 20 percent sodium.

Phosphate concentrations in the Snohomish Basin range from very low in some tributaries to low in the main river at Snohomish and in other tributaries. The Tolt River near Carnation carries extremely low amounts with less than 0.03 mg/l. The Sultan River at Sultan and the Skykomish River at Gold Bar have maximum values of 0.07 mg/l and average values of less than 0.03 mg/l. The main river at Snohomish carries maximum concentrations of 0.12 mg/l or less and averages values less than 0.04 mg/l. The Snohomish River at Snohomish is low in nitrates when compared with other rivers in the Study Area but is much higher in nitrates than its tributaries as maximum values are 0.6 mg/l or less, but average values are 0.2 mg/l.

Most ground-waters are generally low in dissolved solids with concentrations being usually less than 200 mg/l. Hardness of water taken from alluvial materials is around 50 mg/l and that from deeper sands and gravels varies from about 15 mg/l to 150 mg/l. Silica concentration is commonly in the 20 to 40 mg/l range. Iron is the most common objectionable constituent, with maximum concentrations as high as 9 mg/l found in many well waters. This high iron content is especially prevalent where peat or boggy soils are present.

Saline ground-water often occurs in the flood plain and delta areas downstream from Snohomish and at some places along the shoreline. Salinity of ground-water is generally less than 1.5 mg/l of chloride except for wells in the lower flood plain and delta regions where brackish waters are common.

Bacteriological. Bacteriological quality data for the Snohomish area indicate a general trend of increase in coliform concentrations from the headwaters to the mouth. The Skykomish River at Gold Bar generally has MPN values of not more than 50 coliforms per 100 ml. However, there is some increase in coliform concentrations in the lower Skykomish River before it joins the Snoqualmie River. Bacteriological quality data for the Snoqualmie River at Snoqualmie show the MPN values to be highly variable. During the summer and fall months, MPN values have reached 4,600 or more coliforms per 100 ml. Data for the Snohomish River at Snohomish reveal the composite effect of the upper two rivers together with some increase in discharged wastes below their confluence. MPN values are normally found to be about 2,000 with an observed maximum of 24,000 coliforms per 100 ml.

Table 6-3 summarizes coliform concentrations taken from basic sampling.

TABLE 6-2. Surface water quality, Snohomish River

Item	Discharge (cfs)	Dissolved solids (mg/l)	Calcium (Ca) mg/l	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4) (mg/l) mg/l	Total phosphate (PO_4) (mg/l)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Boron (B) (mg/l)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen (mg/l) mg/l	Oxygen saturation (%)	Total (mg/l) mg/l	Noncarbonate (mg/l)	Coliform (MPN)
SKYKOMISH RIVER NEAR GOLD BAR — JULY 1959 THROUGH 1966																											
Maximum	23,700	36	5.2	1.1	2.3	0.9	181	0	4.0	2.5	0.2	0.6	46	0.06	---	7.6	0.52	0.05	7.5	20	20	18.3	13.9	122	18	7	2,400
Mean	---	23	3.8	0.5	1.5	0.5	19	0	2.0	1.1	0.0	0.3	32	0.01	---	5.5	0.09	0.02	---	---	---	8.8	11.6	102	12	0	174
Minimum	748	13	2.0	0.1	0.6	0.2	10	0	0.6	0.2	0.0	0.0	20	0.00	---	3.6	0.01	0.00	6.5	0	0	2.6	9.6	92	7	0	0
Number	31	38	38	38	36	36	38	23	38	38	37	38	38	33	---	38	34	12	37	36	15	37	37	37	38	38	37
SULTAN RIVER NEAR STARTUP — JULY 1960 THROUGH 1966																											
Maximum	---	23	4.1	0.7	1.4	0.6	15	---	3.2	0.9	---	0.1	---	---	---	5.8	0.07	---	---	---	---	---	---	---	13	---	---
Mean	---	23	4.1	0.7	1.4	0.6	15	---	3.2	0.9	---	0.1	---	---	---	5.8	0.07	---	---	---	---	---	---	---	13	---	---
Minimum	---	23	4.1	0.7	1.4	0.6	15	---	3.2	0.9	---	0.1	---	---	---	5.8	0.07	---	---	---	---	---	---	---	13	---	---
Number	---	1	1	1	1	1	1	---	1	1	---	1	---	---	---	1	1	---	---	---	---	---	---	---	1	---	---
SULTAN RIVER AT SULTAN — JULY 1960 THROUGH 1966																											
Maximum	---	56	9.0	2.4	3.3	0.9	38	0	4.8	1.8	0.2	0.8	73	0.07	---	10.0	2.30	0.05	8.1	20	75	21.3	13.7	122	31	2	930
Mean	---	27	4.6	0.8	1.3	0.3	18	0	2.8	0.8	0.1	0.4	38	0.01	---	5.2	0.41	0.01	---	---	---	9.9	11.2	102	15	0	88
Minimum	---	15	2.0	0.1	0.6	0.0	9	0	0.6	0.2	0.0	0.1	20	0.00	---	2.6	0.01	0.00	3.9	0	0	3.5	8.5	80	8	0	0
Number	---	35	35	35	35	35	35	20	35	35	35	35	35	31	---	35	31	12	35	11	16	34	35	34	35	35	35
SNOQUALMIE RIVER AT SNOQUALMIE — JULY 1959 THROUGH 1966																											
Maximum	2,610	33	6.0	1.0	1.8	0.8	22	0	3.0	1.5	0.3	1.8	46	0.12	---	7.9	4.80	0.06	7.4	40	40	17.5	13.2	111	18	2	4,600
Mean	---	25	4.1	0.4	1.2	0.4	15	0	2.0	0.7	0.0	0.5	32	0.02	---	5.7	0.59	0.01	---	---	---	9.1	11.1	99	12	0	1,439
Minimum	134	14	1.5	0.0	0.7	0.1	7	0	0.0	0.2	0.0	0.0	16	0.00	---	3.1	0.02	0.00	6.2	5	5	3.2	9.0	86	6	0	0
Number	15	34	34	34	34	34	34	22	34	34	34	34	34	31	---	34	31	10	34	34	14	36	36	36	34	34	35
TOLT RIVER NEAR CARNATION — JULY 1960 THROUGH 1966																											
Maximum	2,340	47	8.0	1.9	2.1	0.7	32	0	5.6	1.2	0.1	1.0	65	0.03	---	10.0	1.80	0.05	7.5	30	50	23.2	14.7	122	27	2	430
Mean	---	33	5.2	1.0	1.6	0.3	20	0	3.7	0.8	0.0	0.4	43	0.01	---	7.2	0.33	0.01	---	---	---	10.6	11.1	102	17	1	84
Minimum	90	21	3.0	0.3	1.0	0.0	10	0	2.2	0.2	0.0	0.1	24	0.00	---	3.8	0.03	0.00	6.6	0	0	3.7	8.7	86	9	0	0
Number	27	34	34	34	34	34	34	19	34	34	34	34	34	31	---	34	31	11	34	34	15	34	35	34	34	34	34
SNOQUALMIE RIVER NEAR CARNATION — 1947 THROUGH 1948																											
Maximum	7,600	42	7.2	1.0	---	---	29	---	5.4	1.0	0.2	0.9	59	---	---	10.0	0.05	0.01	7.2	---	---	---	---	---	22	2	---
Mean	---	39	6.6	1.0	---	---	25	---	4.6	0.9	0.2	0.7	51	---	---	9.6	0.05	0.01	---	---	---	---	---	---	21	1	---
Minimum	880	36	6.0	1.0	---	---	21	---	3.8	0.8	0.2	0.5	42	---	---	9.2	0.05	0.01	7.2	---	---	---	---	---	19	0	---
Number	2	2	2	2	---	---	2	---	2	2	1	2	2	---	---	2	1	1	1	---	---	---	---	---	2	2	---
SNOHOMISH RIVER AT SNOHOMISH — AUGUST 1959 THROUGH 1966																											
Maximum	40,800	40	7.2	1.6	3.1	0.9	27	0	4.0	2.2	0.2	2.6	62	0.12	---	11.0	3.20	0.05	7.4	20	160	19.0	14.0	128	22	2	24,000
Mean	---	30	4.5	0.9	1.8	0.5	18	0	2.7	1.2	0.1	0.7	40	0.02	---	6.4	0.38	0.02	---	---	---	10.0	11.0	100	15	0	2,050
Minimum	10,000	14	2.0	0.2	0.8	0.0	10	0	0.8	0.0	0.0	0.0	20	0.00	---	3.3	0.04	0.00	6.4	0	0	4.0	8.3	89	8	0	23
Number	19	59	59	59	59	59	59	35	59	59	59	59	59	48	---	59	45	8	59	58	43	62	62	62	59	59	62

Physical. Dissolved oxygen concentrations throughout the Snohomish River system are normally near saturation levels. The minimum recorded DO concentration within the basin is 8.3 mg/1 for the Snohomish River at Snohomish. The maximum recorded DO concentration is 14.7 mg/1 for the Tolt River at the town of Carnation.

Based on the data presented in Table 6-2, the maximum temperature of the Snoqualmie River at Snoqualmie has reached 63.5°F (18.3°C). The maximum temperature for the Tolt River is 73.8°F (23.2°C).

Turbidity of the Snohomish River is rather low when compared to other streams on the east side of Puget Sound. The mean turbidity of the Snohomish River at Snohomish was 13 JTU (Jackson Turbidity Units) for seven years of record. However, the maximum turbidity at this point, occurring during storm runoff, was 160 JTU (Table 6-2). The turbidity of the Skykomish River is appreciably less than that of the Snohomish River, and the Snoqualmie River turbidity values are slightly greater than those of the Snohomish.

Sediment transport in the upper drainage areas is small except during periods of high runoff. Suspended sediment data in the Snoqualmie River system indicate that the South Fork transports more sediment than the other forks of the river.

Based on data obtained in 1965 and 1966, it is estimated that the Snoqualmie River transports an average of 230,000 tons of suspended sediment annually. Recorded suspended sediment concentrations ranged from 4 to 108 mg/1 with a probably maximum estimated to be less than 1,000 mg/1. The Skykomish River transports about 130,000 tons annually. Measured concentrations for the Skykomish River in 1965 and 1966 ranged from 1 to 28 mg/1. The Tolt River transports only small quantities of sediment except during periods of high runoff.

Marine Water

Port Susan Bay has a relatively shallow (usually

TABLE 6-3. Summary of coliform concentrations, Snohomish Basin

	MPN/100 mls							
	Less than 240		240-1,000		1,000-2,400		Greater than 2,400	
	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.
Skykomish (Gold Bar)	35	95	0	0	0	0	2	5
Sultan (at Sultan)	32	91	3	9	0	0	0	0
Snoqualmie (at Snoqualmie)	7	21	16	47	2	6	9	26
Tolt (Carnation)	30	91	3	9	0	0	0	0
Snohomish (at Snohomish)	15	25	28	47	0	0	16	27

Source: *Washington Water Pollution Control Commission*

less than 30 feet) surface layer of highly variable low salinity water. The distribution of the surface layer is difficult to predict. The waters below the surface layer are similar in characteristics to those found in Port Gardner Bay.

Port Gardner Bay and its inner component, Everett Harbor, have been the subject of extensive water quality surveys in the past. The most recent survey focused upon those parameters which were indicative of waste discharges to marine waters—namely sulfite waste liquor, dissolved oxygen, and bacteria.

The minimum observed SWL concentrations are greater than background values (0-2 ppm) at almost all points in the Port Gardner-Possession Sound-Everett area. Highest concentrations occur below the 150-foot depth. Generally, average SWL concentrations at depth exceed 15 ppm and reach 250 ppm near Everett. Maximum SWL concentrations at depth near Everett range from 25 to 750 ppm. In the surface layer (0-35-foot depth), average SWL concentrations range from 10 to 25 ppm, and maximum SWL values range from 15 to 100 ppm. Average SWL concentrations of about 30 ppm are found at mid-depth in the northern portion of Port Susan.

Dissolved oxygen concentrations at about the 30-foot depth in the vicinity of Everett Harbor have been found to be as low as 0.0 mg/1. Minimum values of DO at the surface are about 3.0 mg/1, increasing to about 4.2 mg/1 at about the 10 to 15-foot depth. The maximum DO concentration of about 10.0 mg/1 occurs at the surface.

MPN concentrations in Port Gardner Bay and the open waters of Everett Harbor were less than 300 coliforms/100 ml for three surveys conducted during March, April, and May of 1965, while concentrations in the lower Snohomish River and in certain dock-front areas of the harbor ranged from about 800 to 2,700 coliforms/100 ml.

SOURCES OF WASTE

The raw municipal and industrial wasteload generated in the Snohomish Basin approximates over seven million population equivalents of which five percent is presently removed by treatment before being discharged to fresh and marine waters. The area receiving the largest quantity of waste in relation to the total basin, is the Everett Harbor and Port Gardner area (96 percent). The Snohomish River receives the next largest quantity of wastes, but it is less than two percent of the basin total.

The quantities and general location of waste production and discharges in the basin are shown in Figure 6-3. Sources of waste contributing to the contamination of fresh and marine waters are summarized in Table 6-4. The completion of the Implementation and Enforcement Plans will substantially reduce the strength of present raw waste.

Fresh Water

Sources of waste located along the Skykomish, Snoqualmie, Pilchuck, and Snohomish Rivers produce about 92,500 PE of raw organic wastes daily. During the food processing season, an additional 48,150 PE are produced every day. The production of wastes exceeds 140,650 PE daily in peak season. Completion of the proposed Intrastate Quality Standards will reduce this wasteload.

TABLE 6-4. Summary of municipal and industrial wastes, Snohomish Basin

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Skykomish River						
Sultan	500	500	--	Primary	500	--
Monroe	1,950	2,400	--	Primary	1,700	--
Food processing	--	--	2,400	Monroe	--	2,000
State Reformatory	1,000	1,000	--	Lagoon	400	--
Snoqualmie River						
North Bend	900	1,200	--	Primary	840	--
Snoqualmie	1,200	1,500	--	Lagoon	220	--
Snoqualmie Falls	300	400	--	Primary	250	--
Pilchuck River						
Granite Falls	600	700	--	Primary	450	--
Lake Stevens						
Food processing	--	--	2,500	None	--	2,500
Snohomish River						
Snohomish	4,000	8,400	--	Lagoon	5,000	--
Food processing	--	--	42,000	City	--	33,000
Food processing	--	--	1,250	None	--	1,250
Food processing	--	700	--	Primary	300	--
Paper & allied	--	75,000	--	Primary	60,000	--
Lumber & wood	--	700	--	None	700	--
Ebey Slough						
Marysville	3,000	4,000	--	Lagoon	1,100	--
Food processing	--	--	8,000	City	--	2,000
Tanning	--	--	600	Lagoon	--	350
Possession Sound						
Everett	41,000	45,000	--	Lagoon	2,000	--
Food processing	--	4,000	1,100	None	4,000	1,100
Lumber & wood	--	11,600	--	None	11,600	--
Paper & allied	--	6,391,000	--	None	6,391,000	--
Paper & allied	--	500,000	--	Lagoon	238,000	--
Mukilteo	1,300	1,500	--	Primary	1,000	--
Paine A.F.B.	1,000	1,300	--	Secondary	200	--
Lynwood	10,200	12,000	--	Primary	9,000	--
Edmonds	10,000	31,000	--	Primary	19,000	--
Mountlake Terrace	12,000	(14,000)	--	Edmonds	(8,000)	--
TOTAL[1,2]	88,950	7,094,000	58,000		6,747,000	42,200
Municipal	--	111,000	--		42,000	--
Industrial	--	6,983,000	--		6,705,000	--

1 Figures are rounded.

2 PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

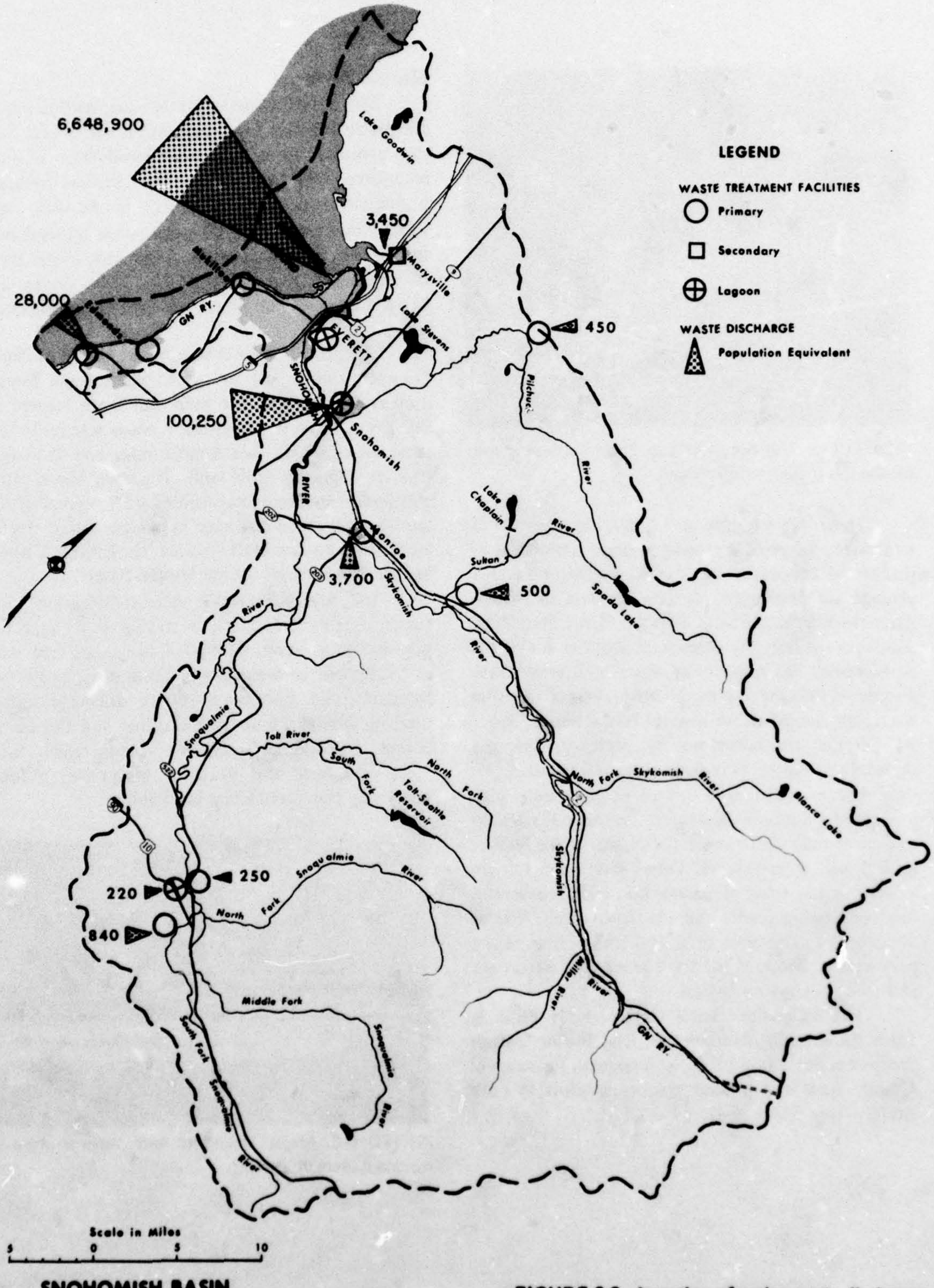


FIGURE 6-3. Location of major waste discharges

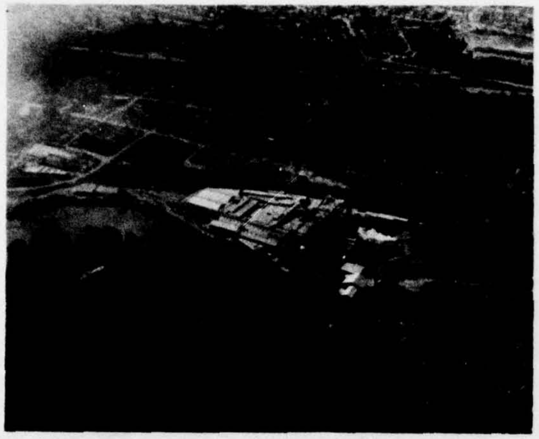


PHOTO 6-5. The Simpson Lee Paper Company mill on the lower Snohomish River.

These wastes are given varying degrees of treatment; 58 percent receive primary treatment; 39 percent of the wastes are treated by lagoon; and 3 percent are discharged into the streams untreated. After treatment, a total of 109,000 PE are discharged daily into the rivers by cities and industries during the peak season. The majority of wastes (92 percent) are discharged into the Snohomish River. Out of the total wastes discharged to fresh water in the basins, about 94 percent are generated by industry; and the remaining six percent are from cities and towns.

The primary waste source to the Snohomish River is the Simpson Lee Paper Company kraft pulp and paper mill located near the mouth of the Snohomish River near Everett. Other waste sources are located in the town of Snohomish, including several food processing plants and the town itself. Wastes discharged to the river total 100,250 PE during the peak season. Most of the food processing wastes are treated by the town's lagoon.

The Snoqualmie River receives 1,310 PE daily from three small communities. The Pilchuck River receives about 3,000 PE daily from both the town of Granite Falls and a food processing plant at Lake Stevens (see Table 6-4).

Marine Water

Cities and industries located near marine waters are producing over seven million PE daily. Less than one percent of this total waste production receives secondary treatment; about one percent receives primary treatment; eight percent of the wastes are treated by lagoon; and 90 percent are released into the marine waters untreated. As a result, wastes from an equivalent population of 6,677,000 people are being discharged, of which most are being generated by industry.

The principal waste sources are the Scott Paper Company sulfite pulp and paper mill and the Weyerhaeuser Company sulfite pulp mill–both located in the city of Everett. Other major waste sources in this same area include two lumber mills and a Weyerhaeuser company kraft mill. Together, these paper and lumber mills are responsible for 99 percent of the basin's total waste discharge to marine waters. Wastes are discharged into Port Gardner, the Everett Harbor, and the tidal area of the Snohomish River.

The city of Everett's waste stabilization pond for treatment of domestic wastes serves a connected population of about 50,000. Paine Air Force Base and suburban communities like Mukilteo, Lynwood, Edmonds, and Mountlake Terrace discharge wastes totaling 29,000 PE to Port Gardner and Possession Sound. Ebey Slough receives wastes which total 3,450 PE from the town of Marysville, a food processing plant, and a tanning plant.

PHOTO 6-6. Major industries and waste sources to marine waters at Everett.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters are summarized in Table 6-5 which focuses on the principal watercourses and problem areas in the basin. The table also indicates the water quality classification established by the State for each water course which defines the type of water uses to be protected in the area.

Anadromous fishes inhabiting the Snohomish River system are chinook, coho, pink, and chum salmon; steelhead and searun cutthroat trout; and searun Dolly Varden. Species of marine fish in the basin include cod, hake, lingcod, greenling, flounder, sole, surfperch, rockfish, herring, dogfish, and ratfish. Significant populations of Dungeness crab prevail along the edge of the Snohomish flats from Mission Beach to Port Gardner and along the shoreline from the Everett boat basin south past Mukilteo to Edmonds.

The basin's marine waters support a moderate to heavy commercial fishery for salmon. Gill netters operate in the Port Susan and Port Gardner areas. Favorite locations include Kayak Point, Tualip Point, Hat Island, Mukilteo, and Meadowdale. The majority of salmon caught are landed at Everett. The average annual contribution (1956-1965) to the Puget Sound and ocean fisheries from the Snohomish Basin is estimated at 464,430 salmon. Saltwater sport fishing for salmon is presently considered light to moderate in Port Gardner. In 1965, more than 160,500 angler trips were recorded in the surrounding waters. The effort by anglers of marine species is light to moderate. In 1965, 4,300 angler trips were recorded.

Based on 1966 survey data, 389,300 man-days of effort were spent fishing in the lakes and ponds of the basin, and a total harvest of 1,143,700 trout and 414,800 other game fish was realized. In the streams, 293,000 man-days were spent with a harvest of more than 955,000 trout.[1] Approximately 206,000 man-days were expended in 1966 in pursuit of steelhead and searun cutthroat trout and 34,500 steelhead and 20,100 cutthroat trout were harvested.

[1] Includes catch of all salmonoids.

Commercial and sport harvest of shellfish species is considered very light at this time. Some crabs, oysters, and hardshell clams are taken annually; however, the magnitude of this harvest is relatively small due to a variety of limiting factors on shellfish production.

The Snohomish Basin ranks third in the Puget Sound in water related recreation demand. There were 3,600,000 water-related recreation days in 1960. By 1980 that number will double. Swimming is by far the most popular activity, followed by camping, picnicking, and fishing.

Water based recreation areas include about 50 miles of shoreline on Puget Sound, numerous lakes, rivers, and small streams. Better known large water areas include Sultan Reservoir and Lake Stevens. The eastern half of the basin contains many attractive, small, high altitude lakes. A group of such lakes is included within the proposed Alpine Lake Wilderness in the Snoqualmie National Forest. Other recreational attractions include the mountainous areas of the Cascade Range and a large section of the Glacier Peak Wilderness. In 1965, there were 112 publicly-administered outdoor recreation areas within the basin.

The surface waters of the Snohomish Basin are used extensively by municipalities and industries. Everett obtains its water supply from the Sultan River. The town of Snohomish gets its water from the Pilchuck River. The Weyerhaeuser Company sulfite paper mill in Everett presently obtains water from the Snohomish River.

Everett's 1963 foreign and domestic coastwise traffic was over 700,000 tons; the domestic internal traffic that year was over 850,000 tons.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. Except for the inner part of Everett harbor, the water quality class in most watercourses in the Snohomish Basin is either good (B), excellent (A), or extraordinary (AA) with the objectives being to meet or exceed the quality requirements for most uses.

TABLE 6-5. Water uses and quality objectives, Snohomish Basin

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[1]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Everett Harbor	A			H	H					L	L	L	L			M	M			L		M	H	
Inner Everett Harbor	C			H	H												L			L		M	H	
Snohomish River, mouth to River Mile 9	B			H	H					L			M			M	M			L		H	H	
Snohomish River to River Mile 18	A			H	H					L			M			M	M			L		H	H	
Snohomish River above Tidal Influence	A			H	H	M							M			M	M							
Snoqualmie River	A			H	H	H							H			H	H		L	L	L			M
Skykomish River	A			H	H	H							H		L	H	H							
Tolt River	A			M	M	M							H			L	H		H	H				
Sultan River	A			H	H	H							H			M	H		H	H				M

[1] See Table 1-5.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs are concentrated in the marine waters where the discharge of pulping, food processing, and municipal wastes are causing unsatisfactory quality conditions. The inner portion of Everett Harbor does not meet a single water quality objective. Outer areas of the harbor do not meet the objectives set for dissolved oxygen, turbidity, toxicity, and aesthetics.

Pulp mills located adjacent to Port Gardner and the Everett Harbor which contribute great amounts of sulfite waste liquor, solids, and oxygen demand to marine waters are affecting the water quality over a broad area. These discharges result in high waste concentrations, sludge deposits, and attendant water quality degradation–conditions which are incompatible with marine life and interfere with other legitimate water uses.

Tidal currents in Possession Sound, Port Susan, Saratoga Passage, and Port Gardner are weak and variable and do not effect rapid dispersion and transport of discharged wastes. Water circulation in the Everett Harbor is weak and does not provide sufficient flushing action for maintenance of acceptable water quality.

High bacterial concentrations throughout Everett Harbor are due to inadequately treated municipal wastes, an unsewered waterfront, and wastes from watercraft.

Water quality in the estuarial reach of the Snohomish River is also affected by pulping and lumbering mill wastes and by discharges from the Everett stabilization pond. SWL concentrations up to 50 ppm maximum are common along with depressions of dissolved oxygen concentrations down to 4 and 5 mg/1.

MPN concentrations on the upper Snohomish River periodically exceed the water quality objectives due primarily to municipal and industrial wastes from the city of Snohomish. Wastes produced by livestock may also be quite significant in contributing to the total bacterial count in the river. Turbidity is high at times due to clay slides which is a natural problem.

In conclusion, the prevailing need is to improve the water quality of the Everett Harbor and Port Gardner system (Possession Sound), and the Snohomish River, especially its lower reach. Waste discharges to these waters have been found to be detrimental to juvenile salmon, sensitive early-life stages of shellfishes, and phytoplankton.

FUTURE NEEDS

The principal factors expected to affect future fresh and marine water quality in the Snohomish Basin will be the growth in population, industrial production, recreation, and agriculture. As this growth occurs, waste production and water quality problems will likewise increase. Forecasts of the quantities and location of wastes are the basis for determining the means to preserve water quality and to protect the water uses of any given watercourse.

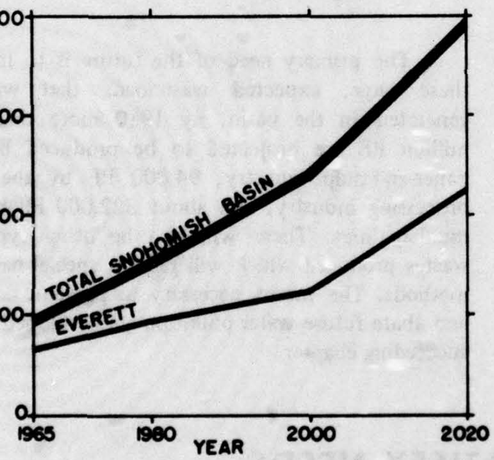


FIGURE 6-4. Population growth projected for the Snohomish Basin.

The 1967 population of 201,300 in the Snohomish Basin is expected to increase 59 percent by 1980, 155 percent by 2000, and 310 percent by 2020. (See Figure 6-4). It is expected that the population increase will be throughout the basin, with growth areas occurring around Everett, Edmonds, Marysville and Snohomish.

Production growth for the major water using industries in the Snohomish Basin is expected to increase 1.4 times between 1980 and 2020 in terms of value added. The basin's economy is now, and will continue to be, based on progressive paper and allied products industries. Slight diversification is offered by a growing food and kindred products industry and a declining lumber and wood industry. (See Figure 6-5).

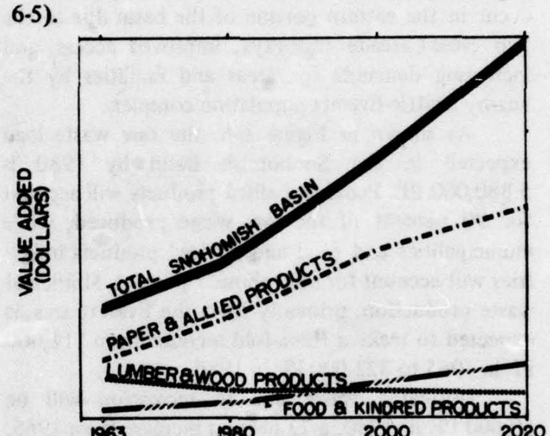


FIGURE 6-5. Relative growth for major water using industries in the Snohomish Basin.

The increased production of the paper and allied products industry is projected to parallel the total basin growth until the year 2000, when it will continue to increase but at a slower rate. In the year 2000, the paper industry will constitute about two-thirds of the total basin product, but will decrease to 56 percent in 2020.

The growth of paper production should cause a timber harvest increase. The rate of timber harvest is expected to nearly parallel the rate of paper products; the difference will be due to a slow decline in the use of logs for lumber and wood production.

The major production of paper products is presently located in Everett along Puget Sound. Future production will most likely remain in the same area because of transportation for finished products, marine water disposal of waste, and available manpower.

Food and kindred products industries are forecast to provide the main diversification of a paper and allied products economy by 2020. In that year food industries will represent about one-fifth of the total basin production.

The production of seasonal food and kindred products is projected to remain distributed throughout the basin with the greater production occurring near Snohomish. The major non-seasonal food production will remain near Everett.

By 1980, nearly 15 million recreation days are forecast for the basin—almost double the 1960 recreation demand. Intense recreation is expected to occur in the eastern portion of the basin due to the two cross-Cascade highways, improved access, and increasing demands for areas and facilities by the nearby Seattle-Everett population complex.

As shown in Figure 6-6, the raw waste load expected in the Snohomish Basin by 1980 is 5,880,000 PE. Paper and allied products will account for 90 percent of the raw waste produced, while municipalities and food and kindred products industries will account for only about 7 percent. Municipal waste production, primarily from the Everett area, is expected to make a three-fold increase from 111,000 PE in 1965 to 322,000 PE in 1980.

Untreated waste due to recreation will be 50,600 PE in 1980, a 72 percent increase from 1965.

Livestock accumulations, especially into larger dairy herds, portends the worst agricultural danger to the quality of Snohomish Basin streamflow. During heavy winter rainstorms, some of the wastes excreted by these animals washes into streams. The quality impact from this source of pollution will increase in the future as the number and density of cows per acre increase.

The present irrigated acreage of 12,800 acres is expected to increase to 48,000 acres by 2020 to meet food and fiber needs. Most of the irrigation will be of the sprinkler type and will rarely, if ever, result in surface wash or in measurable leaching of the soil.

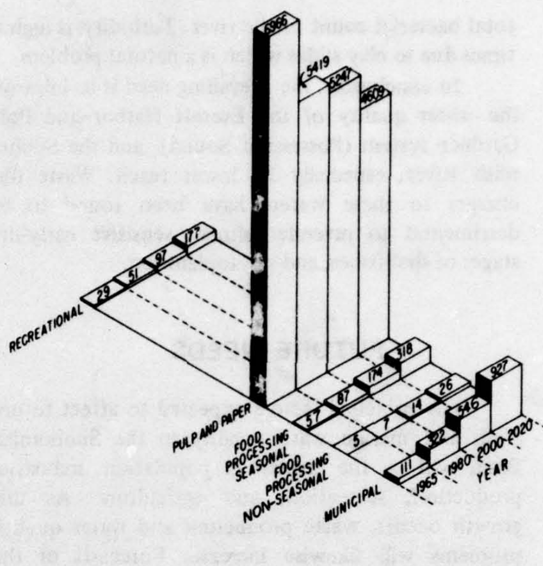


FIGURE 6-6. Projected municipal and industrial untreated wastes for the Snohomish Basin. (Thousands of PE).

The primary need of the future is to manage these large, expected wasteloads that will be generated in the basin. By 1980 more than five million PE are projected to be produced by the paper and pulp industry, 94,000 PE by the food processing industry, and about 322,000 PE by the municipalities. There will also be other types of wastes produced which will require special handling methods. The means necessary to prevent, control, and abate future water pollution are developed in the succeeding chapter.

MEANS TO SATISFY NEEDS

Several elements compose the water quality means for the Snohomish Basin. The central and paramount element is adequate waste collection and treatment. Most wastes are, and will continue to be, organic wastes generated primarily around the Everett area. Collection and treatment facilities will provide waste discharges amenable to acceptance by the water resources. The flow requirements to assimilate the residual wastes, both now and in the future, are small compared with present minimum flows.

The major aspects of the water quality control means are discussed in detail below.

WASTE COLLECTION AND TREATMENT

The serious water quality degradation that exists in Port Gardner Bay is a result of partially treated and untreated wastes from the pulp mills. The high bacterial concentrations on the Snohomish and

Snoqualmie Rivers derive primarily from untreated municipal wastes. These present needs require immediate institution of collection and treatment facilities. This system of facilities is detailed in the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, December 1967. Some of the requirements as outlined in the plan as well as additional requirements not covered in the Standards, are summarized below:

1. **Cities of North Bend and Snoqualmie Falls**–secondary treatment.
2. **City of Snoqualmie**–interception.
3. **City of Granite Falls** and food and kindred industries–secondary treatment.
4. **Cities of Index, Sultan, and Monroe**–secondary treatment.
5. **City of Snohomish**–plant expansion, disinfection and outfall facilities.
6. **City of Everett**–plant expansion, sewer interception and adequate operation.
7. **City of Marysville**–adequate disinfection facilities.
8. **Food processing industries located at Everett and Snohomish**–adequate secondary treatment or waste interception. Simpson Lee Paper Company–removal of all settleable solids from mill effluents prior to discharge and an adequate outfall and diffuser to achieve maximum waste dilution and dispersion.

Everett Harbor

The Scott Paper Company and Weyerhaeuser Company sulfite mills at Everett–primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound; adequate disposal of recovered solids; removal of 80 percent of sulfite waste liquor from mill effluents; and an adequate outfall and diffuser.

Future waste management is also founded upon collection and treatment of wastes from discrete sources. Future population and industrial growth is expected to be large in the basin, concentrated near the marine waters from Edmonds north through Everett and above Marysville. This pattern of growth will call for a system of collection and treatment applicable to the physical environment.

The area from Edmonds to Everett is undergoing rapid growth. Wastes can easily be collected, transferred to treatment plants along the Sound, and the treated effluent discharged to the Sound through adequately designed outfalls.

Everett will need to eventually abandon its lagoon and provide treatment due to lack of land area for expansion. Wastes should be conveyed to treatment in and dispersion into the Port Gardner Bay. The estuarial reaches of the Snohomish River are not disposal areas for absorbing significant loads of treated waste effluent.

The land area north of Marysville is ideally situated for urban development. This area should be sewered on a schedule compatible with settlement. In this area also, wastes should be carried to marine waters for treatment and disposal as the communities south of Everett do. The design and construction of needed interceptor trunk lines and treatment facilities will have to accommodate the problem of initial low population development with steady growth to an ultimate.

Lake Stevens is attracting new homes. Septic tanks presently handle domestic wastes generated in areas around the lake. The beauty of the lake and its usefulness for recreation are both now threatened by wastes in the basin handled in this way. Bacterial contamination and nutrient enrichment leading to excessive algal activity are two prime threats from septic tank effluent drainage. Collection of wastes and diversion from the lake basin for treatment and disposal are pressing projects for the area. A likely receiving body for Lake Steven's basin treated wastes is the Snohomish River.

The towns of Snohomish and Monroe on the upper Snohomish River and on the Skykomish River are expected to retain their rural character through the future. Dairies and other food processing plants will concentrate heavily through this area, and production will intensify. Industrial development is not expected to be significant. Enlargement or replacement of their existing basic set of secondary facilities will be the acceptable pattern.

Similarly, the towns along the Snoqualmie up to the Snoqualmie–North Bend area will remain rural-suburban. Flood threats and flood plain zoning will limit development in this area.

Snoqualmie and North Bend are expected to expand significantly–ultimately growing together. Eventually, central treatment facilities will be a logical development for low-cost, high-efficiency, waste handling.

As shown in Tables 6-6, 6-7, and Figure 6-7, industrial waste treatment investment requirements dominate much of the total expenditure.

Industrial costs[1] will total $12,730,000 by 1980, with an additional $10,310,000 by the year 2000, and $23,000,000 by 2020.

Municipal waste collection and treatment investment requirements[1] are also large. By 1980, a total of $11,290,000 will be needed with an additional $19,580,000 by 2000, and another $16,000,000 by 2020.

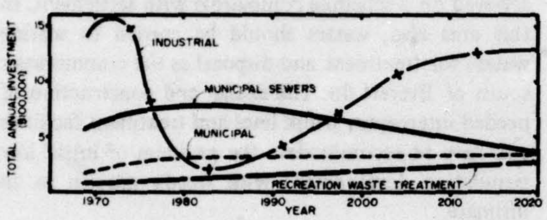


FIGURE 6-7. Relative required rates of investment for waste collection and treatment in the Snohomish Basin.

Sources of funding for municipal facilities are as shown in Figure 6-8, Federal grants of $1,400,000 by 1980, with an additional $2,680,000 by 2000 and an additional $3,000,000 by 2020. By 1980, State grants will total $721,000. In the period from 1980-2000, State grants are estimated to total $1,342,000. From 2000 to 2020 State grants are estimated to total $1,500,000.

The Federal investment in sewers will total over $1,000,000 by 1980, with additional amounts of $3,000,000 and $4,500,000 in the periods 1980 to 2000 and 2000 to 2020.

The Federal investment in sewage treatment facilities for recreational areas will total $870,000 by 1980. Additional expenditures of $2,600,000 and $4,500,000 will be needed for the years 1980-2000 and 2000-2020, respectively.

Political boundaries must be crossed and a regional approach taken to the problem of water pollution. In the near future, a coordinated approach to pollution problems must be made by the county, cities, and special districts in order to drecrease the burden of financing treatment and disposal facilities and to spread the tax base throughout the area. A federation of local governments, along the same lines as METRO, or county services, is proposed as a means for united action to better solve future financing and water quality problems.

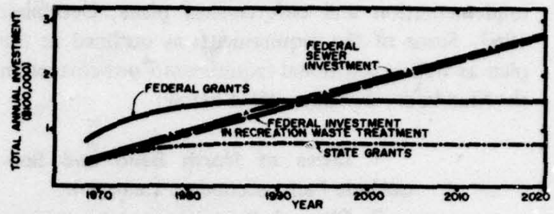


FIGURE 6-8. Government investment requirements[1] for waste collection and treatment in the Snohomish Basin.

FLOW REQUIREMENTS

Waste loadings to the Snohomish River system were projected to be concentrated in three general areas. These centers are North Bend-Snoqualmie on the Snoqualmie River, Monroe on the Skykomish, and Snohomish on the Snohomish River. After compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plans, waste loadings to fresh water of the basin will be reduced from 111,300 PE's presently to 22,900 PE's. The marine wasteloads will be reduced approximately 80 percent.

Based on projected waste discharges to the Snoqualmie, Skykomish and Snohomish Rivers after secondary treatment, minimum flow requirements for water quality control have been determined to be 10 cfs by 1980, 20 cfs by 2000 and 25 cfs by 2020 for the Snoqualmie River; 150 cfs by 1980, 285 cfs by 2000 and 335 cfs by 2020 for the Skykomish River; and 400 cfs by 1980, 750 cfs by 2000 and 890 cfs by 2020 for the Snohomish River. With the one in ten, 7-day lowflows that may be expected for the Snoqualmie and Skykomish Rivers of 450 cfs and 490 cfs and relatively large flows in the Snohomish River (mean annual estimate 9,500 cfs), additional water is not required in these rivers for the maintenance of adequate water quality.

1 Costs are not amortized.

TABLE 6-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Snohomish Basin

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 296	$ 187	$ 106
Disinfection	49	31	18
Outfalls	296	187	106
Interception and sewer system			
a. Municipal	218	164	93
b. Industrial	49	31	18
Combined sewage infiltration and overflow correction	78	24	13
Advanced waste treatment in recreation areas	86	138	222
Sub-Total	$1,072	$ 762	$ 576
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER[2]			
Monitoring—ground water, automatic equipment, etc.	$ 49	$ 12	$ 22
Evaluations—dispersion areas, ecological, productivity	68	12	12
Information system, quality control, plant operation improvement, operation research	123	36	36
Sub-Total	$ 240	$ 60	$ 70
OPERATION AND MAINTENANCE[2]	$ 585	$1,660	$1,880
TOTALS	$1,897	$2,482	$2,526

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

TABLE 6-7. Total amortized capital and operational costs, Snohomish Basin

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	25.2	9.9	9.4
Municipal treatment	6.7	5.7	2.0
Municipal sewers	31.3	26.3	9.1
Recreation	1.7	2.5	1.9
Advanced waste treatment	4.3	6.9	11.1
Sub-Total	69.2	51.3	33.5
Water quality engineering management and evaluation	2.5	1.2	1.4
Operation and maintenance	6.0	33.2	37.6
Total	77.7	85.7	72.5

OTHER MEASURES

Protection and/or enhancement of water quality will require a balanced management system to support waste treatment construction and operation. Focus of future management will be on the lower Snohomish River and Bay areas.

Extensive log rafts are held near the pulp mills on the lower Snohomish River and on Port Gardner Bay. Although not a significant source of pollution, these log rafts exert a degrading effect on the surface waters. Land storage and handling methods are now approaching the low cost of rafting, and may soon replace it.

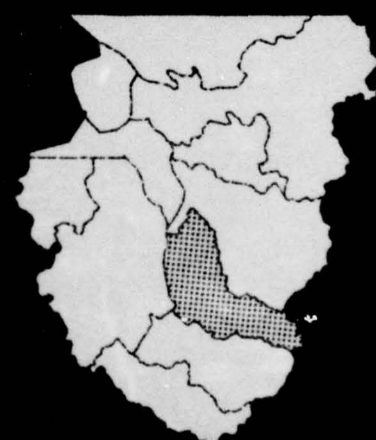
Development of Everett Harbor for industrial sites and major water transport docking facilities will be a continuing effort. This will involve significant dredging activity, as the Snohomish River deposits an estimated 500,000 cubic yards of material in the bay each year. A formal long-term program for removal and placement of this material for the benefit of the Port developments with no adverse water quality effects must be devised by the Port authorities and the State Water Pollution Control Commission.

The poor flushing of Port Susan Bay and the excellent recreation potentialindicates that many industries would not be compatible to this area. Recreation developments such as small boat basins and parks will require adequate waste treatment facilities.

There are two proposed multi-purpose storage projects on the upper Snoqualmie River. The Middle Fork Snoqualmie Project would store water partly contributed from Taylor River. Bank slumping and erosion introduces glacial clay into the stream during periods of high runoff. These colloidal suspensions, when stored in the reservoir and released throughout the year, will adversely increase the turbidity of the Snoqualmie River during the summer-fall months. Investigation of means to insure settling the suspensions in the reservoir prior to release, should be a part of the project.

Water quality surveillance of fresh and marine waters is provided now through a framework system. This system needs expansion with additional stations being established in the estuarial reaches of the Snohomish River, several locations for the gathering of information in the bays and harbors of the basin, and also the establishment of a lake and ground monitoring system.

Cedar-Green Basins



CEDAR - GREEN BASINS

INTRODUCTION

These basins comprise an area of 1,161 square miles which includes 69 square miles of marine waters. There are three principal rivers–the Green-Duwamish, Cedar, and Sammamish.

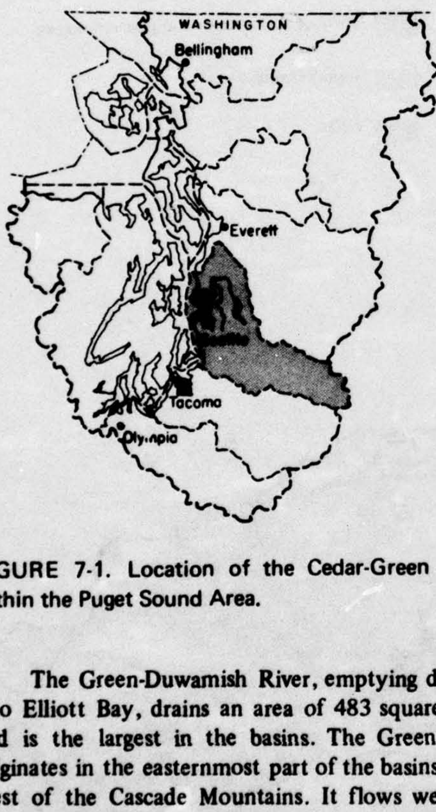


FIGURE 7-1. Location of the Cedar-Green Basins within the Puget Sound Area.

The Green-Duwamish River, emptying directly into Elliott Bay, drains an area of 483 square miles and is the largest in the basins. The Green River originates in the easternmost part of the basins at the crest of the Cascade Mountains. It flows west and north about 60 miles to Tukwila, where it becomes known as the Duwamish River. The Duwamish flows north an additional 12 miles and enters Elliott Bay in Seattle.

In its upper reaches, the Green River is swift and turbulent. Since 1913, this upper portion has been the main watershed for Tacoma's municipal and industrial water supply. Howard A. Hanson Dam, located at Eagle Gorge, has a capacity of 105,650 acre-feet for flood control purposes, but provides 62,000 acre-feet of active storage for municipal and industrial water supply and conservation.

Below Howard A. Hanson Dam, the Green River has cut a deep gorge 12 miles long. Beyond the gorge, the Green flattens out and meanders through the farmlands of the Auburn and Kent valleys. The lower Duwamish flows through the West Waterway. During high water the East Waterway carries part of the Duwamish discharge. The last seven miles of this river have been dredged and improved for navigation and are known as the Duwamish Waterway. The Duwamish Waterway is one of the most industrialized areas in the State.

The Cedar River flows from the crest of the Cascades through timbered country for 50 miles to its outlet in Lake Washington, draining an area of 188 square miles. In the upper reaches of this river is an isolated and protected area–the Cedar River watershed–which covers some 143 square miles.

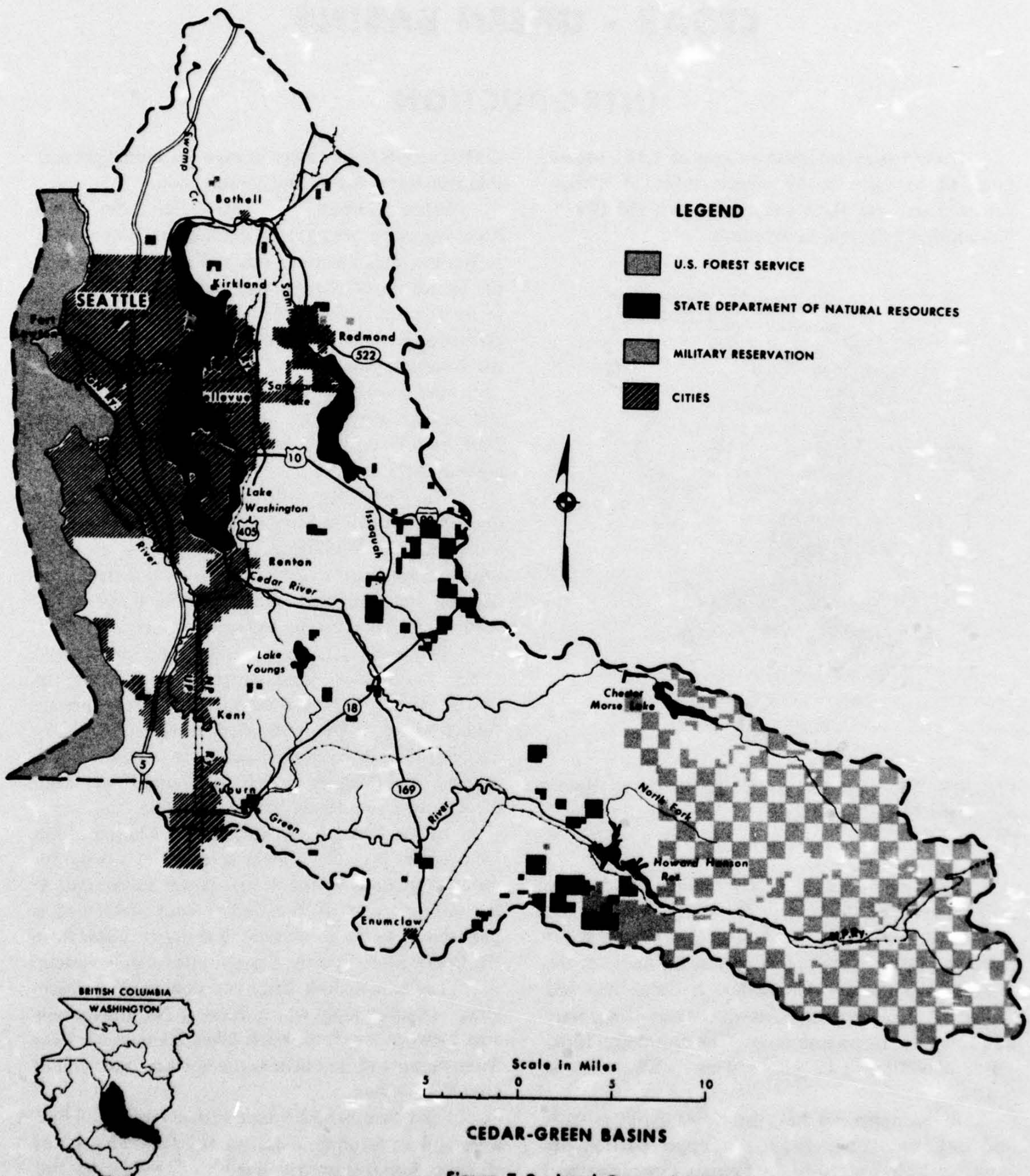
The area is heavily forested and is managed under a sustained yield program by the city of Seattle, the U.S. Forest Service, and several private timber owners. The watershed is closed to entry except for such controlled activities as power development and logging, which are carried on under regulations promulgated by the city of Seattle.

In the Cedar River watershed is Chester Morse Lake which provides 56,000 acre-feet of storage for water supply and hydro-electric power generation. At the western end of the Cedar River Watershed is Landsburg, where a low crest dam diverts water from the Cedar River into the Seattle water supply system.

The Sammamish River is a slow-moving stream about 38 miles long, which drains a 240 square mile area between two fresh-water lakes. Its source is Lake Sammamish and its outlet is the northernmost end of Lake Washington.

Lake Sammamish has a surface area of 4,897 acres and a maximum depth of 106 feet. The shores of Lake Sammamish are lined with residences and summer homes. It is fed primarily by Issaquah and Tibbetts Creeks.

Lake Washington is a 22-mile long fresh-water



CEDAR-GREEN BASINS

Figure 7-2 Land Ownership

body, bounding Seattle on the east. It covers an area of about 50 square miles and is the State's second largest fresh-water lake. The lake is essentially trough-like in shape, reaching depths of over 200 feet in the central portion and shoaling gradually toward each end.

PHOTO 7-1. Chester Morse Lake in the Cedar River Watershed.

Westward from Lake Washington is the ship canal—a system of bays, canal locks, and waterways leading to Puget Sound. The Lake Washington Ship Canal is a large fresh-water complex composed of the Chittenden Locks, Salmon Bay, Lake Union, Portage Bay, Union Bay, and Lake Washington. All these lakes have the same level and are connected by unobstructed channels 30 feet deep at low-lake level. This inland harbor has a total area of 25,000 acres and a shoreline of about 100 miles. Ocean freighters, fishing boats, tugs, and barges enter the canal, tying up at the piers in Salmon Bay.

One of the lakes in Seattle is Green Lake, located in the heart of the north end. It possesses a water surface area of 256 acres and a shoreline of 2.9 miles. Green Lake is heavily used for outdoor recreation. Two municipal beaches are located on the lake.

The main trough of Puget Sound extends along the basins' western front and covers a surface area of 44,602 acres. Landforms and water bodies of this marine area include, from north to south: Meadow Point, Shilshole Bay, West Point, Elliott Bay, Duwamish Head, Alki Point, Point Williams, Brace Point, Point Pulley, and a portion of Poverty Bay.

PHOTO 7-2. Salt water intrusion via the Chittenden Locks increases with summer boat traffic.

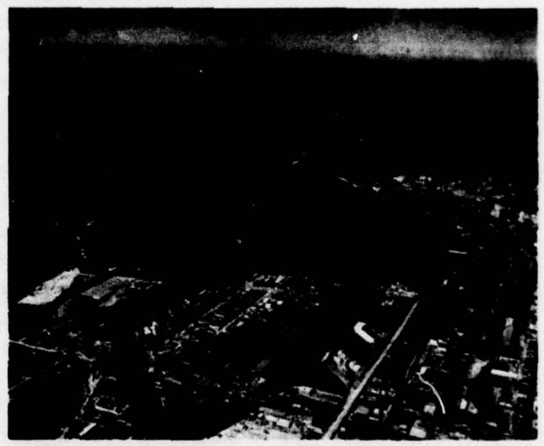


PHOTO 7-3. The Cedar-Green Basins are bounded on the west by the main trough of Puget Sound. In the foreground is Elliott Bay, Seattle's deep-water harbor.

The deepest parts of the marine water area are found in the northern end off Richmond Beach where a depth of over 950 feet has been measured. Another marine trough is located off West Point. Its center is over 660 feet deep throughout its length, shoaling southward to less than 90 feet off Brown Point.

Soils of the bottom lands consist of gravels, sands, loamy sands, and sandy loams in the upper reaches, becoming progressively finer textured to fine sandy loams, silt loams, clay loams, and silty clay loams and clays in the lower reaches. The soils of the glacial basal till terraces (about 50 to 60 percent of the area) consist of gravelly sandy loams and gravelly loams 24 to 40 inches deep over slowly permeable, cemented, gravelly sandy, basal till. The outwash terrace soils consist of deep gravelly sands, gravelly sandy loams, sands, and sandy loams.

Forest land predominates the land use, accounting for 60 percent of the total. Urban buildup is significant, accounting for 22 percent of the land area. This includes the metropolitan area of Seattle, its satellite cities, and suburban residential areas. Agricultural uses are concentrated in the Green and Sammamish River valleys with marginal uses in the upland areas. About 70 percent of the basins' total land area is held in private ownership.

The Cedar and Green Basins–with an estimated 1967 population of 1,072,400–are the most populated of the Puget Sound basins. Seattle is the largest city with some 580,000 dwellers inside its limits, and half as many more nearby. Like any other large metropolis, Seattle is surrounded by a number of satellite cities and new, growing suburban residential areas.

The major center of economic activity in the basins, and for the entire Pacific Northwest, is the metropolitan Seattle area. The pioneer economy was initially based on lumber. It soon expanded to include mining, agriculture, fishing, and shipping. These activities have now been surpassed by manufacturing, trade, education, government, and transportation.

In 1916, a small firm began making two-seater bi-planes here, growing into the Boeing Company and the world's leading producer of commercial jets. Today, Boeing is the life-blood of the basins' economy. Employment growth in the aerospace industry has attained unprecedented heights, reaching a record 98,800 as of June, 1967.

One of the finest seaports in the world is located in Seattle. Seattle Harbor (Elliott Bay) is a deep-water harbor with an expanse of 5,300 acres. Its extensive waterfront is lined with modern terminals equipped to handle any type of cargo. Ships from every part of the globe call at these piers in the continuous exchange of goods.

Although dominated by aerospace, a wide diversification of industries–shipbuilding, forest products, food processing, metals, and other industries–does exist in the basins. Heavy industrial development is concentrated in four areas: (1) the lower reaches of the Green-Duwamish River Valley; (2) along the shores of Elliot Bay; (3) at Lake Union and Salmon Bay, both a part of the Lake Washington Canal; and (4) at the southern end of Lake Washington in the Renton area. Light industry is considerably more dispersed.

Dairying, vegetable growing, and some light industry are the chief supports to the economy in the fertile valleys of the Green, Cedar, and Sammamish Rivers. Vegetable crops–such as beans, cabbage, rhubarb, broccoli, and caneberries–are grown in these areas to supply canneries and freezing plants. These lowlands are utilized for grazing dairy cattle, raising chickens, growing berries, and maintaining farms. New people are pouring into these areas and causing farmlands to be replaced by housing subdivisions, new shopping centers, and freeways. Industry has been moving in at a rapid pace, entombing even more agricultural land.

PHOTO 7-4. Developmental Center and preflight facilities at south end of Boeing Field.

PRESENT STATUS

WATER RESOURCES

Fresh Water

Runoff from the upper part of the Green River watershed has been measured since 1932 at a station near the community of Palmer. The 30-year period of record indicates a mean discharge of 1,080 cfs. The maximum annual runoff (1,500 cfs) of record at this station occurred in 1959 and was 139 percent of the 30-year mean. The minimum annual discharge, in 1941, amounted to 47 percent of the mean. Extreme instantaneous discharges of 12,200 cfs (maximum) and 87 cfs (minimum) have been recorded.

Streamflow records for the Cedar River go back to 1895, making it one of the longest periods of record for a stream in the Puget Sound Region. With the exception of two short periods, continuous measurements have been taken at a gaging station located near Landsburg. These data represent the runoff from approximately the upper half of the Cedar River watershed and closely reflects the natural runoff regimen. During the 1931-60 period of record, the average annual discharge was 680 cfs. The highest annual discharge (940 cfs) was recorded in 1934, which was 139 percent of the 1931-60 mean. The lowest discharge occurred in 1941 when the flow was only 50 percent of the mean. Extreme maximum-and-minimum discharges of 14,200 cfs and 83 cfs have been observed on the Cedar.

A stream gaging site at Bothell measures runoff from 88 percent of the Sammamish River watershed. During the 1939-60 period of record, the average annual discharge was 367 cfs. The maximum discharge recorded occurred in 1965 and was 1,910 cfs. The minimum discharge ever recorded during this 21-year period was 62 cfs in 1951. Streamflow of the Sammamish River is highly dependent on the amount of outflow from Lake Sammamish, which receives 40 percent of the total runoff in the watershed.

These three streams—Cedar, Green, and Sammamish—display runoff patterns similar to other rain and snow fed streams. The highest flows occur during December and January, receding slightly as spring approaches, then merging into the less pronounced snowmelt runoff peak during April, May, and June. Base flows on the Cedar during the dry summer are relatively high due, in part, to the storage influence of Chester Morse Lake and sizeable ground water contributions. The higher discharges of the Green River usually result from winter rains. Pronounced low flows, reaching a minimum in August, reflect the absence of storage in glacial ice and meager contributions from ground-water. Streamflow on the Sammamish is characterized by a series of sharp peaks during October to March and a summer base flow of about 200 cfs.

A low flow frequency analysis has been made by the USGS for 35 gaging stations in the basins based on an 18-year period from April 1, 1946 to March 31, 1964. The 7-day and 30-day flows that may be expected to occur at eight of these stations for a recurrence interval of ten years is shown in Table 7-1.

TABLE 7-1. Low flow frequency 10-year recurrence interval, Cedar-Green Basin

Station	7–Day Low Flow cfs	30–Day Low Flow cfs
Green River near Lester, Wn	27.0	30.0
Newaukum Creek near Black Diamond, Wn.	11.3	12.7
Big Soos Creek near Auburn, Wn.	22.0	23.5
Green River at Tukwila, Wn.	140.0	155.0
Cedar River near Landsburg, Wn.	184.0	210.0
Cedar River at Renton, Wn.	40.0	52.0
Issaquah Creek near Issaquah, Wn.	11.7	12.7
Sammamish River at Bothell, Wn.	72.0	75.0

Source: Appendix III: Hydrology & Natural Environment.

Use of this low flow data shown above should take into account that: (1) the Cedar River at Landsburg is affected by regulation for power development at Chester Morse Lake and Masonry Pool; (2) records of the Cedar taken at Renton are affected by upstream regulation and diversion for municipal use by Seattle; (3) recent channel improvements on the Sammamish River may have changed its low-flow characteristics; and (4) records for the Green River below Palmer are affected by diversion to Tacoma and the operation of Howard A. Hanson Dam for flood control and conservation purposes.

Using fluorescent dye, time of travel studies for the Green-Duwamish River were made on the reach between Palmer and Tukwila, in 1965, by the U.S. Geological Survey. The travel time of the peak dye concentrations near Palmer was 19 minutes per mile; from Kent to Tukwila, 28 minutes per mile. The average time of travel from Palmer to Tukwila was 23 minutes per mile. The discharge of the Green during this study ranged from about 3,500 cfs at Palmer to about 4,500 cfs at Tukwila.

There are three principal reservoirs in the basins; Chester Morse Lake, Youngs Lake, and Howard A. Hanson Reservoir. These storage reservoirs have a combined total capacity of 177,000 acre-feet. Howard A. Hanson Dam is located on the upper Green River. It provides 62,000 acre-feet of active storage for municipal and industrial water supply and conservation purposes. During the summer, the low flows in the Green River are augmented so that approximately 110 cfs remain in the lower reaches for fisheries enhancement. The other two reservoirs are on the Cedar River. However, no low flow augmentation is provided for fisheries enhancement from the Cedar River storage.

Chester Morse Lake is a natural lake in the upper part of the Cedar River watershed. It has been developed to provide 56,000 acre-feet of storage for hydro-electric power as well as water supply. The Masonry Pool Reservoir, located a couple of mines downstream from Chester Morse Lake, has a capacity of 4,000 acre-feet. The masonry dam below Chester Morse Lake was intended to inundate the crib dam to provide increased storage for power and water supply. An immense slide and washout occurred shortly after construction near the right abutment of the dam. Since this failure, the Masonry Pool has been operated near an elevation of 1,546 feet which is the crest elevation of the existing crib dam.

Lake Youngs provides storage (11,000 acre-feet) for the city of Seattle. Seattle diverts municipal water from the Cedar River near Landsburg into off-stream storage in Lake Youngs. This lake is used primarily as a sedimentation basin when the river is turbid.

In operation of the Chittenden Locks, saltwater enters the ship canal and builds up during the low inflow period (April-November). During the December-March period, it is flushed out by large freshwater inflows from Lake Washington. The level of Lake Washington is controlled to rise from 20 to 21.85 feet to provide storage for lock operation during the low inflow period. When salinity at the Mountalke Bridge reaches 10 mg/1, the canal system is flushed with increasing amounts of fresh water to prevent the salinity wedge from entering Lake Washington.

Ground water supplies are plentiful in many places in the basins. The most important aquifers occur in the lowlands in sedimentary deposits of Quaternary age. These sediments are mainly till, recessional outwash, alluvium, and mudflow deposits. The uplands are covered principally by till.

Alluvium occurs mainly on flood plains of the Sammamish, Cedar and Green Rivers; it is composed principally of sand and gravel. Fine sand, silt and clay predominate in the Green River Valley north of Auburn. The water table in the alluvium is generally about the same level as the river. Deeper alluvial aquifers in the lower Green River Valley are confined under artesian pressure.

Sediments older than till are exposed along some margins of the uplands, especially along Puget Sound and the lower Green River Valley. These older sediments include sand and gravel aquifers that contain fresh water at most places. Consolidated rocks of pre-Quaternary age usually do not contain significant aquifers.

Recharge to the lowland aquifers is primarily by direct infiltration of precipitation. These aquifers are estimated to receive about 110,000 acre-feet of recharge in an average year. The natural discharge of ground water is primarily into the lower drainages of the Green, Cedar, and Sammamish Rivers and Lakes Washington and Sammamish.

Marine Water

Prevailing currents, both surface and deep, are parallel to shore northward to Meadow Point, with surface velocities averaging 70 feet per minute (fpm) on the flood tide, and 35 fpm at a depth of 100 feet. Currents in the vicinity of West Point are highly influenced by this projecting land mass. Sea water moving southward is deflected around this point and flows parallel to the shore toward Elliott Bay. On the ebb tide, the sea water swings northeasterly around West Point and into Shilshole Bay. An extensive onshore eddy develops south of the point when high velocities of water occur. Velocities in excess of 100 fpm have been observed in the surface layers under both ebb and flood tide conditions. Currents observed in Elliott Bay were parallel to the shore on each side of the bay and were directed away from the bay's lower end. Longshore flows originate off the outlet of the Duwamish River, and were found to have velocities ranging from 20 fpm to 40 fpm.

PHOTO 7-5. After implementation the interception of sewer outfalls will benefit from treatment and tidal dispersion at West Point.

At certain times, onshore eddies exist north and south of Alki Point. Southward from here, the circulation patterns are greatly affected by the northerly flow in Colvas Passage. Longshore currents between Brace Point and Point Pulley are much stronger (30 fpm) in a southerly direction as compared to about 5 fpm on the ebb or northerly flow. Eddy activity similar to those at West Point and Alki Point exists on each side of Point Pulley. South from here, longshore velocities on the flood tide averaged a little less than 50 fpm in surface and deep-water layers.

WATER QUALITY

Fresh Water

The quality of surface water at selected points in the Cedar-Green Basins is shown in Table 7-2. The major rivers and streams flow out of isolated and protected country. However, industrial development and an increasing population, with their accompanying waste disposal to surface waters, have caused the water quality of some lakes, the downstream sections of major streams and other watercourses, to deteriorate.

In the Seattle area, as in other metropolitan areas, the lack of a governmental unit with adequate jurisdiction made progress in solving inter-community problems very difficult. Most pressing of all was the growing threat of water pollution.

Lake Washington was becoming opaque with scum and algae. Studies showed that sewage effluent was turning the Lake into a well-fertilized garden of algae which was rapidly destroying the Lake's recreational values. Important fisheries resources were being threatened. Sixty raw sewage outfalls were polluting every salt water beach in the area and many were closed to recreational use.

Enabling legislation was passed by the Washington State Legislature in 1957 which allowed the establishment of METRO. In 1961, METRO embarked upon a ten-year program with one objective being to remove all waste inflow to Lake Washington. The program, by early 1970, is expected to have eliminated all raw sewage discharges into the Duwamish River, Elliott Bay and Puget Sound. All sewage treatment plant discharges into Lake Washington and Lake Sammamish have been eliminated and the basic waste collection system necessary to serve virtually all of the entire Cedar-Green basins is nearly complete. To date, METRO has essentially eliminated the contamination of Lake Washington which is now well on its way to regaining its sparkling blue color and more oligotrophic condition.

In the past, a few of the larger lakes of the basins were being "lost" to water pollution. A few years ago Green Lake was a eutrophic body of water plagued by heavy blooms of blue-green algae during the warmer months. Use of the lake was also being affected by seasonal algal blooms, sewage, the routing of urban stormwater to the lake, littoral vegetation, shoaling areas with mud bottoms, semi-domesticated waterfowl, and outbreaks of swimmers' itch. As a result of a study, the Seattle Park Department instituted a program of improving Green Lake involving the addition of large amounts of nutrient-poor city water for dilution purposes, dredging, and shoreline improvements. Since 1962, the lake has been flushed approximately seven times. Lake flushing has decreased the quantity of algae produced, improved the transparency of the water, and virtually eliminated one species of blue-green algae. These remedial actions have allowed Green Lake to practically recover but have not completely eliminated the problem.

A limnological investigation of water quality conditions in Lake Sammamish is presently being conducted by METRO to determine conditions and devise means to prevent further eutrophication. Twelve stations have been established on the lake to collect information on water quality. A substantial quantity of nutrients is being contributed by Issaquah Creek, Tibbetts Creek and several minor tributary streams. The Lake Sammamish blue-green algae population is a classic indicator of lakes undergoing eutrophication. The study so far indicates that the lake is in the early stages of eutrophication and is possibly more degraded than Lake Washington was in 1950.

This discussion of water quality characteristics in the basins is based primarily upon the data presented in the preceding table.

Chemical. The chemical quality of most streams and lakes in the basins is soft, low in dissolved solids, and high in dissolved oxygen concentrations. The highest concentrations of dissolved solids occur in the Duwamish River near Tukwila and in the Lake Washington Ship Canal.

TABLE 7-2. Surface water quality, Cedar-Green Basins

			mg/l											mg/l									mg/l		mg/l		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
GREEN RIVER NEAR PALMER — JULY 1959 THROUGH JULY 1961																											
Maximum	10,900	46	6.6	1.4	3.3	0.5	32	0	3.8	1.5	0.2	0.9	62	0.06	—	17.0	0.58	0.09	7.5	10	—	18.0	13.1	104	22	2	430
Mean	—	37	5.1	0.6	2.5	0.2	22	0	2.1	1.0	0.1	0.2	44	0.02	—	13.5	0.13	0.03	—	—	—	8.8	11.2	100	15	0	114
Minimum	156	28	3.4	0.1	2.0	0.0	13	0	1.4	0.5	0.0	0.0	33	0.00	—	11.0	0.00	0.00	6.2	[illegible]	—	2.0	9.4	90	10	0	0
Number	21	21	21	21	19	19	21	4	21	21	20	21	21	18	—	21	20	4	20	21	—	16	17	16	21	21	17
GREEN RIVER AT PURIFICATION PLANT NEAR PALMER — OCTOBER 1931 AND OCTOBER 1948																											
Maximum	—	39	5.2	1.2	6.9	0.6	29	—	3.2	6.3	0.0	0.2	—	—	—	23.0	0.05	—	7.4	—	—	—	—	—	18	0	—
Mean	—	39	5.1	1.2	4.8	0.6	25	—	2.6	3.9	0.0	0.1	—	—	—	18.5	0.02	—	—	—	—	—	—	—	18	0	—
Minimum	—	39	5.0	1.2	2.7	0.6	21	—	2.0	1.6	0.0	0.0	—	—	—	14.0	0.00	—	7.4	—	—	—	—	—	17	0	—
Number	—	1	2	2	2	1	2	—	2	2	1	2	—	—	—	2	2	—	1	—	—	—	—	—	2	1	—
GREEN RIVER NEAR AUBURN — JULY 1959 THROUGH FEBRUARY 1966																											
Maximum	4,600	71	11.0	3.1	6.0	1.0	50	0	6.4	3.8	0.3	1.9	103	0.13	—	16.0	1.20	0.03	7.9	15	40	24.2	14.1	132	39	0	24,000
Mean	—	51	7.1	1.6	3.6	0.5	32	0	3.8	1.7	0.1	0.7	67	0.03	—	13.2	0.24	0.01	—	—	—	10.1	11.1	101	24	0	1,225
Minimum	172	30	4.0	0.5	2.2	0.0	20	0	2.0	0.0	0.0	0.0	38	0.00	—	9.6	0.00	0.00	6.2	0	0	3.5	8.3	81	14	0	0
Number	63	84	84	84	84	84	84	33	84	84	84	84	84	73	—	84	71	13	84	83	45	87	88	87	84	84	86
GREEN RIVER AT TUKWILLA — OCTOBER 1962 THROUGH APRIL 1966																											
Maximum	—	116	20.0	20.0	16.0	1.7	68	0	9.8	19.0	0.2	4.5	954	0.89	—	18.0	1.70	0.09	7.6	30	70	20.0	12.7	112	133	78	240,000
Mean	—	72	9.0	3.0	7.4	1.0	41	0	5.7	6.8	0.1	2.0	121	0.21	—	14.5	0.58	0.03	—	—	—	10.6	9.7	89	35	2	17,289
Minimum	—	34	4.5	0.5	2.7	0.1	22	0	2.0	1.2	0.0	0.4	46	0.05	—	11.0	0.29	0.01	6.6	0	5	4.5	6.2	66	16	0	230
Number	—	47	48	48	47	47	48	37	47	47	47	47	48	35	—	48	34	7	48	47	36	50	51	50	48	48	50
CEDAR RIVER AT RENTON — JULY 1959 THROUGH MARCH 1966																											
Maximum	1,920	77	12.0	3.7	5.0	0.9	58	0	6.0	2.2	0.1	1.9	112	0.28	—	15.0	1.30	0.06	7.9	10	25	22.8	12.5	118	46	0	4,600
Mean	—	44	7.3	1.4	2.6	0.4	31	0	3.1	1.2	0.1	0.5	62	0.03	—	11.3	0.15	0.02	—	—	—	10.6	10.8	100	24	0	420
Minimum	67	34	5.0	0.6	1.6	0.0	22	0	1.6	0.5	0.0	0.0	46	0.00	—	8.8	0.00	0.00	6.9	0	0	4.1	7.6	77	16	0	0
Number	39	46	46	46	46	46	46	19	46	46	46	46	46	43	—	46	43	13	46	46	18	50	51	50	46	46	50
CEDAR RIVER NEAR LANDSBURG — JULY 1959 THROUGH AUGUST 1962																											
Maximum	1,800	51	11.0	1.6	2.2	0.5	39	0	4.0	2.2	0.2	0.6	73	0.04	—	12.0	0.24	0.01	7.8	5	0	14.5	12.5	106	31	2	230
Mean	—	39	7.1	0.8	1.7	0.3	27	0	2.0	1.0	0.0	0.2	53	0.01	—	10.1	0.05	0.00	—	—	—	9.3	11.1	101	21	0	34
Minimum	335	27	5.0	0.0	1.2	0.0	18	0	0.0	0.5	0.0	0.0	37	0.00	—	4.0	0.00	0.00	7.0	0	0	5.3	9.7	93	14	0	0
Number	21	23	23	23	21	21	23	9	23	23	22	23	21	21	—	23	22	4	22	22	4	20	21	20	23	22	21
SAMMAMISH RIVER AT BOTHELL — JULY 1959 THROUGH MARCH 1966																											
Maximum	1,070	100	12.0	6.6	7.2	2.1	62	0	16.0	4.5	0.5	6.3	145	0.44	—	17.0	2.40	0.02	7.4	40	120	23.6	12.5	119	55	15	11,000
Mean	—	71	9.2	4.0	5.2	1.2	45	0	9.0	3.0	0.1	1.8	105	0.10	—	10.6	0.49	0.01	—	—	—	12.2	9.9	95	39	3	1,788
Minimum	8	57	7.5	2.5	3.5	0.7	32	0	6.6	1.0	0.0	0.3	82	0.00	—	5.1	0.08	0.00	6.6	5	5	5.0	7.3	80	31	0	91
Number	43	53	53	53	53	53	53	14	53	53	53	53	53	50	—	53	50	11	53	53	22	57	57	57	53	53	56
ISSAQUAH CREEK NEAR ISSAQUAH — NOVEMBER 1964 THROUGH APRIL 1966																											
Maximum	—	94	13.0	5.1	7.6	1.2	68	0	12.0	5.0	0.2	6.2	138	0.99	—	20.0	2.60	0.04	7.2	20	350	13.3	12.2	105	53	6	24,000
Mean	—	73	9.7	3.6	5.6	0.8	46	0	7.3	2.7	0.1	3.1	104	0.41	—	15.9	0.73	0.03	—	—	—	9.2	10.7	96	39	2	10,626
Minimum	—	52	5.6	2.2	3.5	0.4	23	0	5.4	1.8	0.1	1.5	67	0.08	—	12.0	0.06	0.02	6.3	5	5	5.8	8.9	85	23	0	36
Number	—	22	22	22	22	22	22	22	22	22	22	22	22	11	—	22	11	2	22	—	11	9	9	9	22	22	9
BIG SOOS CREEK ABOVE HATCHERY NEAR AUBURN — OCTOBER 1962 THROUGH APRIL 1966																											
Maximum	484	81	12.0	4.6	6.3	1.8	58	0	12.0	3.5	0.5	3.7	115	0.19	—	20.0	0.46	0.05	7.7	60	10	15.6	12.8	121	45	6	24,000
Mean	—	71	9.5	3.4	5.4	1.0	45	0	8.6	2.2	0.1	1.7	101	0.06	—	14.6	0.14	0.03	—	—	—	9.8	11.0	100	38	1	1,130
Minimum	20	62	7.5	1.2	4.4	0.5	31	0	5.8	1.0	0.0	0.6	88	0.02	—	11.0	0.03	0.00	6.8	5	0	3.6	9.4	88	30	0	0
Number	24	46	45	45	45	45	45	33	45	45	45	46	46	34	—	45	34	8	46	46	33	49	49	49	46	46	48
LAKE WASHINGTON SHIP CANAL AT SEATTLE — OCTOBER 1964 THROUGH SEPT 1965																											
Maximum	—	333	14.0	14.0	87.0	4.6	48	0	28.0	152.0	0.1	5.9	650	0.29	—	7.9	0.25	0.10	7.5	5	25	20.4	12.5	123	92	53	4,600
Mean	—	174	10.3	7.5	39.9	2.4	41	0	16.3	66.9	0.1	2.3	330	0.17	—	4.4	0.13	0.07	—	—	—	12.6	9.7	93	57	23	1,866
Minimum	—	62	8.4	3.4	6.4	1.1	36	0	8.0	6.5	0.0	1.2	108	0.13	—	1.1	0.08	0.04	6.8	5	0	2.5	7.5	73	35	5	36
Number	—	12	12	12	12	12	12	12	12	12	12	12	12	12	—	12	12	2	12	12	12	12	12	12	12	12	12

Source: State of Washington and U.S. Geological Survey.

The dissolved oxygen values shown in Table 7-2 indicate that most fresh waters in the basins contain adequate amounts of dissolved oxygen for the maintenance of aquatic life. The reach between Tukwila downstream to the mouth of the Duwamish River does, at times, contain water with a dissolved oxygen content less than 5 mg/1.

The lower Duwamish River has been the subject of study by various agencies since 1948, when the city of Seattle began its study of dissolved oxygen in the river in the fall of that year. In August 1949, the dissolved oxygen content in the bottom water was 3.7 mg/l and in the surface layer it was 6.1 mg/1.

The Duwamish River downstream from Tukwila is a stratified estuary. The surface layer of water generally has a dissolved oxygen content greater than 5 mg/1. The longitudinal dissolved oxygen profile for the surface water layer shows no pronounced oxygen sag, but rather a linear decline in oxygen values in a downstream direction. This relationship, however, is tidal dependent. In contrast to this, the bottom layer of water shows a rather severe oxygen sag in the vicinity of South Park. Data from the automatic water quality monitor operated by the cooperative Municipality of Metropolitan Seattle–U.S. Geological Survey program, since 1964 show that the minimum dissolved oxygen content in the bottom water was 0.6 mg/l on September 26, 1966. (Fresh-water discharge is 275 cfs).

As part of a comprehensive water quality program, METRO began in 1961, an extensive study of the physical, chemical, and biological characteristics of the lower Green River and the Duwamish Estuary. Biological and nutrient sampling of the Green-Duwamish River is conducted on a monthly basis during the winter and weekly thereafter. A routine sampling trip in August 1963, showed that the bottom waters of the Duwamish Estuary lacked adequate amounts of dissolved oxygen to maintain aquatic life for any prolonged period. Further sampling during the critical summer period revealed a month-by-month degeneration in oxygen concentrations. Dissolved oxygen decreased from 5.2 mg/l in July to 3.1 mg/l in September. Studies in Lake Union and the Lake Washington Ship Canal, relating to saltwater intrusion and dissolved oxygen depletion, were started in 1964 and have been continued since that time.

Data shows that since 1960 there has been a noticeable decrease in the intrusion of saltwater from Puget Sound into the fresh-water canal. Little intrusion was detected beyond Lake Union in 1966. Dissolved oxygen concentrations have been zero for a number of years in the bottom waters of Lake Union. Sewers previously emptying into these waters have been intercepted by Seattle, but sludge deposits and stormwater overflows continue to degrade Lake Union's water quality.

Phosphate values in the Cedar River are among the lowest in the region. Zero phosphate values have been recorded at the upstream station near Landsburg, and a maximum value of 0.3 mg/l at Renton.

Sammamish River and Issaquah Creek are higher in phosphate. Issaquah Creek has an average value of 0.4 mg/l. The Sammamish River at Bothell has an average value of 0.10 mg/l.

The Green River shows an increase in phosphate from the upstream station at Palmer to Tukwila. Maximum values at Palmer are 0.06 mg/l or less; at Auburn maximum values are 0.1 mg/l or less; and at Tukwila they are 0.9 mg/l or less. Average values are 0.02 mg/l at Palmer, 0.03 mg/l at Auburn, and 0.2 mg/l at Tukwila. The increases in values below Auburn are partially due to waste discharges from domestic and industrial sources which result in relatively high concentrations of mineral nutrients in the river.

Big Soos Creek, tributary to the Green River, has phosphate concentrations similar to the Green River at Auburn where average values are less than 0.1 mg/l.

Nitrate concentrations in the Green River show average values of 0.04 mg/l at Palmer, 0.2 mg/l at Auburn, and 0.4 mg/l at Tukwila. Concentrations at Auburn are influenced by the nitrate contribution from Big Soos Creek, where average values are 1.7 mg/l.

Information collected by METRO and the U.S. Geological Survey from 1963 through 1968 shows an increase in nutrients below the Renton sewage treatment plant outfall. Nutrient concentrations were sufficient to support phytoplankton blooms during 1964, 1965, and 1966 and also before those periods.

The Cedar River at Renton has an average nitrate value of 0.01 mg/l. The Landsburg station has average values of 0.1 mg/l. The Lake Washington Ship Canal has maximum nitrate values of 1.3 mg/l and an average value of 0.5 mg/l.

Significant amounts of iron occur in some stream sections. Iron concentrations in the Sammamish River at Bothell average 0.5 mg/l with a maximum of 2.4 mg/l being recorded. In Issaquah Creek the average is 0.8 mg/l and the maximum 2.6 mg/l. In the lower Duwamish River at Tukwila, the average is 0.6 mg/l and the maximum 1.7 mg/l.

Dissolved solids concentration in most aquifers is usually less than 200 mg/l in the shallower aquifers and somewhat greater—up to 500 mg/l —in deeper aquifers. Hardness of the ground water is generally less than 120 mg/l. Highly mineralized water occurs in some aquifers adjacent to Puget Sound. Silica content averages about 30 mg/l in waters containing less than 200 mg/l of dissolved solids. Brackish water occurs only locally in the deeper aquifers. Some deep aquifers in the southern part of the basins commonly yield water containing more than 50 mg/l of sodium.

Bacteriological. Sanitary quality in the lower reaches of major streams has been a problem for many years. The presence of a high number of coliform organisms in the water samples taken at the stations, as shown in Table 7-3, indicates contamination by sanitary wastes. The Green River above Auburn is bacteriologically satisfactory as the MPN range near Palmer was only 0 to 430. Conditions become worse downstream. At Auburn the range of MPN's was 0 to 4,600. On Big Soos Creek, a tributary of the Green, the MPN range was higher—0 to 24,000. MPN values ranged from 230 to 240,000 on the lower Duwamish River at Tukwila prior to the elimination by Metro of the South Kent and Tukwila treatment plants.

The bacteriological quality of the Cedar River is excellent above Landsburg, where the maximum MPN recorded was only 230. Downstream at Renton, the MPN range was 0 to 2,400.

PHOTO 7-6. Sewage pump stations like this one on the shore of Mercer Island in Lake Washington provide sewage collection to the METRO system, Mercer Island Sewer District.

On the Sammamish river at Bothell, the MPN values are usually less than 1,000 but a high of 11,000 was recorded here. The outlet of Lake Washington showed MPN values ranging from 36 to 4,600. Issaquah Creek, which flows into Lake Sammamish, had coliform concentrations in excess of 11,000 MPN, on the average, and an MPN range of 1,500 to 24,000 prior to the elimination of the municipal and industrial discharges into the creek.

TABLE 7-3. Summary of coliform concentrations, Cedar-Green Basins

Station	MPN/100 mls: Less than 240 — No. of Samples	Less than 240 — % of Total No.	240-1,000 — No. of Samples	240-1,000 — % of Total No.	1,000-2,400 — No. of Samples	1,000-2,400 — % of Total No.	Greater than 2,400 — No. of Samples	Greater than 2,400 — % of Total No.
Lake Washington Ship Canal	5	42	2	17	0	0	5	42
Cedar River at Renton State Highway 5	33	72	10	22	0	0	3	7
Cedar River near Landsburg	21	100	0	0	0	0	0	0
Sammamish River at Bothell	7	13	29	54	4	7	14	26
Issaquah Creek near Issaquah	0	0	0	0	1	17	5	83
Duwamish River at Tukwila	0	0	3	50	0	0	3	50
Green River near Auburn	25	30	39	47	5	6	14	17
Big Soos Creek near Auburn	29	64	13	29	1	2	2	4
Green River near Palmer	15	88	2	12	0	0	0	0

Source: Washington Water Pollution Control Commission

Table 7-3 provides a summary of coliform concentrations taken from basin data sampling.

Physical. The maximum summer temperature, 75.6°F (24.2°C) of the Green River at Auburn is one of the highest recorded stream temperatures in the Puget Sound Area. Other high temperatures have occurred on the Sammamish River, 74.5°F (23.6°C) at Bothell and on the Cedar River, 73°F (22.8°C) at Renton. The Lake Washington Ship Canal has attained a high of 69°F (20.1°C). Summer temperatures on other streams in the basins are considerably cooler; none exceed 65.3°F (18.5°C).

Stream-borne sediment is not a serious problem in the upper parts of the rivers, but it is in the lower reaches. A dense cover of vegetation on most slopes largely precludes excessive soil erosion. Streams in the Cedar watershed transport only small amounts of sediments and have suspended-sediment concentrations less than 20 mg/l. Sediment data collected daily on the upper Green River during the period 1951-1955 showed suspended-sediment concentrations ranging from 1 to 1,350 mg/l. On the lower Green River at Tukwila, the maximum concentration was 1,590 mg/l.

Turbidity runs high for three streams here. The average turbidity for Issaquah Creek was 62.7 JTU. The maximum observed in Issaquah Creek was 350 JTU, the highest turbidity recorded in the basins. The Sammamish River at Bothell showed an average of 20.5 JTU, with an observed maximum of 120 JTU. The average on the Duwamish River at Tukwila is less than that of the other two streams–only 12.7 JTU. The remaining streams have low turbidities, generally less than 6.0 JTU on the average.

Information on temperature, transparency, nutrients, dissolved oxygen, phytoplankton and zooplankton populations, primary productivity and bacteriological data, is not available for other freshwater lakes in the basins. There can be little doubt, however, that the impact of population increases and encroaching suburban developments will cause other lakes to deteriorate at an increasing rate in the future unless protective measures are taken at the time of land development.

Marine Water

Water characteristics throughout the main part of Puget Sound in the basins are quite uniform. The average minimum surface salinity is 27 o/oo, but values of less than 20.0 o/oo have been observed. Lowering of the salinity occurs in early summer when large amounts of fresh-water pour into the Sound from the rivers. The salinity increases abruptly after this minimum and remains at about 30.7 o/oo until early November. The coldest surface water temperatures of 46.8°F (8.2°C) occur in February in response to the cold air temperatures. Maximum surface temperatures of 57.6°F (14.2°C) take place in August. The dissolved oxygen content of these surface waters undergo large changes due to phytoplankton activity. Values of 9 to 11 mg/l are common over the entire Sound. DO values less than 5 mg/l are rare and occur only occasionally. Flushing rates of the main part of Puget Sound are estimated to vary from two to four weeks.

SOURCES OF WASTE

As shown on Table 7-4,[1] the daily untreated municipal and industrial wasteload in the Cedar-Green Basins approximates 839,000 PE, of which 44 percent is presently removed by waste treatment before being discharged to fresh and marine waters. During the food processing season, an additional 58,000 PE are produced. The areas receiving the largest quantities of wastes in relation to the basins' total include Puget Sound (38 percent), Green-Duwamish River (35 percent), and Elliott Bay (27 percent).

The untreated municipal wasteload of 582,000 PE was in large part determined by utilizing influent data from the METRO sewage treatment plants. This procedure does not, however, account for the partial reduction of wastes in the sewerage system while in transit to the sewage treatment plants. With such a large system, much of the waste travels many miles through sewers and may experience a substantial reduction. The raw wasteload generated at the source is considered to be much higher–probably as high as 1,000,000 PE.

The quantities and general location of waste production and discharges in the basins are shown in Figure 7-3. Sources of wastes contributing to the degradation of fresh and marine waters are summarized in Table 7-4. The completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans will substantially reduce the strength of these wastes.

Fresh Water

The numerous towns and industries along the Green-Duwamish River produce about 333,700 PE of wastes daily. During the food processing season, this total is increased by 55,000 PE daily. Auburn, Kent, Renton, Black Diamond, one sewer district, two

[1] Based on 1967 wasteloading information.

PHOTO 7-7. The Green-Duwamish River receives more wastes than any other body of fresh water in the Puget Sound Area.

sewage treatment plants, and a number of industries discharge wastes to the river that are given varying degrees of treatment. About 55 percent of the total wasteload receives secondary treatment; 27 percent receives primary treatment; and 18 percent of the total wastes are discharged into this river untreated. After waste treatment, a total of 144,320 PE are discharged into the river by cities and industries. During the food processing season, an additional 29,000 PE are discharged. Organic and inorganic industrial wastes are discharged directly into the river at various points, but principally into the estuary.

Population equivalents, as shown in Table 7-4, are only a part of the complete picture of industrial pollution, since there are plants discharging oils, chemicals, acids, and many other toxic wastes which cannot be evaluated in terms of population equivalents. These include cyanides, chromates, pickling liquors, caustics, acids, greases, and phenols. The majority of these wastes are neutralized or are otherwise treated, but some are discharged into the estuary untreated.

METRO's treatment plant at Renton provides secondary treatment to 113,300 PE by the activated sludge process, with effluent disposal to the Duwamish River. The treatment process removes approximately 95 percent of the biochemical oxygen demand and suspended solids. Sludge from the plant will be conveyed to the West Point sewage treatment plant for further handling. The Renton plant has a design average sewage flow of 24 million gallons per day and a peak capacity of 76 mgd. The present average flow to the Renton plant is 16 mgd. It has been designed for enlargement to a capacity of 144 mgd and a peak hydraulic capacity of 375 mgd. Ultimately, it is expected to serve a tributary population of approximately one million persons.

Marine Water

Municipalities and industries are discharging sewage and wastes into Elliott Bay and into Puget Sound along the western perimeter of the basins. About 495,000 PE are being produced daily in the vicinity of the marine waters. Less than one percent of this waste receives secondary treatment; 72 percent receives primary treatment; and 27 percent is released into these waters untreated. Wastes from an equivalent population of about 325,000 people are being discharged into the marine waters every day.

The new West Point primary treatment plant is located on Puget Sound west of Fort Lawton. It went into operation on July 5, 1966. Five major sewerage areas will eventually be served by this system. They include Elliott Bay, Southwest Lake Washington, Lake Union, Northwest Lake Washington, and North Lake Washington. The plant has been built to provide a treatment capacity sufficient to accommodate an ultimate sewage flow of 125 mgd. A wet weather hydraulic capacity of 325 mgd makes West Point the largest treatment facility in the Pacific Northwest. Effluent is discharged to Puget Sound 3,600 feet offshore through a 600 foot long diffuser located at a depth of 250 feet.

The disposal of digested sludge at the West Point treatment plant by dilution in the waters of Puget Sound was approved, on an interim basis only, by the Federal and State authorities, to be abandoned in favor of an alternate acceptable method. About 14 tons per day of digested sludge from the Seattle metropolitan area mixed with the liquid effluent are being discharged at this plant. The shoreline and water environment in the vicinity of the West Point outfall is monitored by METRO to insure that the digested sludge-effluent mixture will not degrade the waters of Puget Sound. A visual inspection of the bottom of the Sound and around the West Point outfall was conducted by hard hat divers and television cameras during the summer of 1968 following two years of plant operation. No measurable deposit of sludge could be located and all marine flora and fauna appeared to be normal. The condition of the bottom appeared to be the same as at the time of construction of the outfall.

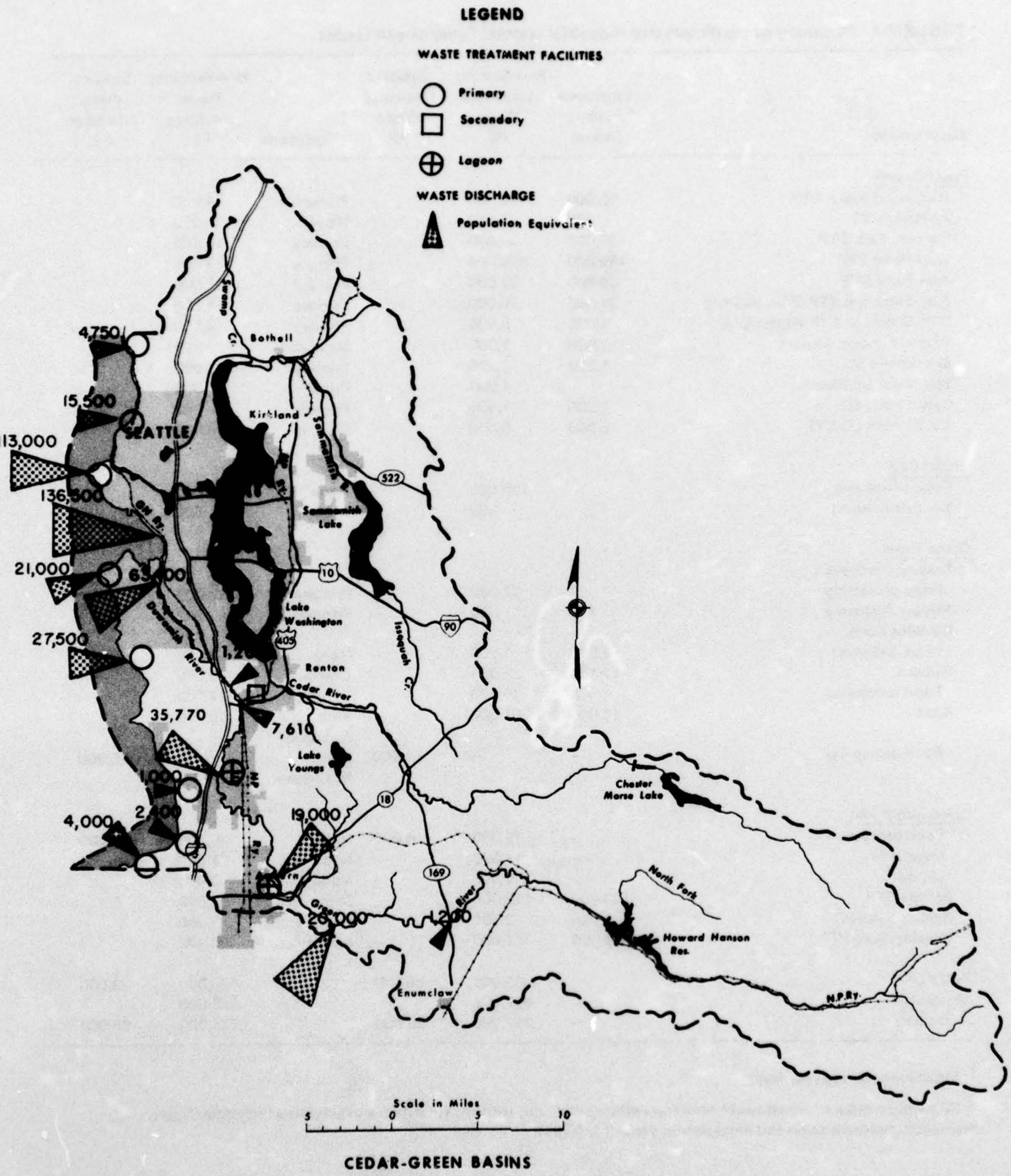


FIGURE 7-3. Location of major waste discharges

TABLE 7-4. Summary of municipal and industrial wastes, Cedar-Green Basins

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Puget Sound						
Richmond Beach STP	15,000	16,300	--	Primary	4,400	--
Highlands SD	300	350	--	None	350	--
Carkeek Park STP	25,000	31,000	--	Primary	15,500	--
West Point STP	180,000	228,000	--	Primary	113,000	--
Alki Point STP	35,000	37,000	--	Primary	21,000	--
S.W. Suburban STP (Salmon Cr.)	24,000	30,000	--	Primary	24,000	--
S.W. Suburban STP (Miller Cr.)	4,000	5,000	-	Primary	3,500	--
Seattle-Tacoma Airport	1,000	1,000	--	Secondary	300	--
Des Moines SD	1,350	1,500	--	Primary	1,000	--
Salt Water St. Park	--	1,000	--	Primary	600	--
Sylvia Pines SD	1,200	1,400	--	Primary	840	--
Lake Haven SD,STP	5,000	6,000	--	Primary	4,000	--
Elliott Bay						
Food processing	--	136,000	--	None	136,000	--
Lumber & wood	--	500	--	None	500	--
Green River						
Newaukum Creek						
Food processing	--	22,000	--	Primary	20,000	--
Auburn Academy	700	1,000	--	Primary	700	--
Big Soos Creek						
Black Diamond	1,026	1,200	--	None	1,200	--
Auburn	17,100	25,000	--	Lagoon	5,000	--
Food processing	--	16,000	--	Primary	14,000	--
Kent	13,000	51,600	--	Kent N. Lagoon	10,770	--
Food processing	--	--	51,000	Kent N. Lagoon	--	25,000
Duwamish River						
Food processing	--	46,000	4,000	None	46,000	4,000
Chemicals	--	11,000	--	None	11,000	--
Metals	--	2,400	--	None	2,400	--
Renton STP	103,500	113,300	--	Secondary	7,610	--
Rainier Vista SD	3,000	3,500	--	Primary	1,200	--
Diagonal Way STP	45,000	51,000	--	Primary	25,400	--
TOTAL[1,2]		83,000	55,000		470,000	29,000
Municipal	--	582,000	--		236,000	--
Industrial	--	257,000	55,000		234,000	29,000

[1] Figures are rounded for 1967.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

Three other sewage treatment plants on Puget Sound–Alki Point, Carkeek Park, and Richmond Beach–are also a part of METRO's system. The Alki Point plant provides primary treatment for 37,000 PE daily and discharges 21,000 PE. Effluent is discharged into Puget Sound 1,400 feet from shore at a depth of 80 feet. The Carkeek Park primary plant treats a raw load of 31,000 PE daily and discharges 15,500 PE daily. Plant effluent is diffused into Puget Sound 2,000 feet from shore at a depth of 200 feet. The Richmond Beach plant is also of the primary type and treats some 16,300 PE daily before discharging 4,400 PE into the Sound.

Large amounts of untreated waste are presently discharged into Elliott Bay by numerous industries. About 136,500 PE are discharged daily into this bay where sport fishing and pleasure boating are carried on extensively.

In the early 1950's more than 60 outfalls were discharging raw sewage into the marine waters of the Cedar-Green Basins. Sewage fields and slicks were becoming visible over a wide range. Bathing beaches were being closed due to high coliform counts and the observed presence of sewage materials in the beach areas. This dismal trend is now being reversed by METRO's $135,000,000 sewage works construction program which is well on its way to saving the Puget Sound from water pollution.

PHOTO 7-8. Elliott Bay receives raw wastes from numerous industries.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the Cedar-Green Basins are summarized in Table 7-5 which focuses on the principal watercourses and problem areas in the basins. Table 7-5 also indicates the water quality classification established by the State for each watercourse which defines the type of water usage to be protected in the area.

The Cedar and Green Rivers are used heavily for domestic and industrial water supply. The upper Cedar River watershed is the major source of water for Seattle and much of King County. It is currently supplying 220 mgd to the city of Seattle. The upper Green River is the principal source of water for the city of Tacoma.

Drainage areas within the Cedar-Green Basins provide extensive and important spawning and rearing areas for anadromous fish–principally chinook, sockeye, coho, and chum salmon and steelhead, searun cutthroat trout and searun Dolly Varden. These fish contribute significantly to the area's recreation use by providing sport for both the local residents and for the many tourists and vacationers visiting the basins. Marine fish and shellfish in the area are likewise harvested mainly by sport methods. The fish and shellfish populations indigenous to the basins are extremely important to the area's economy.

Based on spawning ground survey information, it is estimated that salmon escapements to the rivers and streams for the period 1956-1961 averaged about 198,600 annually. The average annual contribution from 1956 to 1965 to the Puget Sound and ocean commercial and sport fisheries from the Cedar-Green Basin amounted to 579,160 salmon.

Based on 1966 survey data, 368,800 man-days of effort were spent fishing in the lakes and ponds of the basins; and a total harvest of 985,000 trout and 405,600 other game fish was realized. In the streams, 100,200 man-days were spent with a harvest of almost 321,000 trout. About 165,700 man-days were expended in pursuit of steelhead and searun cutthroat trout and 26,440 steelhead and 20,100 cutthroat trout were harvested.

TABLE 7-5. Water uses and quality objectives, Cedar-Green Basins

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[2]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Strait of Juan de Fuca and Puget Sound	AA			H	H				M	H	H	H	L		L	H	H			M		H	M	
Elliott Bay	A			H	H					M	L	M	L		L	M	H			L		H		
Duwamish River, Mouth to Black River Junction	B			H	H											L	L			L		H		
Duwamish River, Black River Junction to Limit of Tidal Influence	A			H	H											M	M			L		L		
Green River, Limit of Tidal Influence to Headwaters	AA[1]			H	H	M							H		L	M	H		H	H	L			
Cedar River	A[1]			H	H	H							M			L	L		H	H				M
Sammamish River	A[1]			H	H	H							L			M	M				L			
Issaquah Creek	A[1]			H	H	H							M			M	M							
Big Soos Creek	A[1]			H	H	H							M				M							
Lake Washington	A[1]			H	H	H		M	M				L		H	H	H						L	
Lake Sammamish	A[1]							M	M	M			L		M	M	M							

[1] Not presently classified. Equal to existing quality.

[2] See Table 1-5.

The population concentration results in the largest recreational use of the area's water resources. Major attractions include waters and shorelines of Puget Sound, Lake Washington, the Ship Canal, and Lake Sammamish. Fine parks and beaches line the shores of Lake Washington, the largest fresh-water lake in the Puget Sound Area. Several thousand boat moorages are located along the shores, and the lake waters are used extensively for swimming, water skiing, and cruising. Smaller but picturesque lakes, like Green Lake and Angle Lake, are also heavily used for outdoor recreation.

The shorelines and waters of the Cedar, Green, and Sammamish Rivers receive a tremendous amount of use by boaters, steelheaders, and picnickers. A unique area is the Green River Gorge–a primeval section, 12 miles long with massive walls rising 300 feet above the river. In 1964, there were 250 publicly-administered outdoor recreation areas within the basins.

PHOTO 7-9. Fresh waters within the basins are used heavily for water supply, fisheries, and recreation.

Navigation is heavy on Elliott Bay, Duwamish River, and Puget Sound. Ships from every part of the globe call here. In 1963, the foreign and domestic coastwise traffic was over 5.8 million tons. The 1963 local internal traffic in the area was over 7.0 million tons. Waterborne commerce on the Lake Washington Ship Canal was over 2.0 million tons for the same year.

Water supply, fisheries, and recreation uses require the highest water quality standards and have set the minimum acceptable quality for most watercourses in the Cedar-Green Basins. As a result, the water quality class is either excellent (A) or extraordinary (AA) with the objectives being to meet or exceed the quality requirements for all uses. The only exception is the lower Duwamish River which is one of the most industrialized waterways in the Puget Sound Area.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs are largely concentrated in areas adjacent to the marine waters of the basins. Most of these needs occur in the Elliott Bay area where unintercepted municipal and waterfront industrial wastes are being discharged to the bay. Most water quality standards–those for bacteria, dissolved oxygen, toxic substances, and aesthetics–will be met after implementation and enforcement by 1972.

The lower Duwamish River is another area where considerable needs exist. The banks of this river are lined with industries, many of which discharge untreated wastes to the river. The only water quality standard being met here is that for the hydrogen ion concentration of pH.[1]

Since establishment of METRO, the water quality of Lake Washington has shown substantial improvement. All municipal waste discharges, with the exception of storm overflows, have been removed from the lake. During heavy rains these overflows enter the lake. A large percentage of the wastes generated by boaters also continue to enter the lake waters untreated. Nutrients have been, and will continue to be, an important factor in the control of water quality in Lake Washington. Algae blooms, promoted by high nutrient concentrations, have in past years degraded water quality. Increased use of the ship canal and locks tying the lake to the Sound, along the larger diversions of water from the Cedar River, has threatened Lake Washington with potential salt water intrusion. Log booming activities on the north and south ends of Lake Washington may create water quality problems.

Flood and storm water control facilities are either lacking or seriously inadequate in major parts of the urban areas. Uncontrolled storm water causes damage to property, prevents the development of areas to their highest and best use, and results in illegal connections of downspouts to sanitary sewer systems. The most pressing need is for major facilities to serve large drainage areas.

Another critical need in this same area is for the separation of combined storm and sanitary sewers which exist in the urban sections. Heavy rainfall causes these sewers to overflow mixed sewage and storm water to the nearest watercourse–Lake Washington, the Ship Canal, the Duwamish River, Elliott Bay, and Puget Sound.

FUTURE NEEDS

The major factors which will affect future water quality in the Cedar-Green Basins are expected to be the growth in population, industrial production recreation. As this growth occurs, wastes and potential water pollution problems could also continue to increase. Forecasts of the quantities and location of wastes are the basis for determining the means to preserve water quality and to protect water uses.

The 1967 population of 1,072,400 is projected to increase 42 percent by 1980, 130 percent by 2000, and 270 percent by 2020. Figure 7-4 indicates the population growth for the basin and the Seattle Service area. It may be noted that a very large percentage of this total basin growth will be concentrated in the Seattle area.

The economy of the Cedar-Green Basins is based primarily on the manufacture of transportation equipment, which completely overshadows all other industries. In 1965, the value added from this industry

[1] After implementation and enforcement all wastes will be intercepted by METRO.

was 2.7 times as great as the the major water using industries. By 2020, production of transportation equipment is projected to increase more than twenty-fold over present levels. Food processing is the most important of the major water using industries in terms of value added. By 2020, this industry is expected to account for about 60 percent of the value added produced by major water using industries. The relative growth of the major industries is shown on Figure 7-5.

The primary metals, stone, clay, glass, and chemicals and petroleum industries are projected to play a relatively minor role in the economy of these basins. Thus, wastes produced in these basins are primarily municipal, including support industries, with some toxic metal plating wastes also produced.

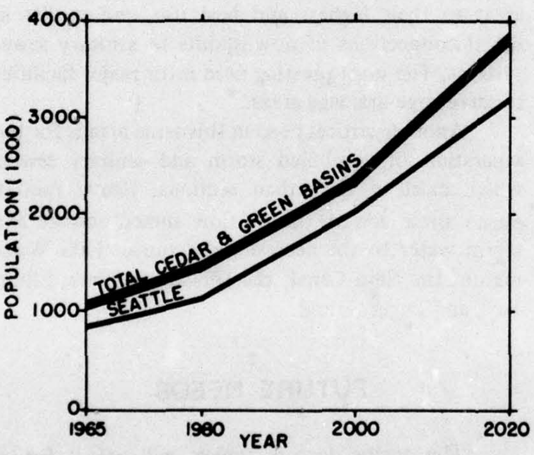


FIGURE 7-4. Population growth projected for the Cedar-Green Basins.

By 1980, more than 20 million recreation days are projected for the basins–more than double present levels. However, future outdoor recreational areas may become limited. Much of the upper waters of the Cedar and Green Rivers are non-recreational areas because they are closed municipal watersheds. The development of lakes as recreational areas, especially Lake Sammamish, is being threatened by septic tank drainage from new residential areas along shores. Future recreational activities on Lake Washington, *the major recreational area*, as well as on Lake Sammamish may diminish if pollution from recreational activities continue.

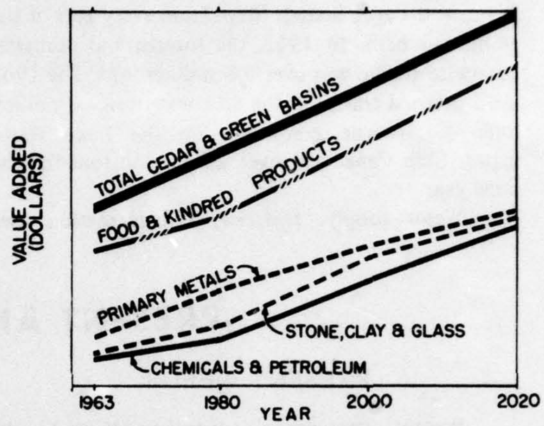


FIGURE 7-5. Relative projected growth of major water using and transportation industries in the Cedar-Green Basins.

As shown in Figure 7-6, the total raw organic wasteload is projected to equal 2,350,000 PE by 1980–nearly a 162 percent increase over present levels. Municipal waste production will account for about 77 percent (1,827,000 PE) of the total raw wasteload by 1980. By 2020, a municipal raw waste production is projected to be almost five times present levels. By 1980, raw wastes produced by the food and kindred industries are projected to be nearly 450,000 PE–19 percent of the total raw wasteload. Raw wastes from recreational activities are projected to increase about 60 percent by 1980. By 2020, this raw waste production is expected to be 5.6 times the present level.

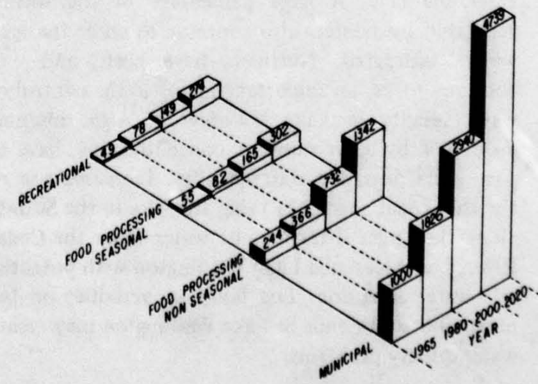


FIGURE 7-6. Projected municipal and industrial raw wastes for the Cedar-Green Basins (thousands of PE).

Three steel plants are located in Seattle. The annual electric steel igot capacity is about 400,000 tons–73 percent of the Pacific Northwest total. The steel industry might pose a potential thermal pollution problem through the improper discharge of cooling waters.

Livestock wastes are not now a serious threat to the quality of water in the Cedar-Green Basins. Agricultural and livestock activities in these basins are giving way to urbanization. Future wastes from these sources, with adequate controls, should have a diminishing effect on water quality.

Although excessive irrigation can impair water quality by leaching or washing sediment and minerals into surface or ground waters, this is not a problem in this basin and is not expected to become one in the future. Irrigation practices in these basins are rather minimal with only 2,600 acres under irrigation in the past four years. Increased urban and industrial sprawl is expected to continue to take more lands out of production in future years.

Tied to irrigation and agricultural practices, however, is the domestic use of pesticides and fertilizers on home lawns and gardens. Considerable amounts of these materials are applied in these basins, which may have played some part in the nutrient enrichment of Lake Sammamish and Lake Washington. Increased use of these materials in the future is expected and, consequently, may present a threat to future water quality. Existing studies by METRO on the quality of storm water, will permit a more precise evaluation of this contribution.

Domestic wastes are expected to be the primary source of most of the future wastes in these basins, generating a 1,830,000 PE by 1980. At that time, food processors–the second largest waste source–will be producing about 450,000 PE and recreationists about 78,000 PE. There will also be toxic wastes from the transportation manufacturing industry requiring special handling techniques. The primary need of the future is to manage these large, expected wasteloads that will be generated in the basins. The means necessary to prevent, control, and abate future water pollution are developed in the succeeding section.

MEANS TO SATISFY NEEDS

Several elements are included in the overall plan for insuring adequate water quality in the Cedar-Green Basins. The most prominent aspect of this plan is an adequate basin-wide waste collection and treatment scheme–well underway by METRO.

The projected Cedar River flow requirements for assimilation of residual wastes are small when compared with the present one-in-ten, 7-day low flow of 40 cfs in the Cedar River at Renton. Flows required for maintenance of adequate fresh-water quality conditions in Lake Washington, however, may be much more significant. Minimum flow requirements for the Green-Duwamish River are more significant and will have to be coordinated with downstream uses.

A water quality monitoring system is an essential tool in support of the existing and future waste treatment construction program. The monitoring program being conducted by METRO and the U. S. Geological Survey should provide adequate data collection in these basins.

Present management procedures for control of pesticides and fertilizers in agricultural and forest operations will need further study aimed at reducing the quantities of these substances which reach the streams in order to adequately protect the quality of water in these basins.

The major aspects of the plan for water quality control are discussed below.

WASTE COLLECTION AND TREATMENT

Substandard water quality existing in Elliott Bay, the lower Duwamish River, and other areas of the Cedar-Green Basins, is due primarily to the discharge of inadequately treated municipal and industrial wastes over the past years. These present needs are expected to be met upon the completion of the current METRO program in 1969. The required facilities are itemized in the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans. Virtually all waste sources listed in this plan are required to be intercepted for treatment by METRO. Adequate outfall and other facilities which are required to maintain water quality are stated in this plan.

In addition to these requirements, the completion of METRO's existing and planned program for adequate waste collection and treatment facilities would be a large step towards the ultimate achievement of adequate water quality in these basins. With completion of this program, more than 60 percent of the total land area of these basins will be provided service by the METRO sewerage system. Separation of storm and sanitary sewers to eliminate all overflows to Lake Washington will aid in the improvement of water quality. The city of Seattle has obtained voter approval for a $76,000,000 separation program. This work is expected to be completed by 1974 and will provide complete separate storm sewer systems for all of that part of the city draining directly to Lake Washington, for the area in West Seattle tributary to the Alki Point treatment plant and for several smaller areas throughout the city where sewer backups have occurred because of indadequate capacity. METRO is installing a system of computer controlled regulators at the outlets of all major combined sewers so that the maximum capacity of the METRO interceptors and combined sewers will be utilized before overflows are permitted. The combination of Seattle's separation program and METRO's computer-controlled regulator system will eliminate a large majority of the summertime overflows and many winter overflows as well.

The required present and projected investment for municipal, industrial, and recreational waste treatment and sewer facilities are presented in Tables 7-6, 7-7 and Figure 7-7.

For municipal facilities[1] a total of $111,000,000 will be needed by 1980, with an additional $270,000,000 by 2000 and an additional $234,000,000 by 2020.

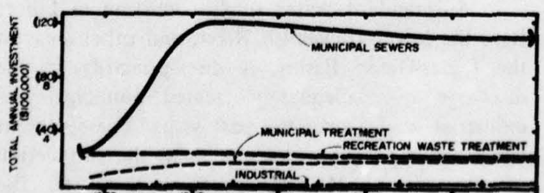


FIGURE 7-7. Relative required rates of investment for waste collection and treatment in the Cedar-Green Basins.

An estimated $240,000 is required annually for recreation waste treatment facilities.[1]

Industrial treatment cost requirements are rather insignificant in comparison to the required investment for municipal and recreational waste treatment facilities. This is due to the lack of large organic waste producing industries which make it possible for most industrial wastes to be discharged directly to the municipal system with minimal cost. Some industrial wastes, particularly those of the metal plating industry, will require special treatment methods prior to discharge.

Federal and State investments are shown in Figure 7-8. The Federal Construction Grants program will need to invest $8,300,000 by 1980 and additional amounts of $16,600,000 from 1980-2000 and $17,200,000 from 2000-2020.

State contributions are estimated to be 50 percent of Federal grants.

Federal investment in sewers will total $12,360,000 by 1980 with additional amounts of $52,000,000 needed by 2000 and $78,800,000 by 2020.

The Federal investment for waste collection and treatment facilities for recreation uses will amount to $2,850,000 by 1980, an additional $5,800,000 for the period 1980-2000 and $3,000,000 for the period 2000-2020.

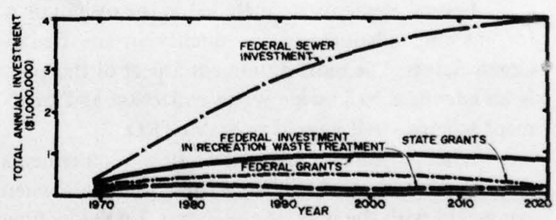


FIGURE 7-8. Government investment requirements[1] for waste collection and treatment in the Cedar-Green Basins.

FLOW REQUIREMENTS

With the exception of effluent discharged to the Duwamish River from the METRO-Renton secondary sewage treatment plant, all adequately treated wastes generated in these basins have been projected to be discharged to marine waters.

[1] Costs are not amortized.

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TABLE 7-6. **Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Cedar-Green Basins**

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$1,352	$ 1,590	$ 578
Disinfection	225	265	96
Outfalls	1,352	1,590	578
Interception and sewer system			
a. Municipal	676	795	289
b. Industrial	225	265	96
Combined sewage infiltration and overflow correction	676	795	289
Advanced waste treatment in recreation areas	147	235	378
Sub-Total	$4,653	$ 5,535	$2,304
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 110	$ 80	$ 88
Evaluations—dispersion areas, ecological, productivity	110	80	88
Information system, quality control, plant operation improvement, operation research	120	82	90
Sub-Total	$ 340	$ 242	$ 266
OPERATION AND MAINTENANCE[2]	$2,670	$ 9,770	$8,610
TOTALS	$7,663	$15,547	$11,180

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

A study has been made by METRO of diverting the Renton plant effluent directly to Puget Sound. Cost estimates were prepared and METRO is committed to diversion of the treatment plant effluent if water quality conditions in the Duwamish River so dictate.

OTHER MEASURES

The existing water quality monitoring program on both fresh and marine waters should be continued in such a manner that will allow for the immediate analysis and interpretation of the data in order to provide a workable water resources management tool. In addition, a complete monitoring system for lakes and ground water should be established.

Although flows are not required on the Cedar River for the purpose of waste assimilation, an analysis of preliminary nutrient balance studies in the Lake Washington system, with incorporation of pro-

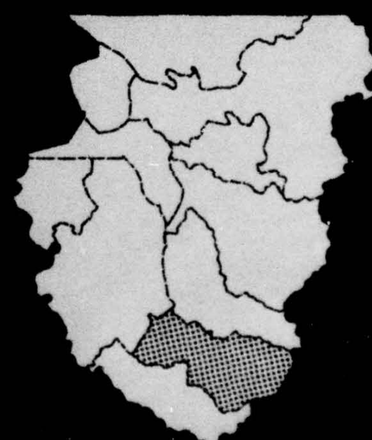
TABLE 7-7. Total amortized capital and operational costs, Cedar-Green Basins

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	--	--	--
Municipal treatment	54.9	64.9	23.8
Municipal sewers	329.4	389.1	142.8
Recreation	5.7	5.6	1.2
Advanced waste treatment	7.4	11.8	18.9
Sub-Total	397.4	471.4	186.7
Water quality engineering management and evaluation	3.6	4.8	5.3
Operation and maintenance	29.4	195.4	172.2
Total	430.4	671.6	364.2

jected water supply diversions from the Cedar River, indicates that high nutrient levels may prevail in Lake Washington.

The Cedar River inflow is presently the major mechanism for control of water quality in Lake Washington. Increased streamflow diversions from the Cedar River will reduce the control capability. In order to resolve this conflict, an in-depth comprehensive investigation of the Cedar River-Lake Washington system should be undertaken. This study should analyze the interrelationships of hydrology, nutrient concentrations, salinity concentrations, and diversions from the system for water supply to determine a basis for management of the system for the maintenance of water quality.

Puyallup Basin



PUYALLUP BASIN

INTRODUCTION

The Puyallup Basin is located in King and Pierce Counties, with the greatest portion (about 85 percent) in Pierce County.

Rugged foothills, valleys, and streams radiating from Mount Rainier occupy the greater part of this 1,203 square-mile area. To the west is the Puget Sound, and beyond the Kitsap Peninsula are the Olympics. Eastward is the city of Tacoma and the flats of the Puyallup River. Farther eastward, prairies with patches of woodland give way to higher elevations, forests, turbulent streams, alpine meadows, and glaciers of Mt. Rainier.

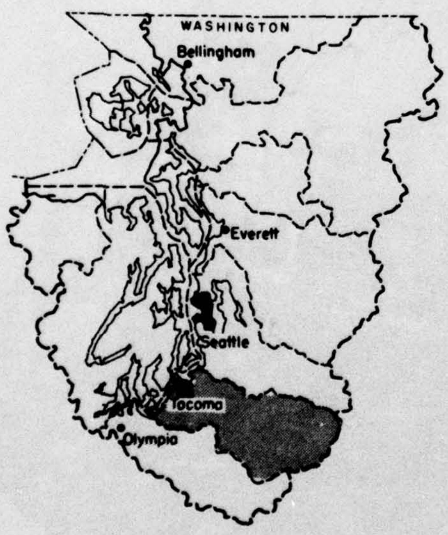


FIGURE 8-1. Location of the Puyallup Basin within the Puget Sound Area.

Heavy rains, plus glacial and snowmelt from the Mt. Rainier area, feed the rivers and streams. The Puyallup River, which flows about 46 miles to its mouth in Commencement Bay, and its major tributaries, the Carbon, Mowich, and White Rivers, drains an area of 972 square miles and accounts for about three-fourths of the total runoff in the basin.

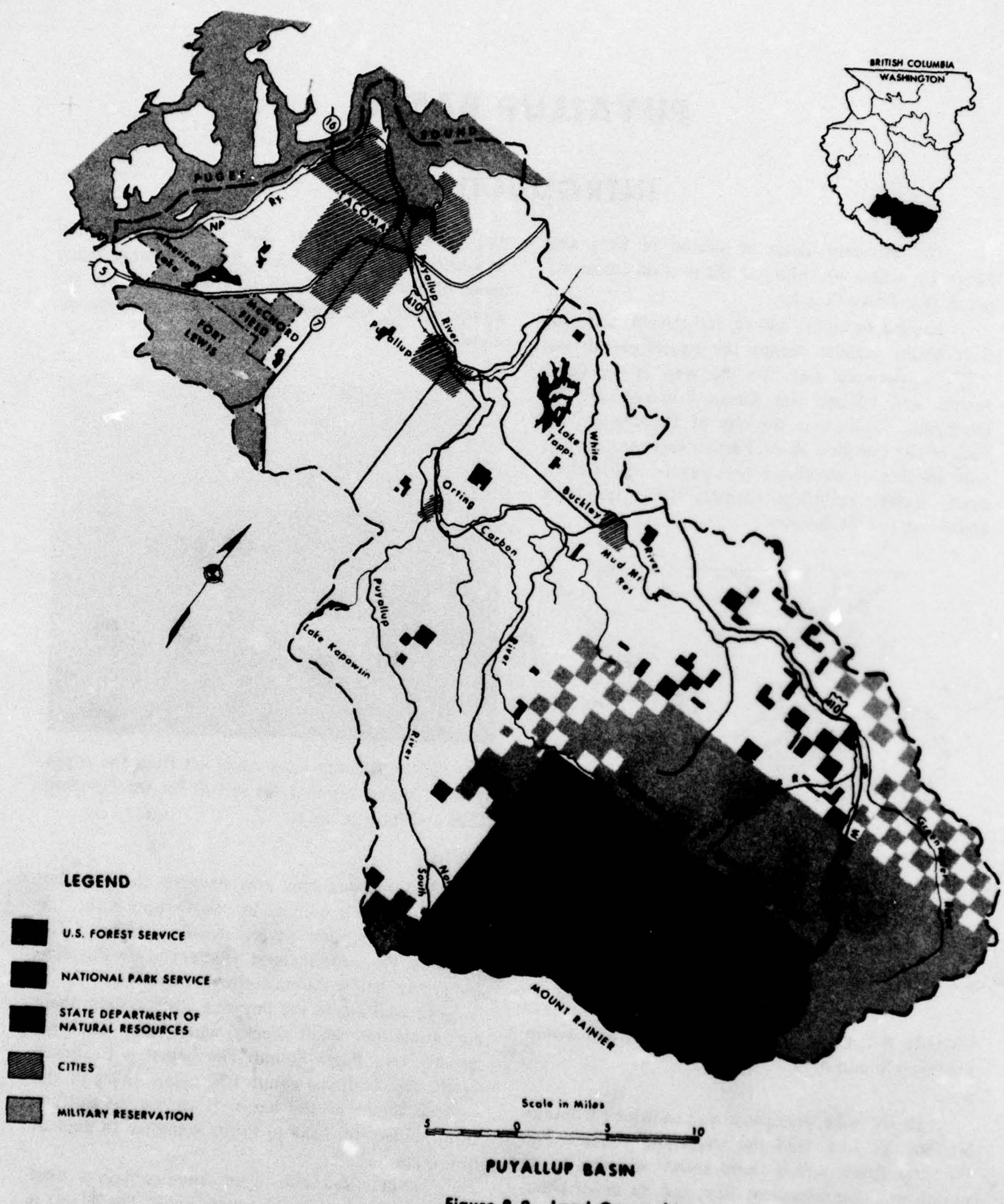
The principal tributary to the Puyallup River is the White River, which has a drainage area of 494-square miles. The White River, is rather milky most of the time with glacial rock flour from the comparatively soft material of Mt. Rainier's volcanic cone.

PHOTO 8-1. Rainfall, plus snowmelt from the slopes of Mt. Rainier, supplies the runoff for the Puyallup River and its tributaries.

The mountainous area between the Puyallup and the White is drained by the Carbon River, the Mowich River, and several smaller streams. The Carbon is the second largest tributary to the Puyallup and joins it below the small town of Orting.

In addition to the Puyallup River system, there are numerous small creeks which also discharge directly into Puget Sound. The largest is Chambers Creek, which drains about 104 square miles of the western slopes of the basin. It carries the outflow from Steilacoom Lake to Puget Sound, a distance of four miles.

Natural and man-made lakes contain a total surface area of about 11 square miles. The largest is Lake Tapps (2,296 acres), created by diverting water from the nearby White River. Two clusters of fresh-water lakes are located in the western uplands–



PUYALLUP BASIN

Figure 8-2 Land Ownership

the Lakes District (American, Gravelly, Steilacoom, and Lake Louise) south of Tacoma, and several in the northwestern part of the basin. Eastward, near the basin's southern perimeter, are two large lakes–Spanaway and Lake Kapowsin. Mowich Lake and numerous smaller alpine lakes lie in the higher elevations. Mud Mountain Reservoir (1,200 acres) on the White River is a Corps of Engineers' flood control project.

The marine water area extends along the basin's western front, and covers a surface area of 23,623 acres. Its landforms and waterbodies include: Ketron Island, The Narrows, Point Defiance, Dalco Passage, Commencement Bay, Point Brown, and a portion of Poverty Bay.

Commencement Bay is one of the world's largest natural protected harbors. It is a deep rectangular-shaped harbor with an average width of nearly two miles and a length of two and one-half miles. The entrance of the Bay between Brown's Point and Point Defiance is four and one-half miles wide. The harbor has an average depth of 150 to 180 feet.

Glacial action during comparatively recent geological time shaped much of the topography here. Advancing and retreating ice sheets covered the prairies and lowlands with a deep mantle of gravel, sand and clay. Numerous lakes and ponds were left behind in the uneven surface in the final retreat of the glaciers. These depressions became American, Spanaway, Steilacoom, and Kapowsin Lakes. A lobe of one ice sheet gouged out Commencement Bay.

Soils of the bottom lands consist of gravelly sands, sands, and sandy loams in the upper reaches, becoming progressively finer textured to fine sandy loams, silt loams, clay loams, and silty clay loams in the lower reaches. The soils of the lower reaches are highly productive. Soils of the glacial terraces are deep gravelly sands, sands, and sandy loams on ablation till, and moderately deep (20-40 inches) gravelly sandy loams, and gravelly loamd overlying slowly permeable cemented gravelly sandy and gravelly sandy clay basal till.

Land use in the basin area changes from intense residential and industrial in Tacoma, through agricultural in the Puyallup and Stuck River valleys, to woodland in the eastern part where most of the area is presently covered by second-growth timber. Woodland use predominates, accounting for 84 percent of the total.

About 349,800 people (1967) live within this basin. According to 1967 estimated population figures, the major city is Tacoma. This city of 156,000 population is the third largest in the State and covers an area of 69 square miles. The second largest city is Puyallup, containing 14,200 people. Several other communities–Sumner, Buckley, Milton, Orting, and Algona–have populations between 1,200 and 4,000. Most development in the basin is adjacent to the shores of Puget Sound, in the Puyallup River Valley, and along the major arterial highway. The rugged eastern sector remains void of concentrated settlement.

PHOTO 8-2. Tacoma is a major seaport with a diversified industrial economy. In the background is Mt. Rainier and to the left is the Puyallup Valley.

The backbone of the area's prosperity continues to be the forest products industry. Harvesting timber in Pierce County has increased over 100 percent since 1954. Food and kindred products represent the second largest category of manufacturing activities. Further growth in manufacturing of forest products and in food processing is expected.

The basin's most heavily industrialized area lies along the shores of Commencement Bay, where over 18,000 persons are employed. Over half of this employment is an industrial complex with a wide category of manufacturing. Along the Bay's 14-mile shoreline is an industrial complex with a wide array of manufacturing concerns. There are more than 500 industries located here, including lumber, pulp and paper mills, furniture manufacturing plants, plywood factories, and food processing plants. Here also is the largest copper smelter on the Pacific Coast, a new electrochemical and metallurgical industrial center, and the home of a diversified shipbuilding industry.

The Port of Tacoma is situated at the head of the Bay. The Port encompasses 3,300 acres of industrial park land with some 320 acres devoted to marine terminal facilities. New and expanding plants are springing up throughout the industrial district. Since 1960 over 70 new industries have moved into the Port.

East from Commencement Bay is the narrow, winding Puyallup Valley, which constitutes the basin's richest farming area. Fertile soils and a mild climate have united to make the Puyallup Valley ideal for cane berries, truck gardening and poultry. Here also is million-dollar industry; where valley farmers cultivate daffodil, tulip and iris bulbs for florists and greenhouse growers. Other agricultural activities—dairying, poultry and livestock—also add much to the economic level of the basin.

The Boeing Company has had a tremendous impact on the economic conditions in the Puyallup Basin, especially in the northwestern area. This is especially true now, with the large Boeing plants located in Auburn and Kent in southern King County, and a possibility of small plants being built just inside the basin.

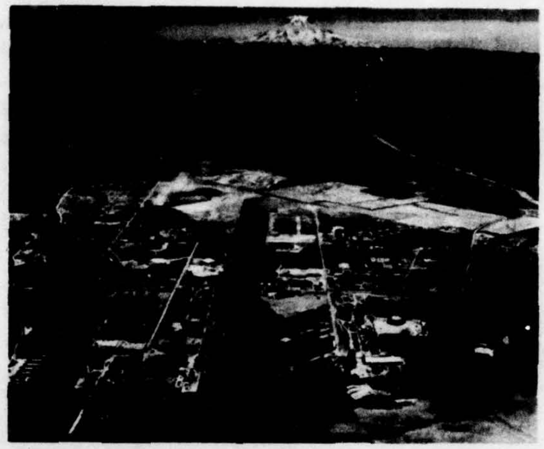


PHOTO 8-3. The industrial area lies along the shores of Commencement Bay. Beyond stretches the Puyallup Valley toward the foothills of Mt. Rainier.

PRESENT STATUS

WATER RESOURCES

Fresh Water

Approximately 98 percent of the basin's runoff is measured at the gaging station on the Puyallup River near Puyallup. During the period 1931-1960 the mean annual discharge at this station averaged 3,432 cfs. Records on the main stem of the Puyallup River near Orting, which include the Mowich River tributary, indicate that the mean annual discharge from the western foothills and slopes of Mt. Rainier is about 703 cfs. Streamflow of the Carbon River, measured at the gaging station near Fairfax, show a mean annual discharge of 426 cfs. The mean annual discharge of the White River near Buckley averaged 1,490 cfs during the period 1931-1960. Many small creeks drain directly into Puget Sound and Commencement Bay. The largest is Chambers Creek with an annual average discharge of 120 cfs.

Streamflows are highest during early summer due to snowmelt and low during the late summer months. The Puyallup River system is characterized by a summer base flow of about 1,600 cfs and an increase in streamflow to about 5,3000 cfs by mid-June due to rising temperatures and snowmelt. Following the snowmelt peak, streamflow returns to minimum base flow as snowpacks are depleted. Runoff is then sustained by ground water and glacial melting.

A low-flow frequency analysis has been made for 12 stations within the basin based on an 18-year period from April 1, 1946, to March 31, 1964. The 7-day and 30-day flows that may be expected to occur at five of these river stations for a recurrence interval of 10 years, is shown in Table 8-1.

There have been two principal reservoirs constructed in the basin. Mud Mountain Dam, used only for flood control, provides 106,000 acre-feet of storage on the White River. A few miles downstream, near Buckley, a timber dam diverts much of the flow through a 14-mile series of flumes and canals to Lake Tapps, a 44,000 acre-feet off-stream reservoir. Discharge from Lake Tapps is used to generate power for the Puget Sound Power and Light Company plant at Dieringer.

TABLE 8-1. Low flow frequency 10-year recurrence interval, Puyallup Basin

Station	7-Day Low-Flow cfs	30-Day Low-Flow cfs
Puyallup River at Puyallup	910	1,150
Puyallup River near Orting	188	260
Carbon River near Fairfax	98	118
White River near Buckley	340	440
Chambers Creek Below Leach Creek near Steilacoom	32	35

Source: Appendix III: Hydrology & Natural Environment.

Part of the Puyallup River flow is diverted through the Electron power plant, 23 miles southeast of Tacoma. The diversion dam, 14 miles upstream from the powerhouse, creates a small reservoir of 120 acre-feet in the stream bed.

Plentiful supplies of ground water exist in much of the lowland areas of the basin. Coarse sedimentary zones of Quaternary age are the important lowland aquifers. These deposits are nearly continuous over about a 420-square-mile area.

Quaternary sediments at the surface are mainly basal till, recessional outwash, alluvium, and mudflow deposits. Glacial and the older semi-consolidated sediments generally yield only small amounts of water to wells. The outwash deposits, consisting mainly of coarse sand and gravel, are the most productive aquifers in the lowlands. A feature of these outwash aquifers is their high transmissibility. Wells tapping them have the greatest specific capacities and the greatest yields of any wells in the area. Alluvium (silt, clay, and fine sand) occurs mainly on the flood plains of the Puyallup and White River Valleys and appears capable of yielding appreciable quantities of water to wells.

Precipitation recharges the lowland aquifers, which may receive an average of about 130,000 acre-feet annually. Most of the ground-water discharge takes place through springs and seeps around the margins of the river valleys or directly into the Puget Sound.

Sand and gravel aquifers probably occur in the mountains in quaternary sediments that cover about a 30-square mile area. Assuming such qualities as saturated thickness and permeability, these aquifers might be developed to supply ground water on a sustained basis. In other mountainous sections ground water is obtainable only from consolidated and semi-consolidated rocks, which yield at best only 10 gpm.

Marine Water

The predominant surface movement in Commencement Bay is outward and results from the outflow of fresh water from the Puyallup River. Tidal studies indicate that fresh water moving out of the river on the falling (ebb) tide spreads across the Bay in a surface layer which extends toward Brown's Point. Studies have shown evidence of a deep, counter-clockwise circulatory current which is strongest on flood tides, but persists on ebb tides. Associated with this current is intermittent upwelling of the denser bottom water and an over-riding toward currents of fresh water from the Puyallup River, as mentioned. This current and circulation pattern produces two relatively quiescent areas within Commencement Bay; one on the east side of the harbor, and the other area near its mouth. The deep portion of the Bay is flushed in roughly one tidal cycle, or 12 hours. Outward current velocities during flood tide as high as 30 fpm have been measured near Brown's Point at 100 feet of depth. Such flow patterns in the Bay may be sufficient in magnitude to effectively prevent any build-up of pollutional load.

The Narrows is an area of strong tidal flows where velocities exceed 600 fpm at maximum flood and 400 fpm at maximum ebb. Submarine topography in The Narrows consists of a smooth, well-scoured channel. Maximum depth is about 175 feet at the channel center 2,200 feet from shore.

Studies in the Chambers Creek area revealed weak and variable eddies adjacent to the shoreline. In the vicinity of Chambers Creek, these eddies were found to extend offshore as far as 2,000 feet.

WATER QUALITY

Fresh Water

A number of water quality parameters on the Puyallup River, plus its significant tributaries and the

Chambers Creek system, have been measured since October 1960. These water quality characteristics are shown in Table 8-2.

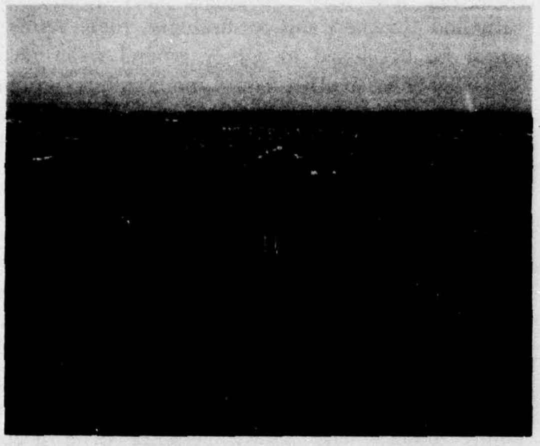


PHOTO 8-4. Strong tidal flows exist in The Narrows.

Chemical–The chemical quality of surface water in the basin is low in hardness and in dissolved solids. Concentrations of total dissolved solids for the Puyallup River system rarely exceed 100 mg/1. Water in the Chambers Creek basin is somewhat more mineralized than streams in the Puyallup Basin. Chambers Creek near Steilacoom and two of its tributaries–Leach and Flett Creeks–often exceed 100 mg/1 of dissolved solids. This slightly higher dissolved solids content is probably due to the large amount of ground water drainage received by the system.

The White River near Sumner is harder and higher in dissolved solids than any other stream in the system. A tributary of the White River, Boise Creek, on the other hand is softer and lower in dissolved solids than any other stream in the basin.

High iron concentrations ranging from 2.9 to 9.4 are common, especially in the Puyallup River and Boise Creek.

Average dissolved oxygen concentrations on the Puyallup River and its tributaries are high, ranging from 10.5 mg/l to 11.6 mg/l. The lowest minimum

TABLE 8-2. Surface water quality (page 1 of 2).

Item	Discharge (cfs)	Dissolved solids (mg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Sulfate (SO_4) (mg/l)	Chloride (Cl) (mg/l)	Fluoride (F) (mg/l)	Nitrate (NO_3) (mg/l)	Specific conductance (µmho)	Orthophosphate (PO_4) (mg/l)	Total phosphate (PO_4) (mg/l)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Boron (B) (mg/l)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen (mg/l)	Oxygen saturation (%)	Total (mg/l)	Noncarbonate (mg/l)	Coliform (MPN)
SOUTH PRAIRIE CREEK AT SOUTH PRAIRIE																			**FEBRUARY 1955 THROUGH SEPT 1955**								
Maximum	902	70	11.0	2.9	5.8	0.7	51	--	7.7	2.2	0.3	1.9	106	---	---	14.0	0.00	0.05	7.3	—	—	—	—	—	39	1	---
Mean	---	57	7.8	2.0	4.1	0.6	35	--	6.1	1.7	0.2	1.1	78	---	---	12.5	0.00	0.03	--	—	—	—	—	—	28	1	---
Minimum	54	43	4.6	1.0	2.5	0.6	18	--	4.5	1.2	0.1	0.3	49	---	---	11.0	0.00	0.02	6.7	—	—	—	—	—	16	0	---
Number	2	2	2	2	2	2	2	--	2	2	2	2	2	---	---	2	2	2	2	—	—	—	—	—	2	2	---
PUYALLUP RIVER AT ALDERTON																			**FEBRUARY 1955 THROUGH AUGUST 1955**								
Maximum	4,190	57	5.6	1.6	3.0	0.8	26	--	5.1	1.0	0.2	1.6	59	---	---	12.0	0.05	0.14	7.2	—	—	—	—	—	21	0	--
Mean	---	52	5.2	1.3	2.8	0.8	23	--	4.1	1.0	0.1	0.9	53	---	---	11.0	0.04	0.08	---	—	—	—	—	—	19	0	--
Minimum	1,020	46	4.8	1.0	2.6	0.7	20	--	3.0	1.0	0.1	0.3	47	---	---	10.0	0.03	0.01	6.8	—	—	—	—	—	16	0	---
Number	2	2	2	2	2	2	2	--	2	2	2	2	2	---	---	2	2	2	2	—	—	—	—	—	2	2	—
WHITE RIVER AT GREENWATER																			**FEBRUARY 1955 THROUGH AUGUST 1955**								
Maximum	3,040	62	5.6	0.9	3.9	0.8	18	--	10.0	1.2	0.3	0.9	58	--	--	14.0	0.02	0.12	7.0	—	—	—	—	—	18	3	—
Mean	---	53	5.0	0.8	3.1	0.7	18	--	7.2	0.9	0.2	0.6	51	---	--	13.5	0.01	0.12	---	—	—	—	—	—	16	2	—
Minimum	723	44	4.4	0.8	2.3	0.6	17	--	4.4	0.5	0.1	0.3	43	---	--	13.0	0.00	0.11	6.9	—	—	—	—	—	14	0	---
Number	2	2	2	2	2	2	2	--	2	2	2	2	2	---	---	2	2	2	2	—	—	—	—	—	2	2	---
GREENWATER RIVER AT GREENWATER																			**FEBRUARY 1955 THROUGH AUGUST 1955**								
Maximum	1,150	50	6.7	1.2	4.3	0.5	33	--	3.3	1.2	0.3	0.9	61	---	--	16.0	0.03	0.08	7.5	—	—	—	—	—	22	0	---
Mean	---	47	5.6	0.9	3.4	0.4	26	--	2.9	1.1	0.2	0.5	51	---	--	15.0	0.02	0.05	---	—	—	—	—	—	18	0	---
Minimum	73	43	4.6	0.5	2.5	0.3	19	--	2.6	1.0	0.0	0.1	41	---	--	14.0	0.00	0.02	6.5	—	—	—	—	—	14	0	---
Number	2	2	2	2	2	2	2	--	2	2	2	2	2	---	---	2	2	2	2	—	—	—	—	—	2	2	---
WHITE RIVER NEAR BUCKLEY																			**AUGUST 1947 THROUGH AUGUST 1955**								
Maximum	3,390	56	7.2	1.2	3.7	0.8	26	--	14.0	1.5	0.3	1.1	61	---	--	17.0	0.07	0.12	7.2	—	—	—	—	—	22	1	---
Mean	---	52	5.3	0.9	2.8	0.8	21	--	8.4	1.0	0.2	0.5	49	---	--	13.4	0.05	0.05	---	—	—	—	—	—	17	0	---
Minimum	655	42	3.2	0.5	1.9	0.7	12	--	3.8	0.2	0.1	0.2	34	---	--	9.5	0.03	0.01	6.6	—	—	—	—	—	10	0	---
Number	4	4	4	4	2	2	4	---	4	4	3	4	4	---	---	4	3	3	3	—	—	—	—	—	4	4	---
BOISE CREEK ABOVE RESERVOIR NEAR ENUMCLAW																			**JANUARY 1963 THROUGH OCTOBER 1964**								
Maximum	29	40	4.5	0.8	3.0	0.8	22	0	2.4	2.0	0.1	1.1	40	0.03	0.08	14.0	0.08	0.02	7.2	15	5	11.0	12.4	98	14	0	150
Mean	---	34	3.6	0.6	2.5	0.5	17	0	1.0	1.3	0.0	0.7	34	0.02	0.04	13.0	0.06	0.01	---	--	---	6.7	11.2	94	12	0	37
Minimum	7	30	3.0	0.4	2.0	0.1	14	0	0.2	1.0	0.0	0.3	29	0.02	0.02	12.0	0.04	0.00	6.8	5	0	3.0	10.2	88	9	0	0
Number	7	8	8	8	8	8	8	8	8	8	8	8	8	8	4	8	4	4	8	8	8	8	8	8	8	8	8
BOISE CREEK AT BUCKLEY																			**JANUARY 1963 THROUGH OCTOBER 1964**								
Maximum	---	67	7.0	1.9	5.5	3.0	32	0	4.6	3.5	0.1	4.7	76	0.64	1.60	18.0	0.65	0.07	6.8	50	20	16.0	11.8	98	24	2	24,000
Mean	---	57	5.9	1.4	3.9	1.8	26	0	3.2	2.4	0.1	3.2	64	0.28	0.93	16.5	0.42	0.04	---	---	--	10.0	10.5	95	21	1	47,938
Minimum	---	49	5.0	1.1	3.0	1.2	22	0	2.4	1.0	0.0	2.0	51	0.11	0.22	15.0	0.29	0.03	6.4	10	5	4.8	9.0	93	[illegible]	0	1,500
Number	---	8	8	8	8	8	8	8	8	8	8	8	8	8	5	8	3	3	8	8	8	8	8	8	8	8	8

TABLE 8-2. Surface water quality (page 2 of 2).

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca) mg/l	Magnesium (Mg) mg/l	Sodium (Na) mg/l	Potassium (K) mg/l	Bicarbonate (HCO_3) mg/l	Carbonate (CO_3) mg/l	Sulfate (SO_4) mg/l	Chloride (Cl) mg/l	Fluoride (F) mg/l	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4) mg/l	Total phosphate (PO_4) mg/l	Silica (SiO_2) (mg/l)	Iron (Fe) mg/l	Boron (B) (mg/l)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen mg/l	Oxygen saturation (%)	Total mg/l	Noncarbonate mg/l	Coliform (MPN)
WHITE RIVER NEAR SUMNER — OCTOBER 1961 THROUGH MARCH 1966																											
Maximum	3,320	88	12.0	4.1	5.3	2.2	49	0	14.0	3.2	0.3	3.3	123	0.28	---	20.0	1.80	0.16	8.7	25	230	26.0	14.8	123	47	8	11,000
Mean	---	63	8.5	2.0	3.8	1.1	34	0	8.6	1.9	0.1	0.7	81	0.09	---	15.4	0.29	0.02	---	---	---	10.7	11.2	104	30	2	1,410
Minimum	57	37	4.4	0.7	2.3	0.3	16	0	4.2	0.5	0.0	0.0	46	0.02	---	10.0	0.02	0.00	6.6	0	0	3.4	8.4	79	15	0	0
Number	38	53	52	52	52	52	52	26	52	52,	52	53	53	47	---	52	49	12	53	53	45	51	51	51	53	53	51
PUYALLUP RIVER AT PUYALLUP — OCTOBER 1961 THROUGH APRIL 1966																											
Maximum	8,830	74	11.0	3.1	5.4	1.8	46	0	12.0	3.0	0.3	2.0	112	0.13	---	18.0	1.60	0.04	7.5	20	100	18.3	12.4	112	40	4	24,000
Mean	---	53	6.8	1.7	3.6	0.9	28	0	6.8	1.6	0.1	0.7	67	0.05	---	13.8	0.44	0.01	---	---	---	9.3	10.8	97	24	1	5,521
Minimum	1,090	36	4.8	0.8	2.2	0.4	20	0	4.0	0.8	0.0	0.1	46	0.01	---	9.9	0.01	0.00	6.3	5	0	2.9	9.3	87	16	0	0
Number	26	42	42	42	42	42	42	28	42	42	42	42	42	28	---	42	30	13	42	42	16	42	43	42	42	42	43
CLOVER CREEK NEAR PARKLAND — OCTOBER 1962 THROUGH SEPTEMBER 1964																											
Maximum	---	81	10.0	4.0	4.8	1.5	48	0	6.8	4.0	0.2	5.2	99	0.15	0.15	23.0	0.30	0.06	7.4	70	5	19.5	13.4	149	38	6	11,000
Mean	---	74	9.0	3.4	4.4	1.0	43	0	4.9	3.0	0.1	3.1	95	0.04	0.07	19.9	0.04	0.02	---	---	---	10.9	11.5	108	36	1	593
Minimum	---	68	7.5	2.4	3.8	0.5	28	0	3.2	2.5	0.0	2.1	84	0.02	0.03	15.0	0.00	0.00	6.6	0	0	6.1	9.3	81	28	0	0
Number	---	24	24	24	24	24	24	12	24	24	24	24	24	24	22	24	19	4	24	24	24	24	24	24	24	24	24
CLOVER CREEK ABOVE STEILACOOM LAKE NEAR TACOMA — OCTOBER 1962 THROUGH SEPT 1965																											
Maximum	---	83	11.0	4.0	5.3	1.5	48	0	8.4	4.5	0.2	7.2	109	0.29	0.35	21.0	0.38	0.02	7.7	30	20	21.0	13.1	142	42	6	24,000
Mean	---	67	9.1	3.1	4.6	0.9	40	0	5.9	3.7	0.1	3.2	95	0.06	0.12	12.7	0.12	0.01	---	---	---	11.2	11.1	105	36	3	1,521
Minimum	---	54	7.5	1.8	4.2	0.6	30	0	4.2	3.0	0.0	0.6	82	0.00	0.03	7.4	0.00	0.00	6.5	5	0	4.5	8.8	81	29	0	0
Number	---	35	35	35	35	35	35	24	35	35	35	35	35	36	34	35	29	6	35	35	35	35	35	35	35	35	35
CHAMBERS CREEK BELOW STEILACOOM LAKE NEAR STEILACOOM — OCT 1962 THROUGH SEPT 1964																											
Maximum	273	88	12.0	4.2	5.7	1.6	60	0	8.6	4.2	0.1	4.6	125	0.88	1.00	19.0	0.11	0.05	8.1	10	5	24.0	13.3	139	47	7	390
Mean	---	73	10.5	3.6	5.1	1.0	47	0	7.3	3.9	0.1	2.2	108	0.25	0.29	13.5	0.04	0.03	---	---	---	12.8	10.8	105	41	3	90
Minimum	27	53	9.5	2.7	4.6	0.7	38	0	5.4	2.8	0.0	0.1	96	0.04	0.05	1.2	0.00	0.00	6.6	0	0	6.1	8.0	76	35	0	0
Number	24	24	24	24	24	24	24	12	24	24	24	24	24	24	23	24	18	4	24	24	24	24	24	24	24	24	24
FLETT CREEK AT TACOMA — OCTOBER 1962 THROUGH SEPTEMBER 1965																											
Maximum	51	156	22.0	8.9	9.0	6.6	75	0	35.0	10.0	0.3	13.0	220	0.98	1.10	22.0	1.10	0.03	7.8	160	120	20.1	13.2	150	85	36	24,000
Mean	---	120	16.0	6.5	7.2	2.7	53	0	20.8	7.9	0.1	10.1	177	0.20	0.28	16.6	0.28	0.01	---	---	---	11.3	8.9	84	67	23	5,343
Minimum	2	98	12.0	4.2	5.1	1.6	30	0	17.0	4.5	0.0	6.8	131	0.07	0.09	12.0	0.02	0.00	6.3	5	0	7.3	4.5	41	47	15	91
Number	24	36	36	36	36	36	36	24	36	36	36	36	36	36	35	36	29	6	36	36	36	36	36	36	36	36	36
LEACH CREEK NEAR STEILACOOM — OCTOBER 1962 THROUGH SEPTEMBER 1965																											
Maximum	33	121	14.0	9.2	6.7	2.1	70	0	17.0	6.5	0.3	5.4	167	0.19	0.51	30.0	0.29	0.06	7.8	100	15	15.0	12.6	111	68	16	11,000
Mean	---	106	11.2	7.6	5.6	1.5	59	0	13.1	4.6	0.1	4.0	145	0.13	0.20	25.6	0.12	0.03	---	---	---	9.9	10.7	97	59	11	1,566
Minimum	6	83	8.0	4.4	4.0	1.1	26	0	11.0	2.8	0.0	1.3	101	0.02	0.11	16.0	0.03	0.00	6.4	0	0	5.8	9.0	82	38	8	0
Number	24	36	36	36	36	36	36	24	36	36	36	36	36	36	35	36	32	6	36	36	36	36	36	36	36	36	36
CHAMBERS CREEK NEAR STEILACOOM — OCTOBER 1962 THROUGH APRIL 1966																											
Maximum	348	100	12.0	6.2	6.2	2.3	57	0	12.0	6.0	0.2	5.6	139	0.94	1.20	23.0	0.52	0.10	7.8	70	20	17.4	13.0	113	56	10	11,000
Mean	---	84	11.0	4.8	5.5	1.3	49	0	9.7	4.6	0.1	4.2	123	0.20	0.28	16.9	0.09	0.04	---	---	---	11.3	10.1	94	47	7	933
Minimum	37	73	8.0	3.3	4.0	0.9	30	0	6.9	3.0	0.0	2.7	97	0.04	0.10	11.0	0.00	0.00	6.7	0	0	6.6	8.3	82	35	2	0
Number	26	49	49	49	49	49	49	35	49	49	49	49	49	36	x35	49	32	10	49	49	36	51	50	50	49	49	51
KAPOWSIN CREEK NEAR KAPOWSIN — FEBRUARY 1955 AND SEPTEMBER 1955																											
Maximum	246	51	4.8	1.4	3.4	0.9	28	---	1.5	2.0	0.3	1.6	53	---	---	16.0	0.08	0.08	6.7	---	---	---	---	---	18	0	---
Mean	---	50	4.1	1.3	3.2	0.9	23	---	1.1	1.5	0.3	1.1	48	---	---	14.5	0.05	0.04	---	---	---	---	---	---	16	0	---
Minimum	6	49	3.4	1.1	3.0	0.9	18	---	0.7	1.0	0.2	0.7	43	---	---	13.0	0.03	0.01	6.6	---	---	---	---	---	13	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
PUYALLUP RIVER NEAR ORTING — JULY 1959 THROUGH MARCH 1966																											
Maximum	3,240	65	7.5	2.3	4.0	1.1	30	0	16.0	2.8	0.3	1.6	74	0.14	---	18.0	9.50	0.11	7.6	40	500	15.0	13.4	108	26	12	430
Mean	---	46	5.2	1.3	2.7	0.6	21	0	5.7	1.1	0.1	0.3	52	0.03	---	13.4	0.68	0.02	---	---	---	8.0	11.4	99	18	2	115
Minimum	265	32	3.5	0.6	1.8	0.2	8	0	1.9	0.0	0.0	0.0	40	0.00	---	8.9	0.02	0.00	6.2	0	0	1.0	9.2	89	13	0	0
Number	24	32	32	32	32	32	32	17	32	32	32	32	32	26	---	31	28	11	32	32	9	29	30	29	32	32	30
CARBON RIVER NEAR FAIRFAX — FEBRUARY 1955 THROUGH AUGUST 1964																											
Maximum	1,760	52	6.5	1.7	4.0	1.0	34	0	3.6	1.5	0.2	1.6	64	0.10	---	12.0	0.90	0.08	7.4	10	370	11.5	12.4	103	23	0	430
Mean	---	39	4.5	1.0	2.9	0.7	23	0	2.3	0.9	0.1	0.5	44	0.03	---	9.6	0.20	0.03	---	---	---	8.0	11.6	101	15	0	143
Minimum	194	23	2.4	0.3	1.7	0.5	12	0	1.4	0.2	0.0	0.0	28	0.00	---	6.9	0.00	0.00	6.6	5	0	5.1	10.6	100	7	0	30
Number	9	9	9	9	9	9	9	7	9	9	9	9	9	7	---	9	9	5	9	9	7	7	7	7	9	9	7

DO recorded for this river system was an 8.4 ppm on the White River near Sumner. The only evidence of any oxygen "sag" in the basin is in the Chambers Creek area where on Flett Creek the minimum dissolved oxygen content dropped to a low of 4.5 mg/l. Average DO concentrations in this entire system are lower than the Puyallup, and range from 8.0 mg/l to 11.5 mg/l.

Total phosphate concentrations in the basin cover a wide range of values. The Puyallup and Carbon Rivers and Clover Creek normally maintain concentrations of 0.06 mg/l or less. Leach Creek appears to continually maintain concentrations throughout the year near 0.12 mg/l. Phosphate values on Boise Creek range from 0.02 mg/l at the upper station to 0.28 mg/l at the lower station near Buckley. Chambers and Flett Creeks have registered phosphate concentrations above 0.90 mg/l.

Nitrate values also range from some of the lowest to some of the highest in the Area. The Carbon River near Orting has been measured at peak values of 0.10 mg/l. The Puyallup River near Orting has a maximum of 0.25 mg/l as compared to a value of 0.45 mg/l at Puyallup. The White River near Sumner has a record maximum of 0.75 mg/l. Nitrate values on Chambers Creek show a maximum recorded value of 1.04 mg/l below Steilacoom Lake. Nitrate concentrations on Flett Creek average 2.28 mg/l.

Most ground water contains less than 200 mg/l of dissolved solids. Water hardness generally does not exceed 60 mg/l. Silica concentrations range between 7 and 54 mg/l, while averaging about 30 mg/l. Objectionable concentrations of iron occur locally, principally in aquifers that underlie the Puyallup and White River flood plains. Sodium concentrations in the lower Puyallup River Valley are rather high, generally exceeding 50 mg/l as compared to less than 10 mg/l in most of the basin.

Bacteriological—The bacteriological quality of streams in the basin is highly variable. The MPN of coliform bacteria in the Puyallup River near Orting, for example, is usually less than 100. Downstream, at Puyallup, MPN values range from 0 to 24,000. Total coliform densities throughout Boise Creek range from 37 to 48,000 MPN, with occassional maximums as high as 240,000 MPN near Buckley.

Sanitary quality in the Chambers Creek area also varies. The MPN values of coliform bacteria in Chambers Creek below Steilacoom Lake are usually less than 100, but occasionally as high as 390. However, downstream near the town of Steilacoom, this same stream has MPN values in excess of 700, with a recorded high of 11,000. Leach Creek has MPN near Parkland and 24,000 MPN farther down-Creek at Tacoma contains an even greater concentration—5,300 MPN. The entire length of Clover Creek is of similar sanitary quality, with maximums of 11,000 MPN near Parkland and 24,000 MPN farther downstream at Lake Steilacoom. Table 8-3 gives a summary of coliform concentrations taken from basic data sampling.

TABLE 8-3. Summary of coliform concentrations, Puyallup Basin

	MPN/100 mls							
	Less than 240		240-1,000		1,000-2,400		Greater than 2,400	
Station	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.
Clover Creek (Parkland)	18	75	5	21	0	0	1	4
Clover Creek (Steilacoom Lake)	16	46	11	31	2	6	6	17
Chambers Creek (Bl. Steilacoom Lk)	21	88	3	13	0	0	0	0
Flett Creek (Tacoma)	4	11	9	25	3	8	20	56
Leach Creek (Steilacoom)	11	31	15	42	3	8	7	19
Chambers Creek (nr. Steilacoom)	36	62	16	28	0	0	6	10
Puyallup River (nr Orting)	29	88	4	12	0	0	0	0
Puyallup River (Puyallup)	3	6	14	29	4	8	28	57
White River (near Buckley)	0	0	0	0	0	0	0	0
Boise Creek (nr. Enumclaw)	8	100	0	0	0	0	0	0
Boise Creek (Buckley)	0	0	0	0	1	13	7	88
White River (nr. Sumner)	30	56	12	22	0	0	12	22

Source: Washington Water Pollution Control Commission

Physcial–Temperatures of the Puyallup River at Orting and its tributary, the Carbon River, are relatively low, (less than 59°F (15°C) during the warmest months) reflecting their glacial origins. The Puyallup warms up downstream and has reached a recorded high of 65°F (18.3°C). The increase in the summertime is probably due to the contribution of warm water from the White River. The low summer flow in the White River near Sumner has attained a temperature as great as 78.8°F (26°C).

High stream temperatures occur in the Chambers Creek area where temperatures over 73°F (23°C) have been recorded. The warmest stream flows occur near Lake Steilacoom where maximums of 75.3°F (24.0°C) on Chambers Creek and 69.8°F (21.0°C) on Clover Creek have been reached. Flett Creek at Tacoma has attained a high of over 68.2°F (20.1°C). Temperature on Chambers Creek near its outlet at Steilacoom have reached a maximum recorded value of 63.4°F (17.4°C).

The White River is heavily laden with sand and silt, with suspended sediment concentrations ranging from 10 to 60,000 mg/l. The sediment load on the Puyallup River ranges from about 1 to 27,100 tons per day. This river probably transports more than a million tons of suspended sediment during a year of normal streamflow. Streams in the basin which are not fed by glaciers generally have suspended sediment concentrations less than 10 mg/l. Water in the Chambers Creek area is practically sediment-free.

The glacial-fed streams are turbid most of the time from their headwaters to mouth. The average turbidity for the White River near Sumner was 20 JTU; for the lower Puyallup, 25 JTU; and for the Carbon River, 61 JTU. The maximum turbidity for these streams ranged from 85 to 370 JTU. Streamflows are less turbid during the winter months when glacial melt is reduced.

Marine Water

Water characteristics throughout the basin are quite uniform. The average minimum surface salinity is 27.4 o/oo, but values of less than 20 o/oo have been observed. The maximum surface salinity is observed in the middle of October when fresh water contributions have been at a minimum and reaches a value of 30.4 o/oo in August.

The surface water temperatures are coldest, 46.8°F (8.2°C), in February. The maximum surface temperatures are observed in August, with an average maximum of 57.6°F (14.2°C).

The dissolved oxygen content of the surface waters undergoes large changes because of phytoplankton activity. In some areas the oxygen content exceeds 29 mg/l, with values of 9 to 11 mg/l being common over the entire marine water area. The excessively high DO is patchy and rather isolated. The minimum surface values are observed in late fall and winter when the phytoplankton activity is at a minimum and may be as low as 5 mg/l. At depth, the dissolved oxygen content is more stable with the maximum of about 8 mg/l occurring in May and the minimum of about 5 mg/l in early fall.

SOURCES OF WASTE

The raw municipal and industrial wasteload generated in the Puyallup Basin approximates over three-quarters of a million population equivalents, of which about 20 percent is presently removed by waste treatment before being discharged to fresh and marine waters. The areas receiving the largest quantities of wastes in relation to the total basin include Commencement Bay (66 percent) and the Puyallup River (over 25 percent with tributaries excluded).

The quantities and general location of waste production and discharges in the basin are shown on Figure 8-3. Sources of wastes contributing to degradation of fresh and marine waters are summarized in Table 8-4. Upon completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, the strength of these wastes will be substantially reduced.

Fresh Water

At the present time, municipalities and industries are daily discharging wastes to rivers and streams equivalent to those from a population of about 270,000 persons. During the food processing season, an additional 42,000 PE are produced every day. Of the total wastes discharged to fresh water in the basin, 45 percent are generated by industry and 55 percent by municipal sources.

The various sources of waste along the Puyallup River and its tributaries produce about 301,500 PE of raw organic wastes daily. During the food processing season, an additional 39,000 PE are produced every day. About 2 percent of the raw wasteload receive secondary treatment; 90 percent receive primary treatment; and 8 percent of the total wastes are

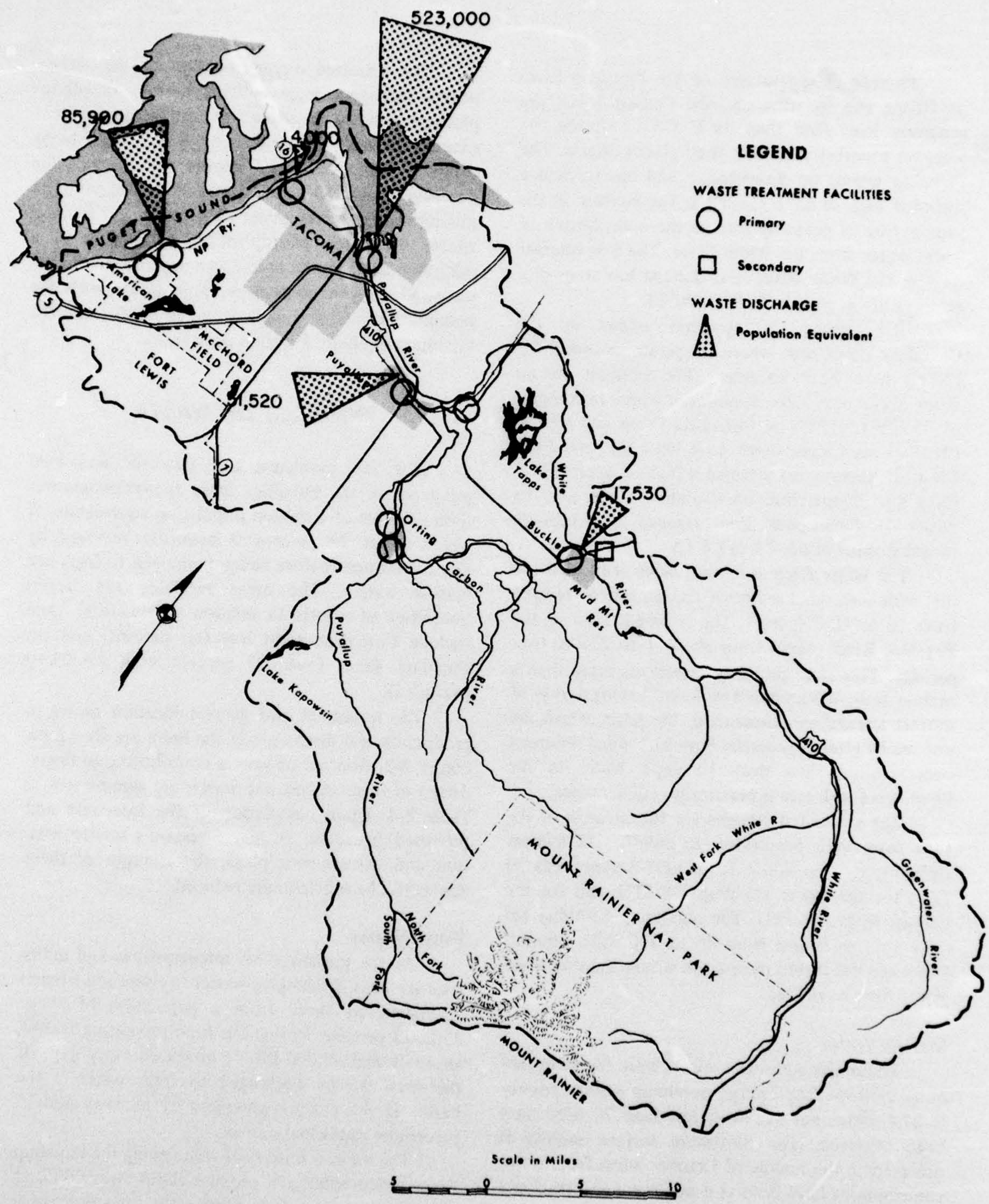


FIGURE 8-3. Location of major waste discharges

dumped into the river system untreated. After treatment of wastes, a total of 197,550 PE are still discharged daily into the Puyallup River system by cities and industries.

A major source of wastes to the Puyallup River originates from Tacoma's number one sewage treatment plant, which serves over two-thirds of the city's population and several industries and discharges 160,000 PE daily after primary treatment. This treatment plant is designed to provide primary treatment for an average flow of 13 million gallons per day. The dry weather flow to the plant often exceeds its hydraulic capacity, with the result that raw sewage is bypassed to the Puyallup River and hence into Commencement Bay. The city of Puyallup discharges 7,500 PE daily, with an additional 10,000 PE discharged daily during the food processing season. During the season, an additional 16,000 PE are discharged daily into the river by industry. Sumner's primary treatment discharges 2,400 PE daily and an extra 6,000 PE seasonally.

Other significant sources of waste are located along tributaries to the Puyallup River. Two industries–a paperboard mill and a food processing plant–discharge 9,500 PE daily into the White River without treatment. Boise Creek, a small tributary to the White River, is another center of wastes where the city of Enumclaw and a Weyerhaeuser lumber mill discharge daily a combined wasteload equivalent to 6,360 persons. Enumclaw accounts for 360 PE of this total, rendering secondary treatment to some 3,000 PE.

Commencement Bay receives 353,000 PE of wastes daily from Tacoma and its industries. The St. Regis Paper and Pulp Mill, located at the mouth of

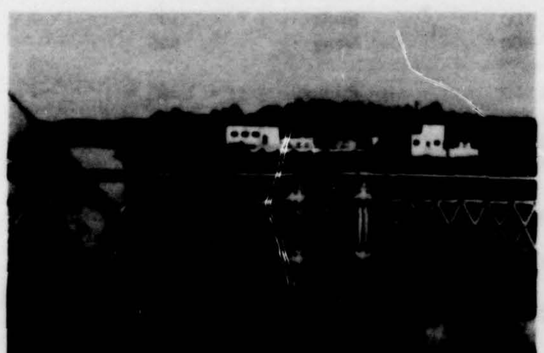


PHOTO 8-5. Tacoma's number one sewage treatment plant is a major source of waste to the lower Puyallup River.

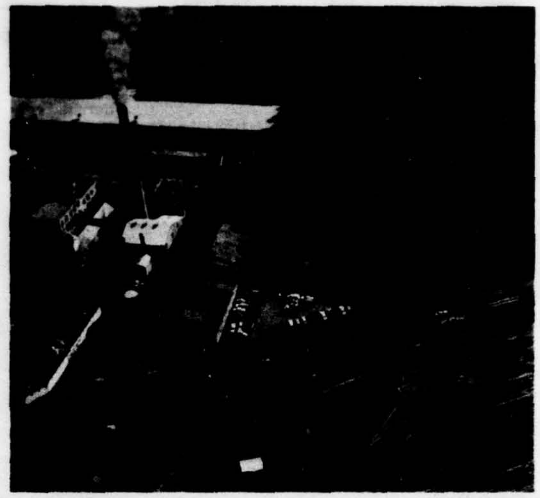


PHOTO 8-6. The West Tacoma Newsprint Company discharges the largest volume of wastes into Chambers Creek estuary.

the Puyallup River, discharges the largest volume of untreated wastes (294,000 PE) into the Bay. Other contributors of waste to Commencement Bay are a sewage plant (40,000 PE daily), several non-intercepted outfalls (10,000 PE daily, and the Container Corporation (7,000 PE daily)).

The Chambers Creek estuary receives a total daily wasteload of 33,100 PE. The West Tacoma Newsprint Company releases the largest volume of wastes into the estuary–31,000 PE daily. An air floatation system is utilized here to remove solids from the waste before discharge to the estuary. This pulp mill produces 220 tons (mechanical process) of groundwood pulp and newspaper print per day with an estimated total water use of approximately 4.5 mgd. Zinc hydro-sulfite is the chemical used primarily for bleaching. The concentration of wood sugars in the process water lends itself to, and enhances the growth, of various slime producing organisms.

The other main effluent discharged to the Chambers Creek tidal basin originates from the Steilacoom sewage system (4,000 PE daily), which includes wastes from the city and Western State Hospital.

Marine Water

About 400,000 PE of municipal and industrial wastes are being discharged into Commencement Bay, the Tacoma Narrows, and along Cormorant Passage

TABLE 8-4. Summary of municipal and industrial wastes, Puyallup Basin

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Puyallup River						
Orting	500	600	--	Primary	350	--
Washington Soldiers Home	150	150	--	Primary	120	--
Food processing	--	1,000	--	None	1,000	--
Puyallup	12,000	14,000	14,000	Primary	7,500	10,000
Food processing	--	--	16,000	None	--	16,000
Paper & allied	--	7,000	--	None	7,000	--
Tacoma STP No. 1.	160,000	250,000	--	Primary	160,000	--
Food & kindred	--	(63,600)	--	Tacoma	(40,000)	--
Carbon River						
Carbonado	425	500	--	None	500	--
Orting STP No. 2	500	600	--	Primary	400	--
White River						
Paper & allied	--	7,500	--	None	7,500	--
Food & kindred	--	2,000	--	None	2,000	--
Rainier St. School	2,000	2,500	--	Secondary	370	--
Buckley	1,800	2,000	--	Primary	1,300	--
Sumner	3,225	3,900	--	Primary	2,400	--
Food & kindred	--	750	--	None	750	--
Food & kindred	--	--	9,000	Sumner	--	6,000
Boise Creek						
Lumber & wood	--	6,000	--	Pond	6,000	--
Enumclaw	2,400	3,000	--	Secondary	360	--
Puget Sound—Commencement Bay						
Chambers Creek						
Flett Creek						
Food & kindred	--	1,900	--	None	1,900	--
Paper & allied	--	31,200	--	None	31,000	--
Steilacoom	5,000	6,000	--	Primary	4,000	--
Tacoma Western Slopes STP	5,048	6,000	--	Primary	4,000	--
Fort Lewis	50,000	70,000	--	Primary	45,000	--
Hylebos Creek & Waterway						
Naval Reserve Training Center	--	100	--	None	100	--
Food & kindred	--	500	--	None	500	--
City Waterway						
Lumber & wood	--	1,700	--	Primary	1,200	--
Food & kindred	--	1,300	--	None	1,300	--
Non-intercepted outfalls	--	10,000	--	None	10,000	--
North End STP	50,000	60,000	--	Primary	40,000	--
Port Industrial Waterway						
Food & kindred	--	3,600	5,000	None	3,600	5,000
Puyallup Waterway						
Paper & allied	--	294,000	--	None	294,000	--
Wapato Creek & Waterway						
Food & kindred	--	2,300	5,000	None	2,300	5,000
TOTAL[1,2]	293,000	790,000	49,000		636,000	42,000
Municipal	--	356,000	--		226,000	--
Industrial	--	434,000	49,000		410,000	42,000

1 Figures are rounded.

2 PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plans—1970-1972.

each day. Of these, 79 percent are produced by industry and 20 percent by municipal sources. About 30 percent of the total raw waste load receives primary treatment and the remainder is discharged to Puget Sound waters without treatment.

A sewage treatment plant, which services the western part of the Tacoma metropolitan area, discharges 4,000 PE daily into the strong currents of the Narrows. This plant is located between Point Defiance and Chambers Creek, just south of the Narrows bridge. It has a design capacity of 2 mgd, average dry weather flow.

The Fort Lewis sewage system, after primary treatment, discharges 45,000 PE daily into Cormorant Passage, which lies between Ketron Island and the mainland. This system serves not only the principal barracks area, but also all adjacent military facilities and the town of Dupont.

PHOTO 8-7. The Commencement Bay area receives the largest quantities of wastes—about two-thirds of the total generated in the basin.

WATER USES AND QUALITY OBJECTIVES

The beneficial uses of fresh and marine water in the Puyallup Basin are shown in Table 8-5 below. The table also contains State water quality classifications for each watercourse that in turn defines the type of water usage to be protected in the area.

Most waters in the basin are used for fish passage, spawning and rearing. The main stem and tributaries of the Puyallup, White, and Carbon Rivers, as well as the independent streams entering Puget Sound, are utilized by anadromous fish. On the upper Puyallup, however, fish passage is limited by an unladdered diversion dam. Anadromous fish found in the Puyallup drainage are chinook, coho, pink, and chum salmon; steelhead and searun cutthroat trout; and searun Dolly Varden.

Resident trout spawn throughout the Puyallup Basin above and below fish barriers. Rainbow trout are plentiful in most streams. Resident cutthroat and brook trout are found in many higher elevation streams and in most beaver dam impoundments.

The marine waters support a relatively light commercial fishery, with Commencement Bay designated as closed waters. A few gill net and purse seine vessels fish the area in the vicinity of Dumas Bay and Dash Point. Principal landing areas are in Seattle and Tacoma. The average annual contribution to Puget Sound and ocean fisheries is estimated to be 149,500 salmon.

Based on 1966 survey data, 383,300 man-days of effort were spent fishing in the lakes and ponds of the basin; and a total harvest of 1,109,100 trout and 610,000 other game fish was realized. In the streams, 106,500 man-days were spent with a harvest of over 366,000 trout.[1] More than 118,000 man-days were spent fishing for steelhead and searun cutthroat trout and 20,100 steelhead and 10,100 cutthroat trout were harvested.

Marine fish species receive only light commercial fishing effort. Herring make up a majority of the catch, and most fish are taken with beach seines and round haul nets from the Narrows area.

Shellfish harvest is principally by sportsmen. Squid are harvested commercially by otter trawl and herring gear mainly in the Tacoma Narrows area and are landed at ports from Tacoma to Blaine.

The Puyallup Basin ranks fourth among Puget Sound Area in total water-related outdoor recreation demand. In 1960, the number of water-related recreation days was 2,500,000. This future will double by 1980. Swimming, picnicking, camping, and fishing are the most popular activities.

The most notable outdoor recreation attraction is Mount Rainier National Park. Its glacier-wrapped slopes and alpine scenery draw people from all over

[1] Includes catch of all salmonids.

the nation and parts of the globe. Point Defiance Park, within the city limits of Tacoma, is an excellent large urban park. The shores and waters of the Tacoma Narrows afford exceptional opportunities for fishing and boating. There are presently 118 publicly administered developed recreation areas within the Puyallup Basin. In 1966, there were over 300,000 visits to these areas.

There is negligible use of surface waters by municipalities or industries in the basin. Tacoma obtains its water supply from the Green River and from wells.

Tacoma is the center of navigation in the basin. Its 1963 foreign and domestic coastwise traffic was over 3,000,000 tons. The 1963 domestic internal traffic was nearly 2,000,000 tons.

Fisheries and recreation uses require the highest water quality standards of all raw water uses and as a result, have set the minimum acceptable quality for most watercourses in the Puyallup Basin. Water quality class is excellent (A), with the objective being to meet or exceed the quality requirements for all uses. The only exceptions to this are the mouth of the Puyallup River (B) and the Port Industrial and City Waterways (C). The water quality class of AA was not assigned to the headwaters of the White or the Puyallup only because of the naturally high turbidity values found in those places.

TABLE 8-5. Water uses and quality objectives, Puyallup Basin

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[2]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Puyallup River, Mouth to River Mile 1	B			H	H								L			L	L						L	
Puyallup River, River Mile 1 to Limit of Tidal Influence	A			H	H								M			M	M						L	
Puyallup River, Tidal Influence to Orting	A[1]			H	H	H							H		L	M	M							
Puyallup River, Orting to Headwaters	A[1]			H	H	H							H		L	M	M							
White River, Confluence to Buckley	A[1]			H	H	M					L†		H		L	M	M							
White River, Buckley to Headwaters	A[1]			H	H	H							H		L	H	H							
Chambers Creek, Mouth to Limit of Tidal Influence	A			H	H											L	M					L	M	
Chambers Creek, Tidal Influence to Headwaters	A[1]			H	H	H							L			L	M							
Commencement Bay	A			H	H					L		L				L	H			L		H	H	
Inner Commencement Bay	B			H	H					L						M	L					M	H	
Port Industrial and City Waterways	C			L	L	L															L	M	M	
Puget Sound	A			H	H					M	H	H	L		L	H	H			M		H	M	

[1] Not presently classified. Equal to existing quality.

[2] See Table 1-5.

† Indian Fishery.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs occur primarily on marine waters and the lower reaches of the Puyallup River, where pulping, toxic, and municipal waste discharges have created generally unsatisfactory water quality conditions. The State-Federal Water Quality Standards for dissolved oxygen, bacteria, turbidity, aesthetics, and toxic or deleterious concentrations are not being met in the waters of Commencement Bay or in the Port industrial and city waterways. Standards for toxics are also not being met on the lower Puyallup River and lower Chambers Creek. Standards for bacteria are not being met on the lower Puyallup River.

The St. Regis pulp and paper mill, located at the mouth of the Puyallup River, is the major source of organic waste now discharged to Inner Commencement Bay. Municipal wastes discharged to the lower Puyallup River from the city of Tacoma are also significant to the water quality of this area. In addition, many large chemical companies and other industries which discharge toxic wastes to the bay waters are located in the industrial complex on Commencement Bay. Municipal, food processing, and some pulping wastes are discharged to the Puyallup and White River. Chambers Creek estuary receives wastes from West Tacoma Newsprint Company which impair water quality in this area.

High bacterial concentrations in the lower Puyallup River and Commencement Bay are most probably due to the municipal and industrial waste discharges from the Tacoma service area. Livestock wastes may also contribute to the bacterial count in the Puyallup and White Rivers.

FUTURE NEEDS

The principal factors expected to affect future fresh and marine water quality in the Puyallup Basin will be the growth in population, industry, agricultural production, and recreation. As this growth occurs, the production of wastes and potential water quality problems will likewise increase. Forecasts on the quantities and location of wastes are the basis for determining the means to preserve water quality and to protect the water uses of any given watercourse.

The 1967 population of 349,800 persons in the Puyallup Basin is projected to increase about 30 percent by 1980, 109 percent by 2000, and 335 percent by 2020. This substantial increase is expected to be centered primarily in the Tacoma service area and in the areas south and southwest of Tacoma. These areas are expected to grow at a faster rate than areas located further east of Tacoma up the Puyallup and White Rivers.

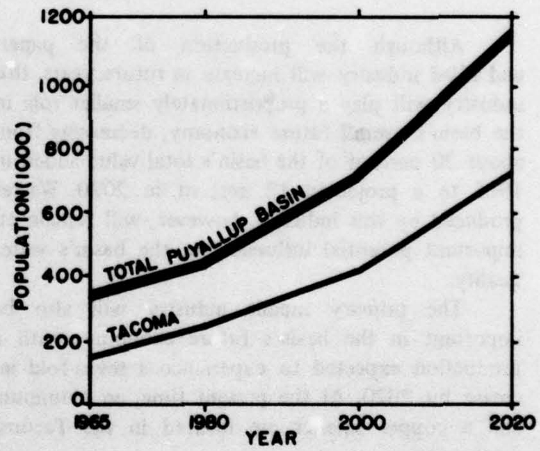


FIGURE 8-4. Population growth projection for Puyallup Basin.

Growth of production for the major water-using and waste-producing industries in the Puyallup Basin is expected to realize a 3.7-fold increase between 1980 and 2020 in terms of value added.

The food and kindred products and chemicals and petroleum industries have been rapidly increasing and are forecast to be very important segments of the basin's future economy. By 2020, food processing will account for 40 percent and chemicals and petroleum for about 30 percent of the total value added for the basin by the major water-using industries. Most of this growth is expected to occur in Tacoma, Puyallup, and Sumner.

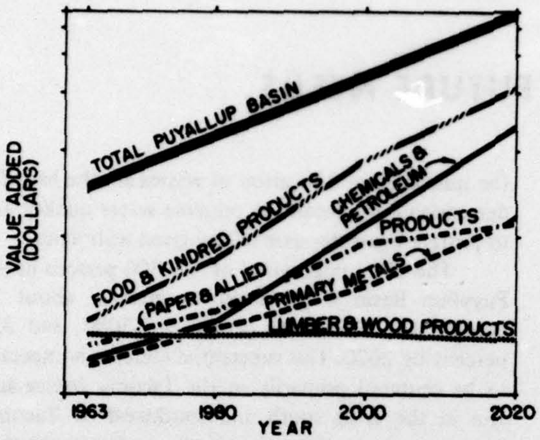


FIGURE 8-5. Relative growth for major water using industries in the Puyallup Basin.

Although the production of the paper and allied industry will increase in future years, this industry will play a proportionately smaller role in the basin's overall future economy, decreasing from about 20 percent of the basin's total value added in 1965 to a projected 12 percent in 2020. Wastes produced by this industry, however, will remain an important potential influence on the basin's water quality.

The primary metals industry will also be important in the basin's future economy, with a production expected to experience a seven-fold increase by 2020. At the present time, an aluminum and a copper smelter are located in the Tacoma service area.

By 1980, 12.6 million recreation days are projected for the basin–almost double the 1960 level. Most of the recreation will occur in the eastern portion of the basin around Mt. Rainier National Park.

As shown in Figure 8-6, the total raw organic wasteload is projected to equal 1,225,000 PE by 1980–about a 60 percent increase over present levels. Municipal waste production will become more significant, increasing from about 356,000 PE in 1965 to about 1,440,000 PE by 2020. Raw wastes from recreational activities are projected to increase about 55 percent by 1980. By 2020, this raw waste production is expected to be 5.4 times the present level.

Livestock wastes are a serious potential agricultural-based threat to the quality of water in the streams of the Puyallup Basin. In 1964 the basin had a cattle-plus-calf population of 29,260. During heavy winter rains, some of the waste from these animals may wash into the streams. The magnitude of this pollution threat will increase in future years. About one-third of the State's fryer chickens are concentrated here and contribute to the problem.

Although excessive irrigation can impair water quality by leaching or washing sediment and minerals into surface or ground waters, this is not a problem in this basin and is not expected to become a problem. The 1966 irrigated acreage was only 3,700 acres, and because of the rapidly expanding urban buildup in this area, irrigated acreage is not expected to expand to any significant degree.

Pesticides have become an almost indispensable land management tool of the farmer and forester. The amounts of these chemicals used in this basin is unknown, but no serious pollution problems are known to have occurred as a result of their use. With proper future use of these chemicals, water quality should not be degraded.

By 1980, more than 437,000 PE are expected to be produced by the paper and allied products industry; 189,000 PE by food processing plants; and 561,000 PE by municipalities. There will also be other types of wastes produced needing special handling methods. Greater wasteloads are predicted through 2020. Adequate management of these wastes generated in the basins will be a prime concern in order to protect the various water uses and to preserve the environment.

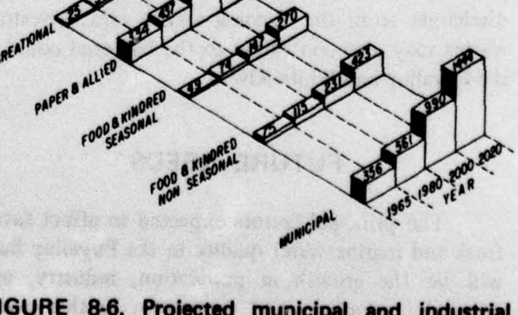


FIGURE 8-6. Projected municipal and industrial wastes for the Puyallup Basin (thousands of PE).

MEANS TO SATISFY NEEDS

Several elements are included in the overall plan for insuring adequate water quality in the Puyallup Basin. The most important aspect of this plan is adequate waste collection and treatment facilities. In this basin, most wastes are organic in nature and concentrated primarily in the Tacoma service area. In future years, toxic wastes will become more important, requiring special treatment methods. Adequate collection and treatment facilities will provide waste discharge amenable to acceptance by the water resources. The flow requirements for assimilation of the residual wastes, both now and in future years, are relatively small when compared with present minimum flows.

Water quality management measures required in support of the treatment construction includes water quality surveillance stations located on Commencement Bay, on Puget Sound west of Tacoma and Steilacoom, and on the lower Puyallup River. Present management procedures for control of pesticides in agricultural and forest operations will meet future water quality protection requirements. The major aspects of the plan for control of basin water quality are discussed in detail below.

WASTE COLLECTION AND TREATMENT

Water quality degradation existing in Commencement Bay and and other areas of the Puyallup Basin is largely due to inadequately treated municipal and industrial wastes. The separate actions required to meet these needs are detailed in the Water Quality Standards and Implementation Plan, December, 1967. These requirements as well as additional requirements for areas not covered by the interstate standards are summarized below:

Puyallup-White Rivers

1. **Cities of Buckley, Sumner, and Puyallup**–secondary treatment and disinfection facilities for collected wastes.
2. **Cities of Carbonado, Orting, Wilkeson, Bonney Lake, Algona, and Pacific**–sewerage systems with secondary treatment and disinfection of collected wastes.
3. **Food processing plants**–located along the rivers–adequate secondary treatment or interception by a municipal system.
4. **City of Tacoma**–secondary treatment[1] disinfection and adequate outfall facilities and provide for collection and treatment of unintercepted waste discharges.

Commencement Bay

1. **St. Regis Paper Company**–secondary treatment[1] and an adequate outfall.
2. **Industries located on Commencement Bay**–which produce toxic wastes–adequate treatment prior to effluent disposal to the Bay.

Chambers Creek–Puget Sound

1. **West Tacoma Newsprint**–secondary treatment[1] and an adequate outfall.
2. **Fort Lewis**–secondary treatment,[1]–disinfection and an adequate outfall.

Substantial future population and industrial growth is projected for this basin. Most of the growth will occur near the marine waters from Fort Lewis to north of Tacoma. The probable future collection and treatment system for this basin is outlined below.

Future wastes from the Fort Lewis area can be collected and conveyed to treatment plants along Puget Sound.

The area between Fort Lewis and Tacoma, which includes the cities of Lakewood and Parkland, is experiencing very rapid growth. At the present time, this area is not adequately sewered. Wastes generated in this area could be collected and provided secondary treat-

[1] Secondary treatment is required unless it can be shown that a lesser degree of treatment will provide for protection of present and future water uses and the preservation or enhancement of existing water quality.

ment with effluent disposal to Puget Sound.

The cities of Puyallup and Sumner will grow substantially. Wastes generated in this area could possibly be treated by one plant with disposal to the Puyallup River.

The towns of Buckley, South Prairie, Wilkeson, Carbonado, and Orting are expected to retain a more rural character, with wastes treated at each location.

Rapid build-up is occurring around Lake Tapps and Bonney Lake. Wastes generated in this area will need to be collected and adequately treated. Treated effluent should not be discharged to the lake. Wastes produced in this area may possibly be conveyed to Sumner.

The towns of Algona and Pacific are situated very close to the basin boundary, northeast of Lake Tapps. This area is expected to be served by METRO facilities through the city of Auburn.

Future wastes generated in the area north of Tacoma which drains to Puget Sound, can be collected and conveyed to treatment plants along the Sound with disposal of effluent to Puget Sound through adequate outfalls.

Considerable investment will be required to meet the present and future waste collection and treatment requirements.

The estimated investment requirements are presented in Tables 8-6, 8-7 and Figure 8-7. Present requirements are large, reflecting the costs associated with compliance with the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans and the result of the generally slower investment rate in previous years. Following the higher initial investment, annual costs reflect the amount required to keep pace with urban and industrial growth and replacement of facilities.

Municipal investment requirements[1] for collection and treatment systems will total $26,000,000 by 1980 with an additional $41,600,000 needed by 2000 and an additional $58,800,000 by 2020.

Cost of sewers will average about 60 percent of the total municipal costs.

The paper and allied products and food and kindred products industries account for more than 90 percent of the present industrial treatment cost requirements[1] and are expected to account for about

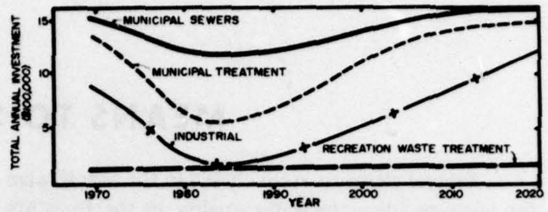


FIGURE 8-7. Relative required rates of investment for waste collection and treatment in the Puyallup Basin.

75-85 percent of the future industrial treatment costs. A total of $5,600,000 is needed by 1980, $7,200,000 from 1980-2000, and $18,400,000 more by 2020.

Sources of funding for treatment facilities are shown in Figure 8-8. The Federal Construction Grants Program should invest over $5,400,000 by 1980; $8,220,000 will be needed by 2000, and an additional $12,000,000 by 2020. State grants will total $2,700,000 by 1980 with an additional $4,110,000 by 2000 and another $5,400,000 by 2020.

The Federal investment in sewers will total nearly $2,000,000 by 1980 with an additional $5,850,000 by 2000 and another $10,300,000 by 2020. The Federal investment in waste collection and treatment facilities for recreation areas will total $1,800,000 by 1980, with an additional $4,800,000 needed by the year 2020.

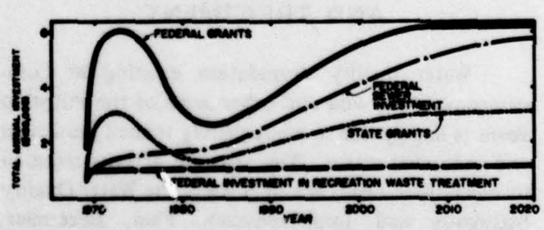


FIGURE 8-8. Government investment requirements for waste collection and treatment in the Puyallup Basin.

FLOW REQUIREMENTS

With the installation of adequate waste treatment facilities in conformance with State Standards and in-plant controls, future waste discharges to the

[1] Costs are not amortized.

TABLE 8-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Puyallup Basin

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 404	$ 295	$ 194
Disinfection	67	49	32
Outfalls	404	295	194
Interception and sewer system			
a. Municipal	202	148	97
b. Industrial	67	49	32
Combined sewage infiltration and overflow correction	202	148	97
Advanced waste treatment in recreation areas	78	125	200
Sub-Total	$1,424	$1,109	$ 846
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 90	$ 80	$ 90
Evaluations—dispersion areas, ecological, productivity	90	70	90
Information system, quality control, plant operation improvement, operation research	80	60	80
Sub-Total	$ 260	$ 210	$ 260
OPERATION AND MAINTENANCE[2]	$ 800	$2,340	$2,130
TOTALS	$2,484	$3,659	$3,236

1 Annual amortized costs.

2 Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

waters of the Puyallup Basin will be reduced to less than present levels.

Based on the waste discharge projections for the Puyallup and White Rivers, the minimum flows required in the Puyallup River near Puyallup have been determined to be 105, 245, and 270 cfs for the years 1980, 2000, and 2020, respectively. Minimum flows required in the White River for maintenance of adequate water quality have been determined to be 45, 120, and 135 cfs for the years 1980, 2000, and 2020, respectively. In the lower Puyallup River near Tacoma, the required minimum flows are 140 cfs by 1980, 210 cfs by 2000, and 240 cfs by the year 2020. The 7-day low flows expected to occur once in 10 years for the Puyallup River near Puyallup and the White River near Buckley are 910 cfs and 340 cfs, respectively.

TABLE 8-7. Total amortized capital and operational costs, Puyallup Basin

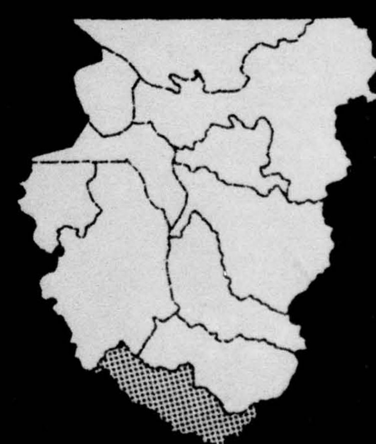
	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	11.1	6.9	7.5
Municipal treatment	21.1	16.0	9.6
Municipal sewers	63.2	48.0	28.7
Recreation	3.6	2.3	1.0
Advanced waste treatment	3.9	6.3	10.0
Sub-Total	102.9	79.5	56.8
Water quality engineering management and evaluation	2.9	4.2	5.2
Operation and maintenance	8.8	46.8	42.6
Total	114.6	130.5	104.6

OTHER MEASURES

Adequate water quality monitoring is an essential element for the water quality program in this area. The existing surveillance program on fresh and marine waters should be continued. Additional stations for the Puyallup River and Chambers Creek should be established.

Although coal mining in the Wilkeson-Carbonado area in recent years has been minimal, plans have been made to export 200,000 tons per year of coking coal to Japan, which will increase coal mining activity in this area. Without exercise of proper controls, intensified mining operations could have an adverse effect on water quality. In addition, stations to monitor lakes and ground water also should be established.

Nisqually-Deschutes Basins



NISQUALLY - DESCHUTES BASINS

INTRODUCTION

This basin, about 70 miles long, encompasses 1,044 square miles of area lying primarily in Thurston County. The Nisqually-Deschutes area is predominantly a drift-covered glacial plain rimmed on the west by many narrow inlets of Puget Sound and on the east by the Cascade foothills and Mt. Rainier. The area is drained by the Nisqually and Deschutes Rivers which flow directly into Puget Sound. The Nisqually River is fed by glaciers on the south side of Mt. Rainier. It flows in a northwesterly direction for over 80 miles and enters Puget Sound at Nisqually Flats about 10 miles northeast of Olympia. The Deschutes River heads in the hills southeast of Yelm, flows 35 miles across benchlands and prairies, and empties into Budd Inlet, the most southerly arm of Puget Sound at Olympia.

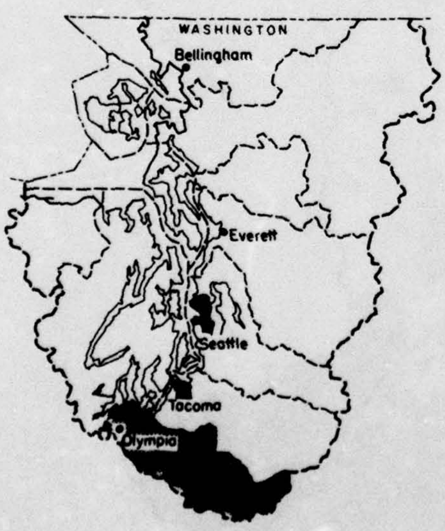


FIGURE 9-1. Location of the basins.

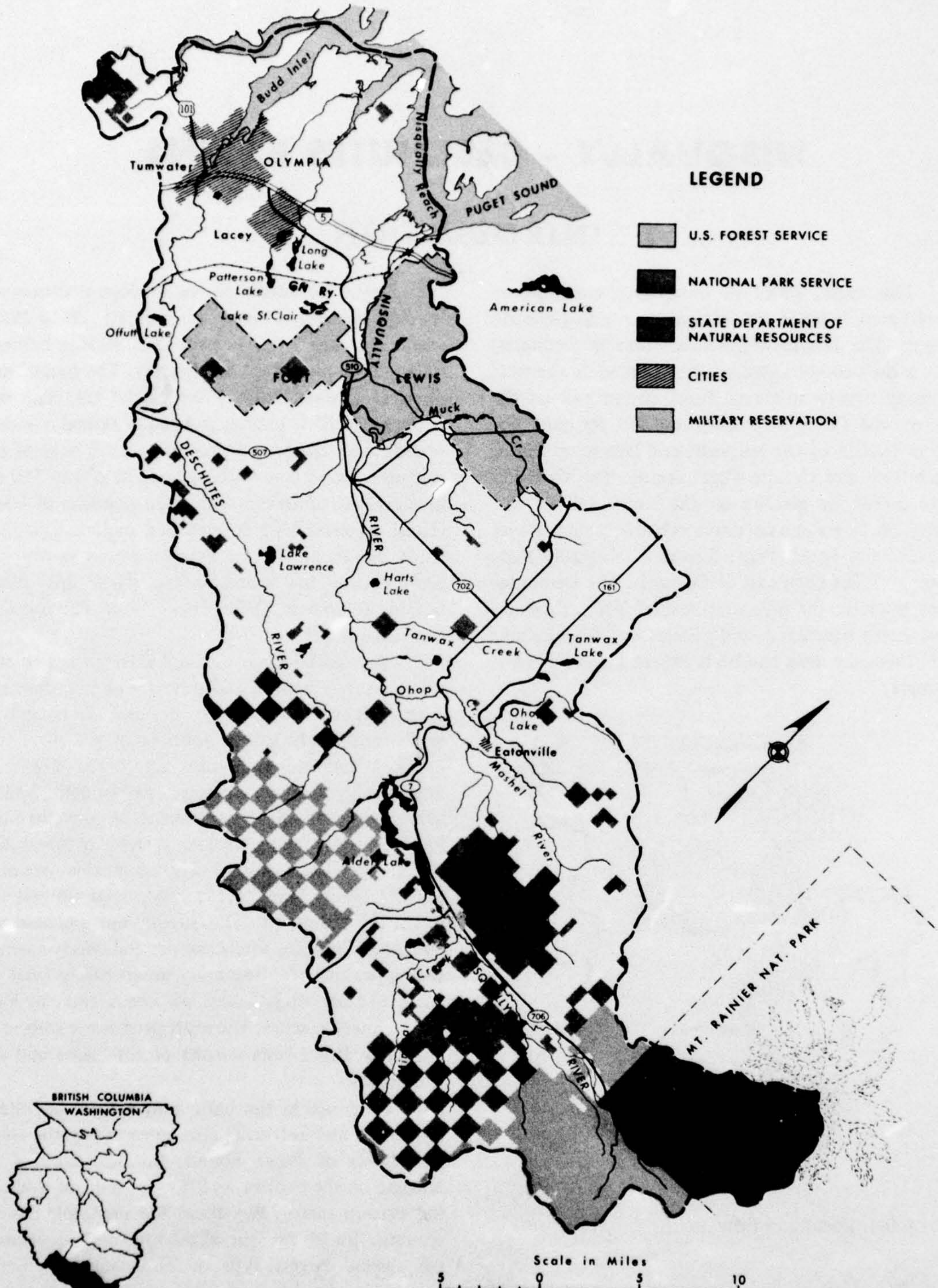
The marine water area covers a surface of 10,000 acres in the southernmost tip of Puget Sound. Its landforms and waterbodies include: Nisqually Reach, Johnson Point, Henderson Inlet, Dana Passage, Budd Inlet and Eld Inlet.

Major ice sheets of the geological Pleistocene Ice Age lay stagnant over this area 10,000 to 25,000 years ago. The ice sheets receded, leaving behind a rolling and lake-dotted topography. The basins' main physical characteristic is the glacial till plain with large areas of flat prairies and gently-sloped moraines, several large lakes, and numerous small bogs of clay and peat. Important flatland areas of 200 to 500 feet in elevation underlain with deep deposits of coarse glacial material were formed and include Chambers, Ruth, Smith and Yelm Prairies. Some rather large lakes occupy low places in the glacial drift plain—notably Chambers, Offut, Hicks, Long, Patterson and Lawrence Lakes.

The glacial plain is dominantly glacial ablation till and outwash sands and gravels. The soils consist of deep, somewhat excessively drained sands, gravelly sands, and sandy loams. An area of the plain lying between the Nisqually and Deschutes Rivers has developed soils under a prairie environment. Soils on other parts of the plain consist of gravelly sandy loams, gravelly loams, silt loams, and clay loams 20 to 40 inches deep over slowly permeable cemented gravelly sandy loam, sandy clay, basal till and silty lacustrine sediments. The stream bottom land soils consist of gravelly sands, sands, and sandy loams in the upper reaches, becoming progressively finer textured to finer sandy loams, silt loams, and clay loams in the lower reaches. The most productive soils in the Nisqually River delta consist of silt loams and silty clay loams.

Land use in the basin ranges from an intense residential and industrial area surrounding the southern shores of Puget Sound, through dairying and farming on the prairies, to heavy growths of timber in the eastern sector. Woodland use predominates and accounts for 85 percent of the total area. Cropland is the second largest type of land use, concentrated chiefly in the lowlands and prairies, and devoted mainly to feed crops to support the dairy and livestock industry. About 64 percent of the basins' total land area is held in private ownership.

Approximately 70,100 people (1967 estimate)



NISQUALLY -DESCHUTES BASINS

Figure 9-2 Land Ownership

live within the Nisqually-Deschutes Basins. The city of Olympia, with a 1967 population of 20,880, is the State Capitol and county seat of Thurston County. The city is a deep seaport and has grown from a pioneer settlement in 1846 to the commercial, trading, and shopping center for southwestern Washington. It is, today, the focal point of progress for the basins. Two satellite communities–Lacey and Tumwater–have populations of 7,650 and 4,698 respectively. Smaller towns in the farming areas such as Yelm and Rainier, have populations of less than 600 persons.

Lumbering and the production of forest products have always been the basins' economic mainstays. While mining, farming and fishing were early industries that helped shape the economy here, today other commodities such as metalcraft, can manufacturing, boat building, cold storage, and meat packing are of marked importance and give the area a diversified commercial base.

The Port of Olympia comprises over 72 acres, mostly around the shore of Budd Inlet. It is equipped to handle any cargo from both ocean vessels and local water freight. Industrial plants have long occupied approximately half of the port property. The West Bay terminal presently serves as an export log receiving, handling and rafting site. Beyond Budd Inlet, the Olympia Harbor accommodates a reserve fleet of over 100 merchant ships of the U. S. Maritime Administration.

Farms within the basins are intensively managed to produce products of high value. Livestock raising is the most common and valuable farm industry. Additionally, dairying, berry growing, and poultry raising play an important part in the economic welfare of the area.

PHOTO 9-1. Mouth of the Deschutes River, with the State Capital, Port of Olympia, and Budd Inlet in the background.

With Olympia being the State Capitol, government is the leading employer in Thurston County, accounting for almost 36 percent of the total employment in 1963. Between 1950 and 1960, government employment increased 28.7 percent in the United States, 13.1 percent in Washington, and 46.6 percent in Thurston County. The manufacturing sector plays a leading role, but increases in employment have been only gradual–2.7 percent in the 1950-1960 decade and 3.10 percent in the 1954-1964 decade.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The natural flow of the Nisqually River is affected by irrigation diversions and regulation at Alder and LaGrande reservoirs. Adjusted flows for the river near McKenna indicate a mean annual discharge of 1,758 cfs during the 30-year period 1931-1960. The maximum discharge (2,540 cfs) occurred in 1956 and was 144 percent of the 1931-1960 mean. The minimum runoff occurred in 1944 and was only 59 percent of the longterm 30-year mean. Another gaging station on the Nisqually near National measures approximately 19 percent of the runoff from this basin. During a 23-year period–1942-1965–the mean annual discharge was 778 cfs. The extreme high and low flows recorded were 11,000 cfs and 108 cfs, respectively.

The Deschutes River drains a relatively narrow, poorly-defined basin in the southern lowlands. A gaging station near Olympia measures about 99 percent of the runoff from the river. The mean annual runoff was 390 cfs for the adjusted period of record. Since 1946, when record collection began at this station, the maximum discharge recorded was 6,650 cfs and the minimum was 66 cfs. The gage at Rainier on the upper headwaters of the Deschutes has recorded a mean annual discharge of 267 cfs based on a period of record from June, 1949 to September, 1965.

PHOTO 9-2. The Deschutes River as it flows through Tumwater.

The natural runoff pattern of the Nisqually River consists of two distinct peak periods each year: One from abundant winter precipitation falling mainly in the form of rain at lower elevations, and a second during the spring from the melting of accumulated snowpacks in the high country. The low-flow period occurs in late summer, but large quantities of glacial meltwater from the slopes of Mt. Rainier augment the flows during the warm months. The summer base flow is usually about 400 cfs.

Deschutes River runoff displays the same pattern as other rain-fed streams of the Puget Sound. A period of high flows occurs during the winter months. Minimum flows occur during the months of August and September, contributed primarily from ground water discharges. The summer base flow of this stream is about 100 cfs.

A low-flow frequency analysis has been made by the U. S. Geological Survey for 13 gaging stations in the basins on an 18-year period from April 1, 1946 to March 31, 1964. The 7-day and 30-day flows that may be expected to occur at four of these stations for a recurrence interval of 10 years are shown in Table 9-1.

TABLE 9-1. Low flow frequency, 10–Year recurrence interval, Nisqually and Deschutes Basins

Station	7–Day Low Flow cfs	30–Day Low Flow cfs
Deschutes River near Olympia	80.0	83.0
Woodland Creek near Olympia	8.8	9.7
Nisqually River near National	178.0	213.0
Nisqually River near McKenna	405.0	500.0

Source: Appendix III: Hydrology & Natural Environment.

Two reservoirs exist in the basins. Both are located on the Nisqually River and are operated by the city of Tacoma for power generation. The Alder Reservoir has 232,000 acre-feet of storage. Immediately downstream from Alder Dam is LaGrande Reservoir with 2,700 acre-feet. No significant upstream storage exists on the Deschutes River. Some storage near the mouth is provided by Capitol Lake which was developed primarily for recreational purposes.

Coarse zones of Quaternary sedimentary deposits are the important lowland aquifers. These sediments are mostly alluvium, recessional outwash, and basal till. Alluvium is one of the most productive ground water aquifers in the basins. It occurs mainly on the flood plain of the Nisqually River and, to a lesser extent, on the Deschutes flood plain.

Most of the lowlands are covered with recessional outwash composed primarily of coarse sand and gravel, with minor amounts of clay and silt. Where favorably situated, moderate to large supplies of water can be withdrawn from these materials. The recessional outwash is a productive aquifer in the basins, but it is susceptible to contamination in areas of extensive development, owing to its stratigraphic position.

Practically all recharge to aquifers in the lowlands is by infiltration of precipitation. These aquifers may receive about 200,000 acre-feet of recharge in an average year.

Marine Water

The marine waters in these basins include the Nisqually Reach, and Henderson, Budd and Eld

Inlets. Maximum depths are about 200 feet.

The Tacoma Narrows is a major mixing zone in which complete top to bottom mixing occurs during most of the tide cycle. All the marine waters in these basins enter through this zone. On flood tides, strong turbulence extends from the Narrows through the Nisqually reach. The result of the mixing is vertically homogeneous marine waters throughout most of the basin.

WATER QUALITY

Fresh Water

Water quality of the Nisqually and Deschutes Rivers has been measured since July 1959. Water quality data as measured by a number of parameters are presented in Table 9-2.

The following discussion of water quality in the basins is based upon the above data gathered from three monitoring stations.

Chemical—The chemical quality of the Nisqually and Deschutes Rivers is low in hardness, low in dissolved solids, and high in dissolved oxygen concentrations. Both streams, however, contain iron in significant amounts. Iron concentrations in the Nisqually River average 48 mg/1, with a maximum of 4.40 mg/1 being recorded. Surface water in the headwaters of the Deschutes River near Rainier is low in iron, but downstream near the outlet at Tumwater, iron concentrations are higher, averaging 3.6 mg/1.

Phosphate values in both streams are similar in occurrence and magnitude, with maximum values less than 0.20 mg/l. The Deschutes River water quality stations at Tumwater and near Rainier do not indicate any increase in phosphates between the upstream and downstream station. The Deschutes River at Tumwater, however, shows a higher nitrate value than the upstream station near Rainier, with maximum value of 0.40 mg/l.

Water in most ground-water acquifers is generally low in dissolved solids, usually less than 150 mg/1. Hardness of the water is generally less than 60 mg/1. Silica is usually in the 20-40 mg/1 range. Objectionable concentrations of iron occur locally, primarily in shallow aquifers that underlie the Nisqually flood plain. More highly mineralized ground water is common near Puget Sound, where freshwater aquifers contain traces of sea water.

Bacteriological—The impact of drainage and land use downstream from Rainier on the Deschutes River is evidenced by the fact that 50 percent of the samples taken at Tumwater exceeded 240 MPN, 21 percent exceeded 1,000 MPN, and 14 percent exceeded 2,400 MPN, as opposed to 14 percent of samples at Rainier being in the 240-1,000 MPN range, and 86 percent being in the less-than-240 MPN range. Table 9-3 summarizes coliform concentrations obtained from basic data sampling.

Physical—Stream-borne sediment is excessive in the Nisqually River. During periods of glacial melt, this river runs turbid and sediment-laden. The suspended-sediment concentration above Alder Lake probably ranges from about 1 to 60,000 mg/l, with

TABLE 9-2. Surface water quality, Nisqually-Deschutes Basins

		mg/l												mg/l									mg/l		mg/l		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
											DESCHUTES RIVER NEAR RAINIER										JULY 1959 THROUGH AUGUST 1962						
Maximum	744	91	12.0	3.2	7.4	0.9	54	0	3.4	12.0	0.1	0.7	131	0.13	...	23.0	0.48	0.02	7.7	25	5	17.2	11.9	106	43	1	930
Mean	...	67	9.0	2.1	5.1	0.5	40	0	2.0	5.8	0.1	0.4	88	0.05	...	19.1	0.17	0.01	...	...	...	10.2	10.5	96	31	0	170
Minimum	38	46	5.5	1.0	3.1	0.2	27	0	1.0	2.0	0.0	0.1	55	0.00	...	16.0	0.03	0.00	6.9	5	0	5.9	8.0	68	19	0	0
Number	21	21	21	21	21	21	21	8	21	21	21	21	21	21	...	21	21	4	21	21	4	21	21	21	21	21	21
											DESCHUTES RIVER AT TUMWATER										OCTOBER 1962 THROUGH PRESENT						
Maximum	1,750	89	12.0	3.8	7.1	1.2	52	0	3.8	11.0	0.1	1.6	122	0.12	...	25.0	0.88	0.03	7.8	20	30	20.1	11.7	118	46	3	2,400
Mean	...	74	9.0	2.7	5.5	0.9	41	0	3.2	6.6	0.1	1.1	95	0.07	...	20.7	0.36	0.01	...	...	...	10.1	10.7	97	34	1	646
Minimum	175	54	5.5	1.7	3.8	0.4	25	0	2.2	2.5	0.0	0.6	59	0.00	...	16.0	0.16	0.00	6.6	5	0	4.0	8.7	88	20	0	0
Number	6	15	15	15	15	15	15	15	15	15	15	15	15	12	...	15	11	6	15	15	10	16	16	16	15	15	16
											NISQUALLY RIVER NEAR MCKENNA										FEBRUARY 1955 THROUGH SEPTEMBER 1955						
Maximum	3,390	48	4.8	1.2	3.0	0.7	24	...	2.5	1.5	0.2	1.2	49	...	...	14.0	0.11	0.05	7.2	30	...	...	...	...	17	0	...
Mean	...	48	4.8	1.1	2.9	0.6	23	...	2.3	1.3	0.1	0.7	49	...	...	12.0	0.06	0.05	...	...	...	...	...	...	17	0	...
Minimum	968	47	4.8	1.0	2.8	0.6	22	...	2.1	1.0	0.1	0.2	48	...	...	10.0	0.02	0.05	7.1	0	...	...	...	...	16	0	...
Number	2	2	2	2	2	2	2	...	2	2	2	2	2	...	...	2	2	2	2	2	...	...	...	...	2	2	...
											NISQUALLY RIVER AT MCKENNA										JULY 1959 THROUGH PRESENT						
Maximum	4,160	61	7.5	2.4	4.2	1.3	41	0	5.2	2.8	0.3	0.9	79	0.19	...	22.0	4.40	0.08	7.5	25	25	20.0	12.8	117	28	0	2,400
Mean	...	47	5.7	1.4	3.1	0.6	27	0	2.6	1.6	0.1	0.3	55	0.04	...	14.8	0.48	0.02	...	...	...	9.5	11.2	101	20	0	247
Minimum	50	37	3.5	0.8	2.3	0.3	18	0	1.4	0.0	0.0	0.0	37	0.00	...	12.0	0.09	0.00	6.2	0	0	4.8	8.6	90	12	0	0
Number	29	37	37	37	37	37	37	24	37	37	37	37	37	33	...	37	32	11	37	37	16	37	37	36	37	37	37

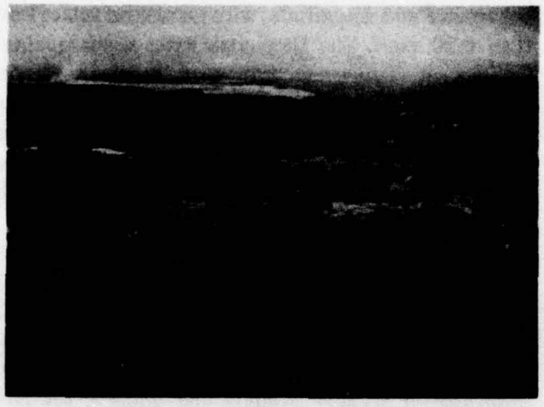


PHOTO 9-3. Nisqually Flats result from the deposition of the substantial sediment loads in the Nisqually River.

most of it being deposited in the lake. Sediment data obtained at McKenna during 1965 and 1966 indicate that a suspended-sediment load of 250,000 to 300,000 tons may be transported by the river during a year of normal runoff.

Similar data for the Deschutes River near East Olympia indicate that the river may transport an average suspended-sediment load of 30,000 tons annually. Excessive erosion is precluded by the heavy cover of vegetation.

Turbidity measurements on both streams have been comparably low. This is surprising in view of the fact that the Nisqually River originates in glaciers and contains substantial amounts of glacial melt water at times. Apparently, resident time in Alder Reservoir allows much of the suspended material to settle.

Marine Water

A minimum salinity of 28 o/oo usually occurs at all depths during the winter. During the summer the salinity increases to about 29.5 o/oo, and the temperature of the surface waters increases to about 60.8°F (16°C) those at depth to over 57.2°F (14°C). The oxygen content of these waters is usually above 6 mg/l at all depths. The surface oxygen content is affected by biological conditions, especially during the spring phytoplankton bloom. Also, the phosphate content of the water is between 0.14 and 0.23 mg/l throughout most of the year, and is also subject to changes by biological activity.

SOURCES OF WASTE

The raw municipal and industrial wasteload generated in the Nisqually-Deschutes Basins totals about 120,888 PE, of which about 20 percent is presently removed by waste treatment before being discharged to fresh and marine waters. The area receiving the largest quantity of waste in relation to the total basin is Budd Inlet (99 percent).

The quantities and general location of waste production and discharges in the basins are shown on Figure 9-3. Sources of wastes contributing to the degradation of fresh and marine waters are summarized in Table 9-4. Upon completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, the strength of discharged wastes will be substantially reduced from present discharges.

Fresh Water

Only one waste discharge to fresh water exists in the basins. The small town of Eatonville discharges 100 PE daily to the Mashel River, a tributary to the Nisqually River.

Marine Water

Cities and industries located on Budd and Henderson Inlets produce 117,900 PE. Less than 1

TABLE 9-3. Summary of coliform concentrations, Nisqually–Deschutes Basin

Station	Less than 240 No. of Samples	Less than 240 % of Total No.	240-1,000 No. of Samples	240-1,000 % of Total No.	1,000-2,400 No. of Samples	1,000-2,400 % of Total No.	Greater than 2,400 No. of Samples	Greater than 2,400 % of Total No.
	MPN/100 mls							
Deschutes (nr Rainier)	18	86	3	14	0	0	0	0
Deschutes (at Tumwater)	7	50	4	29	1	7	2	14
Nisqually (at McKenna)	30	86	3	9	1	3	1	3

Source: Washington Water Pollution Control Commission

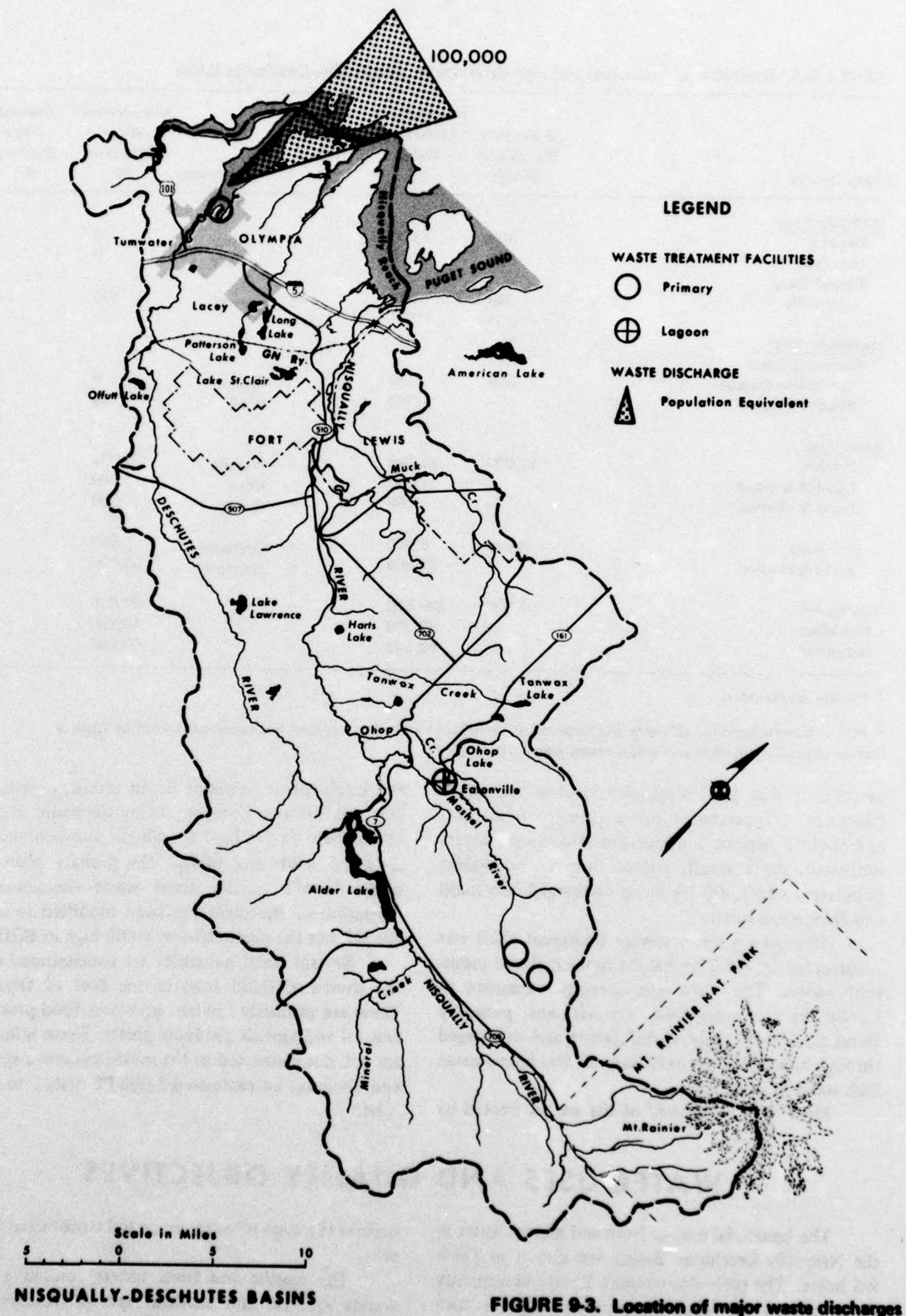


FIGURE 9-3. Location of major waste discharges

TABLE 9-4. Summary of municipal and industrial wastes, Nisqually—Deschutes Basin

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Nisqually River						
Paradise	800	1,000	--	Primary	0	--
Longmire	800	1,000	--	Primary	0	--
Mashell River						
Eatonville	700	900	--	Lagoon	100	--
Henderson Inlet						
Woodland Creek						
St. Martins College	300	350	--	Lagoon	0	--
Food & kindred	--	200	--	None	200	--
Budd Inlet						
Olympia	22,000	49,000	--	Primary	34,500	--
Lumber & wood	--	1,400	--	None	1,400	--
Food & kindred	--	900	--	None	900	--
Tumwater	4,000	6,000	--	Olympia	5,500	--
Food & kindred	--	60,000	--	Olympia	55,000	--
TOTAL[1,2]	28,600	120,800	--		97,600	--
Municipal	--	58,300	--		40,100	--
Industrial	--	62,500	--		57,500	--

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plans—1970-1972.

percent of this total wasteload receives secondary treatment; 97 percent receives primary treatment; and about 2 percent is discharged into marine waters untreated. As a result, wastes from an equivalent population of 97,600 are being discharged into Budd and Henderson Inlets.

Olympia's primary sewage treatment plant was constructed in 1952 to handle municipal and industrial wastes. The plant was recently expanded to handle the increasing load. The effluent, presently about 95,000 PE daily, is disinfected and discharged through an outfall approximately 27 feet below mean high water in Budd Inlet.

More than two-thirds of the wastes treated by the city's plant originate from industry, with the Olympia Brewing Company being the major contributor. Their wastes have a high pH and contain high dissolved solids and BOD_5. The primary plant normally doesn't modify these waste characteristics. Operation of the plant has been modified to adjust the pH, but the plant effluent is still high in BOD.

Several small industries are concentrated along the shores of Budd Inlet in the Port of Olympia. These are primarily lumber, plywood, food products, and oil and asphalt products plants. These industries are still not connected to the municipal sewer system, and discharge an extimated 5,000 PE daily into Budd Inlet.

WATER USES AND QUALITY OBJECTIVES

The beneficial uses of fresh and marine water in the Nisqually-Deschutes Basins are shown in Table 9-5 below. The table also contains State water quality classifications for each watercourse that in turn defines the type of water usage to be protected in the area.

The marine and fresh waters contain a wide variety of fish and shellfish species. Anadromous

TABLE 9-5. Water uses and quality objectives, Nisqually-Deschutes Basin

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[2]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
South Puget Sound west of Brisco Pt. and north tip of Harstene Is.	A			H	H					M		H	L			M	L					M	H	
Budd Inlet	B			H	H					M		M	L			M	L					M	H	
Dischutes River	A[1]			H	H	H							M		L	M	M†		L					
Nisqually River, mouth to River Mile 9	A[1]			H	H	H										M	M		L	L	L			
Nisqually River, River Mile 9 to Headwaters	AA[1]			H	H	H							M			M†	M†		L	L	L			H

[1] Not presently classified. Equal to existing quality.

[2] See Table 1-5.

fishes inhabiting the basins are chinook, coho, pink and chum salmon and steelhead and searun cutthroat trout. Marine fish include species of cod, surfperch, flounder, sole, herring, and rockfish. Shellfish species include red crab; Pacific, native, and Kumamoto oysters; Manila, littleneck, butter, horse, and softshell clams; geoducks; cockles; piddocks; blue mussels; and spot and pink shrimp.

Sport angling is very popular here. The marine waters from the mouths of the rivers to Johnson Point, Cooper Point, and Anderson Island are among the most popular in southern Puget Sound where, in 1965, nearly 135,000 angler-days were recorded. Freshwater salmon angling occurs in the mainstem Nisqually River downstream from State Highway 507 (McKenna Bridge), in Capitol Lake, and in the Deschutes River proper, upstream from the old Highway "99" bridge. On the basis of 1966 data, 358,700 man-days of effort were spent fishing in the lakes, ponds, and reservoirs; and a total harvest of 1,224,400 trout and 550,600 other game fish was realized. In the streams, 83,800 man-days were spent with a harvest of almost 314,000 trout. About 41,800 man-days were expended in pursuit of steelhead and searun cutthroat trout and 5,000 steelhead and 10,100 cutthroat trout were harvested.

Spear fishing interest is growing rapidly in the area, due mainly to the relatively clean marine waters. Sport harvest of shellfish is conducted on a few public access areas on Nisqually Flats and on beach areas west and north of this area, as well as in estuarine and beach areas at Johnson and Cooper Points.

There is very little commercial harvest of marine bottomfish species and the basins' marine waters are closed to commercial salmon fishing. A significant commercial harvest of shellfish, mainly oysters, occurs in the basins. It is estimated that the average annual contribution from 1956 to 1965 to the Puget Sound and ocean commercial and sport fisheries from the Nisqually-Deschutes Basin was 128,720 salmon.

Recreation opportunities abound in these basins. The eastern portion is within Mount Rainier National Park, where visitors can enjoy a variety of leisure time activities. The Park receives nearly three-fourths of the total visitation of publicly-administered recreation areas, of which there were 38 in 1964. Over 8,000 acres of lakes and reservoirs, including the popular Capitol Lake, afford excellent and varied recreation opportunities. Outstanding natural areas include the Deschutes River near Tumwater; the Nisqually River Delta east of Olympia; the Julia Falls and Sawtooth Ridge scenic areas.

The Nisqually-Deschutes Basins rank sixth in the Puget Sound in total water-related recreation demand. In 1960, there were 2,000,000 water-related recreation days. By 1980, that number will double. Picnicking, swimming, and camping are the three most popular outdoor activities.

Municipal and industrial water supplies come mostly (88%) from ground water. Total average daily use for the basins amounts to only about 9.1 mgd. McAllister Springs near the mouth of the Nisqually River supplies Olympia, the major municipal user, and artesian springs serve the Olympia Brewery, the largest industrial user. Future demands are also expected to be met primarily from ground water.

Navigation at Olympia totaled 157,504 tons of foreign and domestic coastwise traffic and 593,688 tons of domestic internal traffic in 1963.

Fisheries and recreation uses require the highest water quality standards of all raw water uses, and as a result, have set the minimum acceptable quality for most watercourses in the Nisqually-Deschutes Basins. The water quality class is good (B), excellent (A), or extraordinary (AA), with the objective being to meet or exceed the quality requirements for all uses. It is expected that Budd Inlet will be reclassified to A in the future.

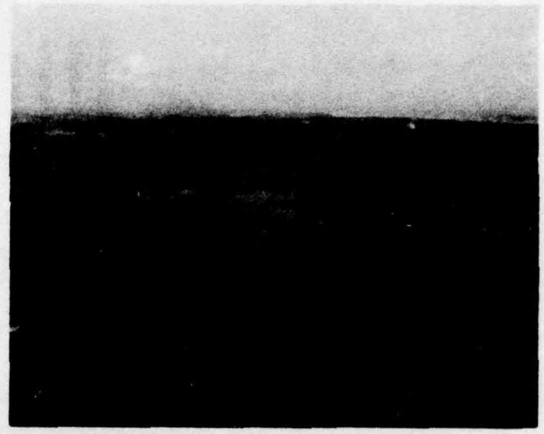


PHOTO 9-4. Long Lake is typical of the several lakes in the basins.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs are concentrated primarily in Budd Inlet where municipal and industrial waste discharges create unsatisfactory water quality conditions. Water quality objectives for dissolved oxygen, bacteria, aesthetics and toxics, are not being met here. In addition, temperature and turbidity is naturally higher than desired levels.

The major sources of waste to these waters are the cities of Olympia and Tumwater. Municipal and industrial wastes which receive primary treatment before discharge into the rather shallow waters of Budd Inlet, are the primary cause of poor water quality in this area.

High coliform counts during each summer's low flow period show the lower reaches of the Deschutes River to be unsatisfactory from a Public Health standpoint. This bacterial contamination needs to be controlled.

The rapid growth of Lacey, and its parallel increasing subsurface domestic waste discharges through septic tank units, poses a serious threat to the bacterial quality of the ground water.

FUTURE NEEDS

The principal factors determining the quantities of future wasteloads in the Nisqually-Deschutes Basins will be population and industrial growth—including rises in agricultural production and in the recreational use of the basins' water resources. As this growth occurs, the production of wastes and water quality problems will likewise increase. Forecasts of the quantities and location of wastes set the basis for determining the means to preserve water quality and thus protect water uses.

The 1967 population of 70,100 persons in the Nisqually-Deschutes Basins is projected to increase about 7 percent by 1980, 50 percent by 2000, and 110 percent by 2020. The Olympia Service Area is expected to account for more than 60 percent of the basins' projected population as shown in Figure 9-4.

Production growth for the major water-using industries in the Nisqually-Deschutes Basins is expected to realize a three-fold increase between 1980 and 2020 in terms of value added.

The food and kindred products industry is expected to account for 73 percent of the total value added by major water-using industries. (See Figure 9-5).

Paper and allied industries and chemical and petroleum industries should continue a moderate increase in production while lumber and wood products industries should decline in production.

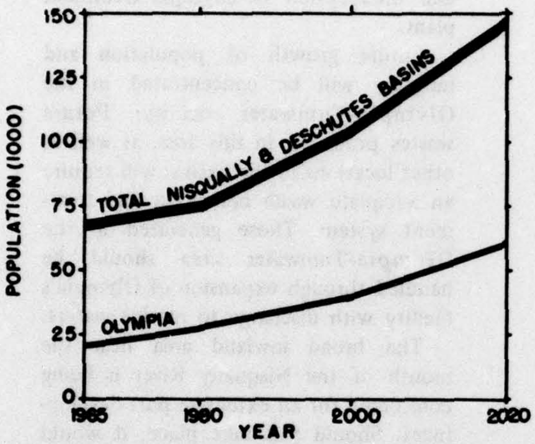


FIGURE 9-4. Population growth projected for the Nisqually-Deschutes Basins.

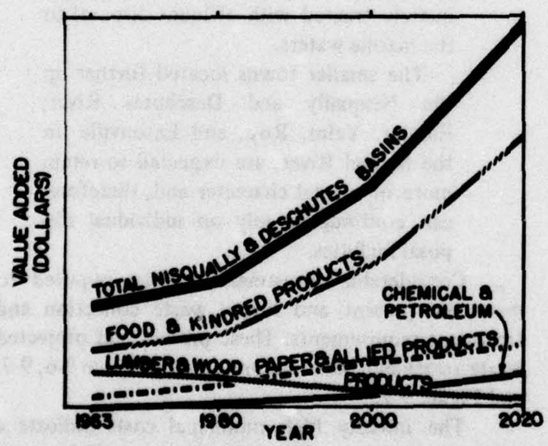


FIGURE 9-5. Relative growth of major water using industries.

The total raw wasteload, shown in Figure 9-6, is projected to reach 187,000 PE by 1980. The major waste producer will be the food and kindred products industry. This industry is expected to account for 49 percent of the basins' total raw wasteload in 1980 and 57 percent by 2020. Municipalities are projected to be the second largest raw waste producer, accounting for about 35 percent (66,000 PE) of the 1980 raw wasteload. Raw wastes from recreational activities are projected to increase about 65 percent by 1980. By 2020, the raw waste production is expected to be almost six times the present level.

Municipal and industrial raw wastes are expected to be concentrated in the Olympia-Tumwater area. A possibility exists for the future development of major port facilities on the Nisqually River estuary—presently called the Nisqually Flats. Should this development occur, this area could also become a center for waste production.

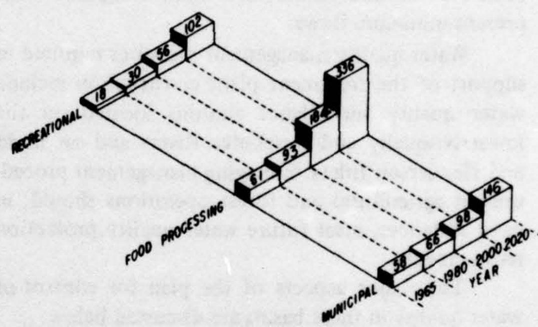


FIGURE 9-6. Projected municipal and industrial wastes for the Nisqually-Deschutes Basins (thousands of PE).

In 1964 about 50,000 head of cattle were located in the Nisqually-Deschutes Basins, ranking it fourth in the area on the basis of total numbers of cattle. The density of 1.1 head per acre of cropland, however, was the highest of all the basins. The wastes produced by these animals pose a threat to the basins' water quality when, during heavy rainstorms, some of the wastes may be washed into streams. This threat will increase as the number and density of the basins' animal population increases.

The present irrigated acreage of 5,600 acres is expected to increase to about 21,000 acres by 2020. Most of this new irrigation will be done by sprinkler application.

Raw wastes produced from activities in these basins are projected to grow gradually to 1980, increasing more rapidly thereafter. The proper handling of these wastes to maintain the required high water quality levels should not be a difficult task, but is a very necessary one. The actions required to achieve the proper waste control program are outlined in the following chapter.

MEANS TO SATISFY NEEDS

Adequate waste collection and treatment is the primary program element for a control of water quality in the Nisqually-Deschutes Basins. Nearly all the generated wastes are produced in the Olympia Service Area. Most of these wastes are, and will continue to be, organic. Minimum streamflow requirements for assimilation of the residual wastes, both present and future, are small compared with present minimum flows.

Water quality management measures required in support of the treatment plant construction include water quality surveillance stations located on the lower Nisqually and Deschutes Rivers and on Budd and Henderson Inlets. Emerging management procedures in agricultural and forest operations should, in most instances, meet future water quality protection requirements.

The major aspects of the plan for control of water quality in these basins are discussed below.

WASTE COLLECTION AND TREATMENT

The existing system of waste collection and treatment facilities is not adequate. The following is the recommended plan for waste collection and treatment construction which includes requirements from the Washington State Water Quality Standards and Implementation Plan of December 1967.

Nisqually River

Longmire—secondary treatment facilities.

Budd Inlet

The City of Olympia—secondary treatment,[1] disinfection and an adequate outfall.

Domestic and industrial wastes of non-sewered industries—interception by the city system.

Domestic wastes in Lacey—sewering and interception to Olympia treatment plant.

Future growth of population and industry will be concentrated in the Olympia-Tumwater vicinity. Future wastes produced in this area, as well as other locations in the basins, will require an adequate waste collection and treatment system. Those generated in the Olympia-Tumwater area should be handled through expansion of Olympia's facility with discharge to marine waters.

The broad lowland area near the mouth of the Nisqually River is being considered for an extensive port development. Should this take place, it would become a major industrial center with possible large quantities of waste being produced. These wastes should be adequately treated with effluent disposal to the marine waters.

The smaller towns located further up the Nisqually and Deschutes River; Rainier, Yelm, Roy, and Eatonville on the Mashel River, are expected to retain more of a rural character and, therefore, can continue to rely on individual disposal facilities.

Considerable investment will be required to meet the present and future waste collection and treatment requirements. These present and projected waste treatment costs are presented in Table 9-6, 9-7, and Figure 9-7.

The initially high municipal costs indicate a substantial modernization and expansion of the existing system to comply with the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans.

Municipal costs[2] will total $3,700,000 by 1980 with an additional $3,100,000 needed by 2000 and an additional $5,000,000 needed by 2020.

An estimated total[2] of $900,000 is required for

1 Secondary treatment is required unless it can be demonstrated that a lesser degree of treatment will provide for protection of present and future water uses and the preservation or enhancement of existing water quality.

2 Costs are not amortized.

waste treatment facilities for recreation areas by 1980. Projections indicate that $1,700,000 is necessary for the period 1980-2000 with an additional $2,200,000 for the period 2000-2020.

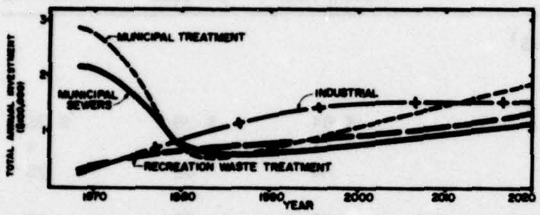


FIGURE 9-7. Relative required rates of investment for waste collection and treatment facilities in the Nisqually-Deschutes River Basins.

The food and kindred and lumber and wood products industries account for most of the present and projected industrial waste treatment costs.[1] An estimated $775,000 will be needed by 1980 with additional sums of $1,960,000 by 2000 and $3,000,000 by the year 2020.

Sources of funding are shown in Figure 9-8. The Federal Construction Grants program will need to invest over $1,000,000 by 1980 with an additional $750,000 by 2000 and another $1,500,000 by 2020. State grants for these periods are projected to be one-half of the Federal contributions. Federal investment in sewers is projected to total $150,000 by 1980; $340,000 from 1980 to 2000; and $750,000 from 2000 until 2020. The Federal investment in waste treatment and collection facilities for recreation areas will total $580,000 by 1980 with an additional $840,000 by 2000 and another $1,160,000 projected by 2020.

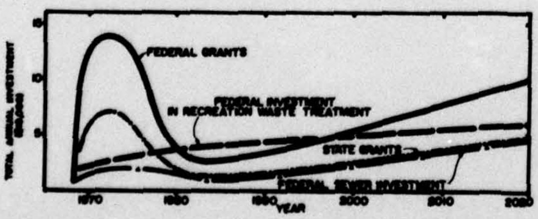


FIGURE 9-8. Government investment requirements for waste collection and treatment in the Nisqually-Deschutes Basins.

FLOW REQUIREMENTS

By 1980, 2000, and 2020, the total discharged wastes to both the fresh and marine waters of the basin are estimated to be about 100,000 PE; 182,000 PE; and 286,000 PE, respectively. These discharges are expected to be concentrated primarily in the Olympia Service Area, with 95 percent of these wastes being discharged to marine waters. The projected waste discharges to the fresh waters of the basin are estimated to be 5,800 PE in 1980; 9,500 PE in 2000; and 11,000 PE in the year 2020. The great majority of these wastes are expected to be discharged from recreation activities within the basin. Based on these projected waste discharges, the minimum flows required for the Nisqually River have been determined to be 30 cfs by 1980, 50 cfs by 2000, and 60 cfs by 2020. For the Deschutes River, required minimum flows for water quality control have been determined to be 10 cfs by 1980, 17 cfs by 2000, and 20 cfs by the year 2020. The 7-day low flows expected to occur once in ten years for the Nisqually River at McKenna and the Deschutes River near Olympia are 405 cfs and 80 cfs, respectively.

OTHER MEASURES

Adequate water quality monitoring is an important aspect of the water quality program. In addition to the existing and proposed monitoring stations in these basins, additional monitoring stations are proposed for Henderson Inlet in light of potential large-scale future development in the Nisqually Flats Area, and for Alder Reservoir–a site for a potential nuclear power plant. Additional stations are also needed in Budd Inlet and for lakes and ground water monitoring.

The potential port development on Nisqually Flats could involve extensive dredging and filling operations. Efforts must be made for the accomplishment of these operations if this area becomes an industrial site without detrimental impact on water quality.

Future development and expansion of boat marinas on Budd Inlet will require the incorporation of adequate facilities for the treatment of domestic wastes.

[1] Costs are not amortized.

TABLE 9-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Nisqually-Deschutes Basins

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 64	$ 39	$ 25
Disinfection	11	7	4
Outfalls	64	39	25
Interception and sewer system			
a. Municipal	32	20	12
b. Industrial	11	7	4
Combined sewage infiltration and overflow correction	32	20	12
Advanced waste treatment in recreation areas	55	77	108
Sub-Total	$269	$209	$190
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 10	$ 4	$ 6
Evaluations—dispersion areas, ecological, productivity	15	2	3
Information system, quality control, plant operation improvement, operation research	10	6	5
Sub-Total	$ 35	$ 12	$ 14
OPERATION AND MAINTENANCE[2]	$ 58	$162	$136
TOTALS	$362	$383	$340

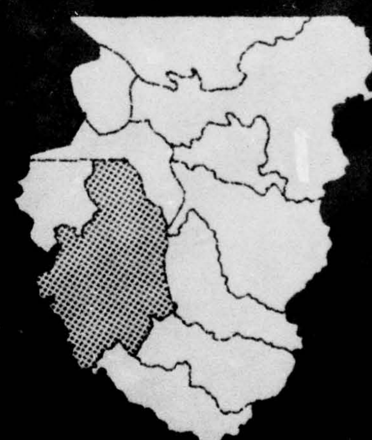
1 Annual amortized costs.

2 Direct annual costs from appropriations, revenue, planning funds, and grants. (Does not include interest).

TABLE 9-7. Total amortized capital and operational costs, Nisqually-Deschutes Basins

	Million Dollars		
	Present 1980	1980-2000	2000-2020
Industrial	1.5	1.9	1.2
Municipal treatment	3.7	1.5	1.0
Municipal sewers	7.3	3.0	2.0
Recreation	1.8	1.7	0.9
Advanced waste treatment	2.8	3.9	5.4
Sub-Total	17.1	12.0	10.5
Water quality engineering management and evaluation	0.4	0.2	0.3
Operation and maintenance	0.6	3.2	2.7
Total	18.1	15.4	13.5

West Sound Basins



WEST SOUND BASINS

INTRODUCTION

These are maritime basins where peninsulas are laced with marine waterways and where inlets and bays provide havens for pleasure boats and ships. Numerous lakes dot the landscape, although most are smaller than 100 acres.

The West Sound Basins encompass an area of 2,620 square miles. They are bounded on three sides by Puget Sound and on the west by the Olympic Mountains. Hood Canal is an arm of Puget Sound which separates the basins into distinct areas–the Olympic and Kitsap Peninsulas.

Topography in the western portion is rough, with altitudes varying from sea level at Hood Canal to over 7,700 feet in the Olympics. Large and swift streams which flow into Hood Canal drain this slope of the basins. The Skokomish, Hamma Hamma, Duckabush, Dosewallips, Big Quilcene, and Little Quilcene are the principal rivers.

FIGURE 10-1. Location of the West Sound Basins in the Puget Sound Area.

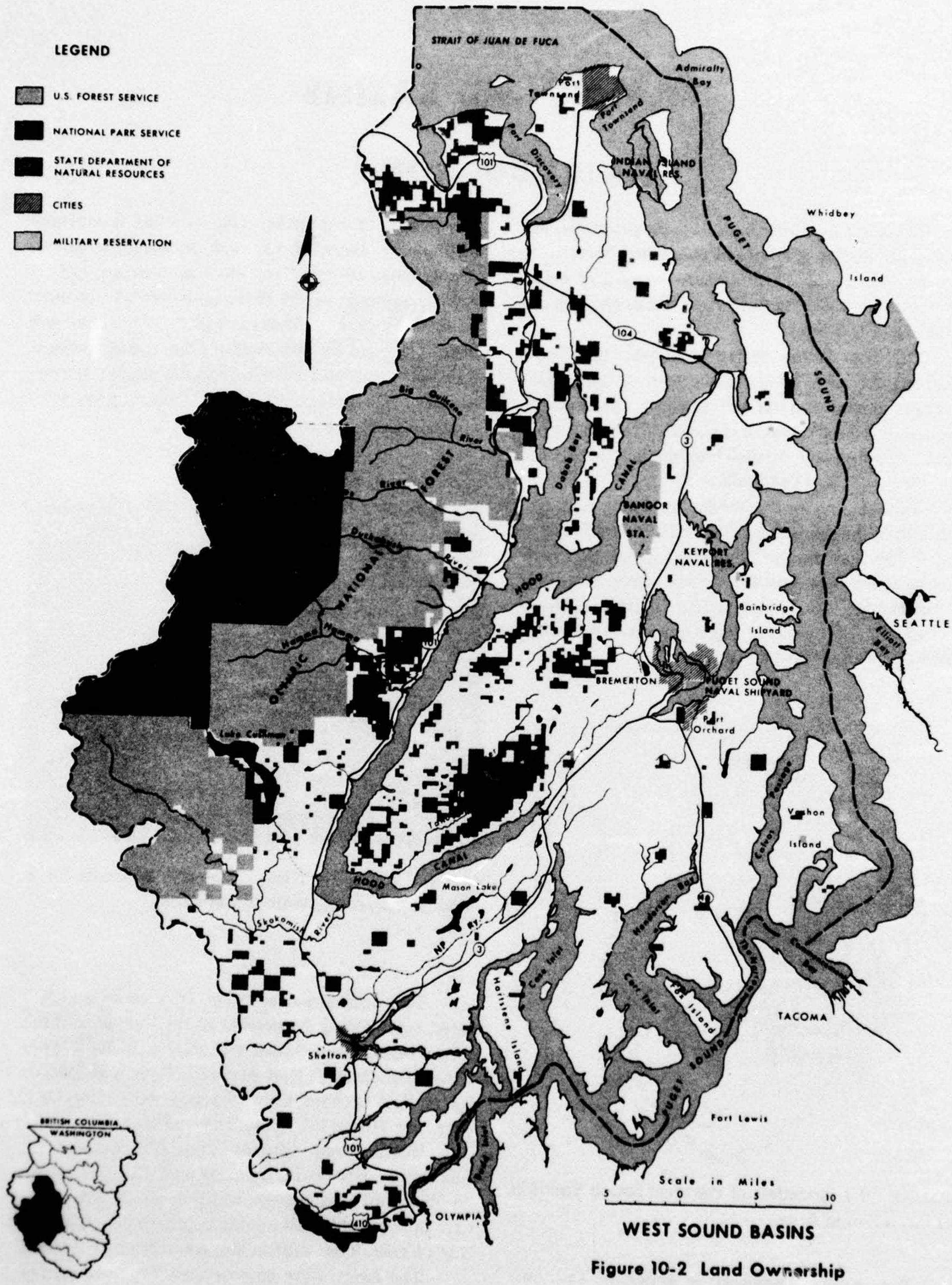
The Kitsap Peninsula is generally flat and undulating with hills and ridges separated by valleys and marine embayments. The shoreline is indented with many bays, coves, and harbors, Numerous islands range in size from less than a square mile in area to upwards of the several hundred square miles of Bainbridge and Vashon Islands. The peninsula itself is drained by hundreds of small stream systems. Twelve streams out of 426 separate stream systems have drainage areas greater than 10 square miles. Most are less than one square mile.

PHOTO 10-1. The Kitsap Peninsula accounts for a good portion of the West Sound Basins.

The marine waters cover an area of 385,500 acres, representing 23 percent of the total area of the West Sound Basins. Major waterbodies include Hood Canal, Dabob Bay, Port Madison, Dyes and Sinclair Inlets, Port Orchard, Colvos Passage, Admiralty, Carr, Case, and Totten Inlets, and Oakland Bay.

Hood Canal extends some 70 miles from Admiralty Inlet on its northern end to Lynch Cove on the south. Its average width is about 1.5 miles. Carr Inlet is the largest inlet in southern Puget Sound. It is 14 miles long, with an average width of 1.7 miles.

The basins have an estimated 1967 population of 134,200. Bremerton is the major center of



WEST SOUND BASINS

Figure 10-2 Land Ownership

population, with 36,170 persons and about 30,000 more residing in the surrounding metropolitan area. Shelton and Port Townsend are towns with populations of around 6,000. The other towns are smaller and scattered.

Forestland accounts for about 90 percent of the acreage. Agricultural cropland accounts for about three percent of the acreage. Most urban buildup is found along the shoreline and bays, leaving the area inland relatively undeveloped. More than 60 percent of the basins' total land area is held in private ownership.

The Navy dominates the basins' economy. The Bremerton shipyard repairs all types of Navy ships, including atomic powered vessels. These require a complex of facilities for such operations as plating, pickling, and galvanizing. Other extensive naval installations include the Keyport's Naval Torpedo Station and the Bangor Ammunition Depot and Polaris Missile Facility.

Crown Zellerbach's 820 tons per day kraft pulp and paper mill in Port Townsend is the basins' major forest products industry as well as this city's major industry. Shelton is also a focal point of the logging industry, containing a complex of Simpson Timber Company plants which include sawmills, an insulating board plant, lumber remanufacturing, and a veneer plant. Pope & Talbott Corporation has a large sawmill and boardmill operation at Port Gamble which utilizes the timber resources of their large land holdings on the peninsula.

Though of less importance than military activities and the forest products industries, agriculture has grown steadily. Dairy farming and general livestock raising (with some specialty crops) are the primary agricultural pursuits. Numerous small dairy, poultry, and berry farms are scattered about the uplands and creek valleys. An important strawberry and raspberry growing industry has developed on Bainbridge Island.

Both Olympia and Pacific oysters are cultivated and harvested on "farms" in the tidewater inlets which lace the basins. Totten Inlet is the center of production. Other commercial oyster farms are located in Oakland Bay, around Harstene Island, at the head of Case Inlet, and on Hood Canal. Most of the oyster production is processed in local plants.

Tourism and outdoor recreation are assuming a more important role in the basins' economy. The increasing construction of vacation homes and boating facilities plus the development of new resorts and tourist accommodations are adding considerably to the basins' economic stability and growth.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The West Sound is drained by a number of rivers and creeks which empty into the waters of Puget Sound. The Big Quilcene, Dosewallips, Duckabush, Hamma Hamma, and Skokomish Rivers are of major importance to the water resources of the area. The mean annual runoff of the Dosewallips River, as measured near Brinnon, adjusted to the period 1931 to 1960 was 475 cfs. Adjusted to the same period, the mean annual runoff of the Duckabush River, also measured near Brinnon, was 407 cfs. The mean annual runoff of the Hamma Hamma near Eldon averaged 337 cfs.

Streams heading in the Olympics exhibit two peak flow periods–one during high winter precipitation and the other during the spring rains and snowmelt period. Further to the south where the effect of the rain shadow is less pronounced, the winter peak becomes dominant and the two seasonal peaks tend to merge into one long period of high flows.

In general, minimum monthly flows for streams in the southern portion of the basin occur during the months of August and September, whereas in the northern areas minimum flows extend into October.

A low flow frequency analysis has been made by the USGS for 22 gaging stations within the West Sound Basins. The 7-day and 30-day low flows that may be expected to occur at seven of these stations for a recurrence interval of ten years, are shown in Table 10-1.

Flows of the North Fork Skokomish River have been regulated for power by Lake Cushman since 1925. This reservoir has over 460,000 acre-feet total storage and 360,000 acre-feet of active storage. The entire runoff of the North Fork Skokomish River is normally stored in Cushman No. 1 reservoir and is diverted from Cushman No. 2 reservoir (immediately downstream) into Hood Canal through the city of Tacoma's power plant near Potlatch. The power diversions here preclude any appreciable discharge in the North Fork Skokomish River below Cushman No. 2 Dam. These are the only major storage reservoirs in the West Sound Basins. All other streams are essentially unregulated.

TABLE 10-1. Low flow frequency, 10–year recurrence interval, West Sound Basins

Station	7–Day Low Flow cfs	30–Day Low Flow cfs
Little Quilcene River near Quilcene, Wn.	7.30	8.40
Dosewallips River near Brinnon, Wn.	106.00	123.00
Duckabush River near Brinnon	58.00	70.00
Skokomish River near Potlatch	151.00	168.00
Union River near Belfair	14.00	15.00
Gold Creek near Bremerton	0.36	0.40
Goldsborough Creek near Shelton	16.00	17.80

Source: Appendix III: Hydrology & Natural Environment.

In places where Quaternary deposits are absent, ground water is obtainable only from older consolidated rocks. In the mountainous Olympic National Park, formed principally of consolidated rocks, well yields of 10 gpm or less can be expected. The most productive aquifers in the northern lowlands are contained in coarse sediments. Near Sequim these deposits are plentiful. Well yields as high as 720 gpm are reported in the northern lowlands, and pumping rates of 200 gpm or more are common.

Recent alluvium occurs principally in the Skokomish River flood plain. It consists of fine sand and silt with minor amounts of clay and peat. Alluvium in the Skokomish River Valley is saturated about to river level. In the northern part of the Kitsap Peninsula, the older acquifers are composed mainly of fine sand and yield little water.

The most productive aquifers of the southern lowlands are contained in coarse Quaternary deposits which are rather continuous over a 900 square mile area.

Most wells in the southern lowlands produce less than 1,500 gpm. The largest yielding well, located at Shelton, was tested at 4,160 gpm with a water-level drawdown of 63 feet.

Practically all recharge to the aquifers is by infiltration of precipitation. Aquifers in the southern lowlands receive about 120,000 acre-feet of recharge per year. The natural discharge of ground water is mostly into the larger streams and into Puget Sound through springs.

Marine Water

Marine water occurs throughout the Basin. For purposes of this oceanographic discussion, they will be treated in four parts: (1) Admiralty Inlet, fronting Port Townsend; (2) Hood Canal; (3) Puget Sound, fronting Bremerton; and (4) South Puget Sound, extending west of the Narrows at Tacoma.

Admiralty Inlet acts as a channel for most of the water entering and leaving Puget Sound. Tidal currents are strong, creating a large mixing zone for the deeper waters of the Strait of Juan de Fuca with the fresher surface waters from Puget Sound. Because of the strong currents, the flushing time is rapid with the various water types requiring only a few tidal cycles to make the transit through the region.

Hood Canal has an entrance sill 190 feet deep which gradually deepens to a basin over 550 feet deep off Quatsap Point. The fresh-water inflows extend along the Canal with the Skokomish River contributing about half of this flow. Thus the surface layer does not show an increase in salinity as it moves seaward, but rather a thick (about 15 feet) fresh-water surface layer is produced that dominates all the main basin.

The flushing mechanism in Hood Canal is complex and difficult to define. The water entering from Admiralty Inlet receives some mixing at the entrance sill, but not so intense that the water column becomes homogeneous. This incoming water then spreads at a level depending upon its density, resulting in a considerable amount of microstructure in salinity and temperature.

The winds are one of the major driving forces in the circulation of Hood Canal. Prevailing winds for most of the year are from the southwest and follow the contour of the basin.

Puget Sound waters in the vicinity of Bremerton and Bainbridge and Vashon Islands have rather uniform water characteristics. These waters are well-mixed and have flushing rates estimated around three weeks.

Southern Puget Sound receives fresh-water inflows from the Nisqually and Deschutes Rivers and several small creeks. All marine waters entering this area pass through the Tacoma Narrows where currents are very strong. The Narrows is a mixing zone where complete top to bottom mixing occurs. Because of this, the waters are vertically homogeneous, with some change in the longitudinal direction.

Since there are no strong driving forces from large fresh-water inflows or winds, the transport characteristics of the south Sound waters are poor. The waters are not readily exchanged and remain resident for some time.

WATER QUALITY

Fresh Water

A summary of the water quality for the seven stations found in the basins is shown in Table 10-2 below.

Chemical and physical water quality data were also obtained for 90 streams and one lake on the Kitsap Peninsula during 1961. These data were gathered and presented in the Washington State Division of Water Resources Bulletin No. 18 entitled "Water Resources . . . of the Kitsap Peninsula . . ." The surface waters were sampled once during the winter (Jan–Feb) period and once during the summer (Aug) period.

Chemical–Most waters in the basin are generally low in hardness with average values for the seven stations ranging from 27 to 63 mg/l. Dissolved solids concentrations are low, with averages ranging from about 42 mg/l to 90 mg/l. Slightly higher dissolved solids are found in Goldsborough Creek where a maximum of 151 mg/l was recorded. Iron concentrations are low, with averages ranging from 0.0 to 0.3 mg/l.

All the streams within the basin exhibit high dissolved oxygen values. Averages range from 10.4 to 12.0 mg/l.

Land use and natural factors have kept total phosphate and nitrate concentrations relatively low. All streams average less than 0.2 of these constituents with many phosphate samples of 0.00 mg/l. Nitrates range from very low in the Olympic Peninsula rivers

TABLE 10-2. Surface water quality, West Sound Basins

		mg/l												mg/l								mg/l		mg/l		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4) (mg/l)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
BIG QUILCENE RIVER NEAR QUILCENE — JULY 1960 THROUGH AUGUST 1966																											
Maximum	—	94	18.0	2.9	7.8	0.4	52	0	3.4	21.0	0.2	1.0	158	0.32	—	12.0	0.48	0.06	7.8	15	5	15.6	13.5	117	57	14	430
Mean	—	62	12.8	2.0	3.6	0.2	45	0	2.4	6.8	0.1	0.3	98	0.03	—	9.6	0.08	0.02	—	—	—	8.9	11.4	102	40	3	42
Minimum	—	43	9.0	1.1	1.6	0.0	36	0	1.6	2.0	0.0	0.0	72	0.00	—	7.2	0.00	0.00	6.8	0	0	3.6	9.8	93	30	0	0
Number	—	29	29	29	29	29	29	16	29	29	29	29	29	27	—	29	27	12	29	29	10	28	27	26	29	29	29
DOSEWALLIPS RIVER AT BRINNON — JULY 1959 THROUGH AUGUST 1966																											
Maximum	—	72	18.0	2.0	3.3	0.6	56	0	8.4	1.5	0.2	0.4	114	0.10	—	9.4	1.30	0.06	7.9	10	80	15.6	13.6	113	52	6	230
Mean	—	53	13.5	1.1	1.7	0.2	43	0	6.2	0.8	0.1	0.2	86	0.02	—	6.7	0.14	0.02	—	—	—	8.8	11.6	103	38	3	29
Minimum	—	38	6.5	0.2	0.9	0.0	27	0	4.2	0.2	0.0	0.0	57	0.00	—	4.3	0.00	0.00	6.9	0	0	3.9	10.0	94	24	2	0
Number	—	29	29	29	29	29	29	16	29	29	29	29	29	27	—	28	27	12	29	29	10	28	26	26	29	29	29
DUCKABUSH RIVER AT U.S. 101 BRIDGE NEAR BRINNON — JULY 1959 THROUGH AUGUST 1966																											
Maximum	1,140	133	47.0	113.0	29.0	1.0	50	0	11.0	1700	0.3	0.4	5660	0.07	—	7.6	0.28	0.17	7.9	10	26	15.1	13.9	130	276	240	430
Mean	—	47	13.0	10.5	3.4	0.2	36	0	4.5	140.1	0.1	0.1	538	0.01	—	6.0	0.06	0.04	—	—	—	8.5	11.8	103	56	28	84
Minimum	64	33	6.5	0.5	0.9	0.0	24	0	2.4	0.2	0.0	0.0	46	0.00	—	3.7	0.01	0.00	7.1	0	0	4.1	8.0	75	20	0	0
Number	22	21	26	26	21	21	27	12	21	27	22	21	27	19	—	22	19	10	27	22	9	26	25	24	26	26	27
HAMMA HAMMA RIVER AT ELDON — NOVEMBER 1961 THROUGH AUGUST 1966																											
Maximum	460	77	23.0	48.0	14.0	0.7	38	0	6.4	686	0.1	0.3	2480	0.03	—	9.1	0.38	0.06	7.8	5	5	13.0	13.9	119	257	228	430
Mean	—	42	9.4	5.2	2.5	0.3	32	0	2.8	80.7	0.0	0.2	277	0.01	—	7.4	0.06	0.01	—	—	—	8.9	12.0	107	46	20	47
Minimum	119	32	5.0	0.8	1.0	0.0	22	0	1.6	0.5	0.0	0.0	41	0.01	—	5.4	0.00	0.00	6.8	0	0	5.5	11.0	100	17	0	0
Number	4	11	12	12	11	11	13	13	11	12	11	11	13	9	—	11	9	9	13	11	10	12	13	12	12	12	13
SKOKOMISH RIVER NEAR POTLATCH — AUGUST 1960 THROUGH AUGUST 1966																											
Maximum	6,840	52	9.5	2.6	2.7	0.6	43	0	2.2	2.6	0.1	0.7	77	0.06	—	14.0	2.90	0.04	7.8	15	70	13.5	15.0	128	33	0	230
Mean	—	46	8.0	1.7	2.0	0.2	36	0	1.1	1.4	0.1	0.2	63	0.03	—	11.7	0.26	0.01	—	—	—	8.7	11.0	97	27	0	56
Minimum	190	31	5.0	0.9	1.4	0.0	24	0	0.0	1.0	0.0	0.0	43	0.00	—	8.3	0.01	0.00	6.7	0	0	5.1	9.6	88	18	0	0
Number	22	26	26	26	26	26	26	12	26	26	26	26	26	24	—	26	24	12	26	26	10	24	24	23	26	26	25
CHICO CREEK NEAR BREMERTON — NOVEMBER 1964 THROUGH SEPTEMBER 1966																											
Maximum	—	64	9.5	3.5	3.4	0.8	50	0	3.6	3.0	0.1	2.7	91	0.08	—	15.0	0.20	0.01	7.7	20	10	17.3	10.6	106	38	2	2,400
Mean	—	51	7.5	2.7	3.0	0.4	37	0	2.8	1.9	0.1	1.0	73	0.04	—	11.3	0.10	0.01	—	—	—	13.7	10.2	102	30	0	1,743
Minimum	—	36	5.2	1.7	2.0	0.0	24	0	0.4	0.5	0.0	0.0	48	0.01	—	8.0	0.06	0.01	6.9	0	0	11.8	9.9	97	20	0	430
Number	—	18	18	18	18	18	18	18	18	18	18	18	18	8	—	18	8	1	18	18	8	3	3	3	18	18	3
GOLDSBOROUGH CREEK NEAR SHELTON — NOVEMBER 1964 THROUGH SEPTEMBER 1966																											
Maximum	—	178	32.0	14.0	4.7	0.7	160	0	11.0	6.2	0.2	1.1	266	0.13	—	19.0	0.66	0.02	8.2	90	20	17.0	12.6	110	138	8	4,600
Mean	—	99	17.0	6.9	3.6	0.4	81	0	5.9	3.2	0.1	0.6	149	0.06	—	14.9	0.33	0.01	—	—	—	10.4	10.5	96	71	4	878
Minimum	—	40	4.8	1.8	2.0	0.1	21	0	2.4	1.5	0.0	0.3	49	0.00	—	8.2	0.17	0.00	6.8	20	0	4.6	8.3	84	20	0	36
Number	—	24	24	24	24	24	24	24	24	24	24	24	24	12	—	24	12	3	24	21	12	23	23	22	24	24	23

to moderately high in the smaller creeks in the south part of the basins and the Kitsap Peninsula.

For ground waters of the West Sound Basins in the southern lowlands dissolved solids normally range between 100 and 200 mg/l, with hardness ranging between 50 to 100 mg/l. In some of the shoreline areas where aquifers may contain traces of seawater, dissolved solids concentrations may exceed 200 mg/l. Nutrient values are generally rather high with phosphates averaging about 0.5 to 0.8 mg/l and nitrates averaging 1 to 2 mg/l. High iron content is seldom reported, although some wells do exhibit slightly high concentrations. In the northern lowlands, the ground water has a dissolved solids content of 200-500 mg/l and hardness of 120-180 mg/l.

Bacteriological–Samples taken from the Dosewallips and Duckabush Rivers near Brinnon, from the Big Quilcene River near Quilcene, from the Hamma Hamma at Eldon, and from the Skokomish River near Potlatch indicate very low average coliform counts. Maximum coliform concentrations at these stations are also relatively low–the highest being 430 MPN. Higher coliform values are observed on Goldsborough Creek at Shelton and Chico Creek near Bremerton. Maximum MPN's at these points were 4,600 and 2,400 coliforms per 100 ml, respectively. Table 10-3 summarizes the coliform concentrations taken from basin data sampling.

Physical–Stream temperatures in the basin are significantly low. The maximum summer temperature of 62.6°F (17.0°C) for the stations listed in Table 10-2 was recorded on Goldsborough Creek. The other stations indicate slightly lower maximums with the Big Quilcene near Quilcene recording a 60°F (15.6°C) maximum temperature.

Smaller streams in the basins have appreciable amounts of color at times, attributed largely to organic solutes derived from swamps and poorly drained marshy areas. These colored waters are especially characteristic of much of the surface water on the Kitsap Peninsula. Maximum color values of 50 and 20 units have been recorded on Goldsborough and Chico Creeks.

Suspended sediment concentrations for most streams in the West Sound Basins are relatively low. Sediment data collected from the Skokomish River near Potlatch during 1965 and 1966 indicate an average yearly transported load of about 100,000 tons. It transports as much as 40,000 tons per day when the mean daily discharge exceeds 10,000 cfs. Sediment data for the Dosewallips, Duckabush, and Hamma Hamma Rivers indicate a much lower average annual transported sediment load of about 4,000 tons.

Turbidity is generally low throughout the basin. Average turbidities for the principal watercourses is less than 10 Jackson Turbidity Units with maximums of only 80 and 70 JTU recorded on the Dosewallips and Skokomish Rivers.

Marine Water

The surface layer of Hood Canal generally ranges in salinity from about 24 o/oo to 28 o/oo. Temperatures exhibit extremes and reflect the prevailing surface air temperatures. During the winter, a typical surface temperature is about 42.8°F (6°C). In

TABLE 10-3. Summary of coliform concentrations, West Sound Basins

	MPN/100 mls							
	Less than 240		240-1,000		1,000-2,400		Greater than 2,400	
Station	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.	No. of Samples	% of Total No.
Big Quilcene (nr Quilcene)	28	97	1	3	0	0	0	0
Dosewallips (at Brinnon)	29	100	0	0	0	0	0	0
Duckabush (U.S. 101 Bridge)	24	89	3	11	0	0	0	0
Hamma Hamma (at Eldon)	12	92	1	8	0	0	0	0
Skokomish (nr Potlach)	25	100	0	0	0	0	0	0
Chico Creek (Bremerton)	0	0	1	33	0	0	2	67
Gorst Creek (Bremerton)	0	0	0	0	0	0	0	0
Anderson Creek (Bremerton)	0	0	0	0	0	0	0	0
Goldsborough (Shelton)	12	52	6	26	1	4	4	17

Source: Washington Water Pollution Control Commission.

the summer, the waters of Lynch Cove region are frequently above 71.6°F (22°C). The oxygen content of the surface water varies from 20 mg/l in spring to 5 mg/l in summer. Surface phosphate content is also quite variable and ranges from nearly zero during the spring plankton bloom to over 1.18 mg/l in the winter.

The waters at depth in Hood Canal are considerably different than the surface waters. In summer, the temperatures are between 50°F (10°C) and 53.6°F (12°C) and the salinity between 30 o/oo and 30.8 o/oo. In the winter, the temperature may drop to about 46.4°F (8°C) and the salinity as low as 29 o/oo. Oxygen content of this water is usually above 5 mg/l and the phosphate content is above 0.18 mg/l.

In Carr Inlet the waters are usually homogenous with depth. Salinity differences are usually less than 1 o/oo and temperatures are usually within 1.8°F (1°C) except during the summer when the surface may be about 5.4°F (3°C) higher than the deeper water. Minimum salinities and temperatures are observed in February at 29.6 o/oo and 46.4°F (8°C) respectively. The surface temperature increases to about 59.9°F (15.5°C) in the summer and is accompanied by a salinity of about 29.8 o/oo. Oxygen content varies from an autumn low of 5.6 mg/l to a spring high of 9.6 mg/l because of the annual phytoplankton bloom.

In Case Inlet, a minimum salinity of 28 o/oo at all depths was observed to occur in winter. The lowest temperature of about 44.6°F (7°C) was observed in late winter. During the summer the salinity increases to about 29.5 o/oo and temperature to about 60.8°F (16°C). Temperature at depth increases to over 57.2°F (14°C). The oxygen content of the waters is usually above 6 mg/l at all depths. The phosphate content remains between 0.14 and 0.23 mg/l throughout most of the year.

Marine water characteristics throughout the eastern part of West Sound are quite uniform. The average minimum surface salinity is 27.4 o/oo, but values of less than 20 o/oo have been observed. The maximum surface salinity of 30.4 o/oo is observed in the middle of October when fresh-water contributions have been at a minimum. Surface water temperatures of 46.8°F (8.2°C) are coldest in February. The maximum surface temperatures are observed in August with an average maximum of 57.6°F (14.2°C). Dissolved oxygen values of 9 to 11 mg/l are common over the entire area. Only on rare occasions does the oxygen at any depth in this basin decline to less than 5 mg/l.

SOURCES OF WASTE

The municipal and industrial wasteload generated in the West Sound Basins approximates 201,000 population equivalents of which only about 14 percent is presently removed by waste treatment before being discharged to marine waters. There are no significant waste discharges to fresh waters. The areas receiving the largest quantities of wastes in relation to the total basins include those waters off Port Townsend (51 percent), Dyes and Sinclair Inlets (28 percent), and Oakland Bay (15 percent).

The quantities and general location of waste production and discharges in the basins are shown in Figure 10-3. Sources of wastes are summarized in Table 10-4. Upon completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, the strengths of wastes presently being discharged will be substantially reduced.

Fresh Water

There are virtually no waste discharges to the streams and rivers of the basins. The possible exception may be a few scattered waste discharges to fresh waters from rural homes, recreationists, animals, etc.

Marine Water

The principal sources of wastes to marine waters average 201,000 PE daily, plus 2,000 PE during the food processing season. About one percent of this total wasteload receives secondary treatment; 37 percent receives primary treatment; and the remainder is untreated. As a result, wastes from an equivalent population of 173,800 are being discharged into Puget Sound.

The major waste source is the Crown Zellerbach pulp and paper mill which discharges 96,000 PE daily to Port Townsend Bay. This pulp mill is responsible for 56 percent of the basins' total waste discharge. The city of Port Townsend and Fort Flagler State Park also contribute wastes totaling 6,110 PE to the Bay. This channel receives about 60 percent of the total wasteload going to marine waters.

Organic waste discharges from the Bremerton area are almost entirely municipal. An estimated 34,750 PE are discharged to Dyes and Sinclair Inlets from two Bremerton sewage treatment plants and two Kitsap Sewer Districts. Sanitary wastes produced at the Naval Shipyard located at Bremerton are treated by the city sewage treatment plant No. 2. Industrial wastes produced here are neutralized before going to marine waters.

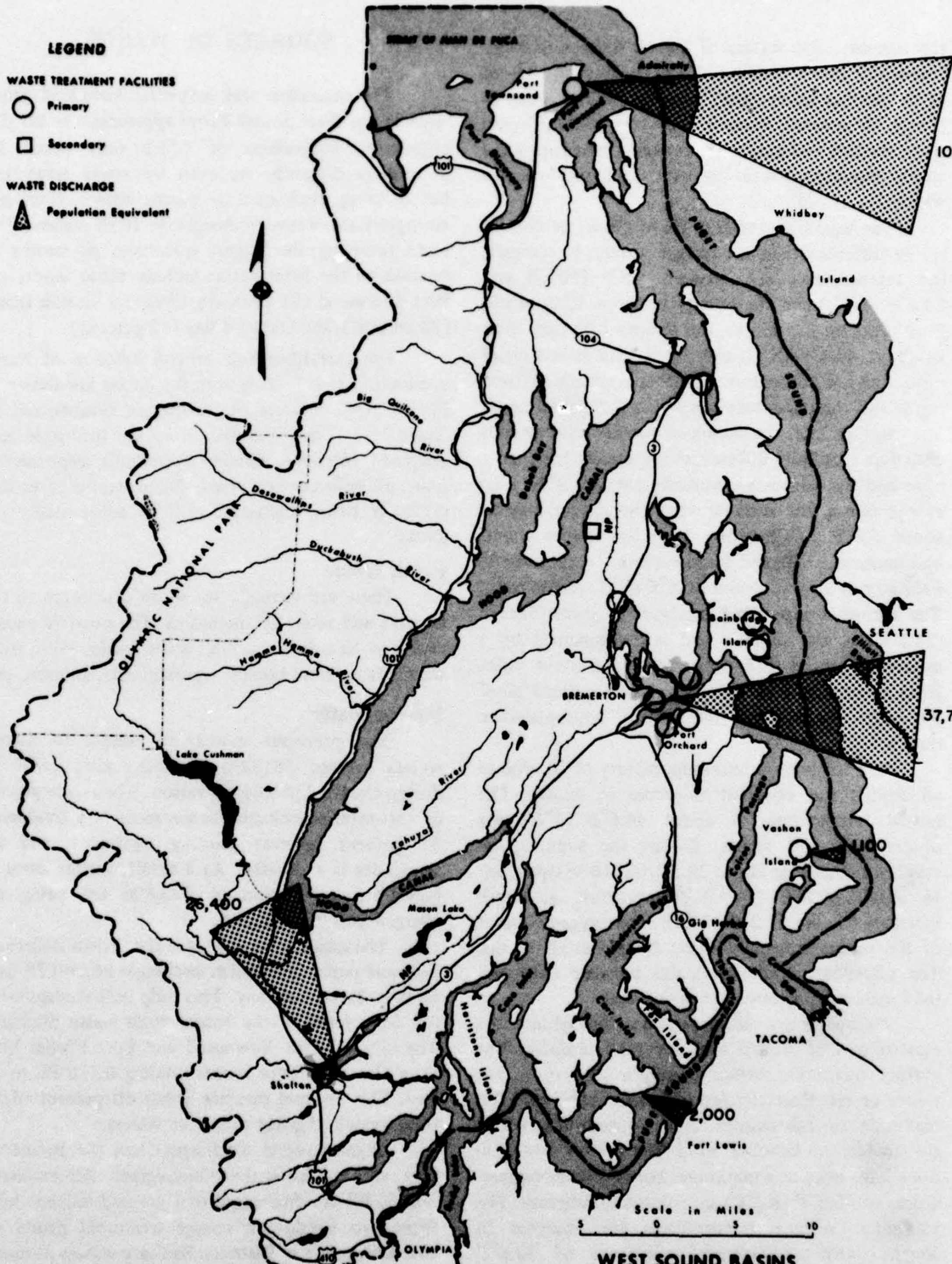


FIGURE 10-3. Location of major waste discharges

TABLE 10-4. Summary of municipal and industrial wastes, West Sound Basins

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Puget Sound						
Kingston Nike Base and Army Housing	200	225	–	Primary	200	–
Winslow	900	1,100	–	Primary	630	–
Food & kindred	–	–	1,000	None	–	1,000
Creosote	40	50	–	Primary	30	–
Vashon SD	300	320	–	Primary	200	–
Food & kindred	–	–	1,000	None	–	1,000
McNeil Federal Penn.	1,800	2,000	–	None	2,000	–
Port Townsend						
Port Townsend	5,000	6,000	–	None	6,000	–
Paper & Allied (400T/D)	–	96,000	–	None	96,000	–
Fort Flager State Park	–	200	–	Secondary	110	–
Hood Canal						
Port Gamble	100	150	–	Primary	100	–
Bangor NAD	800	1,000	–	Secondary	200	–
Liberty Bay						
Poulsbo	1,500	1,800	–	Primary	1,000	–
Keyport Naval Torpedo Station	1,400	1,500	–	Primary	1,200	–
Dyes & Sinclair Inlet						
Port Orchard	3,000	3,500	–	Primary	3,000	–
Kitsap SD No. 6	600	700	–	Primary	650	–
Kitsap SD No. 5	1,500	2,000	–	Primary	1,300	–
Bremerton No. 1 STP	18,700	23,000	–	Primary	13,800	–
Bremerton No. 2 STP	20,000	24,000	–	Primary	16,000	–
Ships at Dock	2,500	3,000	–	None	3,000	–
Oakland Bay						
Shelton	4,000	4,500	–	Primary	3,400	–
Paper & allied	–	30,000	–	Pond	23,000	–
TOTAL[1,2]	62,340	201,000	2,000	–	171,800	2,000
Municipal	–	75,000	–	–	52,800	–
Industrial	–	126,000	2,000	–	119,000	2,000

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

Another source of wastes to Dyes and Sinclair Inlets comes from sea-going vessels. Ships are continually being brought into the Naval Shipyard for repairs. Normally the personnel remain aboard while repairs are being made. All wastes (approximately 3,000 PE daily) from these ships are untreated.

The third major waste source is the Simpson Timber Company in the city of Shelton which contributes 23,000 PE to the waters of Oakland Bay.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the West Sound Basins are summarized in Table 10-5 on the following page. Table 10-5 also indicates the water quality classification established by the State for each watercourse which defines the type of water uses to be protected.

TABLE 10-5. Water uses and quality objectives, West Sound Basins

Use Intensity
- L—Light
- M—Medium
- H—Heavy

Watercourse	Assigned Class	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Strait of Juan de Fuca and Puget Sound	AA			H	H				H	H	M	L			L	H	H			M		H	M	
Sequim Bay	A			L	M				M	L	M	L			L	L	H					L	L	
Port Townsend	A			H	H				H	L	L	L			L	M	H					M	M	
Port Gamble	A			L	L				L		M	L			L	M	H					L	L	
Dyes & Sinclair Inlets	A			M	M				M	L	H	M			M	H	H					H	L	
South Puget Sound	A			H	H				M	L	H	L				M	L					M	H	
Oakland Bay	B			M	M				L		H	L				L	L			L		M	M	
Tanuya River	A[1]			H	H	H						H			M	H	H							
Union River	A[1]			H	H	H						H			M	H	H		H	H				
Dosewallips River and tributaries	AA[1]			H	H	H						H			L	M	H							
Big Quilcene River and tributaries	AA[1]			H	H	H						H			L	M	H		H	H				
Little Quilcene River	AA[1]			H	H	H						H			M	M	H		H	H	H			
Duckabush River and tributaries	AA[1]			H	H	H						H			L	M	H							
Hamma Hamma River and tributaries																								
Skokomish River	AA[1]			H	H	H						H			L	H	H		L					H
Hood Canal	AA[1]			H	H				H		L	H												

[1] Assigned class tentative pending hearing on water quality standards for intrastate waters.

PHOTO 10-2. The city of Bremerton and the Naval Shipyard are major sources of waste to Dyes and Sinclair Inlets.

Four Pacific salmon species utilize West Sound Basin drainages. These include chinook, coho, pink, and chum. Anadromous game fish utilizing the basins include steelhead and searun cutthroat trout and searun Dolly Varden.

The highly diversified environments and ecological riches offered by the marine waters of the West Sound Basins provide suitable habitat for a great variety of marine fishes. Also, the extensive marine area associated with the large number of streams and rivers entering saltwater provides both space and productivity to support abundant populations of fish. Those fish presently contributing to the basins' commercial or sport fisheries include species of the cod family, ling and greenling; flounder and sole; surfperch; rockfish; herring; shark; and ratfish. Prominant shellfish species include Pacific oyster; littleneck, butter, Manila, and geoduck clams; and spot shrimp.

A relatively intense commercial fishery for salmon takes place in the more northern marine waters of the basins from Discovery Bay southeast into the entrance of Hood Canal and from Hood Canal to Bainbridge Island. The waters surrounding Vashon-Maury Island also receive heavy commercial fishing effort. No commercial salmon fishing is allowed in basin waters south of the Tacoma Narrows. The average annual contribution from 1956 to 1965 to Puget Sound and ocean commercial and sport fisheries from the rivers and streams in the West Sound Basin was 853,960 salmon.

Generally, the marine fish species receive light to moderate commercial and sport fishing effort. The commercial harvest of marine fish is conducted principally by otter trawl vessels; however, some hook and line fishermen also utilize these waters.

Sport angling for salmon in saltwater is extremely popular throughout the basins. It is estimated that in 1965 somewhere between 250,000 and 300,000 angler trips were made on the basins' waters. Hood Canal alone received nearly 50,000 angler trips in that year. Sport fishing, specifically for marine fish species, is performed in virtually every segment of the basins' marine environment. Sport angling from boats, piers, or beach areas is especially heavy in Sequim and Discovery Bays, in certain areas along Admiralty Inlet, in the waters surrounding Bainbridge and Vashon-Maury Islands, in the Tacoma Narrows and the inter-island waterways of Southern Puget Sound, and in virtually all of Hood Canal.

Based on 1966 survey data, 335,300 man-days of effort were spent fishing in the lakes and ponds of the basins; and a total harvest of 1,338,000 trout and 242,200 other game fish was realized. In the streams, 74,500 man-days were spent with a harvest of almost 194,000 trout.[1] About 119,700 man-days were spent fishing for steelhead and searun cutthroat trout and about 7,200 steelhead and 50,200 cutthroat trout were harvested.

The commercial and sport harvest of shellfish from West Sound waters is considered relatively intense, with emphasis on oysters, hardshell clams, crabs, and shrimp. Sport harvest of shellfish occurs over virtually every section of beach or tideland within the basins.

The West Sound Basins have the most extensive saltwater recreation resources of any of the basin or island areas within the Puget Sound Area. The central and eastern portions are completely interlaced with a complexity of sheltered waters of high recreation value—augmented by attractive islands, bays, and fresh water lakes. In the western portion are the beautiful Olympic Mountains. Numerous streams and Lake Cushman provide further attraction within the mountainous reaches.

The West Sound Basins rank second only to the Cedar-Green Basins in outdoor water-related recreation demand. Recreational use of the basins' waters is tremendous; it is one of the most vital economic factors in the area. In 1960, there were 4,000,000 water-related recreation days. By 1980 that number will more than double. Swimming is the number one activity, but there are nearly as many boat operators as there are swimmers. Camping, fishing, and picnicking are also extremely popular. In 1964 there were 148 publicly-administered outdoor recreation areas within the basins.

Water for municipal and industrial purposes is obtained primarily from surface water supplies. In fact, 77 percent (37 mgd) of the water supplied is drawn from surface water sources. The Union River, Gorst Creek, and Anderson Creek for Bremerton and the Big Quilcene River for Port Townsend are the major sources in the basins. By 2020 it is estimated that 95 percent of Bremerton's total supply will come from surface waters.

Navigation at Port Townsend in 1963 amounted to 158,240 tons of foreign and domestic coastwise traffic and 593,479 tons of domestic internal traffic. Shelton handled 239,168 tons of domestic internal traffic in 1963.

The future of the West Sound Basins is tied firmly to recreation and fisheries. These uses require the highest water quality standards of all raw water uses. As a result, for most watercourses in the West Sound Basins, the water quality class is excellent (A), or extraordinary (AA), with the objective being to meet or exceed the quality requirements for all uses. Although log rafts occupying large portions of marine waters adversely affect water quality and recreation use, it is expected that this problem will decline in the future as it is now almost as economic to store and handle logs on land. Thus, Oakland Bay and South Sound may be classified higher in the future as the local problems are met and solved.

[1] Includes catch of all samonids.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Most water quality problems occur on marine waters. These include untreated or inadequately treated municipal wastes, untreated pulp mill wastes, log raft debris, and untreated wastes from large ships as well as pleasure craft.

Port Townsend Bay receives treated municipal wastes from Port Townsend as well as untreated wastes from the Crown Zellerbach kraft pulp mill. The municipal wastes produce high bacterial concentrations which preclude recreation uses. The pulp mill wastes introduce oxygen-demanding and toxic wastes which at times adversely affect the marine biota. The area is fortunate in that the bay has good transport characteristics or the impairment of water quality would be more severe.

Port Gamble Bay has been affected by inadequately treated municipal wastes and by forest industry (log rafting) wastes. These have produced high bacterial concentrations, low dissolved oxygen levels, and aesthetically displeasing water.

Bremerton and the Puget Sound Naval Shipyard discharge wastes to Sinclair Inlet. Inadequacies in disinfection and outfall design, coupled with the poor dispersion characteristics of this bay, result in periodic high bacterial concentrations. Additionally, troop ships docked at the shipyard discharge untreated wastes directly into the bay, creating an oxygen demand and health hazard. The shipyard's handling of plating and radioactive wastes has conformed to recommended procedures, and thus these wastes have not had an adverse impact on water quality.

Shelton is on the tip of South Puget Sound along Hammersley Inlet. The Simpson forest products mill uses the inlet as a vast log rafting area as well as a receiver of their treated process wastes. The results are traces of toxic elements, beds of log bark with a sizeable oxygen demand, and floating debris. In addition, the log rafts reduce surface circulation of the inlet, which already has poor transport characteristics.

The many isolated, small bays and inlets are being threatened by people in pleasure craft and recreation homes. This threat will become even more significant in future years as the recreation activities increase.

FUTURE NEEDS

This basin's unique marine recreational attributes indicated that future growth will be concentrated in recreation homes and suburbs supporting Seattle-Tacoma. The poor land transportation network will prove to be a limiting factor on big industrial growth. These are the significant considerations in the following projection of elements which will generate the waste loads that will be discharged to the water resources. The quantities and locations of these waste sources have been projected to serve as the basis for determining the measures required in handling the resulting wasteloads so as to insure future adequate water quality.

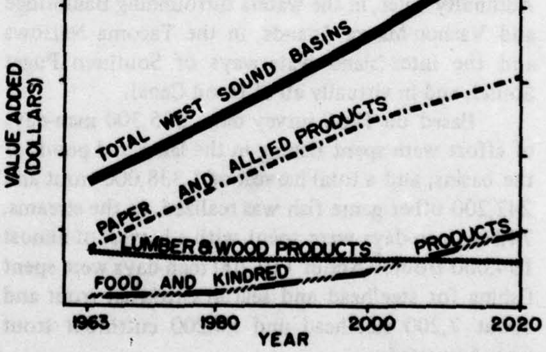


FIGURE 10-4. Relative growth for major water using industries in the West Sound Basins.

Production of the major water using industries for West Sound is expected to increase 1.83 times between 1980 and 2020 in terms of value added. Paper and allied production is assumed to continue its important role in the basins' economy. By 2020, paper products will account for half of the total value added from major water using industries. (See Figure 10-4.) Food and kindred industries should also show an increase in production. In 2020, food and kindred industries will account for one-third of the total value added of the major water using industries.

The Naval shipyard at Bremerton is predicted to maintain its importance in naval ship repair and maintenance. The changing power sources for naval vessels will mean an increasing amount of radioactive material handling and disposal by the shipyard. This could be the most significant future waste to be handled at this installation.

The population of the West Sound Basins was 134,200 in 1967. It is expected to increase 44 percent by 1980, 122 percent by 2000, and 254 percent by 2020. Figure 10-5 shows the present and projected population of the entire basins and of Bremerton.

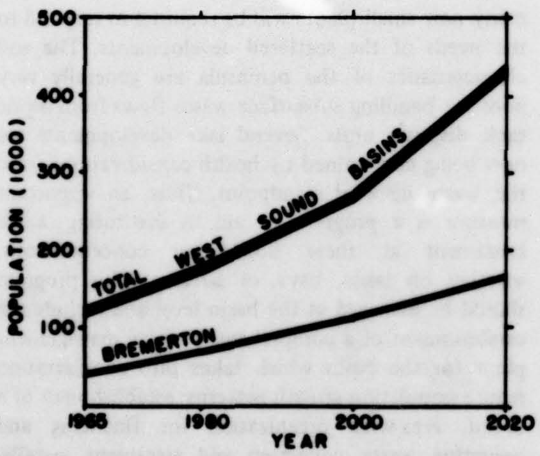


FIGURE 10-5. Population growth projected for the West Sound Basins.

Major population growth areas are predicted to be on the east side of the basins. With improved transportation means, greater ease of commuting between the industrial areas in and around Seattle-Tacoma and Bremerton and environs, it will mean the increased growth of residential developments. These will gradually spread along the east side until 2020 when they will be fairly solid from Bainbridge Island to Fox Island. Port Townsend and Shelton are expected to grow more slowly, primarily to support the forest products industries in these areas. An area where it is especially difficult to predict population growth is the shoreline around Hood Canal. This area is eminently suitable for development from a recreation and aesthetic standpoint. For this study, it is expected that by about 2000 fairly dense clusters of mixed permanent and recreation homes will line both shores.

Recreation growth will be large, and the forecast is that it will almost double every 20 years. Fifteen million recreation days are forecast by 1980. The wealth of lakes, streams, and marine bays and inlets show the reasons for an optimistic prediction. Recreation will take many forms. The most significant will probably be marine-water activities such as sailing, scuba diving, swimming, and fishing. The many lakes are now feeling the pressure of cabin development projects for recreation purposes. Lake Cushman is in the midst of a sizable development along the east shore, and several small lakes on the peninsula are being developed similarly. These are setting the pattern for potential big growth. The Olympic National Park and the basin's rivers are recreation attractions that will receive significant use.

These large and diverse recreation activities will result in a similarly scattered production of wastes. The developments around lakes will produce the greatest concentration. Boating activities on marine waters will periodically present concentrated problems in bays and inlets.

The amount of agricultural cropland (less than 4 percent) and the pattern of agricultural activities (mostly pasture and hay crops for about 40,000 cattle) were not projected to change significantly. The small amount of irrigation presently practiced will not increase greatly. Agricultural management techniques will improve in the future, yielding a net effect of less water quality impacts. The largest present factor affecting water quality—animal wastes in streams—is subject to improvement through these advanced techniques.

Timber harvest is expected to increase 50 percent by the year 2000. This will require expansion of the logging road system. The rugged terrains and unstable soils in areas along the Olympic Mountains are susceptible to yields of high sediment loads from erosion along these roads. This waste could be a significant future problem in the basins.

The municipal, industrial, and recreational wastes produced for the years 1965, 1980, 2000, and 2020 are shown in Figure 10-6. Of the total 567,000 PE foreseen for 1980, paper and allied industries will produce 57 percent. Municipal waste production, with major centers being Bremerton, Port Townsend, Shelton, and Port Orchard; is expected to increase from 75,000 PE in 1965 to 186,000 PE in 1980. Municipal waste in 2020 will probably account for more than one-third of the total waste produced which will be almost seven times the 1965 production. Wastes generated in 1980 from recreational activities will amount to 54,000 PE and are expected to rise to 188,000 PE by 2020.

The future needs of the people in the West Sound Basins are to manage the predicted wasteloads so as to preserve the outstanding environment. Their major potential growth factors–recreation opportunities and aesthetics–demand this. The means necessary to prevent, control, and abate future water pollution are developed in the next chapter.

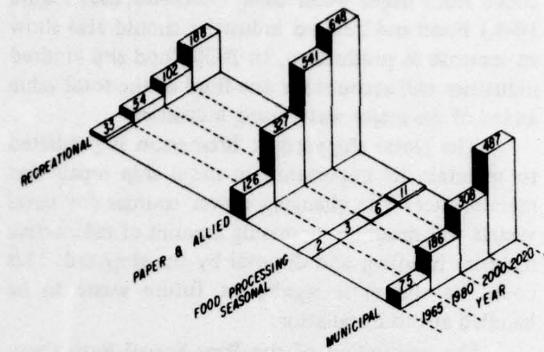


FIGURE 10-6. Projected municipal and industrial wastes for the West Sound Basins (thousands of PE).

MEANS TO SATISFY NEEDS

The many and diverse wastes produced in the West Sound Basins call for many handling methods to minimize the impact on natural water quality. Again, waste collection and treatment of all concentrated discrete wastes is the foundation of the water quality management plan. Other elements are integrated into the plan to insure the effectiveness of treatment. The continued use of the marine waters as the sink receiving most residual wastes results in little requirement for fresh surface water flows.

WASTE COLLECTION AND TREATMENT

Present needs can, to a great extent, be met through the immediate construction and proper operation of waste collection and treatment facilities. The separate actions required to meet these needs are outlined in the Washington State Water Quality Standards and Implementation Plan, December 1967. These requirements are summarized below:

1. Port Townsend, Fort Warden, and Crown Zellerbach at Port Townsend–adequate treatment and outfall facilities.

2. Naval Shipyard–interception of industrial shipboard wastes to Bremerton.

3. Shelton and Simpson Timber Company–modification in log storage and handling practices.

The projected waste sources are similarly scattered. A large part of these wastes can be treated through enlargement or replacement of the above complex of treatment plants. In the basins, however, many new small plants will be required to respond to the needs of the scattered developments. The soil characteristics of the peninsula are generally very poor for handling subsurface waste flows from septic tank disposal units. Several lake developments are now being constrained by health considerations from the waste disposal standpoint. Thus, an important measure is a program to aid in instituting waste treatment at these population concentrations, whether on lakes, bays, or streams. This program should be managed at the basin level and include the establishment of a comprehensive waste management plant for the basin which takes into consideration future population growth patterns; establishment of a broad, area-wide organization for financing and operating waste collection and treatment installations; and supporting Federal research to devise economical small size sewer and treatment installations.

Waste collection and treatment from pleasure boats and at County, State, and Federal Parks will have to be provided in increasing numbers of sites. These should be included in the above program for housing developments.

The present and projected municipal, industrial and recreational waste treatment costs are presented in Tables 10-6, 10-7, and Figure 10-7.

Municipal costs[1] are projected to total $7,400,000 by 1980 with an additional $16,000,000

[1] Costs are not amortized.

needed by 2000 and an additional $24,500,000 by 2020.

With the paper and allied products industry accounting for 90 percent of expenditures, industrial costs[1] are projected to total $2,300,000 by 1980, $4,400,000 from 1980-2000, and $8,000,000 in the interval 2000-2020

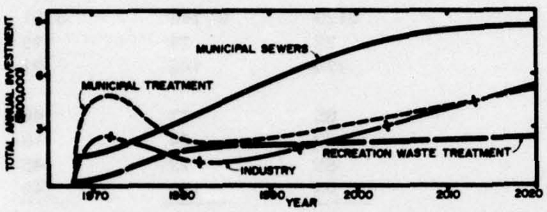


FIGURE 10-7. Relative required rates of investment for waste collection and treatment in the West Sound Basins.

Sources of funding are shown in Figure 10-8 The Federal Construction Grants Program will need to invest $2,200,000 by 1980; an additional $2,800,000 by 2000; and $3,500,000 from 2000 until 2020. State grants will total over $1,000,000 by 1980; $1,400,000 from 1980-2000 and $1,800,000 from 2000-2020. Federal investment in sewers is expected to total $390,000 by 1980 with an additional $1,175,000 by 2000 and still another $6,000,000 by 2020.

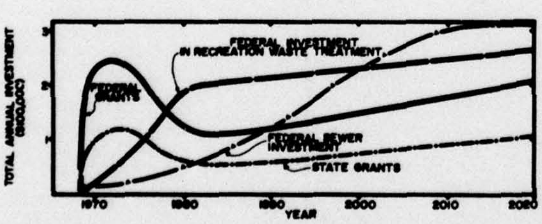


FIGURE 10-8. Government investment requirements[1] for waste collection and treatment in the West Sound Basins.

[1] Costs are not amortized.

Federal investment in waste treatment facilities for recreation areas will total $1,210,000 by 1980 with additional amounts of $4,300,000 and $4,800,000 from 1980 to 2000 and 2000 to 2020, respectively.

FLOW REQUIREMENTS

Treated wastes have been projected to be discharged to marine waters. Residual wasteloads to streams from natural causes or recreation activities are expected to be small and easily accepted by the streams. Therefore, flow requirements were not estimated for the basin.

OTHER MEASURES

A plan of radioactive waste disposal will be required as a joint State-Federal output in the near future as the problem emerges. Bremerton Naval Shipyard will be faced with a growing demand for handling radioactive materials, and the disposal practices must not impair the water resources.

Another necessity is a program for inspection and patrol of recreation boats and sites to insure compliance with waste handling requirements. The mobility of the pleasure craft will make enforcement of regulations a future problem.

Hood Canal and South Sound, west of Tacoma Narrows, are ideal recreation areas. The transport characteristics of the South Sound are poor. Both of these factors point to the conclusions that residual wasteloads must be kept to a minimum in these areas, particularly from those industries which would have a significant impact on these watercourses.

Present water quality monitoring is concentrated on the eastern rivers of the Olympic Peninsula. These streams and lakes on the peninsula and the marine waters have intermittent and fragmented measurements. These, however, are the areas where most wasteloads and potential pollution problems will be. The surveillance program should be expanded to meet the increasing need for measurements as developments take place, and to include lakes and ground-water monitoring.

TABLE 10-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, West Sound Basins

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$129	$ 146	$ 91
Disinfection	22	24	15
Outfalls	129	146	91
Interception and sewer system			
a. Municipal	65	73	46
b. Industrial	22	24	15
Combined sewage infiltration and overflow correction	65	73	46
Advanced waste treatment in recreation areas	98	153	240
Sub-Total	$530	$ 639	$544
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 25	$ 6	$ 8
Evaluations—dispersion areas, ecological, productivity	40	6	8
Information system, quality control, plant operation improvement, operation research	10	6	8
Sub-Total	$ 75	$ 18	$ 24
OPERATION AND MAINTENANCE[2]	$119	$ 429	$431
TOTALS	$724	$1,086	$999

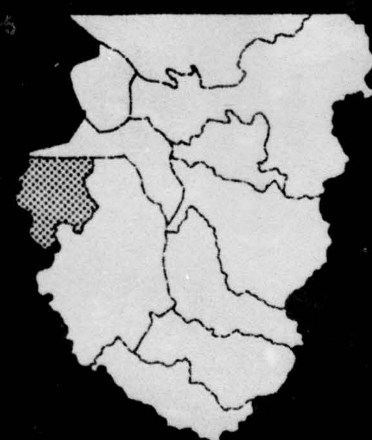
1 Annual amortized costs.

2 Direct annual costs, from appropriations, revenues, planning funds, and grants. (Does not include interest).

TABLE 10-7. Total amortized capital and operational costs, West Sound Basins

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	4.6	4.3	3.3
Municipal treatment	5.1	5.6	3.5
Municipal sewers	19.0	20.7	13.0
Recreation	2.4	4.2	2.0
Advanced waste treatment	4.9	7.7	12.0
Sub-Total	36.0	42.5	33.8
Water quality engineering management and evaluation	0.8	0.4	0.5
Operation and maintenance	1.3	8.6	8.6
Total	38.1	51.5	42.9

Elwha-Dungeness Basins



ELWHA - DUNGENESS BASINS

INTRODUCTION

These basins are located in the counties of Jefferson and Clallam, with the greatest portion (about 75 percent) being in Clallam County. The Olympic Mountains, together with their outlying foothills, occupy most of the region.

The major watercourses of these basins are the Elwha and the Dungeness Rivers. The Elwha River is about 40 miles long from headwaters near Mt. Olympus to its outlet in the Strait; it drains 321 square miles in the western portion of the basins.

The Dungeness River is about 30 miles long from its glacier-fed headwaters between Mt. Deception (7,788 feet) and Mt. Constance (7,743 feet) to its confluence with the Strait. It flows northward through mountainous areas draining some 198 square miles of the basins' eastern portion. The river contains several sizeable tributaries such as Canyon Creek, Gray Wolfe, and Silver Creek. The Dungeness River is an important spawning stream for anadromous fish, and a salmon hatchery is located on the river near Sequim.

The area between the Elwha and the Dungeness Rivers is drained by many short, swift streams, of which Morse Creek is the major one.

Both natural and man-made lakes are found here, containing a total surface area of 1,400 acres. The three of the largest ones are on the Elwha, and include two reservoirs: Lake Aldwell (321 acres) and Lake Mills (451 acres). The other large lake is Lake Sutherland (361 acres), which is in a narrow basin near the foot of Mt. Storm King. The remaining surface area is made up of smaller lakes located in the lowlands and cradled high in the alpine areas.

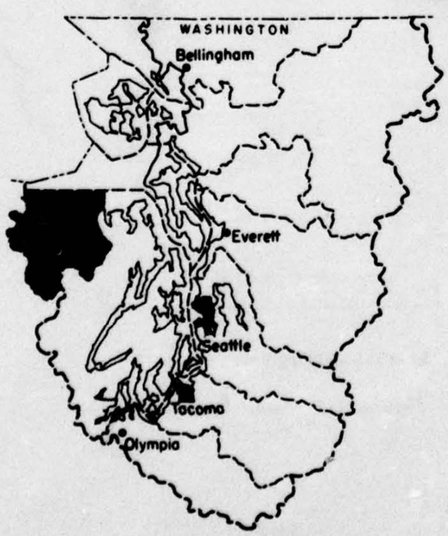


FIGURE 11-1. Location of the basins.

The marine water area consists of approximately 30 miles of shoreline, paralleling the Strait of Juan de Fuca, and encompasses 107 square miles of the surface area. The major waterbodies are New Dungeness Bay, Port Angeles Harbor, and a portion of Fresh Water Bay. The Strait of Juan de Fuca is one of the two channels–the Strait of Georgia being the other–connecting Puget Sound with the Pacific Ocean.

The soils of the flood plains consist of gravelly sands, sands, and gravelly sandy loams in the upper reaches and adjacent to the streams, becoming progressively finer textured to fine sandy loams, silt loams, and silty clay loams on the lower reaches and alluvial fan areas. Most of the glacial plain terrace soils are gravelly sandy loams, gravelly loams, and clay loams 18-40 inches deep, over slowly permeable dense, gravelly loam and gravelly clay basal till. The upland soils consist of stony loams, gravelly loams, and gravelly clay loams ranging from less than one foot to five feet and more in depth over bedrock.

The Elwha-Dungeness Basins contain 448,000 acres of land and inland water. Forest lands pre-

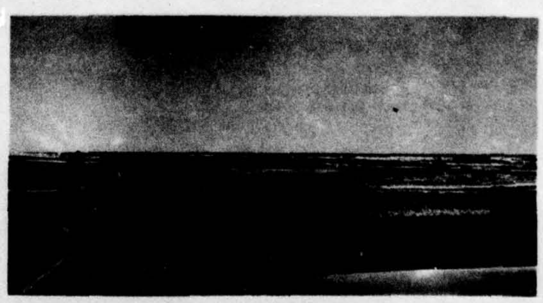
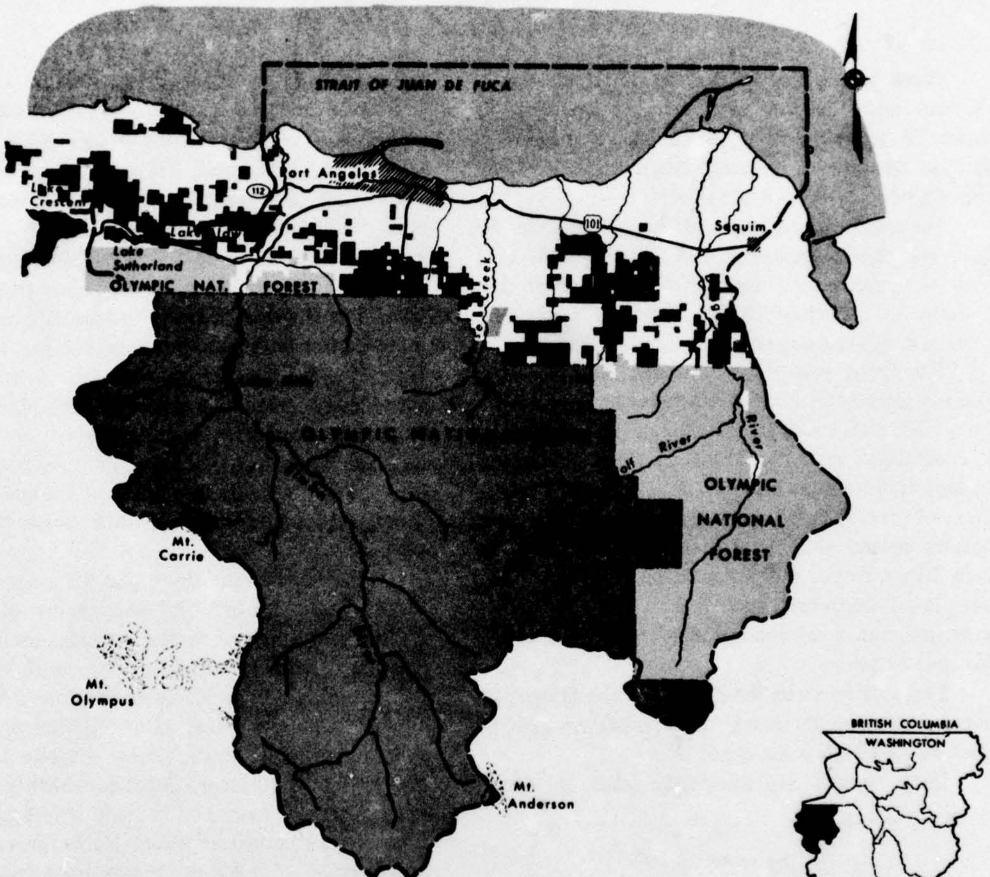


PHOTO 11-1. The shoreline consists of many fine sand and gravel beaches.



LEGEND

- U.S. FOREST SERVICE
- STATE DEPARTMENT OF NATURAL RESOURCES
- NATIONAL PARK SERVICE
- MILITARY RESERVATION
- CITIES

Scale in Miles
5 0 5 10

ELWHA-DUNGENESS BASINS

Figure 11-2 Land Ownership

dominate, accounting for 78 percent of the total. More than three-fourths of the basins' total land area is held in Federal ownership.

About 28,500 people (1967 estimate) live in the Elwha and Dungeness Basins. The two major population centers are Port Angeles with 15,800 persons in 1967 and Sequim with 1,450. Most settlement has occurred along the narrow coastal area. The more rugged and inaccessible southern part remains barren of people due to its national park status.

The economy here rests primarily on wood manufacturing firms, government, trade (wholesale and retail), and agriculture.

PHOTO 11-2. The Sequim-Dungeness area is devoted chiefly to agricultural activities.

Timber supplies from private lands and the Olympic National Forest provide raw material for forest products industries at Port Angeles, Sequim, and at unincorporated Carlsborg. Paper and pulp production has become the largest industry and is, today, the backbone of the area's economy. Lumber and pulp mills at Port Angeles, and sawmills at Sequim and Carlsborg help sustain the local economy and provide seasonal employment for part time farmers.

Port Angeles, county seat of Clallam County, serves as the principal commercial center. Industrial plants line the water's edge. There are 56 manufacturing firms here which contribute to the commercial importance of Port Angeles.

Ediz Hook, a narrow split of sand, curves into the Strait and protects Port Angeles Harbor, coastwise, and ocean freighters load and unload in this harbor which is the first port of entry for ships entering into Puget Sound.

The Sequim-Dungeness area is the agricultural hub of the basins. Dairying and livestock are the primary farm enterprises, but some crops are grown. Hay and pasture crops, grain, berries, and seed crops make up the major land use of the irrigable areas. The town of Sequim is the trade center for the surrounding fertile agricultural area.

Tourism is a rapidly growing industry due to its wealth of great scenic and recreation assets. Olympic National Park is a big attraction for recreationists. Thus, numerous business establishments have been developed to furnish services or sell directly to the tourist consumer.

The favorable climate, coupled with an abundance of natural attractions, is causing new land developments, aimed at developing the area into a retirement and tourist-vacation center for the State of Washington. Resorts, recreation homes, and retirement communities contribute to making this basin an important tourist and retirement center.

PRESENT STATUS

WATER RESOURCES

Fresh Water

The Elwha-Dungeness Rivers are the primary water resources of the basins. Between these two river basins is Morse Creek and several smaller streams which drain a 171-square mile area. Runoff is supplied by snowpacks and rainfall originating in the vicinity of the high mountain ranges. The runoff for the entire area amounts to about 45 inches annually. During the period from 1931-1960, the average annual discharge of the Elwha River was 1,500 cfs, recorded at the McDonald Bridge near Port Angeles. Variations in annual runoff in this same period included a low of 859 cfs for the 1944 water year, and a high of 2,050 cfs for the 1954 water year.

The Dungeness River has less than half the unit runoff of the Elwha which reflects its lower elevation and its general location in the "rain shadow" of the Olympic Peninsula. Records for the Dungeness show an annual average of about 382 cfs during the 30-year period from 1931 to 1960. The minimum recorded discharge at the USGS stream gage near Sequim was 200 cfs during the 1944 water year, and the maximum was 549 cfs in 1954.

These two rivers share similar seasonal runoff variations. Flows in both the Elwha and Dungeness peak during the winter period of high precipitation, and again in late spring or early summer during a combination of spring rains and snowmelt. Generally, the greatest monthly flows occur in May and June. By contrast, winter flows are more variable and are often characterized by sharp rises due to storms.

Both the Elwha and Dungeness exhibit mini mum flows during the summer when precipitation is least and snowpacks are depleted. Following the spring rains and the snowmelt peak, streamflow recedes to minimum base flow, usually by the end of September. All of the smaller tributaries to the Strait of Juan de Fuca–like Morse, Siebert, and McDonald Creeks–have extremely low flows during the summer, because their watersheds store little snow and receive small amounts of precipitation.

A low-flow frequency analysis has been made of the Elwha and the Dungeness based on an 18-year period from April 1, 1946 to March 31, 1964. The 7-day and 30-day low flows that may be expected to occur on these rivers for a recurrence interval of ten years are shown in Table 11-1.

TABLE 11-1. Low flow frequency—10-year recurrence interval—Elwha-Dungeness Basins.

Stations	7-Day Low Flow cfs	30-Day Low Flow cfs
Elwha River at McDonald Bridge near Port Angeles, Washington	300	375
Dungeness River near Sequim, Washington	95	109

Source: Appendix III: Hydrology & Natural Environment.

There are two dams and storage reservoirs on the Elwha River. This river has been partly regulated at Lake Aldwell since 1911 and at Glines Canyon Dam (Lake Mills) since 1927. These two private power developments have a combined total storage of 69,000 acre-feet. Their combined active storage of 29,000 acre-feet is used solely to meet power demands. No storage or minimum flow releases are established to augment low flows for fish enhancement. Agreements do exist, however, which guarantee 30 cfs below the city of Port Angeles diversion dam. This amount of water cannot be considered as an enhancement to the fishery of the Elwha River. No reservoir exists on the Dungeness River.

Plentiful supplies of ground water can be found in several mountainous and lowland places of the Elwha and Dungeness Basins. The most productive lowland aquifers are coarse sedimentary zones of Quaternary deposits, which are continuous over about 90 square miles. Virtually all of the ground water in the lowlands is derived from sands and gravels deposited by the northward flowing streams or as glacial outwash. Generally, this material is permeable enough to allow moderate yields of ground water.

Natural precipitation is the chief source of ground water recharge to the aquifers. Runoff from the Olympic Mountains may also contribute substantial amounts of recharge, as the annual precipitation in the Sequim-Dungeness area is low, but the ground water supply is quite abundant. Another source of recharge is directly from irrigation, which has caused a rise in the water table of as much as three feet in some areas during the summer months.

The amount of natural recharge to aquifers in the lowlands may be as much as 10,000 acre-feet per year. Probably no more than one-half of this recharge can be intercepted by wells, owing to the steep hydraulic gradients which often exceed 100 feet per mile.

Marine Water

Large volumes of tidal flows pass through the strait and largely dominate the marine water circulation.

Port Angeles Harbor is partially enclosed by Ediz Hook, a sandspit fingering three miles into the Strait. Depths in the southern half of the harbor are less than 60 feet, while in the northern half depths to 192 feet occur.

Currents in Port Angeles Harbor consist of a dominant eddy motion, generated by currents in the adjacent Strait of Juan de Fuca, superimposed upon weak tidal filling and emptying currents. The eddy develops near between Ediz Hook and Dungeness Spit and, in general, transports water alongshore in the direction opposite to main currents in the Strait.

Due to interaction and resonance effects in Puget Sound, flood and ebb currents in the Strait are not necessarily in phase with their respective counterparts of rising and falling tide levels at Port Angeles. Thus, the harbor may either fill or empty coincident with flood or ebb current in the Strait.

Net circulation of surface waters in the Port Angeles area is characterized by:

1. A net anticlockwise circulation within Port Angeles Harbor, due to predominance of northside flood and southside ebb motion.

2. A net ebb-direction transport in the Strait of Juan de Fuca of about two miles per day, due to seaward movement of freshwater land drainage.

3. A net eastward drift alongshore between Port Angeles Harbor and Dungeness Spit, due to eddy movement associated with net ebb-direction transport in the Strait.

The main effects of net circulation on waste distribution in the Port Angeles area are the general restriction of wastes to the southern portion of the harbor, the movement of some wastes eastward alongshore toward Dungeness Spit, and their eventual transport seaward once dispersed into the Strait.

WATER QUALITY

Fresh Water

Water quality of the Elwha-Dungeness Rivers has been measured on a monthly basis from July 1959 to July 1960, and then quarterly thereafter to 1966. The following discussion is based on this data gathered from monitoring stations located on the Elwha at McDonald Bridge near Port Angeles and on the Dungeness near Sequim.

Chemical–Concentrations of total dissolved mineral solids for the river and streams rarely exceed 100 mg/l and they contain soft water most of the time.

Dissolved oxygen concentrations throughout the length of these rivers are near saturation. DO concentrations on the Elwha have ranged from a low recorded value of 10.0 mg/l to a high of 14.1 mg/l. The DO concentrations on the Dungeness have ranged from a minimum value of 8.5 mg/l to 13.5 mg/l.

Seasonal changes in all dissolved constituents occur to a small extent. The Dungeness River is slightly higher in hardness and magnesium over all seasons of the year than the Elwha River. The Elwha River carries a higher concentration of sulfate.

Nitrate values of record are less than 0.30 mg/l for the Elwha River and less than 0.60 mg/l for the Dungeness. All samples since 1960 have shown that the Dungeness River in all seasons has nitrate values twice as high as the Elwha, and in regard to this chemical parameter, the rivers are not basically similar.

Phosphate samples for the Elwha River are less than 0.11 mg/l and less than 0.06 mg/l for the Dungeness River. All seasons show that the concentration of phosphate in the Elwha River is twice as great as that in the Dungeness River.

Both rivers may be characterized as low in nutrients.

Bacteriological–The sanitary quality of these streams is generally excellent. Data indicate that they have low MPN values of coliform bacteria, usually less than 100. On the Elwha, the MPN ranges from a low of 0 to maximum value of 430. The MPN values on the Dungeness range from 0 to 230.

Table 11-3 summarizes coliform concentrations obtained from basic data sampling.

TABLE 11-2. Surface water quality–Elwha-Dungeness Basins

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Sulfate (SO_4) (mg/l)	Chloride (Cl) (mg/l)	Fluoride (F) (mg/l)	Nitrate (NO_3) (mg/l)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4) (mg/l)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen (mg/l)	Oxygen saturation (%)	Total (mg/l)	Noncarbonate (mg/l)	Coliform (MPN)
ELWHA RIVER NEAR PORT ANGELES																					**JULY 1959 THROUGH 1966**						
Maximum	6,500	67	16.0	1.7	2.3	0.6	51	0	9.2	1.0	0.3	0.3	106	0.11	...	7.8	0.62	0.03	8.0	10	60	15.5	14.1	116	46	6	430
Mean	...	54	13.4	1.0	1.8	0.2	41	0	7.5	0.7	0.1	0.1	86	0.02	...	6.1	0.15	0.01	...	...	...	9.2	11.6	104	38	4	23
Minimum	346	42	10.0	0.1	1.2	0.0	32	0	4.9	0.0	0.0	0.0	63	0.00	...	3.0	0.00	0.00	6.4	0	0	3.2	10.0	95	29	2	0
Number	25	28	28	28	28	28	28	15	28	28	28	28	28	27	...	28	27	11	28	28	14	29	27	27	28	28	29
DUNGENESS RIVER NEAR SEQUIM																					**JULY 1959 THROUGH 1966**						
Maximum	1,300	94	23.0	3.9	4.1	0.6	79	0	10.0	2.2	0.2	0.6	152	0.06	...	14.0	4.40	0.04	7.9	10	65	16.1	13.5	114	69	5	230
Mean	...	70	16.9	2.3	2.7	0.3	60	0	7.2	1.1	0.1	0.2	115	0.01	...	6.5	0.45	0.01	...	...	...	9.2	11.2	101	52	2	42
Minimum	102	50	12.0	1.2	1.6	0.0	44	0	4.4	0.2	0.0	0.0	80	0.00	...	3.0	0.01	0.00	6.3	0	0	2.4	8.5	87	37	0	0
Number	25	29	29	29	29	29	29	16	29	29	29	29	29	27	...	29	27	12	29	29	10	29	27	27	29	29	29

TABLE 11-3. Summary of coliform concentrations, Elwha-Dungeness Basins

Watercourse	MPN/100 mls: Less Than 240 — No. of Samples	Less Than 240 — % of Total No.	240-1,000 — No. of Samples	240-1,000 — % of Total No.	1,000-2,400 — No. of Samples	1,000-2,400 — % of Total No.	Greater Than 2,400 — No. of Samples	Greater Than 2,400 — % of Total No.
Elwha River	27	96	1	4	0	0	0	0
Dungeness River	29	100	0	0	0	0	0	0

Source: Washington Water Pollution Control Commission

Physical—Maximum temperatures of both streams—Elwha and Dungeness—are generally low in comparison to other streams in the Puget Sound Area. Temperatures on the Elwha have reached a maximum recorded value of 59.9°F (15.5°C). A maximum of 61°F (16.1°C) has been recorded on the Dungeness River. The Elwha is generally 0.9°F to 4°F warmer during most months. This warmer temperature may be, in part, attributed to stabilizing effects of Lake Mills, a power reservoir located above the Port Angeles station.

The lower maximum temperatures of these two streams are due to the predominantly high altitude and northern latitude of their watersheds. These streams are also among the few in the Puget Sound Area that are north-south oriented, and thus experience less exposure to solar radiation than east-west oriented rivers.

Stream-borne sediment is generally not excessive in the basins due to the stony and shallow soils at high elevations and to the profuse cover of vegetation which prevents excessive soil erosion. Some sediment problems do occur, but they are usually local in nature, resulting from construction, logging, or farming operations. The Elwha River transports about 25,000 tons of sediment during a year of normal streamflow. In contrast, the Dungeness River transports less than 1,000 tons of sediment in an average year. Suspended sediment concentration in most streams of the basins is generally less than 20 mg/l.

The average turbidity for the Elwha was 12 JTU and the Dungeness 7 JTU. The maximum turbidity observed was 65 JTU for the Dungeness and 60 JTU for the Elwha. Color values are equally low, ranging from 0-15 units for the Dungeness and 0-10 units for the Elwha. The average color value for both rivers is well below standard of 15 for color, the recognized standard for drinking water.

Marine Water

Water of oceanic type (below 328 feet) in the Strait of Juan de Fuca varies in salinity from a winter minimum of 32.3 o/oo to a summer maximum of 33.9 o/oo. The temperature of this deep water will vary from a winter high of 47.1°F (8.4°C) to a summer low of 43.3°F (6.3°C) with corresponding oxygen contents of 7 mg/1 and 3 mg/1. The surface waters exhibit an average maximum salinity of 31.6 o/oo in late summer and a minimum of 30.8 o/oo in late winter. The corresponding surface temperatures are 52.2°F (11.2°C) and 45.7°F (7.6°C) and the oxygen values for the same time are 6.4 mg/1 and 11.0 mg/1.

During the summer months phosphate values of the surface water slowly increase from a low of 0.42 mg/l to an average of about 0.15 mg/l.

Minimum amounts of phosphates at all depths are observed in winter and are usually above 0.18 mg/l.

The waterfront area of the Port Angeles Harbor is significantly contaminated in an area roughly two miles long on the southern and western sides.

Water movement in the Strait is relatively rapid; and, although there is a significant natural dilution and dispersion of SWL (sulfite waste liquor) is not achieved at all times. Float studies have indicated that on flooding tides SWL movement is to the west and north, and significant concentrations of SWL in the surface layer off Ediz Hook have been detected.

Waste disposal from the Port Angeles Harbor may be influenced by the natural phenomenon of upwelling deep ocean waters which are deficient in dissolved oxygen.

Water circulation within Port Angeles Harbor is specifically complicated by the existence of Ediz Hook where the physical relationship of land and water movements tend to create pooling conditions.

The southern portions of the Elwha-Dungeness Basins are within the boundaries of the Olympic National Park.

Three pulp and paper mills discharge raw wastes into harbor waters. The southern one-quarter of the harbor is adversely influenced by municipal and industrial wastes, and the northern three-fourths of the harbor shows characteristics equivalent to water found off-shore in the Strait of Juan de Fuca.

Average surface SWL concentrations in the harbor exceed 15 mg/l essentially over the entire area and about 50 mg/l in about 50 percent of the area. Serious water quality degradation–SWL values above 800 mg/l, DO approaching zero, PH depressed, and presence of toxic sulfides–occurs in the dockfront areas near each of the three pulp mills.

SOURCES OF WASTE

The municipal and industrial wasteload generated in the Elwha-Dungeness Basins approximates over three million population equivalents, of which less than one percent is presently removed by waste treatment before being discharged to marine waters. The area receiving the largest quantity of waste in relation to the total basins is Port Angeles Harbor.

The quantities and general location of waste production and discharges in the basins are shown in Figure 11-2. Sources of waste are summarized in Table 11-4. Upon completion of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, the strength of discharged wastes will be substantially reduced.

Fresh Water

There are no known discharges to fresh waters in the basins.

Marine Water

The principal location of pollution centers about the Port Angeles area are where numerous industrial plants line the water's edge. Here both municipal and industrial wastes are discharged into the harbor water.

The two major sources of pulp mill wastes in the Port Angeles area are Rayonier Inc. sulfite pulp

TABLE 11-4. Summary of municipal and industrial wastes, Elwha-Dungeness Basins

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Strait of Juan de Fuca						
Paper & allied (Crown Z.)	--	145,000	--	None	145,000	--
Port Angeles						
Port Angeles	15,300	22,800	--	None	22,800	--
Paper & allied (Fiberboard)	--	264,000	--	None	264,000	--
Paper & allied (Rayonier)	--	2,820,000	--	None	2,820,000	--
Lumber / wood (Pen Ply)	--	2,400	--	None	2,400	--
Food & kindred	--	2,500	--	None	2,500	--
U. S. Coast Guard Station	200	200	--	Land	--	--
Morse Creek						
Hart of the Hills	--	100	--	Secondary	20	--
Sequim Bay						
Sequim	1,000	1,250	--	Secondary	250	--
Sequim Bay State Park	--	240	--	Primary	150	--
TOTAL[1,2]	16,500	3,258,600	--	--	3,257,200	--
Municipal	--	24,600	--	--	23,200	--
Industrial	--	3,234,000	--	--	3,234,000	--

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

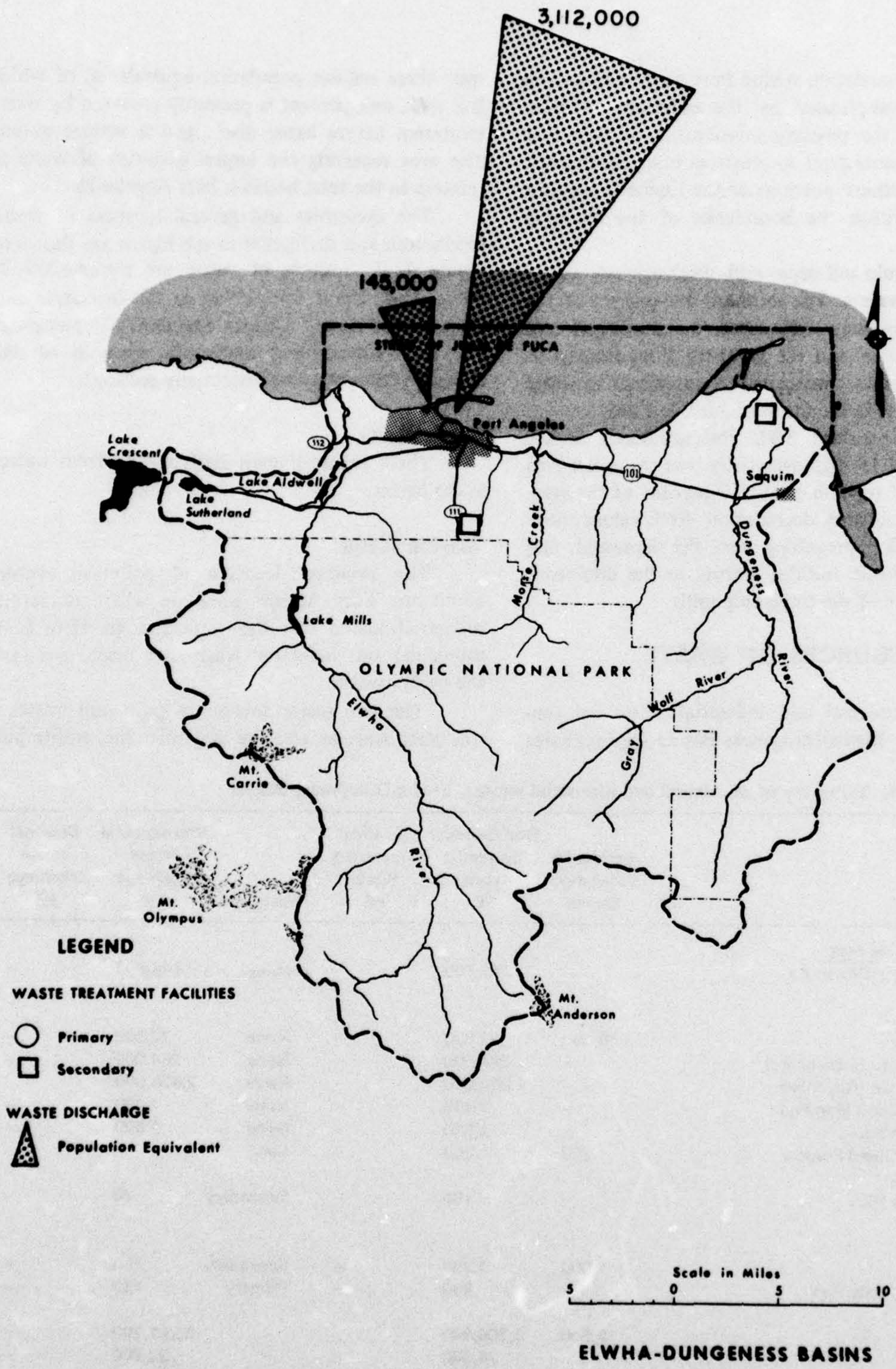


FIGURE 11-3. Location of major waste discharges

mill and Fibreboard Paper Products Corp. sulfite pulp and board mill. Both mills discharge untreated process wastes directly into the harbor.

The Rayonier mill contributes over 90 percent of the total discharged wasteload to the harbor. This mill produces pulp by the calcium-base sulfite process and averages 467 tons of pulp per day. On an average day, Rayonier, Inc. discharges 36 million gallons of wastes, containing 235 tons of BOD_5 (2,820,000 PE) and 1,157 tons of solids, into the harbor waters.

PHOTO 11-3. Rayonier Pulp and Paper Mill is a source of water pollution in the basins.

The Fibreboard mill, located near the west end of Port Angeles Harbor, produces about 191 tons per day of bleached sulfite and groundwood pulp and board stock for packaging and wallboard. This mill discharges, per day, a waste volume totaling over four million gallons, containing 22 tons of BOD_5 (264,000 PE) and 0.2 tons of solids.

The city of Port Angeles discharges, after primary treatment, domestic waste effluent from a population of 15,300 into Port Angeles Harbor. The average daily wasteload discharged by the city is estimated at 15,000 PE.

The U.S. Coast Guard Air Station at the end of Ediz Hook discharges domestic wastes into four septic tanks and thence into drainfields on the Hook. These facilities are designed to handle wastes from over 225 persons, and they are considered adequate by the Washington State Health Department.

The Crown Zellerbach mill, located at the inner end of the harbor, has a daily production of about 400 tons of pulp and 480 tons of newsprint and telephone directory paper. This mill discharges, per day, an estimated waste volume of about nine million gallons, containing 12 tons of BOD_5 (145,000 PE) and 47 tons of solids. directly outside the harbor. Generally, these wastes are dispersed seaward by Strait currents and thus do not affect the main Port Angeles area.

The combined wasteload from all waste sources in the basins exceeds 3,200,000 PE. The Rayonier and Fibreboard mills are the principal sources, accounting for about 95 percent of the daily wasteload.

PHOTO 11-4. The Crown Zellerbach Mill discharges pulping wastes directly to the Strait of Juan de Fuca.

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of fresh and marine waters in the Elwha-Dungeness Basins are summarized in the table below, which focuses on the principal watercourses and problem areas in the basins. The table also gives the State water quality classification for each watercourse which defines the type of water usage to be protected in the area.

The Elwha and Dungeness Rivers are used for the spawning and rearing of anadromous fish. The Pacific salmon and anadromous trout species to be found in the area are chinook, coho, pink, and chum salmon; steelhead and searun cutthroat trout; and searun Dolly Varden. These fish contribute significantly to recreation use by providing sport for both the local residents and for the many tourists and vacationers visiting the basins. The principal species of shellfish and other marine invertebrate in the area are the Dungeness crab, littleneck and softshell clam, and octopus. These are harvested by both sport and commercial methods.

Salmon produced in the basins contribute to fisheries in the Strait of Juan de Fuca and Upper Puget Sound. The average annual contribution to these fisheries during the period 1956 to 1965 was 195,810 salmon.

The marine waters support a light to moderate commercial fishery for salmon. A few gill-net vessels and some seiners ply these waters, principally offshore near the Canadian-United States border.

Saltwater sport fishing for salmon is very popular, as reflected by the nearly 90,000 angler-days logged in the adjacent waters in 1965. Popular fishing sites include Dungeness Spit, Green Point (at mouth of Siebert Creek), and Ediz Hook.

Based on 1966 survey data, 53,600 man-days of effort were spent fishing in the lakes and ponds of the basins; and a total harvest of 134,700 trout and 15,600 other game fish was realized. In the streams, 16,300 man-days were spent with a harvest of almost 45,000 trout.[1] About 42,000 man-days were spent fishing for steelhead and searun cutthroat trout and over 5,000 steelhead and 10,100 searun cutthroat trout were harvested.

The Elwha-Dungeness Basins rank tenth among basins in the Puget Sound in demand for outdoor recreation. Water-related activities were estimated to be 650,000 recreation days in 1960 and are expected to double by 1980. Picnicking, fishing, and swimming are the three most popular activities in the basins.

The main recreation attractions are the saltwater, rivers and streams, and the Olympic mountains. Other outstanding natural areas include Ediz Hook, Hurricane Ridge, the Tyler peak scenic area, and the Dungeness Spit which is one of the finest saltwater recreation resources within the Puget Sound. In 1964, there were 15 publicly administered outdoor recreation areas within the basins.

The Elwha and Dungeness Rivers are the primary water suppliers of the basins. The total average daily water use is over 55 mgd, of which only 0.8 mgd are furnished by groundwater. Morse Creek supplies Port Angeles with 3.8 mgd, serving a pop-

[1] Includes catch of all salmonids

TABLE 11-5. Water uses and quality objectives, Elwha-Dungeness Basins

Use Intensity
L—Light
M—Medium
H—Heavy

Watercourse	Assigned Class	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Strait of Juan de Fuca and Puget Sound	AA			H	H				M	H	H	H	L		L	H	H			M		H	M	
Port Angeles Harbor	A			L	H	L			L	L			L		M	M	H			L		L	H	
Dungeness River mouth to Canyon Creek	A			H	H	H							H		M	H	H			M		H		
Dungeness River and tributaries from Canyon Creek to Headwaters	AA[1]			H	H	H							H		L	M	H							
Elwha River and tributaries	AA[1]			H	H	H							H		L	H	H			H	H			H

[1]Assigned class tentative pending hearing on water quality standards for intrastate waters.

ulation of 15,700. Industry, however, is the big water user, accounting for about 90 percent of the total daily requirement for the basins.

Navigation at Port Angeles amounted to 530,279 tons of foreign and domestic coastwise traffic in 1963. The harbor is the first port of entry for ships coming into Puget Sound. In the same year, the domestic internal traffic was 650,547 tons.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, the water quality class for most watercourses in the Elwha-Dungeness Basins is either excellent (A) or extraordinary (AA) with the objective being to meet or exceed the quality requirements for all uses.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

Present water quality control needs are on marine waters, where pulping and municipal waste discharges are causing unsatisfactory water quality conditions. There are no major discharges of waste to fresh waters in these basins. Generally, clean water prevails in the rivers and streams from source to their final rendezvous with the Strait.

The State-Federal water quality standards for coliform, DO, temperature, pH, turbidity, toxic or deleterious, and aesthetics are not being met in the Port Angeles Harbor. Pulp mills are discharging high waste concentrations, creating sludge deposits, and continuing to degrade the quality of marine waters surrounding each mill, the city waterfront, the harbor, and the shorelands to the east.

These pulp wastes are damaging to marine life in the area. Acute damages occur within the harbor adjacent to each mill and mainly associated with the concentrated sulfite liquors and settleable solids in the mill effluents. Chronic damages occur throughout the area and are associated with dilute concentrations of sulfite waste liquors. Sludge deposits continue to seriously degrade the water quality. Floating sludge, buoyed to the surface by gases of decomposition and having an odor of hydrogen sulfide, has been frequently observed in the harbor. These conditions are incompatible with marine life and interfere with other legitimate water uses.

The waste assimilation capacity of the Port Angeles area is seriously limited by the presence of a large, slow moving, predominantly anti-clockwise eddy circulation of water between the harbor and Dungeness Spit. This eddy tends to confine mill wastes to shallower waters along shore before eventually dispersing them to the Strait of Juan de Fuca. This is resulting in waste concentrations that are seriously damaging to the marine environment. Further, currents are too weak to scour and remove the extensive sludgebed formed at the western end of the harbor. Thus, the hydraulic characteristics of the Port Angeles Harbor-Dungeness Spit eddy system are not adequate to accept the large volumes of strong untreated pulp and paper processing wastes without resulting in pollution of the marine waters.

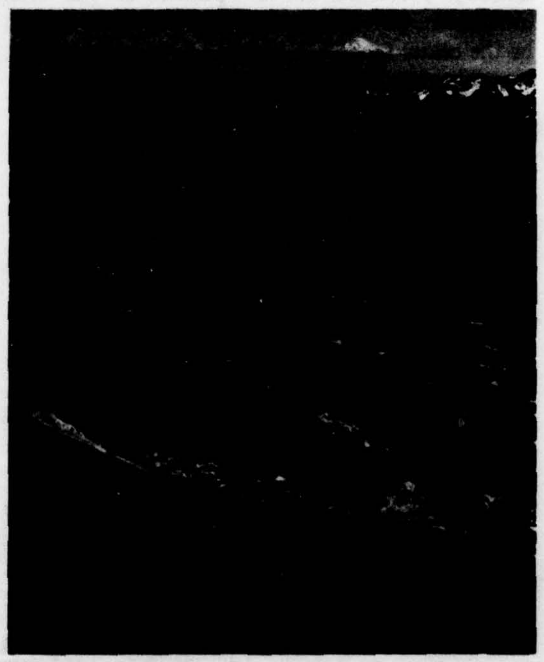


PHOTO 11-5. The major water quality problems are concentrated in Port Angeles Harbor, where pulping and domestic waste discharges are degrading the marine waters.

FUTURE NEEDS

The principal factors expected to affect future fresh and marine water quality in the Elwha-Dungeness Basins will be the growth in population, industry, agricultural production, and recreation. As this growth occurs, the production of wastes and water quality problems will likewise increase. Forecasts on the quantities and location of wastes are the basis for determining the means to preserve water quality and to protect the water uses of any given watercourse.

The population of 28,500 persons in the Elwha-Dungeness Basins is projected to increase about 5 percent by 1980 and 45 percent by 2020. Port Angeles will probably remain the fastest growing and largest municipality.

Production for major water using industries in the Elwha-Dungeness Basins is expected to more than double from 1980 to 2020 in terms of value added.

By 2020, paper and allied industries are expected to account for 62 percent of the production for major water using industries. In 1965, this industry accounted for 57 percent of the total production. Port Angeles will probably continue to be the center for this industry.

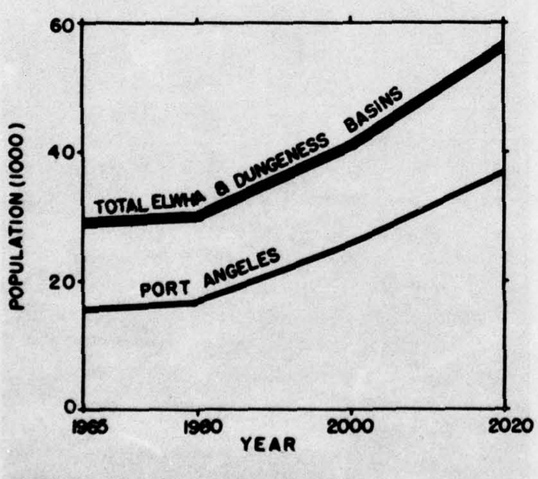


FIGURE 11-4. Population growth.

Food and kindred industries are forecast to gain in importance by increasing from over 6 percent in 1965 to over 28 percent in 2020 of the total value added for major water using industries. Food processing growth is also expected to concentrate in the Port Angeles area.

Lumber and wood production should remain about the same with very little increase. Lumber and wood products manufacturing are now located mainly in Port Angeles.

About 1.3 million recreation days are forecast for the basins by 1980—double the 1960 level. Intense recreation is expected to occur along the marine waters, Elwha and Dungeness Rivers and tributaries, and in the mountains and forests of the Olympic National Park.

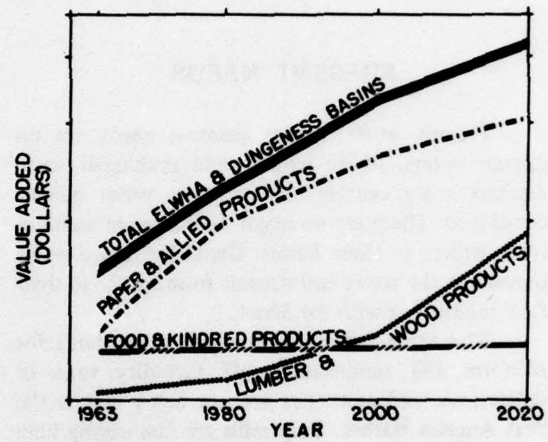


FIGURE 11-5. Relative growth for major water using industries.

Figure 11-6 shows that the paper and allied industries are projected to produce about 2,650,000 PE, accounting for 99 percent of the raw waste produced in the basins in 1980.

Municipalities are expected to form the second largest raw waste producer.

Food processing industries are expected to produce 4,000 PE in 1980 which is double the 1965 amount of 2,000 PE.

Major municipal and industrial raw waste producers are expected to remain located in Port Angeles.

Recreational raw waste will increase 52 percent, from 6,100 PE in 1965 to 9,300 PE in 1980.

Livestock handling poses an agricultural threat to the quality of water in the future. The basins rank second highest in the Puget Sound in number of cattle per acre of cropland. Some of these animal wastes wash into streams during heavy rainstorms. This water pollution problem will intensify as the total number and density of cattle increase.

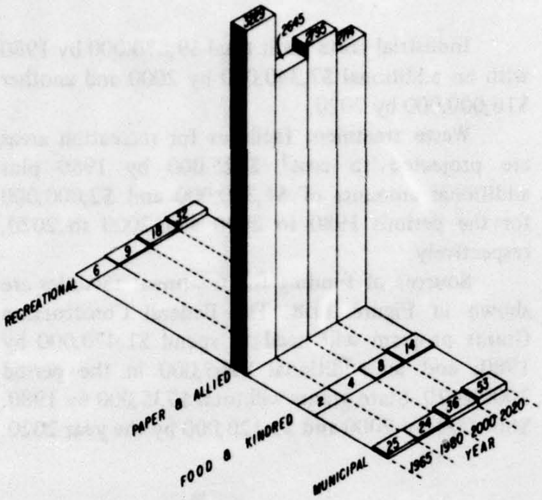


FIGURE 11-6. Projected municipal and industrial wastes for the Elwha-Dungeness Basins (thousands of PE).

The primary need of the future is to manage these large, expected wasteloads that are generated in the basins. The major objectives will be the same—to protect the various uses of water and to preserve the outstanding environment. The means and management programs necessary to prevent, control, and abate future water pollution are developed in the succeeding section.

MEANS TO SATISFY NEEDS

Several elements comprise the water quality means for the Elwha-Dungeness Basins. The central and paramount one is adequate waste collection and treatment. Major aspects of the water quality control means are discussed in more detail below.

WASTE COLLECTION AND TREATMENT

Adequate pollution abatement will require significant reduction in SWL concentrations throughout the marine waters, physical removal of existing sulfide-producing sludge beds, prevention of further solids accumulation, and maintenance of tolerable levels of DO and pH in Port Angeles Harbor. These measures must be met primarily by treatment of the wastes for removal of settleable and volatile dissolved solids, rather than by changes in disposal practices. Such a plan is outlined in the Interstate Water Quality Standard's implementation plan of December 1967. The separate requirements are detailed in the implementation plan and include:

Ediz Hook (Class A Section)

1. **City of Port Angeles**—primary treatment and effluent chlorination for all domestic wastes with discharge through a deep diffuser outfall.

2. **Pen Plywood Corp.**—in-plant controls for the removal of glue wastes, and all wastes intercepted by a municipal system. Merril and Ring Western Lumber Co.—domestic wastes intercepted by a municipal system.

3. **Rayonier, Inc. and Fibreboard Paper Products Corp.**—primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound; adequate facilities for the disposal of recovered solids or sludge; a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into deeper waters to achieve maximum dilution and dispersion; removal to land by dredging of the existing sludge bed in the waterways adjacent to each mill.

Strait of Juan de Fuca

1. **Crown Zellerbach Corp.**—design and construct facilities and provide in-

plant controls similar to Rayonier and Fibreboard above; a screening lagoon for log barker effluent.

These waste collection and treatment requirements will abate water pollution in Port Angeles Harbor and the Strait. Future wasteloads are expected to occur in and around Port Angeles, Sequim, and along the Strait of Juan de Fuca. These future wastes, in most cases, can be treated by the existing system and above complex of municipal and industrial treatment facilities with adequate expansion and replacement.

Outdoor recreation is expected to become a "prime industry" in the basins. Substantial waste collection and treatment facilities will be required to serve this future growth. A few major recreation complexes are anticipated that will involve large numbers of people and generate many small satellite developments to handle the traveling public and more specialized recreation pursuits. Since most of the recreation potential will develop on Federal lands, the Federal Government will be required to provide or insure provision of most of these facilities.

A substantial continuing investment will be required to meet present and future waste collection and treatment requirements. These investment requirements are shown in Tables 11-6, 11-7 and Figure 11-7. Municipal treatment costs will be high initially in order to comply with the State Implementation Plan. The industrial sector shows an immediate rise in investment to provide adequate treatment of present wastes.

Municipal costs[1] are expected to total $3,200,000 by 1980 with an additional $1,120,000 needed by 2000 and an additional $3,300,000 by 2020

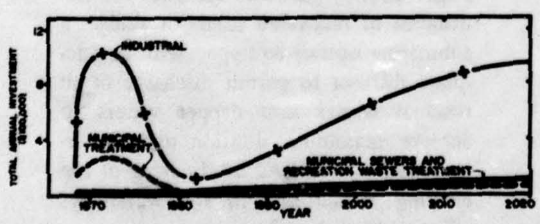


FIGURE 11-7. Relative required rates of investment for Elwha-Dungeness Basins.

Industrial costs[1] will total $9,870,000 by 1980 with an additional $7,340,000 by 2000 and another $16,000,000 by 2020.

Waste treatment facilities for recreation areas are projected to cost[1] $525,000 by 1980 plus additional amounts of $1,300,000 and $2,000,000 for the periods 1980 to 2000 and 2000 to 2020, respectively.

Sources of funding for treatment facilities are shown in Figure 11-8. The Federal Construction Grants program will need to spend $1,470,000 by 1980; and an additional $165,000 in the period 2000-2020. State grants will total $735,000 by 1980, $860,000 by 2000 and $1,120,000 by the year 2020.

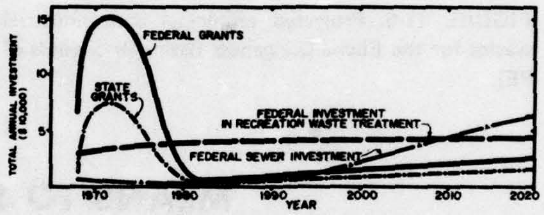


FIGURE 11-8. Government investment requirements[1] for waste collection and treatment in the Elwha-Dungeness Basins.

The Federal investment for sewer construction will total $25,500 by 1980, an additional $125,000 for the period 1980-2000 and $840,000 for the period 2000-2020. The Federal Government in waste treatment facilities for recreation areas will total $500,000 by 1980 with an additional $1,660,000 needed by the year 2020.

FLOW REQUIREMENTS

The Elwha and Dungeness Rivers flow, for the greater part of their length, through a natural sanctuary–Olympic National Park–where outdoor recreation is the primary use. Hence, waste loadings on these streams will be light and minimum flows for such other resources as fish should be sufficient to maintain desirable water quality. The proposed Intrastate Quality Standards will provide very strict effluent conditions, probably requiring advanced waste treatment.

[1] Costs are not amortized.

TABLE 11-6. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, Elwha-Dungeness Basins

	Annual Costs (Thousands of Dollars) 1967 Dollars		
	Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$161	$ 56	$ 52
Disinfection	27	9	9
Outfalls	161	56	52
Interception and sewer system			
a. Municipal	81	28	26
b. Industrial	27	9	9
Combined sewage infiltration and overflow correction	81	28	26
Advanced waste treatment in recreation areas	18	25	35
Sub-Total	$556	$211	$209
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 10	$ 7	$ 8
Evaluations—dispersion areas, ecological, productivity	15	9	10
Information system, quality control, plant operation improvement, operation research	10	6	8
Sub-Total	$ 35	$ 22	$ 26
OPERATION AND MAINTENACE[2]	$150	$345	$268
TOTALS	$741	$578	$503

[1] Annual amortized costs.

[2] Direct annual costs from appropriations, revenue, planning funds and grants. (Does not include interest).

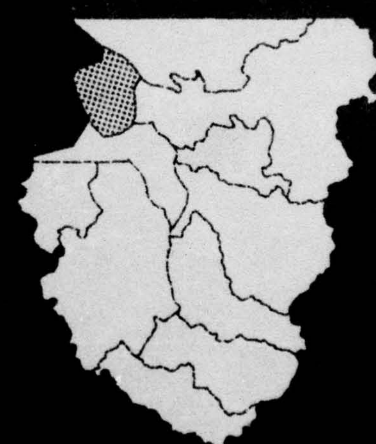
TABLE 11-7. Total amortized capital and operational costs, Elwha-Dungeness Basins

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	19.5	7.1	6.5
Municipal treatment	1.9	0.4	0.4
Municipal sewers	8.9	1.5	1.9
Recreation	1.1	1.3	0.8
Advanced waste treatment	0.9	1.3	1.8
Sub-Total	32.3	11.6	11.4
Water quality engineering management and evaluation	0.4	0.4	0.5
Operation and maintenance	1.7	6.9	5.4
Total	34.4	18.9	17.3

OTHER MEASURES

A water quality surveillance program is an essential element in any plan to maintain adequate water quality. The Washington Pollution Control Commission's existing surveillance program should be expanded to include lakes and ground-water monitoring as well as fresh and marine waters.

San Juan Islands



SAN JUAN ISLANDS

INTRODUCTION

The San Juan Islands form an archipelago of 172 islands. The surrounding waters are sheltered, the climate is mild, and there are countless protected bays and harbors.

The Islands vary in size from rocky inlets and reefs, visible at low tide, to areas of over 50 square miles. The three main islands are Orcas, San Juan and Lopez Islands.

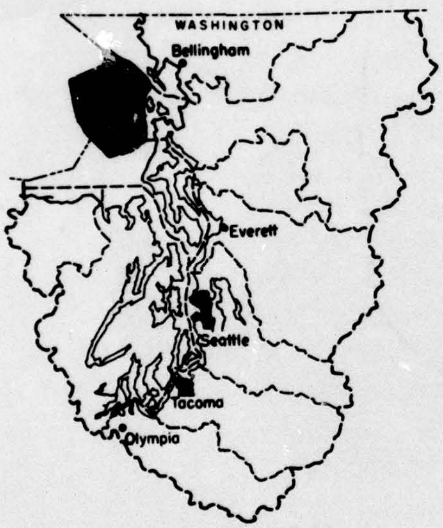


FIGURE 12-1. Location of the San Juan Islands within the Puget Sound Area.

This Island group owes its existence to the partial submergence of a range of mountains extending as a spur of the Cascades from the mainland to Vancouver Island. Orcas Island rises abruptly out of the sea to a height of 2,409 feet. It has the greatest range in elevation and the most varied relief and irregularity of shoreline. San Juan, Lopez and Shaw Islands are primarily rolling plateaus with localized hills of less than 500 feet above sea level. The maximum elevation of Waldron Island is 612 feet and of Stuart Island is 527 feet.

There are only a few streams on the Islands, most of which flow intermittently.

The major marine channels in the San Juan Islands are Haro Strait, Rosario Strait, and San Juan Channel.

The resident population of the San Juans estimated to be 2,600 in 1967, has not varied greatly since 1930. One characteristic of the Islands is a marked summer increase in numbers of persons visiting the area, living in vacation homes, or staying at resorts each year. A summertime population of 23,600 was estimated for 1965. There is little urban population, since no town or city exceeds 2,500 persons. The largest town is Friday Harbor, the only incorporated town of the islands.

The 113,000 acres that comprise the land and inland water area of the San Juans are primarily in forest (55 percent). About 90 percent of the Island's total land area is held in private ownership.

The economy of the San Juan Islands is primarily tourist-oriented. The services industry is the major industry, growing more than 60 percent since 1950. In 1960, services alone accounted for over 25 percent of the total persons employed in the islands.

Services, trade, and construction industries together employ over one-half of the area's labor

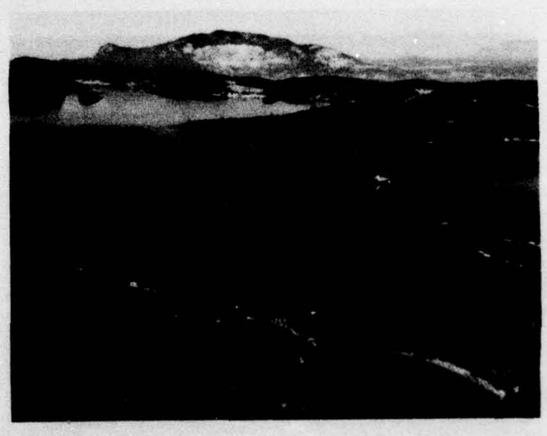
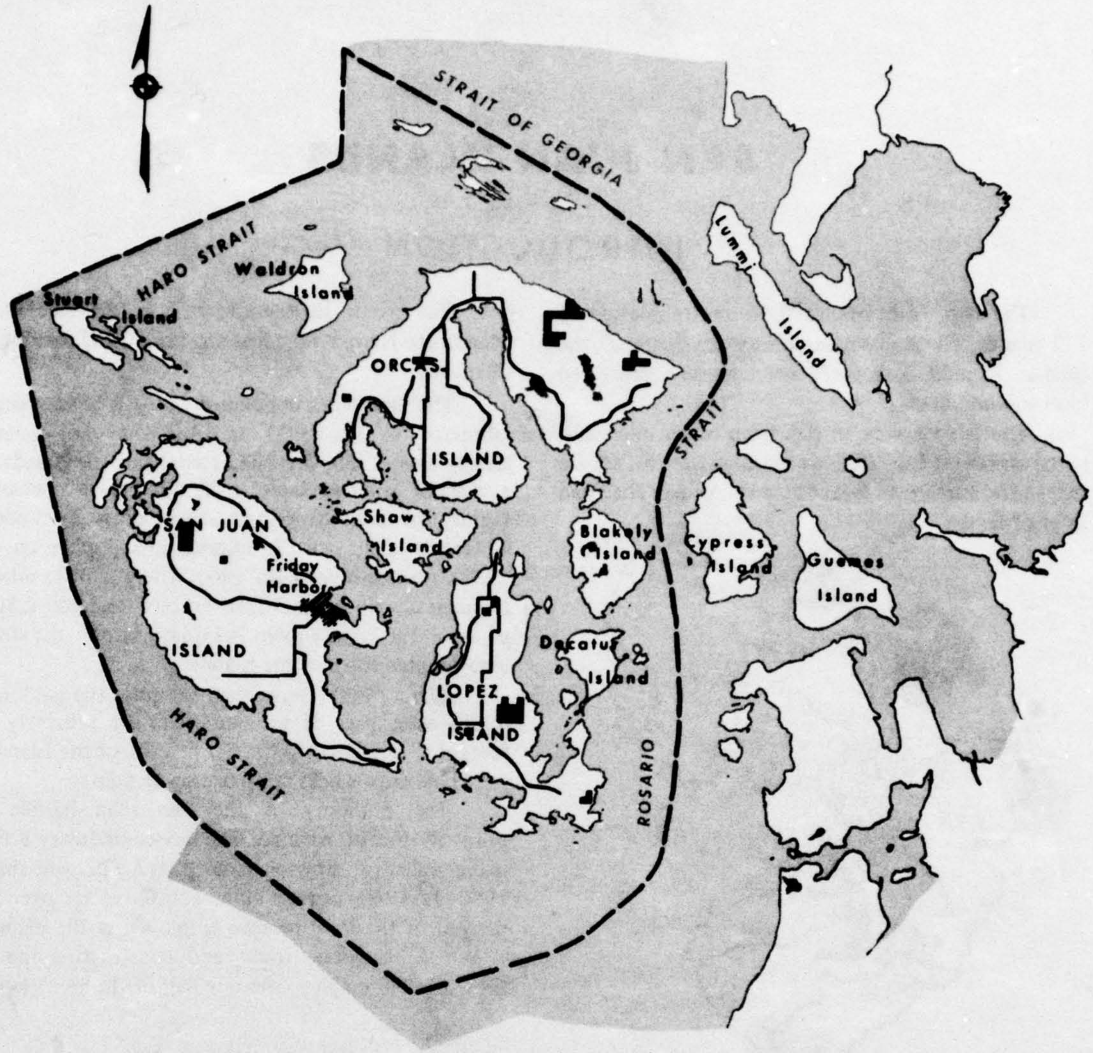


PHOTO 12-1. The natural beauty and setting of the San Juan Islands make them a unique resource to the people of Puget Sound.



LEGEND

STATE DEPARTMENT OF NATURAL RESOURCES

CITIES

Scale in Miles

5 0 5 10

SAN JUAN ISLANDS

Figure 12-2 Land Ownership

force. A substantial decline in manufacturing has occurred since 1950, especially in the number of employees in food manufacturing.

Agriculture has declined in importance. Many farm enterprises that were formerly of primary importance have disappeared; some have been converted to recreation endeavors. Today, the Islands are particularly noted for sheep raising. Much of the interior of the large Islands is used for the grazing of these animals and other livestock.

PRESENT STATUS

WATER RESOURCES

Fresh Water

Stream flow data are not available, but precipitation data indicate that the average annual runoff ranges from about 5 inches in the southerly islands to 15 inches in the north.

The small lakes and reservoirs on the Islands comprise about 1.4 square miles; reservoirs that are used for municipal and irrigation purposes contain about 1,600 acre-feet of storage. Low runoff volumes and lack of natural holding basins preclude the likelihood of future significant storage projects.

The better aquifers are in coarse zones of Quaternary sediments. Yields of wells completed in Quaternary aquifers rarely exceed 20 gpm–the largest yield recorded in the area is 50 gpm. Some wells are drilled as deep as 500 feet into the older consolidated rocks to obtain sufficient water. These aquifers generally are not capable of furnishing more than 10 gpm.

Marine Water

Haro Strait is 36.6 miles long. Water depths of 985 feet to 1215 feet are common in this channel. Rosario Strait is 29.8 miles long; it has an average depth of 198 feet with greater depths to 490 feet deep, so it does not contribute significantly to the overall circulation through the San Juan Islands. These deep channels serve as mixing areas for the waters of Georgia Strait and the Strait of Juan de Fuca.

Currents in Haro Strait are strong, often reaching 4.3 miles per hour. In Rosario Strait, the currents are in the vicinity of 3.1 miles per hour. Currents in the other channels are fairly strong with speeds up to 2.5 miles per hour being common. The direction of the currents in Haro and Rosario Strait are northerly on the flood and southerly on the ebb. A definite counter-clockwise circulation is established around the San Juan Islands.

WATER QUALITY

Fresh Water

Although specific analytical data are not available, surface water is probably similar in quality to that of ground water, as low flows of streams are supported by contributions from ground water. The sanitary quality of lakes and streams may be impaired somewhat in localized areas as a result of septic tank drainages.

The deeper ground water aquifers seem to contain the softest water; the highest known value of hardness is 179 mg/l. Contaminated water from shallow wells, caused by sewage disposal from septic tanks, has been reported locally.

Marine Water

In Haro Strait, the surface water is coldest in February with an average low of about 44.2°F (6.8°C) and a high of about 53.6°F (12°C) in July.

PHOTO 12-2. The major industry of the islands is tourism.

The highest salinities are observed in winter (31.1 o/oo) and the lowest in July (27.6 o/oo). In water below 500 feet. maximum salinity is observed in August (32.5 o/oo) in response to the high salinity water intruding into the Strait of Juan de Fuca. This deep water is also oxygen poor and phosphate rich and is the cause of low oxygen content water which may appear along the west side of San Juan Island in July or August.

The surface salinity in Rosario Strait is similar to that of Haro Strait, but the deep waters attain maximums of about 32 o/oo.

The dissolved oxygen content of the waters in the San Juans vary from a surface high of over 10 mg/l during the spring phytoplankton blooms to a low of 5.6 mg/l in early fall. On the average, waters are usually above 80 percent saturated with oxygen.

SOURCES OF WASTE

Fresh Water

Water from some of the shallow dug wells tested by the County Health Department has been found to be unsafe for human consumption. Septic tank effluent at times has been reported surfacing in the East Sound Area. Drainage conditions in the major portions of the Islands are poor for septic tank facilities.

Marine Water

The raw municipal and industrial waste load in the San Juan Islands is generated from Friday Harbor. About 800 PE are being produced daily, with an additional 2,800 PE in the tourist and canning season. This waste load is discharged to marine waters without treatment.

The quantity and general location of waste production and discharges at Friday Harbor are shown on Figure 12-3. Sources of wastes are summarized in Table 12-1. As a result of the Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, the strength of existing waste discharges will be reduced by 60 percent. These figures are shown in Table 1-9.

The sewage collected by the town of Friday Harbor is discharged into the harbor through three outfalls. Waste from several seafood canneries here are also discharged directly into the harbor.

On occasion, sewage debris is visible in some of the other harbors and yacht basins of the islands. Pleasure craft congregating in the bays, harbors, and channels impose a load of untreated wastes on the waters they use. Most pleasure craft and other vessels are not equipped to adequately handle or treat their wastes.

PHOTO 12-3. Pollution from watercraft is becoming more widespread throughout the islands.

TABLE 12-1. Summary municipal and industrial wastes, San Juan Islands

Water Course	Estimated Population Served	Non-Seasonal Untreated Waste PE	Seasonal Untreated Waste PE	Treatment	Non-Seasonal Waste Discharge PE	Seasonal Waste Discharge PE
Puget Sound Waters						
Friday Harbor	760	800	--	None	800	--
Food & kindred	--	--	1,000	None	--	1,000
Food & kindred	--	--	1,800	None	--	1,800
TOTAL [1,3]	760	800	2,800	--	800	2,800
Municipal	--	800	--	--	800	--
Industrial	--	--	2,800	--	--	2,800

[1] Figures are rounded.

[2] PE's will be reduced for all waste discharges after compliance with the Interstate and proposed Intrastate Quality Standards implementation and enforcement plan—1970-1972.

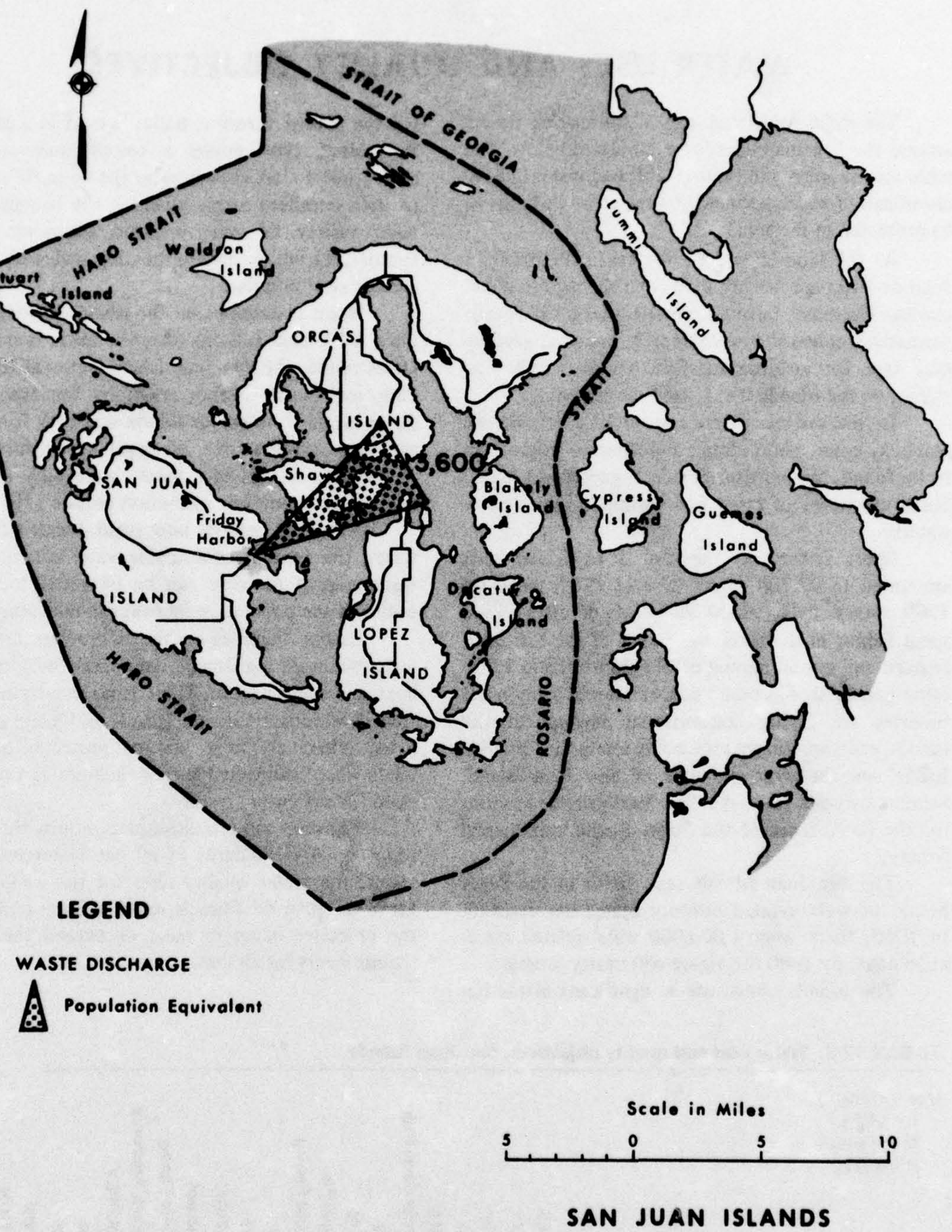


FIGURE 12-3. Location of major waste discharges

WATER USES AND QUALITY OBJECTIVES

The major beneficial uses of the marine waters around the San Juan Islands are tabulated below. The table also supplies the State-established water quality classification which defines the type of water usage to be protected in the area.

As the table shows, the waters in the Strait of Juan de Fuca are heavily used for fish migration and rearing. The small, intermittent streams on the Island themselves constitute an extremely marginal production area for anadromous fish. There is only one stream on the Islands that is used for spawning.

In the marine waters surrounding the Islands, chinook, coho, pink, chum, and sockeye salmon are to be found. Marine fish include lingcod and herring. Small quantities of crabs and shrimp occur in these waters.

Sport fishery in the San Juan Island area amounted to 97,700 angler trips in 1965. Based on 1966 survey data, 9,600 man-days of effort were spent fishing in the lakes and ponds of the San Juan Islands; and a total harvest of 37,000 trout and 3,000 other game fish was realized. Commercial salmon net fisheries are highly concentrated throughout the Islands and particularly productive along the "Salmon Banks" on the west shoreline of San Juan Island. Salmon harvests from the San Juan Islands account for the lion's share of the Puget Sound commercial fishery.

The San Juan Islands rank ninth in the Puget Sound in water-related outdoor recreation demand. In 1960, there were 1,000,000 water-related recreation days. By 1980 this figure will nearly double.

The islands constitute a significant attraction for the tourist vacation trade. Set off in a group by themselves, they posses a certain quaintness and charm not found elsewhere in the Area. In addition to their excellent scenic qualities, the Islands offer a wide variety of water-oriented recreation opportunities, of which fishing, boating and scuba diving are the most popular.

Major attractions on the islands include Moran State Park and Rosario resort-vacation complex on Orcas Island, the San Juan Island National Historical Park, and Roche Harbor resort on San Juan Island. Sucia Island is noted for its unusual rock formations and is a great source of fossil specimens for all collectors. In 1964, there were 27 publicly-administered outdoor recreation areas on the islands.

Although there is now small demand for fresh water, the amount of available water is limited. The water supply problem can be expected to become critical if the population increases in the future.

Harbor facilities on the Islands are limited to ferry landings, log dumps, and piers for local small boat and barge traffic. There is no significant industrial development on the Islands and none is anticipated. There are many natural protected bays and inlets where additional harbor facilities can be developed for any future needs.

Fisheries and recreation uses require the highest water quality standards of all raw water uses. As a result, the water quality class for the water of the Strait of Juan de Fuca is extraordinary (AA), with the objective being to meet or exceed the quality requirements for all uses.

TABLE 12-2. Water uses and quality objectives, San Juan Islands

Use Intensity
L–Light
M–Medium
H–Heavy

Watercourse	Assigned Class[1]	FISHERIES	Salmonoid	Migration	Rearing	Spawning	Warm Water Game Fish	Rearing	Spawning	Other Food Fish	Commercial Fishing	Shellfish	WILDLIFE	RECREATION	Water Contact	Boating and Fishing	Environment Aesthetics	WATER SUPPLY	Domestic	Industrial	Agricultural	NAVIGATION	LOG STORAGE & RAFTING	HYDRO POWER
Strait of Juan de Fuca and Puget Sound	AA			H	H					H	H	H	L		L	H	H			M		H	M	

[1] See Table 1-5.

PRESENT AND FUTURE NEEDS

PRESENT NEEDS

The rural population relies primarily on septic tanks or other individual means for sewage disposal. But soil conditions are not well-suited to on-site sewage disposal through septic tanks. Small population centers are growing and aggravating the problem.

The town of Friday Harbor and YMCA Camp Orkila are discharging wastes directly to marine waters, impairing the aesthetics and recreation uses of the waters.

The spread of population throughout the Islands and the increase of people in the summer makes the installation of proper treatment facilities difficult and costly.

Tourism and outdoor recreation are the backbone of the Island's economy yet, adequate public sewage disposal facilities are not being provided at parks, boat marinas, beaches, etc. Sewage disposal from pleasure craft is another major concern.

FUTURE NEEDS

The principal factors affecting the future water quality of the San Juan Islands will be population and recreation. The expected growth of these factors will increase the quantity of waste and, consequently, water quality problems. The prediction of quantities and locations of future wastes is necessary in determining the means of treatment that will insure water quality of a given watercourse.

Figure 12-4 shows that the 1965 population of 2,600 is expected to increase 8 percent by 1980, 43 percent by 2000, and 96 percent by 2020. Friday Harbor is expected to remain the largest municipal area in the future.

Production, in terms of value added, for major water-using industries is expected to decrease and cease by 2000.

Lumber and wood production is expected to terminate by 1980.

Food and kindred production is expected to remain the same until 1980 when production will decrease and finally terminate in 2000.

Growth of recreation in the San Juan Islands will be substantial. By 1980, the number of recreation days expected is two and one-half million—1.8 times the 1960 amount. Water related recreation days is expected to be three times non-water related recreation days. In 1980, boating and fishing are expected to be major recreational activities.

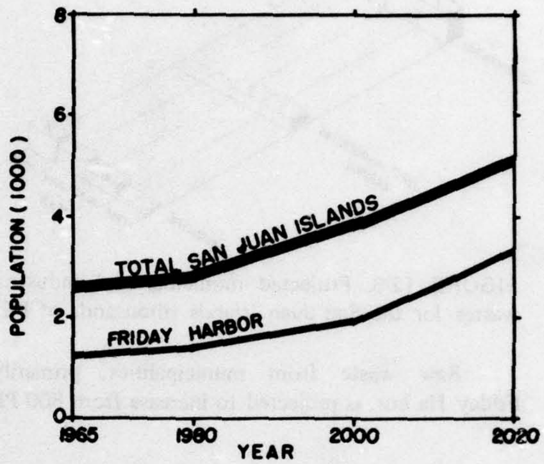


FIGURE 12-4. Population growth.

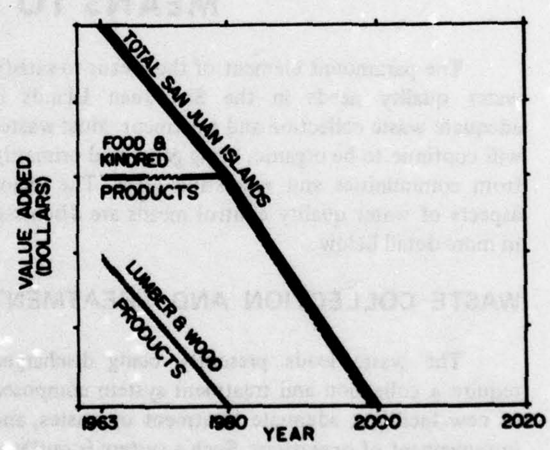


FIGURE 12-5. Relative growth for major water using industries.

Figure 12-6 shows the relative breakdown of 16,700 raw PE expected for 1980. The majority (64%) of raw waste will be due to recreational activities. By 2020, recreation will probably represent 86 percent of the total raw waste.

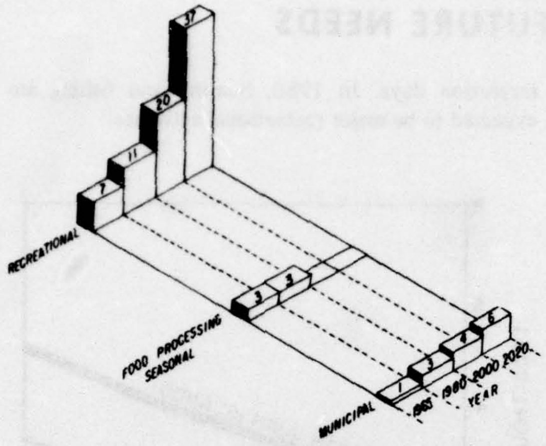


FIGURE 12-6. Projected municipal and industrial wastes for the San Juan Islands (thousands of PE).

Raw waste from municipalities, primarily Friday Harbor, is projected to increase from 800 PE in 1965 to 3,250 PE in 1980. Municipal waste will account for 19 percent of the raw waste in 1980. By 2020, municipal waste production is projected to be 670 percent of the 1965 production.

Raw waste production from food processing is expected to remain at 2,800 PE until 1980. By 2000 no food processing is expected.

The problem of pollution from watercraft is becoming widespread throughout the islands. What once were negligible wastes are now a significant factor in the overall pollution picture. The growing popularity of boating is likely to increase this source of pollution to even greater proportions than is true at present.

The primary need in future years will be to adequately manage these expected wasteloads. Growth of population and water-related recreation will demand it. The means to prevent, control, and abate future water pollution in the San Juan Islands are summarized in the succeeding chapter.

MEANS TO SATISFY NEEDS

The paramount element of the means to satisfy water quality needs in the San Juan Islands is adequate waste collection and treatment. Most wastes will continue to be organic, being generated primarily from communities and recreation areas. The major aspects of water quality control means are discussed in more detail below.

WASTE COLLECTION AND TREATMENT

The waste loads presently being discharged require a collection and treatment system composed of new facilities, adequate treatment of wastes, and improvement of operations. Such a system is outlined in the Washington State Water Quality Standards and Implementation Plan, December, 1967. The separate actions required are summarized below.

Strait of Juan de Fuca and Puget Sound

1. **Friday Harbor**—primary treatment with disinfection and an adequate marine outfall to disperse wastes. A town project, with Federal and State assistance, is now underway, which will intercept existing raw discharges to Friday Harbor and provide primary treatment before discharge by way of a deep water outfall. This project will include a treatment plant, interceptor line, two lift stations, and approximately 1,800 feet of outfall line.

2. **YMCA Camp Orkila**—secondary treatment with disinfection, and an adequate outfall.

Future wastes can, in most cases, be treated by the above system of municipal treatment facilities. As the urban areas grow to meet each other in the future, interceptors leading to a central treatment facility may allow increased efficiency of operation at lower cost.

The large influx of recreationists during the summer seasons will require waste treatment facilities at parks and campgrounds, as well as for summer home and recreation lot developments. Wastes from outdoor recreation activities must be collected and adequately treated, in order to preserve the recreation and scenic qualities of the San Juans.

Legislation is needed to initiate an effective program for the control of sewage pollution from watercraft. Support from the county and local levels should be given to a statewide program to control four major waste categories from vessels; namely, sewage, bilge and ballast waters, litter and related solids, and oil. As part of the overall program, adequate shore treatment and disposal facilities should be provided at all significant points, such as marinas and commercial ports.

The investment required to meet present and future waste collection and treatment requirements is shown in Tables 12-3, 12-4 and Figure 12-7.

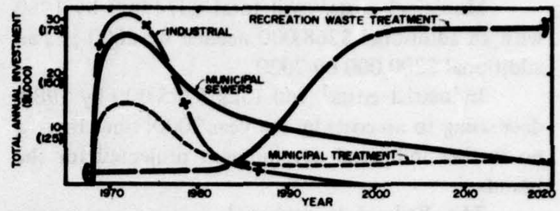


FIGURE 12-7. Relative required rates of investment for waste collection and treatment facilities in the San Juan Islands.

TABLE 12-3. Costs for waste collection, treatment, and outfall facilities and quality systems to meet water quality standards, San Juan Islands

	Annual Costs (Thousands of Dollars) 1967 Dollars Present-1980	1980-2000	2000-2020
STANDARDS FOR INTERSTATE AND INTRASTATE WATERS[1]			
Upgrade treatment, plant expansion or modification—municipalities and industries	$ 15	$ 17	$ 9
Disinfection	3	3	2
Outfalls	15	17	9
Interception and sewer system			
a. Municipal	10	11	6
b. Industrial	1	1	1
Combined sewage infiltration and overflow correction	8	9	5
Advanced waste treatment in recreation areas	--	--	--
Sub-Total	$ 52	$ 58	$32
WATER QUALITY ENGINEERING DEVELOPMENT, MANAGEMENT AND[2] EVALUATION PROGRAMS FOR MARINE, FRESH AND GROUND WATER			
Monitoring—ground water, automatic equipment, etc.	$ 15	$ 2	$ 4
Evaluations—dispersion areas, ecological, productivity	10	4	4
Information system, quality control, plant operation improvement, operation research	10	2	2
Sub-Total	$ 35	$ 8	$10
OPERATION AND MAINTENANCE[2]	$ 13	$ 60	$52
TOTALS	$100	$126	$94

1 Annual amortized costs.

2 Direct annual costs, from appropriations, revenue, planning funds, and grants. (Does not include interest).

Municipal costs[1] will total $374,000 by 1980 with an additional $268,000 needed by 2000 and an additional $200,000 by 2020.

Industrial costs[1] will total $225,000 by 1980, decreasing to no costs by the year 2000, since there is no further industrial development projected for the islands.

The Federal investment[1] in waste treatment facilities in recreation areas will total $1,225,000 by 1980 with additional sums of $2,700,000 needed by 2000 and $3,400,000 needed by 2020.

Sources of funding are shown in Figure 12-8. The local entities must pay for a sizeable portion in order to meet waste collection treatment needs as they develop. However, Federal grants will total $60,000 by 1980 with additional amounts of $39,000 and $37,500 in the time periods 1980 to 2000 and 2000 to 2020, respectively. State grants will be one-half of Federal grants for the same periods. Federal investment in sewers will total $28,000 by 1980 with an additional $43,000 needed by 2000 and another $48,000 needed by 2020.

OTHER MEASURES

A water quality surveillance program for the marine waters is an essential element. Stations have been established by the Washington Pollution Control Commission in Rosario Stratis off Lawrence Point on Orcas, in Haro Straits off Waldron Island, and in San Juan Channel off Friday Harbor to regularly measure the marine water characteristics. The Commission should expand a surveillance program to include ground-water monitoring also.

At least for the present, the economics of sewer system construction and the scattered population concentrations among the Islands favor the formation of a number of sewer districts to meet sewage disposal needs. By 1980 the county should provide under the County Services Act sewage disposal facilities to assure a coordinated and orderly system.

[1] **Costs are not amortized.**

The Interstate and proposed Intrastate Quality Standard's implementation and enforcement plans, sets out classification of watercourses and treatment facilities necessary to maintain and/or improve existing water quality.

An in-depth study to adequately define the magnitude, scope, and significance of water pollution in the San Juan Islands should be undertaken by the county, with financial and technical assistance from the State and Federal levels of government.

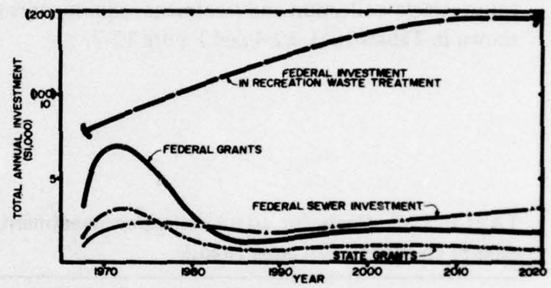


FIGURE 12-8. Government investment requirements[1] for waste collection and treatment in the San Juan Islands.

TABLE 12-4. Total amortized capital and operational costs, San Juan Islands

	Million Dollars		
	Present-1980	1980-2000	2000-2020
Industrial	0.5	--	--
Municipal treatment	0.3	0.1	0.1
Municipal sewers	1.0	0.3	0.1
Recreation	1.4	2.6	1.4
Advanced waste treatment	--	--	--
Sub-Total	3.2	3.0	1.6
Water quality engineering management and evaluation	0.4	0.2	0.2
Operation and maintenance	0.1	1.2	1.0
Total	3.7	4.4	2.8

RECOMMENDATIONS OF THE SECOND SESSION, POLLUTION OF INTERSTATE WATERS OF PUGET SOUND ENFORCEMENT CONFERENCE STRAIT OF JUAN DE FUCA, THEIR TRIBUTARIES & ESTUARIES

Seattle, Washington,
September 6-7 and October 6, 1967

1. Georgia-Pacific Corp. at Bellingham shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Design and construct facilities which will either remove a minimum of 80 percent of the sulfite waste liquor from mill effluents or limit sulfite waste liquor discharges to 3,600,000 pounds per day, based on 10 percent solids by weight. These facilities are to be completed and placed into operation no later than September 30, 1972.

c. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

d. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

e. Modify chipbarge unloading operations to eliminate spillage of wood chips. This shall be completed no later than September 30, 1970.

2. Scott Paper Co. at Anacortes shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

3. Scott Paper Co. at Everett shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Design and construct facilities which will either remove a minimum of 80 percent of the sulfite waste liquor from mill effluents or limit sulfite waste liquor discharges to 5,500,000 pounds per day, based on 10 percent solids by weight. These facilities are to be completed and placed into operation no later than September 30, 1972.

c. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

d. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

e. Modify chipbarge unloading operations to eliminate spillage of wood chips. This shall be completed no later than September 30, 1970.

4. Weyerhaeuser Co. sulfite mill at Everett shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Design and construct facilities to either remove a minimum of 80 percent of the sulfite waste liquor from mill effluents or limit sulfite waste liquor discharges to 2,200,000 pounds per day, based on 10 percent solids by weight. These facilities are to be completed and placed into operation no later than September 30, 1972.

c. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

d. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

e. Modify chipbarge unloading operations to eliminate spillage of wood chips. This shall be completed no later than September 30, 1970.

5. Simpson Lee Paper Co. at Everett shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Provide an outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the waters of the Snohomish to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

6. Crown Zellerbach Corp. at Port Angeles shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. The date that these facilities shall be placed in operation is contingent upon a reasonable length of time for the company to stabilize mill property now being eroded away through wave action.

b. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation concurrently with the primary treatment facilities.

c. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

7. Fibreboard Paper Prod. Corp. at Port Angeles shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

c. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

8. Rayonier Incorporated at Port Angeles shall:

a. Design and construct primary treatment facilities to remove all settleable solids from mill effluents prior to discharge into Puget Sound. Adequate facilities for the disposal of recovered solids or sludge shall also be provided. These facilities shall be placed in operation no later than September 30, 1970.

b. Design and construct facilities to either remove a minimum of 80 percent of the sulfite waste liquor from mill effluents or limit sulfite waste liquor discharges to 3,700,000 pounds per day, based on 10 percent solids by weight. These facilities are to be completed and placed into operation no later than September 30, 1972.

c. Provide a submarine outfall equipped with an adequate diffuser to permit discharge of all residual wastes into the deeper waters adjacent to the mill to achieve maximum waste dilution and dispersion. The outfall is to be designed and located by an extensive outfall evaluation of the receiving watercourse and is to be completed and placed in operation no later than September 30, 1970.

d. Remove, by dredging, the existing sludge bed in the waterways adjacent to the mill and dispose of the sludge on land when feasible. The schedule for this operation will be dependent upon integrating it with the construction of primary treatment and outfall facilities.

9. The city of Bellingham shall:

a. Provide for collection and treatment of wastes discharged by the Fairhaven sewer and other unintercepted waste discharges no later than March 31, 1970.

b. Construct a submarine outfall from the present primary plant into the deep water of Bellingham Bay to achieve maximum waste dilution and dispersion no later than March 31, 1970.

c. Conduct an engineering study to determine whether a higher degree of treatment than primary treatment will be necessary to comply with receiving water standards and submit an engineering report no later than December 31, 1969.

10. The city of Everett shall:

a. Provide chlorination of the waste stabilization pond effluent no later than July 31, 1968.

11. The city of Port Angeles shall:

a. Provide for collection of all domestic waste discharges and treatment of the wastes by providing primary treatment and effluent chlorination with discharge into a deep water outfall no later than March 31, 1969.

METROPOLITAN MUNICIPAL CORPORATIONS
(RCW 35.158)

The growth of urban populations and the movement of people into suburban areas has created problems of sewage disposal, garbage disposal, water supply, public transportation, planning, and parks and parkways which extend beyond the boundaries of cities, counties, and special districts. For reasons of topography, location and movement of population, and land conditions and development, one or more of those problems cannot be adequately met by individual cities, counties and districts of many metropolitan areas.

Metropolitan municipal corporations provide and coordinate certain specified public services and functions for prescribed geographic areas including two remote cities and towns and all or part of one or more counties.

Cities and counties may act jointly to meet those common problems in order that the proper growth and development of the metropolitan areas of the state may be assured and the health and welfare of the residents may be secured.

Any area of the state containing two or more cities, at least one of which is a city of the first class, may organize as a metropolitan municipal corporation for the performance of certain functions.

No metropolitan municipal corporation shall include only a part of any city, and every city is either wholly included or wholly excluded from the boundaries of such corporation. No area may be included within the boundaries of more than one metropolitan municipal corporation.

A metropolitan municipal corporation has the power to perform any one or more of the following functions, when authorized:

(1) Metropolitan sewage disposal.
(2) Metropolitan water supply.
(3) Metropolitan public transportation.
(4) Metropolitan garbage disposal.
(5) Metropolitan parks and parkways.
(6) Metropolitan comprehensive planning.

All functions of local government which are not authorized to be performed by a metropolitan municipal corporation, continue to be performed by the counties, cities and special districts within the metropolitan area.

A metropolitan municipal corporation may be created by vote of the qualified electors residing in a metropolitan area. An election to authorize the creation of a metropolitan municipal corporation is by resolution or petition in the following manner:

(1) A resolution or concurring resolutions calling for such an election may be adopted by either:

(a) The city council of a central city; or

(b) The city councils of two or more component cities other than a central city; or

(c) The board of commissioners of a central county.

(2) A petition calling for such an election signed by at least four percent of the qualified voters residing within the metropolitan area.

Any resolution or petition calling for such an election describes the boundaries of the proposed metropolitan area, names the metropolitan function or functions which the metropolitan municipal corporation are authorized to perform initially and states that the formation of the metropolitan municipal corporation will be conducive to the welfare and benefit of the persons and property within the metropolitan area.

Upon receipt of a duly certified petition or valid resolution calling for election for the formation of metropolitan municipal corporation, the board of commissioners of the central county fixes a date for a public hearing.

The commissioners may make such changes in the boundaries of the metropolitan areas as they deem reasonable and proper, but may not delete any portion of the proposed area which would create an island of included or excluded land, may not delete a portion of any city, and may not delete any portion of the proposed area which is contributing or may reasonably be expected to contribute to the pollution of any watercourse or body of water in the proposed area when the petition or resolution names metropolitan sewage disposal as a function to be performed by the proposed metropolitan municipal corporation.

If a majority of the persons residing within the central city votes in favor and a majority of the persons voting on the proposition residing in the metropolitan area outside of the central city votes in favor, the metropolitan municipal corporation is established.

At the same election, the voters approve or reject a proposition authorizing the metropolitan municipal corporation, if formed, to levy at the earliest possible time permitted by law on all taxable property located within the metropolitan municipal corporation a general tax, for one year, of one mill in excess of any constitutional or statutory limitation for authorized purposes of the metropolitan municipal corporation.

The one mill proposition to be effective must be approved by a majority of three-fifths of the persons voting on the proposition to levy such tax and the number of persons voting on the proposition must constitute not less than forty percent of the total number of votes cast in the area of the proposed metropolitan municipal corporation at the last preceding county or state general election.

A metropolitan municipal corporation may be authorized to perform one or more metropolitan functions in addition to those which it has previously been authorized to perform, with the approval of the voters at an election.

One or more additional metropolitan functions may be called by a resolution for a petition in the following manner:

(1) A resolution calling for such an election may be adopted by:

(a) The city council of the central city; or

(b) The city councils of two or more component cities other than a central city; or

(c) The board of commissioners of the central county.

(2) A petition calling for such an election by at least four percent of the registered voters residing within the metropolitan area.

Any resolution or petition names the additional functions which the metropolitan municipal corporation is authorized to perform.

An election on the authorization of the additional metropolitan functions is required.

A metropolitan municipal corporation is authorized to perform one or more functions in addition to those which it previously has, without an election, by resolution of the metropolitan council.

A copy of such resolution is transmitted to the legislative body of each component city and council. If a concurring resolution is returned from at least two-thirds of each component city and council, the metropolitan council is authorized to perform the additional functions.

A metropolitan municipal corporation is governed by a metropolitan council composed of the following:

(1) One member selected by, and from, the board of commissioners of the central county;

(2) One additonal member selected by the board of commissioners of each component county for each county commissioner district containing ten thousand or more persons residing in the unincorporated portion of such commissioner district lying within the metropolitan municipal corporation who shall be either the county commissioners from such district or a resident of such unincorporated portion.

(3) One member from each of the six largest component cities who shall be the mayor of such city, if such city shall have the mayor-council form of government, and in other cities shall be selected by, and from, the mayor and city council of each of such cities.

(4) One member representing all component cities other than the six largest cities to be selected by and from the mayors of such smaller cities.

(5) One additional member selected by the city council of each component city containing a population of ten thousand or more for each sixty thousand population over and above the first ten thousand, such members to be selected from such city council until all councilmen are members and thereafter to be selected from other selected offices of the city.

To carry out the purposes of the metropolitan municipal corporation and to perform authorized functions, a metropolitan municipal corporation may contract with the United States or any agency thereof, any state or agency thereof, any other metropolitan municipal corporation, any county, city, special district, or governmental agency and any private person, firm or corporation for the purpose of receiving gifts or grants or securing loans or advances for preliminary planning and feasibility studies, or for the design, construction or operation of metropolitan facilities. A metropolitan municipal corporation may contract with any governmental agency or with any private person, firm or corporation for the use by either contracting party of all or any part of the facilities, structures, lands, interests in lands, air rights over lands and rights of way of all kinds which are owned, leased or held by the other party and for the purpose of planning, constructing or operating any facility or performing any service.

The metropolitan council of a metropolitan municipal corporation upon the affirmative vote of two-thirds of the members of such council may make planning, engineering, legal, financial and feasibility studies preliminary to or incident to the preparation of a recommended comprehensive plan for any metropolitan function, and may prepare such a recommended comprehensive plan before the metropolitan municipal corporation has been authorized to perform such function. The studies and plan may cover territory within and without the metropolitan municipal corporation. Arecommended comprehensive plan prepared pursuant to this section for any metropolitan function may not be adopted by the metropolitan council unless the metropolitan municipal corporation has been authorized to perform such function.

Whenever a recommended comprehensive plan for the performance of any additional metropolitan function has been prepared and the metropolitan council has found the plan to be feasible the council may by resolution call a special election to authorize the performance of such additional function without the filing of the petitions or resolutions.

If the metropolitan council determines that the performance of such function requires enlargement of the metropolitan area, a resolution containing a description of the boundaries of the proposed metropolitan area may be adopted only after a public hearing before the council.

If the metropolitan municipal corporation is authorized to perform the function of metropolitan sewage disposal the council provides in a resolution that local governmental agencies collecting sewage from areas outside the metropolitan area will not thereafter be required to discharge such sewage into the metropolitan sewer system or to secure approval of local construction plans from the metropolitan municipal corporation unless such local agency first enters into a contract with the metropolitan municipal corporation for the disposal of such sewage. The metropolitan council may also provide in such resolution that the authorization to perform such additional function be effective only if the voters at an election also authorize the issuance of any general obligation bonds required to carry out the recommended comprehensive plan.

Annexations to a component city after the establishment of a metropolitan municipal corporation is by the same act of annexation to the corporation.

Annexation to a city which is not within such metropolitan municipal corporation is by either (1) such city may be annexed to the metropolitan municipal corporation by ordinance of the legislative body of the city concurred in by resolution of the metropolitan council, or (2) if such city shall not be so annexed such annexation shall remain within the metropolitan municipal corporation unless the city shall by resolution request the withdrawal of such annexation subject to any outstanding indebtedness of the metropolitan corporation and the metropolitan council will by resolution, consent to such withdrawal.

Any other area adjacent to a metropolitan municipal corporation may be annexed thereto by vote of the qualified electors.

If a metropolitan municipal corporation is authorized to perform the function of metropolitan sewage disposal, it has the power to:

(1) Prepare a comprehensive sewage disposal and storm water drainage plan for the metropolitan area.

(2) Acquire by purchase, condemnation, gift, or grant and to lease, construct, add to, improve, replace, repair, maintain, operate and regulate the use of metropolitan facilities for sewage disposal and storm water drainage within or without the metropolitan area, including trunk, interceptor and outfall sewers, whether used to carry sanitary waste, storm water, or combined storm and sanitary sewage, lift and pumping stations, sewage treatment plants, together with all lands, properties, equipment and accessories necessary for such facilities. Sewer facilities which are owned by a city or special district may be acquired or used by the metropolitan municipal corporation only with the consent of the legislative body of the city or special districts owning such facilities. Cities and special districts are authorized to convey or lease such facilities to metropolitan municipal corporations or to contract for their joint use on such terms as may be fixed by agreement between the legislative body of such city or special district and the metropolitan council, without submitting the matter to the voters of such city or district.

(3) Require counties, cities, special districts and other political subdivisions to discharge sewage collected by such entities from any portion of the metropolitan area into such metropolitan facilities as may be provided to serve such areas when the

metropolitan council declares by resolution that the health, safety, or welfare of the people within the metropolitan area requires such action.

(4) Fix rates and charges for the use of metropolitan sewage disposal and storm water drainage facilities.

(5) Establish minimum standards for the construction of local sewer facilities and approve plans for construction of such facilities by component counties or cities or by special districts wholly or partly within the metropolitan area. No county, city, or special district shall construct such facilities without first securing such approval.

(6) Acquire by purchase, condemnation, gift, or grant, to lease, construct, add to, improve, replace, repair, maintain, operate and regulate the use of facilities for the local collection of sewage or storm water in portions of the metropolitan area not contained within any city or sewer district and, with the consent of the legislative body of any city or sewer district, to exercise such powers within such city or sewer district and for such purpose to have all the powers conferred by law upon such city or sewer district with respect to such local collection facilities. All costs of such local collection facilities are paid for by the area served thereby.

If a metropolitan municipal corporation is authorized to perform the function of metropolitan sewage disposal, the metropolitan council forms a metropolitan sewer advisory committee from each component city which operates a sewer system. The function of such advisory committee is to advise the metropolitan council in matters relating to the performance of the sewage disposal function.

GLOSSARY

API separator:	Short for American Petroleum Institute separator. Separates oil from water.
Aquifer:	A geologic formation that is water-bearing and that transmits water from one point to another.
BOD:	(Biochemical Oxygen Demand) The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is not related to the oxygen requirements in chemical combustion, but is determined entirely by the availability of the material as a biological food and by the amount of oxygen utilized by the micro-organisms during oxidation. Usually expressed in terms of BOD_5, it is the quantity of oxygen utilized in a five-day period at 20°C.
cfs:	(Cubic Foot per Second) A unit of discharge for measurement of flowing liquid equal to a flow of one cubic foot per second past a given section. Also called second-foot.
COD:	(Chemical Oxygen Demand) The quantity of oxygen utilized in the chemical oxidation of organic matter. It is a measure of the amount of such matter present.
Chlorination:	The application of chlorine to water, sewage, or industrial wastes generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.
Coliform Bacteria:	A group of enterobacteriaceae from the tribe Escherichieae composed of three genera; namely, Escherichia, Aerobacter, and Klebsiella.
DO:	(Dissolved Oxygen) The oxygen dissolved in water or other liquid, usually expressed in milligrams per liter or percent of saturation.
Effluent:	Municipal or industrial waste water which is partially or completely treated or in its natural state, flowing from a process basin, or treatment plant.
Eutrophication:	The process of overfertilization of a body of water by nutrients which produce more organic matter than the selfpurification process can overcome.
gpd:	Gallons per day.
Hardness:	A characteristic of water; chiefly due to the existence therein of the carbonates and sulfates and occasionally nitrates and chlorides of calcium, iron, and magnesium; which causes "curdling" of

the water when soap is used, increased consumption of soap, deposition of scale in boilers, injurious effects in some industrial process, and sometimes objectionable taste in the water. It is commonly computed from the amounts of calcium and magnesium in the water and expressed as equivalent calcium carbonate.

Hydrogen ion concentration (pH): The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithm of the reciprocal of the hydrogen ion concentration.

JTU: (Jackson Turbidity Units) the JTU, as the name implies, is a measurement of the turbidity, or lack of transparency, of water. It is measured by lighting a candle under a cylindrical transparent glass tube and then pouring a sample of water into the tube until an observer looking from the top of the tube cannot see the image of the candle flame. The number of JTU's varies inversely with the height of the sample (e.g., a sample which measures 2.3 cm has a turbidity of 1,000 JTU's whereas a sample measuring 72.9 cm has a turbidity of 25 JTU's.)

Lagoon: A relatively shallow basin, built by excavation of the ground and diking, for the purpose of treating wastes by storage under conditions that favor natural biological treatment and accompanying bacterial reduction.

mgd: Millions of gallons per day.

mg/l: Milligrams per liter.

MPN: (most probable number) In the testing of bacterial density by the dilution method, that number of organisms per unit volume which, in accordance with statistical theory, would be more likely than any other possible number to yield the observed test result or which would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml.

MWe: Million watt electrical.

Outfall: A sewer, drain, or conduit from which sewage, industrial wastes, or drainage is discharged.

Population Equivalent (PE): The average daily amount of BOD_5 exerted by the organic waste from one person. A value of 0.17 pounds of BOD_5 is normally equated to one PE.

pH: See Hydrogen ion concentration. The neutral value of pH is 7.0. Higher values indicate an alkaline solution and lower values indicate an acid solution.

ppm: Parts per million.

Primary Waste Treatment: The removal of settleable, suspended, and floatable solids from waste water by the application of mechanical and/or gravitational forces. In primary treatment, unit processes such as sedimentation, flotation, screening, centrifugal action, vacuum filtration, dissolved air flotation, and others designed to remove settleable, suspended, and floating solids have been used. Generally, a reduction in dissolved or colloidal solids has been obtained in primary treatment, but this effect is incidental and not the planned purpose of primary treatment.

Oligotrophic: The condition of a lake which has low nutrient levels and usually high dissolved oxygen concentration.

Runoff: That part of rainfall or other precipitation that reaches watercourses or drainage systems.

SWL: An abbreviation for sulfite waste liquor, a by-product of sulfite-type pulp and paper mills.

Salinity: The relative concentration of dissolved salts in seawater and is determined by various methods when compared to the international standard of Eau de Mer Normale. Usually expressed in parts per thousand = 0/00.

Secondary Treatment: The removal of dissolved and colloidal materials that, in their natural state as found in waste water, are not amenable to separation through the application of primary treatment. Secondary treatment will generally reduce the BOD_5 of sewage by 85 percent.

Sediment: (1) Any material carried in suspension by water which will ultimately settle to the bottom after the water loses velocity. (2) Fine water-borne matter deposited or accumulated in beds.

Service Areas: An area described for planning purposes whose boundaries would include the future population or industrial activities which could logically and functionally obtain water supply and waste disposal services from a central or integrated system or where the problems are so interrelated that the planning should be done on an integrated basis.

Sludge: The accumulated settled solids deposited from sewage or industrial wastes, raw or treated.

TDS: Total dissolved solids.

Tertiary (Advanced) Treatment: Selective application of biological, physical, and chemical separation process to effect removal or organic and inorganic substances, primarily phosphorous and nitrogen, that resist conventional treatment practices.

Turbidity: (1) A condition of a liquid due to fine visible material in suspension which may not be of sufficient size to be seen as individual particles by the naked eye, but which prevents the passage of light through the liquid. (2) A measure of fine suspended matter (usually colloidal) in liquids.

PHOTOGRAPH CREDITS

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12-4	Washington State Department of Commerce and Economic Development No. 71-6-4

BIBLIOGRAPHY

Beck, R.W. and Associates. Preliminary Comprehensive Water and Sewer Plan for Island County, Washington. 1968.

Brown and Caldwell. The Collection, Treatment and Disposal of Sewage and the Collection and Disposal of Storm Water: Metropolitan Tacoma Sewage and Drainage Survey. 1957.

Brown and Caldwell. Metropolitan Seattle Sewage and Drainage Survey. March, 1968.

Carey and Kramer. Preliminary Report on Sewerage System Improvements for the Town of Friday Harbor, Washington. 1963.

Clark Coleman & Rupeiks, Inc. San Juan County Comprehensive Plan. 1966.

Cornell, Howland, Hayes & Merryfield, Engineers and Planners. An Engineering Report on a Preliminary Investigation of a Sewage Treatment System, City of Port Angeles, Washington. 1966.

Garling, M.E., Molenaar, and Dee. Water Resources and Geology of the Kitsap Peninsula and Certain Adjacent Islands: Washington Department of Conservation and U.S. Geological Survey, Water Supply Bulletin No. 18. 1965.

Gray and Osborne. City of Bremerton, Kitsap County, Washington Engineering Report on Sewage Works Expansion. 1965.

Gray and Osborne. A Plan for Replacement and Expansion of Water Supply and Transmission Facilities for the City of Everett. 1963.

Isaac, G.W.; Denison, J.G.; and Stein, J.E. An Oceanographic Survey of Port Angeles Harbor. 1963.

Liesch, Bruce A.; Price, Charles E.; and Walters, Kenneth L. Geology and Ground-Water Resources of Northwestern King County, Washington: Washington Department of Conservation and U.S. Geological Survey, Water Supply Bulletin No. 20. 1963.

Livingston & Moore, Inc. Chemical and Biochemical Analysis of the Performance of the Stanwood, Washington Oxidation Pond. 1963.

Livingston & Moore, Inc. Report on 1963 Operation of Sewage Oxidation Lagoon at Stanwood, Washington. 1963.

Molenaar, Dee; and Wallace, Eugene F. Geology and Ground-Water Resources of Thurston County, Washington, Volume 1: Washington Department of Conservation and U.S. Geological Survey, Water Supply Bulletin No. 10. 1961.

Noble, John B. A Preliminary Report on the Geology and Ground-Water Resources of the Sequim-Dungeness Area, Clallam County, Washington: Washington Department of Conservation and U.S. Geological Survey, Water Supply Bulletin No. 11. 1960.

Saxton, Walter W. and Young, Albert. Investigation of Sulfite Waste Liquor Pollution in Fidalgo and Padilla Bays.

Snohomish County Planning Department. Comprehensive Plan Text, Arlington Planning Area. 1964.

Snohomish County Planning Department. Comprehensive Plan Text, Stanwood Planning Area. 1964.

Southwest Snohomish Joint Planning Council. Comprehensive Plan, Southwest Snohomish County. 1966.

Stevens & Thompson, Inc. Port of Bellingham Sewerage Facilities for Bellingham, Washington. 1966.

Stevens, Thompson, Runyan & Ries, Inc. Industrial Waste Survey for Port of Bellingham. 1966.

Stevens, Thompson, Runyan & Ries, Inc. Master Plan of Water, Sewerage and Drainage Facilities for Ferndale, Washington. 1967.

Sylvester, Robert O. and Rambow, Carl A. An Initial Study of Water Resources of the State of Washington. February 1967.

Sylvester, Robert O. and Clogston, Fred L. A Study of the Preoperational Marine Environment in the Vicinity of the Texas Company Refinery Puget Sound Works, Anacortes, Washington. 1958.

U.S. Department of the Interior, Federal Water Pollution Control Administration. The Cost of Clean Water. January 1968.

U.S. Department of the Interior, Federal Water Pollution Control Administration. North and Middle Fork Snoqualmie Project, Snohomish River Basin, Washington: Water Supply and Quality Control Study. 1966.

U.S. Department of the Interior, Federal Water Pollution Control Administration. Pollutional Effects of Pulp and Paper Mill Wastes in Puget Sound. March 1967.

U.S. Department of the Interior, Federal Water Pollution Control Administration. Reconnaissance Investigation, Skagit River Basin Project, Puget Sound Basin, Washington. 1966.

Washington State Water Pollution Control Commission. Sources and Extent of Lake Washington Pollution: Pollution Series, Bulletin No. 29. 1943.

Washington State Water Pollution Control Commission. Investigation of Pollution in Port Angeles Area: Technical Bulletin No. 23. 1957.

Washington State Water Pollution Control Commission. An Investigation of Pollutional Effects in Lake Washington: Technical Bulletin No. 18. 1955.

Washington State Water Pollution Control Commission. Water Quality Standards and Implementation and Enforcement Plan for Interstate and Coastal Waters. December 1967.

Washington State Water Pollution Control Commission. An Investigation of Pollution in the Green-Duwamish River: Technical Bulletin No. 20. 1955.

Washington State Water Pollution Control Commission. Sources of Pollution in Lake Washington Canal and Lake Union: Pollution Series, Bulletin No. 10. 1943.

Washington State Water Pollution Control Commission. An Investigation of Pollution in the Vicinity of the Fort Lewis Sewer Outfall: Technical Bulletin No. 10. 1951.

Washington State Water Pollution Control Commission. A Reinvestigation of Pollution in Port Gardner Bay and the Lower Snohomish River: Technical Bulletin No. 11. 1951.

Washington State Water Pollution Control Commission. An Investigation of Pollution in Port Gardner Bay and the Lower Snohomish River. 1949.

Washington State Water Pollution Control Commission. A Summary of the 1960-1961 Data from the Snohomish River-Port Gardner Bay Water Quality Survey: Water Quality Data Bulletin No. 62-1. 1961.

Washington State Water Pollution Control Commission. Pollution of Everett Harbor: Bulletin No. 3. 1941.

Washington State Water Pollution Control Commission. Supplementary Report on Pollution of Everett Harbor: Bulletin No. 23. 1942.

Washington State Water Pollution Control Commission. An Investigation of Water Quality Conditions in Chambers Creek Estuary: Technical Bulletin No. 24. 1958.

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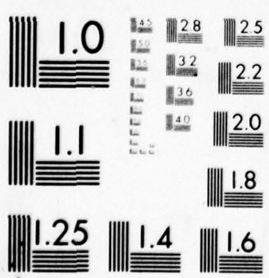

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Washington State Water Pollution Control Commission. An Investigation of Certain Water Quality and Biological Conditions in Boise Creek: Research Bulletin No. 63-1. 1963.

Washington State Water Pollution Control Commission. An Investigation of Pollution in Commencement Bay and the Puyallup River System: Technical Bulletin No. 8. 1950.

Water Resources of the Nooksack River Basin and Certain Adjacent Streams: Washington Department of Conservation and U.S. Geological Survey, Water Supply Bulletin No. 12. 1960.

Washington State Water Pollution Control Commission. Limnological Survey of Selected Washington Lakes, September 1968.

Water Resources Management and Public Policy. Seattle: University of Washington Press, 1968. Edited by Thompson and Sylvester.

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