PART II

CHARACTERISTICS OF METROPOLITAN SEATTLE AREA

Chapter 3. Physical Geography
Chapter 4. Economic Development
Chapter 5. Population

Chapter 3
PHYSICAL GEOGRAPHY

Physical geography is concerned with the physical features of the earth and their form, movement, and changes. Local geography, as defined by topography, geology, climate and water areas, influences in many ways the design, construction, cost, and operation of sewerage and drainage facilities. At Seattle, water areas are of particular significance in that they require protection from pollution and nuisance and provide at the same time a means for the safe disposal of storm runoff and suitably prepared sewage effluents.

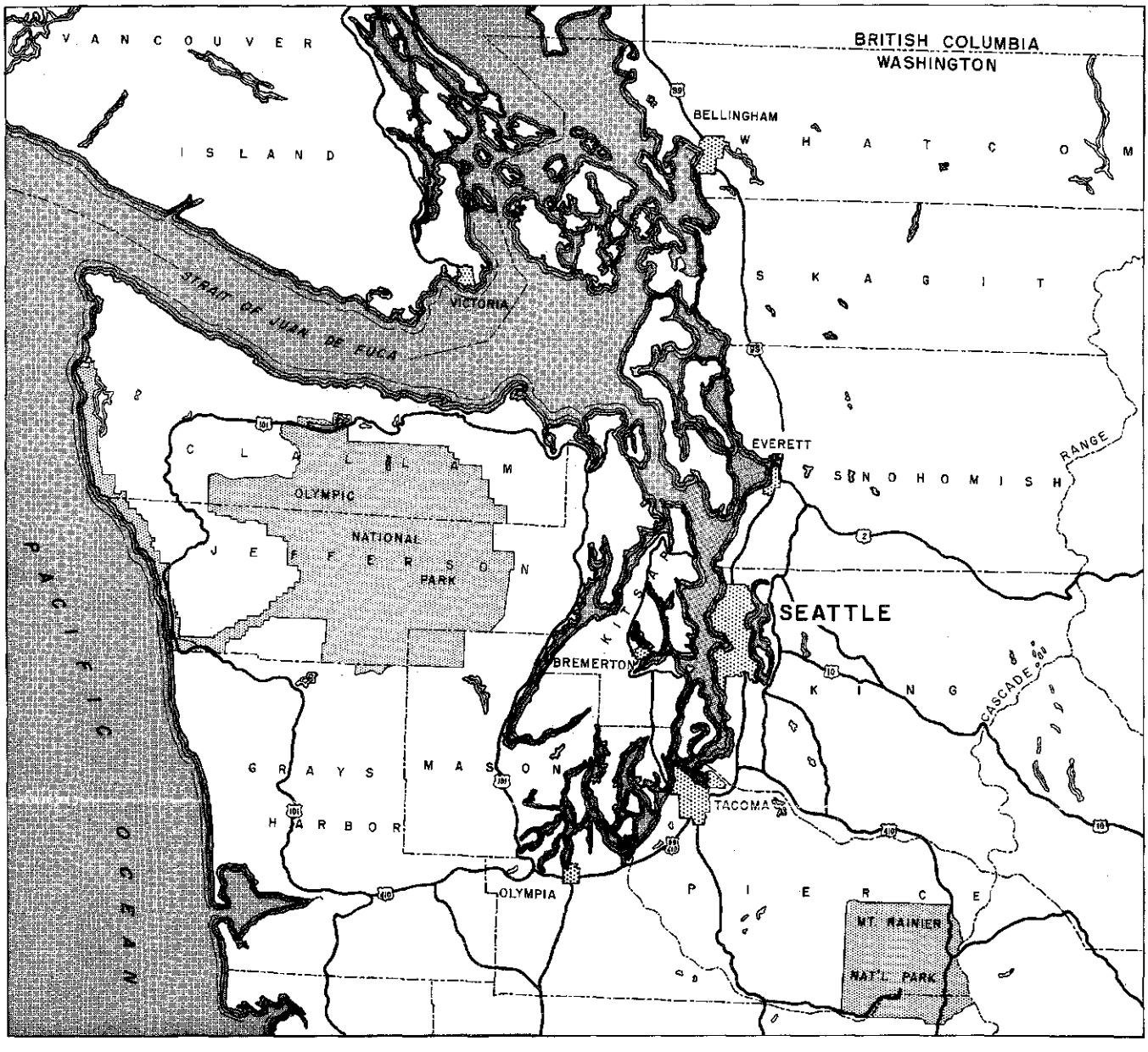


Fig. 3-1. Puget Sound Basin

The Cascade Mountains to the east and the Olympic Mountains to the west define the limits of the section of the Puget Sound Basin lying within the United States. Seattle and its metropolitan area are situated along the southeasterly shoreline of Puget Sound about 90 miles inland from the Pacific Ocean and 100 miles south of the Canadian border.

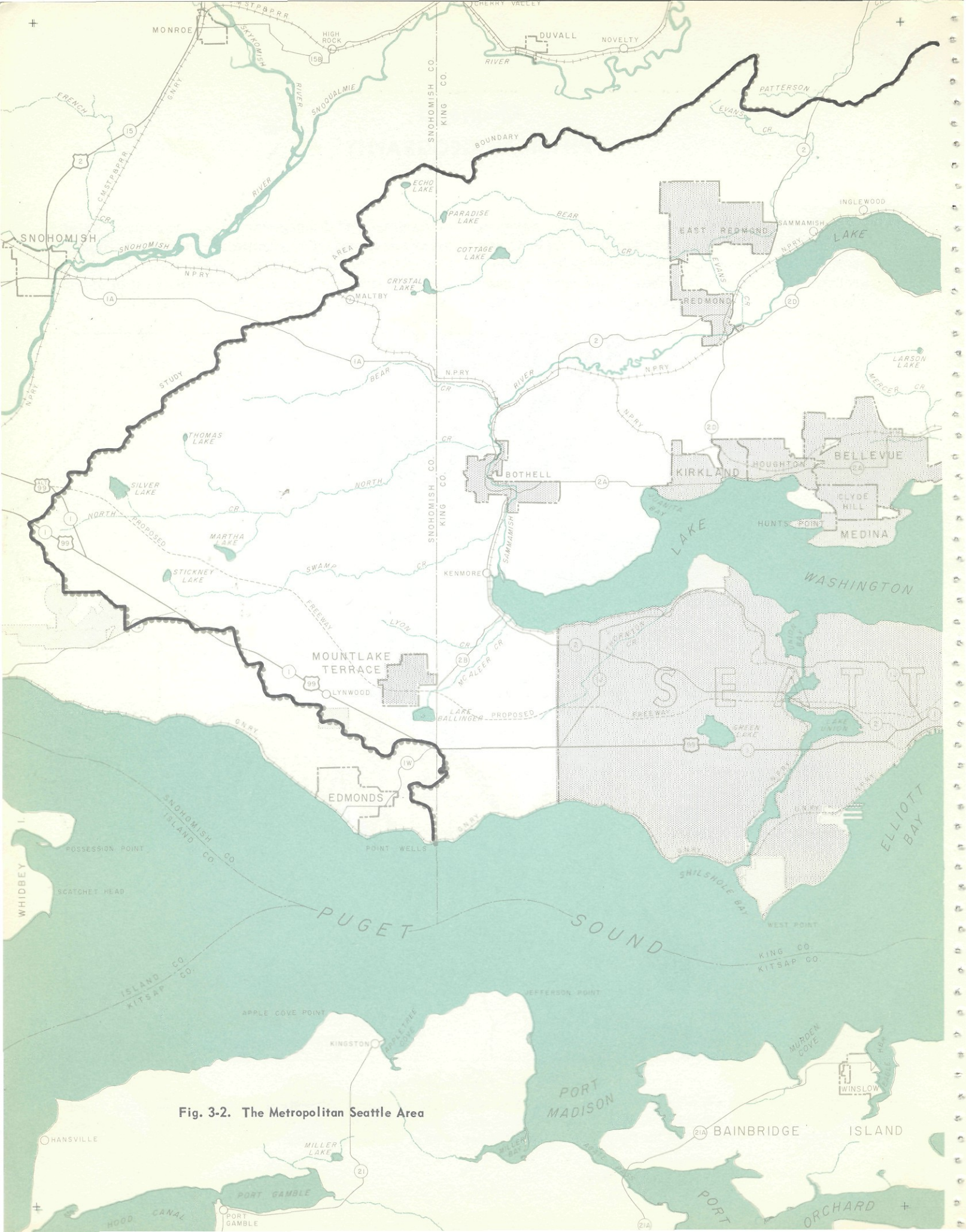
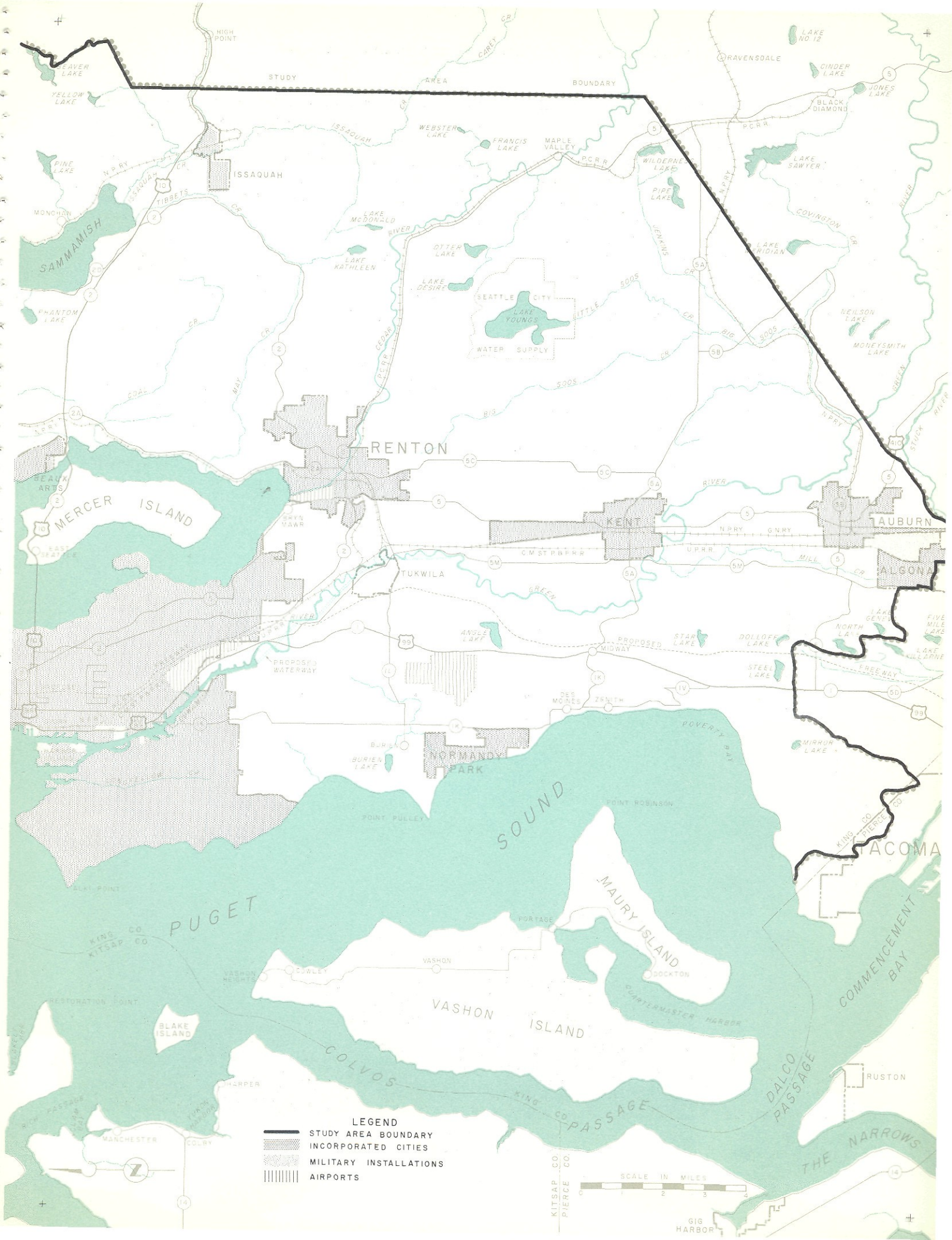


Fig. 3-2. The Metropolitan Seattle Area

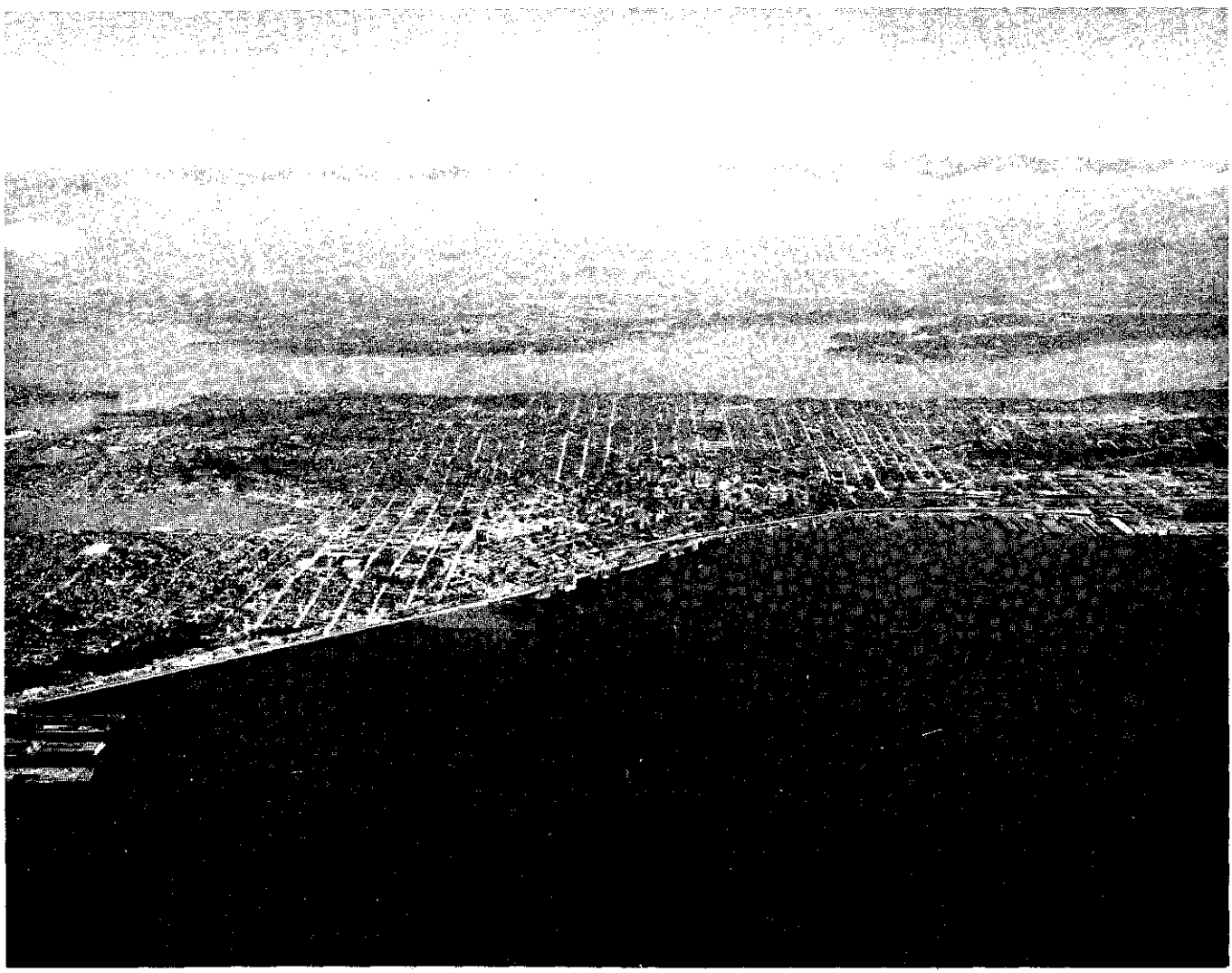

STUDY AREA BOUNDARY
HIGH POINT
BEAVER LAKE
YELLOW LAKE
ISSAQUAH
SAMMAMISH
MONOHON
PINE LAKE
PHANTOM LAKE
WEBSTER LAKE
FRANCIS LAKE
MAPLE VALLEY
LAKE MCDONALD
LAKE KATHLEEN
OTTER LAKE
LAKE DESIRE
SEATTLE CITY WATER SUPPLY
LAKE YOUNGS
RENTON
MERCER ISLAND
BEACH ARTS
EAST SEATTLE
BRYN MAWR
TUKWILA
KENT
AUBURN
ALGONA
RAVENSDALE
LAKE NO. 12
CINDER LAKE
JONES LAKE
BLACK DIAMOND
LAKE SAWYER
WILDERNE LAKE
PIPE LAKE
LAKE MERIDIAN
NEILSON LAKE
MONEYSMITH LAKE
FIVE MILE LAKE
LAKE GENEVA
NORTH LAKE
LAKE KILLARNE
ANGLE LAKE
STAR LAKE
DOLLOFF LAKE
STEEL LAKE
MIRROR LAKE
PROPOSED WATERWAY
PROPOSED FREEWAY
MIDWAY
DES MOINES
ZENITH
BURIEN
BURIEN LAKE
NORMANDY PARK
POVERTY BAY
POINT ROBINSON
POINT PULLEY
PUGET SOUND
ALKI POINT
KING CO.
KITSAP CO.
PIERCE CO.
TACOMA
MAURY ISLAND
PORTAGE
DOCKTON
VASHON
EWLEY
VASHON ISLAND
QUARTERMASTER HARBOR
COMMENCEMENT BAY
RESTORATION POINT
BLAKE ISLAND
COLVOS PASSAGE
DALCO PASSAGE
THE NARROWS
RUSTON
HARPER
MANCHESTER
COLBY
GIG HARBOR
LEGEND
STUDY AREA BOUNDARY
INCORPORATED CITIES
MILITARY INSTALLATIONS
AIRPORTS
SCALE IN MILES
0 1 2 3 4

LOCATION AND LIMITS OF THE METROPOLITAN AREA

At the outset of a survey concerned with sewerage and drainage problems of a large metropolitan area, the most difficult task from a technical standpoint is that of establishing geographically logical limits for study and planning purposes. This task involves a consideration of many factors. It can be said, however, that economy in construction and operation of sewerage and drainage systems requires that boundaries be established on a watershed rather than political basis.

In Seattle at present there is no legal or physical boundary by which the metropolitan area may be effectively defined. For sewerage planning purposes, it may be regarded broadly as the area stemming from the central city, Seattle, which has common or topographically related problems and is likely to become fully urbanized during the life of the planned facilities. This basic concept, together with an analysis of topographic features and expected future development, was taken into account in determining the boundaries of the planning area. Shown in Fig. 3-2, this area extends from the vicinity of Silver Lake on the north to the city of Auburn on the south and from Puget Sound inland for a distance of 18 miles at the point of its greatest width. In all, it encompasses an area of about 575 square miles, or 370,000 acres, of which 320,000 acres lie in King County and 50,000 acres lie in Snohomish County. Actually, the boundary crosses the Pierce County line at several points, but the acreage within that county is quite small.

In addition to Puget Sound, the principal physical features of the area are its rather rugged terrain, much of it heavily wooded, and its numerous lakes and rivers. Lake Washington, with a length of about 25 miles and an area of about 22,000 acres, practically bisects the area from north to south. Lake Sammamish, which is the next largest, has an area of about 4,700 acres and lies in the east-central section. These, together with numerous smaller



SEATTLE, central city of the metropolitan area, lies between Puget Sound (foreground) and Lake Washington (center). These bodies of water and the many other smaller lakes are one of the area's outstanding physical features.

lakes, provide about 140 miles of fresh water shoreline. There are three principal rivers, the Green-Duwamish, the Cedar, and the Sammamish, and many minor creeks and streams.

Taken as a whole, perhaps the most impressive physical feature of the metropolitan area is its outstanding natural beauty. With the rugged background formed by the Cascade Mountains on the east and the Olympic Mountains on the west across Puget Sound, the combination of large water areas, many miles of shoreline, and irregular wooded terrain is truly one of nature's masterpieces.

Compared with other metropolitan areas of the United States, the Seattle area is fairly new. In addition to Seattle, which was incorporated less than 100 years ago, the area now contains 18 incorporated cities. Two of these, Auburn and Kent, were established before the turn of the century, and six of them, Renton, Kirkland, Tukwila, Bothell, Redmond and Issaquah, were incorporated between 1900 and 1914. The remaining ten, Algona, Houghton, Bellevue, Beaux Arts, Clyde Hill, Normandy Park, Hunts Point, Medina, East Redmond and Mountlake Terrace became cities during the past 10 years and are indicative of the rapidity with which fringe areas have been developing.

TOPOGRAPHY

Topography, as related to ground slope and natural drainage features, determines to a large degree the route, size and slope of collection sewers and, in general, the extent to which an area is tributary to a common point. It determines also the necessity for pumping of sewage and the location of pumping stations. Moreover, topography has a direct bearing on population distribution and growth.

Fig. 3-3 shows the over-all configuration of the ground surface and defines the primary watershed areas. It should be noted that the watersheds of Cedar River and Green-Duwamish River extend beyond the boundaries of the metropolitan area and that the total areas given below refer only to those portions of these watersheds which lie within the study area.

Principal Topographic Features

Bounded on the west by Puget Sound and on the east by the foothills of the Cascade Range, the metropolitan area is topographically an area of striated hills, rolling glaciated uplands, and deeply incised adjoining troughs. Its principal physical features, such as large lakes, major stream valleys and intervening ridges, have a general north-south trend, paralleling the axis of Puget Sound.

An exception to the glaciated north-south topography is the prominent east-west ridge between the south end of Lake Washington and the foothills of the Cascade Range to the east. Composed of sedimentary rocks flanking a core of igneous rocks, this ridge rises to about elevation 2,000 at Squak and Tiger mountains near Issaquah, dividing the eastern part of the study area into north and south sections. North of the east-west ridge, the upland areas lie generally above elevation 300 and rise to a maximum of about elevation 500. South of the ridge, the upland areas are approximately 100 feet higher, lying above elevation 400 and containing ridges which rise to elevation 600 near the boundaries of the area.

In the city of Seattle, south of the Lake Washington Ship Canal, the dominating topography is one of more gently rounded hills lying 200 to 300 feet above sea level, with the summits rising to approximately elevation 400. West Seattle has a similar topography with corresponding features lying about 100 feet higher.

Upland sections of the metropolitan area present a glacial relief in which stream courses are often poorly defined, and local basins and depressions of retarded drainage are occupied by areas of marsh, swamp, or lake. These sections terminate generally in steep bluffs which descend about 200 feet to adjoining troughs occupied by interhill stream valleys, lake basins, and Puget Sound.

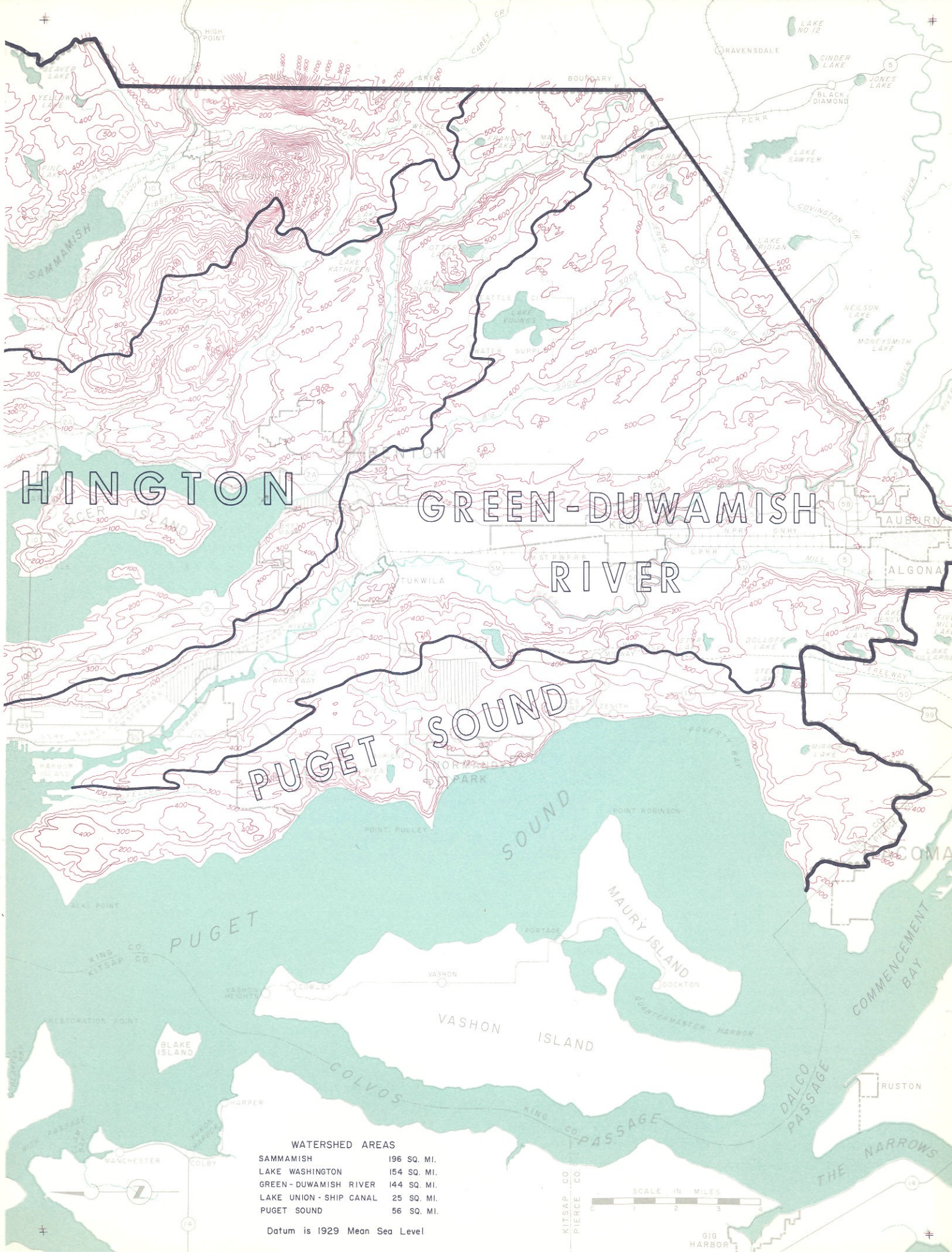
Major Watersheds

Although it drains ultimately to Puget Sound, the metropolitan area is divided naturally into four major watersheds. The largest of these, the Lake Washington watershed, encompasses almost 350 square miles and thus constitutes about 60 per cent of the study area. Bounded by uplands and ridges on the west, Lake Washington cannot drain directly to Puget Sound but is connected to the Sound through the Lake Washington Ship Canal. Formerly both the lake and Cedar River drained into the Duwamish via the Black River, but lowering of the lake level at the time the Government Locks were constructed changed the natural drainage direction and the Cedar became instead a principal tributary to Lake Washington.

Topographically, the Sammamish River valley is a part of the Lake Washington drainage basin. In the planning of sewerage facilities, however, this valley is considered separately because of its large area (196 square miles) and the elevation of the intervening ridge which separates it from Lake Washington.

The Green-Duwamish watershed, which drains directly to Elliott Bay, comprises an area of 144 square miles, making it the second largest in the study area. Direct drainage of the southeastern portion of the study area to the Green-Duwamish River valley is prevented by a slight ridge paralleling the top of the easterly valley wall. Instead, this area

Fig. 3-3. Topography and Major Watersheds



WATERSHED AREAS

SAMMAMISH	196 SQ. MI.
LAKE WASHINGTON	154 SQ. MI.
GREEN-DUWAMISH RIVER	144 SQ. MI.
LAKE UNION-SHIP CANAL	25 SQ. MI.
PUGET SOUND	56 SQ. MI.

Datum is 1929 Mean Sea Level

drains southerly to Big Soos Creek and then into the Green River east of Auburn.

Of the remaining 81 square miles of watershed in the metropolitan area, 25 square miles drain to the Lake Washington Ship Canal system. On that basis, only 56 square miles, or 10 per cent of the total, are tributary directly to Puget Sound.

Principal Hydrographic Features

Lake Washington has an east-west bottom configuration shaped essentially in the form of a "W". Deeper in the central portion, the lake shoals toward the north and south ends. It has an average depth of over 150 feet and reaches its maximum depth of 220 feet north of the Lake Washington floating bridge off Madison Park. While its steeply inclined sides below surface level are a continuation of the adjacent bluffs, the lowering of the lake level to its present elevation exposed a wave-cut terrace around much of the perimeter. Fathometer soundings, as performed by the Department of Oceanography of the University of Washington, indicate that fragments of this terrace extend into the lake from the present shoreline.

Puget Sound, which bounds the metropolitan area on the west, is one of the deepest salt water basins in the United States. A partially drowned, glacially modified drainage system, the sound is generally "U" shaped below water and has an average bottom elevation of about 600 feet below sea level. While the bottom normally drops off sharply a short distance from shore, it slopes gradually in the vicinity of West Point to a depth of 100 feet approximately 3,000 feet from shore, then breaks sharply to a depth of about 800 feet. Similar shoaling conditions do not exist elsewhere within the study area except in the vicinity of Point Wells near the north King County line.

GEOLOGY

The geology of an area is significant in the planning of sewerage works in that formations encountered in the construction of pipelines, tunnels and other structures affect design and construction requirements and thus have a direct bearing on cost. Geological conditions may be determining factors in choosing routes of principal sewers and may even influence the over-all scheme of sewerage to a marked degree. Moreover, soil formations, both surface and subsurface, determine the feasibility of local sewage disposal by means of septic tanks and leaching fields.

Geological History

Early geologists recognized two periods or stages of glaciation, giving the name Admiralty to the earliest stage and Vashon to the last. In recent years, geologists have found evidence of two and possibly three glacial stages in the formations previously assigned to the Admiralty period. As in other glaciated regions, glaciation of the metropolitan area occurred over a period of hundreds or thousands of years.

Glaciers carry with them debris ranging from clay size particles to stones of all dimensions. This material, referred to collectively as drift, is deposited by (1) glacial ice, (2) ice and streams working together, and (3) streams issuing from the melting glacier. As the forward movement occurs, unsorted drift or till is plastered over the existing topography by the bottom of the glacier. The weight of the overlying ice compresses the till to a dense, compact, often cemented material. When the forward movement stops and the ice stagnates and melts, drift is deposited in irregular heaps due to the varying debris load within the ice. Kettles or undrained depressions varying from a few feet to hundreds of yards in diameter are formed by the melting of isolated masses of ice surrounded or buried by drift.

As the ice retreats and melts, the meltwater forms streams which serve to carry debris away from the glacier front. Depending on the size and velocity of these streams, material may be deposited immediately outward from the glacier, or previously deposited materials may be picked up and differentially transported. Melting rates fluctuate and are manifested, in the case of a fast rate, by large outpourings of material which aggrade outwash plains of great extent. Lakes are formed by the accumulation of meltwater in depressions or by dammed-up valleys. In these lakes, fine clay and silt-size sediments are deposited, often in thick beds of soft material. Similar clay deposits from previous glacial periods, subsequently consolidated under later glacial ice, are the source of the hard tough blue clays exposed in the bluffs throughout the metropolitan area.

Deposition of sediments during retreat of the glacier preceding the Vashon glaciation resulted in an aggraded flood plain extending over the entire Puget Lowland. Following uplift of the plain, an interglacial period of extensive stream erosion occurred which cut deep valleys in the surface of the flood plain, forming intervalley hills and establishing the general topography as it exists today.

Glaciers of the Vashon period, in their advance southward from Canada, modified the interglacial topography by plastering till over the upland surfaces and deepening the valleys which were most in sympathy with the over-all trend of ice movement. Within the metropolitan area, the Vashon till sheet generally is a relatively thin veneer which covers the slopes and summits of the interglacially formed hills and, in some places, the floors of the interhill valleys. Increasing in thickness in the northern part of the area, the till sheet reaches its maximum thickness of about

150 feet north of the Snohomish-King County line. Extensive morainic and outwash deposits laid down during the early Vashon retreat appear to have obliterated completely the interglacially eroded valleys in the Puget Sound basin south of the metropolitan area. While this obscuring of interglacial topography occurred locally in some instances, the pre-Vashon valleys within the metropolitan area which were exposed by the ice retreat were generally little modified by outwash and recessional morainic deposits.

As the ice retreated northward, a series of glacial lakes formed between the ice front and the drainage divide south of Olympia. As this artificial basin filled with glacial meltwater, these lakes coalesced to form a master lake. At its maximum, the master lake, given the name of Lake Russell, extended from Olympia to the vicinity of Everett and its surface lay at 160 feet above the present sea level. After the ice retreated to a point where the Strait of Juan de Fuca was reopened, the lake was destroyed and marine waters invaded the basin.

Since the disappearance of the glacial ice, the area has been uplifted slightly, and moderate warping or tilting done to the south has occurred, with the axis of tilting lying just south of the city of Seattle. Moderate postglacial erosion of the upland areas has taken place, as have deposition and delta-building in the valleys. Wave-cutting at the bases, and subsequent sloughing of the upper parts, has caused retreat of the cliffs, particularly those facing Puget Sound.

Available Geological Information

Although mapping of the surface geology in Seattle has not been completed, unpublished data are available from various sources. Definitive subsurface geological data, however, are not available from any source and little is known about the interior composition of the hills, such as the distribution or continuity of formations. Surface soils have been classified and mapped on a pedological basis by the United States Department of Agriculture and results thereof have been published for King[1] and Snohomish[2] counties. Well logs, together with data from previous soils explorations, are available but the latter are generally limited to highway routes and to lowland areas and filled tidelands where industrial expansion has taken place. In the upland areas, particularly east of Lake Washington, drilling data are generally lacking. Considerable unpublished information concerning bottom conditions in Lake Washington was obtained from the Department of Oceanography, University of Washington. On the other hand, little is known about bottom conditions in Puget Sound.

Although available information and data concerning the geology of the metropolitan area are generally meager, they are sufficient for preliminary planning purposes. It should be pointed out, however, that the sewer routes selected in this report should not be considered as specific in every instance and that, as a part of final design, minor departures from selected routes may, and probably will, be necessary because of soil conditions. On the whole, such departures will not affect the relative merits of the various alternatives presented, nor should they have a significant effect on total costs. It should be emphasized, however, that adequate exploration programs and geological examinations of samples must be undertaken as a part of final design and prior to selection of precise routes.

Soil and Foundation Conditions

On the basis of available information, certain generalizations may be made as to the foundation conditions which exist in the metropolitan Seattle area. It is important to note at the outset, however, that because there have been at least three and possibly four periods of glaciation, considerable horizontal and vertical variation in subsurface geology can be expected. Nevertheless, generally similar conditions will occur in similar land forms, such as the upland regions and hills, the lowland valleys, and the troughs occupied by Lake Washington and Puget Sound. Notable exceptions to the generalized conditions are the prominent slide areas found in the bluffs and the bedrock exposures which exist in certain locations.

Upland Areas and Hills. In general, a shallow weathered soil from two to six feet in depth has formed over the upland areas and is underlain extensively by hard cemented till. Where post-glacial erosion has removed the till cap, firm compact clay (hard pan) often underlies the surface soil. East of Lake Washington, along the area south of Highway 10, sandstone and shale rock are found at shallow depths. Morainic deposits of sand and gravel and recessional outwash deposits are also found over much of the uplands, extending in some instances to great depths and over a considerable area. Peat deposits have accumulated along the courses of many small creeks draining the upland areas as well as in local kettle-like depressions. Ground water tables vary seasonally but may be generally high where underlain by shallow impermeable strata. Except where peat deposits are encountered, the upland soils have excellent bearing capacities for foundations of structures and good bedding conditions for pipelines.

Soil formations composing the interior of the hills within the metropolitan area may be grouped into three

[1] *Soil Survey, King County Washington, U.S. Department of Agriculture, Series 1938, No. 31, 1952.*

[2] *Soil Survey, Snohomish County Washington, U.S. Department of Agriculture, Series 1937, No. 19, 1947.*

general classifications: (1) firm, generally dry, compact clays and silts, (2) hard cemented till, and (3) water-bearing sands and gravels. Of these, the firm clays and silts predominate at the lower elevations and require excavation with mechanical equipment. In tunnels, the firm clays and silts stand with minimum support. The cemented till also requires minimum support and, when encountered in confined places such as trenches or tunnels, may necessitate blasting for economical excavation.

Sand and gravel generally constitute a subterranean pocket or reservoir of water, and are of primary concern when encountered in tunneling operations. In such cases, the quantity of water which must be handled is dependent upon the gradation or size of the particles as well as upon the extent of the deposit. Horizontal well-points installed in advance of the tunnel face may be necessary if large quantities of water are encountered. Chemical stabilization or solidification processes, developed in recent years, also may be resorted to in order to reduce the water inflow and the amount of tight lagging required for support. Of the ten major tunnels driven in Seattle during the last sixty years, four encountered difficult water conditions. Of these, three were constructed in the period from 1892 to 1912 prior to the development of modern construction equipment and techniques for handling such problems.

Lowland Valleys. Soil conditions in the lowland areas consist of alluvial deposits of soft clay, silts, and fine to coarse sands intermixed with gravel. These soils may be grouped into two general classifications: (1) silty alluvium composed of the fine grained, low strength, more compressible soils occupying the low areas and depressions, and (2) sandy alluvium composed of the more granular, permeable soils having better supporting characteristics and lying at slightly higher elevation. Being alluvial in origin, the lowland soils are generally sorted as to size but occur in lenses or pockets rather than as stratified deposits of uniform elevation. The higher sandy soils, being more granular, are easily drained. Peat, up to 12 feet in depth, is widely distributed throughout the lowland areas but is found more frequently in areas adjacent to the bluffs forming the valley walls.

High groundwater tables are encountered in the lowland areas. Water is found at depths from one to six feet below the surface during summer months and is generally at or above the ground surface during the winter.

Valley soils frequently require piles or other special foundations for the support of structures and usually require a special bedding of granular material for pipelines. While similar to the alluvial valley soils, soils underlying the reclaimed tidelands are often more compressible and may require piling for support of larger size pipelines.

Lake Washington Trough. Considerable unpublished data have been obtained by the Department of Oceanography during a core sampling study of the bottom sediments in the deeper portions of Lake Washington. These data disclose that much of the lake bottom consists of a layer, up to 40 feet deep, of soft, almost fluid, organic peat-like sediment overlying an unknown depth of soft, compressible glacial blue clay. A core drilled in 190 feet of water between Union Bay and Evergreen Point extended 140 feet below the lake bottom without penetrating the soft clay deposits. Closer to shore, data from borings indicate that the steeply inclined sides of the lake bottom are composed of firm, compact glacial deposits similar to those exposed in the adjoining bluffs. Evidence indicates also that only relatively shallow soft sediments have been deposited on the wave-cut terrace where it extends outwards from shore. In the shallow area at the south end of the lake, loose silts and sands have been deposited during delta-building by the Cedar River. At the north end of the lake, in the Kenmore area, the lake bottom is composed of sand and gravels washed into the lake from the upland morainic deposits to the north. Near the mouth of the Sammamish River, these sands and gravels are overlain by alluvial soils.

Puget Sound Trough. Little is known about the bottom conditions of Puget Sound. Sampling has been confined to grab samples of sediments lying immediately on the bottom. Work performed offshore from Point Wells indicates that the steeply inclined sides of Puget Sound may be composed of firm materials similar to those found in the steep bottom slopes in Lake Washington. Bottom areas denoted as rocky on the navigation charts may be either these firm glacial deposits or glacial erratics ranging up to many feet in diameter.

Slide Areas. Slide areas are prevalent in the bluffs bounding the upland areas where a considerable depth of sand overlies impermeable clay formations. Where these conditions are encountered, the cause of sliding may be ascribed to water percolating downward through the sand deposit to the upper face of the clay layer and draining outward to the cliff face, causing sloughing and slumping in the cohesionless sand. Large slide areas are particularly noticeable along the cliffs facing Puget Sound where wave-cutting of the underlying clay formations occurs. A pronounced example of areal sliding is located along the south and west side of Magnolia Bluff extending from Smith Cove to south of West Point. North of West Point toward Shilshole Bay, four large slide areas are located.

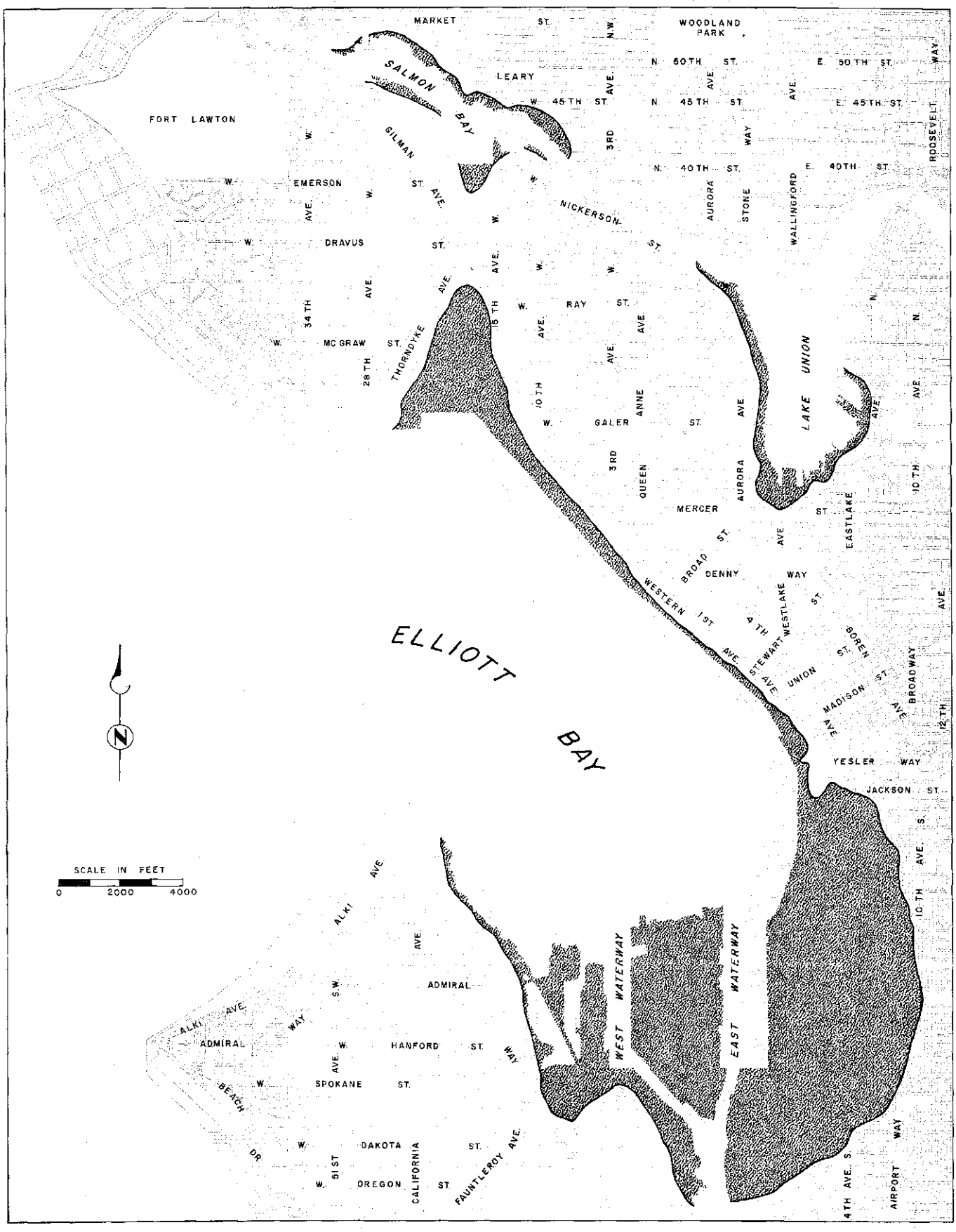


Fig. 3-4. Reclaimed Tidelands

Formerly submerged, the shaded areas have been filled and reclaimed for industrial use. As the need for industrial land developed, shorelands were reclaimed first around Lake Union and later along Elliott Bay. Following construction of the Government Locks, additional land was reclaimed along the Ship Canal. Special problems are involved in the planning of sewerage and drainage facilities across these areas because of lack of surface slope and difficult foundation conditions.

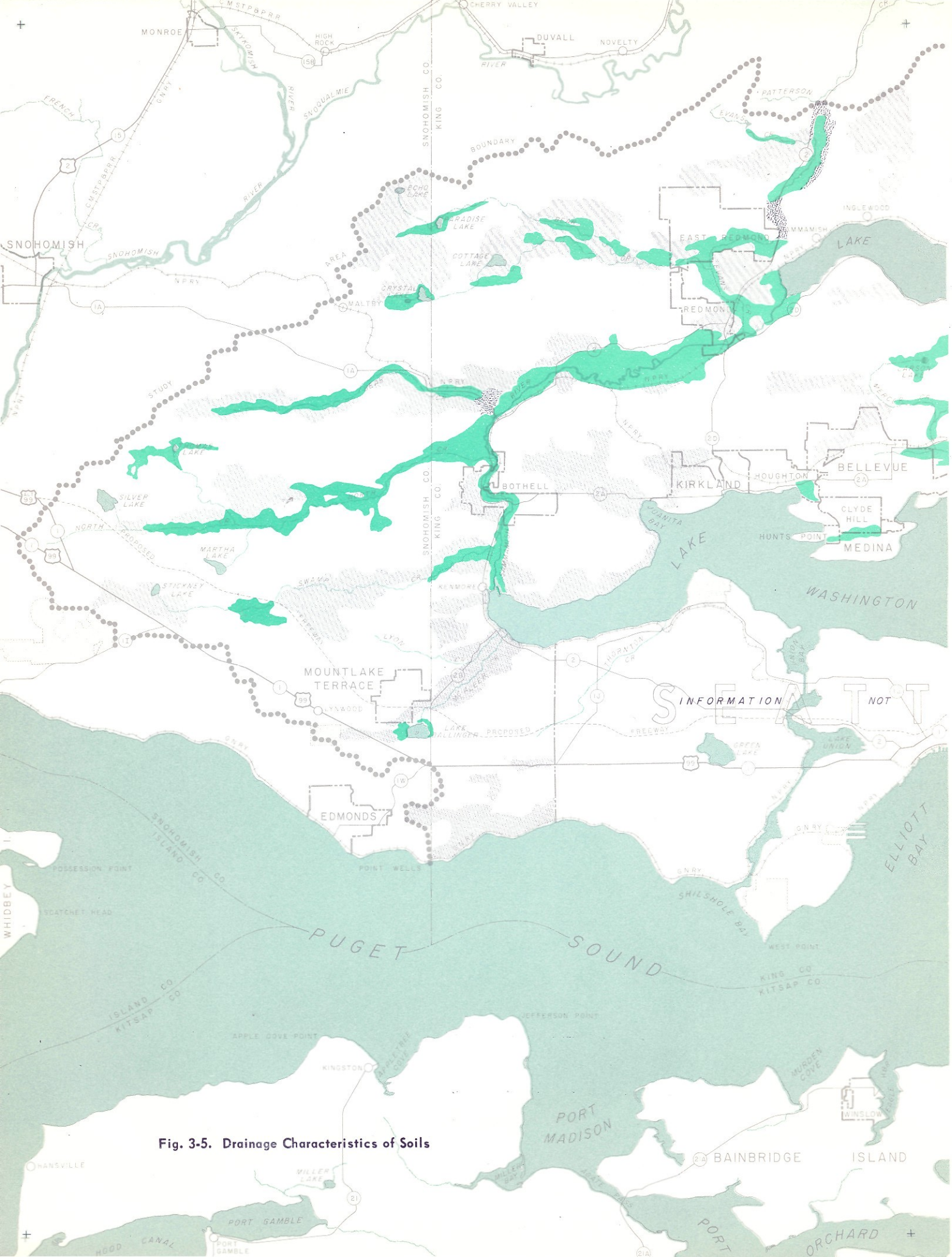
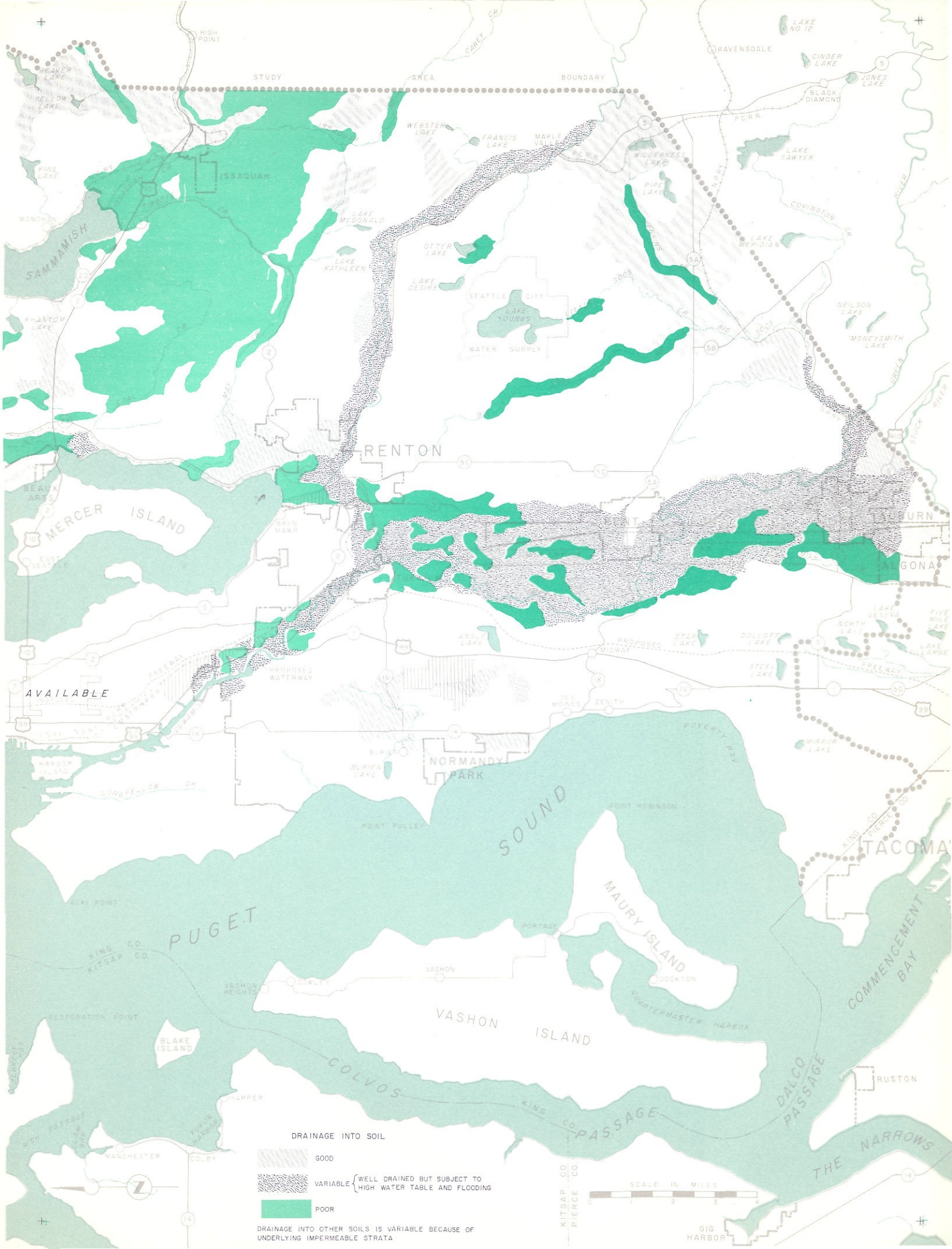


Fig. 3-5. Drainage Characteristics of Soils


STUDY AREA BOUNDARY
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MONOHON
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OTTER LAKE
LAKE KATHLEEN
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MERCER ISLAND
EAST SEATTLE
BRYN MAWR
ALGONA
LAKE GENEVA
NORTH LAKE
FIVE MILE LAKE
LAKE KILLARNE
ANGLE LAKE
PEARL LAKE
DOLLOFF LAKE
PROPOSED MIDWAY FREEWAY
STEEL LAKE
PROPOSED WATERWAY
AVAILABLE
DES MOINES
ZENITH
POVERTY BAY
MIRROR LAKE
HARBOR ISLAND
BURIEN
BURIEN LAKE
NORMANDY PARK
LONGFELLOW CR
POINT ROBINSON
POINT PULLEY
PUGET SOUND
KING CO
PIERCE CO
TACOMA
ALKI POINT
MAURY ISLAND
PORTAGE
KING CO
KITSAP CO
VASHON
VASHON HEIGHTS
DOCKTON
QUARTERMASTER HARBOR
COMMENCEMENT BAY
RESTORATION POINT
BLAKE ISLAND
VASHON ISLAND
COLVOS PASSAGE
KING CO
DALCO PASSAGE
RUSTON
HARPER
YOUNG HARBOR
MANCHESTER
COLBY
THE NARROWS
KITSAP CO
PIERCE CO
SCALE IN MILES
0 1 2 3 4
GIG HARBOR
DRAINAGE INTO SOIL
GOOD
VARIABLE
WELL DRAINED BUT SUBJECT TO HIGH WATER TABLE AND FLOODING
POOR
DRAINAGE INTO OTHER SOILS IS VARIABLE BECAUSE OF UNDERLYING IMPERMEABLE STRATA

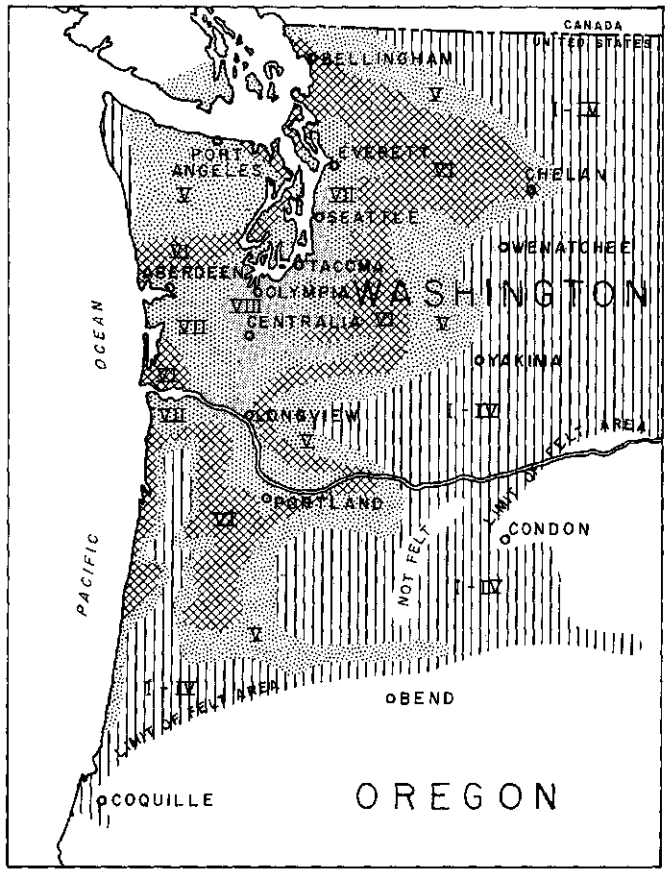


Fig. 3-6. Isoseismal Map for Earthquake of April 13, 1949

Very strong to ruinous motion was observed in the metropolitan area during this earthquake, which had its epicenter near Olympia.

One of these, extending for approximately 1,300 feet along the bluff and from 300 to 500 feet back from the toe, is centered above the portal of the North Trunk sewer tunnel. An estimated 10,000 to 200,000 cubic yards of material are sliding at this location.

Bedrock. Bedrock in the metropolitan area consists of marine shales, sandstones and conglomerates, with intercalated basalts. Bedrock is not well exposed except in a relatively narrow belt extending westerly from Issaquah across Seward Park to the Duwamish valley. It appears also at Alki Point where it passes beneath Puget Sound.

Major exposures of bedrock occur on the high ridge west of Issaquah and at various locations along the west side of Beacon Hill south to the Black River junction. Bedrock is also exposed along the west side of the Duwamish valley in the vicinity of Tukwila.

Reclaimed Areas. In recent years, some of the shoreland areas have been filled in and reclaimed for industrial purposes, thus modifying their natural condition. Since a wide variety of materials, including sawdust, have been used as a fill, piling or other special foundations may be required therein for structural support. Fig. 3-4, prepared from old topographic maps, shows the extent of reclaimed areas in the vicinity of Seattle.

Limitation on Local Sewage Disposal

Downward drainage characteristics of the subsoils, as well as of the surface soils, have an important bearing on the efficiency of the septic tank and leaching field method of local sewage disposal. As shown by Fig. 3-5, which was prepared from Department of Agriculture Soil Survey maps, drainage characteristics of soils in the metropolitan area range from good to poor. Rapid downward drainage occurs where the surface soils are underlain by porous morainic deposits. Much of the area, however, is underlain by till, firm clay or rock at depths varying from two to six feet. Under such a condition, leaching field drainage may serve adequately for a number of years until population density increases and the area builds

Table 3-1. Comparison of Local Climatological Data

Station	Index number[a]	Elevation, feet	Record, years		Temperature, °F		Precipitation, inches	
			Temp.	Precip.	Normal	1956	Normal	1956
Bothell	0826	105	23	24	50.0	b	38.10	38.29
Everett	2675	120	42	42	50.1	50.0	32.46	39.83
Kent	4169	40	31	39	51.2	50.7	36.59	37.61
Seattle								
Boeing Field	7483	14	28	28	52.2	51.5	34.28	32.17
Federal Office Building	7488	14	66	79	53.2	52.3	32.05	32.11
Maple Leaf Reservoir	7463	422	–	10	–	–	34.56	30.68
Naval Air Station	7468	21	–	26	–	–	30.87	30.48
University of Washington	7478	60	36	46	51.9	52.5	32.04	32.75
Seattle-Tacoma Airport	7473	366	12	12	50.7	49.7	33.93	36.85

Source: "Local Climatological Data - Washington, Annual Summary, 1956" and earlier years, U.S. Weather Bureau.

[a]*Official U.S. Weather Bureau designation for station.*

[b]*Data missing.*

up to such an extent that effluent contributions exceed the absorptive capacity of the soil. Similarly, seasonal variation in the ground water table below the more permeable sandy soils limits the use of septic tanks in the valley and lowland areas. In both of these cases, drainage conditions are shown as variable (Fig. 3-5) because adequate drainage would not be available at all times.

Areas shown as having poor drainage characteristics, and therefore as being unsuitable for septic tank use, include the peat deposits in the uplands and the silty alluvial deposits in the valleys and lowlands. Also included in this category is the east-west bedrock ridge extending from Issaquah to Lake Washington.

Seismic Conditions

The Pacific Northwest area is considered to be a seismically active area, or major earthquake zone. Because of the thickness and extent of Pliestocene sediments in the Puget Lowland section, however, earthquake faults are not generally apparent and are therefore unmapped.

In the period from 1841 to 1949, 108 strong motion earthquakes were noted in Washington, Oregon, western Idaho and western Montana. Major earthquakes of intensity VII on the modified Mercalli scale occurred in the immediate area on November 12, 1939 and February 14, 1946.

The most recent major shock, which occurred on April 13, 1949, produced strong motion in an area of more than 10,000 square miles in western Washington and northwestern Oregon. This shock caused a loss of 8 lives and injury to 62 persons, and resulted in property damage variously estimated as costing anywhere from 15 to 50 million dollars. As shown by the isoseismal map in Fig. 3-6, intensities of VI, VII, and VIII on the modified Mercalli scale were felt in the metropolitan area at that time[3].

CLIMATE

Sewerage and drainage functions are affected in various ways by climatic factors. Air temperature, for example, determines the time and extent of the season of outdoor sports involving intimate contact

[3]*Source: "The Trend in Engineering", University of Washington, January 1953.*

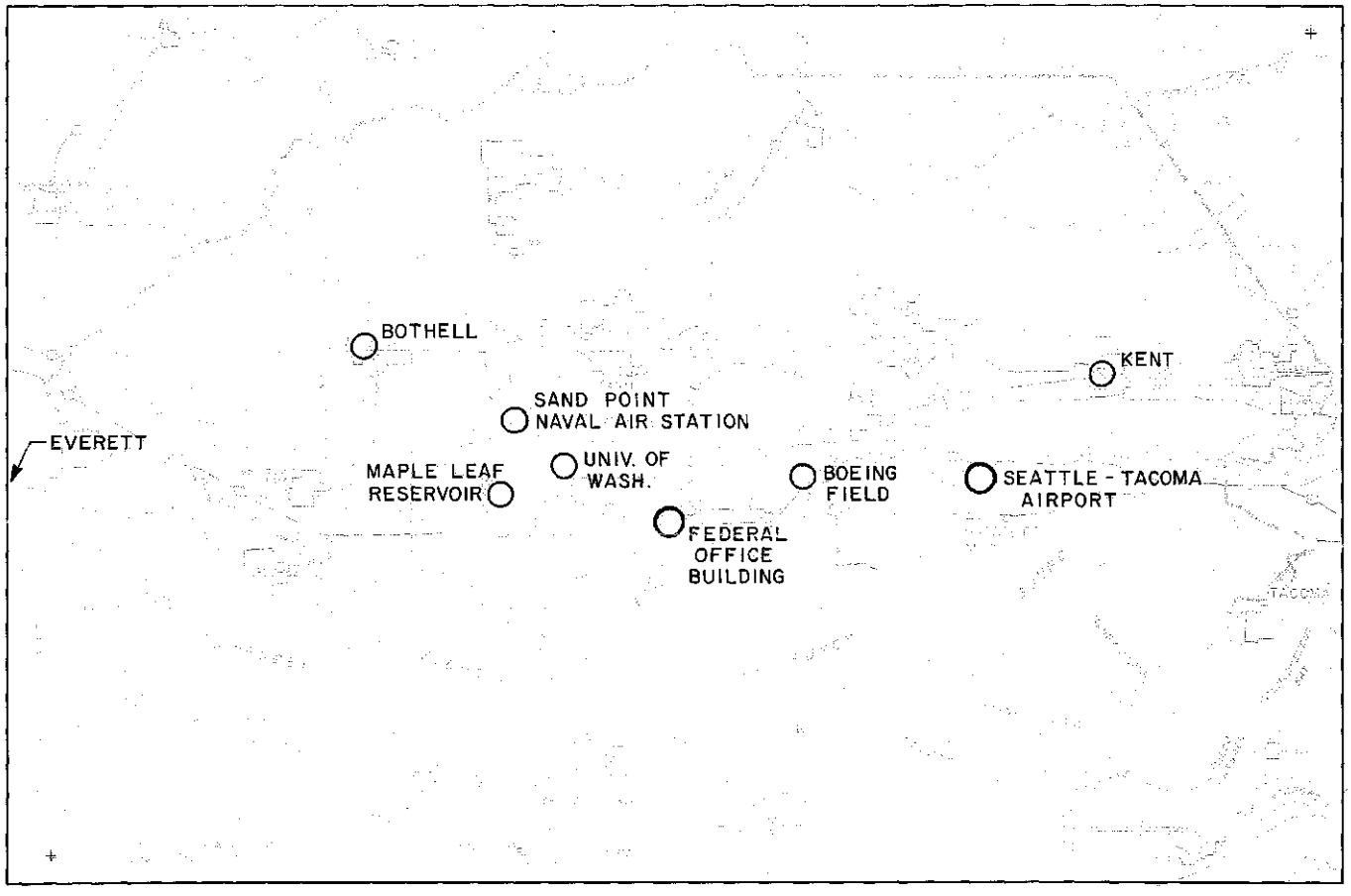


Fig. 3-7. Location of Climatological Stations

Climatological data are reported by the U.S. Weather Bureau for the nine locations shown.

with surface waters, both salt and fresh. Because surface water temperatures are related to air temperatures, a high air temperature condition accelerates biological activity, which in turn brings about the destruction and stabilization of organic matter contained in sewage and treated sewage effluents. During cold weather a greater amount of heat is required for heating sludge digestion tanks than in warm weather.

Wind has both beneficial and detrimental effects. When a wind is blowing, the rate of oxygen absorption in bodies of water is increased as is the rate of evaporation. Oxygen absorption is of importance in supplying oxygen for stabilization of wastes discharged to receiving waters, while evaporation aids in the drying of digested sewage sludge on open air beds or in lagoons. Wind also determines the distance and direction which disagreeable odors may travel and, in some cases, may require that provision be made for odor control or elimination. In recreational areas situated in the vicinity of waste discharges, wind induced onshore surface currents may impose added requirements for a higher degree of treatment. On the other hand, winds may cause choppy surface conditions which aid in the mixing of sewage effluent with the main body of water.

Rainfall is by far the most significant of the climatic factors. It governs the required capacity of storm drainage facilities and, through infiltration, may have a profound effect on collection systems designed solely for sanitary sewage. An analysis of the relationship between rainfall frequency, duration, and intensity is of prime importance in the design of storm drainage facilities. When utilized with appropriate runoff coefficients, these factors determine the quantity of storm water which must be conveyed to a suitable point of disposal. This relationship must be considered also in the design of intercepting sewers which serve combined systems carrying both storm runoff and sanitary sewage.

General Climatic Conditions

Marine air from the Pacific Ocean, 90 miles to the west, readily penetrates inland and is, to a large degree, the source of the equable year-round temperatures prevailing in the metropolitan Seattle area. To a lesser degree, the extensive water surfaces of Puget Sound serve to equalize temperature extremes. On the other hand, the Cascade mountains usually serve during winter months to block the westward movement of cold continental air masses. Average daytime temperatures during the winter are in the 40° to 50° F range, while those at night are in the 30° to 40° F range. Summer temperatures range generally from 70° to 80° F in the afternoon and from 50° to 60° F during the night.

Rainfall, modified considerably by the Olympic Mountains to the west, occurs during a pronounced, though not sharply defined rainy season and totals between 30 and 40 inches per year. The Olympics serve further to deflect or retard inland movement of the more severe storms occurring along the coast.

Local variations in temperature and precipitation, as recorded by the nine stations which report to the United States Weather Bureau, are indicated by the data in Table 3-1. Locations of these stations are shown in Fig. 3-7. For the area as a whole, temperatures in 1956 were slightly below normal, while precipitation was above normal. Variations between stations are attributable to the effects of local topography and the locations of the stations with reference to the sound and adjacent waters. It should be noted also that the actual instrument location at a given station can be such as to cause variations or erroneous readings of the same order of magnitude as the area-wide variations indicated in Table 3-1.

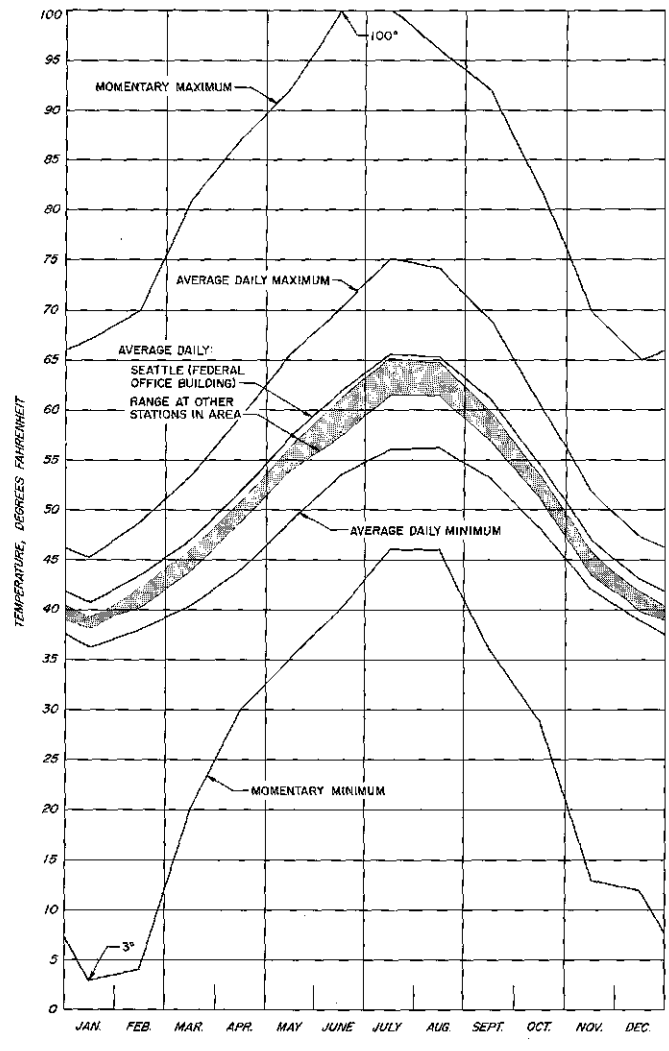


Fig. 3-8. Air Temperatures in Seattle

Air temperatures in Seattle are indicative of those in other portions of the metropolitan area. Average monthly temperatures at the other climatological stations vary by a maximum of 4° F.

Table 3-2. Temperature Data for Seattle

Month	Normals[a]			Extremes of record[b]		Normal degree days[a]
	Monthly	Daily Maximum	Daily Minimum	Highest	Lowest	
January	40.7	45.2	36.2	67	3	753
February	43.5	48.8	38.1	70	4	602
March	47.0	53.4	40.5	81	20	558
April	51.8	59.4	44.1	87	30	396
May	57.3	65.6	48.9	92	35	246
June	61.8	70.2	53.4	100	40	107
July	65.6	75.1	56.1	100	46	49
August	65.2	74.2	56.2	96	46	45
September	61.0	68.8	53.2	92	36	134
October	54.4	60.5	48.2	82	29	329
November	47.0	51.8	42.1	70	13	540
December	43.1	47.3	38.9	65	12	679
Year	53.2	60.0	46.3	100	3	4,438

Temperatures expressed in degrees Fahrenheit.

Source: "Local Climatological Data with Comparative Data – Seattle, 1956", U.S. Weather Bureau.

[a]*For 30-year period 1921-1950.*

[b]*For 64-year period ending in 1956.*

The season during which significant use of beach areas takes place normally extends from May through September. In any one year, however, actual use may begin earlier or end later, depending on climatic conditions then prevailing.

Temperature

Average annual temperatures do not vary greatly from year to year. Since 1905, averages recorded at the downtown Seattle station, now located at the Federal Office Building, have fallen within a range of 6.3° F, marked by a high of 55.5° F for the year 1940 and a low of 49.2° F for the year 1916.

Monthly and daily temperatures, of course, are subject to more variation. Fig. 3-8 shows temperature data for the downtown Seattle station and indicates by a shaded zone the range in average temperatures at the other climatological stations. Basic data from which the Seattle curves are plotted are given in Table3-2.

Table 3-3. Relative Humidity Data

Month	Seattle, Boeing Field[a]				Seattle-Tacoma Airport[b]			
	4:30 a.m.	10:30 a.m.	4:30 p.m.	10:30 p.m.	4:30 a.m.	10:30 a.m.	4:30 p.m.	10:30 p.m.
January	86	80	74	83	88	85	83	87
February	87	78	69	83	89	82	75	85
March	86	70	59	78	88	77	68	83
April	86	63	52	75	88	67	54	76
May	86	61	50	74	88	65	53	76
June	86	63	52	74	90	67	57	79
July	86	63	47	72	91	69	50	77
August	88	68	51	76	92	71	53	80
September	91	72	57	81	94	75	59	84
October	92	80	69	87	94	82	74	88
November	90	82	77	87	89	84	81	87
December	87	83	78	85	89	87	84	87
Year	88	72	61	80	90	76	66	82

Relative humidity is expressed in per cent.

Source: "Local Climatological Data with Comparative Data – 1956" for Seattle, Federal Office Building station and for Seattle-Tacoma Airport station.

[a]*Period of record 17 years; equipment formerly at Federal Office Building station moved to this location in 1939.*

[b]*Period of record 7 years.*

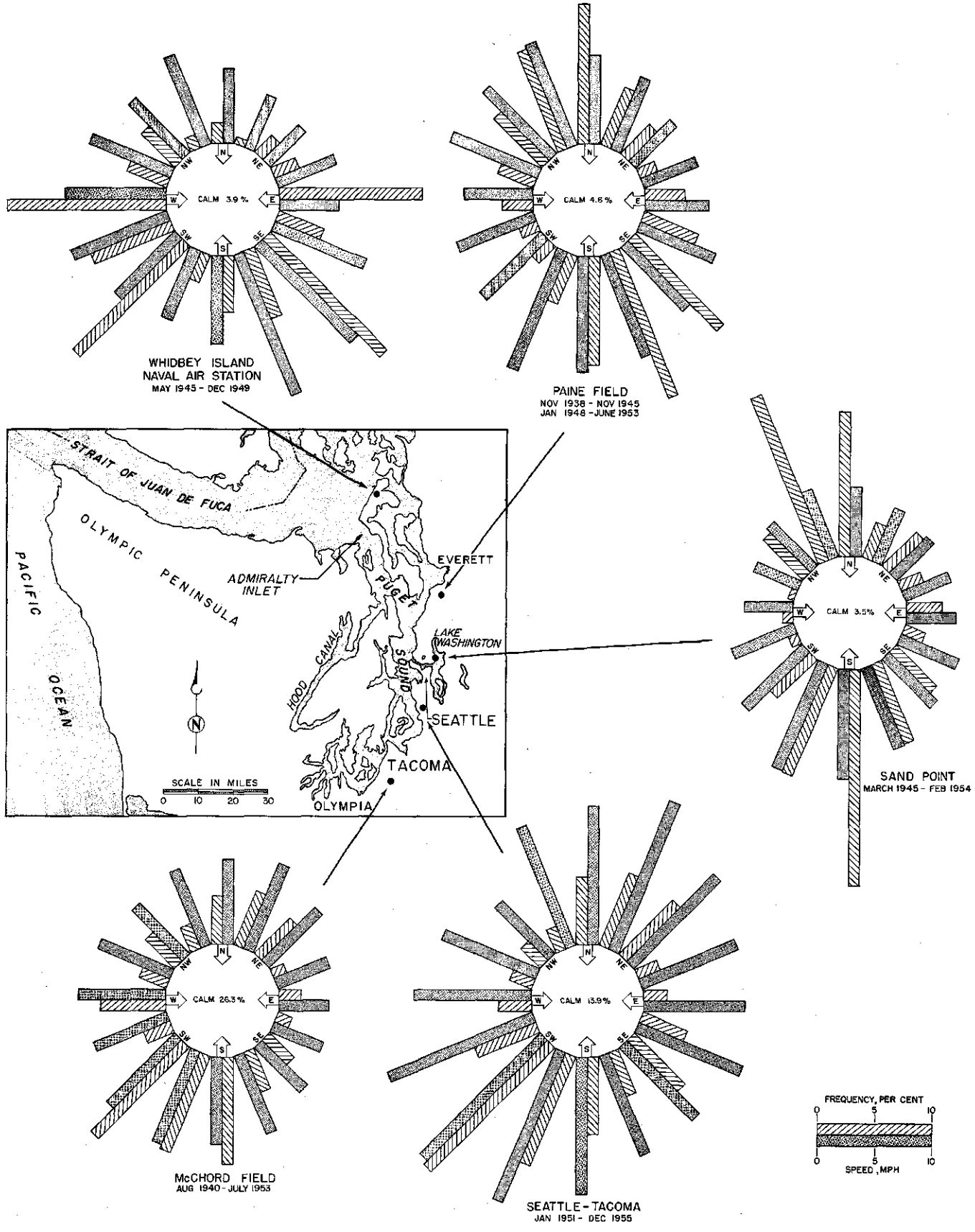


Fig. 3-9. Annual Wind Summary for Central Puget Sound Region

Frequency and velocity data were developed by the Air Weather Service and are given in Table 3-4. The prevailing wind direction varies from southwest at McChord Field to east at Whidbey Island and reflects the topographic effects of the Olympic and Cascade mountain ranges.

Table 3-4. Wind Summary for Central Puget Sound Region

Wind origin	Frequency of occurrence, per cent					Average velocity, mph				
	Whidbey Island	Paine Field	Sand Point	Seattle-Tacoma	McChord Field	Whidbey Island	Paine Field	Sand Point	Seattle-Tacoma	McChord Field
N	1.8	12.1	12.7	5.9	4.2	6.5	7.7	6.1	12.0	7.4
NNE	0.6	5.4	3.3	6.9	4.6	5.1	6.8	5.1	14.1	8.1
NE	2.1	3.5	4.2	6.7	4.4	4.4	5.1	4.6	10.8	6.5
ENE	2.3	1.5	2.1	2.1	1.2	5.5	5.1	4.4	9.1	4.8
E	12.5	3.5	3.2	2.2	1.9	5.2	5.6	4.4	9.0	4.3
ESE	4.2	5.1	1.9	4.3	1.3	8.6	7.2	5.5	10.0	4.6
SE	14.6	11.5	5.0	6.3	3.0	11.8	7.8	6.0	9.0	5.5
SSE	6.3	13.8	7.5	4.1	3.8	13.2	9.6	7.6	9.4	7.4
S	4.9	9.5	19.0	6.8	9.4	7.8	10.1	9.7	12.0	7.7
SSW	2.5	4.5	10.2	10.3	9.1	6.5	11.2	10.1	14.2	8.8
SW	13.6	2.1	4.8	15.4	11.3	7.5	7.5	7.3	15.0	8.5
WSW	7.5	1.7	0.8	5.8	5.6	9.0	7.2	5.8	13.7	8.9
W	14.0	2.6	0.9	2.8	5.7	8.9	6.0	4.3	10.3	7.7
WNW	3.8	3.4	0.5	2.0	2.5	7.9	8.3	4.2	8.9	6.9
NW	4.2	6.0	4.9	2.4	3.5	6.8	8.3	5.4	9.5	6.2
NNW	1.2	9.4	15.7	2.1	2.3	8.4	9.7	6.4	11.3	7.1
Calm	3.9	4.6	3.5	13.9	26.3	–	–	–	–	–
Total	100	100	100	100	100	8.1	7.9	6.9	10.3	5.6

Source: "Surface Wind Summaries" for stations listed obtained from Air Weather Service, Data Control Unit, U.S. Weather Bureau.

Period of Record: Whidbey Island Naval Air Station, May 1945 - December 1949.
Paine Field, November 1938 - November 1945 and January 1948 - June 1953.
Sand Point Naval Air Station, March 1945 - February 1954.
Seattle-Tacoma Airport, January 1951 - December 1955.
McChord Air Force Base, August 1940 - July 1953.

Normal monthly temperatures at the downtown station, computed for the 30-year period 1921-1950, vary about 25° F from January, the coldest month, to July, the warmest month. At other stations within the metropolitan area, average monthly temperatures may vary by 5° F from those at the Seattle station (Fig. 3-8). Consistently higher averages at the latter are attributable to the fact that minimum temperatures in the central or downtown business district rarely fall as low as they do in outlying areas.

Monthly averages of maximum and minimum temperatures reached each day (Table 3-2) indicates that maximum temperatures in July average 75.1° F as compared to minimums of 36.2° F in January. In 64 years of record, including 1956, the highest instantaneous or momentary temperature recorded at the Seattle station was 100° F in June 1955, while the lowest was 3° F in January 1893. Since 1893, the lowest reading was 11° F in January 1950.

Relative Humidity

Relative humidity data for the downtown Seattle station and for Seattle-Tacoma airport (Table 3-3) indicate essentially equal values at both stations. Lowest humidities normally occur in July and the highest in December. As applied to sewage treatment, relative humidity is significant in that a high humidity tends to retard the drying of digested sewage sludge on open air drying beds.

Wind

Surface winds at various locations within the metropolitan area are subject to considerable variation in direction, velocity and frequency. In general, prevailing winds in the Puget Sound basin are from a southerly direction during the winter months, while northerly winds occur more frequently during the summer. The strongest winds are almost always from the southwest.

Variations in wind direction, speed and frequency are illustrated in Fig. 3-9. This figure was prepared from annual summaries (Table 3-4) of wind observations made at Whidbey Island Naval Air Station, Paine Field (Snohomish County Airport), Sand Point Naval Air Station, Seattle-Tacoma Airport, and McChord Air Force Base just south of Tacoma. It will be seen that prevailing directions vary from southwest at McChord Field to southeast at Whidbey Island. Monthly variations at Seattle-Tacoma Airport are given in Table 3-5 and are shown graphically in Fig. 3-10.

Evaporation

Since 1948, evaporation data have been collected at Maple Leaf Reservoir, a unit of the Seattle water system situated in the north central section of the city. Table 3-6 gives the total evaporation and total precipitation averaged by months for the period 1948 to 1956 inclusive. It also gives the net evaporation, or the difference between total evaporation and precipitation, for the year 1956. Monthly total and net evaporation and total precipitation are shown graphically in Fig. 3-11 as averages for the period of record.

For 1956, as a whole, precipitation exceeded evaporation by 1.03 inches (Table 3-6). During the summer months, with higher temperatures and lower precipitation, evaporation was in excess of precipitation, while the reverse was true during the winter months. The data for June 1956 reflect an abnormal condition wherein precipitation (3.56 inches) was much greater than the average (1.81 inches) for June.

As applied to sewerage, a negative value for net evaporation indicates that sludge drying beds either must be equipped for removal of excess water or must be provided with covers. In addition, their capacity must be sufficient to hold sludge produced during winter months for subsequent drying during summer months.

Occurrence of Sunshine, Clouds and Fog

Table 3-7 lists data pertaining to sunshine, clouds and fog, as recorded at the downtown Seattle station. Similar data for Seattle-Tacoma Airport show generally comparable conditions.

On the average, these records indicate that 72 days per year are completely clear from sunrise to sunset, and that 46 of these, or 64 per cent, occur during the

Table 3-5. Monthly Wind Frequency and Speed Data for Seattle-Tacoma Airport

Direction	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Frequency, per cent						
N	3	4	5	7	7	7	8	7	10	7	3	3
NNE	5	6	5	8	7	6	8	7	11	10	5	5
NE	4	5	5	8	9	7	8	8	10	8	4	4
ENE	1	1	2	3	2	2	3	3	2	2	2	2
E	4	3	4	2	2	1	1	1	1	2	3	3
ESE	9	6	6	2	2	1	1	1	2	4	9	9
SE	9	7	7	5	4	2	2	3	4	8	13	12
SSE	6	5	4	4	3	2	2	3	3	5	6	6
S	10	9	7	5	6	5	4	4	6	9	9	10
SSW	16	12	12	8	8	9	7	8	10	11	9	13
SW	15	14	18	16	18	24	16	15	12	11	11	14
WSW	3	5	7	7	8	10	8	7	5	4	3	2
W	1	2	2	4	4	4	6	5	3	1	1	1
WNW		1	1	2	3	3	4	4	2	2	1	
NW		1	1	3	4	3	5	6	3	1	1	
NNW	1	2	1	3	4	3	3	3	3	1	1	
Calm	12	17	11	13	11	12	12	15	15	14	19	15
						Speed, mph						
N	12.2	11.3	13.5	12.9	12.2	12.6	11.5	11.3	12.3	10.5	10.3	11.6
NNE	12.0	11.5	12.1	13.0	11.4	12.1	11.4	11.3	12.1	12.5	11.6	13.5
NE	9.7	9.0	10.3	11.4	11.2	11.5	11.3	10.6	10.9	10.2	11.5	10.8
ENE	7.4	7.3	9.2	9.7	9.4	9.9	10.1	9.1	7.9	7.9	9.3	9.3
E	10.1	7.3	10.5	8.9	7.4	8.9	7.9	6.3	6.4	6.9	9.7	11.2
ESE	10.1	9.3	10.1	8.3	8.6	7.7	7.6	6.1	7.7	8.8	11.6	12.4
SE	9.1	8.4	8.4	9.0	8.0	8.0	7.3	7.3	7.5	9.6	9.8	10.3
SSE	9.9	8.9	9.3	10.3	8.9	8.2	8.3	7.8	8.2	9.9	10.3	10.1
S	13.7	12.2	12.4	11.2	9.5	8.8	9.1	8.3	9.5	11.7	12.6	13.4
SSW	16.9	16.3	15.6	14.6	11.4	11.2	10.2	10.1	11.0	14.6	16.5	16.5
SW	18.4	17.8	17.3	17.0	14.6	13.5	11.4	11.6	11.9	15.2	16.2	17.2
WSW	16.4	15.4	17.2	16.3	13.3	12.3	10.7	10.9	11.9	13.6	15.2	16.4
W	8.3	10.3	12.4	11.4	11.6	9.8	10.2	9.6	9.0	9.3	8.1	11.8
WNW	8.7	6.0	8.8	9.2	9.3	9.0	9.7	9.2	8.3	8.0	8.1	8.0
NW	6.4	7.7	8.7	10.1	9.9	10.3	9.3	9.4	8.7	8.1	11.8	10.4
NNW	11.7	10.5	12.7	12.4	11.8	11.7	10.8	11.0	10.6	9.3	10.6	9.5

Source: "Summary of Hourly Observations — Seattle-Tacoma Airport, January 1951 - December 1955", U.S. Department of Commerce, Weather Bureau.

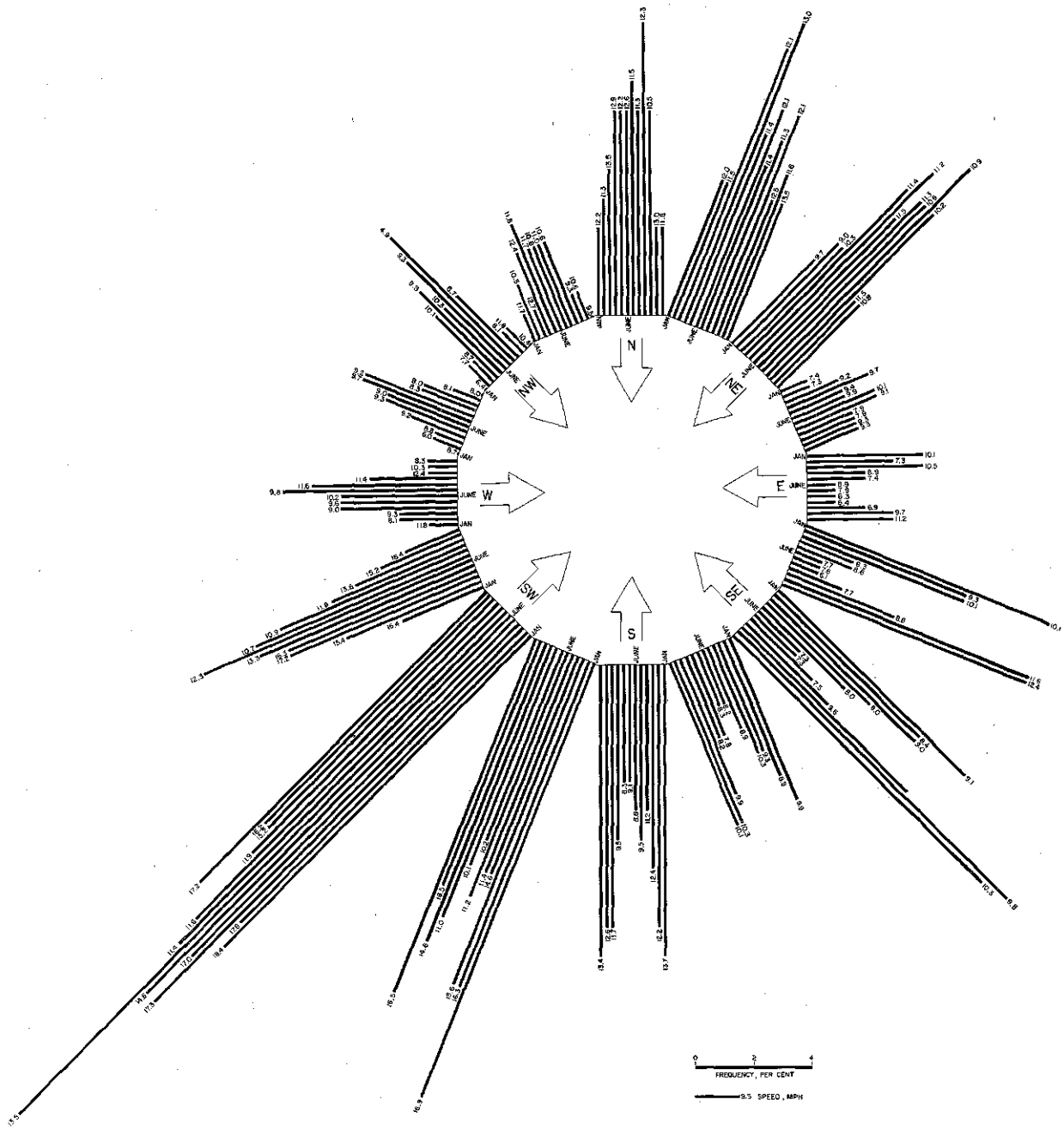


Fig. 3-10. Monthly Frequency, Speed and Direction at Seattle-Tacoma Airport

In contrast to Fig. 3-9, which shows average conditions for the entire year, this figure illustrates monthly variations. Data for the 5 years, 1951 - 1955, were utilized.

five-month period, May through September. Considering the year as a whole, 20 per cent of the days are clear, 25 per cent partly cloudy, and 55 per cent completely overcast.

About 45 per cent of the total possible sunshine occurs during an average year, while a higher average, 54 per cent, occurs during the five summer months. The degree or extent of cloudiness, expressed in terms of relative sky cover, is shown in Table 3-7. A value of 10 represents complete sky cover from sunrise to sunset, whereas lower values indicate increasing sunshine and clear periods. For the 23-year period of record, sky cover averages 6.8 per year and 5.7 per summer.

Heavy fog occurs infrequently, averaging only 24 days per year. This condition develops on an average of about 5 times during summer months and is confined mostly to winter months.

Table 3-6. Evaporation Data for Maple Leaf Reservoir, Seattle

Month	Long term average			1956
	Total evaporation inches	Precipitation[a] inches	Net evaporation inches	Net evaporation inches
January	0.62	6.17	−5.55	−7.47
February	0.86	4.48	−3.62	−2.01
March	1.68	2.85	−1.17	−4.32
April	3.17	1.82	1.35	2.99
May	4.61	1.69	2.92	5.36
June	5.07	1.81	3.26	0.74
July	6.29	1.13	5.16	7.20
August	5.09	0.97	4.12	4.84
September	3.61	1.79	1.82	1.10
October	1.69	3.15	−1.46	−2.49
November	0.78	4.92	−4.14	−1.53
December	0.57	4.29	−3.72	−3.09
Year	34.04	35.07	−1.03	1.32

Source: "Climatological Data - Washington, Annual Summary", 1948 to 1956 inclusive, U.S. Weather Bureau.

[a]*Averaged from individual monthly data excluding those with no corresponding evaporation data.*

Snowfall

Although the higher peaks of the Cascade and Olympic mountains are covered with snow for a good portion of the year and snow falls frequently at elevations as low as 2,000 feet, snowfall within the metropolitan area is not frequent and varies considerably from year to year. For the 23-year period ending in 1956, the mean yearly fall is 8.6 inches. Because the snow very often melts before it reaches measurable depth, falls of one inch or more are rare, occurring on an average of two times per year during the period of record.

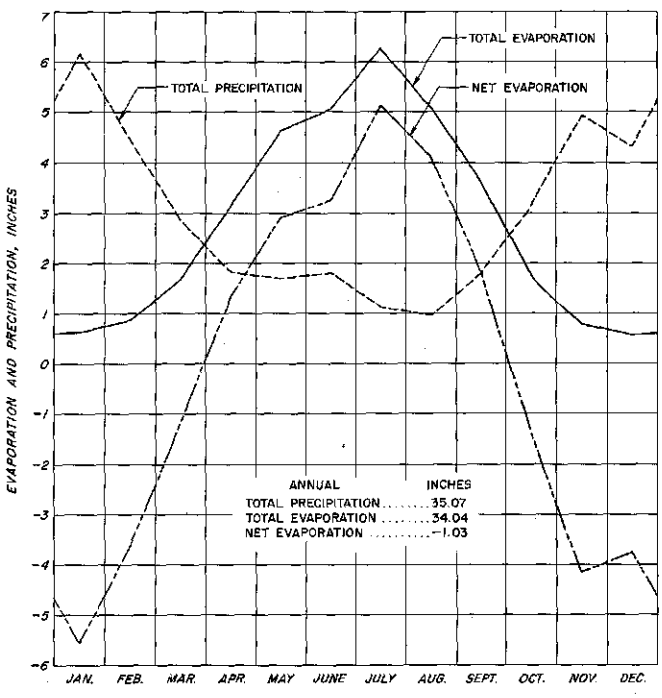


Fig. 3-11. Evaporation at Maple Leaf Reservoir, Seattle

Data for the period 1948-1956 indicate that, on an annual basis, precipitation exceeds evaporation by 1.03 inches.

Table 3-7. Long-Term Sunshine and Cloud Data

Month	Per cent of possible sunshine	Average sky cover[a]	Mean number of days[b]			
			Clear	Partly cloudy	Cloudy	Heavy fog[c]
January	28	8.0	3	5	23	2
February	34	7.7	3	6	19	2
March	42	7.4	4	8	19	2
April	49	6.8	5	10	15	1
May	53	6.4	7	10	14	
June	48	6.4	7	8	15	
July	61	4.8	12	10	9	
August	55	5.2	11	9	11	1
September	53	5.7	9	8	13	4
October	36	7.1	5	8	18	5
November	27	8.0	3	6	21	4
December	24	8.1	3	5	23	3
Year	45	6.8	72	93	200	24

Source: "Local Climatological Data, Seattle (Federal Office Building), 1956". U.S. Weather Bureau.

Period of record 23 years, 1933-1956, except heavy fog.

[a]*Expressed as a relative proportion of 10 which would indicate complete sky cover from sunrise to sunset.*

[b]*From sunrise to sunset, except fog which is for 24-hour period.*

[c]*61-year period of record as reported in above source for 1955.*

Table 3-8. Normal and Long-Term Precipitation Data, Seattle

Month	Monthly				Maximum in 24 hrs. inches
	Normal inches	Average inches	Maximum inches	Minimum inches	
January	4.49	4.80	10.93	1.43	2.47
February	3.87	3.68	8.10	0.34	2.69
March	3.06	2.96	7.23	0.42	2.92
April	1.94	2.13	5.53	0.16	1.74
May	1.61	1.73	4.67	0.09	1.35
June	1.25	1.38	3.70	0.03	1.42
July	0.52	0.60	2.36	0.00	1.22
August	0.87	0.68	2.50	Trace	1.43
September	1.56	1.67	3.46	0.08	1.91
October	3.08	2.92	7.43	0.02	2.22
November	4.46	5.07	9.50	1.04	3.20
December	5.34	5.26	15.33	1.00	3.52
Year	32.05	32.88	15.33	0.00	3.52

Source: "Local Climatological Data, Seattle, 1956", U.S. Weather Bureau, also 1955.

Period of record 65 years, 1892-1956, except normal which is based on 1921-1950.

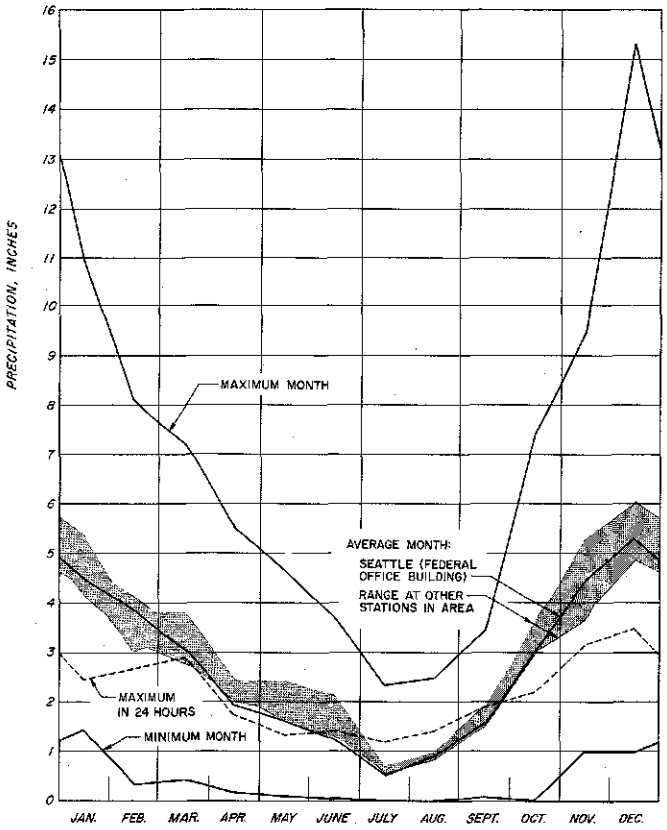


Fig. 3-12. Precipitation in Seattle

Only 18 per cent of the normal yearly precipitation occurs during the five months, May - September. Monthly normal precipitation at stations in the metropolitan area varies by about 1 inch.

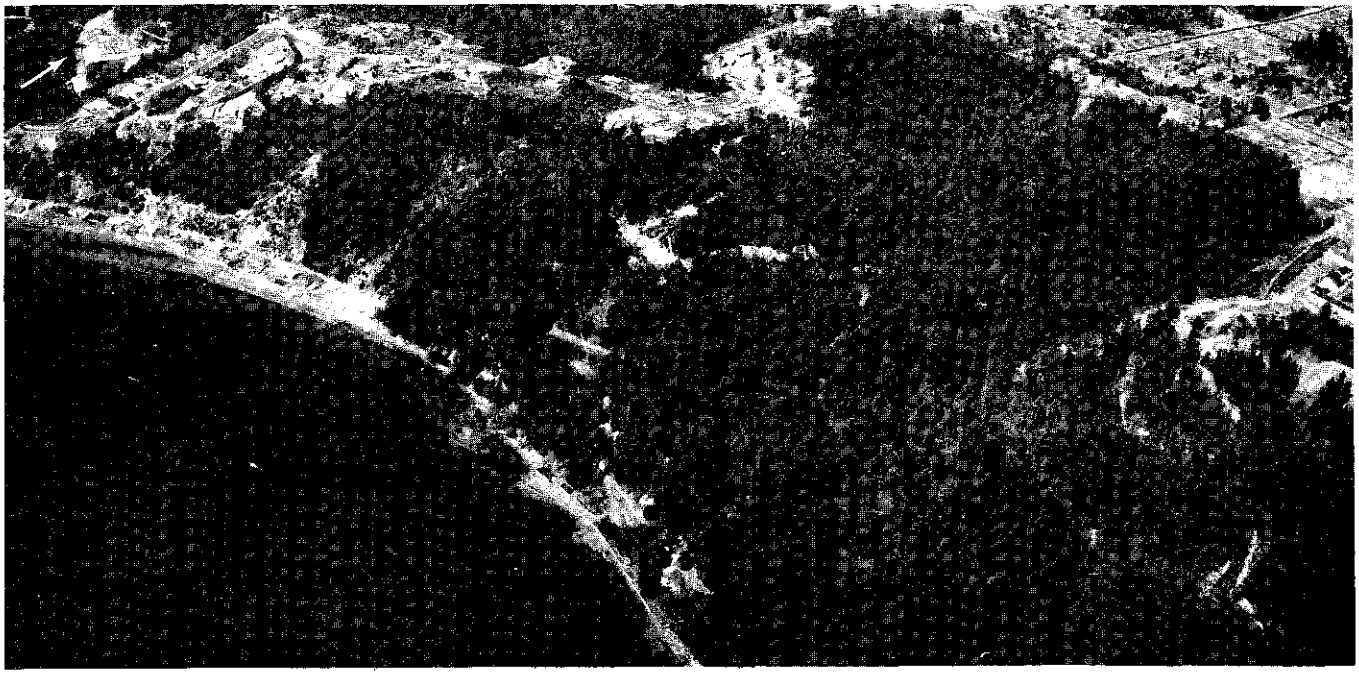
Deep snowfalls in the Seattle area and elsewhere along the shores of Puget Sound occur only when a storm is so oriented that it brings cold air directly out of Canada, or when it has traveled only a short distance over water. Since 1904, the records show traces of snow for seven winters and falls totaling over 20 inches for four winters. The maximum for one winter occurred in 1915-1916 and totaled 60.9 inches, while the greatest fall in 24 hours, 11.5 inches, occurred during January 1943.

Precipitation

As shown previously (Table 3-1), total annual precipitation over the metropolitan area varies somewhat with location. Annual and monthly averages for the downtown Seattle station are given in Table 3-8, together with the minimum and maximum months of record.

Variation in normal monthly precipitation is shown in Fig. 3-12 for downtown Seattle, while the range for other weather stations in the metropolitan area is indicated by the shaded zone in the same figure. A total of 5.81 inches normally falls during the five-month period, May through September. This represents 18 per cent of the annual normal precipitation.

Table 3-9 lists both the number of hours and the number of days during which various amounts of precipitation occurred. These data are based on an analysis by the U.S. Weather Bureau and represent annual averages for a five-year period, 1951 through 1955.



RAINFALL, through infiltration, has a significant effect on sewerage systems designed solely for sanitary sewage. Infiltration studies for various systems, including that tributary to the sewage treatment plant of the Southwest Suburban Sewer District (arrow) are described in Chapter 7.

Table 3-9. Occurrence of Precipitation at Boeing Field, Seattle

Range of precipitation, inches	Hours per year in stated range			Days per year in stated range		
	Summer (May - September)	Winter (October - April)	All Year	Summer (May - September)	Winter (October - April)	All Year
Trace	230	609	839	18	26	44
0.01	66	256	322	6	12	18
0.02 - 0.09	96	422	518	14	35	49
0.10 - 0.24	11	53	64	10	30	40
0.25 - 0.49	0.2	0.8	1	7	21	28
0.50 - 0.99	0.2	0	0.2	2	12	14
1.00 - 1.99	0	0	0	0.4	3	3
2.00 and over	0	0	0	0	0.2	0.2
Total	403	1,341	1,744	57	139	196

Source: Unpublished tabulation "Frequency of Precipitation Amounts, Boeing Field, Seattle, Washington". U.S. Weather Bureau.

Based on period January 1951 through December 1955. Values greater than 1 have been rounded to nearest whole number.

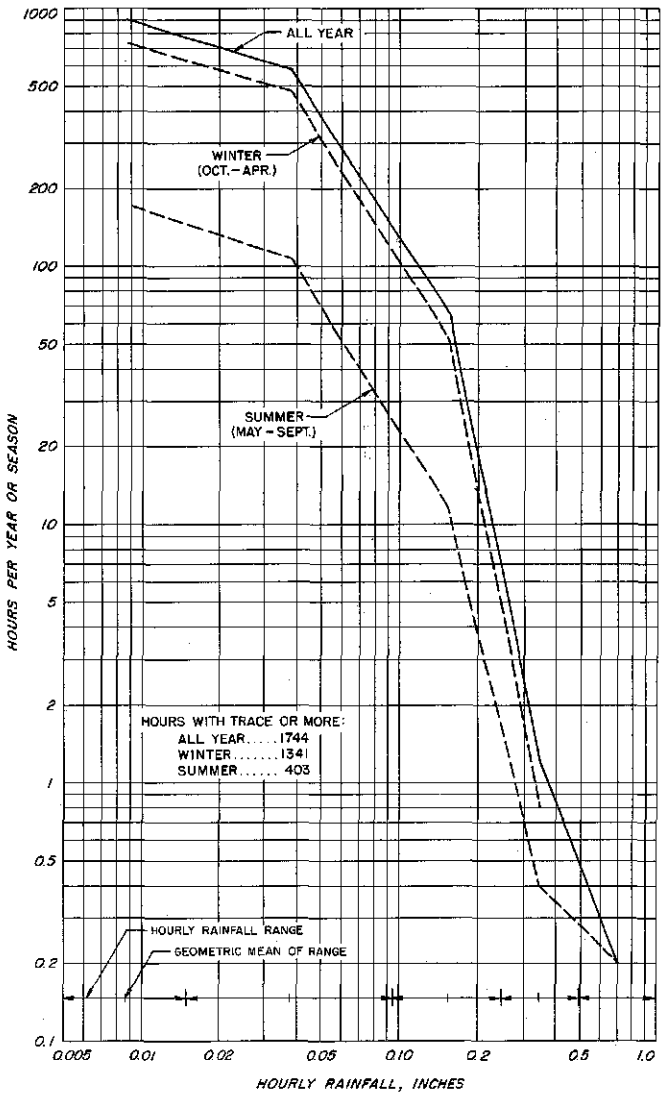


Fig. 3-13. Frequency of Occurrence of Hourly Precipitation

Based on data given in Table 3-9, the curves show the total hours during which precipitation equaled or exceeded each range.

Relative frequencies of occurrence are shown by grouping the data into summer and winter periods. For the summer season, rainfall of 0.01 inch or more occurred during 173 hours, or 4.6 per cent of the total number of hours in the season. On a daily basis, total falls of 0.01 inch or more occurred on 39 days, or 25.5 per cent of the days in the five-month period.

Fig. 3-13 shows the total number of hours per year and per season in which the hourly precipitation equaled or exceeded each indicated range of values. This figure was plotted by cumulating the hourly values in Table 3-9 from the highest range of rainfall to the lowest. Similarly, Fig. 3-14 shows the number of days per year and per season in which daily precipitation amounts equaled or exceeded each range.

Types of Storms

Most of the rainfall in the Seattle region comes from moving storms or areas of low barometric pressure which are common to the middle latitudes. Precipitation from these storms covers relatively large areas.

Thunderstorms, or thunder showers, which cover a relatively small area with short duration rainfall of high intensity, are rather infrequent (Table 3-10. During the 20 years analyzed, a total of 127 thunderstorms occurred in Seattle and of these, 66 took place during the summer for an average of about 3 per summer. It is evident, therefore, that this type of storm is not significant with respect to either recreational activities or, to any great extent, the frequency, intensity and amount of rainfall during the summer months.

Frequency, Duration and Amount of Rainfall

Design of storm drainage facilities requires a knowledge of the relationship between the frequency, intensity and duration of rainfall. Similar information is

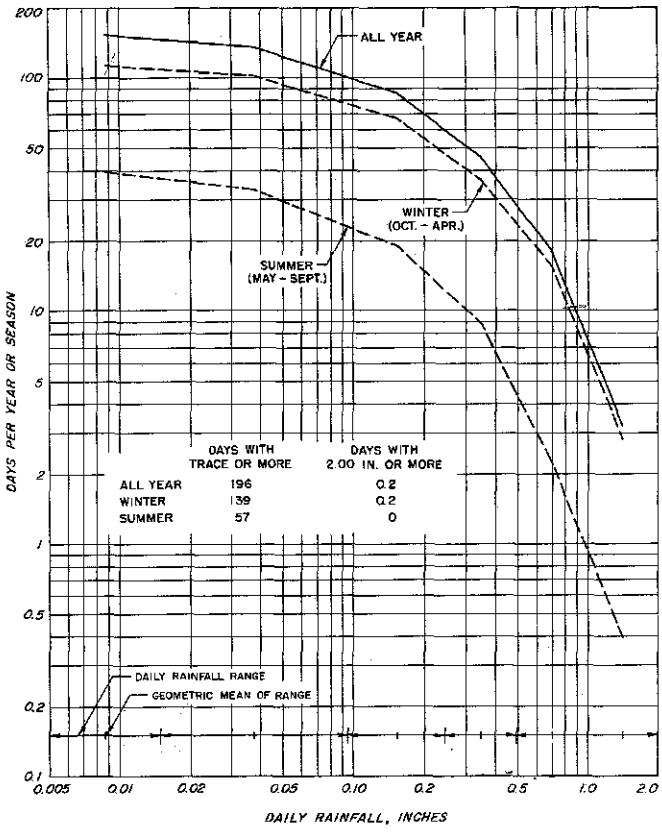


Fig. 3-14. Frequency of Occurrence of Daily Precipitation

Prepared in the same manner as Fig. 3-13, this figure shows the number of days in which precipitation amounts equaled or exceeded specified ranges.

required also for the design of intercepting sewers in areas served by combined sewers. In developing rainfall frequency-intensity-duration data for the Seattle study area, full use was made of records and data obtained from the U.S. Weather Bureau and from a recently completed sewerage and drainage study for the city of Tacoma, Washington[4].

Because the frequencies of storm recurrence considered for storm drain design and for intercepting sewer design are not of the same magnitude, it was necessary in each case to develop separate frequency-intensity-duration relationships. For storm drainage, recurrence intervals of one year and more are of most importance and the relationships must be based on an analysis of data covering the twelve months of the year. For intercepting sewers and related structures, however, recurrence intervals of less than one year are of most importance. In this case, conditions during the summer or recreational season must be anticipated and the relationships must be based on an analysis of data for the five summer months, May through September.

[4] *"Metropolitan Tacoma Sewerage and Drainage Survey", Brown and Caldwell, June 1957.*

Table 3-10. Total Number of Thunderstorms at Seattle in 20 years

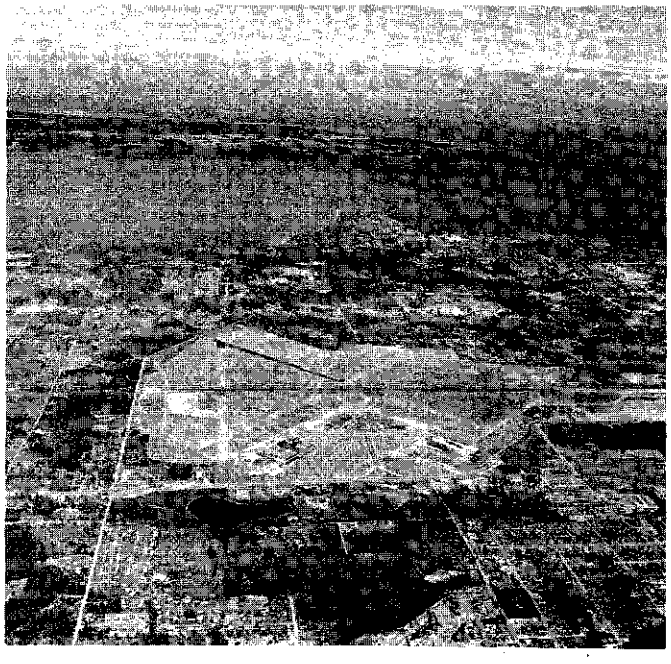
Season	Time of day				Total
	0000-0600	0600-1200	1200-1800	1800-2400	
Winter	0	0	0	2	2
Spring	1	1	20	6	28
Summer	6	9	23	28	66
Autumn	2	4	19	6	31
20 year total	9	14	62	42	127

Source: "Hydrometeorological Report No. 5, Thunderstorm Rainfall". U.S. Weather Bureau 1945.

Period of record 1906 to 1925, inclusive.

Analysis for Storm Drainage Design. Analyses of frequency-intensity-duration relationships have been made by the U.S. Weather Bureau for the period from 1903 to 1951 and are based on the automatic rain gage records of the downtown Seattle station. Results of these analyses were published recently in graphic form[5]. Curves plotted in Fig. 3-15 are based on information there presented and show the amount or depth of rainfall which occurs during a specific time interval or duration and which will be equaled or exceeded at a particular frequency over a long period of time. It must be pointed out that these curves do not represent the variations in rainfall which occur

[5] *"Rainfall Intensity-Duration-Frequency Curves", U.S. Department of Commerce, Weather Bureau Technical Paper No. 25, December 1955.*



U.S. WEATHER BUREAU STATION at Seattle-Tacoma Airport is one of the two principal sources of climatological information in the metropolitan area.

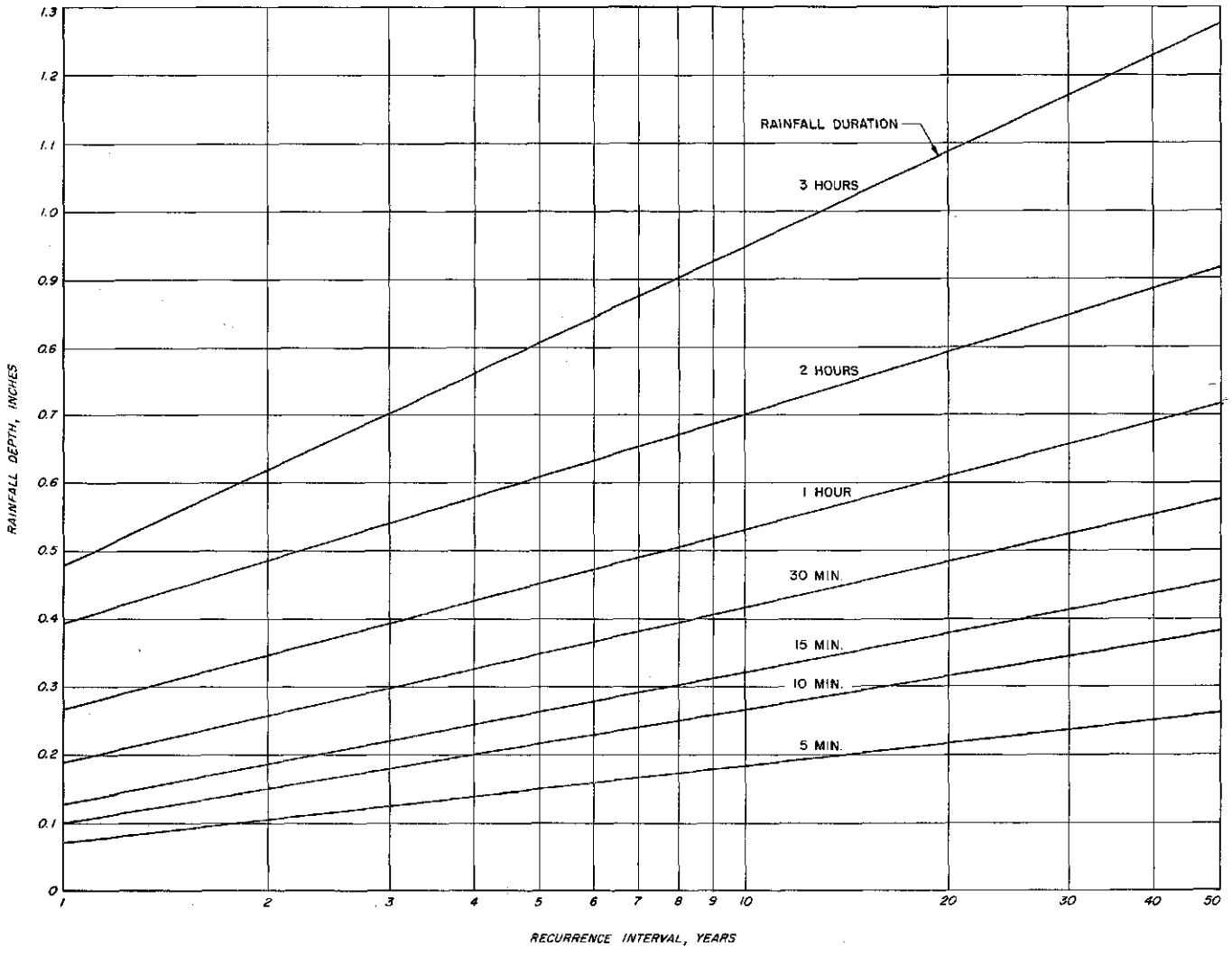


Fig. 3-15. Rainfall Frequency at Seattle, January through December

Based on curves developed by U. S. Weather Bureau and published in "Rainfall Intensity-Duration-Frequency Curves", Technical Paper No. 25, the curves indicate frequency of occurrence of specified rainfall amounts during various time intervals. Curves were derived from analysis of data covering the period 1905 - 1950 and do not represent the pattern of a typical storm.

during the course of a particular storm. It is extremely unlikely that any one storm would follow more than a small portion of a particular frequency pattern.

A design curve for a specific recurrence interval can be made by converting rainfall amounts for each duration to intensity. Curves thus prepared are presented later in Chapter 13 in connection with a discussion of design criteria for storm drainage improvements.

Analysis for Intercepting Sewer Design. Because of the availability of similar data developed for the Tacoma area, it was not necessary to make a detailed analysis of summer rainfall in Seattle. The Tacoma curves, based on an analysis of automatic rain gage charts for the summer months of 1940 through 1949, were modified to account for known differences in the frequency-intensity-duration relationships between the two cities.

Two independent analyses were made to determine the necessary modification. Of these, the first involved a determination, for summertime frequencies, of the relationship between 60-minute duration rainfalls at Tacoma and Seattle. In so doing, use was made of clock-hour data for the 10-year period as published by the U. S. Weather Bureau in "Hourly Precipitation Data". To develop the required information, the first step was that of tabulating the measured hourly amounts of rainfall in descending order of magnitude for each station. The frequency of recurrence for each amount was then determined by dividing the period, 10 years, by the order of magnitude of that amount. For example, the amount which was 10th in order of magnitude was equaled or exceeded a total

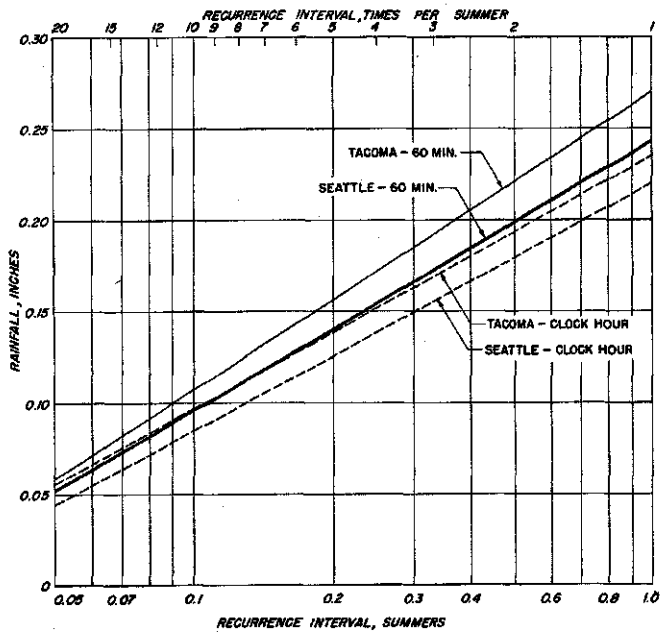


Fig. 3-16. Frequency of Clock-Hour and Maximum 60-Minute Rainfalls at Tacoma and Seattle

Clock - hour rainfalls at Seattle were compared with those recorded at Tacoma to determine the relationship between rainfalls at these stations.

of 10 times in 10 summers, and therefore has a recurrence interval of one year. This amount may be expected, on the average, to be equaled or exceeded once per summer. Similarly, the amount 50th in order of magnitude represents the amount which will be equaled or exceeded five times per summer.

Fig. 3-16 shows recurrence intervals for clock-hour amounts of precipitation at Seattle and Tacoma. The amounts of rainfall which are recorded in a clock-hour are not necessarily the maximum amounts which may fall in a 60-minute period. To illustrate this fact, the figure also shows the maximum 60-minute rainfalls for various frequencies as determined in the Tacoma study. For a given frequency, the maximum 60-minute fall is about 115 per cent of the clock-hour fall.

A comparison of the clock-hour amounts for Seattle and Tacoma indicates that, for a given frequency, rainfalls at Seattle are 90 per cent of those at Tacoma. The 60-minute curve for Seattle was drawn accordingly.

The second analysis was made for the purpose of determining whether the same factor is applicable to other rainfall durations. This was accomplished by a comparison of the intensities recorded in Weather

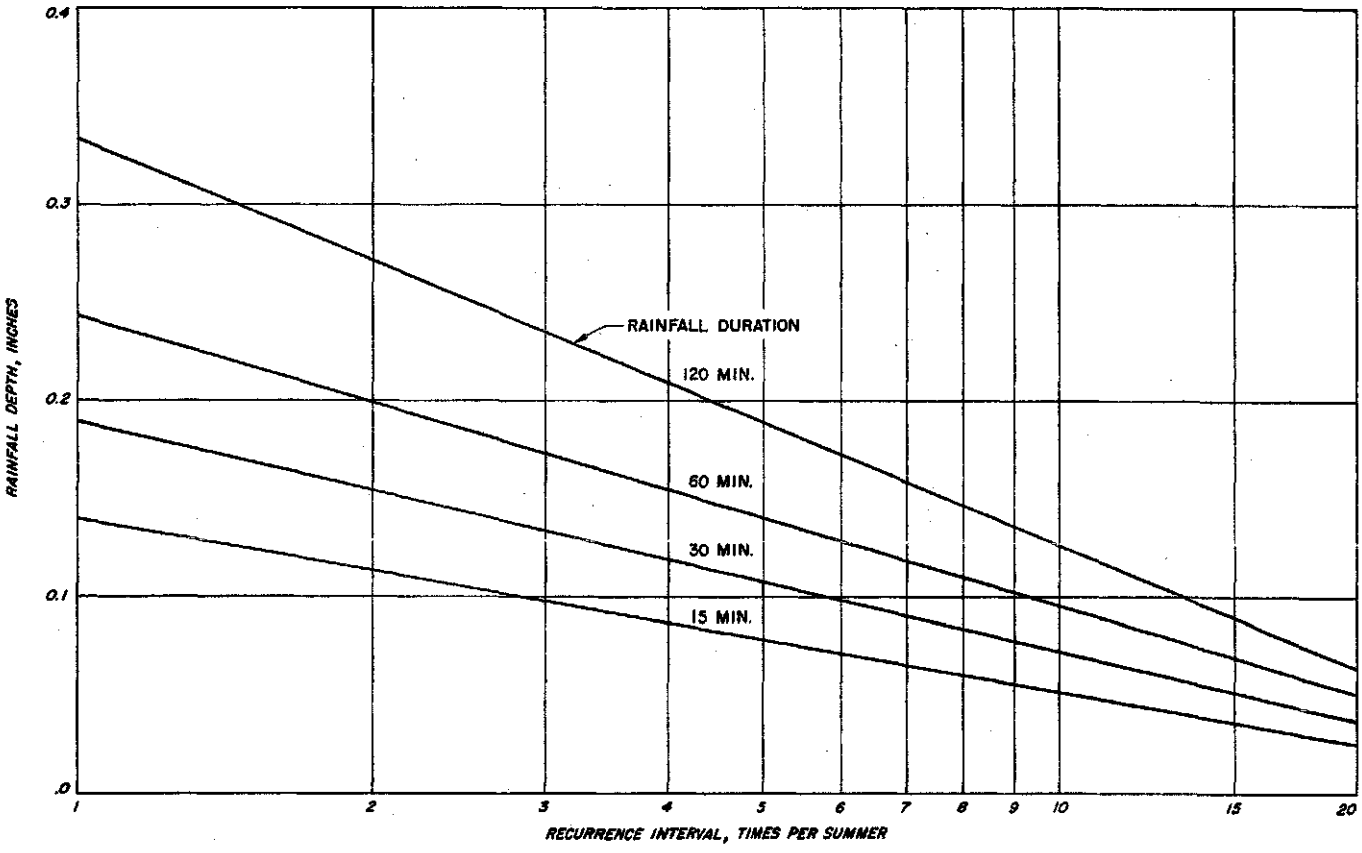


Fig. 3-17. Rainfall Frequency at Seattle, May through September

It was found that rainfalls at Seattle were 90 per cent of those recorded at Tacoma for frequencies and durations of interest in design of intercepting sewers. Curves for Seattle were adapted from similar Tacoma data based on analysis of individual storms during the summer months from 1940 - 1949.

Bureau Publication No. 25. For the more frequent occurrences and for durations between 15 and 120 minutes, Seattle intensities are about 90 per cent of those at Tacoma. This value was applied to the Tacoma curves in developing the summer rainfall curves for Seattle (Fig. 3-17).

Chapter 4
ECONOMIC DEVELOPMENT

As a background or basis for the study of population presented in Chapter 5, this chapter deals with the economic environment of the metropolitan area, including land and water uses, trade and commerce, and public utilities. It deals also with future land use patterns as they relate to sewerage and drainage planning.

Statistical data for the many factors affecting economic environment are not available for the metropolitan area as a whole. It is necessary, therefore, to present and evaluate such data as are available for city, county and regional units within and contiguous to the study area.

The metropolitan Seattle area has been long recognized as the major center of economic activity in the state of Washington, if not in the entire Pacific Northwest. The pioneer economy, initially based on lumber, soon expanded to include mining, agriculture, fishing and, of necessity, shipping. While still important, these activities have been surpassed by manufacturing and service industries.

By far the biggest factor in the development of the present economy of the metropolitan area is the growth of the Boeing Airplane Company. Employment in aircraft production in King County has increased from 6,000 in 1940 to 64,000 in June 1957. During the same period, the total number of all employed persons increased from 195,000 to 381,000.

Fig. 4-1 shows the relative magnitude of some of the economic factors discussed herein and illustrates the proportions applicable to King County, the Puget Sound area, the state of Washington and the Pacific Northwest.

LAND AND WATER USE

Land uses in the metropolitan Seattle area range from intense residential, commercial and industrial in the city of Seattle, to undeveloped cut-over lands and second growth timber in the northeastern, eastern and southeastern portions. Developed lands outside of Seattle include numerous small cities and suburban residential areas (Fig. 3-2). Agricultural uses are centered in the Green and Sammamish River valleys, with marginal uses in the upland areas.

Surface waters of the area are utilized for shipping, commercial fishing, harbor commerce, recreation, various types of industrial operations and, to a limited extent, domestic water supply. Use of the waters of Puget Sound, and of the Lake Washington and Green-Duwamish drainage basins is disclosed in detail in Part IV.

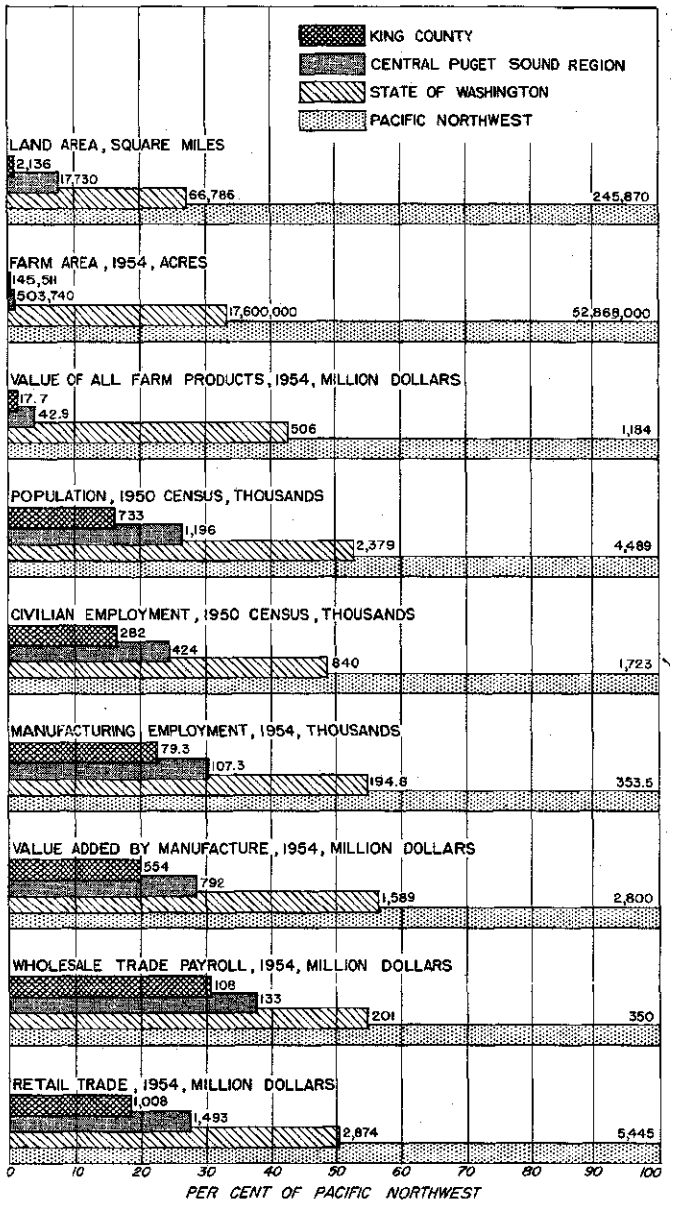


Fig. 4-1. Indices of Economic Activity

King County and the central Puget Sound region (King, Kitsap, Pierce and Snohomish Counties) are more highly urbanized and less dependent on agriculture than are the State of Washington and the Pacific Northwest (Washington, Oregon and Idaho). King County in particular is the center of manufacturing and trade. Data obtained from publications of U.S. Department of Commerce.

Table 4-1. Land Uses in City of Seattle, 1952 - 1954

Land use	Area, acres
Single family homes	17,435
Duplexes	578
Apartments	927
Business	999
Commercial	1,063
Manufacturing	1,590
Railroads	653
Public, semi-public	8,113
Streets	13,930
	45,288
Vacant	8,583
Total, land area	53,871
Submerged lands	1,186
Total city area	55,057

Source: City of Seattle Planning Commission.

Land uses in the city of Seattle, as determined during the period 1952-1954 by the Seattle Planning Commission, are listed in Table 4-1. Since about 10,000 single family dwellings have been constructed in the city subsequent to the Planning Commission study, the amount of vacant land (Table 4-1) has been reduced by about 25 per cent.

Residential Development

The major portion of the metropolitan area is now, or in the future can be made suitable for residential use. From Seattle, the central city, development has taken place to the north, east, and south, and has been spotty rather than uniform. Fig. 4-2 shows the number of residential units constructed and the type of construction within King County as a whole from 1950 through 1956. Construction outside the city of Seattle amounted to 38 per cent of the total for the county in 1950, to 65 per cent in 1955, and to 54 per cent in 1956. For the seven-year period, 55 per cent of all residential construction was in areas outside Seattle. Furthermore, 98 per cent of the outside construction consisted of single family homes as compared to 69 per cent within the city.

Residential expansion by tract type construction, such as that currently taking place, results in fully developed areas surrounded by relatively unimproved areas. This in turn tends to magnify and complicate the problems involved in providing necessary municipal utilities and services, including sewerage and drainage.

Industrial Development

Extractive industries, such as forestry, fishing, and mining, were developed early in the history of Seattle. In fact, the first lumber shipment was to San Francisco in 1852, the year the first permanent settlement was established. Early manufacturing operations were concerned primarily with the production of machinery and equipment for logging, fishing and shipbuilding.

Almost all of the standard manufacturing classifications are now represented in the metropolitan area. Growth of manufacturing industries has, of course, brought with it the usual proportion of nonmanufacturing and service type industries.

Many of the manufacturing categories represented in the early development of Seattle have been expanded by the addition of new products. For example, forest products now include plywood, pulp, furniture, and prefabricated structures in addition to cut lumber; food products include condiments and synthetic vanilla in addition to seafood and fruit and vegetable packs; and transportation equipment, after being limited initially to shipbuilding, is now expanded to include military and civilian aircraft, trucks, and refrigerated railroad cars. Additionally, the over-all industrial base has been broadened by the introduction of new industries and the manufacture of such products as plastics and fibreglass, certain types of building materials, textiles, and sporting goods.

As to the future, the outlook is toward a continuing expansion of the industrial base. For example, construction of several oil refineries is now or soon will be under way. These in turn will provide a local

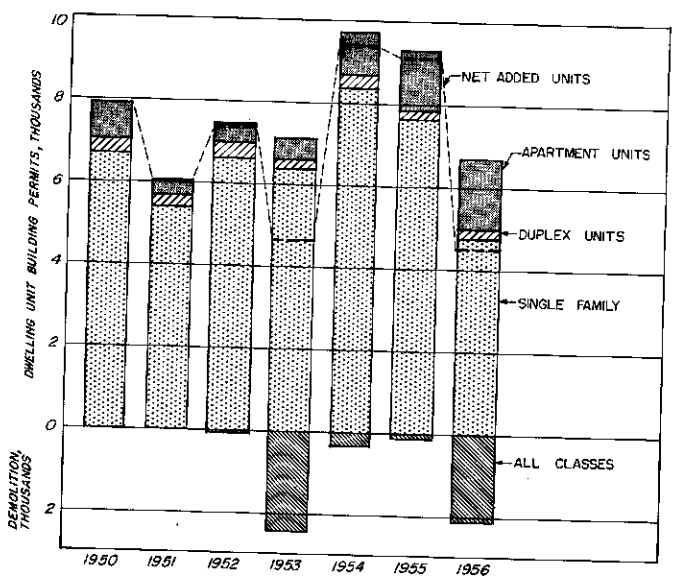


Fig. 4-2. Residential Construction in King County

In the seven-year period, 1950-1956, permits were issued for construction of almost 54,000 residential units. Of these, 85 per cent were single family residences. Demolished units, totaling over 5,000, were largely temporary war housing structures. Total residential units increased from 248,638 in 1950 to 297,716 by the end of 1956. Data obtained from Seattle Planning Commission.

source of petroleum products, as well as raw materials for the manufacture of petrochemical materials. A possible source of raw material for synthetic chemical industries became available in 1956 with the advent of natural gas.

Recently, a great deal of emphasis has been placed on long-range programs for industrial expansion. Several organizations are very active locally in this field, as is the Department of Commerce and Economic Development, a newly established agency of the state of Washington. One of the principal aims of the latter is the expansion of the industrial base of the entire state.

Industrial Areas. According to a study by the Seattle Planning Commission in 1952, 4,648 acres within King County were then utilized by industries, of which 1,590 acres were within the city of Seattle. Most of the heavy industrial development in the metropolitan area is situated in the lower reaches of the Green-Duwamish River valley and along the shores of Elliott Bay, Lake Washington Ship Canal, and Lake Union.

Future developments of any magnitude in the heavy industrial field are expected to be confined, at least initially, to the Green-Duwamish Valley. This is because of availability in that area both of flat land and of rail and water transportation. At present, the first stages of long-range plans for industrial development in the Duwamish valley are being implemented by the Port of Seattle Industrial Development District. Improvements now under way, together with those planned for the future, will provide a new industrial area of slightly over 3,000 acres.

Light industry is considerably more dispersed than heavy industry and is centered generally in developed areas adjacent to rail and arterial highway facilities. Future growth of light industry is expected to follow the same pattern and to utilize presently undeveloped land in areas where adequate transport services are available. It is possible, however, that operations of this type may develop also in close proximity to residential areas. Current experience in the San Francisco Bay area indicates that, with proper planning, neighboring development of light industrial and residential areas results in mutual advantages.

Industrial Classifications. Although a wide diversification of industries in the metropolitan area is in-

Table 4-2. King County Employment Statistics

Classification	Employees, thousands						
	1940 March	1944 July	1946 July	1950 Year	1954 Year	1956 Year	1957 January to June
Manufacturing industries							
Food, kindred products	7.1	8.2	8.4	8.3	7.4	7.4	6.8
Apparel, textiles	1.9	2.4	2.4	2.3	2.4	2.5	2.4
Lumber, wood products	7.1	7.3	5.6	7.9	6.1	6.8	6.5
Primary metals	2.0	4.7	3.0	2.3	2.0	2.5	2.7
Metal products, machinery	4.2	7.8	5.9	7.2	7.8	8.1	7.8
Transportation equipment							
Aircraft	6.0	38.8	10.0	19.5	36.8	43.2	58.1
Shipbuilding, repair	1.2	30.0	7.9	1.6	3.1	3.2	3.2
Other	0.7	1.1	1.8	1.9	2.7	3.2	2.8
Other manufacturing	6.9	6.6	7.2	8.4	9.5	10.3	10.1
Total manufacturing	37.1	106.9	52.2	59.4	77.8	87.2	100.4
Non-manufacturing							
Mining, forestry, fishing	2.4	1.6	1.6	1.7	1.6	1.5	1.2
Contract construction	8.6	9.0	12.9	13.4	12.5	15.0	15.4
Transportation, utilities, communication	16.9	22.1	24.1	25.9	25.9	27.5	27.6
Trade, services	64.4	84.8	97.3	110.1	119.9	130.0	129.0
Government	22.7	58.8	45.1	37.9	42.9	44.9	45.2
Total, non-manufacturing	115.0	176.3	181.0	189.0	202.8	218.9	218.4
Agriculture	6.7	10.8	10.6	8.1	7.9	7.8	6.5
Miscellaneous[a]	36.7	24.4	32.3	39.2	39.8	40.0	40.2
Total employment	195.5	318.4	276.1	295.7	328.3	353.9	365.6

Source: "Labor Force and Employment in the Seattle Area (King County)", Washington State Employment Security Department.

[a]*Includes self-employed, domestic servants, and others.*

Table 4-3. King County Manufacturing Statistics

Major industry group	1954				1947	
	Establishments, number	Employees, number	Payroll, $1,000	Value added,[a] $1,000	Employees, number	Value added,[a] $1,000
Transportation equipment	60	40,479	193,284	177,942[b]	20,156	67,097
Food and kindred products	226	9,393	38,723	67,389	8,113	45,566
Lumber and wood products	187	4,931	20,846	32,364	5,562	37,901
Fabricated metal products	146	4,134	19,058	32,290	3,574	21,351
Printing and publishing	190	3,631	16,601	27,004	3,225	22,830
Machinery, excluding electrical	128	3,137	15,262	23,811	3,248	16,860
Primary metal industries	41	2,304	10,588	17,103	2,499	12,943
Apparel and related products	88	2,372	7,080	11,407	2,293	8,520
	1,066	70,381	321,442	389,310	48,670	233,068
All other industries[c]	401	8,892	36,427	164,567	6,100	32,354
Total	1,467	79,273	357,869	553,886	54,770	265,422

Source: "1954 Census of Manufacturers, Washington, Preliminary Report", U.S. Department of Commerce, Bureau of the Census.

[a]*Defined as the value of shipments less costs of materials, supplies, fuel and electric energy.*

[b]*Incomplete value; see next footnote.*

[c]*Also includes values withheld from specific groups to avoid disclosing figures for individual companies.*

dicated by King County employment statistics (Table 4-2), it is nevertheless evident that employment is dominated by aircraft production. This is attested to by the fact that three out of five workers in the manufacturing industries are employed in the production of aircraft.

A similar domination is reflected by the manufacturing statistics given in Table 4-3 for 1954. This year was chosen because it is the latest one for which U.S. Bureau of the Census figures are available.

In considering the figures for the values added by manufacturing (Table 4-3), it should be realized that the specific value given for the transportation industry does not represent the true total for that group. In compiling statistics of this type, the practice is to exclude any values which would disclose information pertaining to the specific operations of a single company. On the other hand, the true values are actually included in the total both for all other industries and for the county as a whole.

On a state-wide basis, the leading manufacturing industry is again that of transportation equipment, principally aircraft[1]. For a twelve-month period ending September 30, 1956, aircraft industry payrolls amounted to a total of $222.9 million, representing 21.8 per cent of the total manufacturing payroll of $1,021 million for the entire state. During the same period, employment in aircraft production averaged 41,800, representing 20.3 per cent of the state-wide manufacturing industry employment total of 206,000. Table 4-4 lists state-wide payrolls in 1954 and 1956 for major manufacturing industry groups.

[1]"Summary of Pacific Northwest Industries, Annual Review," *Seattle First National Bank, April 1957.*

Transportation

In the field of passenger and freight transportation, the Seattle area not only serves western Washington and the Pacific Northwest but is the gateway to the shortest air and sea routes from a mainland port in the United States to Alaska and the Orient. Because of the favorable location of the area with respect to both overseas markets and mainland commerce, the transportation industry will continue to expand and will become an increasingly important segment of the total economy.

Water Transport. Marine transportation always has been and will continue to be a major feature of business activity in the metropolitan area. Elliott Bay is deep enough to accommodate all types of vessels and has a total shoreline of 10.6 miles. Of this

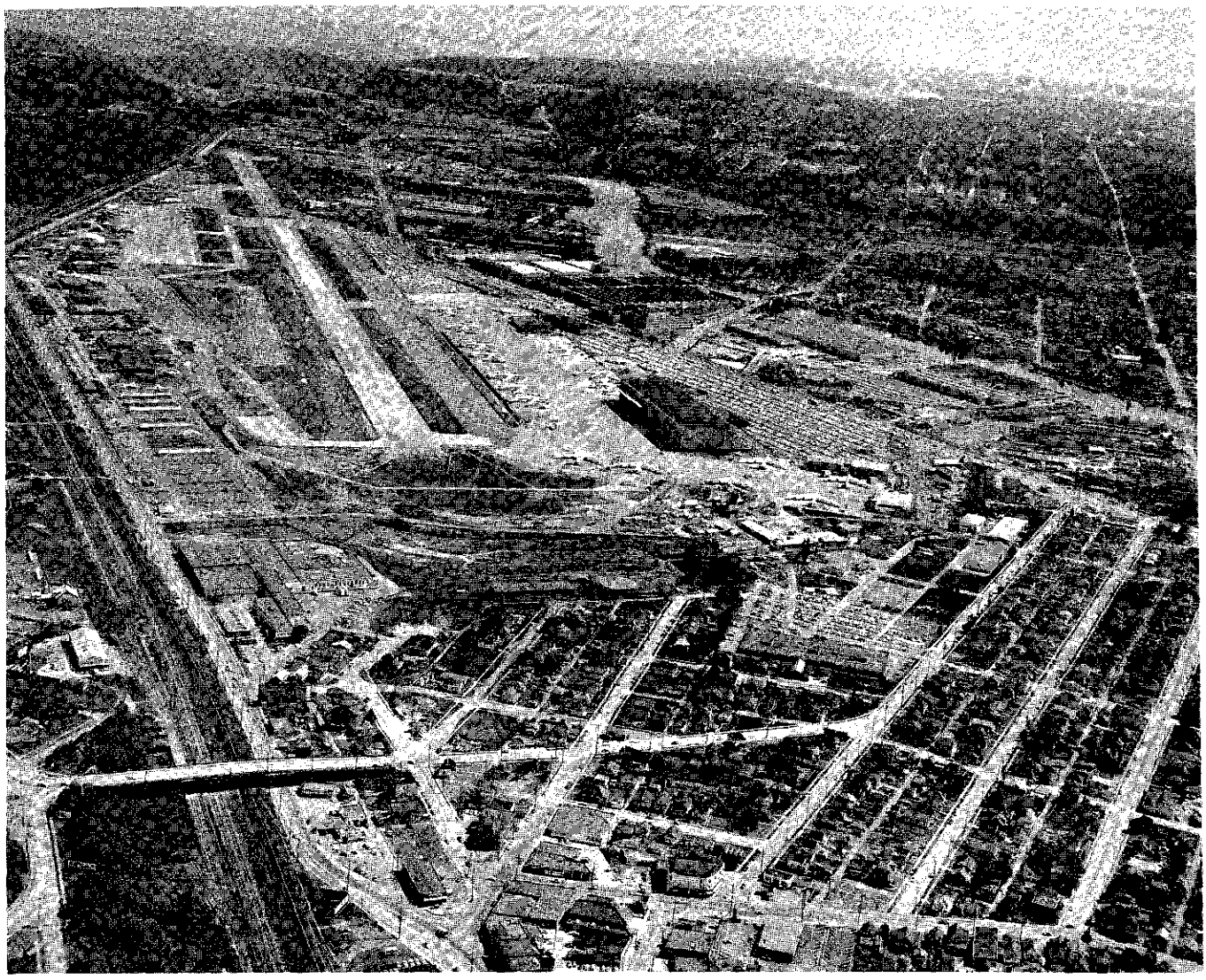
Table 4-4. Payrolls in Washington Manufacturing Industries

Industry group	Payroll,[a] million dollars		
	State of Washington		King County
	1956	1954	1954
Food products	102.8	97.4	38.7
Forest products	348.8	284.8	27.4
Metals and chemicals[b]	483.2	402.1	246.9
Other	86.2	70.7	43.8
Total	1,021.0	855.0	356.8

Source: "Summary of Pacific Northwest Industries, Annual Review", Seattle First National Bank, June 1955 and April 1957.

[a]*For 12-month period ending September 30 of year stated.*

[b]*Includes aircraft production.*



BOEING FIELD and the main Seattle Boeing plant (right) are located adjacent to Duwamish River. Employment at Boeing, largest individual industry in the metropolitan area, increased from 6,000 in 1940 to 64,000 in June 1957. Headquarters for air cargo and non-scheduled air lines are located on left side of field.

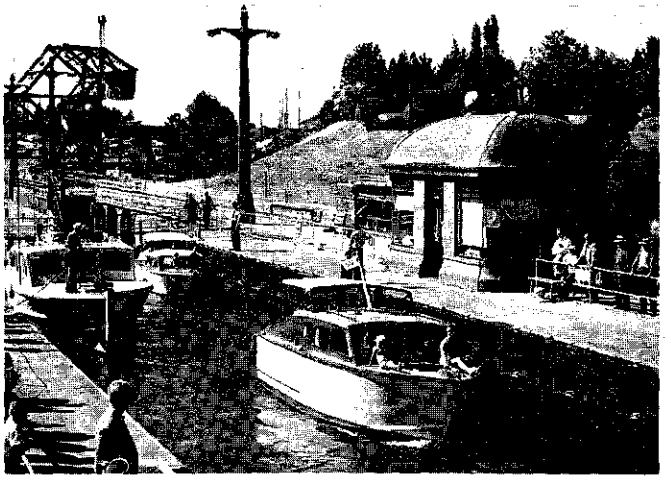
total, 8.7 miles, or 82 per cent, are occupied by marine enterprises. Duwamish waterway provides an additional 10.5 miles of shoreline, of which 1.7 miles are developed for marine uses.

Waterfront loading facilities consist of more than 90 piers, docks and wharves. Public docks and port services are provided by the Port of Seattle, a municipal corporation which has the power to purchase, lease, construct and operate various types of marine facilities. In 1956 the Port of Seattle owned properties valued at $37.7 million.

Lake Washington ship canal and Chittenden (Government) Locks, constructed in 1916, provide access to Lake Union and Lake Washington for vessels with a maximum draft of 30 feet. Of the 8.8 miles of shoreline in the ship canal area, which includes Lake Union and Salmon Bay, 6.3 miles are utilized by marine users. Moorage space is available for 1,000 fishing boats at the Fishermen's Terminal in Salmon Bay. This area is used extensively by vessels fishing Pacific Northwest and Alaskan waters. Use of the Lake Washington shoreline for water oriented industries, including shipyards, has declined greatly in recent years.

In the period from 1946 to 1956, the total traffic tonnages for Seattle Harbor increased from 9.6 to 13.7 million tons, or over 40 per cent. Seattle Harbor, as defined by the U.S. Corps of Engineers, extends from Point Wells on the north to Fauntleroy Ferry slip on the south and includes the ship canal, Lake Union, and Lake Washington,.

A breakdown of the number and types of vessels inbound and outbound during 1955 is given in Table 4-5. Although the number reported for the ship canal,



CHITTENDEN LOCKS, constructed in 1916 and operated by the U.S. Corps of Engineers, are located on the Lake Washington ship canal. Ship traffic on the canal, connecting Lake Washington and Puget Sound, totaled 60,000 vessels in 1955. Over half the number of vessels were recreational craft.

Lake Union and Lake Washington represents nearly half of the total for the harbor as a whole, this particular group includes a preponderance of recreational craft.

Highway Facilities. A system of state and county roads and highways serves developed sections of the metropolitan area. In addition, the area is traversed by two major transcontinental routes, U.S. 99, the Pacific Coast highway, and U.S. 10, the northern east-west highway. Auto ferries provide connections with the Olympic Peninsula to the west across Puget Sound, with various islands in the sound, and with Victoria, B.C. on Vancouver Island. Consideration is presently being given to the construction of a bridge across the sound.

Construction in 1940 of the floating bridge across Lake Washington has been a major factor in hastening development of the communities east of the lake. Traffic, however, has reached such proportions, particularly during morning and evening rush hours, that planning of a second floating bridge is now in progress.

Design of a limited access freeway connecting Seattle with Everett to the north and Tacoma and Olympia to the south is a current project of the State Highway Department. When constructed, this freeway will alleviate congested traffic conditions on U.S. 99 both north and south of Seattle and will tend to stimulate further residential and light industrial development in contiguous areas.

U.S. Highway 10 which is planned for an ultimate six to eight lane width, is now being widened to four

Table 4-5. Seattle Harbor Traffic in 1955

Class	Seattle Harbor[a]		Ship Canal[b]	
	Inbound	Outbound	Inbound	Outbound
Self-propelled vessels, number				
Dry cargo or passenger	36,128	36,163	821	823
Tanker	835	831	101	99
Tug and towboat	22,374	22,384	4,987	4,987
Fishing boats	c	c	6,179	6,540
Recreational craft	c	c	17,798	17,974
	59,337	59,378	29,886	30,243
Non-self-propelled vessels, number				
Dry cargo	4,709	4,688	1,488	1,465
Tanker	2,374	2,368	298	289
	7,083	7,056	1,786	1,754
All vessels, total number	66,420	66,434	31,672	31,997

Source: *"Waterborne Commerce of the United States, 1955. Part 4: Waterways and Harbors, Pacific Coast, Alaska, and Pacific Islands", Department of the Army, Corps of Engineers.*

[a]*Extending from Pt. Wells to Fontleroy ferry slip and including ship canal, Lake Union and Lake Washington.*

[b]*Includes Lake Union and Lake Washington.*

[c]*Included in other classes.*

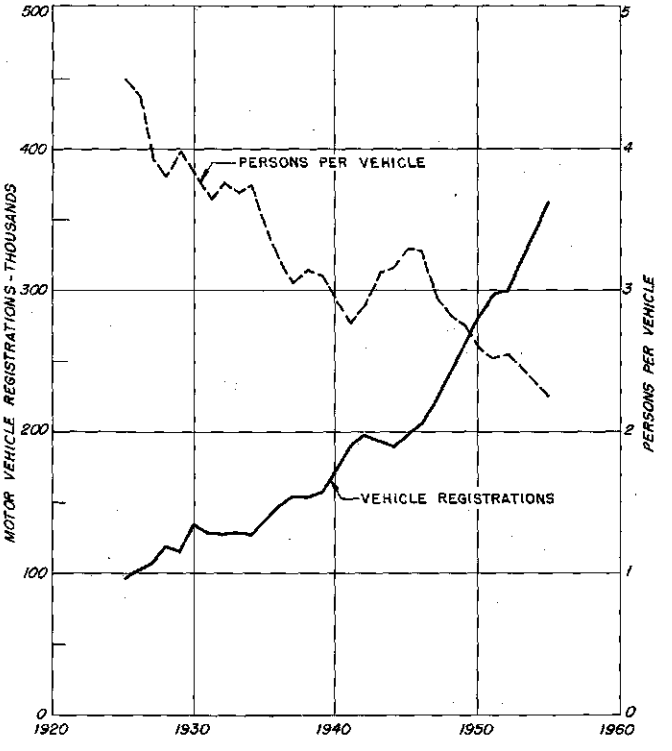


Fig. 4-3. Motor Vehicle Registrations in King County

From 1925 to 1955, motor vehicle registrations increased from 95,000 to 362,700. Passenger cars account for 80 percent of the vehicles in the county. Increasing urbanization and dependence on highway transportation contribute to the decreasing number of persons per vehicle. Data from State Department of Licenses.

Table 4-6. Motor Vehicle Registrations in 1955

Type	Washington State, thousands	Central Puget Sound Region[a]		King County		
		thousands	per cent of state	thousands	per cent of state	per cent of region
Passenger	927.0	459.6	49.6	292.0	31.5	63.5
Trucks	205.0	80.0	39.0	47.8	23.3	59.7
Trailers	76.7	29.8	38.9	16.4	21.4	55.0
Miscellaneous[b]	30.0	10.9	36.4	6.5	21.6	59.6
Total	1,238.7	580.3	46.9	362.7	29.4	62.6

Source: Department of Licenses, State of Washington.

[a]*Includes King, Pierce, Snohomish and Kitsap Counties.*

[b]*Includes vehicles for hire, private busses, motorcycles, and vehicles of all governmental agencies.*

lanes in the section over Snoqualmie Pass. A new limited access freeway paralleling the east shore of Lake Washington ultimately is to connect with both the proposed Tacoma-Everett freeway and Highway 2 across Stevens Pass.

Fig. 4-3 illustrates graphically the great increase in the number of motor vehicles registered in King County since 1925 together with the concomitant decrease in number of persons per vehicle. King County has over 30 per cent of the passenger vehicles in the state and over 60 per cent of those in the four counties, King, Pierce, Snohomish and Kitsap, making up the Central Puget Sound region (Table 4-6).

More than 100 carriers are engaged in furnishing motor freight service to Pacific Northwest points and the rest of the country. Transcontinental bus service is offered by two interstate lines.

Railroads. The metropolitan area is served by four transcontinental railroads, Great Northern, Milwaukee, Northern Pacific, and Union Pacific. These provide access to marketing points east and south as well as a connection to Vancouver, B.C. In addition, there is a local network of railway routes, dating back to early logging and mining activities.

Air Transportation. Seattle-Tacoma International Airport (Sea-Tac) and Boeing Field are the major airports serving the area. The former is the center of commercial air transport activity, while the latter is used mostly by Boeing Airplane Company for aircraft produced at its adjacent plant. Boeing Field is used also by air cargo and non-scheduled passenger carriers. Other fields in the area include those at Renton Municipal Airport, Bellview Airport, and Paine Field. Sand Point Naval Air Station is situated on the west shore of Lake Washington.

Traffic at Sea-Tac, which is owned and operated by the Port of Seattle, is increasing yearly (Table 4-7). In the short period from 1954 to 1956, the number of revenue passengers and the weight of air freight and air express increased over 20 per cent, and the amount of air mail increased more than 60 per cent. In terms of overseas passengers, Sea-Tac ranks third nationally, following New York and Miami. Runways are adequate for the largest transport planes now in

Table 4-7. Air Traffic at Seattle-Tacoma Airport

Classification	1954	1955	1956
Revenue passengers, number	1,048,383	1,181,564	1,286,126
Air mail, pounds	11,489,440	17,276,289	18,872,471
Air freight, pounds	26,259,194	29,962,543	32,259,329
Air express, pounds	2,297,904	2,542,549	2,837,967
First class mail[a], pounds			2,211,150

Source: "Annual Report", Port of Seattle, 1955 and 1956.

[a]*Service started in January 1956.*

SEATTLE - TACOMA AIRPORT is center for commercial air traffic, both domestic and overseas. In 1956, the total number of revenue passengers was 1,286,126, a 22 per cent increase since 1954. Construction now underway will extend runway to 10,400 feet, long enough for use by jet airliners and transport planes.

Table 4-8. Value of Farm Production in King County

Product	Value in million dollars	
	1954	1949
Field crops		
Vegetables	2.1	2.7
Fruits and nuts	1.0	0.8
Horticultural specialties[a]	2.4	2.6
Other field crops	0.04	0.06
	5.54	6.16
Livestock and products		
Dairying	6.6	6.0
Poultry	3.9	3.7
Other livestock	1.5	2.5
	12.0	12.2
Forest products[b]	0.18	0.07
Total farm products	17.7	18.4

Source: "1954 Census of Agriculture", U.S. Department of Commerce, Bureau of the Census, Vol. I, Part 32, Washington and Oregon.

[a]*Includes nursery and greenhouse products, flower and vegetable seeds and plants.*

[b]*Includes saw timber, posts and Christmas trees.*

service. At present, however, the main north-south runway is being lengthened from 7,500 feet to 10,400 feet to accommodate jet transports.

Boeing Field is owned and operated by King County and is conveniently located for transportation of air cargo in the industrialized Duwamish Valley. A single runway, 10,000 feet in length, is adequate for present and anticipated future needs.

Renton Municipal Airport is used by the Renton plant of the Boeing Airplane Company and by private planes. Its 5,400 foot runway would be difficult to lengthen because of adjacent highly developed land on the south and Lake Washington on the north.

Paine Field, a former Air Force base in the northern part of the area, is now partially owned by the U.S. Army but the runway section is owned by Snohomish County. The latter is operated as the Snohomish County Airport and is used also by the Army under a lease arrangement.

Agriculture

Soil classification studies by the State College of Washington indicate that there are about 540,000 acres of farm land in King County. These include 70,000 acres suitable for commercial farming, 45,000 acres of below-average land yielding a low economic return, and 425,000 acres of marginal or poorer land with little or no agricultural value.

As reported by the U.S. Census Bureau in the 1954 Census of Agriculture, the number of farms in King County decreased from 5,496 in 1950 to 5,181 in 1954 and the occupied farm acreage decreased from 153,301 to 145,111 acres. For the central Puget Sound region, farm acreage declined nearly 8 per cent between 1950 and 1954, whereas the total for the state increased about 1 per cent.

A comparison of the occupied farm acreage in King County with the figures given above for various classes of land indicates that a minimum of 30,000 acres classified as poor and marginal is actually utilized for farming. Undoubtedly, this contributes to the fact that operators of over 60 per cent of the farms in King County also engage in some type of off-farm employment.

Agricultural operations in the metropolitan Seattle area are confined largely to the fertile valleys of the Green and Sammamish rivers. It is expected, however, that the continuing pressure for residential and

Table 4-9. Washington and Puget Sound Fisheries Statistics

Species	Fish landings, million pounds				Washington value, million dollars			
	Washington		Puget Sound[a]		Catch[b]		Processed[c]	
	1955	1956	1955	1956	1955	1956	1955	1956
Salmon	61.8	31.1	48.7	20.0	11.8	10.9	21.0	20.8
Bottom fish	42.3	42.5	41.7	41.8	2.3	3.0	3.4	4.5
Halibut	16.1	16.2	16.1	16.2	2.6	3.6	3.4	5.0
Other food fish and livers	7.9	10.9	5.3	8.5	0.8	1.2	3.6	4.2
Oysters	10.1	10.6	3.4	3.4	1.3	1.5	6.0	7.4
Other shellfish	9.8	11.2	2.8	2.0	1.2	1.6	2.3	2.6
Total[d]	148.6	122.5	118.1	91.9	20.1	21.6	39.8	44.5

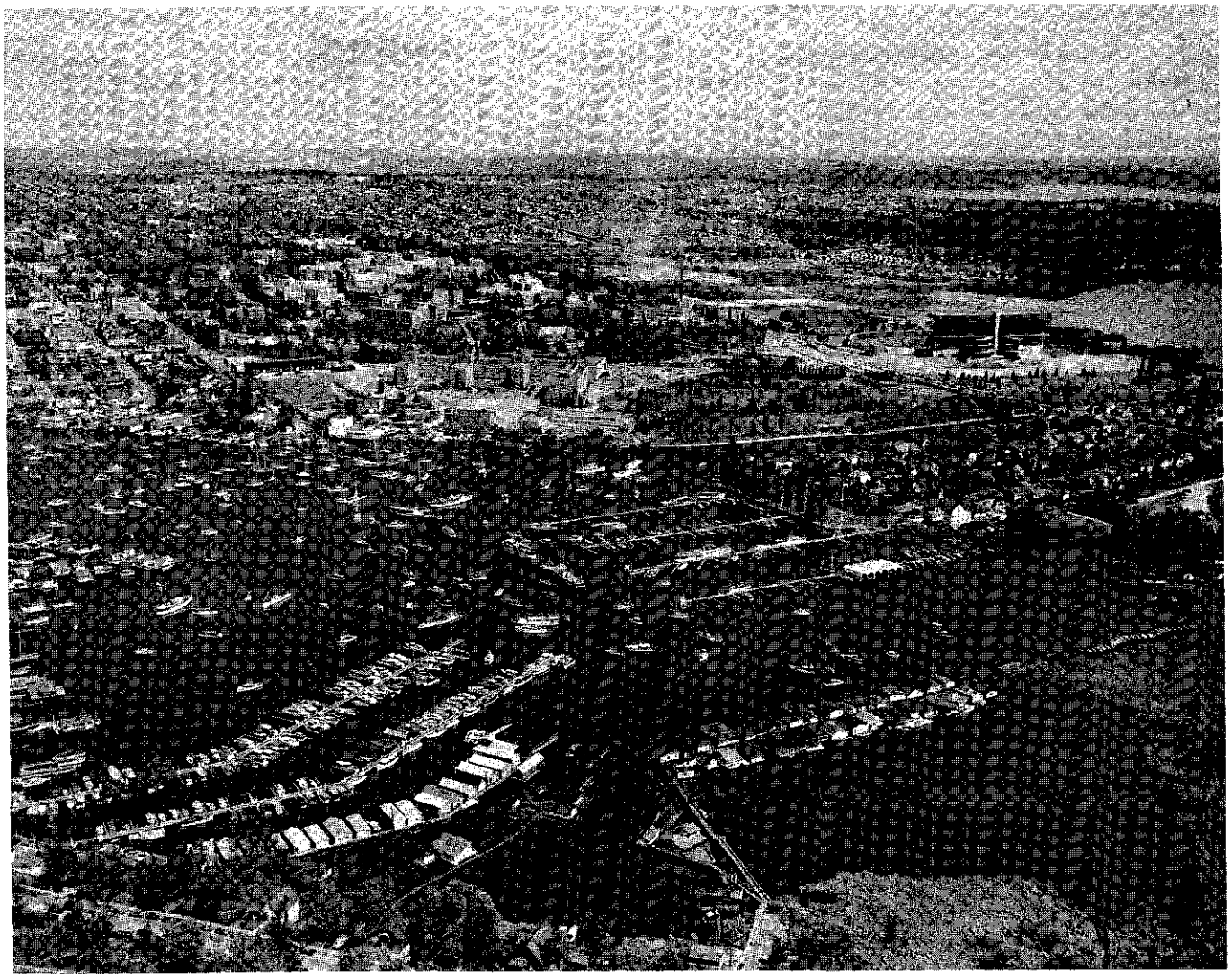
Source: "1956 Fisheries Statistical Report", State of Washington, Department of Fisheries.

[a]*Includes all fish landed at Puget Sound ports from catches in the Sound and Pacific Ocean.*

[b]*Price paid to fisherman for his catch.*

[c]*Wholesale, before shipment, value after canning, filleting, salting, or freezing; includes all by-products.*

[d]*Determined from sum of individual figures before rounding off.*



PORTAGE BAY, west of Lake Washington, is extensively used for mooring recreational craft. University of Washington, top, has an enrollment of over 14,000.

industrial development of the valley lands will lead to a further decline in farm acreage.

Farm Products. For the state as a whole, the value of farm products increased from $365 million in 1949 to $506 million in 1954. By comparison, values in the central Puget Sound region decreased from $43.7 million to $42.9 million during the same period.

Similarly, farm products in King County decreased from $18.4 million in 1949 to $17.7 million in 1954 (Table 4-8). In 1954, the value of dairying and dairy products amounted to $6.6 million or 37 per cent of the total for the county. Employment in agriculture is highest during the three months, July through September, and lowest during January. In the last 10 years, the number of employees in this category ranged from an average minimum of about 5,500 in January to a maximum of 11,000 to 14,000 in September.

Fisheries

Long recognized as a major center of commercial fishing, Seattle receives catches from Puget Sound, Alaska and the offshore waters of the Pacific. About two-thirds of the commercial salt water licenses sold in the state during 1956 were issued in the Puget Sound district.

Salmon is by far the most important commercial catch, accounting for roughly one-half of both the annual catch and the processed value of the Puget Sound fisheries industry (Table 4-9). Although the 1956 catch was quite low compared to 1955, total values for the two years were about the same. Good demand, combined with a short supply, served to nearly double unit values in 1956.

Sport or pleasure fishing in the waters of the sound is enjoyed by many thousands of residents and visitors every year. No accurate count of their numbers can be made, however, because licenses are not required.

Table 4-10. Parks and Other Recreational Areas in Seattle

Type	Number	Area, acres	
		Total	Water
Major parks	7	1,188	349
Minor parks	23	358	
Squares, view points	70	14	
Boulevards	8	361	
Waterfront parks and beaches[a]	23	103	85[b]
Golf courses	4	425	
Special areas[a]	19	370	
Total	–	2,819	434

Source: "Planning for Recreation", City of Seattle Planning Commission, 1954.

[a]*Includes some duplication with other types listed; area stated only for those not elsewhere covered.*

[b]*Total shoreline length, 18.2 miles.*

According to the State Department of Fisheries, sport catches of silver and chinook salmon totalled 476,000 in Puget Sound in 1956. For all the waters of the state, including the Columbia River, the total was 680,000.

Recreation

Endowed as it is with an abundance of natural attractions, the metropolitan Seattle area affords outstanding opportunities for recreational activity. This asset, coupled with that of scenic beauty, brings many thousands of visitors and a resulting tourist trade of considerable economic magnitude.

Recreational Facilities. Two national parks, Rainier and Olympic, and several state parks are within a few hours drive of the metropolitan area. Additionally, many public and private resorts are conveniently situated along the shores of lakes and streams and in the Olympic and Cascade ranges. Unlimited opportunities are available for hiking, camping, picnicking, and fishing in summer months and for hunting, skiing, and tobogganing in the colder months.

Boating. Puget Sound and Lake Washington, as well as the many small lakes in the metropolitan area, are used extensively for boating, sailing, and water skiing. In 1955, for example, the number of trips through Chittenden Locks by pleasure craft of all kinds totalled nearly 35,000 (Table 4-5). It is claimed, furthermore, that one out of every seven to eight Seattle families owns a power-driven boat.

From the standpoint of spectator and general community interest, the outstanding sports event in the boating field is the annual hydroplane competition on Lake Washington. The Gold Cup races, together with the attendant activities during Seafair week, attract nationwide attention.

Local Parks and Beaches. Within the metropolitan area itself there are three state parks: Saltwater, on the sound near Des Moines; Bridal Trail, east of Lake Washington near Houghton; and Lake Sammamish, at the south end of that lake.

The Seattle Park Department operates and maintains 7 major and 23 minor parks in addition to a large number of community recreation centers, playfields, squares and parkways (Table 4-10). This department also operates 23 waterfront parks and beaches on Puget Sound and Lake Washington. Recreational facilities occupy over 18 miles of shoreline. Attendance at supervised bathhouses and pools in 1955, as reported by the Park Department, totalled nearly 229,000 persons.

Military Installations

The Army, Navy, Air Force, and Coast Guard maintain establishments in the metropolitan area. Locations of the major installations are shown in Fig. 3-2.

Army. Fort Lawton, which borders Puget Sound south of Shilshole Bay, is the principal Army installation in the area. Others are the Seattle District Engineers Office on East Marginal Way, and the Quartermaster Depot at Auburn. Operations at the Army Terminal were terminated in mid 1957 with the transfer of its functions to a Navy installation at Pier 91. Chittenden Locks, though not a strictly military establishment, are owned by the U.S. Army and operated by the Corps of Engineers.

Table 4-11. Wholesale Trade in 1954 and 1948

Operation	Number of establishments		Sales, $1,000,000	
	1954	1948	1954	1948
Washington				
Merchant wholesalers	2,796	2,091	1,725	1,225
Manufacturers' branches	500	463	799	526
Petroleum and other fuels	698	608	340	236
Merchandise agents	355	297	389	346
Assemblers of farm products	309	323	205	227
Total	4,658	3,782	a	a
King County				
Merchant wholesalers	1,296	1,034	867	645
Manufacturers' branches	314	323	673	438
Petroleum and other fuels	51	49	108	77
Merchandise agents	272	227	298	258
Assemblers of farm products	8	6	8	13
Total	1,941	1,639	a	a

Source: *"1954 Census of Business, Wholesale Trade, Washington", U.S. Department of Commerce, Bureau of the Census, Bulletin W-1-47.*

[a]*State and county values are classified by the Census Bureau as "not applicable".*

ELLIOTT BAY waterfront is center of Seattle harbor activity. In 1955 the harbor ranked fourth in terms of domestic trade tonnage and sixth in foreign trade tonnage of Pacific Coast ports. Alaska Way viaduct, along waterfront, carries U.S. 99 highway traffic through congested downtown area of city.

Navy. Navy installations in the metropolitan area consist of the Sand Point Air Station on the shore of Lake Washington, the Naval Station and Supply Depot in Smith Cove at the northern extremity of the Elliott Bay waterfront, and the Reserve Ship Yards on Harbor Island at the mouth of Duwamish River. Sand Point Air Station is used also as the headquarters of the thirteenth Naval District and as a training base for a reserve unit of the U.S. Air Force.

Coast Guard. Coast Guard operations are centered at a base just upstream from the Government Locks in Salmon Bay. This base is used by patrol boats operating in Puget Sound and Lake Washington and serves in addition as a supply point for light ship stations. Pier 70 on the Elliott Bay waterfront also is utilized by the Coast Guard.

Air Force. There are no Air Force installations in the metropolitan area but reserve training units are based at Paine Field and at Sand Point Naval Air Station.

TRADE AND COMMERCE

Over one-half of the wholesale and retail establishments in the state are located in the Central Puget Sound counties. These establishments account for more than 50 per cent of the dollar value of the total trade.

Wholesale Trade

Wholesale trade, as measured by the number of establishments and the dollar value of total sales, increased substantially in the seven-year period from 1948 through 1954 (Table 4-11). During this period, the total number of establishments increased 123 per cent in the state as a whole and 119 per cent in King County. The largest gain was in the category of merchant wholesalers, which includes wholesalers, jobbers, distributors, foreign trade merchants and other related operations. In 1954, this category accounted for 60 per cent of the state's total number of wholesaling operations and for 67 per cent of those in King

Table 4-12. Regional and Local Wholesale Trade in 1954

Area	Total		Merchant wholesalers		Other Others types	
	Establishments, number	Payroll, $1,000,000	Establishments, number	Payroll, $1,000,000	Establishments, number	Payroll, $1,000,000
Washington	4,658	201	2,796	1,725	1,862	1,733
Central Puget Sound Region[a]	2,503	133	1,708	1,105	795	1,187
King County[b]	1,941	108	1,296	867	645	1,087
Auburn	8	0.08	5	0.7	3	1.0
Renton	17	0.7	14	4.2	3	1.4
Seattle	1,818	105	1,220	846	598	1,035
Rest of county	98	2.6	57	14	41	49

Source: "1954 Census of Business, Wholesale Trade, Washington", U.S. Department of Commerce, Bureau of the Census, Bulletin W-1-47.

[a]*Includes Kitsap, King, Pierce and Snohomish Counties.*

[b]*County payroll and sales totals computed before rounding off figures for political subdivisions.*

County. It also accounted for roughly one-half of the total sales value.

As indicated by the data in Table 4-12, the central Puget Sound Region accounted in 1954 for 54 per cent of the state's wholesale establishments and for 66 per cent of the payroll. These data reveal also that more than 75 per cent of the establishments and payroll were in King County and that this type of business activity is centered in the metropolitan Seattle area.

Retail Trade

Retail trade statistics for 1948 and 1954 (Table 4-13) indicate approximately equal rates of growth for the state, the Puget Sound Region, and King County. During the seven-year period, the number of retail establishments increased just under 10 per cent, while the dollar value of retail sales increased about 30 per cent. The latter is due to the decreased value of the dollar, to increased purchases per capita, and to the increase in population between 1948 and 1954.

Within King County, the greatest percentage increase in sales occurred in the cities of Auburn and Kent where the 1954 values were 158 and 162 per cent of the 1948 values. At Seattle, retail trade increased to 135 per cent of the 1948 value, and accounted for over 80 per cent of the county total in both 1954 and 1948.

Retail sales are divided by the Bureau of the Census into eleven major groups. In 1954, the food group accounted for 22 per cent of the total value in King County as a whole (Table 4-14). This was followed by the automotive and the general merchandise groups each with 14 per cent. In other words, 50 per cent of the total value falls in these three groups.

Foreign Commerce

In foreign trade tonnage, Seattle ranked sixth among the major Pacific Coast ports in 1955 (Table 4-15). In 1956, trade with Canada and Mexico accounted for 60

Table 4-13. Regional and Local Retail Trade in 1954 and 1948

Area	Establishments, number		Sales, $1,000,000	
	1954	1948	1954	1948
Washington	26,806	24,875	2,874	2,204
Central Puget Sound Region[a]	13,034	12,173	1,493	1,117
King County[b]	8,178	7,607	1,008	749
Auburn	145	118	19	12
Kent	131	81	11	6.8
Kirkland	112	89	10	7.1
Renton	231	187	28	19
Seattle	6,381	5,583	827	610
Rest of county	1,178	1,549	113	95

Source: "1954 Census of Business, Retail Trade, Washington", U.S. Department of Commerce, Bureau of the Census, Bulletin R-1-47.

[a]*Includes King, Kitsap, Pierce and Snohomish Counties.*

[b]*Total sales value computed before rounding off figures for political subdivisions.*

Table 4-14. Distribution of Retail Sales in King County, 1954

Business group	Sales in thousand dollars						
	Total	Auburn	Kent	Kirkland	Renton	Seattle	Remainder
Food stores	220,457	4,468	4,018	2,400	6,667	166,449	36,455
Eating, drinking places	83,267	824	595	508	1,713	70,605	9,022
General merchandise	143,214	813	606	884	1,859	134,327	4,725
Apparel	54,492	568	191	126	1,585	50,035	1,987
Furniture, appliances	43,853	604	673	494	1,911	35,650	4,521
Automotive	143,325	6,318	2,247	3,466	5,974	111,168	14,152
Gasoline stations	62,671	1,066	729	707	2,440	46,144	11,585
Lumber, building equipment	51,473	831	633	580	2,657	36,437	10,335
Drug stores	31,320	a	305	360	1,155	24,635	4,152
Other retail	113,902	2,593	978	757	2,097	92,631	a
Non-store retail[b]	60,082	a	184	72	36	59,120	a
Total	1,008,056	18,668	11,159	10,354	28,094	827,201	112,580

Source: "1954 Census of Business, Retail Trade, Washington", U.S. Department of Commerce, Bureau of the Census, Bulletin R-1-47.

[a]*Omitted to avoid disclosure of information which could be associated with operation of a single establishment.*

[b]*Includes mail order houses, house-to-house sales, and vending machine operations.*

per cent of the imports, while 45 per cent of the exports went to Japan and Korea. Limestone, limerock and gypsum rock accounted for 40 per cent of the import tonnage, and wheat and barley for 60 per cent of the export tonnage.

Fig. 4-4 portrays the development of foreign trade at Seattle since 1900. Variations in the totals of import and export tonnage follow those of national and world economy and, for the latter, reflect the status of trade with the orient.

Domestic Commerce

Domestic waterborne commerce includes four major classifications: coastwise, internal, intraport, and local. For the entire group in 1955, Seattle ranked fourth on the Pacific Coast, with a total of 11.1 million tons. Los Angeles Harbor ranked first with 14.4 million tons and was followed in order by Richmond Harbor and Portland.

Seattle Harbor receipts and shipments in 1955 are listed in Table 4-16 for coastwise, internal, and intraport categories. Local commodity movements totalled 629 thousand tons. Of these, the principal items, in thousand tons were: residual fuel oil, 238; rafted logs, 125; gas oil distillate fuel oil, 83; motor fuel and gasoline, 63; and lumber and shingles, 23. Total tonnage of domestic shipping in 1956 was 11.8 million

Table 4-15. Comparative Foreign Trade Figures for 1955

Harbor	Total, 1,000 tons	Exports, 1,000 tons	Imports, 1,000 tons
Los Angeles, Calif.	4,885	3,155	1,730
Long Beach, Calif.	3,066	2,277	789
Richmond, Calif.	1,748	767	981
San Francisco, Calif.	1,661	801	860
Portland, Ore.	1,408	1,258	150
Seattle, Wash.	1,357	698	659
Carquinez Strait, Calif.	1,283	145	1,138
Tacoma, Wash.	1,257	817	440
Oakland, Calif.	868	773	95
Redwood City, Calif.	174	93	81
San Diego, Calif.	149	93	56

Source: "Waterborne Commerce of the United States, 1955. Part 4, Waterways and Harbors: Pacific Coast, Alaska and Pacific Islands". Department of the Army, Corps of Engineers.

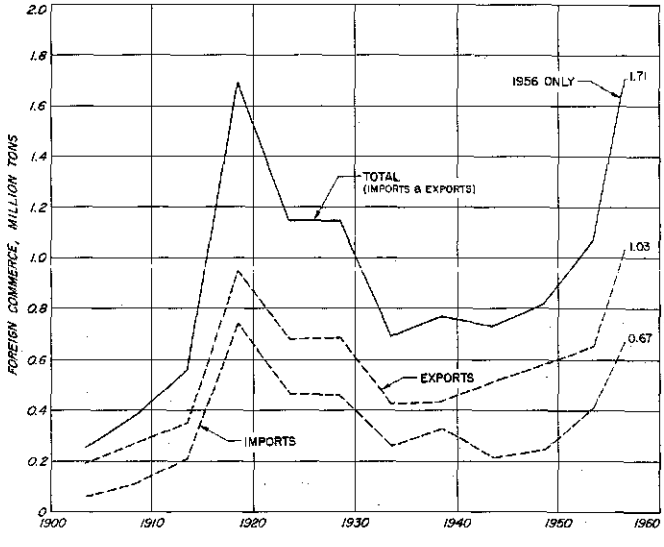


Fig. 4-4. Foreign Trade and Commerce, Seattle Harbor

Average values for five-year periods from 1905 through 1955. In 1956, total tonnage of foreign trade items exceeded the average for any five-year period. Exports have consistently exceeded imports.

Table 4-16. Leading Domestic Receipts and Shipments, Seattle Harbor, 1955

Receipts		Shipments	
Commodity[a]	1,000 tons	Commodity[a]	1,000 tons
Coastwise		Coastwise	
Gas, oil, distillate, fuel oil	1,759	Lumber and shingles	50
Motor fuel and gasoline	1,424	Building cement	31
Residual fuel oil	1,266	Motor fuel and gasoline	21
Crude petroleum	118	Rolled finished steel mill products	19
Petroleum asphalt	89	Posts, poles and piling	18
	4,656		139
All other commodities	469	All other commodities	510[b]
Total	5,125	Total	649
Internal		Internal	
Sand, gravel, crushed rock	1,515	Gas, oil, distillate, fuel oil	395
Rafted logs	597	Residual fuel oil	377
Motor fuel and gasoline	170	Motor fuel and gasoline	322
Gas, oil, distillate, fuel oil	155	Rafted logs	139
Residual fuel oil	114	Wheat	85
	2,551		1,318
All other commodities	284	All other commodities	289
Total	2,835	Total	1,607
Intraport		Intraport	
Rafted logs	62	Gas, oil, distillate, fuel oil	132
Lumber and shingles	7	Motor fuel and gasoline	26
Posts, poles and piling	2	Residual fuel oil	26
	71		184
All other commodities	3	All other commodities	21
Total	74	Total	205

Source: "Waterborne Commerce of the United States, 1955. Part 4: Waterways and Harbors, Pacific Coast, Alaska and Pacific Islands". Department of the Army, Corps of Engineers.

[a]*Department of Commerce classifications.*

[b]*Indicative of wide variety of commodities; about half of this total accounted for by commodities not specifically covered by the classifications.*

tons, a 6 per cent increase over the 11.1 million tons in 1955.

Tourist Trade

On a statewide basis, the value of the tourist industry has more than doubled since 1948. According to estimates by the State Department of Conservation and Development[2], tourists and vacationists spent a total of $271 million in the state in 1956, as compared to $116 million in 1948. These totals include such items as food and lodging, gasoline and other transportation costs, entertainment, gifts, and photographic and other equipment.

In 1956, over one million out-of-state automobiles entered the state and the total number of tourists, including those using other forms of transportation was estimated at 3.7 million persons. The average tourist party numbered 3.3 persons, stayed 7.38 days and spent $9.87 per day per person.

Seattle is the leading convention city in Washington. Data compiled by the Bureau of Economic and Business Research of Washington State University[3] indicate that, in 1952, Seattle had a total of 72,000 convention visitors who spent a total of $4.2 million.

A long-term, continuing program aimed at attracting increased numbers of tourists to the state is presently being developed by the new State Department of Commerce and Economic Development.

PUBLIC UTILITIES

Abundant and relatively cheap sources of water and power are available to the metropolitan Seattle area and have played a major role in its economic development.

[2]"A Report on Washington 1956 Vacation Travel," *Department of Conservation and Development, Bureau of Progress and Industrial Development.*

[3]"An Analysis of Convention Business in Washington State."

Table 4-17. Operating Water Supply Agencies

Name	Area, square miles	Connections 1957[a]	Source of supply[b]	Capacity,[c] mgd
Cities				
Auburn		2,750	S	6.0
Bothell	1.00	700	W	0.3
Houghton			d	
Issaquah		931		0.230
Kent		2,225		2.7
Kirkland	3.70	2,521	W	
Pacific				
Redmond		600	W	0.237
Renton			e	
Seattle	91.57[f]	172,060	R	205
Tukwilla	1.00	280	e	
Water Districts				
1 Yarrow	0.40	162	S	0.300
4 Three Tree Point	1.50	475	S	0.500
14 Bryn Mawr				
17 Hunts Point	0.30	90	g	0.112
20 Boulevard Park	9.50	6,950	e	1.000
22 Beaux Arts	0.13	94	W	0.108
23 Medina	1.40	400	g	2.000
25 Duwamish		420[h]	e	0.105
35 Foster		460	e	0.325
38 Riverton Heights			e	5.970
42 North City			e	42.214
43 Riverton Heights	7.00	1,725	W	1.080
45 White Center		1,000	e	0.062
49 Burien	1.00	3,000	W	
53 Angle Lake	1.00	181	W	
54 Des Moines	1.00	525	W	0.650
56 Redondo	3.40	581	S	1.000
57 Lake Ridge		57	e	
58 Spring Glen	4.00	725	e	0.800
61 White Center			e	3.118
62 Earlington			e	
63 Lake Ridge		735	e	
64 Steel Lake	6.00	601[h]	W	0.200
68 Bellview	8.10	6,100	L	8.000
69 Skyway	0.16	187	e	0.052
72 Juanita	9.90	500	W	0.360
75 Midway	11.40	3,500	W	2.450
77 Skyway			e	4.668
78 Cedar River	0.75	220	e	0.898
79 Kenmore	8.50	1,510	e	0.176
80 Christopher	16.00	500	S	0.160
81 Rose Hill	4.00	600	d	2.000
82 Pine Lake	1.40	98	W	0.050
83 Lake Forest	4.00	650	W	
85 Seahurst	1.00	392[h]	S	
87 Thomas	2.00	89	S	0.043
88 Skyway	0.19	135	e	0.729
90 Coalfield	6.50		W	0.350
91 Mercer Island	0.22	207	W	0.140
93 Mercer Island	1.67	1,092	W	0.750
97 Eastgate Hills	1.87	800	W	2.000
Private Companies				
East Hill Comm. Well Co.	2.00	180	W	0.060
Independent Water Co.		120	S	0.090
Lake Center Water Coop.	21.00	800	W	1.00
Lakota Coop. Water Assn.		35[h]	S	
Meridian Water Co.			i	
Normandy Park Water Co.		350	W	0.395
Richmond Beach Water Co.		630	W	0.720
South Auburn Water Assn.			W	0.010
Star Lake Water Co.	4.00	200	W	0.400
Washington Water Service	15.00	2,000	L	1.500
Weowna Beach Corp.	0.06	30		0.010

Source: "Government in Metropolitan Seattle, Bureau of Governmental Research and Services, University of Washington, 1956.

[a]*Number of services, not persons. Figures include any services outside district or city boundary.*

[b]*W - well, S - spring, L - lake, R - river; primary source of supply.*

[c]*Capacity of existing facilities.*

[d]*Purchases water from Kirkland.*

[e]*Purchases water from Seattle.*

[f]*Includes outside areas; actual city land area is 84.17 sq. mi.*

[g]*Purchases water from WD 68.*

[h]*1955 data.*

[i]*Purchases water from Kent.*

Water

There now are a total of 76 governmental and private agencies engaged in supplying water in the metropolitan area (Fig. 4-5 and Table 4-17). These include 10 cities, 43 water districts, and 11 private companies or cooperatives in King County, and 4 water districts in Snohomish County. Additionally, there were 8 more districts in 1956 which, although legally formed, were not yet actually delivering water to consumers.

Sources of Supply. At present, water is obtained from rivers, wells, lakes, springs and creeks. Water for the city of Seattle and for contiguous areas served by the city system (Fig. 4-5) is derived from Cedar River. The city sells water on a wholesale basis to

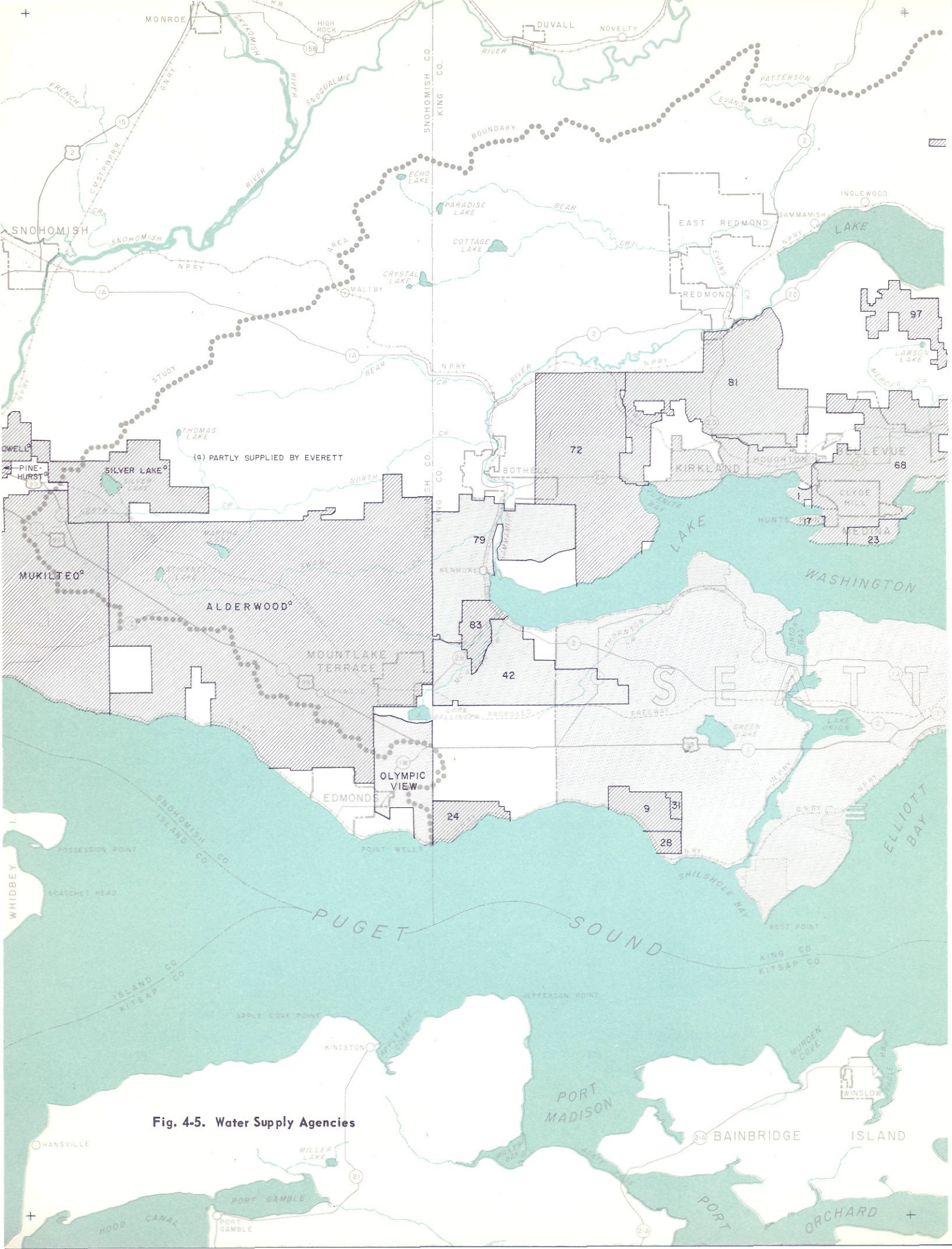
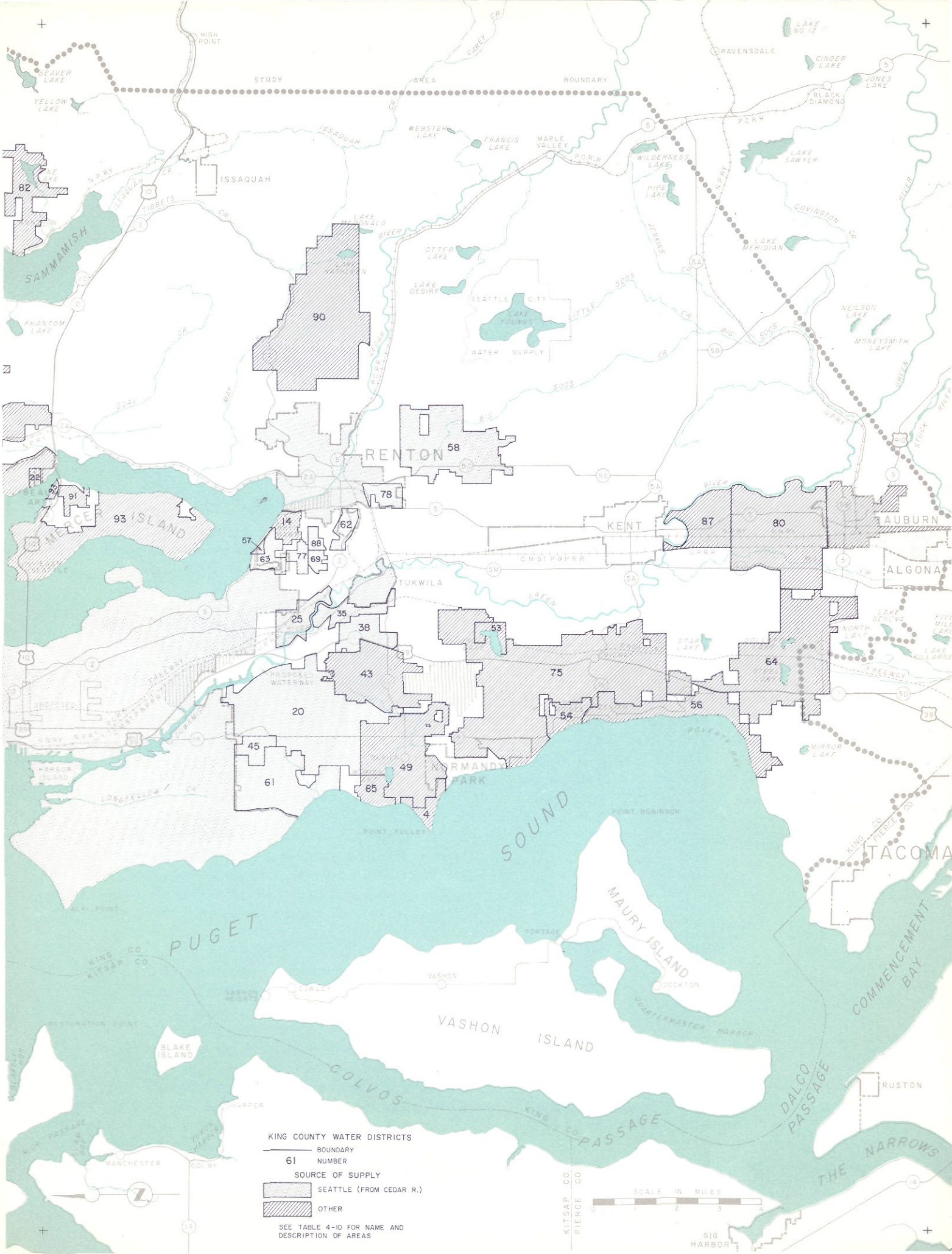


Fig. 4-5. Water Supply Agencies


STUDY AREA BOUNDARY
HIGH POINT
BEAVER LAKE
YELLOW LAKE
ISSAQUAH
SAMMAMISH
PHANTOM LAKE
WEBSTER LAKE
FRANCIS LAKE
MAPLE VALLEY
RAVENSDALE
LAKE NO. 12
CINDER LAKE
JONES LAKE
BLACK DIAMOND
WILDERNESS LAKE
PIPE LAKE
LAKE SAWYER
COVINGTON CR
LAKE MERIDIAN
NEILSON LAKE
MONEYSMITH LAKE
LAKE MCDONALD
OTTER LAKE
LAKE DESIRE
SEATTLE CITY WATER SUPPLY
LAKE YOUNGS
RENTON
KENT
AUBURN
ALGONA
TUKWILA
MERCER ISLAND
NORMANDY PARK
TACOMA
LAKE GENEVA
NORTH LAKE
MIRROR LAKE
POINT ROBINSON
POINT PULLEY
PUGET SOUND
MAURY ISLAND
PORTAGE
VASHON
DOCKTON
VASHON ISLAND
QUARTERMASTER HARBOR
COMMENCEMENT BAY
BLAKE ISLAND
COLVOS PASSAGE
DALCO PASSAGE
THE NARROWS
RUSTON
GIG HARBOR
MANCHESTER
COLBY
HARPER
YELLOW HARBOR
KING CO
KITSAP CO
PIERCE CO
SCALE IN MILES
0 1 2 3 4
KING COUNTY WATER DISTRICTS
BOUNDARY
61 NUMBER
SOURCE OF SUPPLY
SEATTLE (FROM CEDAR R.)
OTHER
SEE TABLE 4-10 FOR NAME AND DESCRIPTION OF AREAS

17 outlying agencies in King County and to Water District No. 1 in Snohomish County. In 1956, the water department reported that 586,600 persons were served directly by the city system and than an additional 74,750 persons were served by districts which purchase water from Seattle. These together represent approximately 80 per cent of the population of the metropolitan area.

Wells are the primary source of supply for most water districts. District 68, however, supplies Bellview and adjacent areas with filtered water taken from Lake Washington. Lake Washington is the source of supply also for the Shorewood Apartments on Mercer Island and many individual private users. The Washington Water Service Company, which serves part of the eastern portion of the metropolitan area takes its supply from Lake Sammamish.

Although it is possible in some cases to augment local sources now in use, it is evident that future water supply developments will involve the Cedar, Tolt, and Skykomish rivers. It might become possible also to serve a portion of the southern part of the metropolitan area, particularly Auburn and Kent, with water from the Green River. This river is currently the major source of supply for the city of Tacoma.

Because of the magnitude of the expenditures involved in developing new sources, it is anticipated that many of the existing districts will, in the future, become dependant upon Seattle for water. At maximum development, the Cedar and Tolt rivers will yield an estimated 455 mgd (million gallons per day), comprising 305 mgd from the Cedar and 150 mgd from the Tolt. At prevailing rates of consumption, these two sources could supply the metropolitan area for the next 40 to 60 years. As a part of its long-term program, however, the city of Seattle has filed for water rights on the north fork of the Skykomish River.

Table 4-18. Chemical Quality of Cedar River Water

Constituent	Concentration, ppm[a]
Silica (SiO_2)	7.0
Iron (Fe)	0.09
Aluminum (Al)	0.005
Calcium (Ca)	3.76
Magnesium (Mg)	1.2
Potassium (K)	0.28
Sodium (Na)	1.99
Bicarbonate (HCO_3)	19.4
Sulfate (SO_4)	2.8
Chloride (Cl)	0.5
Total hardness ($CaCO_3$)	14.2
Total solids	44
pH	7.8

Source: "Annual Report, 1956," City of Seattle Water Department. Sample collected from Beacon Avenue sample tap November 11, 1956.

[a]*Except pH.*

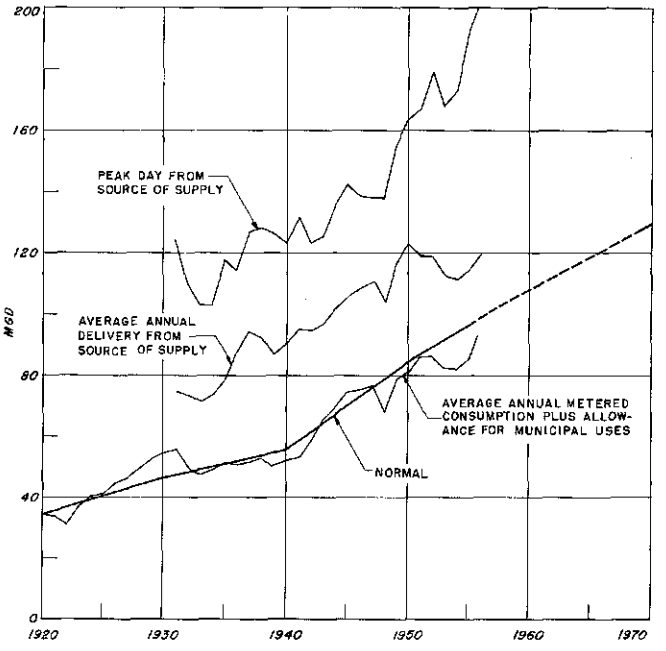


Fig. 4-6. Water Consumption in Seattle System

System is 100 per cent metered. Estimated normal consumption in 1970 is 190 mgd. Data and estimates from Seattle Water Department.

The city of Everett also derives water from rivers of the Cascade Range and has long-term plans to serve substantial portions of the area north of the Snohomish County line. In view of this and the Seattle potential, it can be concluded that Lake Washington will be utilized for domestic water to a lesser extent in the future than it is at present.

Water Quality. Cedar River water, as supplied by the city of Seattle, is of excellent quality (Table 4-18) and is suitable for almost all domestic and industrial purposes without any treatment other than chlorination. A similar situation obtains with respect to other existing and potential sources in the Cascades. Local sources, on the other hand, are of generally less acceptable quality.

Annual Water Consumption. Because of wide variations in the type of development in areas served by the various systems, water consumption figures vary greatly when expressed on a population or per capita basis. For the Seattle system, average annual consumption, exclusive of transmission and distribution losses, increased from 35 mgd in 1920 to 80 mgd in 1950 and 93 mgd in 1956 (Fig. 4-6). The 1956 figure includes 7.2 mgd used for various unmetered municipal services. In terms of population served, the water department estimates that average uses during

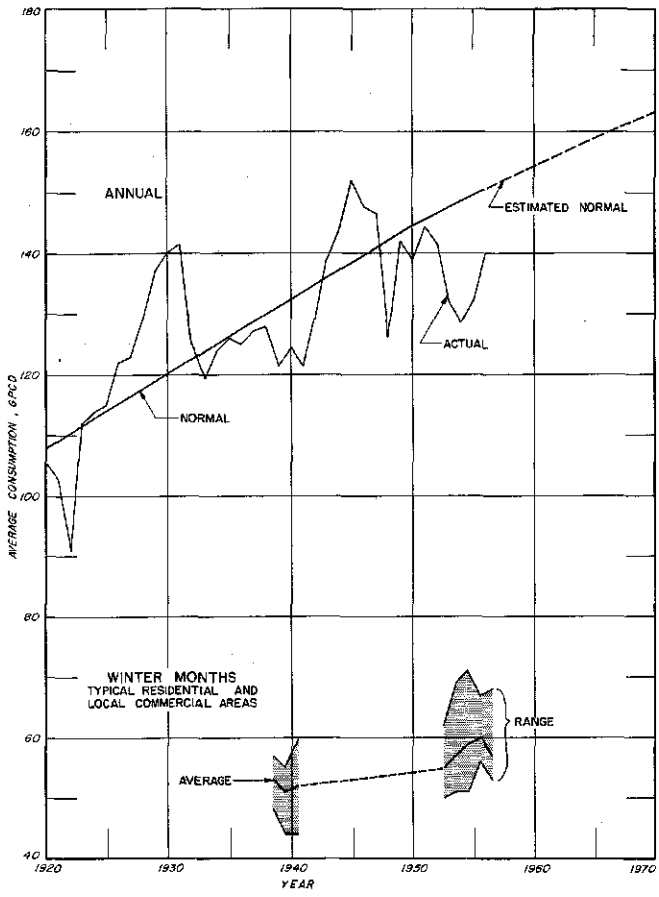


Fig. 4-7. Per Capita Water Consumption in Seattle System

Anticipated increases in industrial uses and increases in residential uses of automatic washing machines, dishwashers and garbage grinders indicate that per capita consumption, exclusive of transmission and distribution losses, will increase to 160 gpcd in 1970. Data and estimates from Seattle Water Department.

the three years were 105, 138 and 140 gallons per capita daily. These and the other per capita figures represent combined domestic, industrial and municipal uses and are typical for large systems having intensively developed industrial and commercial areas, as well as a large residential population. Variations from year to year in the average daily consumption stem principally from differing requirements for irrigation water during relatively dry and wet summers.

Increases in per capita water use (Fig. 4-7) have been taking place for many years not only in Seattle but in many other systems throughout the country. This may be attributed in part to (1) increased use of water for industrial purposes, and (2) increased household use of automatic washing machines, dishwashers and garbage grinders. The Seattle Water Department estimates that per capita consumption will increase from the present level of about 150 gpd to over 160 gpd by 1970. Should that trend continue, the rate will be in excess of 180 gpd by the year 2000.

Seasonal variations in consumption in the Seattle system are shown in Fig. 4-8. Summer demands, which are affected primarily by temperature and rainfall and the corresponding necessity for irrigation, are about 137 per cent of the yearly average and may vary considerably from year to year. Winter demand, on the other hand, is more nearly the same from year to year and approximates 85 per cent of the yearly average.

Winter Water Consumption. From the standpoint of sewerage, water consumption figures for the winter or nonirrigating season are particularly significant. At that time, practically all water delivered to consumers is discharged to the sewers and thus is a direct measure of sewage volume other than that added by infiltration of ground water and inflow of surface drainage.

Winter water consumption data, as indicated by quarterly readings of consumer meters, were obtained from the Seattle Water Department for three meter routes in specific residential-local commercial areas. In each case, these areas were nearly identical to those tributary to a sewage metering point (Chapter 7). Additional data were obtained, however, for other meter routes in areas of similar nature.

Information concerning metered sales by the city to suburban water districts and records of water pro-

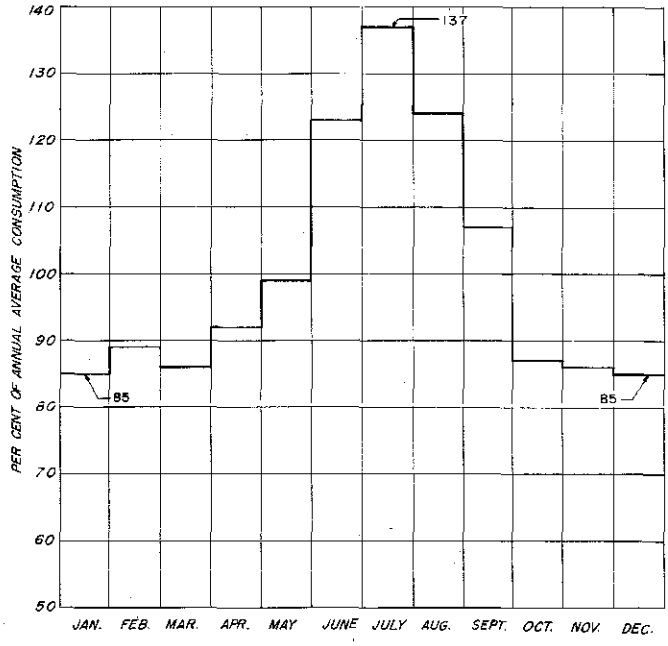


Fig. 4-8. Monthly Variation in Water Consumption

Average monthly consumption in Seattle's system normally ranges from 135 to 85 per cent of the annual average consumption. Consumption, particularly in summer months, varies considerably from year to year because of fluctuations in rainfall and lawn sprinkling. Data from Seattle Water Department.

Table 4-19. Winter Water Consumption, 1955 - 1956

Description of area[a]				Consumption	
Designation	Number of services	Persons per household[b]	Total connected population	mgd	gpcd
Auburn	2,500	3.5[c]	8,750	0.50	57
Kent	2,040	3.5[c]	7,150	0.47	66
Seattle - Ballard	8,108	3.1	25,000	1.45	58
Seattle - Greenwood	4,957	3.2	16,000	1.00	62
Seattle - Lake City	7,011	3.3	23,200	1.24	53
Seattle[d]					
13	277	3.3	915	0.06	65
95	370	3.3	1,220	0.06	49
58	278	-	-	0.05[e]	
59	265	-	-	0.06[e]	
89	379	3.1	1,180	0.07	59
Shorewood Apartments			2,300[f]	0.16	70
King County Water District No.					
20	5,810	3.3	19,200	1.13	59
25	415	3.0	1,250	0.07	56
42	5,187	3.3	17,200	0.73[g]	43
45	587	3.5	2,050	0.09	44
57	48	3.3	160	0.01[h]	48
61	2,783	3.2	8,900	0.52[g]	58
68	4,500	3.2	14,400	0.82	57
77	582	3.3	1,920	0.11	57
79	1,238	3.1	3,840	0.20	52
Total			154,535	8.68	
Weighted average					56

[a]*See Fig. 4-5.*

[b]*Unless otherwise shown, determined from 1950 census tract data.*

[c]*King County Planning Commission estimate, 1957.*

[d]*Water meter routes located as follows: 13 - Ennis Arden Tract; 95 - upper Rainier Valley; 58 and 59 - commercial along Bothell Way; 89 - Magnolia.*

[e]*Omitted from total; included in Lake City total.*

[f]*Estimated from number of units.*

[g]*Water department delivery less 10% for system losses.*

[h]*Rounded from 7,700 gallons per day.*

duction in districts and cities having independent supplies were obtained from the individual operating agencies. In utilizing these data, net consumption was determined by deducting an allowance of 10 per cent for system losses.

Per capita consumption was obtained by dividing the net consumption by the product of the number of meters and the average 1950 household population. Figures for the latter were taken for the particular census tract or tracts in which the water district or water meter route was situated.

Winter water consumption in the residential-local commercial areas averages 56 gpcd and ranges from 65 to 44 gpcd (Table 4-19). Deviations from the average bear no relation to the size of the area but do, to some extent, reflect its economic status. For example, meter route 13 in the Seattle Highlands area shows an average winter consumption of 65 gpcd, whereas meter route 95 in the lower income neighborhood bordering Yesler Way shows 49 gpcd.

Long-term records in certain residential areas of Seattle (Fig. 4-7) indicate that net winter consumption has increased by only about 10 per cent since 1938. Meter routes from which these records were obtained are in older residential districts where population changes have been negligible and thus permit direct comparison over a long period. The difference between the curve for the older districts and that showing gross annual per capita consumption for the system as a whole may be due to some extent to the static nature of the selected areas. Increased consumption for commercial and industrial purposes, coupled with greater summer irrigation demands in new single-

family dwellings, is believed to account for most of the difference between the two curves.

Industrial Water Consumption. Winter water consumption data were obtained also from three meter routes covering the heavy to medium industrial area extending along the Duwamish Waterway from Harbor Island to Boeing Field. Average daily consumption in this gross area of 975 acres was 3.1 mgd, or 3,200 gpad (gallons per acre per day). Values for the individual routes ranged from 1,840 to 3,700 gpad.

Higher consumption occurs in other seasons of the year, particularly the summer months when large quantities of water are used for gravel washing and cold storage operations. Such operations, however, are not significant with respect to the volume of sewage and industrial waste, as the waste water they produce is suitable for direct discharge to adjacent waterways.

Cost of Water. Costs of water are determined by the costs of transmission, treatment, pumping, storage and distribution. For the Seattle system, the total cost amounted to $122.09 per million gallons in 1956 and to $128.70 in 1955.

Monthly water rates for a normal 3/4-inch residential service are $1.00 for the first 300 cubic feet and 10 cents for each additional 100 cubic feet. As a matter of interest, rates for similar service in San Francisco include a fixed charge of $1.10 for a 3/4-inch service, plus 25.9 cents per 100 cubic feet for the first 3,300 cubic feet.

Power

Two major agencies, the city of Seattle Department of Lighting, and the Puget Sound Power and Light Company, serve the metropolitan area with electric power and light. City Light's service zone covers the area between Puget Sound on the west and Lake Washington on the east and extends from the Snohomish County line on the north to the vicinity of South 160th Street on the south. Puget Sound Power and Light's service area covers most of the remainder of the area, including Renton, Tukwila, and the area east of Lake Washington. This company also serves eight counties in western Washington, excluding areas therein which obtain power from municipal systems and public utility districts.

Prior to 1951 there was a considerable overlapping in the service areas of the two purveyors. Through a purchase agreement in that year, City Light took over all distribution in its present service area and has since maintained a continuing program to eliminate the many duplicate components.

Power Sources. The hydroelectric generating station at Cedar Falls was the first to be constructed by City Light. This station, with an initial capacity of 2,400 kw (kilowatts), was constructed in 1905 as an adjunct to the water department's development on Cedar River. Additions since that time consist of three hydro stations on Skagit River, Gorge, Diablo, and Ross, and two steam stations, Lake Union and Georgetown, both of which are now used only rarely. Upon completion of the Gorge high dam in 1959, the total capacity of these stations will be increased from the present level of 693,000 kw to 750,000 kw.

An application has been submitted by the city to the Federal Power Commission for a license to construct the so-called Boundary project on the Pend Oreille River near the Washington-British Columbia border. In addition, preliminary studies of two more sites on Skagit River, Copper and Thunder Creeks, are now in progress. The Boundary project will produce 540,000 kw, and the Skagit River sites a maximum of 200,000 kw. Completion of these projects will bring the total generating capacity of city owned facilities to nearly 1.5 million kw.

Puget Sound Power and Light develops hydroelectric power at its Dieringer powerhouse south of Auburn, utilizing water diverted from White River. It also has a 70,000 kw steam plant at Renton. Additional hydroelectric plants are located at several other sites in

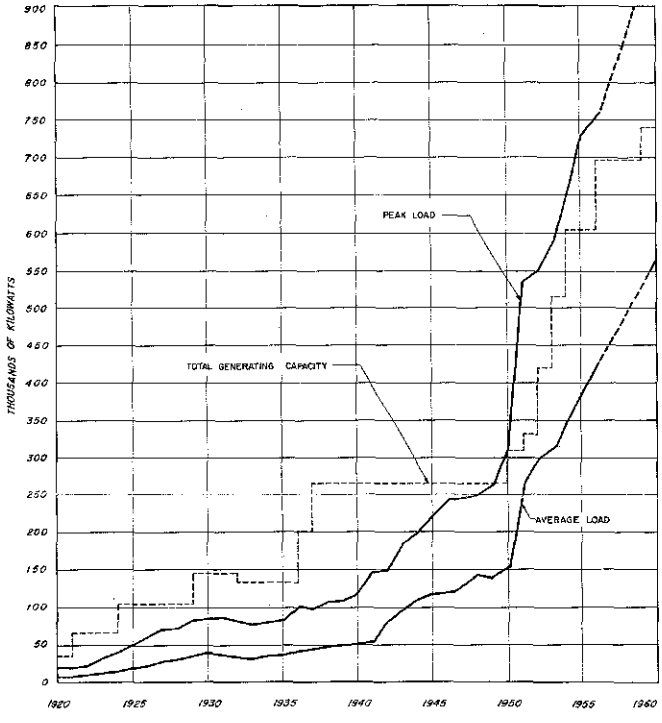


Fig. 4-9. Generating Capacity and Power Consumption, Seattle City Light System

With improvements scheduled for completion by 1960, total generating capacity of the system will have been nearly tripled from the 1932 - 1950 level. Since 1950 the system has utilized power from outside sources to meet peak load requirements. Data from Seattle Department of Lighting.

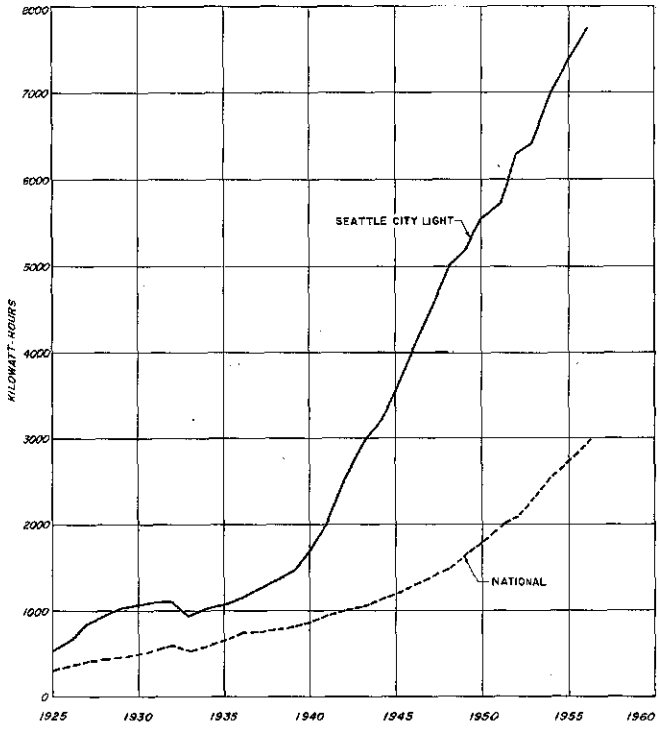


Fig. 4-10. Average Annual Residential Power Consumption

Power consumption for residential use in the Seattle City Light system was 2.6 times as great as in the nation as a whole in 1956. For residential service, costs are approximately one per cent per kilowatt hour. Data from Seattle Department of Lighting.

western Washington, including Rock Island on Columbia River. Total generating capacity, including the steam plant at Renton, is 278,250 kw. Projected additions of over 800,000 kw will bring the total to over 1 million kw when all currently proposed sites are developed and proposed enlargements are completed.

Seattle City Light and Puget Power and Light, along with three other western Washington electric utilities, Tacoma City Light, Chelan County Public Utility District, and Snohomish County Public Utility District No. 1, formed the Puget Sound Utilities Council in 1956. By creating an operating "pool" of electric energy through integrated operation of reservoirs and a flexible system of interchanges, this organization has achieved a saving in output which otherwise would have been lost.

Power and light systems serving the metropolitan area are also a part of the much larger Northwest Power Pool. As such, they have available both surplus and firm power commitments from other members, principally the Bonneville Power Administration which generates over 50 per cent of the power produced in the Pacific Northwest.

By the time all of the feasible hydroelectric resources in the Northwest have been developed, the demand for power is expected to exceed the combined capabilities of all such sources. Eventually, therefore, it will be necessary to turn to steam generation of power, using either conventional or nuclear fuels. Since it is estimated that 15 to 20 years may elapse before this step becomes necessary, it is quite conceivable that technological developments in the use of nuclear fuels will make them economically attractive for power generation.

Power Consumption. Since 1950, peak loads on the City Light system have exceeded generating capacity and have been met by purchases from other sources (Fig. 4-9). Similarly, sales of surplus power have been made to other suppliers at such times at it has been possible to do so.

During 1956 the total electrical input through the City Light system was over 3.7 billion kwh (kilowatt hours), which is equivalent to a continuous load of 424,000 kw. Actual power output from City Light plants averaged 310,000 kw and the balance, 114,000 kw, was supplied through interchanges and purchases from outside sources.

The largest use of power in 1956 was by the Aluminum Company of America, which purchases an average of 30,000 kw for use at its East Wenatchee and Vancouver, Washington alumina reduction plants. This power is supplied by Seattle as part of its purchases from the Pend Oreille County Public Utility District and is transmitted over lines of the Bonneville Power Administration. In 1956, City Light contracted to supply 37,500 kw required for the operation of two 100-ton electric furnaces at the new Seattle plant of the Bethlehem-Pacific Coast Steel Company.

Average residential consumption in Seattle, as in the rest of the nation, has been increasing for many years (Fig. 4-10). Consumption in 1956 was 7,800 kwh, or 2.6 times the national average of 3,000 kwh.

Table 4-20 lists power sales in 1956 according to various types of use. The difference between the total sale of 3.255 million kwh and the total input of 3.7 billion kwh is accounted for by system losses and by power used in the operation of City Light facilities.

Table 4-20. Seattle City Light Power Sales in 1956

Type of use	Power sales	
	million kwh	per cent
Residential	1,537	47
Commercial and industrial	1,450	45
Public street lighting	49	2
Other public agencies	177	5
Railroads and railways	41	1
Other sales	1	
Total sales	3,255	100

Source: "1956 Annual Report", City of Seattle, Department of Lighting.

Table 4-21. Comparative Electric Power Bills

Type of use	Demand, kw	Consumption, kwh	Typical monthly electric bill, dollars			
			Seattle[a]	Portland	San Francisco	Los Angeles[a]
Residential		25	0.75	1.00	1.45	1.00
		100	2.52	3.05	3.64	2.77
		250	4.40	5.25	6.44	4.90
		500	5.14	6.25	9.44	6.65
Commercial power	1.5	150	3.30	4.95	5.90	4.40
	3.0	375	6.83	9.90	12.73	8.90
	6.0	750	12.45	15.40	24.60	16.10
	12.0	1,500	23.70	25.85	44.85	29.50
	30.0	6,000	79.50	85.25	138.00	76.70
Industrial service	75	15,000	172.00	214.00	270.00	164.00
	75	30,000	238.00	313.00	405.00	269.00
	150	30,000	305.00	388.00	490.00	289.00
	150	60,000	437.00	541.00	736.00	457.00
	300	60,000	572.00	703.00	896.00	529.00
	300	120,000	836.00	942.00	1,348.00	857.00
	500	100,000	928.00	904.00	1,443.00	849.00
	500	200,000	1,348.00	1,209.00	2,173.00	1,364.00
	1,000	200,000	1,798.00	1,751.00	2,663.00	1,649.00
	1,000	400,000	2,500.00	2,361.00	4,069.00	2,558.00

Source: "Typical Electric Bills — Cities of 50,000 Population and More", Federal Power Commission, 1956.

Based on rates in effect January 1, 1956.

[a]*Municipally-owned utilities.*

Cost of Power. Charges by Seattle City Light for various classes of electric service are given in Table 4-21. This table also gives comparable charges at Portland, San Francisco and Los Angeles.

Monthly rates in Seattle for single family residences using electricity as the sole means of cooking, water heating and lighting are $5.00 for the first 500 kwh or less, 0.7 cents per kwh for the next 2,000 kwh, and 0.9 cents per kwh for all over 2,500 kwh. During 1956, the average cost of residential power to those having the all-electric rate was slightly under 1 cent per kwh, whereas the cost under the standard residential rate was slightly over 1.5 cents per kwh. It is of interest here to note that the national average residential cost in 1956 was slightly over 2.5 cents per kwh.

Natural Gas

Use of natural gas began in 1956 with the completion of a pipeline from the San Juan Basin in Colorado and New Mexico. This new fuel is distributed locally by the Seattle Gas Company, which formerly served much of Seattle with manufactured gas. Quantities allocated to the company are adequate both for residential and for greatly expanded industrial use. It is expected that the availability of natural gas will lead to the future establishment of many new industrial plants, particularly in the industrial area of the Green-Duwamish Valley where the main transmission line is located.

FUTURE LAND USE

Land use plans serve as a general guide in locating parks, schools and highways, and in determining utility requirements. They serve also as a necessary preliminary step in setting up zones for the various classifications of residential, commercial, industrial and agricultural use.

Studies leading to the preparation and adoption of comprehensive land use plans have, since 1950, been a major activity of the Seattle, King County and Snohomish County Planning Commissions. Although adopted as an official expression of intent, these plans do not have the legal status of zoning and are subject to revision in the light of changing conditions and outlook.

Land use plans applicable to the study area (Fig. 4-11) were developed from a composite map of the entire Everett-Seattle-Tacoma metropolitan complex which was prepared by the Puget Sound Regional Planning Council. In the generalized plan here shown, local retail areas, small parks and other minor details have been omitted, and the proposed Duwamish and lower Green River industrial development has been added.

The sewerage and drainage survey is primarily concerned with two classes of use, namely, residential and local commercial, and industrial and central commercial. It is concerned also with the location of

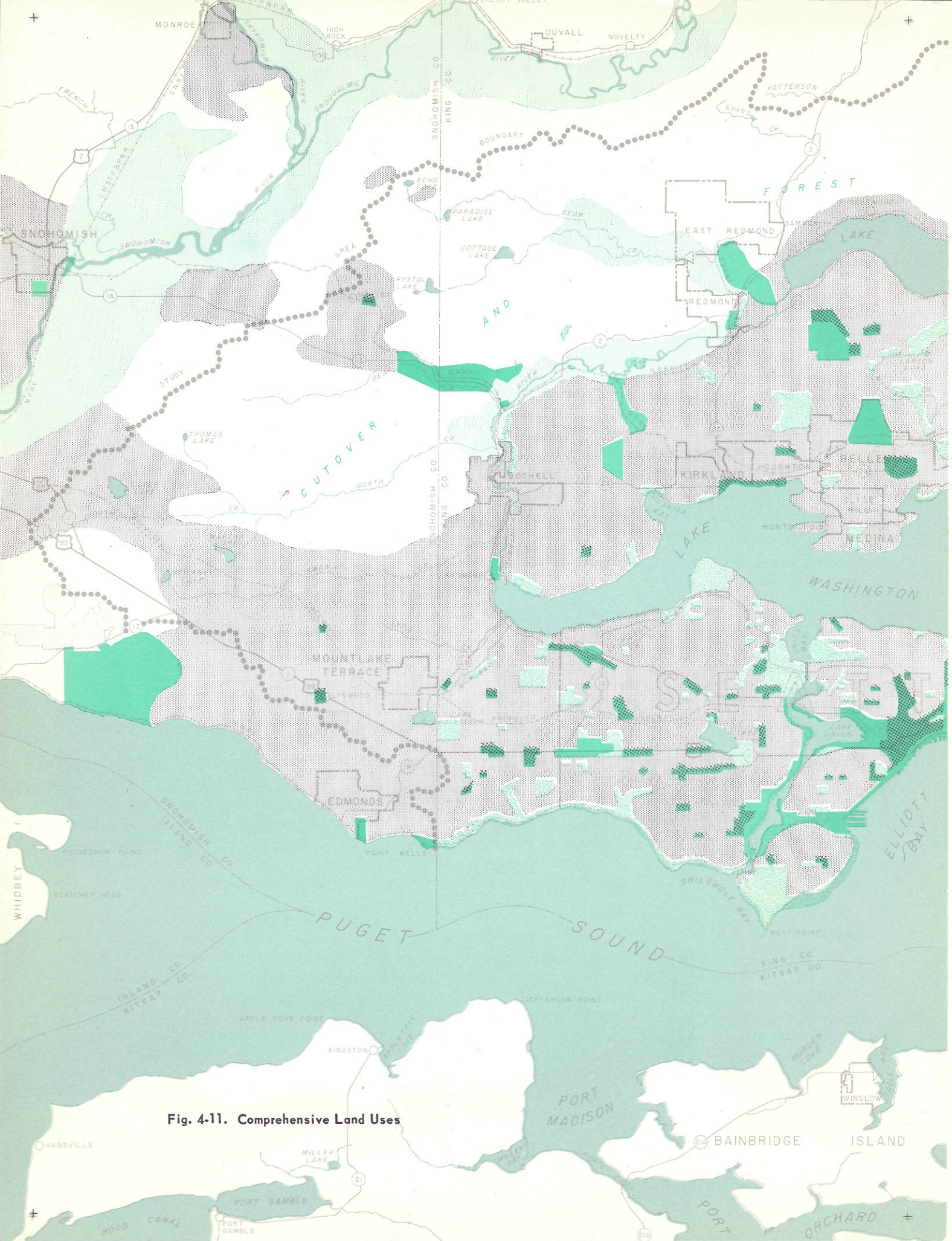
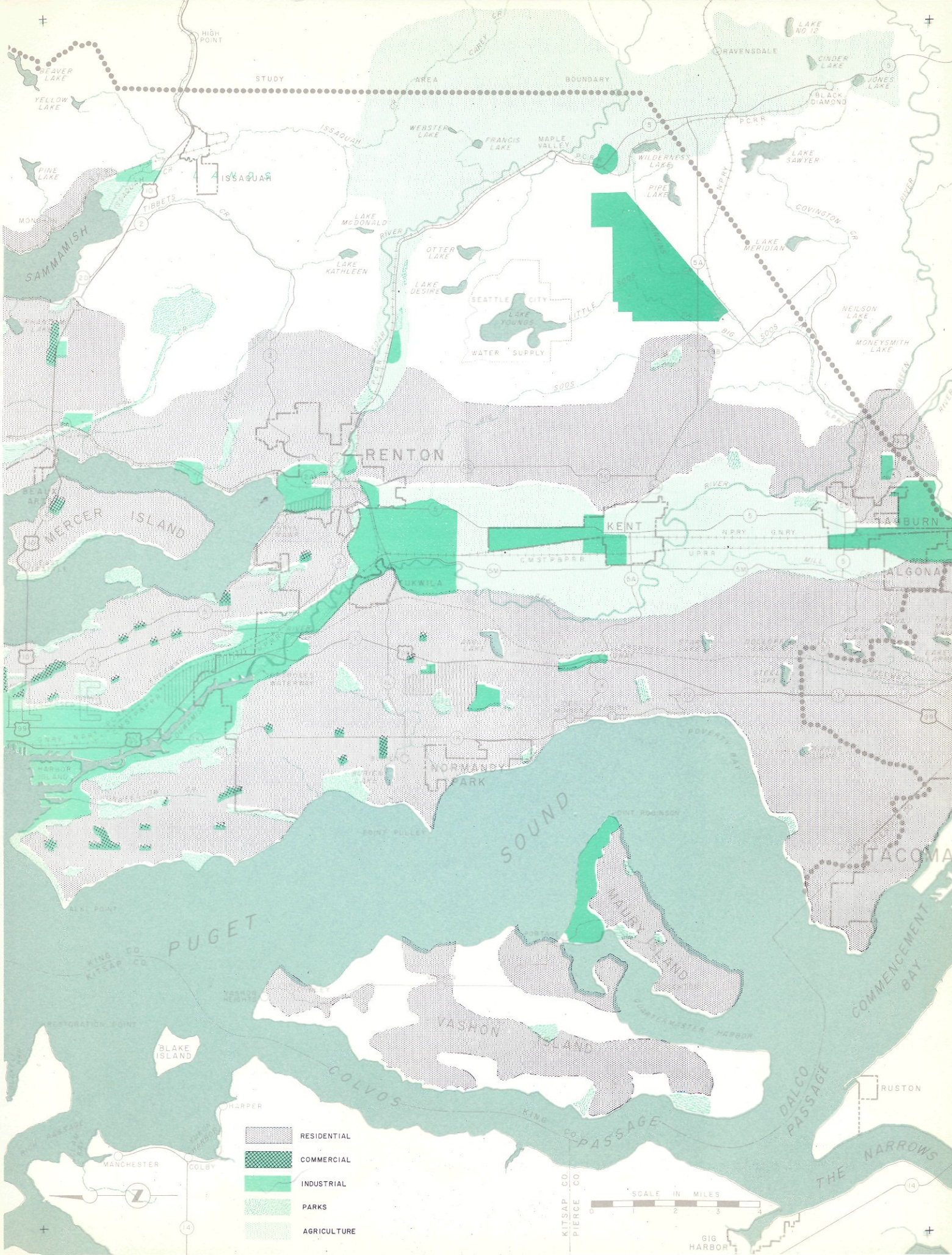


Fig. 4-11. Comprehensive Land Uses


STUDY AREA BOUNDARY
HIGH POINT
BEAVER LAKE
YELLOW LAKE
PINE LAKE
ISSAQUAH
WEBSTER LAKE
FRANCIS LAKE
MAPLE VALLEY
RAVENSDALE
LAKE NO 12
CINDER LAKE
JONES LAKE
BLACK DIAMOND
WILDERNESS LAKE
PIPE LAKE
LAKE SAWYER
COVINGTON CR
LAKE MERIDIAN
NEILSON LAKE
MONEYSMITH LAKE
LAKE MCDONALD
LAKE KATHLEEN
OTTER LAKE
LAKE DESIRE
SEATTLE CITY WATER SUPPLY
LAKE YOUNGS
SAMMAMISH
RENTON
MERCER ISLAND
KENT
AUBURN
ALGONA
TUKWILA
NORMANDY PARK
TACOMA
PUGET SOUND
VASHON ISLAND
BLAKE ISLAND
COLVOS PASSAGE
DALCO PASSAGE
COMMENCEMENT BAY
THE NARROWS
RUSTON
MANCHESTER
COLBY
GIG HARBOR
KING CO.
KITSAP CO.
PIERCE CO.
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
PARKS
AGRICULTURE
SCALE IN MILES
0 1 2 3 4

agricultural lands, parks, woodlands, and otherwise undeveloped areas. This is because the lower rates of runoff from such areas must be taken into account in the planning of drainage facilities. Similarly, plans for the development of waterfront parks and beaches must be considered in planning for the disposal of effluents from sewage treatment plants.

Residential and Local Commercial Areas

Except for minor areas of steep or unstable banks and hillsides, all land not specifically reserved for other purposes is considered to be suitable for residential purposes, including attendant schools, local shopping centers and local parks. Areas in Fig. 4-11 for which no use is defined are subject to future residential development. Presently, these areas are largely cut-over lands or second growth woodlands having soils of submarginal agricultural value.

For sewerage and drainage planning, it is necessary to anticipate both the areal extent and the population density of future residential areas. These factors are considered in the next chapter.

Industrial and Commercial Areas

In industrial and central commercial areas, the volume and composition of sewage and the amount of storm runoff are controlled generally by the type of development. This in turn involves many variables, including the nature and number of waste producing industries, the extent of building and paved areas, and employment density.

The central commercial area of downtown Seattle is now well defined. Any expansion will be at the expense of adjoining densely populated apartment house areas, and will have little if any effect on sewerage and drainage planning.

In addition to the downtown area, the term "commercial area" applies to large suburban professional and commercial office developments. Developments of the type described as "industrial park" which may include professional and commercial establishments in addition to warehouses and light industries, are considered herein as industrial areas.

Since industry is a basic factor in the economy of the metropolitan area, its expansion in proportion to the anticipated growth in population must be assumed and future land uses must be planned accordingly. In the absence, therefore, of specific information concerning the types of industries which are likely to develop during the period under consideration, it is essential that a reasonably valid projection be made of the probable location and the areal extent of industrial zones, both light and heavy.

Employment and Manufacturing. Statistics relating to manufacturing employment in King County are given in Table 4-22 and shown in Fig. 4-12. These are for an 18-year period from 1940 through June 1957 and cover total employment, total population, and population in the age group of 20 to 64 years. It will be seen that employment ranged from a minimum of 52,000 in March 1940 to a maximum of 107,000 in July 1944, and that the 20 to 64 year age group provides more than 90 per cent of the labor force. Following the end of the war, employment dropped in 1946 to the pre-war total of 52,000, after which it rose rather steadily and reached a peak of 108,700 in June 1957. For the first six months of 1957, the average was 100,000.

To explain the increase in the past year, it may be pointed out than an unprecedented peace-time increase in aircraft manufacturing employment occurred in the 12-month period July 1956 to June 1957. In that period, employment in the aircraft field rose from 42,900 to 64,000, or almost 50 per cent. During the same 12 months, all other manufacturing employment increased by only 500, while non-manufacturing employment showed a slight drop.

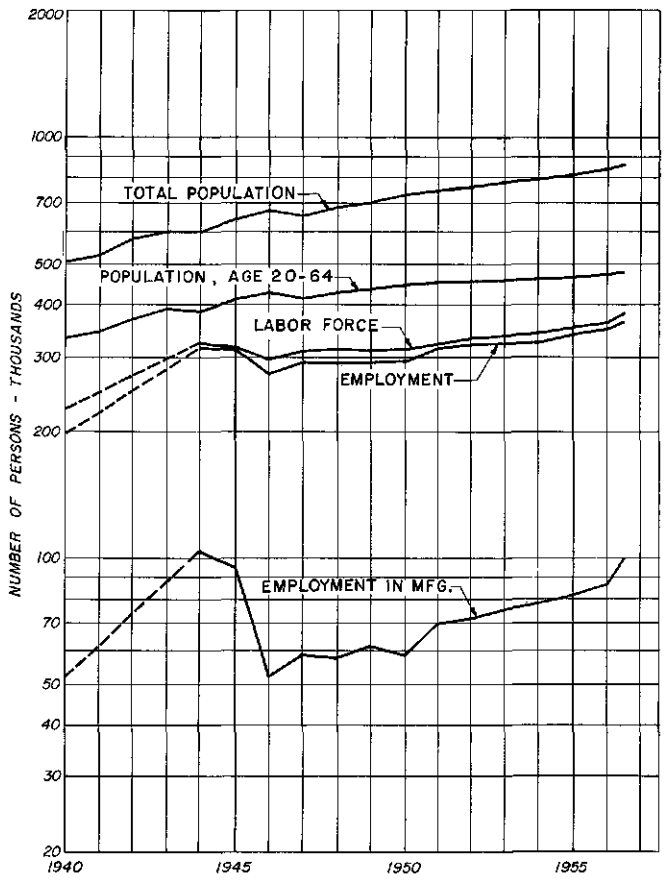


Fig. 4-12. King County Employment and Population, 1940-1957

Labor force and employment figures include nonresidents of King County who actually are employed in the county. Data for 1957 are for the first six months of the year. Data from Washington State Department of Employment Security and Seattle Planning Commission.

Table 4-22. Average Annual Labor Force and Employment in King County, 1940 - 1957

Year	Labor force, thousands	Employment,[a] thousands			Population, thousands	
		Total	All manufacturing	Aircraft manufacturing	Total	Age 20 - 64
1940	227[b]	195[b]	52[b]	6[b]	507	334
1944	324[c]	318[c]	107[c]	39[c]	600	388
1945	319[c]	313[c]	95[c]	35[c]	643	414
1946	299[c]	276[c]	52[c]	10[c]	672	430
1947	312	293	59	13	653	415
1948	314	292	58	15	685	430
1949	313	293	62	24	706	438
1950	314	296	59	20	734	449
1951	327	317	70	23	750	453
1952	335	322	72	29	764	456
1953	340	326	76	33	781	460
1954	347	328	78	37	795	462
1955	357	342	82	38	812	464
1956	367	354	87	43	841	475[e]
1957	378[d]	366[d]	100[d]	58[d]	859	480[e]

Year	Per cent of age 20-64 population				Manufacturing employment	
	Labor force	All employment	Manufacturing employment	Aircraft manufacturing employment	Per cent of all employment	Per cent of total population
1940	68	58	15.6	1.8	28	10.2
1944	84	82	27.6	10.1	34	17.8
1945	77	76	22.9	8.5	30	14.8
1946	70	64	12.1	2.3	19	7.7
1947	75	71	14.2	3.1	20	9.0
1948	73	68	13.5	3.5	20	8.4
1949	72	67	14.1	5.5	21	8.8
1950	70	66	13.1	4.5	20	8.1
1951	72	70	15.5	5.1	22	9.3
1952	73	71	15.8	6.4	22	9.5
1953	74	71	16.5	7.2	23	9.8
1954	75	71	16.9	8.0	24	9.8
1955	77	74	17.7	8.2	24	10.1
1956	77	75	18.3	9.0	25	10.4
1957	79	76	20.8	12.1	27	11.7

Sources: Washington State Employment Security Department, U.S. Bureau of the Census, and Seattle Planning Commission.

[a]*Employees within King County includes some residents of Pierce, Kitsap, and Snohomish Counties.*

[b]*As of March.*

[c]*As of July.*

[d]*Average for first 6 months of 1957 (preliminary report).*

[e]*1953 estimates of age distribution corrected for current high birth rate.*

In August of 1957, Boeing announced that cutbacks and program revisions in defense contracts would necessitate a personnel reduction of 6,000 to 8,000 by the end of 1957. Fortunately, because of the short duration of the high employment condition and because the reduction will be accomplished largely through normal attrition, the impact on the local economy is not expected to be serious. Nevertheless, this incident serves to illustrate one of the problems associated with an economy which depends heavily on a single industry.

In terms of total employment, manufacturing has accounted for 19 to 34 per cent, with 20 to 25 per cent representing the normal peace-time range. Nationally, most metropolitan areas fall within the 20 to 25 per cent range, although 23 to 25 per cent is regarded as an optimum.

Relationships between employment in King County

and both the total and the age 20 to 64 population (Table 4-22 and Fig. 4-12) are obscured by the inclusion of a considerable number of workers who reside in Pierce, Kitsap, and Snohomish Counties. This situation accounts in part for the increase of 64,000 in the labor force between 1950 and 1957, as compared to only 31,000 in the 20 to 64 age group.

Total employment in King County, expressed as a percentage of its population, has been relatively constant since 1948, ranging from 40.3 per cent to 42.8 per cent. In the absence, however, of adequate employment statistics for the Central Puget Sound Region, it can be assumed that the ratio of employment to the total population supported by that employment has declined. This condition is general throughout the country and is due to a decline in the 20 to 64 age group proportion of the total. In King County, the decline was from 66.7 per cent in 1940 to 57.8 per cent in 1955. As stated in the next chapter, this trend is expected to be reversed after 1960.

For the purposes of this report, it is assumed that 60 per cent of the population will be in the age 20 to 64 group, that 65 per cent of these will be gainfully employed, and that employment in manufacturing will not normally exceed 23 per cent of total employment. On that basis, 9 per cent of the population will be employed in manufacturing.

For a projected population of 2,240,000 by the year 2030 (Chapter 5), the corresponding total in manufacturing will be about 200,000.

Areal Extent of Industrial Zones. Land requirements for manufacturing industries differ for various types of operations. Heavy industries such as petroleum refining, steel rolling and fabrication, and the manufacturing of chemicals, paper, and wood products may require one acre for every 2 to 20 employees. Lighter industries, such as aircraft, machine parts, electronic equipment, textile, garment, and food products may have up to 300 employees per acre. These are net manufacturing densities and are based on the actual plant area plus areas required for landscaping, off street parking and loading, interior plant roads and sidings, and open storage. Vacant lands held for plant expansion are not included. Gross industrial density, on the other hand, is determined by dividing manufacturing employment by net manufacturing area plus all vacant land, roads, railroad rights-of-way, and the land occupied by industrial service industries such as repair shops, warehouses, scrap yards, machinery sales and service, trucking concerns, and shipping terminals.

Table 4-23. Summary of Employee Density Study of Recent Manufacturing Industries, Duwamish Industrial District

	Group A[a]	Group B[b]	Group C[c]
Number of manufacturing plants	21	10	7
Net manufacturing area, acres	61.1	51.9	158.8
Number of employees	1,481	1,234	1,561
Net manufacturing density, employees per acre			
Weighted average	24.3	23.8	9.8
Maximum	43.5	43.5	23.2
Minimum	5.5	12.5	2.6

[a]*All new industrial plants constructed in Duwamish industrial district between June 1950 and February 1954.*

[b]*Sample of Group A selected for detailed study.*

[c]*Selected industries, constructed between 1930 and 1954, having adequate off-street parking and of types likely to become established in proposed Duwamish Port Industrial District. Includes proposed foundry in Issaquah expected to require 100 acres.*

Source: Knappen-Tippetts-Abbett-McCarthy, "Development Plan for Duwamish and Lower Green River Valley", 1954.

Land uses in the Duwamish industrial district presently are equally divided between manufacturing and service industries. Based on a detailed study of this area, consultants to the Duwamish and Green River Joint Survey Board[4] report a net manufacturing density of 20 employees per acre and a gross industrial density of 9.5 per acre. These figures exclude the aircraft industry, which at Seattle had a net density of 300 per acre in 1957.

In the case of new establishments, the present trend in both light and heavy industries is toward lower employee densities. Automation, the provision of adequate off-street parking space and loading facilities, and the demand for a pleasant working environment all contribute to this trend. For example, it is assumed[4] that the proposed port development district will have a net manufacturing density of 9.8 employees per acre and a gross industrial district density of 3.5 per acre. These figures are based on a summary of a study of newer industries in the Duwamish Valley (Table 4-23) and provide the following land uses:

	Per cent
Net manufacturing	35
Net service industries	18
Vacant, for future expansion	20
Roads and highways	16
Railroads	9
Utilities and others	2

In the aforementioned study, a gross industrial density of 9.5 is assumed for vacant land within present industrial areas, while a gross density of 3.5 is assumed for dispersed sites. It should be noted, however, that the port development study was concerned primarily with heavy industry and that the projections

[4]*Knappen-Tippetts-Abbett-McCarthy,* Development Plan for the Duwamish and Lower Green River Valley, *1954.*

were limited to 1970, by which time only scattered development of dispersed sites is expected.

For purposes of the sewerage and drainage study, it is believed that a value of 8.0 for the average gross density of all industrial areas by the year 2030 is a reasonable assumption. It is expected that the low value of 3.5 for the Duwamish-Lower Green River project will be offset by the following conditions at other locations.

1. The extremely high density of the aircraft industry.
2. The generally higher density of other light industries.
3. The probable lower ratio of service industries at dispersed sites.
4. The inclusion in the Duwamish district of the principal railroad terminal yards and port terminal facilities.

On the basis of 8.0 persons per gross industrial acre and 200,000 employed in manufacturing, the total industrial area required to serve the projected future population within the study area is 25,000 acres.

Location of Industrial Acres. Locations of present and projected industrial zones within the study area are shown on the land use map (Fig. 4-11). These zones are essentially as depicted in the composite land use plan of the Puget Sound Regional Planning Conference. The principal exception is the industrial area shown in the lower Green River valley south to South 180th Street.

In considering the location of industrial areas, it should be noted that urban planners everywhere are concerned over the high rate at which prime agricultural lands within and adjacent to metropolitan communities are being diverted to other purposes. To avoid this economic loss and the consequent impact on food costs, particularly truck produce, there is a strong movement among planners to preserve as much of the best agricultural land as is reasonably possible.

Locally, the Duwamish-Green-Puyallup valley between Tacoma and Seattle comprises the best agricultural land of the two counties. Since, however, level terrain is the most economical to develop for both industrial and residential purposes, agriculture throughout the valley is being gradually replaced. Eventual extinction can be prevented only through strict zoning by the counties and continued adherence to such zoning in areas annexed to valley cities. Yet economic and political forces arrayed against complete and continued agricultural zoning are of such magnitude that total exclusion of industry on a permanent basis cannot be expected. It is believed, therefore, that the development indicated in Fig. 4-11 represents a reasonable compromise.

In general, the dispersed industrial sites (Fig. 4-11) follow the recommendations of a joint study in 1951 by the King County and Seattle Planning Commission and the Seattle Chamber of Commerce. The extensive heavy industrial area east of Kent, known as the Covington site, will probably develop only if industrialization of the Green River valley is restricted as indicated on the map.

The total area of the industrial zones, both existing and projected, is 24,800 acres. This is adequate for the predicted future population of the study area.

Chapter 5
POPULATION

In the growth of any metropolitan area, the gradual change of land use from rural to urban residential, commercial, and industrial brings with it an inevitable demand for adequate sewerage and storm drainage service. For planning purposes it is essential that the magnitude and extent of this demand be anticipated. Sewage characteristics, both as to quality and strength, are directly related to the size of the contributory population and its sustaining industries. The extent of drainage and sewage collection systems, as well as the location and size of principal trunk and intercepting sewers, pumping stations and treatment and disposal works are affected by the areal distribution of the population.

The long useful life of sewerage and storm drainage facilities, coupled with the relative economy of large conduits as opposed to a multiplicity of smaller conduits, necessitates forecasts of population growth much farther into the future than is normally desirable. For example, local collection drains and sewers are commonly designed for ultimate or saturation development of the area they serve. And similarly, trunk and interceptor drains and sewers are usually designed to meet the demands which will be imposed on them 50 or more years in the future.

Projections of population growth and distribution are required also for the purposes of determining when specific facilities are likely to be needed and of formulating an orderly program of stage construction and financing. The ultimate success, therefore, of any storm drainage or sewerage plan depends upon a searching analysis of the many controlling factors or conditions which affect population growth and urban development.

FACTORS AFFECTING POPULATION GROWTH

Factors involved in projecting population growth of a metropolitan area include:

1. General population trends.
2. Birth and death rate trends.
3. National state migration patterns.
4. Industrial and commercial opportunities.
5. Availability and economy of power, water, fuel, and transportation.
6. Availability of areas suitable for residential and industrial expansion.
7. Desirability of living conditions as reflected by climate, recreational and educational facilities, and social environment.

Each of these factors is to be evaluated in the light of past and present experience. In view, however, of the fact that population growth is subject to the influence of unpredictable future events, all projections referenced to specific years must be regarded at best as probable rather than precise.

General Population Trends

More than 15 years of economic prosperity in the United States have brought about an unexpected upsurge in the national population. As of July 1, 1957, the official estimate was 171 million, representing an increase of more than 13 per cent since 1950. Estimates of growth to the year 1975, made in 1953 by the U. S. Bureau of the Census, were revised upward in 1955 because of continuing high birth rate. If the present trend continues, the expected totals are 228

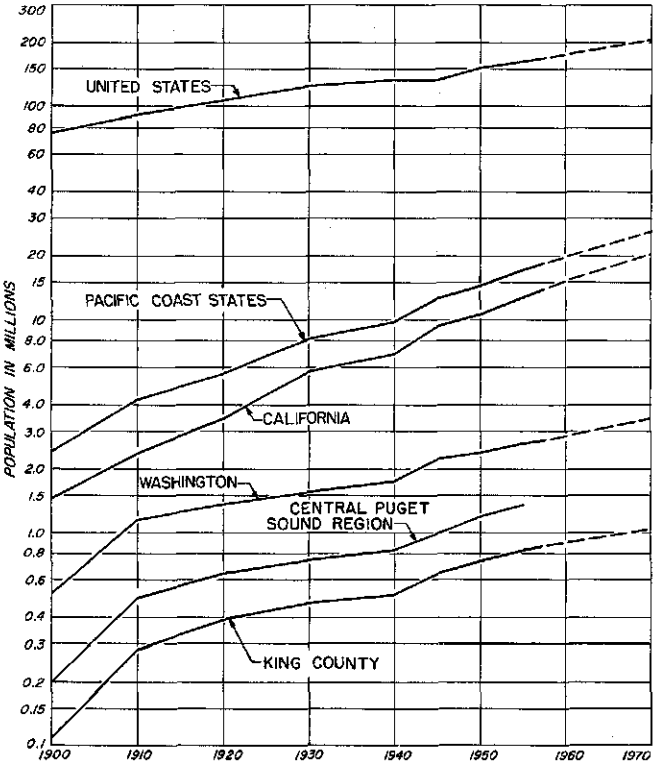


Fig. 5-1. General Population Trends, 1900-1970

For the semi-logarithmic plotting here employed, equal slopes show equal rates of growth, regardless of numerical increase. Since 1910 Washington and the Central Puget Sound Region have grown at a rate intermediate to that of the United States and the three Pacific Coast states. See Table 5-1 for tabulated values and data sources.

million by 1975, 300 million by 1990, and 400 million by 2010. Even if birth rates were to decline by 1975 to the low prewar level, the expected population in that year would be 207 million and would climb to about 300 million in 50 years. In other words, within the design period to be considered in this report, total population of the United States will be at least two times, and possibly three times greater than it was in 1950.

An accelerated rate of urbanization is revealed by recent population statistics. In the period from 1950 to 1955, the standard metropolitan areas of the country, of which there are 168 according to the U.S. Bureau of the Census, had a population increase of over 11.6 million as compared with an increase of 12 million for the country as a whole. Growth of the metropolitan areas is due not only to natural increase but to migration from rural areas and smaller communities. It is apparent, therefore, that the growth of Seattle and its environs is not a local phenomenon but is characteristic of a nation-wide metropolitan trend.

As a result of westward migration, the population of the Pacific Coast states (Fig. 5-1 and Table 5-1)

Table 5-1. Past Populations and Current Projections to 1970

Year	United States		Pacific States		California		Washington	
	Population 1,000	per cent increase	Population 1,000	per cent increase	Population 1,000	per cent increase	Population 1,000	per cent increase
1880	50,156		1,115		865		75	
1890	62,948	25.4	1,888	69.0	1,213	40.5	357	376.
1900	75,995	20.7	2,417	28.0	1,485	22.4	518	45.0
1910	91,972	21.0	4,192	73.5	2,378	60.1	1,142	120.
1920	105,711	14.9	5,567	32.8	3,427	44.1	1,357	18.8
1930	122,775	16.1	8,194	47.2	5,677	65.7	1,563	15.2
1940	131,669	7.2	9,733	18.8	6,907	21.7	1,736	11.1
1945	132,481[a]		12,800[a]		9,344[a]		2,206[a]	
1950	151,132	14.5	14,487	48.8	10,586	53.3	2,379	37.0
1955	165,270[b]		17,253[b]		12,961[b]		2,607[b]	
1957	171,229[b]						2,667[b]	
1960	179,375[c]	18.7	19,986[c]	38.0	15,273[c]	44.3	2,849[c]	19.8
1965	193,491[c]		22,851[c]		17,661[c]		3,123[c]	
1970	209,242[c]	16.7	26,071[c]	30.5	20,296[c]	32.9	3,459[c]	21.4

Year	Central Puget Sound Region[d]		King County		Snohomish County		Seattle	
1880			7					
1890			64	826.			43	
1900	196		110	72.	24		81	88.3
1910	482	146.	285	159.	59	146.	237	193.
1920	634	31.6	389	36.8	68	15.	315	32.9
1930	737	16.3	464	19.1	79	16.	366	16.2
1940	820	11.3	505	8.9	89	13.	368	0.5
1945			643[e]				431[e]	
1950	1,196	45.9	733	45.2	112	26.	468	27.2
1955	1,329		812[e]		131		550[e]	
1957			859[e]				572[e]	
1960			892[e]	21.7	145[f]	30.	579[g]	23.8
1965			953[e]		158[f]		597	
1970			1,018[e]	14.1			609[g]	5.2

Source: U.S. Decenial Census except as noted.

[a]*Statistical Abstract of the United States, 1956.*

[b]*Current estimates of U.S. Bureau of the Census. Estimate for U.S. includes armed forces overseas.*

[c]*U.S. Bureau of the Census, Current Population Reports, Page 25, No. 160. Based on Series 1 illustrative projections, plus allowance (for U.S. projections) for armed forces overseas equal to number overseas in 1957.*

[d]*Snohomish, Kitsap, King, and Pierce Counties.*

[e]*Seattle Planning Commission.*

[f]*Snohomish County Planning Commission, 1954.*

[g]*Seattle Planning Commission, CPR No. 14, rev. May 1956 and adjusted to 1956 city limit.*

Table 5-2. Average Rates of Population Growth, 1910 - 1955

Area	Average annual rate of growth, per cent	Years required to double the population
United States	1.30	54
Washington	1.85	38
United States urban areas	2.12	33
King County	2.36	30
Pacific Coast states	3.20	22
California	3.83	18

has grown, historically, at a faster rate than that of the nation. Although most of this growth has occurred in California, the rate of population increase in Washington has been greater, quite consistently, than that of the United States. Average annual rates of growth since 1910 (Table 5-2) show further that King County has grown slightly faster than the average for all urban areas in the country. For the population to double itself, the time ranges from 54 years for the United States as a whole to 18 years for California. Washington at 38 years and King County at 30 years lie about half-way between these extremes.

The Seattle metropolitan area merges on the south with that of Tacoma and on the north with that of Everett. Bremerton, across Puget Sound to the west, is linked economically with Seattle and will be tied more closely following completion of the planned construction of a bridge across the sound. The four counties of Snohomish, King, Kitsap and Pierce, therefore, form an economic unit which has been termed the Central Puget Sound Region. Population growth of this region, as shown in Table 5-1, has paralleled that of King County.

Since 1910, Seattle has grown at a slower rate than the county. Moreover, the actual numerical gain within the city since 1930 has been less than that outside the city. Population trends since 1950 are shown in Table 5-3 for those portions of King and Snohomish counties, both incorporated and unincorporated, which lie within the sewerage and drainage study area. Of the total of 864,000 estimated to reside within the study area in 1957, 640,000 live in 19 incorporated cities and towns. Changes in population between 1950 and 1957 reflect the effect not only of numerical growth but of incorporation and annexation. The latter, of course, lead to increases in the incorporated areas at the expense of the unincorporated areas.

Annual estimates of population growth of Seattle and the principal suburban areas within King County, as developed by the Seattle Planning Commission for each census tract, show relative changes between the central city as constituted April 1, 1954 and the major suburban divisions. Based largely on data obtained from residential building permits, these studies reveal that the total population increase of 126,000 in King County from 1950 to 1957 consists of 46,000 within Seattle as constituted in April 1954, 66,000 in suburban areas, and 14,000 in other parts of the county. Although the largest numerical increase, 27,000, occurred in suburbs to the south of the city, the rate of growth has been greatest in the areas north of the city and east of Lake Washington.

Birth and Death Rate Trends

Changing economic conditions and social attitudes bring about changes in birth rate which drastically affect the natural increase in population. Based upon the low birth rate in the 1930-40 decade, Thompson

Table 5-3. Population of Political Divisions within the Sewerage and Drainage Study Area

Political division	1950[a]	1957[b]
Within King County		
Seattle	519,664	572,000
Algona	c	1,303
Auburn	6,497	7,900
Beaux Arts	c	325
Bellevue	c	10,500
Bothell	1,019	1,446
Clyde Hill	c	1,654
East Redmond	c	516
Houghton	1,005	2,050
Hunts Point	c	365
Issaquah	955	1,196
Kent	3,278	4,150
Kirkland	4,713	5,550
Medina	c	2,213
Normandy Park	c	2,991
Redmond	573	1,005
Renton	16,039	16,900
Tukwila	800	1,022
Subtotal, incorporated	554,543	633,000[d]
Unincorporated areas	151,000[e]	197,000
Subtotal, study area in King County	706,000[d]	830,000
Within Snohomish County		
Mountlake Terrace	c	7,381
Unincorporated areas	15,000[e]	27,000
Subtotal, study area in Snohomish County	15,000	34,000
Total	721,000	864,000

[a] *U.S. Bureau of the Census, except as noted.*

[b] *Incorporated areas as estimated by Washington State Census Board. Unincorporated areas as estimated by Seattle and King County Planning Commissions and Snohomish County Planning Commission staff.*

[c] *Incorporated since April 1950.*

[d] *Rounded to nearest 1,000.*

[e] *Estimate from census data. In King County this includes 60,000 persons in areas subsequently annexed to City of Seattle.*

and Whelpton[1], in 1942, estimated that the population of the United States would reach a maximum of 160 million by 1990 and that it would decline thereafter. Due, however, to a subsequent upsurge in birth rate, the figure of 160 million was actually reached in 1954. On the other hand, the death rate is relatively stable and can be projected with greater confidence. Trends in the two rates, birth and death, are portrayed in Fig. 5-2 for King County and Washington. Differences between the two sets of curves represent the rate of natural increase, which, in King County, has ranged from minus 0.1 per 1,000 population in 1936 to 17.6 in 1947. Numerically, the natural increase in county population in the 1930-40 decade was only 6,300 as compared with 76,300 during the 1940-50 decade.

Crude birth and death rates, which are those expressed as the number per year per thousand of population, are affected by the age and sex composition of that population. For the curves in Fig. 5-2, the age factor accounts for the generally rising death rate between 1920 and 1936 and in part for its decline since that time. In making population studies, the specific rates of fertility and mortality for each five-year age group provide more reliable bases for estimation of growth than the so-called crude rates.

Because of the low birth rate during the 1930-40 depression years, the percentage of the population now in the age range of 18 to 27 years, which is the most productive, is abnormally low. For that reason, a marked decline in the crude birth rate between 1955 and 1960 has been anticipated. That such a decline has not occurred, or at most has been slight, results from an offsetting increase in the fertility (or more properly, reproductivity) rate for this age range. Significant also is the fact that specific fertility figures (Table 5-4) show a considerably higher rate for Washington than for the nation as a whole. For the years since 1950, this difference may be due in part to an underestimation of the state population, particularly of the increase due to inmigration of people of childbearing age. In any case, the relatively high income now being earned by the younger groups has resulted in marriage and the raising of families at an earlier age than has heretofore been economically practicable.

The current high rate of reproduction is evidenced not only in the younger age groups but to a lesser degree through age 44. Vital statistics reports show a definite trend toward more families of three or four children and a reduction in the number both of small families and very large families. In Washington in 1955, 90 per cent of all births, by order of child in the family, occurred in the first to fourth child group, and the births of second children slightly exceeded those of first children. This trend is evident in all income groups and, coupled with the movement to single-family suburban homes, is the fulfillment of

[1] *Thompson, W. S. and Whelpton, P. K.,* Estimates of Future Population of the United States, 1940 - 2000, *Scripps Foundation for Population Research.*

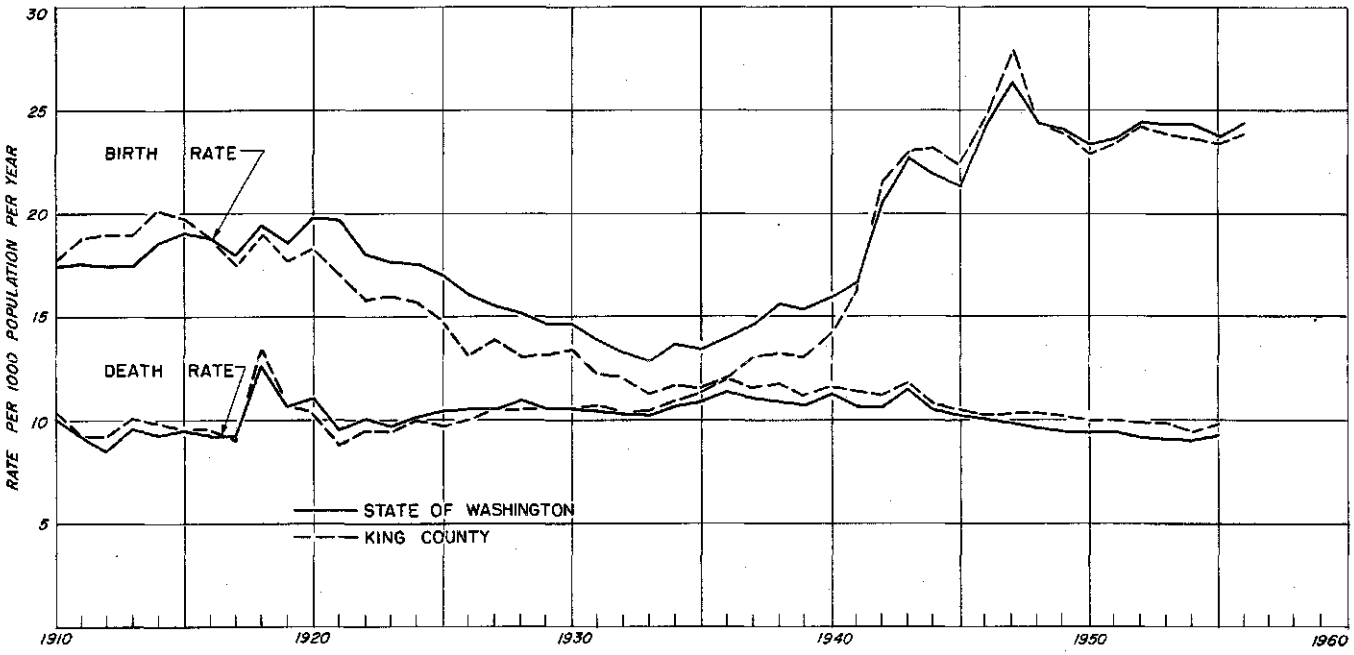


Fig. 5-2. Birth and Death Rates, Washington and King County, 1910-1956

Live birth rates shown have not been adjusted for under-registration. All rates are by place of occurrence for years 1910-1933 and by place of residence since 1933, Natural increase, which is the difference between births and deaths, is greatly affected by changes in birth rate. Sources: Vital Statistics,Summary, Washington State Department of Health; Seattle Planning Commission.

Table 5-4. Specific Age-Fertility Rates for the State and Nation, 1940 - 1956

Year	Annual births per 1,000 women by age of mother							
	Under 15	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 and over
Washington[a]								
1940	b	39	131	125	69	31	9	0.9
1950	b	88	211	164	110	46	13	0.7
1954	0.3	95	268	195	112	53	14	0.8
1955	0.3	93	277	196	110	53	14	0.7
1956	0.3	100	284	204	112	56	15	0.9
United States[c]								
1940	0.7	54	136	123	83	46	16	1.9
1950	1.0	82	197	166	104	53	15	1.2
1952	0.9	85	218	180	113	56	15	1.2
1954	1.0	90	236	188	116	59	16	1.1

[a]*From vital statistics reports, Washington State Department of Health. Values for 1954 - 56 are based on age distribution of female population interpolated from Table 5, Series M3, First Revision of Population Forecasts, Washington State Census Board, January 1956.*

[b]*Included with births to 15-19 year group.*

[c]*From Statistical Abstract of the United States, 1956.*

a long-held ideal of American family life. The current birth rate, therefore, instead of reflecting a postwar reaction of limited duration, may well prevail as long as economic conditions continue to be favorable.

Change in age composition of the population of Washington, resulting largely from the decline and subsequent rise in birth rate, is illustrated by five age distribution graphs in Fig. 5-3. Forward movement of the trough created by the "depression crop" of 1930-40 children is evident in the 15 to 24 year age groups in the graph for 1955. Despite the present high fertility rates of these groups, their numerical disadvantage is expected to result in the secondary trough seen in the graphs for 1965 and 1975. By 1975, the 1945-55 "bumper crop" will be in the period of greatest fertility and may, under favorable economic and social conditions, create the secondary wave of children evident at the left of the graph. In all cases, of course, the projected patterns are subject to many influences, including migration to and from the state.

Migratory Trends

Along with fertility, migration both into and out of a state or community is a major factor in population growth. It is a factor which is difficult to predict, however, because such movements are markedly affected both by local and by national economic conditions. Historically, the growth of Washington has been due largely to migration. Census data show that as of 1950, 42 per cent of the population was native to the state, 50 per cent was born in other states, and 8 per cent was foreign-born.

Fig. 5-4 shows the states of origin of the 1,164,660 persons who had moved to and resided in Washington in 1950. Of these, 613,255 came from the north central states, while 128,420 came from Oregon and California. In contrast, 349,585 natives of Washington resided in other states in 1950. Of this group, however, 212,390 had moved to Oregon and California, representing a net loss to those states of 83,980.

In 1950, the ratio in Washington of American-born inmigrants to outmigrants was 3.3 to 1. Excluding the inter-Pacific state migration, the ratio was 7.5 to 1. Similar data for the census years 1920, 1900, and 1880, also depicted in Fig. 5-4, show the earlier migration pattern and its expansion over the 70-year period.

Whereas the data in Fig. 5-4 reflect the effect of all migration prior to the years indicated, Fig. 5-5 shows that which occurred in two specific periods, 1935 to 1940 and 1940 to 1950. During 1935 to 1940, net inmigration was 16,070 per year and the ratio of inmigration to outmigration was 1.75 to 1. In 1949 to 1950, net inmigration had declined to 2,260 and the ratio was only 1.06 to 1.

Estimates by the Washington State Census Board of net inmigration, based on vital statistics reports and on estimates of population for intercensal years, are presented in Table 5-5. The great influx which occurred during World War II is estimated to have reached a peak of about 128,000 in 1942. This influx centered on the Puget Sound area and was brought about by shipbuilding, aircraft construction, shipping, and military training activities. In 1946, return to a peacetime economy which could not immediately support the new populace resulted in outmigration of an estimated 87,000 persons. During the remainder of the decade, inmigration again took place.

In both the state and King County, and for each decade prior to 1950, population increases from mi-

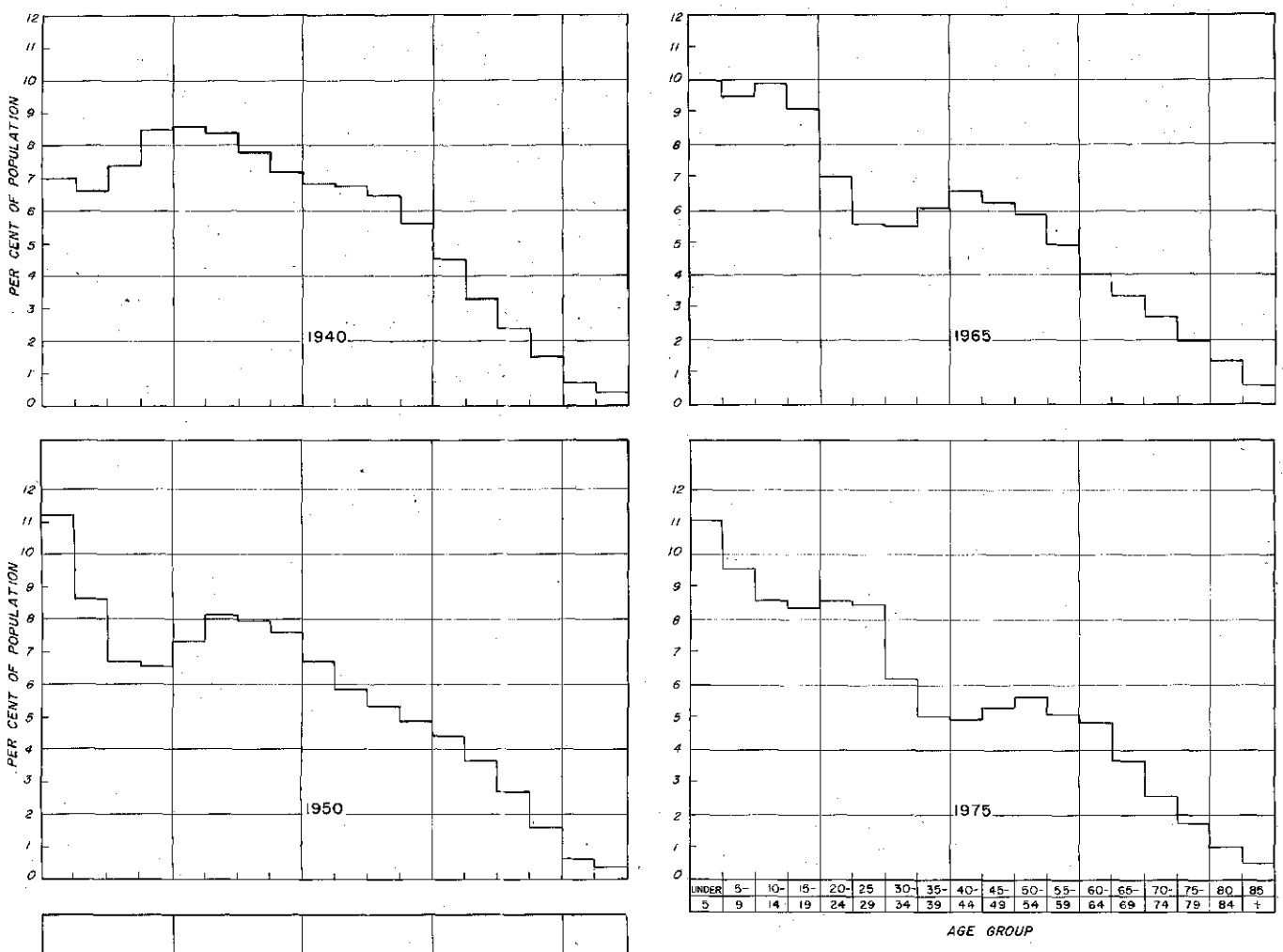


Fig. 5-3. Past and Projected Age Composition of Population, State of Washington, 1940 - 1975

Note forward movement of wave troughs and crests caused by changes in birth rate. Sources: U.S. Bureau of the Census and Washington State Census Board.

gration exceeded substantially those attributable to the birth rate. According to current population estimates and birth and mortality reports, average net annual inmigration to the state was about 9,000 persons per year from 1950 to 1956 inclusive. Inmigration to King County during the same period averaged about 6,000 persons per year. While both figures are subject to considerable error, they are numerically far less than the natural increase for the same periods (Fig. 5-6).

Actually the turning point in the inmigration and natural increase relationship occurred in 1946. Its continuation since then is attributable to enlarged population and high birth rate, as well as to cessation of wartime migration. Net migration to Washington since 1950, though substantial, is but a small fraction of the total westward migration, which is continuing at a rate of about 370,000 persons per year.

In the future, migration to Washington is expected to be an important but not predominant factor in population growth. Providing economic conditions are favorable, it appears likely that migration to the northwest in general and to the Puget Sound Region in particular will increase substantially over that of the current decade. This outlook is based on consideration of such factors as anticipated growth of the whole country, historic and undiminished westward movement, and eventual limitations to growth in California and the southwest imposed by available water supplies.

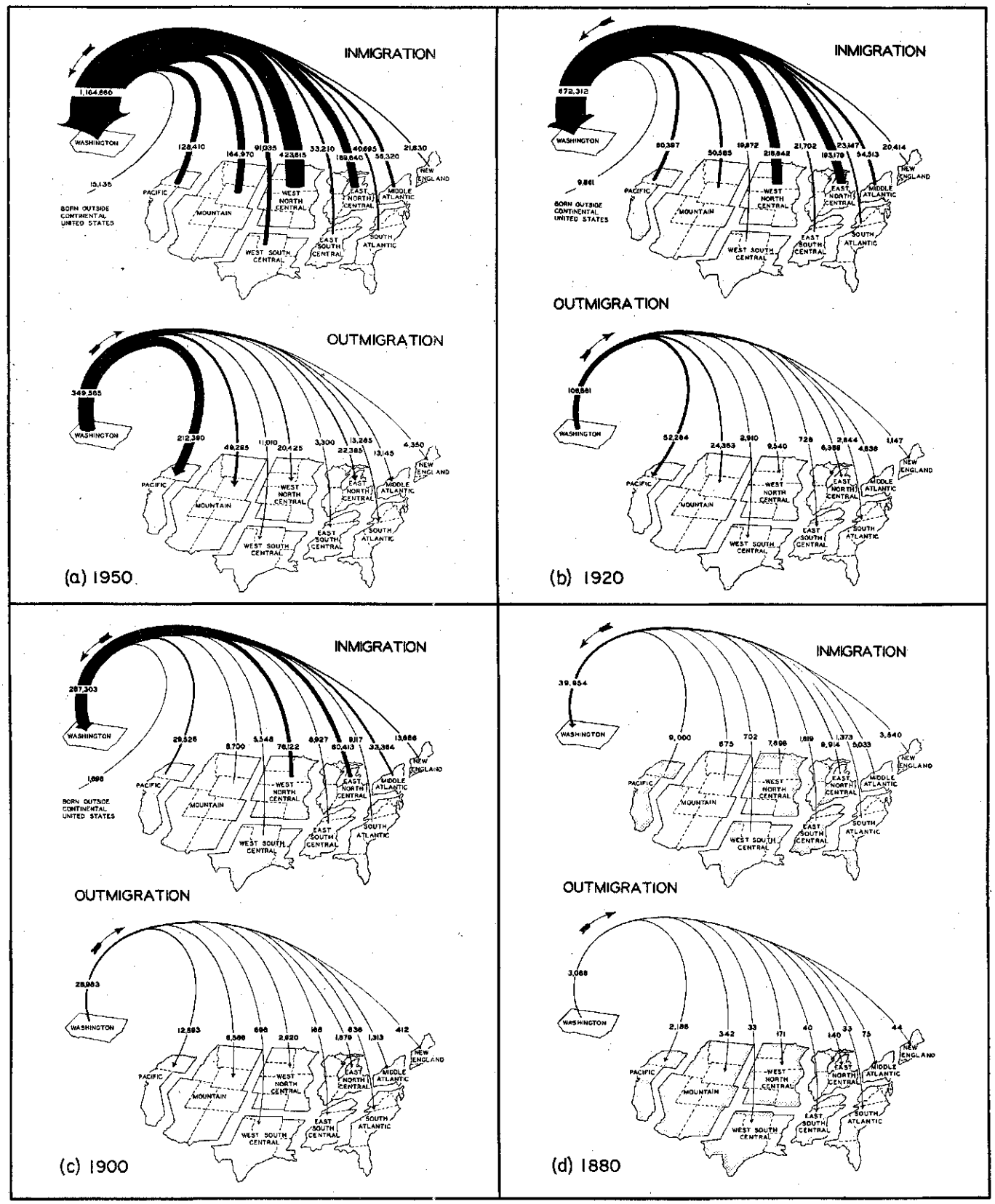


Fig. 5-4. Migration Patterns, State of Washington, 1880 - 1950

Each figure shows the number of native Americans born in other states but residing in Washington in the year shown, and the number born in Washington but residing in other states. Reproduced from *Population Growth and Distribution, State of Washington*, Washington State Census Board, 1955.

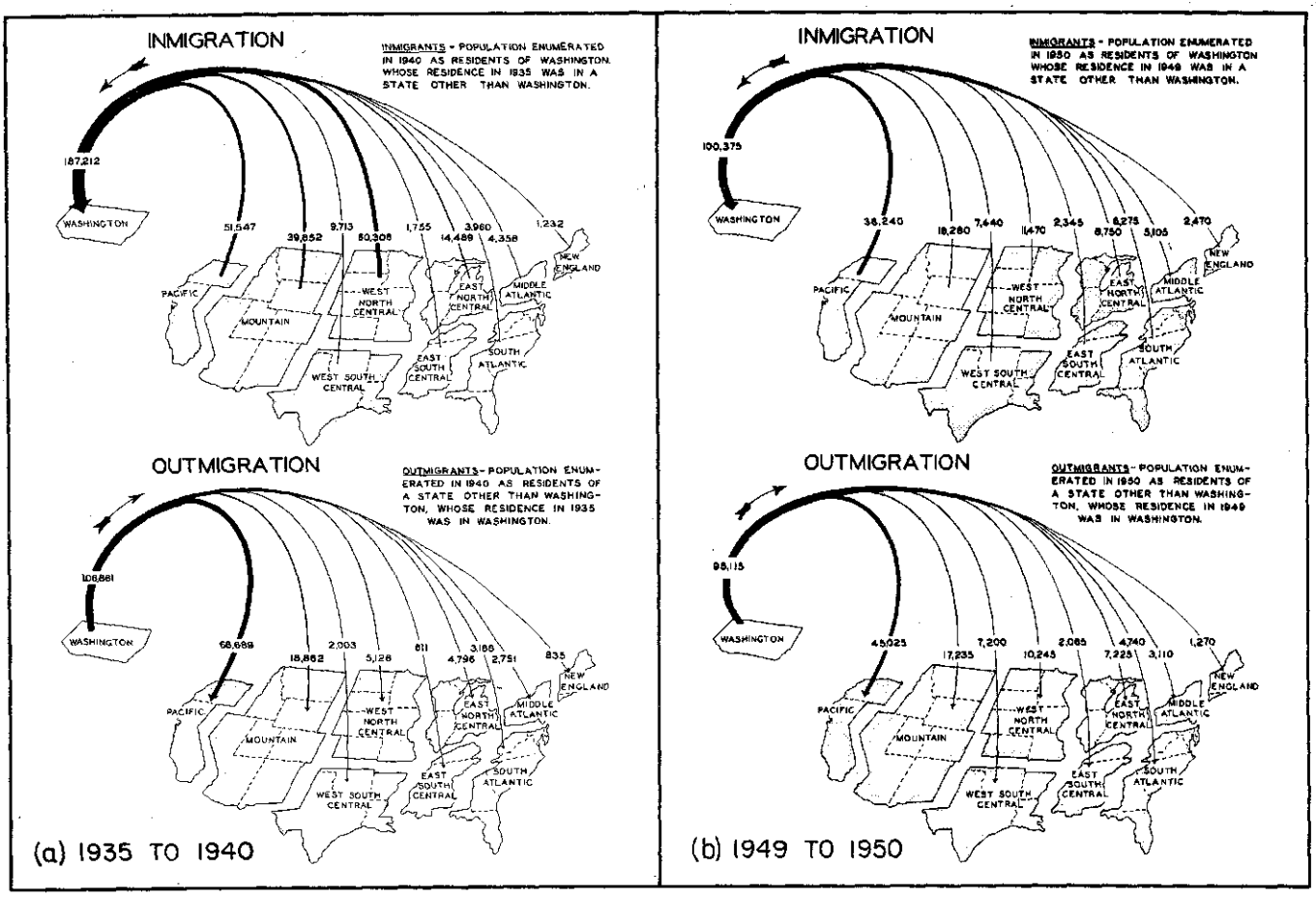


Fig. 5-5. Migration to and from Washington, 1935-1939 and 1949-1950

Each figure shows the migration which occurred during the stated period. Source: *Population Growth and Distribution, State of Washington,* Washington Census Board, 1955.

Industrial and Commercial Opportunities

In the final analysis, future population growth of the metropolitan Seattle area will depend largely upon the opportunity for gainful employment. As evidenced during and immediately after World War II, employment prospects have had an immediate effect on migration to and from the state and the metropolitan area.

Despite the rise in population, there has been an actual decline since 1950 in the number of persons in the 20 to 29 year age group. This has occurred both in the state and in King County, and has been reflected in the number of young persons entering the labor market each year. By 1960, the "wartime crop" will begin to enter the labor market and will reverse the current trend with respect to the proportion of the population in the working-age group. In the event employment opportunities do not match this forthcoming addition to the labor force, population growth due to inmigration would cease and would probably be followed by a period of net outmigration.

As the northwest continues to grow in population, it will support in larger measure the local manufacture of both industrial and consumer goods for the regional market and, in turn, will become less dependent on its forest products and other natural resources. In King County, a broader industrial base will stabilize an economy which now depends too heavily on the aircraft industry. Fortunately, diversified industrial expansion has been taking place in the Puget Sound region and in King County at a slow but apparently increasing pace.

Table 5-5. Estimated Annual Net Migration to Washington, 1910-1949

Period	Average annual net migration
1910-1919	11,500
1920-1929	10,200
1930-1934	6,500
1935-1939	16,000
1940-1949	40,000

Source: Schmid, C. F., Kalbach, W. E., and Miller, V. A., Population and School Enrollment Trends and Forecasts, Washington State Census Board.

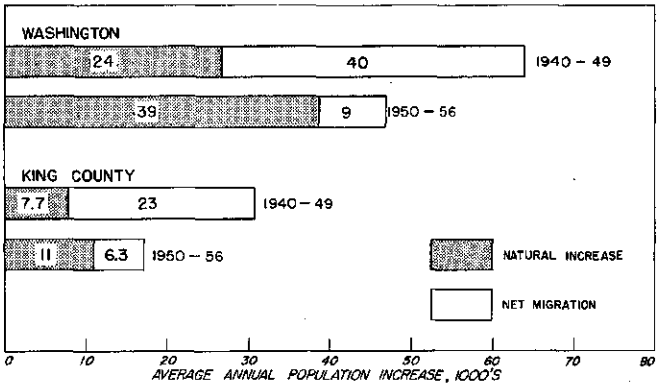


Fig. 5-6. Net Inmigration and Natural Increase Washington and King County, 1940-1956

Inmigration has been the predominant factor in population growth in each decade prior to 1950, whereas natural increase now predominates. The reversal in trend occurred about 1946. Source: U. S. Bureau of the Census, Vital Statistics Summary, Washington State Department of Health; and Seattle Planning Commission.

Utilities and Transportation

The availability of power, water, and fuel in the central Puget Sound region, and the cost thereof compared to other parts of the country, have been discussed in Chapter 4. With the current fuel supply improvement brought about by importation of natural gas, with a continuation of the vigorous program for maintaining an adequate and economical power supply, and with judicious use of its water supply potential, the region can continue to offer industry advantages in utility service. With respect to transportation, the necessity for long hauls is a deterrent to industrial production for the national market. This situation is offset, however, by the favorable location of Puget Sound as harbor for transpacific commerce. Eventual improvement in far-east political and economic conditions would broaden the opportunities for further industrial development.

Physical and Social Environment

The ample availability of suitable sites for industrial and residential development has been described in the preceding chapter. No permanent limitations exist with respect to areas suitable for residential expansion. In the case of industry, however, competition within the region for new industries will tend to limit development to areas which are situated favorably with respect to topography, to marine, rail and highway transport, and to the provision of economical utility services, including sewerage and drainage.

Environmental advantages of the metropolitan Seattle area, including climatic, recreational, educational, and cultural, have been discussed previously. Each of these is significant in the population study to the extent that it attracts industry, encourages inmigration, and retards outmigration.

POPULATION PROJECTION

Many methods may be used for projecting population growth. Among them the principal ones are:

1. A graphical or mathematical projection of the curve of past population growth. One of these, the logarithmic trend method, gives results reasonably comparable to more complex techniques when applied to fast-growing areas in the west.
2. A projection based on relationships between population growth in an area and past growth in other older areas of comparable environment. This method was not used because it fails to take into account external factors related to the time of growth of the areas assumed to be comparable.
3. A projection based upon the trend in the proportion of the area's population to that of the next larger economic or political division. Known as the ratio method, this method requires as a first step a valid projection for the larger division.
4. A determination of the optimum holding capacity, or ultimate population, which an area can contain comfortably, and an estimation of the rate of growth toward that optimum. In the absence of a limiting condition, such as areal extent or water supply, this method is not entirely applicable.
5. A forecast based upon specific assumptions with respect to natural increase and migration. The most accurate of these, the cohort-survival method, takes into account the present age and sex composition of the population, the trends in specific age-fertility rates and age-sex-mortality rates, and the volume and age composition of inmigrants.

High and Low Projections

In utilizing the above methods, it is common practice to prepare a series of projections, each based on specific assumptions as to conditions expected to prevail during the period of projection. Since a considerable spread is generally found between the highest and lowest results obtained, those who use the data must select the projection appropriate to their particular purpose.

For planning sewerage and drainage works, the projection indicating the greatest rate of growth which reasonably may occur should be selected. If actual growth falls below this rate, facilities so designed will simply be adequate for a longer period, and increments scheduled for stage construction will be deferred accordingly. For financing purposes, however, the projection of least growth likely to occur must be considered. This is particularly important for projects involving financing by utility revenue.

Population Studies and Projections Available to the Survey

The Washington State Census Board has prepared cohort-survival projections for the state to 1965,

based on one assumption as to fertility rates and on five different rates of inmigration[2,3]. Stanford Research Institute has used the cohort-survival method to make a single projection to 1975 for each of eleven western states[4]. A similar but less precise procedure, known as the component method, has been used by the Bureau of the Census in preparing projections from 1950 census data[5]. A report on population growth of the northwest states, published in 1952 by the Columbia River Inter-Agency Committee, is based on one of the earlier census bureau projections and is of particular value because it contains revisions allowing for the economic outlook and resources of the region[6].

Population studies and projections made by the Planning Commissions of Seattle and of King and Snohomish counties have been of great value to the sewerage and drainage survey. In 1952, the Seattle Planning Commission prepared a projection for King County based on crude birth and death rates[7]. In the same year it also prepared a projection to 1970 for Seattle, using census tracts based on land occupancy[8]. These were followed in 1953 by a cohort-survival study and three projections for King County to 1970, utilizing low, medium, and high assumptions as to inmigration and the same assumptions as to fertility as were employed by the Washington State Census Board[9]. Early in 1954 the Seattle Planning Commission staff made an informal projection to the year 2000 by extrapolation from the 1970 medium cohort-survival study. Also in that year, projections to 1970 were prepared for the principal city and suburban divisions of King County[10]. These were revised in May 1956 to include development on the west side of Lake Sammamish.

Starting with a base study and report in 1954[11], the Seattle Planning Commission has issued annual reports on current population estimates by census tracts, political subdivisions, and major county divisions. These estimates, based largely on residential construction permit data and on military and institutional reports, provide a reasonably reliable history of population growth and distribution since the 1950 census.

The King County Planning Commission, in 1952 and 1953, prepared a series of comprehensive land use plans for major divisions of the county. These plans, together with information developed by the commission in subsequent special studies, have been used to define the optimum land occupancy pattern for much of the sewerage and drainage study area. In 1954, the Snohomish County Planning Commission made a projection to 1965 for the county and also for an area lying southward from Everett to the county line. In this study, the ratio method was used along with state projections by the Washington State Census Board. Additionally, the Snohomish County Planning Commission conducted an informal census by census tracts in 1954 and has made estimates of near ultimate populations for specific school service areas in the southern part of the county.

In utilizing the above mentioned projections for King and Snohomish counties, it should be noted that all are based either directly or indirectly on the future specific age-fertility rates assumed by the Washington State Census Board in its cohort-survival study. In that study, it was assumed that, after 1950, fertility rates for the 20-24 year and 30 to 34 year age groups would remain substantially the same as in 1950, and that the rates for all other age groups would decline in varying degrees. Resulting crude birth rates were estimated to be 23.9 per 1,000 persons per year for 1950-55, 18.8 for 1955-1960, and 18.1 for 1960-65. In comparison, the apparent birth rate was 24.1 in 1950-55, and since then has increased to 24.5 instead of declining. Fertility rates have increased in even greater degree. If the high rates continue, the state estimate of growth due to natural increase by 1960 will be low by about 70,000 persons and the Seattle Planning Commission estimate for King County will be low by more than 20,000.

For the period 1960-65, assuming that 1956 rates (Table 5-4) continue, fertility rates will be 27 to 63 per cent higher than those projected by the State Census Board for the specific age groups, and the crude birth rate will remain approximately at the current level of 24 per 1,000 persons per year. Beyond

[2] *Schmid, C. F., et al.*, Population and Enrollment Trends and Forecasts, State of Washington, *Washington State Census Board, 1953.*

[3] First Revision of Population Forecasts, State of Washington, 1955 to 1965, *Washington State Census Board, January 3, 1956.*

[4] *Nielson, H. C.*, Population Trends in the United States Through 1975, *Stanford Research Institute, August 1955.*

[5] *Current Population Reports, Series P25, No. 78, 110, 123, and 160. U. S. Bureau of the Census.*

[6] Population Projections for the Pacific Northwest States and Region, 1960 and 1975, *Columbia Basin Inter-Agency Committee, 1952.*

[7] *Current Planning Research No. 8, May 15, 1952, Seattle Planning Commission.*

[8] Population Forecasts for the City of Seattle by Census Tracts, *CPR No. 19, September 15, 1952, Seattle Planning Commission.*

[9] Population Trends and Projections, Seattle Standard Metropolitan Area, 1900 - 1970, *CPR No. 13, November 1, 1953, Seattle Planning Commission.*

[10] Population Trends and Projections, Seattle Metropolitan Area by Major Divisions, 1920 - 1970, *CPR No. 14, April 1, 1954, Seattle Planning Commission.*

[11] Population Trends in the Seattle Standard Metropolitan Area, 1950 - 1954, *CPR No. 15, November 1, 1954, Seattle Planning Commission.*

1965, the crude birth rate would tend to rise as the depression-born generation passes beyond the age of parenthood and is replaced by the larger wartime and postwar generation.

Official state and King County projections for 1960, 1965 and 1970, based on medium inmigration, along with revisions thereto based on the assumption of continued high fertility rate, are given in Table 5-6. For the two assumptions as to fertility, the tabulated figures show a difference in total population of about 6 per cent by 1965 and 11 per cent by 1970. For King County, the population growth due to natural increase between 1960 and 1970 would rise from 76,000 to 171,000. In the absence, therefore, of any indication toward a decline in fertility rates, the official short-range projections must be considered as somewhat conservative.

Procedure Employed in Population Projection

As indicated earlier, population projections to serve the purposes of this report must cover a period equal to or greater than that represented by the longest economic life of any of the facilities likely to be constructed. With that requirement in mind, projections were developed to the year 2030 for the sewerage and drainage study area. As a preliminary step, estimates of saturation or ultimate population density were made for Seattle and for each of the principal suburban divisions of the presently developing metropolitan area. This work was done by the three planning commission staffs in consultation with the survey staff, and takes into account the comprehensive land use plans which have been developed for Seattle and the suburban divisions. For the high projection, it was assumed that, on the average, the 2030 population would be 80 per cent of the saturation total.

Table 5-6. Short-Range Population Projections for Washington and King County

Projection	Population in thousands		
	1960	1965	1970
State of Washington			
Declining fertility[a]	2,832	3,058	
Constant fertility[b]	2,900	3,240	
Difference	68	182	
King County			
Declining fertility[c]	892	953	1,018
Constant fertility[b]	912	1,007	1,133
Difference	20	54	115

[a]*With constant medium inmigration of 10,000 per year, from First Revision of Population Forecasts, State of Washington, 1955 to 1965, Washington State Census Board, January 3, 1956.*

[b]*Above projections revised to 1956 specific age fertility rates for Washington, given in Table 5-4.*

[c]*With medium inmigration of 7,500 per year, 1950 to 1960, and 5,000 per year, 1960 to 1970, from CPR No. 13, Seattle Planning Commission.*

In this phase of the work, the population study divisions were those previously established by the Seattle Planning Commission. In addition to eleven divisions within the city, they included seven divisions covering roughly the area northward to the Snohomish County line, eastward to Lake Sammamish and Renton, and southward to Salt Water State Park.

Populations for the intermediate years, 1980 and 2000, were derived by extrapolation to 2030 of the King County 1970 projection. These were then distributed among the several divisions on the basis of local conditions likely to affect their rates of growth. While such a procedure is applicable to the above noted population study divisions, all of which lie within the presently developing urban pattern, it is of questionable validity in the outlying and largely undeveloped areas in the northeastern, eastern and southern portion of the sewerage and drainage study area. The problem, therefore, was to estimate the additional population likely to reside in the present fringe areas.

For the purpose of the sewerage survey, the procedure used in developing the high projection was to extend the United States population to the year 2030 by the logarithmic trend method, assuming continuation of the 1954-55 fertility rate. With that as a base, the populations of the Pacific states, of Washington, of the Puget Sound region, and of King and Snohomish counties were estimated by the ratio method. The two county populations were then distributed, taking into account the previous determination for the urban divisions which would be approaching saturation limits. In so doing, allowance had to be made for urban development on Vashon Island and in Kitsap County as integral parts of the metropolitan Seattle area. An allowance had to be made also for the metropolitan development of Everett.

For the low projection, the growth of the state was reduced to the lowest rate which has occurred in any prior 30-year period. In addition, the relationship of the low to the high projection was determined for subsequent application to the survey study area.

Projection of State, Region, and County Populations

As a base for local projections, the population of the United States is assumed to climb to 228 million by 1975, 400 million by 2010, and 550 million by 2030. The high rate of increase thus indicated is predicated on a continuation of the 1954-55 fertility rates.

For 1975, the forecasted population of 228 million is taken from the Series AA projection of the U.S.

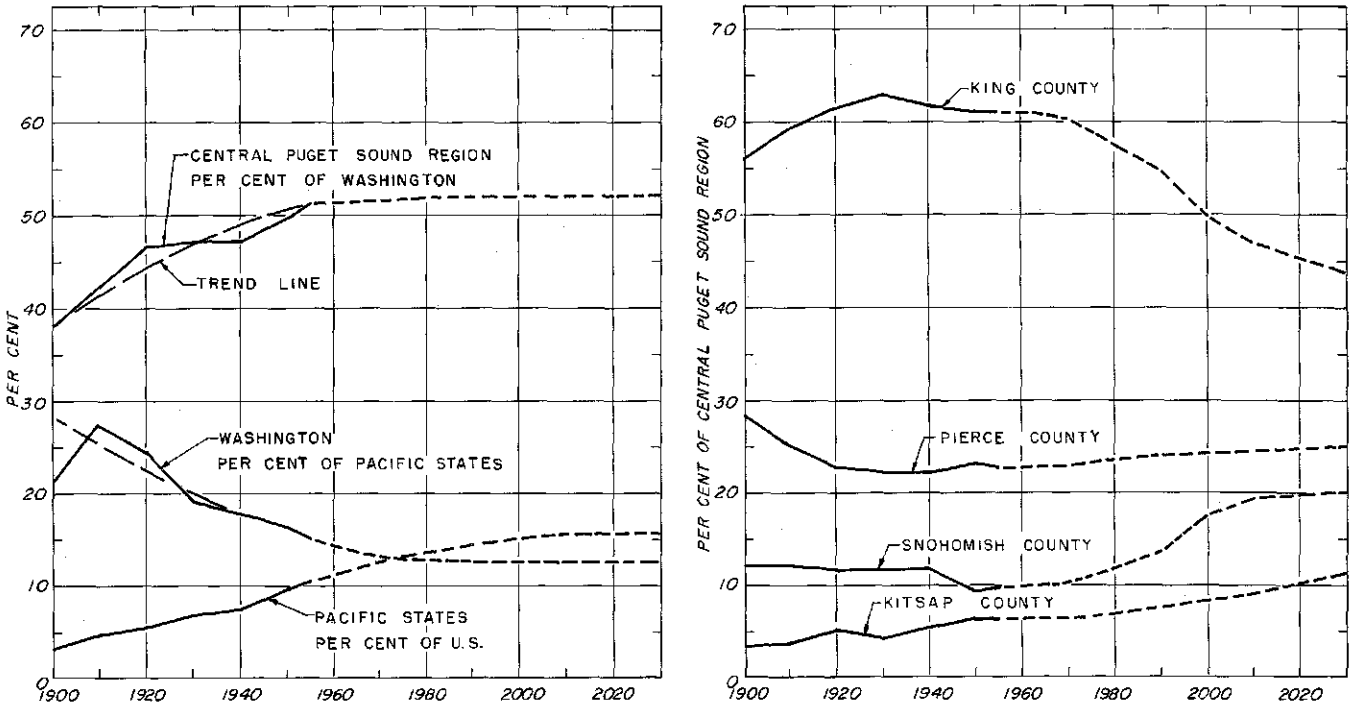


Fig. 5-7. Population Ratios Expressed as Per Cent of Next Larger Division

Bureau of the Census[12]. Figures for the two later years are obtained by extrapolation of the 1975 projection at an average increase of 1.61 per cent per year. Since this rate exceeds all prior rates of national growth between 1900 and 1950, some question may be raised as to the propriety of using it in developing a high projection of reasonable attainment.

Insofar as the projection to 1975 is concerned, the 1.61 per cent per year rate of increase is currently being exceeded and the economic outlook for the next decade[13] is favorable toward its continuation. For the long range outlook, demographers note that revolutionary technological advances in the last 15 years have placed the nation on the threshold of a new era of material well-being for which there is no historical precedent. On that basis, the validity of the high population projection will depend not on the inherent productive capacity of the nation, but on how effectively we meet the economic, social and political problems arising from the predicted advances.

In applying the high projection to the local scene, it was assumed that past and projected trends in population ratios will come to equilibrium in 40 to 50 years. As shown in Fig. 5-7 and Table 5-7, this assumption implies that the ratio of the Pacific states to the nation will end its rise by that time and that the population of those states will grow thereafter at about the same rate as the nation. It also implies that the ratio of Washington to the other Pacific states, which has been declining since 1910, will become constant at about the end of the present century. By combining the two ratios, it was determined that the ratio of the population of Washington to that of the nation should rise from 1.59 per cent in 1955 to 1.94 per cent by the year 2010 and thereafter should remain at that level.

Since 1900 the population of the central Puget Sound region, comprising King, Pierce, Snohomish, and Kitsap counties, has increased from 38 per cent to 51 per cent of that of the state. As the trend line, however, indicates that the rate of increase has been declining, it is assumed that the ratio will stabilize at about 52 per cent. This implies that while the four counties will continue to comprise the principal metropolitan center of the state, other urban centers in Washington, along with the remainder of the Puget Sound region, will grow in the future at a rate equal to the four-county area.

Within the central Puget Sound region, the ratio of population in King County to that of the region has been declining since 1930. Kitsap County has shown an almost continuous rise since 1900, while changes in the ratios for the other two counties have not been consistent. In the absence of established trends suitable for mathematical extrapolation, the curves in Fig. 5-7 were extended on the basis of present conditions and probable future developments.

[12] Revised Projections of the Population of the United States, by Age and Sex: 1960 to 1975, *Current Population Reports, Series P25, No. 123, October 1955, U.S. Bureau of the Census.*

[13] Potential Economic Growth of the United States During the Next Decade, *Committee Staff Report to the Joint Committee on the Economic Report, 83rd Congress, 2nd Session.*

Table 5-7. Population Ratio Expressed as Per Cent of Next Larger Division

Year	Pacific to U.S.	Washington to Pacific	Central Puget Sound Region to Washington	King County	Pierce County	Snohomish County	Kitsap County
				to Central Puget Sound Region			
1900	3.17	21.4	38.0	56.1	28.3	12.2	3.4
1910	4.55	27.4	42.2	59.0	25.1	12.2	3.7
1920	5.37	24.4	46.0	61.4	22.7	10.7	5.2
1930	6.69	19.1	47.2	62.9	22.2	10.7	4.2
1940	7.40	17.8	47.2	61.6	22.2	10.8	5.4
1950	9.57	16.4	49.7	61.0	23.2	9.4	6.4
1955	10.5	15.1	51.2	61.1	22.7	9.8	6.4
1960	11.2[a]	14.3[a]	51.4	61.0	22.7	9.9	6.4
1965	11.9[a]	13.7[a]	51.5	60.8	22.8	10.0	6.4
1970	12.5[a]	13.3[a]	51.6	60.2	22.9	10.4	6.5
1975	13.1	13.1	51.7	59.0	23.4	10.9	6.7
1980	13.5	12.9	51.8	57.6	23.6	11.8	7.0
1990	14.4	12.7	51.9	54.8	23.9	13.7	7.6
2000	15.2	12.6	52.0	50.0	24.2	17.5	8.3
2010	15.5	12.5	52.0	47.0	24.5	19.3	9.2
2020	15.5	12.5	52.0	45.2	24.8	19.8	10.2
2030	15.5	12.5	52.0	43.7	25.0	20.0	11.3

[a]*From Series 1 projection, Illustrative Projections of the Population, by States, 1960, 1965 and 1970. Current Population Reports, Series P-25, No. 160, August 1957.*

Considering the present stages of urban and industrial development in King County, it is assumed that the population of this county will continue to decline in relation to the other three. It is assumed also that Pierce County, which is presently well developed, will have a relative gain at a slow rate which will taper off at the close of the study period. Snohomish County, particularly in the vicinity of Everett and southward, is expected to grow rapidly until the end of the century and at a slower pace thereafter. Kitsap County is expected to grow at a gradually accelerating pace not only because of its own industrial development but also because of its close ties to Seattle.

High Population Projection. High population projections for Washington, for the central Puget Sound region, and for King and Snohomish counties, as listed in Table 5-8, are based on the aforementioned high projection of national population and on the ratios given in Table 5-7. Forecasts for the state (Fig. 5-8) fall below the figures given in Table 5-6 for 1960 and 1965 but show an increased rate of growth after 1970. The slower initial rate derives from the lower fertility rates for the nation as compared to the state (Table 5-4), while the rise after 1970 results from births to the large postwar generation. Beyond 1970, the projected totals for the state are 4,320,000 by 1980, 6,500,000 by 2000, and 10,600,000 by 2030.

For King County, the high projection indicates a population of 1,290,000 by 1980, 1,690,000 by 2000, and 2,400,000 by the year 2030. Up to 1970, as in the case of the state, the projection falls below the short range estimate based on current King County fertility rates (Table 5-4). On the other hand, the 2030 forecast of 2,400,000 exceeds a tentative projection of the Seattle Planning Commission staff by more than forty per cent. This is because the latter assumes a lower initial rate of growth and a continuous decline in the rate to an average of 0.96 per cent per year during the last 30 years.

For Snohomish County, the high projection indicates a population of 264,000 by 1980, 592,000 by 2000, and 1,100,000 by 2030.

Low Population Projection. To obtain a low projection suitable for consideration of financing problems, a forecast of the state population was developed, using an increase of 1.41 per cent per year. This is the least rate of growth the state experienced in any 30-year period.

Based on the 1.41 per cent annual rate, the projected low population is 87.5 per cent of the high projection for 1980, 77 per cent for the year 2000, and 71.5 per cent for 2030. Percentages for intermediate years are given in Table 5-8. By applying these percentages to the high projection for King County, the resulting low projection for the county falls below the Seattle Planning Commission medium projection for all years.

Population Projection Within the Study Area

As outlined previously, population estimates for the sewerage and drainage survey study area were

Table 5-8. Projected State, County, and Study Area Population, 1957 - 2030

Year	Washington			Central Puget Sound Region,[c] 1,000	King County, 1,000	Snohomish County, 1,000	Survey Study Area, 1,000
	High, 1,000	Low,[a] 1,000	Ratio,[b] per cent				
1957	2,670			1,370	859	134	864
1960	2,880	2,850	99.0	1,480	900	147	910
1970	3,480	3,270	94.0	1,800	1,080	187	1,080
1980	4,320	3,770	87.5	2,240	1,290	264	1,260
1990	5,300	4,350	82.0	2,760	1,510	378	1,500
2000	6,500	5,000	77.0	3,380	1,690	592	1,740
2010	7,750	5,730	74.0	4,030	1,900	780	1,920
2020	9,100	6,590	72.5	4,730	2,140	935	2,090
2030	10,600	7,600	71.5	5,500	2,400	1,100	2,240

[a]*Low estimate based on average annual increase of 1.41 per cent per year.*
[b]*Ratio of high estimate to low estimate.*
[c]*Comprising King, Snohomish, Kitsap and Pierce Counties.*

derived primarily on the basis of near-saturation conditions in presently developing divisions of the area. On the other hand, the population within the fringe portions, which also must be included, was derived through distribution of the total populations previously projected for King and Snohomish counties.

Population study divisions within the survey area (Fig. 5-9) include 11 divisions within the city limit of Seattle, 12 others in King County, and that part of Snohomish County within the Lake Washington watershed. With few exceptions, those within King County comprise one or more entire census tracts. In a few cases, census tracts were split because of widely divergent topographic and land use conditions.

Study divisions within the city and seven others (North 2; East 1, 2 and 3; and South 1, 2 and 3) are as defined in 1954 by the Seattle Planning Commission. For these divisions, near-saturation conditions may reasonably be assumed to develop within the design period. Except for minor adjustments, the population and population density forecasts given in Table 5-9 for the year 2030 and intermediate years are the same for each division as those tentatively established by the planning commission staffs.

For the year 2030, the projected populations for Seattle and the seven King County divisions amount to a total of 1,417,000 persons. A similar study by the Snohomish County Planning Commission staff indicates a near-saturation population of 223,000 for the western and central portion of the Lake Washington watershed lying within Snohomish County. For those portions, therefore, of the survey study area which are subject to near-saturation development within the design period, the estimated population totals 1,640,000.

The balance of the study area, comprising about 250 square miles of land area, or 43 per cent of the total, is for the most part not likely to reach near-saturation levels within the design period. To arrive at a reason-

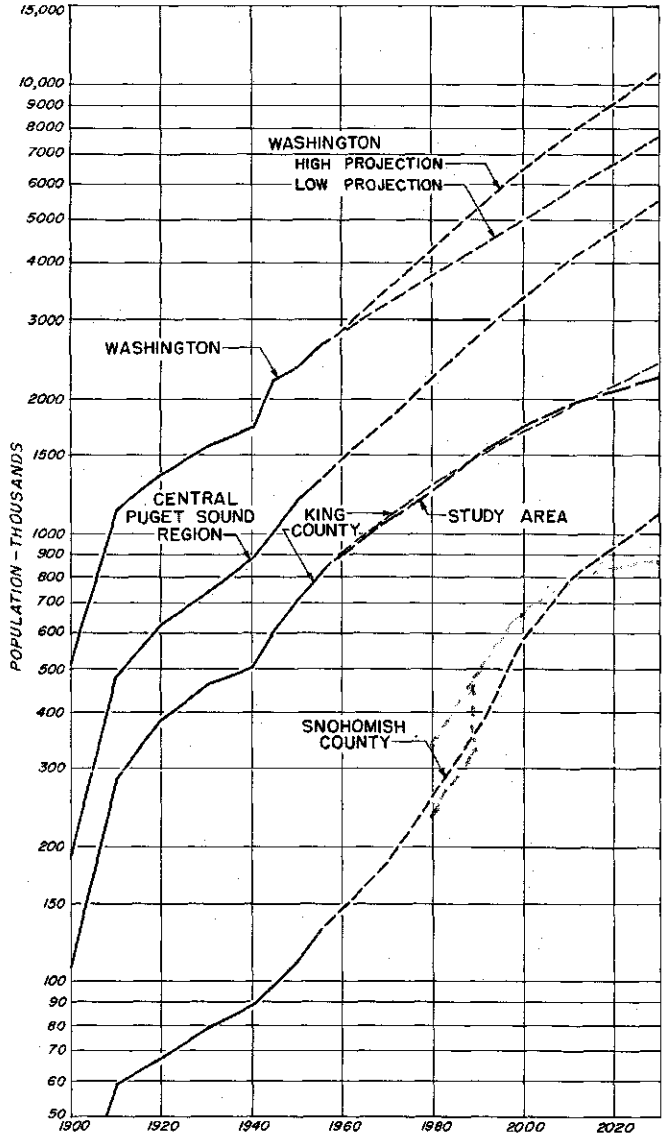


Fig. 5-8. Projected State, County, and Study Area Populations, 1957-2030

WEST SEATTLE has experienced rapid growth and development is estimated now to be about 90 per cent of the ultimate.

able population estimate for this portion requires a careful consideration of factors influencing development both within and outside of the study area. Outside the study area, these factors include:

1. The proposed bridge across Puget Sound via Vashon Island. This link will increase greatly the suburban development on the island, which has an area of 36 square miles and could ultimately accommodate a population of 75,000 to 100,000.

2. A continued urbanization of the Federal Way area. Although it lies within King County, this area is for the most part within the topographic sewerage area of Tacoma and is close to Tacoma's heavy industrial zone. A projected population of 100,000 by 2010[14] for all portions of King County within the sewerage area of Tacoma may well increase to 120,000 by 2030.

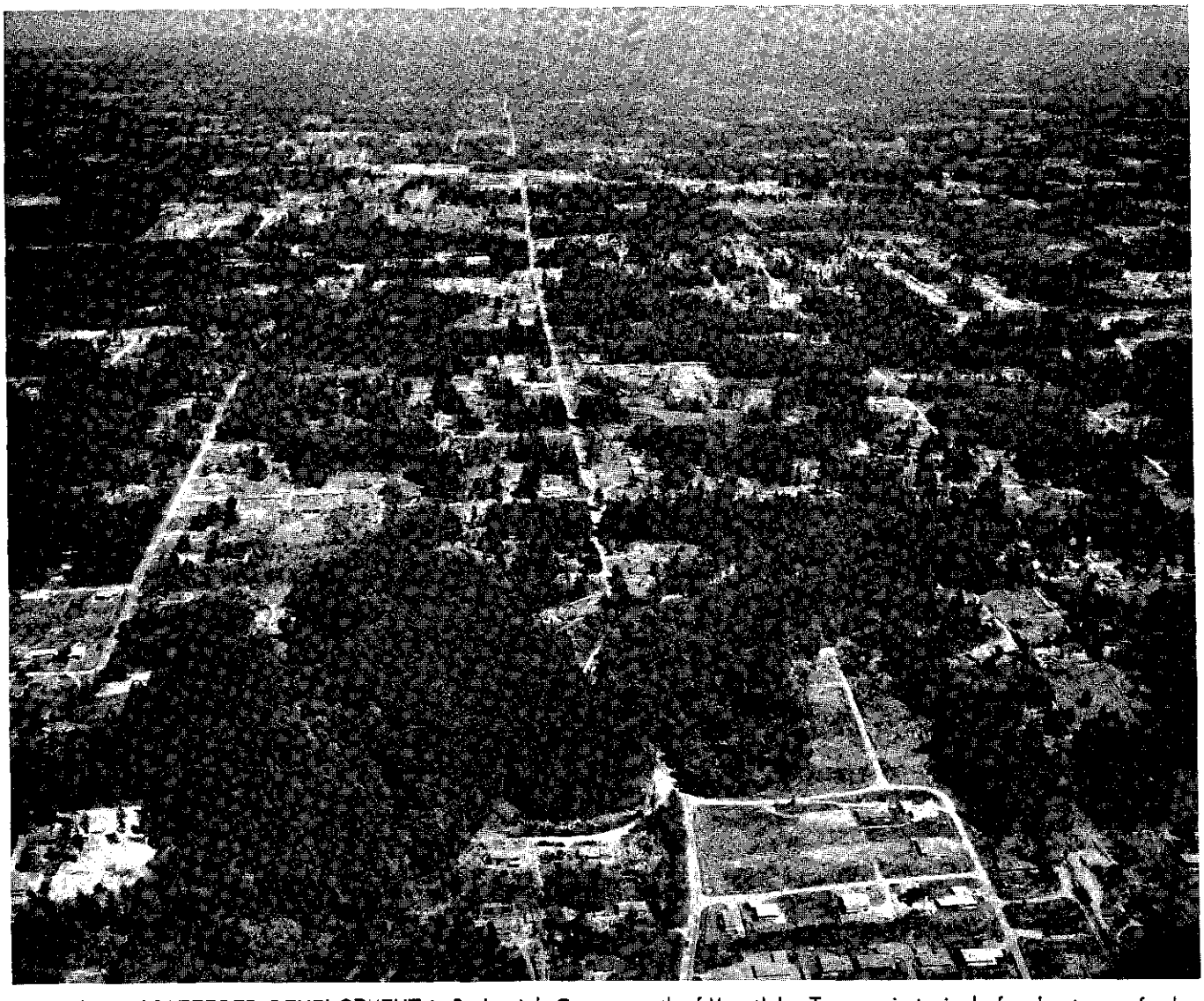
[14] "Metropolitan Tacoma Sewerage and Drainage Survey", *Brown and Caldwell, 1957.*

3. The growth of satellite communities. Communities lying between the survey study area and the Cascades, both existing and yet to be created, eventually will experience vigorous growth. A similar pattern of development has been typical of other metropolitan areas and is strengthened at present by the trend toward dispersal of light industry.

4. A diversification of industry in Snohomish County. Based largely on forest products in the past, the industrial economy of Snohomish County will be bolstered in the future by the oil refineries planned for construction both north and south of Everett. Further diversification and dispersal can be expected and will bring with it a widespread development of new residential areas.

Within the sewerage and drainage study area, factors influencing future development include:

1. The southward movement of the center of heavy



PRESENT SCATTERED DEVELOPMENT *in Snohomish County, north of Mountlake Terrace, is typical of early stages of suburban residential growth.*

industry. The proposed extension of navigable water in the lower Duwamish River and the construction of sites for heavy industry southward to 180th Street, along with continuing industrialization in the vicinity of Kent and Auburn, will shift the center of industrial employment southward. Early stimulation of residential development on both sides of the Green River valley can be expected as a result of this movement. Eventually, either the valley will be completely industrialized, or if agricultural zoning is enforced, the proposed Covington heavy industrial area will be developed. In either case, this will promote residential development in the adjoining or surrounding southeast division.

2. The freeway and bridge program. Construction of the proposed system of freeways and expressways, coupled with a second Lake Washington crossing, not only will facilitate travel within presently congested areas but will extend commuting distances and thus affect residential distribution.

3. A dispersion of light industry. Development of numerous small sites for light industry in the eastern and northern divisions of the study area will affect population growth in these divisions.

With the foregoing factors taken into account, it was estimated that the five study divisions within King County (East 4 and 5, South 4 and 5, and Southeast) will have a population in the year 2030 of about 560,000. This total is expected to be divided among the five divisions on the basis set forth in Table 5-9.

Within Snohomish County, enlargement of the study area eastward to include all of the watershed tributary to Lake Washington added 10,440 acres to the area of 38,400 acres for which the tentative near-saturation population previously had been estimated. Based on the county land-use plan for the watershed, modified

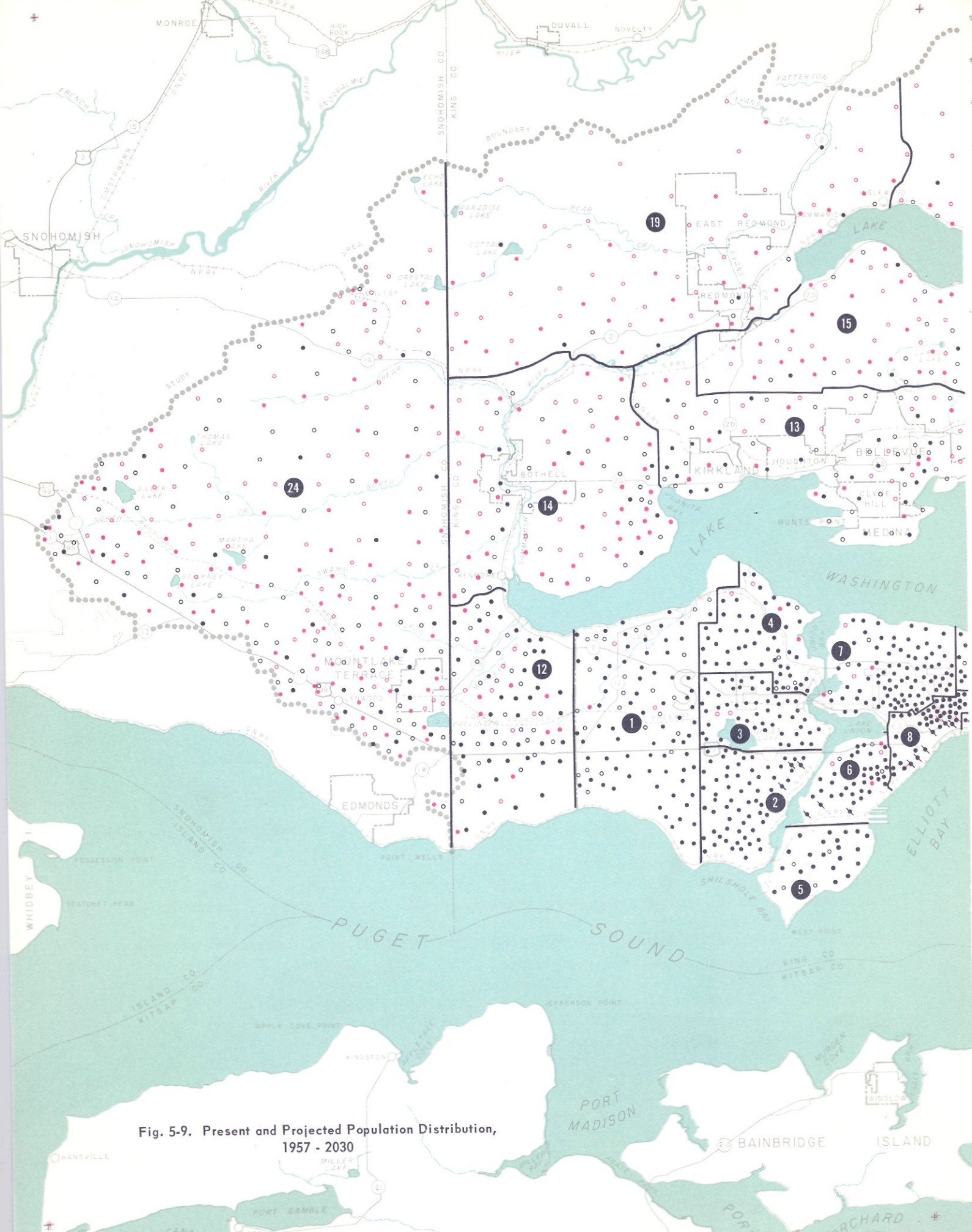


Fig. 5-9. Present and Projected Population Distribution, 1957 - 2030

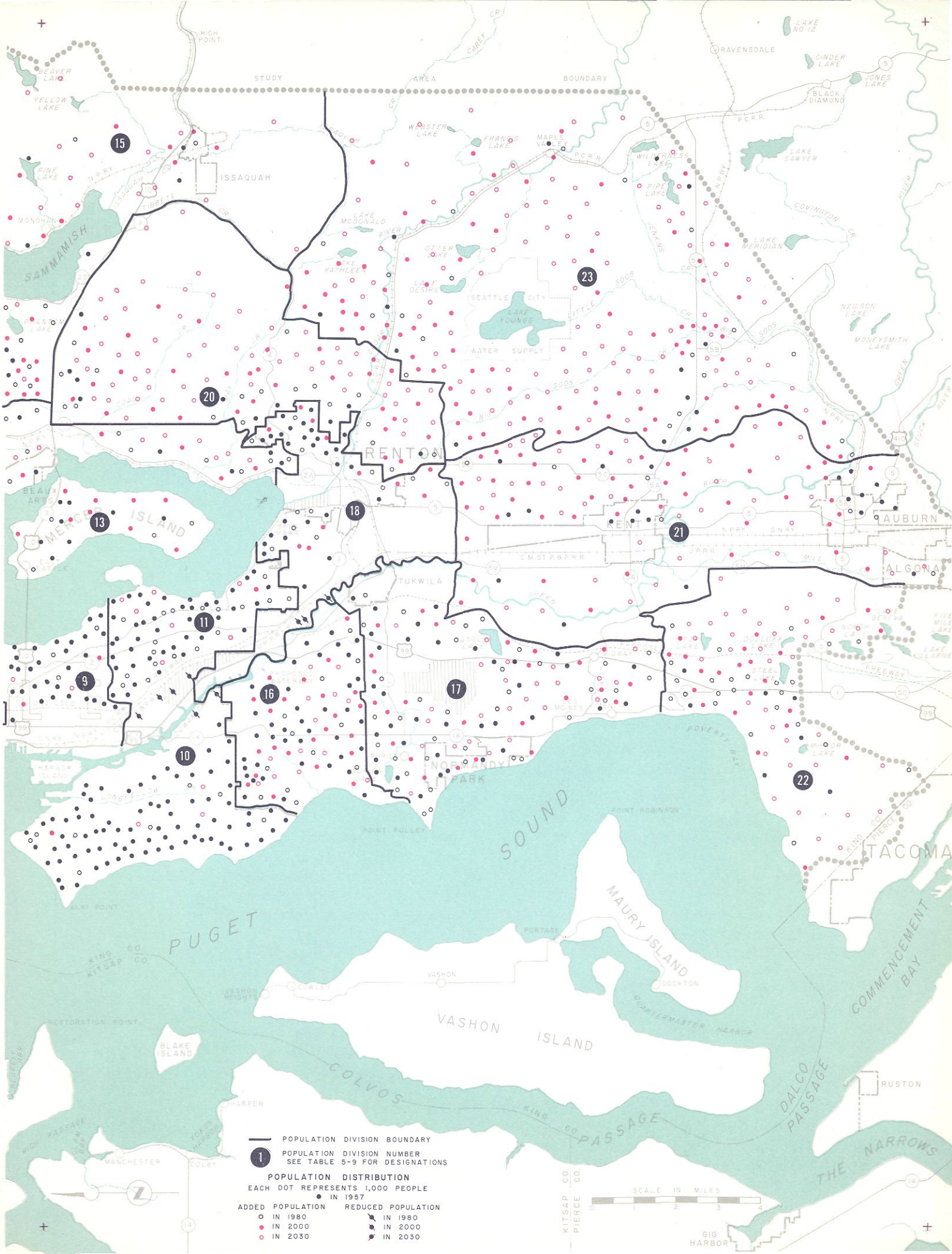

STUDY AREA BOUNDARY
HIGH POINT
BEAVER LAKE
YELLOW LAKE
RAVENSDALE
LAKE NO 12
CINDER LAKE
JONES LAKE
BLACK DIAMOND
WEBSTER LAKE
FRANKS LAKE
MAPLE VALLEY
WILDERNESS LAKE
PIPE LAKE
LAKE SAWYER
COVINGTON CR
LAKE MERIDIAN
NEILSON LAKE
MONEYSMITH LAKE
ISSAQUAH
SAMMAMISH
LAKE MCDONALD
LAKE KATHLEEN
OTTER LAKE
LAKE DESIRE
SEATTLE CITY WATER SUPPLY
LAKE YOUNGS
RENTON
BEAUX ARTS
MERCER ISLAND
KENT
AUBURN
ALGONA
TUKWILA
NORMANDY PARK
POVERTY BAY
POINT ROBINSON
POINT PULLEY
TACOMA
PUGET SOUND
ALKI POINT
KING CO
KITSAP CO
MAURY ISLAND
PORTAGE
VASHON
DOCKTON
QUARTERMASTER HARBOR
VASHON ISLAND
COMMENCEMENT BAY
RESTORATION POINT
BLAKE ISLAND
COLVOS PASSAGE
DALCO PASSAGE
RUSTON
HARPER
MANCHESTER
COLBY
THE NARROWS
PIERCE CO
KITSAP CO
PIERCE CO
GIG HARBOR
SCALE IN MILES
0 1 2 3 4
POPULATION DIVISION BOUNDARY
POPULATION DIVISION NUMBER SEE TABLE 5-9 FOR DESIGNATIONS
POPULATION DISTRIBUTION
EACH DOT REPRESENTS 1,000 PEOPLE
IN 1957
ADDED POPULATION
IN 1980
IN 2000
IN 2030
REDUCED POPULATION
IN 1980
IN 2000
IN 2030

Table 5-9. Present and Projected Population Distribution of Study Area

Population division[a]	Area, acres[b]	Population, thousands				Density, persons per acre			
		1957	1980	2000	2030	1957	1980	2000	2030
Seattle - 1957 limits									
1. Broadview - Lake City	10,400	72	97	98	100	6.9	9.3	9.4	9.6
2. Ballard - Fremont	3,810	63	60	60	60	16.5	15.7	15.7	15.7
3. Green Lake - Wallingford	2,760	47	47	47	49	17.0	17.0	17.0	17.8
4. Ravenna - View Ridge	3,530	47	51	53	55	13.3	14.4	15.0	15.5
5. Magnolia	2,450	21	26	26	26	8.6	10.6	10.6	10.6
6. Queen Anne	2,450	33	33	35	37	13.5	13.5	14.3	15.1
7. Capitol Hill - Madrona	4,350	82	85	87	89	18.8	19.5	20.0	20.5
8. Downtown	1,470	44	38	36	34	30.0	25.9	24.5	23.1
9. Rainier Valley - Mt. Baker	5,330	38	42	43	44	7.1	7.9	8.1	8.3
10. West Seattle	10,170	80	85	86	89	7.9	8.4	8.5	8.8
11. Columbia - Rainier Beach	6,320	45	59	63	67	7.1	9.3	10.0	10.6
Subtotal - Seattle	53,040	572	623	634	650	10.8	11.8	12.0	12.3
12. North 2	9,690	36	66	78	85	3.1	5.7	6.7	7.3
13. East 1	23,320	39	88	114	146	1.7	3.8	4.9	6.3
14. East 2	16,480	10	40	78	97	0.6	2.4	4.7	5.9
15. East 3	34,080	16	47	106	180	0.5	1.4	3.1	5.3
16. South 1	8,300	39	50	73	87	4.7	6.0	8.8	10.5
17. South 2	15,920	36	72	97	122	2.3	4.5	6.1	7.7
18. South 3	10,000	31	39	50	50	3.1	3.9	5.0	5.0
19. East 4	34,210	6	12	39	82	0.2	0.4	1.1	2.4
20. East 5	21,750	4	16	35	55	0.2	0.7	1.6	2.5
21. South 4	28,850	20	27	76	113	0.7	0.9	2.6	3.9
22. South 5	15,450	7	31	54	91	0.5	2.0	3.5	5.9
23. Southeast	50,330[c]	14	33	117	216	0.3	0.7	2.3	4.3
Subtotal - King County	321,420	830	1,144	1,551	1,974	2.6	3.6	4.8	6.1
24. Snohomish County	48,840	34	113	190	264	0.7	2.3	3.9	5.4
Total	370,260	864	1,257	1,741	2,238	2.3	3.4	4.7	6.0

[a]*See Fig. 5-9 for location of population divisions.*

[b]*Gross area excluding major lakes, waterways, and undeveloped tidelands.*

[c]*Excluding Lake Young reservoir and Seattle Water Department property having total area of 2,560 acres.*

slightly in light of the county projection, the population of the Snohomish County portion of the study area was estimated to reach 264,000 in the year 2030. For the entire study area, therefore, the population forecasts give a total of 2,238,000 persons in 2030 (Table 5-9).

Totals for the intermediate years, 1980 and 2000, are based on the estimated rate of growth within each of the population divisions.

Detailed Distribution of Study Area Population

In developing the population projections, the method used for that purpose required a general distribution of population among the major divisions of the study area. This information, together with that developed from available data on existing distribution and from future land use plans, was utilized in preparing the detailed distribution illustrated by the dot map in Fig. 5-9. In analyzing the land use plans, consideration was given in particular to the locations of industrial zones, recreational areas, and highways.

It will be noted that certain areas within Seattle already have attained their maximum population. In a few, such as the downtown section and certain industrial areas, a decrease is predicted. Within the design period, the net growth within the present limits of Seattle is expected to be 80,000 as compared to 1,370,000 in the remainder of the study area.

Average densities predicted for the several divisions in 2030 range from 2.4 to 20.5 persons per gross acre. For the entire study area, the average density is estimated to be 6.0 persons per gross acre.

Population density, along with land use for commercial and industrial purposes, governs both the volume of sewage and the amount of storm runoff from a particular area. For that reason, the dot map (Fig. 5-9) is used later to obtain both design population and population density values for the individual sewerage and drainage service areas.