Water Resources of the Tacoma Area Washington

By W. C. GRIFFIN, J. E. SCEVA, H. A. SWENSON, *and* M. J. MUNDORFF

WATER RESOURCES OF INDUSTRIAL AREAS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499-B

Prepared in cooperation with the Tacoma, Wash., Department of Public Utilities, Water Division

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

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WATER RESOURCES OF THE TACOMA AREA, WASHINGTON

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ABSTRACT

The Green, Puyallup, and Nisqually Rivers in the Tacoma area assure an ample supply of water, greatly in excess of that used at present. On the average, about 4,100 mgd (million gallons per day) flows into Puget Sound from surface streams draining the area. The potential ground-water recharge from precipitation is estimated at not less than 550 mgd, of which perhaps as much as one-half to two-thirds feasibly could be recovered if the effects on water levels and streamflow could be tolerated. In 1955 the total water withdrawn, both surface and ground water, was about 140 mgd, or less than 3 percent of the total supply.

Flows of most of the streams in the area are sustained by summer snowmelt at the headwaters or by ground-water inflow, and even during low-flow periods the quantity of surface water available is adequate for many uses. Low flows could be augmented by additional storage. After construction of the Eagle Gorge Dam on the Green River, operation of its reservoir will more than double the dependable low-flow supply at the Tacoma municipal system's headworks.

Ground water in the Tacoma area is largely controlled by the geology and topography of the area. The unconsolidated glacial drift and alluvium that underlie the area contain acquifers of high porosity and permeability and yield extremely large amounts of water, as much as 14 mgd from a single well.

The sand and gravel acquifers are discontinuous and occur as lenses, and therefore the quantity of water available differs greatly from place to place. The outwash sand and gravel deposits of the Vashon glaciation include the best aquifers in the area. These deposits generally extend not more than 200 to 300 feet below the land surface. Older sand and gravel aquifers lie at depths as great as 2,000 feet. Their permeability generally is much less than the permeability of the outwash sand and gravel of the Vashon glaciation; but, because of the large drawdown potentially available, greater amounts of water can be obtained from these older aquifers than would otherwise be expected.

The total quantity of ground water available is limited only by the recharge, which under current conditions comes almost entirely from precipitation, and by practical considerations of drilling and pumping. Opportunity for recharge on the gravel plains is excellent, and a rough estimate of average annual recharge from the 35 to 45 inches of precipitation is 1 mgd per square mile, or

a total of 550 mgd for the 550 square miles included in the area. Though probably not more than one-half to two-thirds of this amount could ever be recovered economically, the amount available is several times the present use of ground water, which is approximately 50 mgd. Also, induced infiltration from streams to nearby wells could increase the recharge greatly, though surface-water rights would have to be considered.

Streams heading in the Cascade Range yield soft waters of low dissolved-solid content. The maximum concentration of dissolved solids in 39 samples from 12 streams was only 99 ppm (parts per million). The hardness of surface supplies on the basis of these 39 samples did not exceed 51 ppm. Streams of glacial origin are turbid and at times transport large loads of suspended sediment. Use of these streams would require extended treatment for clarifying the water. Nonglacial streams transport small to moderate sediment loads during periods of storm runoff but are practically clear most of the year. Most ground-water supplies have low concentrations of dissolved solids and generally meet quality-of-water standards for domestic, industrial, and irrigation uses. Some wells, however, notably in the Puyallup River valley, yield water in which the concentration of iron is objectionable.

Public-supply systems served more than 290,000 people in 1955, and the use of water averaged 70.1 mgd. Wells and springs supplied about 30 percent of this output and almost 50 percent of the total population. The Green River gravity system, the primary source of water for the city of Tacoma, provides about 52 mgd. This system can deliver a continuous flow of 73 mgd to McMillin Reservoir. A peak capacity equivalent to a rate of 105 mgd has been recorded for short intervals for the flow between the reservoir and the city. Tacoma's auxiliary well supply has a capacity of 62.2 mgd. About 10 percent of the city's annual supply is derived from wells. The municipal water system supplies water of excellent quality. About one-third of Tacoma's daily water output is delivered to domestic consumers and two-thirds to industry, commerical establishments, water districts, municipal parks and buildings, and similar users.

INTRODUCTION

The demand for water has increased rapidly during the last few decades and is certain to continue to increase in the future, especially in areas of industrial expansion and centers of growing population. A knowledge of the occurrence, quantity, and quality of the water resources that can be utilized is essential if these demands are to be met. This investigation answers such questions as: What are the sources of water; what quantities of water are available, especially during a drought; what is their chemical and physical quality; how much is already being used; what is the effect of use on the quantity and quality; and what are the magnitudes and frequencies of floods?

In addition to answering these questions, this report summarizes and interprets information on the availability and quality of the water resources in suitable form for use in the early stages of planning utilization. However, additional information, usually requiring additional investigations, may be necessary for the design of specific water-supply facilities.

Information on the water resources of the Tacoma area has been collected in cooperation with local and State agencies since 1909.

The area of investigation covers approximately 550 square miles that includes the city of Tacoma, northwestern Pierce County, and a small part of southwestern King County (pl. 1). The Green River now serves as a source of municipal water supply. Other streams outside the Tacoma area are also possible sources of water. Therefore, some information on flow, sediment, and chemical quality of the Green, White, Carbon, Puyallup, and Nisqually Rivers, which drain nearly 2,000 square miles east and south of Tacoma, has been included in this report.

The availability and quantity of water vary widely throughout the Tacoma area. To increase the utility of the report and to simplify description of the water supply, the 550-square-mile Tacoma area has been divided into subareas: the Tacoma Upland, the Puyallup River Valley, the Buckley Upland, the Northeast Tacoma Upland, and the Nisqually River Valley (pl. 2).

Many abbreviations and hydrologic terms used throughout are defined at the end of the report.

PHYSICAL ENVIRONMENT

The water resources of any area must be considered in relation to the physical environment. Not only do the geology, topography, and climate directly affect the amount, distribution, and quality of surface and ground water available, but these same factors also affect the utilization of the water for industrial, agricultural, and domestic supplies.

TOPOGRAPHY

The Tacoma area and the surface drainage basins to the east and south discussed in this report lie across two physiographic provinces. The eastern part is within the Northern Cascade Mountains section of the Sierra-Cascade Mountains province, and the western part is within the Puget Trough section of the Pacific Border province. The Cascades form a north-south-trending glaciated mountain range that contains many peaks rising to heights of 5,000 to 7,000 feet. Mount Rainier, 14,410 feet in altitude, in the extreme southeastern part of the total area described herein, rises majestically above the surrounding peaks.

The Puget Trough section, which includes the Tacoma metropolitan area, is, in general, a broad plain that extends from the Cascade Mountains on the east to the Olympic Mountains on the west. This plain, known locally as the Puget Lowland, is only 200 to 700 feet in altitude.

The plain is transected by many steep-walled alluviated and marine embayments which divide it into isolated remnants or uplands. The uplands range in size from a few square miles to several hundred square miles. Part of the city of Tacoma occupies the northern end of one of the larger uplands in the Puget Trough.

DRAINAGE

The five major streams described in this report head in the Cascade Mountains and drain into Puget Sound (pl. 1). From north to south they are the Green, White, Carbon, Puyallup, and Nisqually Rivers. The Green River heads in the mountains north of Mount Rainier, and the other four rivers have as their source glaciers on the slopes of Mount Rainier. The White River formerly separated into two channels about 3 miles southeast of Auburn to form (a) the Stuck River which flowed south to its confluence with the Puyallup River at Sumner, and (b) the White River which flowed north to its junction with the Green River at Auburn and continued north to join the Black River near Renton and form the Duwamish River. Many years ago the White River was diked at the Stuck River distributary, so that all flow remained in the Stuck River; thus, the White River became the Stuck River at that point. The old White River channel between the Stuck and Green Rivers was abandoned and that between the Green and Duwamish Rivers became the Green River. After entering the Puget Lowland, the Green River now flows north through the broad alluviated valley and becomes the Duwamish River, which terminates at Elliott Bay in Seattle. In 1960 the Stuck River was renamed White River (U.S. Board on Geographic Names, August 1960); so the White River now terminates at the Puyallup River, which flows down the broad valley that ends at Commencement Bay in Tacoma. The Carbon River also empties into the Puyallup River. Throughout this report the name Stuck River is used to designate the lower reaches of the White River because this is the name most familiar to residents of the Tacoma area. The Nisqually River, which forms the southern boundary of Pierce County, discharges into Puget Sound at Nisqually Reach. Many small streams that have partially dissected the isolated uplands of the Puget Trough flow off the uplands and join the major trunk streams or discharge directly into Puget Sound.

SUMMARY OF GEOLOGY

The overall area of this report encompasses two distinctly different geologic terranes. The eastern part, which lies within the Northern Cascade Mountains section of the Sierra-Cascade Mountains province, is underlain by volcanic, metamorphic, and consolidated sedimentary rocks. These rocks have been folded, faulted, uplifted, and eroded to form the rugged Cascade Mountains. Mount Rainier, in the southeastern part, is a large volcanic cone that formed on top of this mountainous terrane.

The western part, in the Puget Lowland, is underlain by a great thickness of semiconsolidated and unconsolidated materials that partly fill the large north-south structural basin known as the Puget Trough. These materials include clay, silt, sand, gravel, glacial till (boulder clay), and thin strata of peat, and they extend in some places to depths exceeding 2,000 feet. They were deposited in lakes, or by streams, during Recent, Pleistocene, and late Tertiary time. The Pleistocene deposits consist largely of glacial drift laid down from the Vashon Glacier that occupied the area late in the ice age. Individual strata generally show marked changes in lithology; a clay stratum may grade laterally into a sand stratum, and a sand stratum may grade into gravel. These changes in lithology make stratigraphic correlation difficult and uncertain.

The water-bearing characteristics of the rock materials in the two geologic terranes are entirely different. The rocks that form the Cascade Mountains, with the possible exception of some of the lavas of Mount Rainier, have low porosity and permeability and absorb little precipitation. However, the thin layer of weathered rock, slopewash, and talus that mantles the mountains is both porous and permeable. This mantle absorbs part of the precipitation and discharges it by evaporation, transpiration, and spring flow.

The rock materials underlying the western part of the area vary rather widely in degree of permeability—from high in the strata of coarse sand, or sand and gravel, to low in the strata of clay, silt, fine sand, and till.

CLIMATE

The climate around the city of Tacoma is moderated by the nearby Pacific Ocean to the extent that winter tempertures in the Puget Sound lowland are usually above freezing and summer temperatures usually remain below 80°F. Precipitation is heavy during the winter and light in the summer. According to Thornthwaite (1931), the climate of most of the Puget Lowland would be classed as humid and the mountainous region would be classed as wet. However, precipitation in the summer is often so light that the climate of both regions for this season may be comparable to that of a subhumid or semiarid region.

The city of Tacoma and its immediate surroundings receive on an average less than 40 inches of precipitation per year, according to the records of the U.S. Weather Bureau. The average for the period of record, 1878–1955, is 38.65 inches and the normal, 1921–50, is 35.20 inches per year. An inspection of figure 1, an isohyetal map of annual average precipitation, indicates that appreciably more precipitation falls on the mountainous area to the east and that locally it may total more than 100 inches per year.

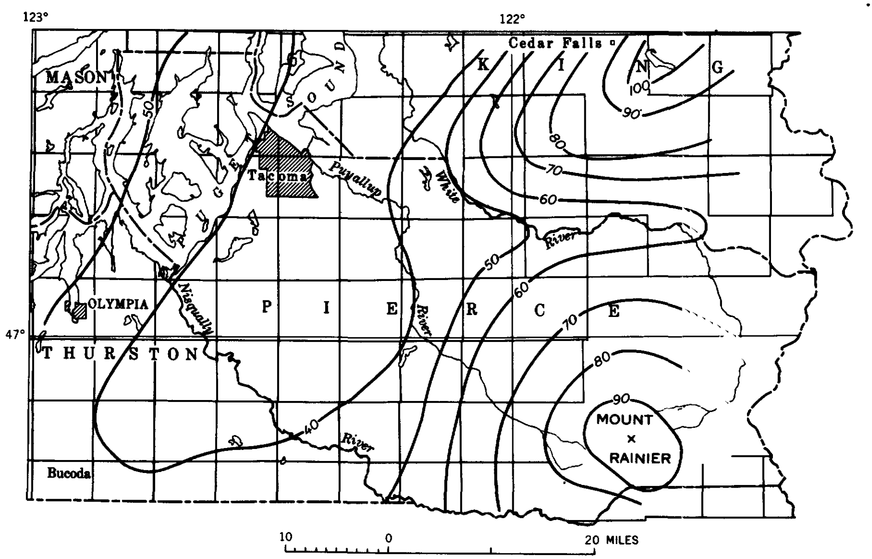

FIGURE 1.—Isohyetal map of average annual precipitation, in inches (data from U.S. Weather Bureau).

Figures 2 and 3 show the monthly precipitation at Tacoma and Longmire. The average July and August precipitation in the lowlands, as represented by Tacoma, corresponds closely with that in the mountains, as represented by Longmire. However, the average winter precipitation in the mountains greatly exceeds that in the lowlands. The monthly maximums and minimums were plotted to indicate the recorded ranges in precipitation at these two stations.

A large part of the winter precipitation in the mountains is snow, but most of that in the lowlands is rain. Consequently, much of the runoff from the mountains is delayed until the snowpack melts during spring months, whereas periods of maximum runoff in the lowlands correspond closely to periods of maximum precipitation.

The amount of precipitation at any location within the area varies greatly from year to year. The annual precipitation at Tacoma for the period of record beginning in 1878 is shown in figure 4. This figure shows that below-average precipation was recorded for as long as 9 consecutive years (1922–30), and above-average precipitation was recorded for 6 consecutive years (1899–1904). Such long periods of

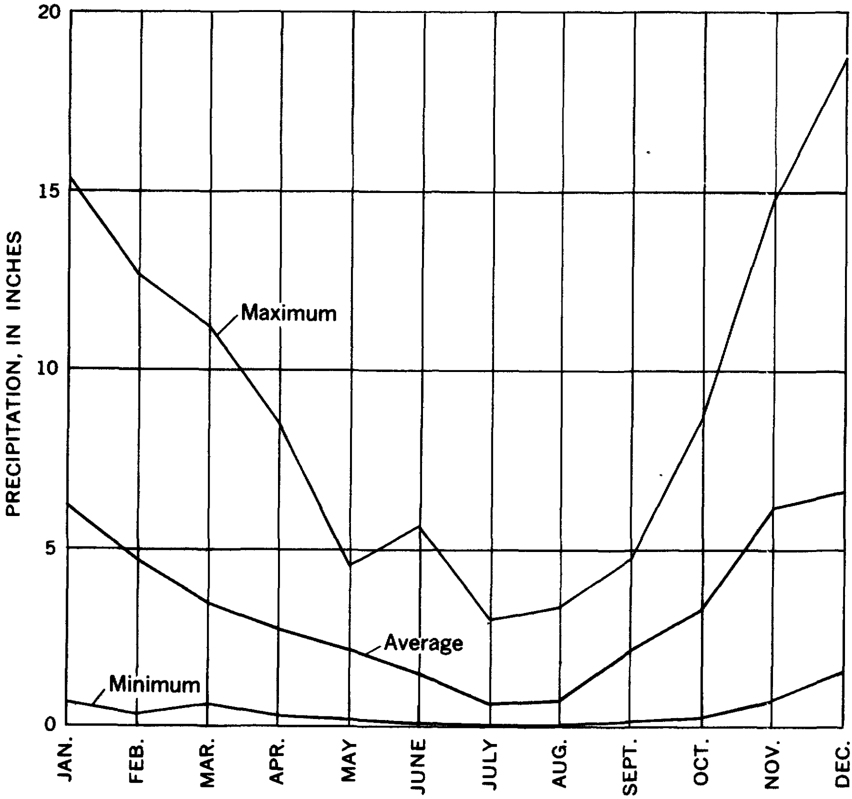

FIGURE 2.—Average, maximum, and minimum monthly precipitation recorded at Tacoma (data from U.S. Weather Bureau).

above- or below-average precipitation result in large changes in the supply of surface and ground water.

Temperatures are an important factor in the hydrologic regimen, for they determine whether precipitation will occur as snow or rain and therefore affect the outflow characteristics of a drainage basin. Temperatures are also an important factor in evaporation and transpiration; consequently, the water loss from a drainage area is a function of temperature.

The city of Tacoma has a typical marine climate with mild winters and warm, but not hot, summers. The highest temperatures occur during July and August and the lowest during December and January, as indicated in figure 5.

The amount of evaporation is largely dependent upon the temperature. In the Tacoma area the period of maximum evaporation potential coincides with the period of minimum precipitation. This relation (fig. 6) results in a much smaller water loss by evaporation than would result if the period of maximum evaporation potential

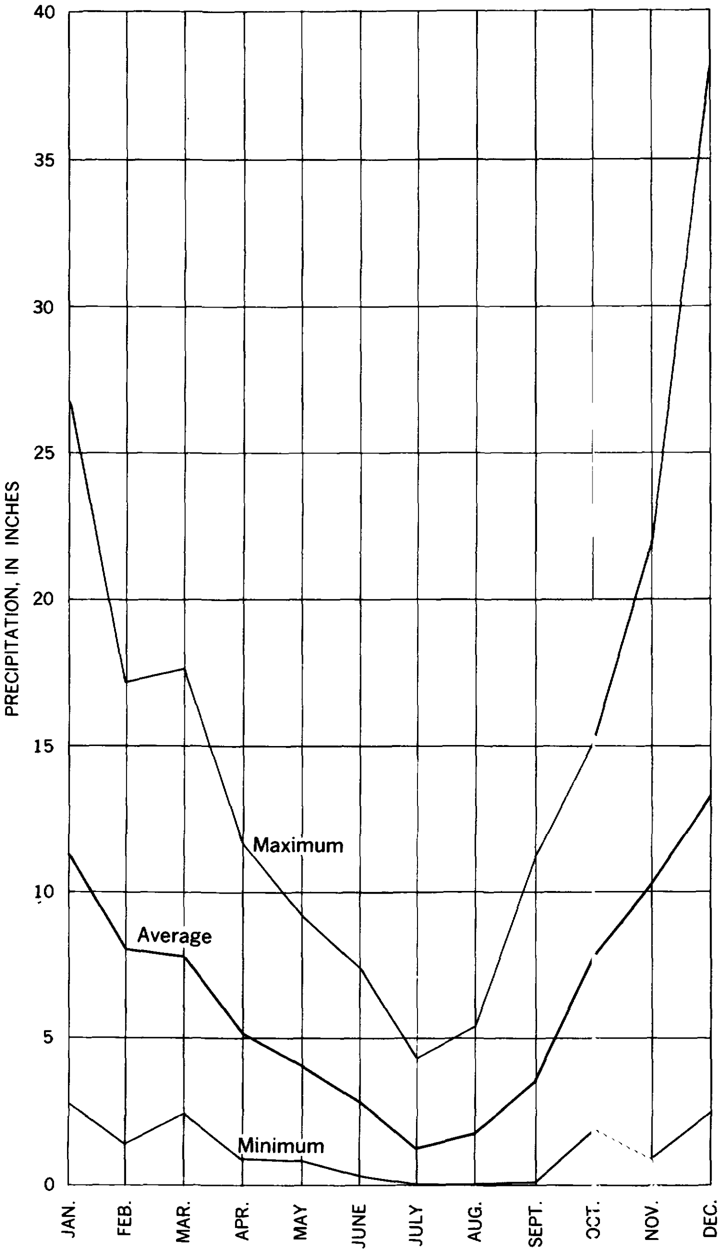

FIGURE 2.—Average, maximum, and minimum monthly precipitation recorded at Longmire (data from U.S. Weather Bureau).

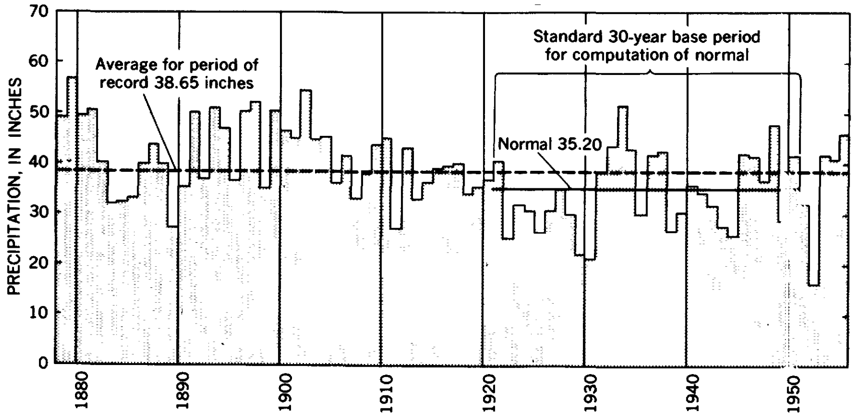

FIGURE 4.—Annual precipitation recorded at Tacoma, 1878–1955 (data from U.S. Weather Bureau).

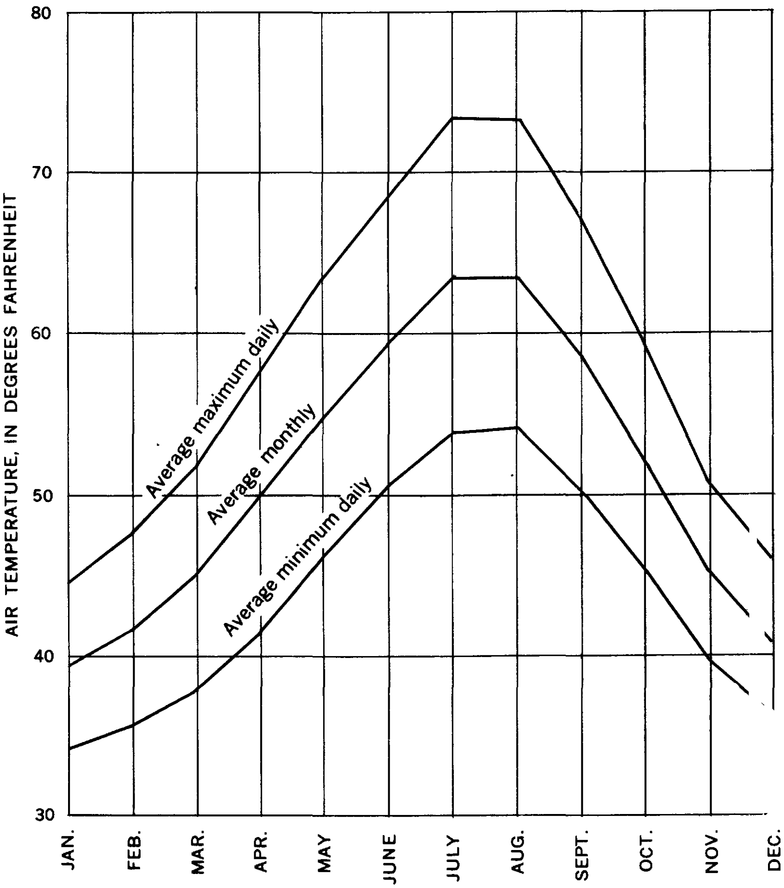

FIGURE 5.—Average maximum and minimum daily, and average monthly air temperature at Tacoma (data from U.S. Weather Bureau).

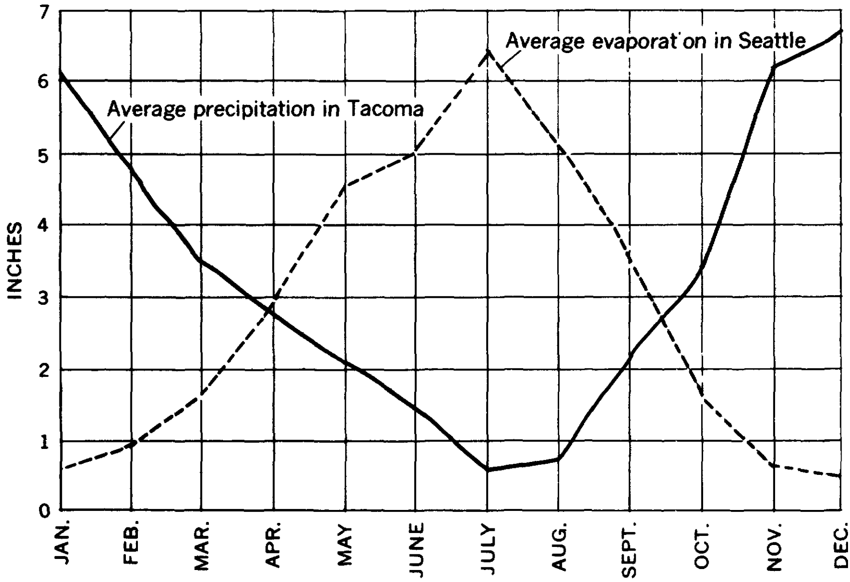

FIGURE 6.—Average precipitation at Tacoma compared to average evaporation at Seattle (evaporation measured in standard Weather Bureau pan; data from U.S. Weather Bureau).

coincided with the period of highest precipitation, or if precipitation were distributed more evenly throughout the year.

The out-of-phase relation of maximum precipitation to evaporation results in a greater runoff and a much greater recharge to aquifers than would otherwise occur. However, because the precipitation during the period of maximum evaporation potential (which is also the growing season) is small, there is need for supplemental irrigation—a need which is unusual in most areas receiving 38 to 50 inches of precipitation a year. Furthermore, the need for irrigation of lawns and gardens during the period of low precipitation results in additional loads on municipal water systems.

CULTURAL ENVIRONMENT

Utilization of water in the Tacoma area is closely related to the size and growth trends of communities, the size and kinds of industries, and to the types of agricultural enterprises. A brief review of these factors will aid in understanding present water use and in evaluating potential future water use.

POPULATION

The first permanent settlement in the Tacoma area, other than Indian villages was Nisqually House, established more than 100 years ago by the Hudson's Bay Co. on the bluff overlooking Nisqually Bay. Since that time, the Tacoma area has had a continuous increase in population.

By 1860 the population of what is now Pierce County had grown to 1,115. In 1869 the first townsite plat was filed for the area now known as the Oldtown section of Tacoma. When the Northern Pacific Railway was completed across the Cascade Mountains at Stampede Pass in 1884, a tremendous influx of settlers increased the population from 3,319 in 1880 to 50,940 in 1890. The building of other transcontinental railroads in the early 1900's caused further large increases in population. By 1940 the population of Pierce County had grown to 182,081. With the industrial expansion during World War II the County had another large increase in population, which reached 275,876 by 1950. The estimated population at the end of 1955 was about 300,000.

INDUSTRY

The Tacoma area supports a wide variety of industries, though the processing of forest products predominates in the industrial economy. Table 1 shows the number of manufacturing plants of various types in Pierce County; most of these industries are in the Tacoma metropolitan area.

TABLE 1.—*Manufacturing plants in Pierce County, 1955*

[Data from Washington Employment Security Department. Statistics are for the second quarter of the year]

Type	Establishments	Persons employed
Apparel and other fabricated products	11	544
Chemicals and allied products	26	921
Electrical machinery, equipment, and supplies	7	97
Fabricated metal products	26	457
Food and kindred products	60	2,609
Furniture and fixtures	32	1,240
Logging, lumber, and wood products	174	5,862
Machinery (except electrical)	21	387
Other durable goods manufacturing	29	345
Other nondurable goods manufacturing	5	27
Printing, publishing, and allied industries	38	734
Professional and scientific instruments	4	16
Pulp, paper, and allied products	8	1,359
Smelting, refining, casting	11	1,961
Stone, clay, and glass products	13	151
Transportation equipment	22	644
Total	487	17,354

Many of these industries, especially the paper, chemical, and primary metals industries, require large quantities of water. The St. Regis Paper Co. alone used an average of 20.1 mgd (million gallons per day) in 1955.

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AGRICULTURE

Agriculture, consisting principally of dairying and the cultivation of berries, vegetables, and bulbs, ranks high in the economy of the Tacoma area. The Puyallup River valley produces more raspberries, blackberries, and daffodil bulbs than any other section of the State.

In 1950 the total farm land in Pierce County, according to the U.S. Census of Agriculture, was 165,932 acres. Census data show that small farms are becoming fewer and that the average size of a farm is increasing. The larger size of farms and the increased intensity of cultivation practiced in recent years have resulted in a greater use of irrigation within the area.

NATURAL RESOURCES

Other than water, the most valuable resource of the Tacoma area is its forests. The harvest of fir, hemlock, and cedar furnishes a wide variety of forest-product manufacturing and sales, including lumber, plywood, poles, shingles, pulp, paper, and Christmas trees. An abundant supply of alder supports a large furniture-manufacturing industry In 1952, 233 million board feet of timber was harvested in Pierce County.

The production of sand and gravel is the most important mining industry in the area, and the deposits are very extensive. Some coal of Eocene age is produced from mines along the foothills of the Cascades, but production has dropped appreciably in the last few decades.

Salmon and other fish in Puget Sound sustain a fairly large sport and commercial fishery.

OCCURRENCE OF WATER

Precipitation is the source of all fresh water supplies. Of the precipitation that reaches the ground, part evaporates, part infiltrates the soil and rocks, and part runs off directly to the streams. The infiltration and runoff are delayed if the water is held at the surface as snow or glacial ice. A small amount of the water that infiltrates the ground is evaporated directly from the soil; a larger amount is held by capillary forces until it is returned to the atmosphere by plant transpiration, and the remainder percolates downward to the water table. The water that reaches the ground-water bodies moves slowly under the influence of gravity toward points or areas of discharge. Ground-water discharge occurs naturally by evapotranspiration or by flow through seeps and springs, which may be either at the land surface or below the surfaces of streams and lakes or of Puget Sound. The circulation of water from atmosphere to earth and back to the atmosphere is called the hydrologic cycle. The cycle usually is complex and is controlled by such factors as climate, topography, and geology.

Locally, the hydrologic cycle is greatly influenced by the presence of Mount Rainier. This mountain intercepts moisture-laden prevailing winds with the result that precipitation amounting to more than 100 inches annually falls at higher altitudes along the western face of the mountain. Much of this precipitation is in the form of snow, which may be held for several months (or where in the form of glaciers, for many years) before melting to augment the streamflow or the ground-water supply. Thus, the hydrologic cycle is further complicated in this area by the fact that the glacier-melt runoff represents the release of precipitation stored in prior years, whereas the growth of glaciers represents the impoundment of current precipitation.

Streamflow is highly variable; it varies greatly not only from day to day, but from year to year, as shown in figure 7. The magnitude and frequency of floods and low flows, the storage required to maintain a given flow, and the maximum time that the discharge will be less than a given flow are characteristics of a stream that must be evaluated before the resource can be developed efficiently. These characteristics are illustrated in this report by duration curves, low-flow frequency curves, curves showing maximum period of deficient discharge, draft-storage curves, hydrographs of daily or annual flow, and flood-frequency curves.

Flow characteristics for different areas may appear to be dissimilar because records for different years were used in comparison. Other records may be dissimilar because of different hydrologic conditions in the drainage basins. In order that flow characteristics for different areas may be compared, the curves should represent the same period of time, so that the meteorological trends influencing one record may be reflected in the other record also. Where records do not represent the same length of time, those for the shorter period can be adjusted to those for the longer period. Such adjustments were made in this report in the construction of duration curves for selected gaging stations; a 25-year period (water years 1930–54) was used.

By means of a regional study, adjustments to a 24-year base period (April 1, 1930 to March 31, 1954) were made in the tabulations and curves showing the magnitude and frequency of annual low flows (see p. 33). Tables giving storage requirements are for the entire period for which records were collected.

Gaging-station records for the major rivers and their tributaries and for other smaller streams in the study area were collected at the

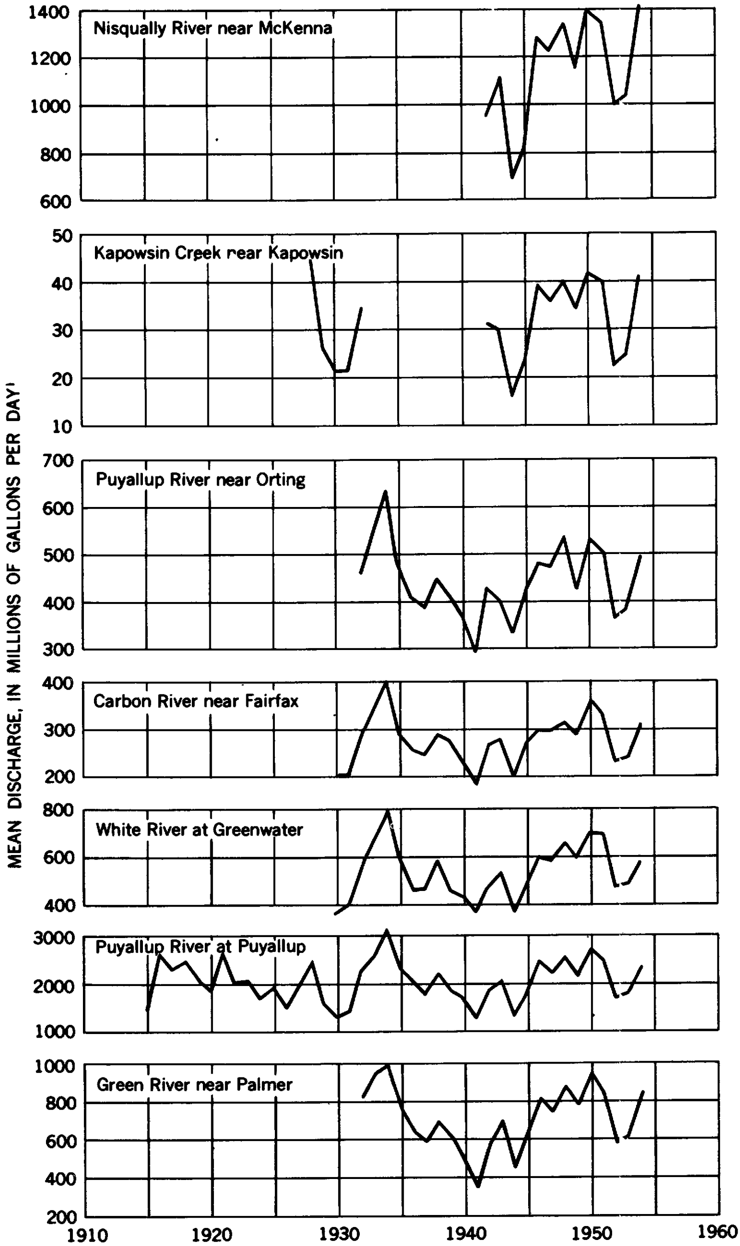

FIGURE 7.—Hydrographs of annual discharge at selected gaging stations.

places shown on plate 1. A few gaging-station records were started early in the present century. All the larger streams have been gaged at one or more sites for a period of at least sufficient length to include periods of major floods and droughts.

Of the water that infiltrates the soil, part is retained by capillary forces, and the rest continues to move downward by the force of gravity until it reaches the water table, the upper surface of the zone in which the rocks are saturated with water. At places a stratum of hardpan or clay may impede the downward percolation of water and cause it to collect in a zone of saturation above the regional water table. This zone of saturation may be a perched or semiperched water body, depending upon local conditions. The rate at which water will infiltrate the ground and recharge the aquifers is governed by the character of both the surface and the subsurface materials. The lateral flow of water through the aquifers—from areas of higher hydrostatic head to areas of lower hydrostatic head—is largely determined by the amount of this difference in head and by the thickness, permeability, and areal extent of the aquifers. These characteristics also largely determine the yield that can be obtained from wells.

Where the aquifer is confined beneath some relatively impermeable stratum, the elevation of the piezometric surface (the height to which water will rise in a cased well) may be considerably different from that of the water table. Wells tapping confined aquifers are called artesian wells, and if the piezometric surface happens to be above the land surface such wells will flow.

In this report the discussion of aquifers is restricted to those in that part of the Tacoma area lying within the Puget Lowland. Here the aquifers are permeable strata in unconsolidated and semiconsolidated glacial and alluvial deposits. The permeability of the bedrock underlying these deposits is probably low. As this bedrock lies at great depth under most of the lowland, it will not be considered further. In the Tacoma area there are five rock units which contain aquifers or serve as aquifers. These are (a) Recent alluvium, (b) till of the Vashon glaciation, (c) outwash of the Vashon glaciation, both above and below the till, (d) pre-Vashon unconsolidated deposits of Pleistocene age, and (e) older semiconsolidated sedimentary deposits. The character and water-bearing properties of these units are described in outline form in table 12 (p. 82). Their areal extent is shown on plate 2 except for (b), which is not shown because the water-bearing units in it are small and scattered.

Natural waters contain dissolved salts and gases and may retain significant amounts of sediment in suspension. The kinds of rocks in contact with the water and the rate of flow determine to a large extent the quality of the water. The ranges in the concentration of dissolved materials will usually be much wider for surface waters than for ground waters; however, the concentrations in ground waters will generally average higher than those in streams. The sedimentation and turbidity problem in this area is most noticeable in the glacial streams, which at times transport large quantities of sediment. Streams of nonglacial origin are almost sediment free except during periods of high discharge. The quality of the water is a factor that must be taken into consideration in the economic evaluation of both surface- and ground-water supplies.

TACOMA UPLAND

The broad Tacoma Upland is bordered by the Puyallup River Valley on the north and northeast, Puget Sound on the west, the Nisqually River Valley on the southwest, and the Ohop Valley on the southeast. The part of the upland within the Tacoma area is shown on plate 2. It is, in general, a flat-topped upland that slopes gently northwestward.

Most of the city of Tacoma, several small towns, and many rural residential districts are located in the northern half of the upland. The Fort Lewis Military Reservation occupies most of the western part. The southeastern part is largely unsettled, although it does support some agriculture.

Water supplies for most of the Tacoma Upland are obtained locally from wells and springs tapping outwash sand and gravel deposits and the underlying pre-Vashon unconsolidated deposits, and from the small streams draining the area. However, substantial additional quantities are imported from the Green River by the city of Tacoma. Although there are no large streams in the Tacoma Upland, the Nisqually and Puyallup Rivers as well as the waters of Puget Sound are available as sources of water for the area.

The principal uses of water withdrawn in the upland are for public water-supply systems and institutional supplies; however, the amount used for irrigation is increasing. As most industries are in the valleys, the quantity of water used by industry in the upland is small compared with that used for other purposes.

There is considerable interchange between surface and ground water on the Tacoma Upland. Many of the small lakes and ponds are fed by ground-water discharge from semiperched or perched aquifers. Downward percolation from the ponds and from semiperched and perched aquifers recharges the underlying zone of saturation. In the western part of the upland, water-table aquifers in the upper part of the main zone of saturation discharge into American, Gravelly, and

Steilacoom Lakes, along the eastern sides of these lakes. American and Gravelly Lakes, which have no surface outlets, lose water by evaporation and by seepage along their west margins. The western edge of American Lake is slightly above the adjacent water table; this higher level results in a large amount of outflow into the adjacent aquifers. Sequalitchew Springs, which are within a quarter of a mile of the southwestern end of American Lake, discharge about 10,000 gpm (gallons per minute); this discharge is chiefly subsurface outflow from American Lake.

GROUND WATER IN THE TACOMA UPLAND

The aquifers beneath the Tacoma Upland are recharged by precipitation on the upland and locally to a minor extent by water imported to the upland from the Green River by the Tacoma water system. The Puyallup River Valley and its southward continuation, the Ohop Valley, which isolate the Tacoma Upland from the foothills area, preclude any recharge from the Cascade Mountains.

The entire Tacoma Upland, an area of approximately 360 square miles, normally receives about 38 inches of precipitation a year. This is equivalent to about 730,000 acre-feet per year, or 650 mgd, for the entire upland. It is estimated that 50 to 60 percent of the precipitation, or 360,000 to 440,000 acre-feet per year, may become ground-water recharge. This is equivalent to 1,000 to 1,200 acre-feet per square mile, or 0.9 to 1.1 mgd per square mile.

From these estimates, it is apparent that the water supply for the city of Tacoma, which averaged about 55 mgd in 1952, would require a minimum recharge area of 50 to 60 square miles if supplied entirely from ground water. Continuous withdrawals of this magnitude, however, would affect the water regimen over a much larger area by reducing natural discharge.

Most of the natural ground-water discharge takes place through springs and seeps around the margins of the upland into the Puyallup or Nisqually River valleys or directly into Puget Sound. One of the largest, Maplewood Spring near Puyallup, has a discharge which at times exceeds 20 mgd or 30 cfs (cubic feet per second).

AQUIFERS

In the Tacoma Upland, outwash sand and gravel deposits and the underlying pre-Vashon unconsolidated deposits include the most productive aquifers. Glacial till and the older semiconsolidated sediments generally yield only small amounts of water to wells (fig. 8).

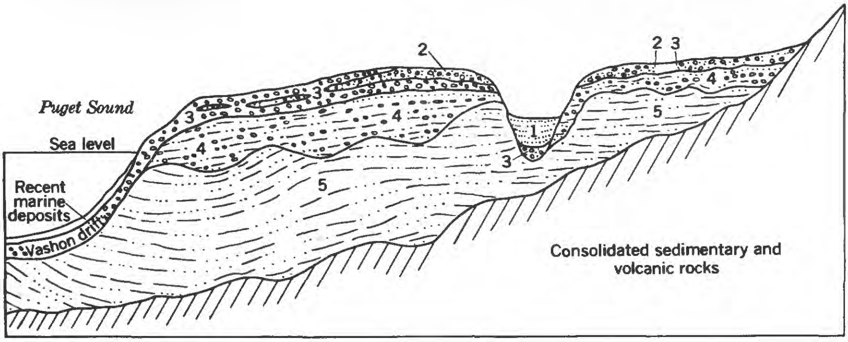

FIGURE 8.—Diagrammatic section of the Tacoma area showing the rock units that include aquifers; 1, alluvium; 2, till of the Vashon glaciation; 3, outwash deposits of the Vashon glaciation; 4, pre-Vashon unconsolidated deposits; 5, older semiconsolidated sediments.

Part of the Tacoma Upland is mantled by till from the Vashon glaciation in an unsorted mixture of clay, silt, sand, gravel, and boulders, which was deposited directly by ice during the last advance of a glacier into the Tacoma area (fig. 9). The till is generally light gray and has almost the appearance of concrete.

FIGURE 9.—Typical till of the Vashon glaciation.

The till of the Vashon glaciation is not a productive aquifer, but where it is sufficiently thick (20–30 feet) it generally will yield small supplies of perched ground water to large diameter wells. The till is an important aquifer for small water requirements, especially in areas where the regional water table is at a depth of 100 or more feet below the surface. In such areas a 15- to 25-foot well may furnish a supply adequate for domestic requirements, whereas a 200- to 300-foot well would be required if the water were not obtained from the till.

The outwash deposits, which consist mostly of coarse sand and gravel (fig. 10), are the most productive aquifers in the Tacoma

Figure 10.—Typical sand and gravel outwash deposits of the Vashon glaciation.

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Upland as well as elsewhere in the report area. The broad prairies in the region south of Tacoma are underlain by sand and gravel, which were deposited by large meltwater streams that flowed westward across the area during both the advance and recession of the ice. The recessional outwash material in this area is mostly coarse gravel and ranges from a few feet to more than 200 feet in thickness. Where these deposits are thin, they generally lie above the water table and do not serve as aquifers. However, where they do extend below the water table, they are productive aquifers. The advance outwash materials, which probably are as much as 100 feet thick, generally contain a larger proportion of sand than the recessional outwash and, at some places, are chiefly sand; but, at others, lenses of coarse sand and gravel are important aquifers. The recessional outwash is missing or is confined to narrow channels between till ridges at many places on the uplands, but the advance outwash may underlie both the channels and the ridges.

Locally, the outwash materials have a transmissibility of more than 2,000,000 gpd per foot, a very high value for sand and gravel. They have a great lateral variation in transmissibility, however, as shown by table 2.

TABLE 2.—*Coefficients of transmissibility of aquifers in different parts of the Tacoma area*

Subarea	Aquifer	Coefficient of transmissibility	Well symbol (pl. 3)
Tacoma Upland	Outwash of Vashon glaciation	58,000	*FF*
	Do	[1] 93,000	*V*
	Do	60,000	*AA*
	Do	[1] 750,000	*S*
	Do	[1] 2,900,000	*M*
	Pre-Vashon unconsolidated deposits	14,000	*W*
	Do	[1] 8,500	*Y*
	Do	[1] 13,000	*Z*
	Do	22,000	*L*
	Do	[1] 36,000	*P*
Puyallup River Valley	Recent alluvium	1,000	*J*
	Pre-Vashon unconsolidated deposits	[1] 21,000	*DD*
Buckley Upland	Outwash of Vashon glaciation	25,000	*EE*
Northeast Tacoma Upland	Pre-Vashon unconsolidated deposits	35,000	*A*
	Do	[1] 5,900	*D*
	Older semiconsolidated deposits	14,000	*B*

[1] Based on pumping-test data supplied by Robinson and Roberts, ground-water consultants, and analyzed by U.S. Geological Survey.

Because of the high transmissibility of these outwash aquifers, wells tapping them have the greatest specific capacities and the greatest yields of any wells in the Tacoma area. The greatest specific capacity observed was that of a well at the city of Tacoma Utilities Building (*R*, pl. 3) which was pumped as a rate of 2,500 gpm (gallons per minute) for 4 hours; at the end of this period it had a drawdown of 2.2 feet and a specific capacity of almost 1,140 gpm per foot.

Another well, Tacoma well 11–A (*S*, pl. 3) pumped at a rate of 9,130 gpm for 24 hours with a drawdown of 24.2 feet, showed a specific capacity of about 377 gpm per foot of drawdown. Well 11–A is in Tacoma's municipal well field in an abandoned outwash channel passing through South Tacoma. This and other large-capacity wells at this field receive most of their water from outwash sand and gravel aquifers at depths generally less than 150 feet below land surface.

A well owned by the Lakewood Water District (*V*, pl. 3) is 110 feet deep and obtains water from an outwash aquifer. Although it yields 2,300 gpm, the drawdown is about 65 feet, and the specific capacity, about 35 gpm per foot of drawdown, is much smaller than that of the city of Tacoma wells. Elsewhere in the Tacoma Upland, a few wells that obtain water from outwash aquifers have specific capacities exceeding 300 gpm per foot.

A few other wells receive water from shallow outwash aquifers, but owing to the belief that the shallow aquifers are easily contaminated, many public-supply and institution wells extend through these deposits and tap underlying aquifers. This is particularly true for the heavily populated suburban area immediately south of Tacoma.

For the Tacoma area as a whole, the contact between the deposits of Vashon age and the underlying pre-Vashon unconsolidated deposits is unconformable. This contact ranges from about 700 feet above sea level to 300 feet or more below sea level. In the Tacoma Upland, as well as elsewhere, aquifers in the pre-Vashon unconsolidated deposits are sand and gravel (fig. 11); these generally have transmissibilities much lower than those of the outwash aquifers (table 2). The deeper wells of the city of Tacoma, which are as much as 356 feet in depth, receive water chiefly from aquifers of pre-Vashon age. Although the yields from these deeper sand and gravel aquifers are large, they generally are considerably less than the yields from the overlying outwash deposits. Clay and silt strata are common in the pre-Vashon unconsolidated deposits, and even though at many places in the Tacoma Upland moderately large supplies of water are obtained from properly constructed wells, some wells have been drilled several hundred feet without penetrating large-capacity aquifers.

The altitude of the top of the older semiconsolidated deposits ranges from about 700 feet above sea level where the deposits are exposed along the Mashel and Nisqually Rivers near LaGrande to more than 600 feet below sea level near the mouth of the Puyallup River. Where the older semiconsolidated deposits are overlain by the pre-Vashon unconsolidated deposits, the contact between the two

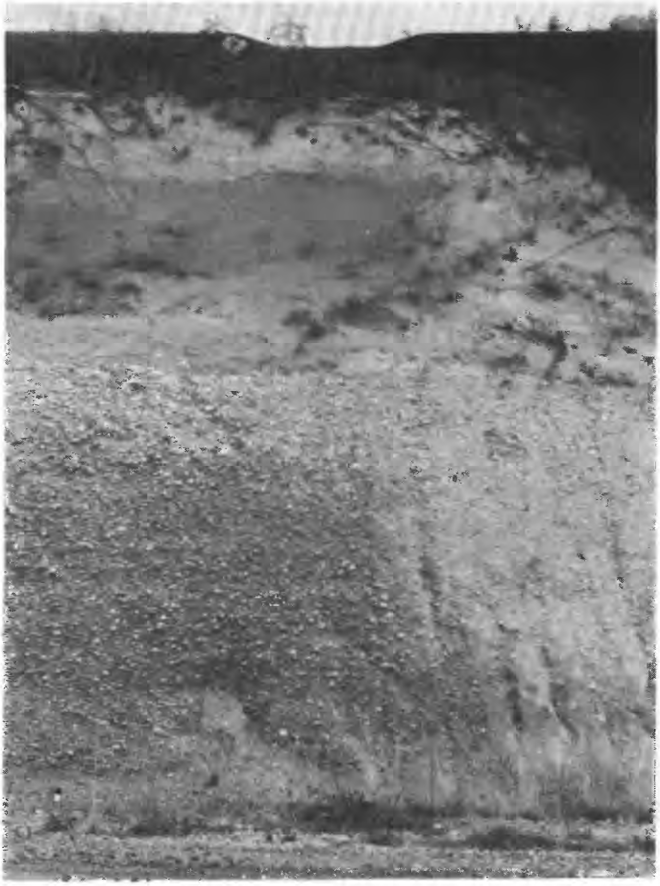

FIGURE 11.—Typical sand and gravel strata in the pre-Vashon unconsolidated deposits.

is not always apparent in well logs because of the similarity of lithology in the two materials. Through that part of the area in which the two can be distinguished, the altitude of the contact seems to range from 500 feet above sea level to as much as 600 feet below sea level.

Sand or sand and gravel strata or lenses in the older semiconsolidated deposits serve as aquifers for many deep wells in the Tacoma area. Large yields, at places exceeding 1,000 gpm, have been developed from aquifers in these deposits. However, such yields are not common, and specific capacities of wells and aquifer transmissibilities are generally smaller in the semiconsolidated than in the unconsolidated deposits. For example, a test of well *B* (pl. 3; table 2) indicated a transmissibility of 14,000 gpd per foot. This well is considered one of the more productive wells tapping these semiconsolidated materials. The typically lower transmissibility of these older deposits is due partly to a greater proportion of fine-grained material (fig. 12). On the Tacoma Upland, attempts to obtain large

FIGURE 12.—Typical clay and silt strata in the older semiconsolidated deposits.

quantities of water from these deposits have not been very successful; for example, well *X* (pl. 3), which is 2,261 feet deep, was drilled mostly through clay, silt, and fine sand of the semiconsolidated deposits for the bottom 2,000 feet, before an adequate yield was obtained.

For the area as a whole, deep drilling in quest of large supplies of water seems practical only if a satisfactory supply cannot be obtained from shallower wells and if another source is not available.

WATER LEVELS AND WATER-LEVEL FLUCTUATIONS

Fluctuations of water levels in wells tapping an aquifer result from a combination of several factors, including variations in the rates of natural and artificial recharge, natural discharge, and pumpage. In the vicinity of wells being pumped at varying rates, water-level fluctuations reflect these variations. Water levels in wells obtaining water from confined aquifers are affected also by barometric changes and at places by tidal changes. However, these barometric and tidal changes generally cause only small fluctuations of water levels in wells in the Tacoma area.

Water levels in wells on the Tacoma Upland range from more than 250 feet below land surface to about 20 feet above the land surface. Beneath most of the upland, water levels are less than 60 feet below the land surface, although in the Midland, Summit, and Woodland areas, water levels range from about 100 to 200 feet below the surface. In general, water levels are lower in wells around the margin of the upland than in wells near the center of the upland.

The altitude of the water table is shown by contour lines on plate 3. Because the direction of movement of ground water in any area generally is normal to the contours, it is apparent that most of the ground water beneath the Tacoma Upland moves northward or northwestward.

Water levels in the Tacoma Upland have a marked seasonal fluctuation. Rising water levels indicate a period when recharge exceeds discharge, and declining water levels indicate periods when discharge exceeds recharge. The magnitude of fluctuations varies from aquifer to aquifer and from place to place. Generally, however, the range of annual fluctuation is about 7 feet, although water levels fluctuate as much as 20 feet in some of the shallow perched or semiperched aquifers and less than 4 feet in some of the deeper aquifers. Low-water levels generally occur in late fall or early winter and high-water levels in late winter or spring. Figure 13 shows typical hydrographs for perched, water-table, and confined aquifers in the Tacoma Upland.

To date, no marked perennial decline of water levels is known in the Tacoma area. A small decline in the South Tacoma area (see well *O*, fig. 14) that has occurred since 1951 is largely due to deficient precipitation but may in small part be due also to ground-water withdrawals in that area.

QUALITY OF GROUND WATER

Many wells and springs in the Tacoma Upland furnish water of excellent quality. Productive outwash sands and gravels deposited by meltwater streams yield water suitable for public supplies. The dissolved-solids and silica content and the hardness of water from several wells tapping sand and gravel aquifers are shown in figure 15. The average concentration of dissolved solids in samples from 36 wells and springs was 95 ppm (parts per million), and the average hardness of the samples was 48 ppm.

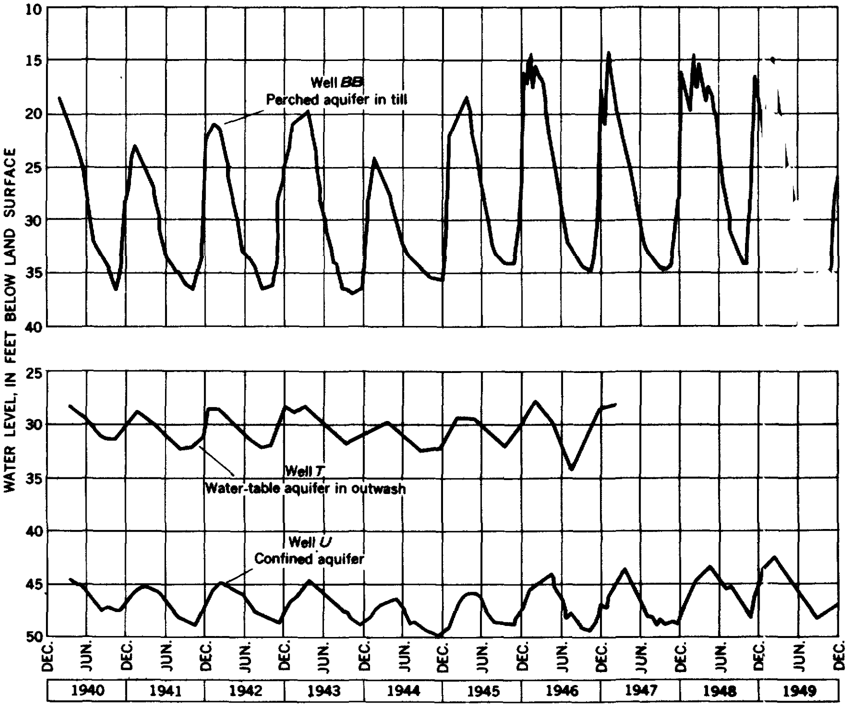

FIGURE 13.—Hydrographs of wells typical of perched, water-table, and confined aquifers in the Tacoma Upland.

Water from 3 wells ranging in depth from 125 to 151 feet (fig. 10) is typical in chemical quality of that obtained from outwash deposits of Vashon age. A chemical analysis of typical water from one of these wells (*N*, pl. 3) is given in the following tabulation (date of sampling, April 21, 1952):

	Parts per million		*Parts per million*
Silica (SiO_2)	31	Chloride (Cl)	5.3
Iron (Fe)	.11	Fluoride (F)	.1
Calcium (Ca)	8.8	Nitrate (NO_3)	4.3
Magnesium (Mg)	8.0	Dissolved solids	100
Sodium (Na)	5.5	Hardness as $CaCO_3$	55
Potassium (K)	1.2	pH value	7.3
Bicarbonate (HCO_3)	54	Color units	3
Sulfate (SO_4)	11		

Many wells in the pre-Vashon unconsolidated deposits of the Tacoma Upland yield water of remarkably constant chemical composition. Well *X* (pl. 3), 1,008 feet deep, yielded water in which the concentration of dissolved solids in samples taken in 1947, 1951, and

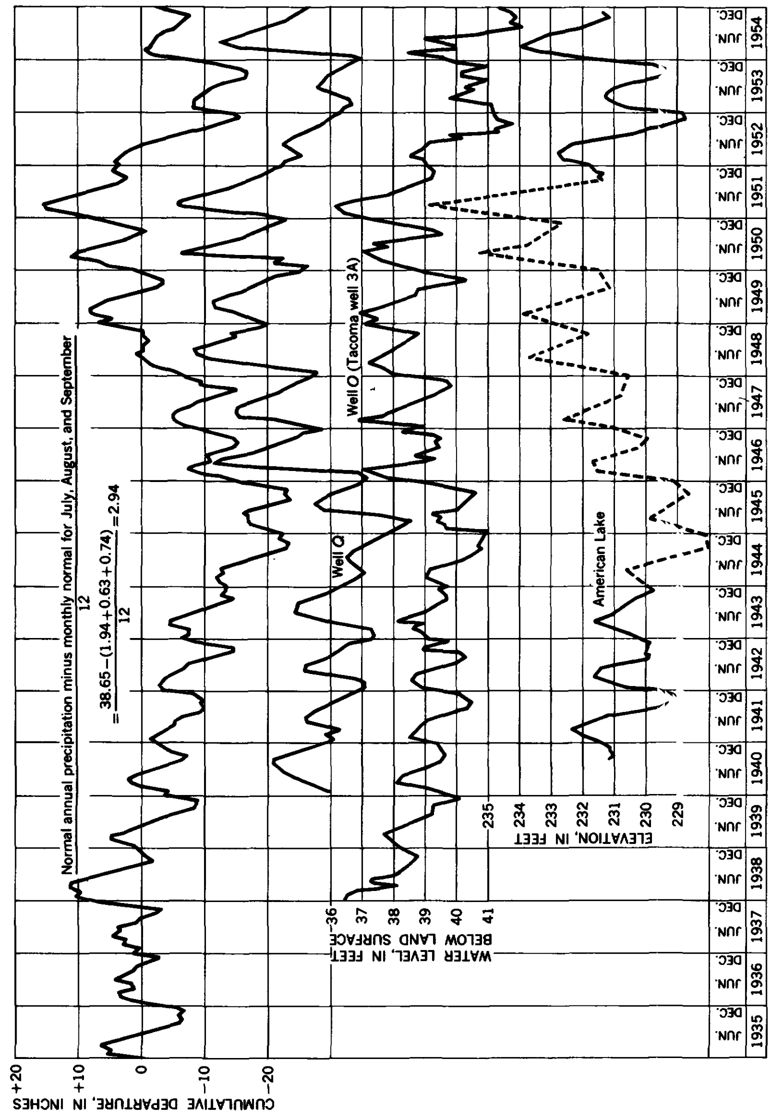

FIGURE 14.—Levels of two wells in the Tacoma Upland and American Lake compared to the cumulative departure of precipitation from normal at Tacoma.

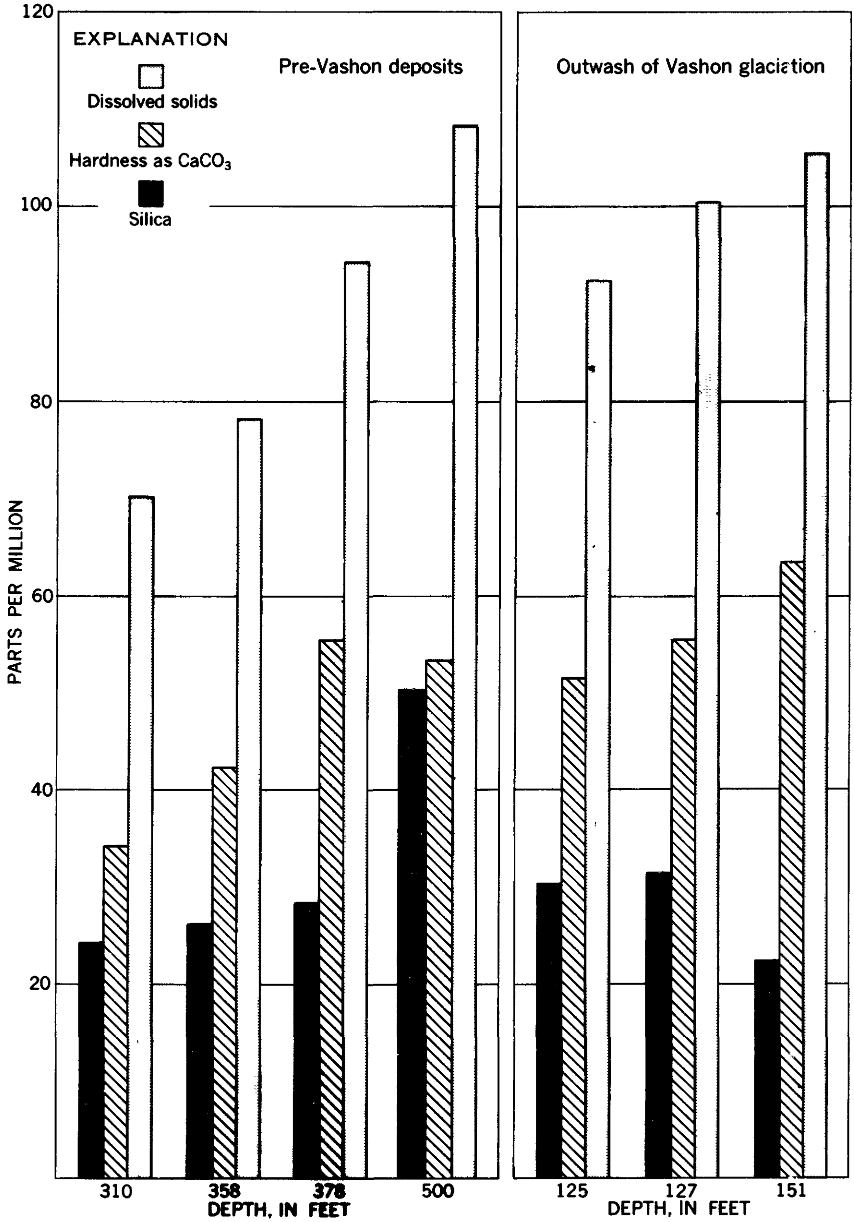

FIGURE 15.—Dissolved solids and silica in water and hardness of water from sand and gravel aquifers.

1954, ranged from 101 to 108 ppm. Analyses of water from this well are listed in table 3.

TABLE 3.—*Composition of water from well (X, pl. 3) 1,008 feet deep, tapping the pre-Vashon unconsolidated deposits in the Tacoma Upland*

[Analytical results in parts per million except as indicated]

Composition of water	Year sample collected		
	1947	1951	1954
Silica (SiO_2)	53	48	48
Iron (Fe)	.06	.07	.10
Calcium (Ca)	7.8	7.8	9.0
Magnesium (Mg)	5.2	5.0	5.3
Sodium (Na)	9.1	7.2	6.3
Potassium (K)	9.1	5.3	2.7
Bicarbonate (HCO_3)	66	68	66
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	2.6	3.1	4.0
Chloride (Cl)	2.3	2.4	2.4
Fluoride (F)	.2	.1	.2
Nitrate (NO_3)	.0	.2	.0
Dissolved solids:			
Residue on evaporation at 180°C	108	104	101
Sum	113	113	110
Hardness, as $CaCO_3$	41	40	44
Noncarbonate	0	0	0
Specific conductance, in microhmos, at 25°C	112	113	117
pH	7.7	7.7	7.3

CHAMBERS CREEK

Chambers Creek, one of the small streams draining the Tacoma Upland, carries the outflow from Steilacoom Lake to Puget Sound, a distance of about 4 miles. The flow of the Creek is measured about 1½ miles downstream from Steilacoom Lake outlet and a quarter of a mile downstream from Leach Creek (station 17, pl. 1); it is partly regulated by gates at the outlet of Steilacoom Lake. There are some diversions above the gage. Additional descriptive information for the gaging station is given in table 13.

The average flow of the creek during the period of record, water years 1938–40 and 1944–54, was 72 mgd (112 cfs). The lowest daily flow during the same period was 20 mgd (31 cfs). Flow-duration data for the period of record are given in figure 16. (See also table 4.) The relatively flat slope of the curve indicates less variability in the partly regulated daily flow of Chambers Creek than in most streams.

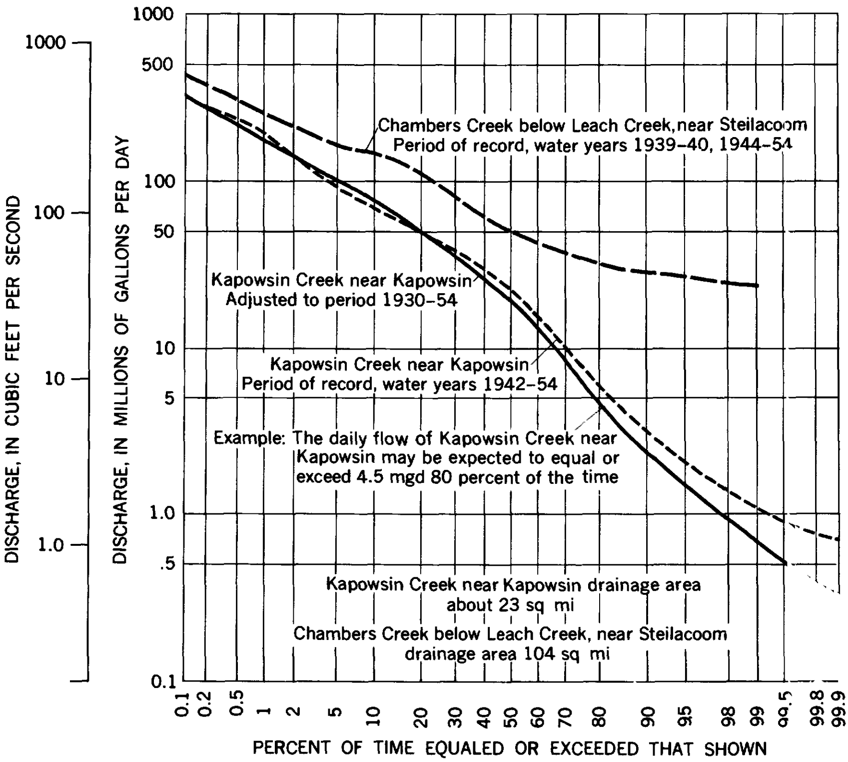

FIGURE 16.—Duration curve of daily flow, Chambers Creek and Kapowsin Creek.

TABLE 4.—*Duration of daily flow*

Station (pl. 1)	Stream and location	Water years	Flow, in million gallons per day, which was equaled or exceeded for indicated percentage of time										
			1	2	3	5	7	10	15	20	25	30	40
17	Chambers Creek below Leach Creek	1939, 1940	268	220	199	177	164	149	127	108	92	80	63
		1944–54											
20	Kapowsin Creek near Kapowsin	1942–54	188	145	122	97	92	71	58	49	43	37	29
		1930–54	175	140	122	99	93	74	60	50	42	36	26
21	Puyallup River near Orting	1930–54	1,690	1,310	1,120	950	830	740	650	580	530	490	421
22	Carbon River near Fairfax	1930–54	1,070	810	700	590	530	473	418	371	331	300	252
24	South Prairie Creek at South Prairie	1950–54	840	650	550	432	362	303	252	220	196	181	148
		1930–54	755	600	520	432	373	318	259	220	189	165	130
27	Puyallup River at Alderton	1944–54	4,150	3,200	2,700	2,300	2,010	1,800	1,600	1,400	1,270	1,180	1,020
		1930–54	3,900	3,000	2,600	2,150	1,930	1,700	1,500	1,300	1,200	1,120	950
28	White River at Greenwater	1930–54	1,880	1,580	1,430	1,230	1,100	983	842	745	670	609	516
29	Greenwater River at Greenwater	1930–54	584	484	432	370	333	296	244	208	177	155	118
31	White River near Buckley	1944–54	3,400	2,850	2,550	2,200	2,000	1,750	1,500	1,350	1,220	1,100	930
		[1] 1930–54	3,300	2,750	2,450	2,100	1,900	1,650	1,400	1,250	1,120	1,020	850
37	Puyallup River at Puyallup	1915–54	8,000	6,200	5,300	4,500	4,050	3,600	3,150	2,800	2,500	2,300	2,000
		1930–54	7,800	6,000	5,200	4,400	3,900	3,500	3,050	2,750	2,500	2,300	2,000
47	Green River near Palmer	1932–54	3,450	2,580	2,220	1,850	1,620	1,400	1,170	1,050	930	820	650
		1930–54	3,450	2,580	2,220	1,850	1,620	1,430	1,220	1,000	880	790	620

TABLE 4.—*Duration of daily flow*—Continued

Station (pl. 1)	Stream and Location	Water years	Flow, in million gallons per day, which was equaled or exceeded for indicated percentage of time											
			50	60	70	75	80	85	90	93	95	97	98	99
17	Chambers Creek below Leach Creek	1939, 1940 1944-54	52	45	38	35	33	31	29	28	27	26	25	--------
20	Kapowsin Creek near Kapowsin	1942-54	22	16	10	7.5	5.5	4.0	2.9	2.30	1.95	1.60	1.38	1.12
		1930-54	18	13	7.9	6.0	4.5	3.2	2.3	1.75	1.45	1.08	.89	.66
21	Puyallup River near Orting	1930-54	361	313	272	249	227	205	175	155	139	119	105	86
22	Carbon River near Fairfax	1930-54	213	178	150	136	122	107	91	80	71	61	54	46
24	South Prairie Creek at South Prairie	1950-54	121	96	72	60	45	34	28	25	24	22	21	20
		1930-54	102	80	58	47	38	31	26	23	21	19	18	17
27	Puyallyp River at Alderton	1944-54	885	766	657	600	556	495	434	381	346	293	258	197
		1930-54	823	714	600	543	491	429	359	315	285	250	228	197
28	White River at Greenwater	1930-54	441	374	318	287	261	231	199	179	164	147	136	123
29	Greenwater River at Greenwater	1930-54	91	67	49	42	36	31	27	24	23	21	20	18
31	White River near Buckley	1944-54	800	680	570	520	470	420	360	325	292	255	233	202
		[1] 1930-54	720	610	510	460	410	365	310	275	245	210	188	159
37	Puyallup River at Puyallup	1915-54	1,700	1,490	1,300	1,200	1,110	1,030	930	860	770	680	620	530
		1930-54	1,730	1,510	1,300	1,200	1,090	980	860	770	700	620	560	480
47	Green River near Palmer	1932-54	500	370	245	195	155	125	103	92	85	77	73	69
		1930-54	475	350	230	180	145	120	98	89	82	75	72	67

[1] Flow that could have been expected if Mud Mountain Reservoir had been in operation the entire period.

The water of Chambers Creek is soft, low in dissolved solids, and of excellent chemical quality. Two samples collected from the creek at high and low stages show that the water contains a slightly higher concentration of mineral substance in the summer when the flow is low, although the difference is negligible. About 20 percent of the residue on evaporation is silica, a principal constituent of waters in the region. Water in Chambers Creek is practically sediment free. In nine samples for which data are reported in table 18, concentrations of suspended sediment ranged from 4 to 10 ppm. On some days the stream transported less than 1 ton of suspended sediment. The quality of water in Chambers Creek is similar to that in Steilacoom Lake, modified only by inflow from Leach Creek. Chambers Creek apparently presents no major pollution problem.

KAPOWSIN CREEK

Kapowsin Creek rises in Kapowsin Lake and flows northward about 3 miles to enter the Puyallup River. The city of Tacoma has plans under consideration for the use of Kapowsin Lake to increase the city water supply. A dam would be built at the lake outlet to increase the storage capacity, and water would be diverted into the lake from the Puyallup River from a point below the tailrace of the Puget Sound Power and Light Co.'s Electron powerplant.

The flow of Kapowsin Creek is measured half a mile downstream from the lake (station 20, pl. 1). Descriptive information for the gaging stations is given in table 13. The average flow during the period of record, water years 1928–32 and 1942–54, was 31.3 mgd (48.5 cfs). The lowest daily flow in each year of record is given in table 14.

The flow of Kapowsin Creek shows a rather large variation for a stream draining a lake, not only from year to year as shown in figure 12, but also from day to day as shown in plate 4. Two flow-duration curves for Kapowsin Creek are shown in figure 11. One is for water years 1942–54, and the other is adjusted to water years 1930–54 by correlation with the flow of Greenwater River at Greenwater (see also table 4).

The recurrence intervals of low flows given in table 5 may be useful in many problems concerned with the design of water-use projects. Assuming that the flow during the period April 1, 1930, to March 31, 1954, was typical, the same recurrent intervals may be expected. For example, suppose that a flow of 0.9 mgd (1.4 cfs) is required for a water supply. Table 6 shows that the mean flow for 7 days may be expected to be as low as 0.9 mgd at average intervals of 3 years. Because 3 years is the average frequency of occurrence, the chances are 1 in 3 that the flow will be lower in a particular year.

TABLE 5.—*Magnitude and frequency of annual low flow at selected gaging stations*

[Result of a regional analysis of streamflow for the period April 1,1930, to March 31,1954]

Station (pl. 1)	Stream and location	(Consecutive days	Lowest flow, in million gallons per day, for the indicated recurrence intervals, in years						
			2	3	5	10	15	25	50
20	Kapowsin Creek near Kapowsin.	1	1.10	0.81	0.61	0.44	0.36	0.29	0.21
		7	1.22	.90	.68	.48	.40	.32	.24
		30	1.92	1.39	1.00	.69	.57	.45	.34
		60	2.60	1.90	1.40	.96	.80	.62	.46
		90	3.60	2.60	1.90	1.27	1.03	.81	.60
21	Puyallup River near Orting.	1	127	108	89	70	60	48	36
		7	144	124	105	81	69	57	41
		30	175	153	131	107	93	69	58
		60	212	189	163	134	119	100	79
		90	243	220	193	162	144	126	103
22	Carbon River near Fairfax	1	68	58	50	40	36	31	25
		7	75	64	54	43	39	33	27
		30	94	80	68	55	49	49	35
		60	117	99	83	69	61	52	43
		90	136	116	100	82	73	63	53
24	South Prairie Creek at South Prairie.	1	20	18	17	16	15	14	13
		7	20	19	18	16	16	15	13
		30	24	22	20	18	17	16	15
		60	28	24	22	20	19	17	16
		90	34	28	24	21	20	19	17
31	White River near Buckley	1	------	------	------	------	------	------	------
		7	230	190	160	130	120	100	83
		30	290	250	200	170	150	130	103
		60	380	320	270	210	190	160	130
		90	460	390	320	260	230	200	170
37	Puyallup River at Puyallup.	1	------	------	------	------	------	------	------
		7	690	600	530	450	410	360	310
		30	820	730	640	540	490	440	370
		60	980	880	780	660	590	520	440
		90	1090	990	880	740	680	600	520
47	Green River near Palmer	1	76	70	66	60	57	54	50
		7	78	72	68	62	59	56	52
		30	89	80	74	68	65	62	57
		60	101	91	82	74	71	67	63
		90	129	105	92	82	76	71	66

Storage quantities that would have been required to maintain specific rates of outflow during the period of record by supplementing critical low-flow rates are given in table 6. Values of storage given in the table are net requirements exclusive of evaporation, dead storage, and seepage losses. The 1954 water-year hydrograph of daily flows and the wide variation between maximum and minimum daily discharge that has been recorded for each day of the year are given in plate 4. The hydrographs of maximum and minimum daily discharge do not depict the sequence of flow rates.

Lake Kapowsin water is a pale brownish-yellow, and Kapowsin Creek, fed by the lake, is the same color. The creek water is low in dissolved solids, very soft, slightly acidic (as indicated by its pH), and except for color is satisfactory for domestic and industrial use. The creek carries negligible amounts of sediment; the maximum observed rate of sediment transport on February 8, 1955 was 10 tons per day, which corresponds to a concentration of 13 ppm (table 18). No information is available on the pollution of Kapowsin Creek.

TABLE 6.—*Storage required to assure regulated flow*

[Stations located on pl. 1]

Kapowsin Creek near Kapowsin (station 20; 1928–32, 1942–54)		Puyallup River near Orting (station 21; 1932–54)		Carbon River near Fairfax (station 22; 1930–54)		South Prairie Creek at South Prairie (station 24; 1950–54)		Green River near Palmer (station 47; 1932–54)	
Regulated flow (mgd)	Storage (million gallons)	Regulated flow (mgd)	Storage (million gallons)	Regulated flow (mgd)	Storage (million gallons)	Regulated flow (mgd)	Storage (million gallons)	Regulated flow (mgd)	Storage (million gallons)
2	60	60	200	40	200	20	--------	70	200
4	280	80	600	60	800	30	800	80	650
6	560	100	1,200	80	1,950	40	2,200	90	1,350
8	910	120	2,300	100	3,600	50	3,800	100	2,200
10	1,290	140	3,700	120	5,800	60	5,500	120	4,300
12	1,690	160	5,200	140	8,300	70	7,300	140	6,700
14	2,110	180	7,000	160	11,000	80	9,200	160	9,500
16	2,550	200	9,000	178	13,500	90	11,000	180	12,600
		220	11,200					200	16,600
		240	13,500					230	17,500
		260	16,200						
		280	19,200						
		300	22,000						

PUGET SOUND

Puget Sound is an economical source of water and supplies some industries that are able to use saline water. The salinity of Puget Sound water is less than that of the ocean. Measurements by the U.S. Coast and Geodetic Survey (1954) show that the salinity of Puget Sound water at Tacoma ranges from 21,000 ppm to slightly more than 26,000 ppm (fig. 17). Average salinity of ocean water is about 35,000 ppm. The recorded temperature of Puget Sound water at Tacoma ranges from about 45° to 57°F (U.S. Coast and Geodetic Survey, 1956).

The range of tidal fluctuation at Tacoma, from information furnished by the U.S. Coast and Geodetic Survey, is about 20 feet, although daily fluctuations are generally about 12 feet. These tidal movements cause noticeable daily fluctuations of water levels in many of the deeper wells adjacent to Puget Sound.

PUYALLUP RIVER VALLEY

The flood plains of the Puyallup River and its chief tributaries are called the Puyallup River Valley in this report. (See inset map, pl. 2.) "The Tideflats," the flood plain adjacent to the mouth of the Puyallup River, is the heart of the Tacoma industrial area. The chief industries are lumber and wood products, paper, chemicals, metal reductions and fabrication, shipbuilding, and food processing. In the upper valley, industry gives way to agriculture; the broad flood plains of the Puyallup River and its main tributaries are the most productive agricultural area in Pierce County.

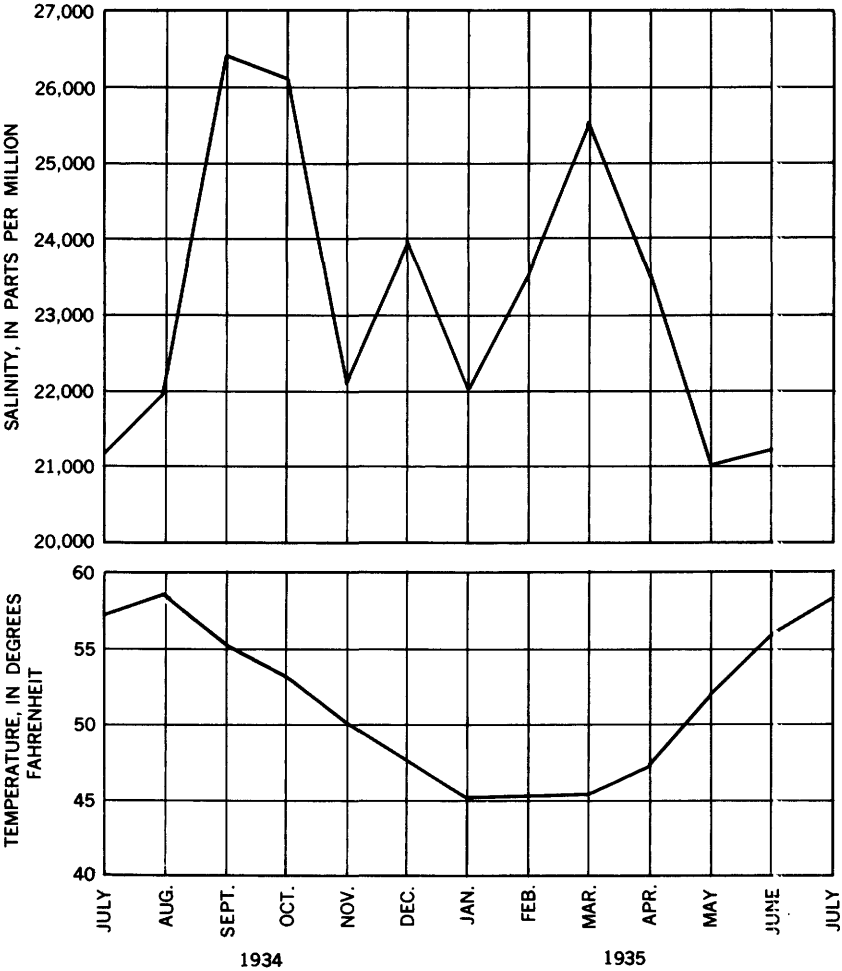

FIGURE 17.— Salinity and temperature of Puget Sound water at Tacoma (U.S. Coast and Geodetic Survey, 1954, 1956)

Most industries in the Tideflats obtain their water from the Tacoma municipal system. The largest water user is the St. Regis Paper Co., which used an average of 20.1 mgd during 1955. Some industries use water from streams and wells in addition to water obtained from the municipal supply. (See table 10.) In the upper valley, irrigation water is obtained from wells and streams. The water of Puget Sound is available in the Tideflats area (see p. 34).

PUYALLUP RIVER

The Puyallup River and its tributaries are the major potential sources of water in the Tacoma area. This river rises in the Mowich,

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Puyallup, and Tahoma Glaciers on the western slopes of Mt. Rainier, flows 46 miles generally northwestward, and discharges into Commencement Bay at Tacoma. For nearly half its length, the river flows through mountainous terrain and its channel has the gradient typical of mountain streams. In its lower reaches the river flows through rolling lowlands, the valley widens, and the gradient decreases. The flow of the Puyallup River is measured at three locations: near Orting (station 21), at Alderton (station 27), and at Puyallup (station 37). Seven gaging stations are currently operated on tributaries (pl. 1).

PUYALLUP RIVER NEAR ORTING

The average flow of the Puyallup River at the gaging station about 4 miles south of Orting was 450 mgd (697 cfs) during water years 1932–54. The lowest daily flow during the same period was 38 mgd (59 cfs). Flow-duration data given in table 4 and figure 18 have been adjusted to the period 1930–54 by using records of Carbon River near Fairfax and of Puyallup River at Puyallup. The curve derived from these data is typical of streams of glacial origin.

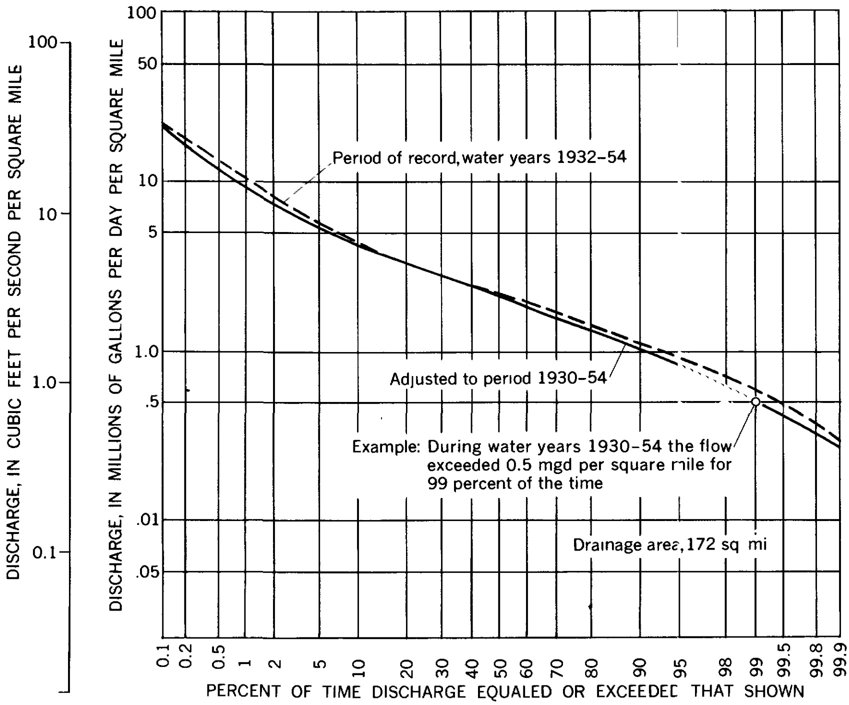

FIGURE 18.—Duration curve of daily flow, Puyallup River near Orting.

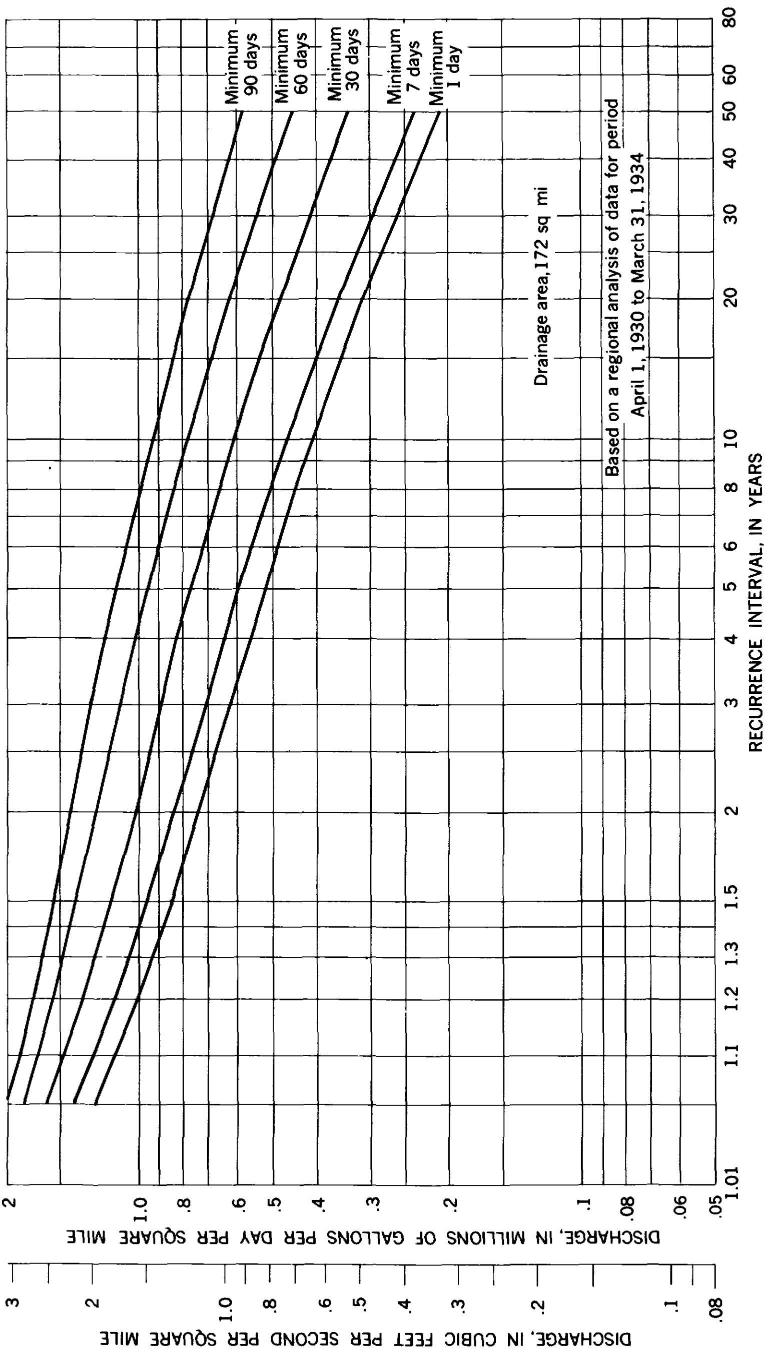

FIGURE 19.—Low-flow frequency curves, Puyallup River near Orting.

Glacial melting sustains the flow during the summer and reduces the variability in flow. The average daily flow of the Puyallup River near Orting exceeds 0.5 mgd per square mile, or 86 mgd (133 cfs), for 99 percent of the time. The low-flow frequency curves (fig. 19) and the table of annual low flow (table 5) also illustrate the sustained high flow for this stream. The minimum flow shown for the 1-day period is the flow that is available without storage. If this flow is insufficient, it is necessary to provide storage. The amount of storage required for Puyallup River near Orting can be obtained from the draft-storage curve given in figure 20 (see

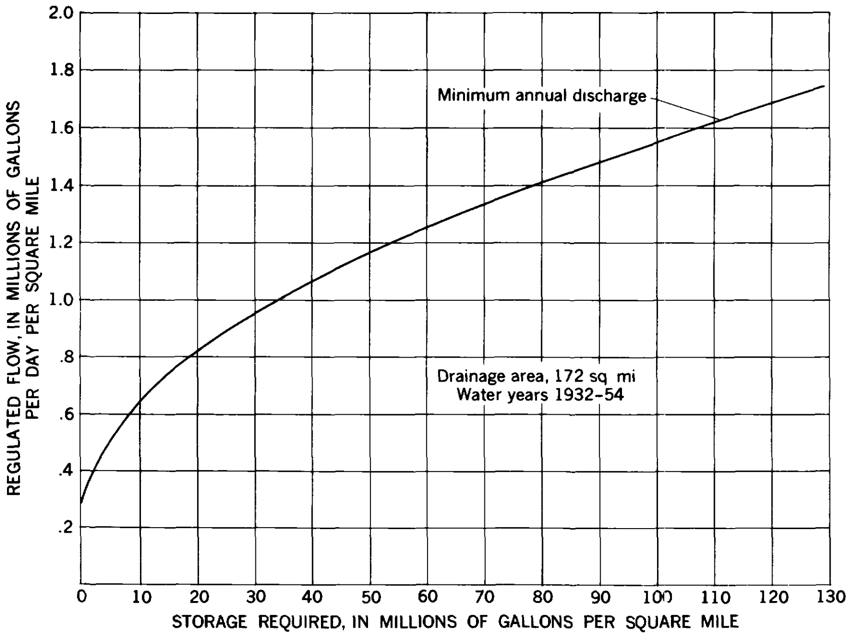

FIGURE 20.—Storage requirements, Puyallup River near Orting.

also table 6). The storage indicated in the figure does not include dead storage and water lost by seepage and evaporation. The hydrographs of maximum and minimum daily flows and of daily flow during 1954 are given in plate 4.

The water of Puyallup River near Orting is low in dissolved solids and very soft; at low flow it is slightly more mineralized than at flood flow. On February 8, 1955, when the river was discharging 2,090 mgd, the color of a sample of water was 40 units on the standard platinum-cobalt scale (table 15). As in other glacial streams, the dissolved solids load is of secondary importance to the sediment load. The river is turbid most of the time from headwaters to mouth. The maximum rate of sediment discharge in 9 samples collected during 1954–55 was 4,310 tons per day on February 8, 1955 (table 18). Figure 21 shows the relation of suspended-

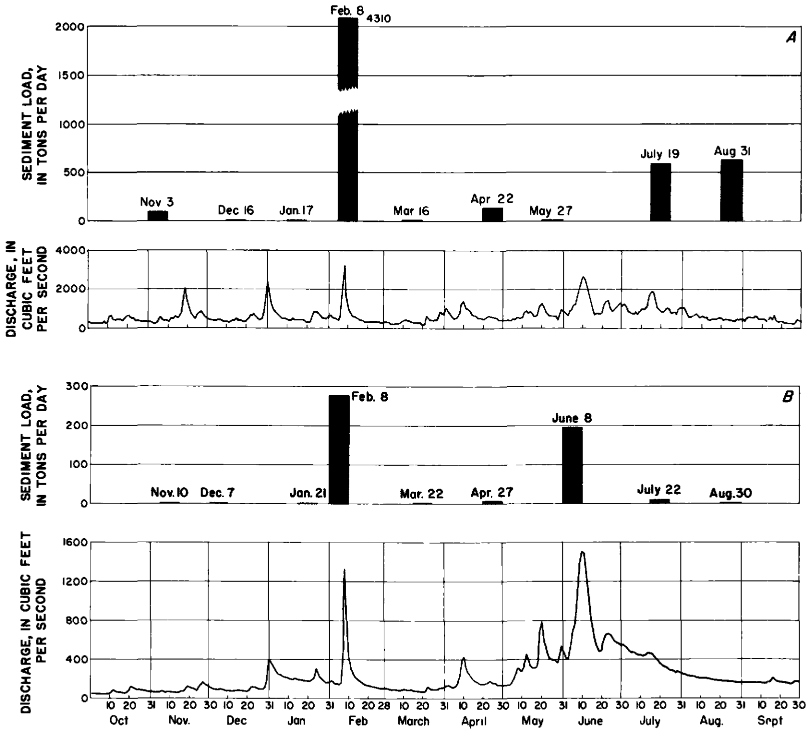

FIGURE 21.—Suspended-sediment load and streamflow for typical glacier-fed and non-glacier-fed streams. *A*, Puyallup River near Orting, a glacier-fed stream. *B*, Greenwater River at Greenwater, a non-glacier-fed stream.

sediment load to streamflow for Puyallup River near Orting, a typical glacier-fed stream, and for Greenwater River at Greenwater, a typical non-glacier-fed stream. On the basis of a sediment measurement made July 19, 1955, the material in suspension at the Orting station consists mainly of silt or fine sand. Seventy-two percent of the suspended sediment was less than 0.062 mm, the upper limit for classification as silt.

Pollution in the upper reaches of the Puyallup River has not been studied thoroughly, but pollution abatement is no doubt a less critical problem in the Orting area than in more populous districts downstream.

PUYALLUP RIVER AT ALDERTON

The average flow of the Puyallup River at Alderton for the water years 1915-26 and 1944-54 was 1,027 mgd (1,589 cfs). The lowest daily flow during the same period was 97 mgd; flow-duration data are given in table 4. The gaging station (station 27, pl. 1) is located half way between Alderton and Sumner.

The chemical quality of the river water at Alderton is similar to that upstream near Orting. Except for turbidity and color during peak flows, Puyallup River water would meet domestic and most industrial requirements. More than 3,000 tons of sediment moved past the Alderton station on February 9, 1955 (table 18). River pollution abatement requirements in the Alderton and Sumner areas are being met in some places by construction of new waste-treatment plants.

PUYALLUP RIVER AT PUYALLUP

The average flow of the Puyallup River at Puyallup during water years 1915-54 was 2,109 mgd (3,263 cfs), or 2,632,000 acre-feet per year. The lowest daily flow during the same period was 259 mgd. Flow-duration data are given in table 4, and other information on low flow and storage requirements is given in tables 5 and 6. Hydrographs of daily flow are given in plate 6.

The flow is measured downstream from all important tributaries and is affected by regulation, diversion, and storage. A large part of the flow of the White River, a tributary, is diverted into Lake Tapps (usable capacity, 50,400 acre-feet) and reaches the Puyallup River above the station via Stuck River. Some water is diverted for irrigation. Flood flows are reduced by Mud Mountain Reservoir on the White River. Water is also stored in smaller ponds and reservoirs on tributaries and on the upper Puyallup River. Diurnal fluctuations are caused by the operation of hydroelectric plants and by glacial melt.

Mud Mountain Dam was constructed on the White River to control floods in the lower Puyallup River basin (see p. 55). The flood-stage frequency curves (fig. 22), which were developed from data furnished by the Corps of Engineers, U.S. Army, show the effect of the reservoir on floods at the gaging station on Puyallup River at Puyallup. The upper curve shows the frequency of floods of various stages that might be expected without the reservoir. It is based on floods that occurred during the period 1915-51; floods for the period 1943-51 were adjusted for reservoir storage. The lower curve shows the frequency of floods of various stages that might be expected on the basis of the 1915-51 records had Mud

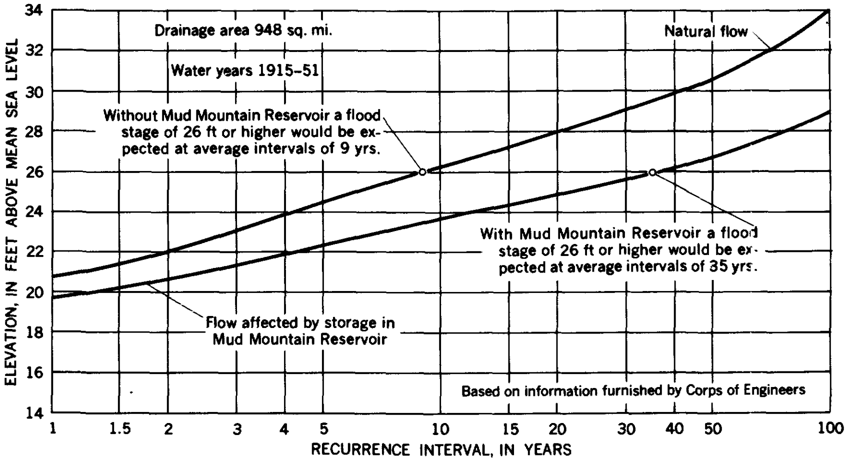

FIGURE 22.—Flood-stage frequency curve, Puyallup River at Puyallup

Mountain Reservoir been in use during the entire period. As an example of the effect of the reservoir, a flood reaching an elevation of 26 feet above mean sea level would have an expected average recurrence interval of 9 years without reservoir storage and of 35 years with storage. Profiles of the December 12, 1955, flood (26,000 cfs) and a "design flood" of 50,000 cfs on the lower Puyallup River are given in figure 23.

The chemical quality of the water of Puyallup River at Puyallup does not differ materially from that at upstream stations. Samples collected during high and low stages show very similar quality and concentrations. Sediment loads at Puyallup are greater than at Alderton because of inflow from the Stuck River. A sediment discharge rate of almost 7,000 tons per day occurred with a stream discharge of 5,570 mgd (8,620 cfs) on February 9, 1955. On several days the river carried more than 1,000 tons of sediment (table 18). The earlier findings of the Corps of Engineers are a further example of sedimentation rates in the lower Puyallup River. From a series of soundings in the Puyallup waterway at Tacoma after several strong freshets in November 1909, the Corps of Engineers reported sediment in excess of a million cubic yards. Most of the sediment had been transported and deposited during the month.

The turbidity of Puyallup River makes the water undersirable for some uses. Samples of water examined in the laboratory have not cleared after standing for several months.

The extent of industrial pollution in the lower reaches of the Puyallup has not been determined completely. Some plants have definite plans for new or more adequate waste-disposal units

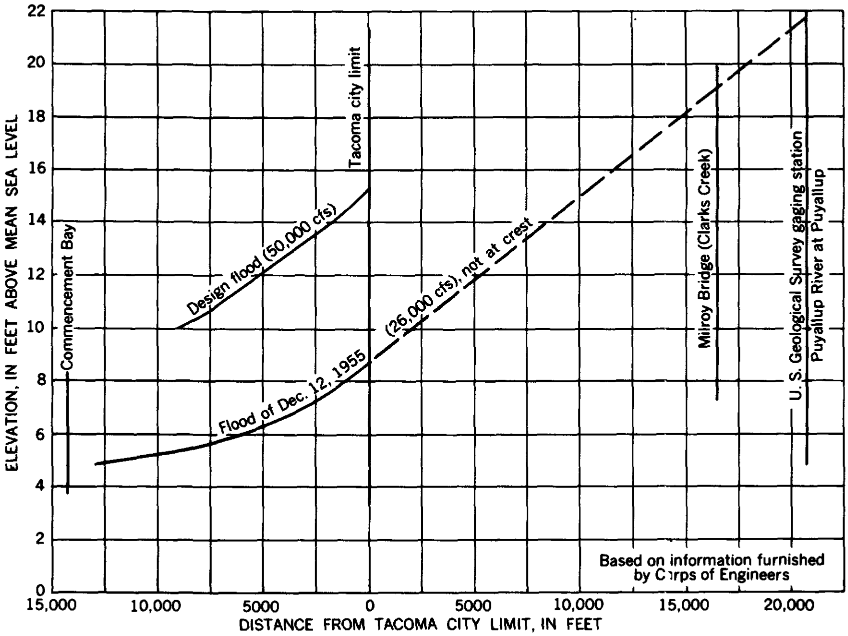

FIGURE 23.—Flood profiles on the Puyallup River from Commencement Bay to the gaging station at Puyallup.

STUCK RIVER

Stuck River is the name applied to the lower reaches of the White River. Prior to 1906 the White River was divided, the greater part of the flow going into the present Green-Duwamish basin and the remainder into the Puyallup River through the Stuck River channel. The flood of 1906 changed the course of the White River from the Green to the Stuck River, and in 1914 the change was made permanent by a dike constructed by King and Pierce Counties. The average flow of the river at a site 3 miles north of Sumner during water years 1946–54 was 398 mgd (616 cfs). The Puget Sound Power and Light Co. diverts 388 to 582 mgd (600 to 900 cfs) above the gaging station into Lake Tapps for use at the Dieringer powerplant and then returns it to the river below the gaging station. The flow of the river is partly regulated by Mud Mountain Reservoir (see p. 55). Flow-duration data and other data on low flows are not given because of the large diversion around the gaging station.

The Stuck River is a glacier-fed stream and, except for turbidity and occasional color, the chemical quality of the water is satisfactory for most uses.

Regulation by Mud Mountain Reservoir materially affects the sediment loads, which in 9 measurements ranged from less than 1 ton per day to 27,100 tons per day (table 18). On June 9, 1955, the particle-size distribution in one sample indicated a composition of 70 percent sand, 22 percent silt, and 8 percent clay.

GROUND WATER IN THE PUYALLUP RIVER VALLEY

Precipitation on the valley floor and runoff from the adjacent valley slopes recharge the shallow alluvial aquifers in the valley. During periods of high river stage some water moves from the river into the alluvial materials, but during lower river stages ground water discharges into the river. Some recharge occurs also by upward leakage from underlying artesian aquifers. The water table remains at shallow depths beneath the flood plains throughout the year; it thus affords only limited storage for additional ground water and causes the rejection of much potential recharge from precipitation or from the river.

The deeper aquifers beneath the valley floor are probably recharged almost entirely by ground water moving out from beneath the adjacent uplands. This conclusion is based chiefly upon observation of the difference in heads in the aquifers, for the deeper aquifers generally have slightly higher heads than the shallow alluvial aquifers; furthermore, there is a marked difference in quality between water in the shallow aquifers and water in the deeper aquifers.

The shallow aquifers discharge chiefly into the Puyallup River. However, a considerable amount of water is discharged directly to the atmosphere by evaporation and transpiration. The amount pumped from shallow wells is small; most wells obtain water from deeper aquifers.

The deeper artesian aquifers discharge into Puget Sound at the mouth of the Puyallup Valley. They also discharge by upward leakage into aquifers having lower heads. In addition, withdrawals from the deeper artesian aquifers by wells is responsible for a fairly large part of the discharge.

AQUIFERS

The broad valleys of the Puyallup River and the tributary Stuck River are partly filled with glacial till and outwash deposits overlain by Recent alluvial and marine deposits (pl. 2). Recent alluvium together with recessional outwash of Vashon age form the shallow unconfined aquifers mentioned above; the advance outwash of Vashon age and pre-Vashon unconsolidated deposits mainly form the deeper aquifers. The outwash deposits, consisting of sand or sand and

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gravel, are generally quite permeable and are tapped by most of the domestic and irrigation wells in the valleys. The outwash materials range from a few feet to a few tens of feet in thickness Upstream from the city of Puyallup, wells generally penetrate the outwash aquifers within the uppermost few hundred feet; wells range from about 300 feet at Puyallup to less than 150 feet near Orting. Most ground-water development along this reach of the river has been from the outwash rather than from the shallow alluvial aquifers. At most places downstream from Puyallup, the Vashon drift is composed of sand and till; the till is not an aquifer, but the sand strata usually are capable of yielding small to moderate supplies. These aquifers are at progressively greater depths downstream from Puyallup; they are at a depth of 600 feet or more under the central part of the Tideflats.

Wells in the center of the valley floor generally tap a greater thickness of the Recent alluvial and marine deposits, as well as the outwash, than wells along the margins of the valley. At places along these margins, little or no outwash was observed above the pre-Vashon unconsolidated or the older semiconsolidated deposits. Most of the industrial wells on the Tideflats obtain water from sand or sand and gravel strata of pre-Vashon age. As the slopes of the pre-Vashon Puyallup Valley are steep and somewhat irregular, wells only short distances apart may tap the pre-Vashon deposits at greatly different depths. Where the younger deposits extend to depths of 500 to 600 feet below sea level, the pre-Vashon materials are chiefly fine-grained silt and sand, although they do contain some gravel lenses.

Wells in the Tideflats area that fail to obtain sufficient water from the alluvium or the Vashon drift generally are drilled 300 to 500 feet, and occasionally more, into deposits underlying the Vashon materials so as to penetrate a sufficient number of aquifers to develop an adequate supply. Where the pre-Vashon deposits are penetrated at shallower depths, they generally contain more aquifers, chiefly sand or sand and gravel strata, so that more water is obtained; therefore less penetration into the pre-Vashon deposits is required. The average depth of 12 industrial wells and 1 public-supply well on the Tideflats is 750 feet, and the average reported yield is about 700 gpm. A well owned by the St. Paul & Tacoma Lumber Co. (well K, pl. 3), the deepest well on the Tideflats, was drilled to a depth of 1,501 feet, and the well casing was perforated at many horizons from 655 to 1,486 feet. This well was reported to have a yield of about 775 gpm.

WATER LEVELS AND WATER-LEVEL FLUCTUATIONS

Water levels in the shallow aquifers in the valley are near or at the land surface. Deeper wells, whose water levels reflect the piezometric surfaces of the artesian aquifers, commonly have slightly higher water levels than the shallow wells. Many wells in the lower valley flow at the surface, and some on the Tideflats have heads as much as 20 feet above the land surface. Flowing wells occur in the Puyallup River Valley and northward in the valleys of the Stuck and Duwamish Rivers, beyond the area of this investigation.

Hydrographs of two wells in the Puyallup River Valley and the monthly mean stage of the Puyallup River are given in figure 24 which shows that water-level fluctuations in these wells correspond closely in time and range to the monthly mean river stage.

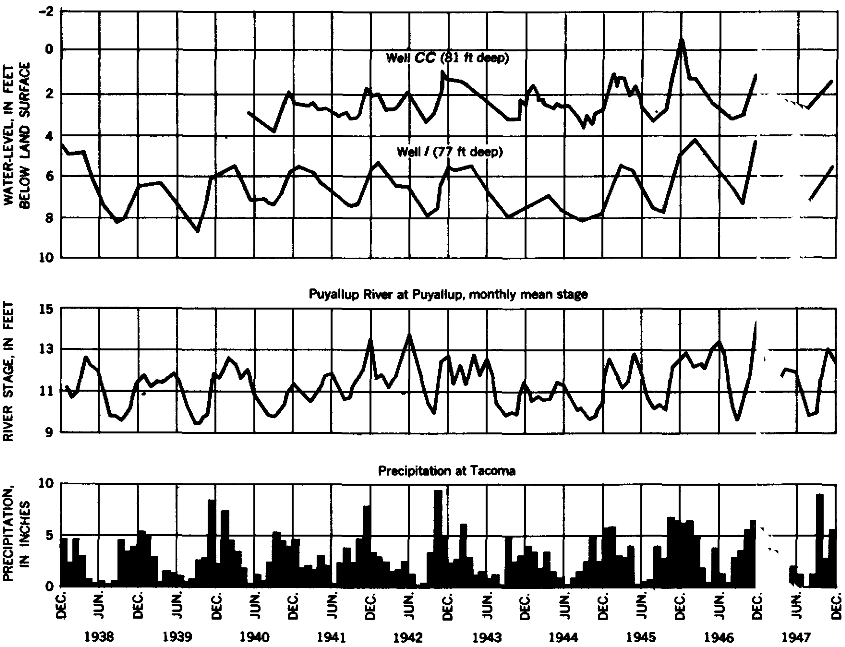

FIGURE 24.—Hydrographs of water levels in two shallow wells in the Puyallup River Valley, monthly mean stage of the Puyallup River at Puyallup, and precipitation at Tacoma.

QUALITY OF GROUND WATER

Wells in the Puyallup River Valley yield water of moderate dissolved-solids content and hardness. Silica is a conspicuous constituent. Except for objectionable amounts of iron in some supplies, ground water is suitable for general use. Of 6 wells that range in depth from 450 feet to 856 feet, 4 yield water in which iron exceeds 1 ppm.

BUCKLEY UPLAND

The Buckley Upland is the broad plain lying east of the Stuck and Puyallup River valleys and extending from the Green River valley on the north to South Prairie Creek valley on the south. It is not completely shown on plate 2. This subarea has low relief; it generally ranges in altitude from 600 to 700 feet. The Buckley Upland is only partly developed as an agricultural and residential area.

The Carbon, White, and Green Rivers and South Prairie Creek either border or cross the Buckley Upland and are sources of water for that area. Ground water can be obtained from alluvium of Recent age, from outwash sand and gravel of Vashon age, and from aquifers of pre-Vashon age. Water is used in the Buckley Upland for domestic purposes and irrigation. The upper Green River has been developed as a public water supply for the city of Tacoma.

GREEN RIVER

The Green River rises in the Cascade Range and flows northwestward for about 60 miles to enter Puget Sound through the Duwamish River at Seattle. Originally the White River merged with the Green River near Auburn, but since November 1906, when a low dam separating the channels was constructed, the White River has flowed through the channels of the Stuck and Puyallup Rivers into Tacoma Harbor (see p. 42). The Green River formerly overflowed into Lake Washington at Renton through a flood channel called Black River. This channel is now dammed to prevent recurrence of such overflow.

The flow of the Green River is measured near Palmer and near Auburn. Other gaging stations that have been operated at other points in the Green River basin are shown on plate 1. The gaging station near Palmer (station 47, pl. 1), in operation since October 1931, is 1½ miles upstream from the diversion dam and intake of Tacoma's water-supply system. The drainage area at this point is 230 square miles. There is no regulation or diversion above the station.

The gaging station near Auburn (station 58, pl. 1) has been in operation since August 1936 at a site 1½ miles east of Auburn. The drainage area above the station is 382 square miles (excluding 4 square miles in the vicinity of Youngs Lake). The city of Tacoma diverts as much as 73 mgd (113 cfs) from the Green River near Palmer, several miles upstream, for municipal use, and there is minor regulation on Little Soos Creek, a tributary.

The lowest daily flow near Palmer in water years 1932–54 was 52 mgd, and that near Auburn in water years 1937–54 was also 52 mgd.

Flow-duration data for the gaging station near Palmer are given in table 4. Hydrographs of daily flow for the station near Palmer are shown on plate 4, and other information on low flow and storage requirements is shown in tables 6 and 7.

Extensive flood damage occurs in the lower part of the basin where the river meanders through a fertile valley. The city of Kent lies in this flood plain and has been subjected to frequent flooding. A flood-stage frequency curve for Green River near Palmer (fig. 25)

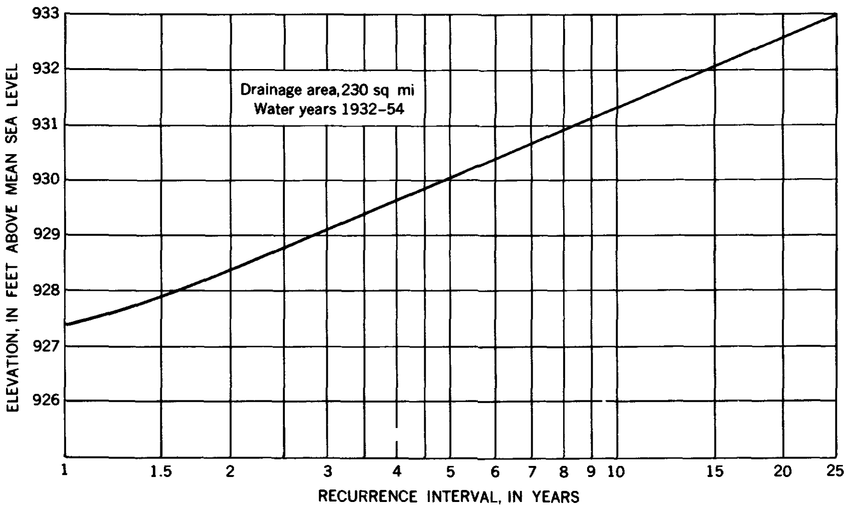

FIGURE 25.—Flood-stage frequency curve, Green River near Palmer.

gives the recurrence intervals for the period of record for floods reaching various elevations above mean sea level; a similar curve for Green River near Auburn is given in figure 26. The Corps of Engineers is constructing a dam on the upper part of the Green River near Eagle Gorge as a part of a water conservation and flood-control project. Plans call for conserving water from April to the beginning of the flood season, in late October or early November. During the season April to October enough water will be stored and released to provide a minimum flow of 136 mgd (210 cfs) at the Palmer gaging station. Flood flows at Auburn will be reduced to a maximum of 12,000 cfs, which would be equivalent to an elevation of approximately 64 feet above mean sea level.

The chemical quality of Green River waters near Palmer and near Auburn is nearly the same. Low flows produce a slight increase in mineral concentration, although the water remains very soft and retains its low content of dissolved minerals. The range in dissolved solids in 5 samples collected near Palmer between 1938 and 1955 was

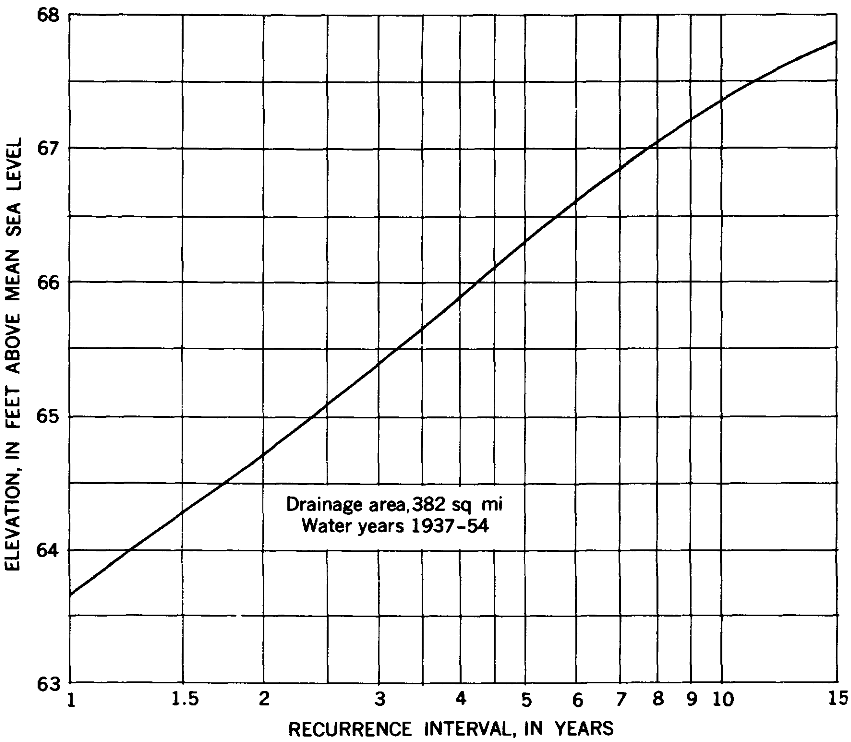

FIGURE 26.—Flood-stage frequency curve, Green River near Auburn.

32 to 46 ppm; the range in hardness of the samples was 10 to 20 ppm. These values are lower than those for most streams of the area. In 1910, during a study of quality of surface waters of Washington, the U.S. Geological Survey analyzed samples of water from the Green River at Hot Springs, a few miles upstream from the Palmer gaging station.

At high stages the river carries large quantities of suspended sediment. During average or below average flows the sediment load may be small; a discharge of suspended sediment of only 6 tons per day has been observed near Auburn (table 18).

Since 1950 the U.S. Geological Survey and the city of Tacoma have cooperated in a study of sedimentation of Green River water near Palmer. Samples are collected daily or oftener by the city for determinations of turbidity, suspended sediment, and water temperature. At high stages, samples are also collected for measurement of particle-size distribution. Sediment yield in Green River near Palmer is summarized in table 7.

TABLE 7.—*Summary of annual suspended-sediment discharge, Green River near Palmer, 1951–55*

Water year	Total runoff (acre-feet)	Suspended sediment		
		Total load (tons)	Concentration (parts per million)	
			Maximum	Minimum
1951	915, 690	57, 190	80	1
1952	639, 080	6, 370	207	1
1953	670, 600	37, 631	430	1
1954	936, 730	82, 394	1, 350	1
1955	794, 030	43, 649	607	1

Mean monthly flow and sediment loads for water years 1951–55 are plotted in figure 27. In the 1951 water year, 75 percent of the total sediment for the year was transported past the gaging station in February; in 1952, 58 percent was transported in February; in 1953, 78 percent in January; in 1954, 90 percent in December; and in 1955, 68 percent in February. Particle-size distribution showed some variation with streamflow. When river discharge was 905 mgd (1,400 cfs), the median diameter was 0.0095 mm; at a discharge of 10,700 mgd (16,550 cfs), the median diameter was 0.03 mm (fig. 28). At low flow much of the coarse material has settled out of the water, and the sediment in suspension contains proportionally more fine-grained material. At high stages the increased stream velocities and turbulence keep the coarse particles in suspension; the sediment sample may then consist of 40 to 50 percent sand. The low-flow sediment sample plotted in figure 24 consisted of 14 percent sand, 48 percent silt, and 38 percent clay. The high-flow sample was composed of 35 percent sand, 45 percent silt, and 20 percent clay. In the low-flow sample, 86 percent by weight of the sediment had diameters less than 0.0625 mm, the upper limit for silt. In the high-flow sample, 65 percent by weight was smaller than 0.0625 mm in diameter. Particle-size analyses of suspended sediment for water years 1951–55 are given in table 8.

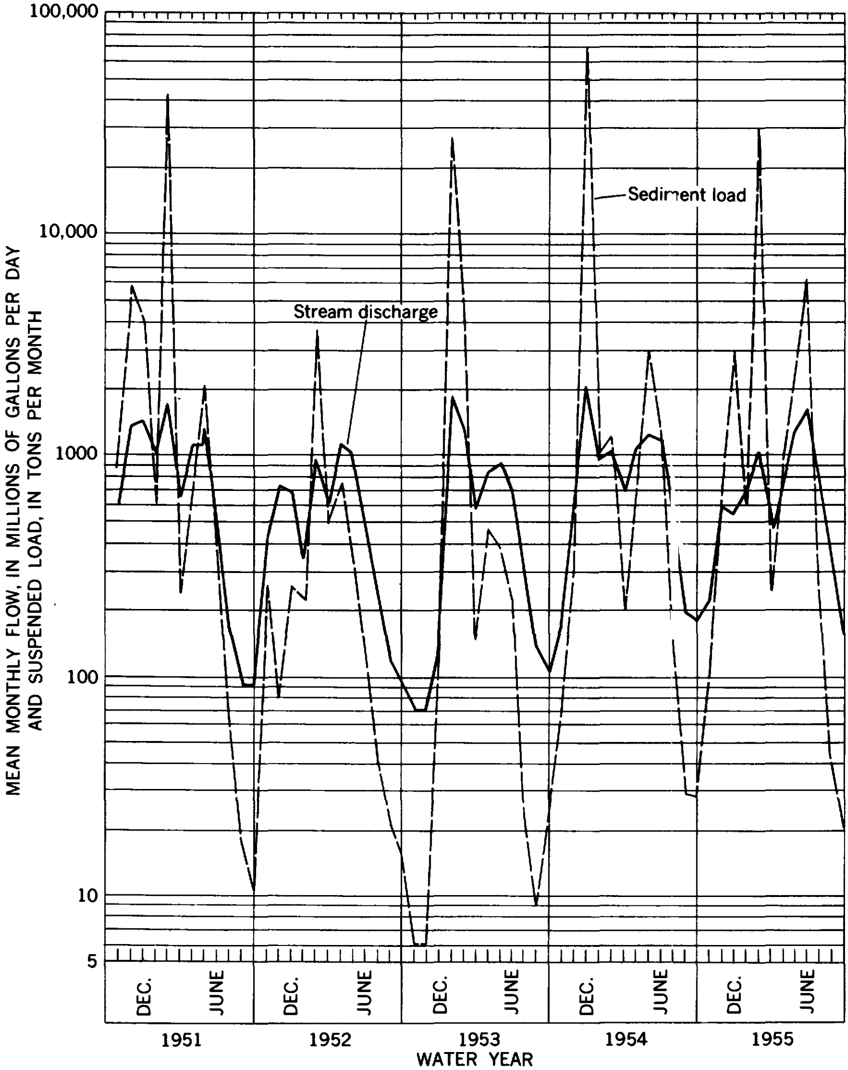

FIGURE 27.—Stream discharge and sediment load, Green River near Palmer.

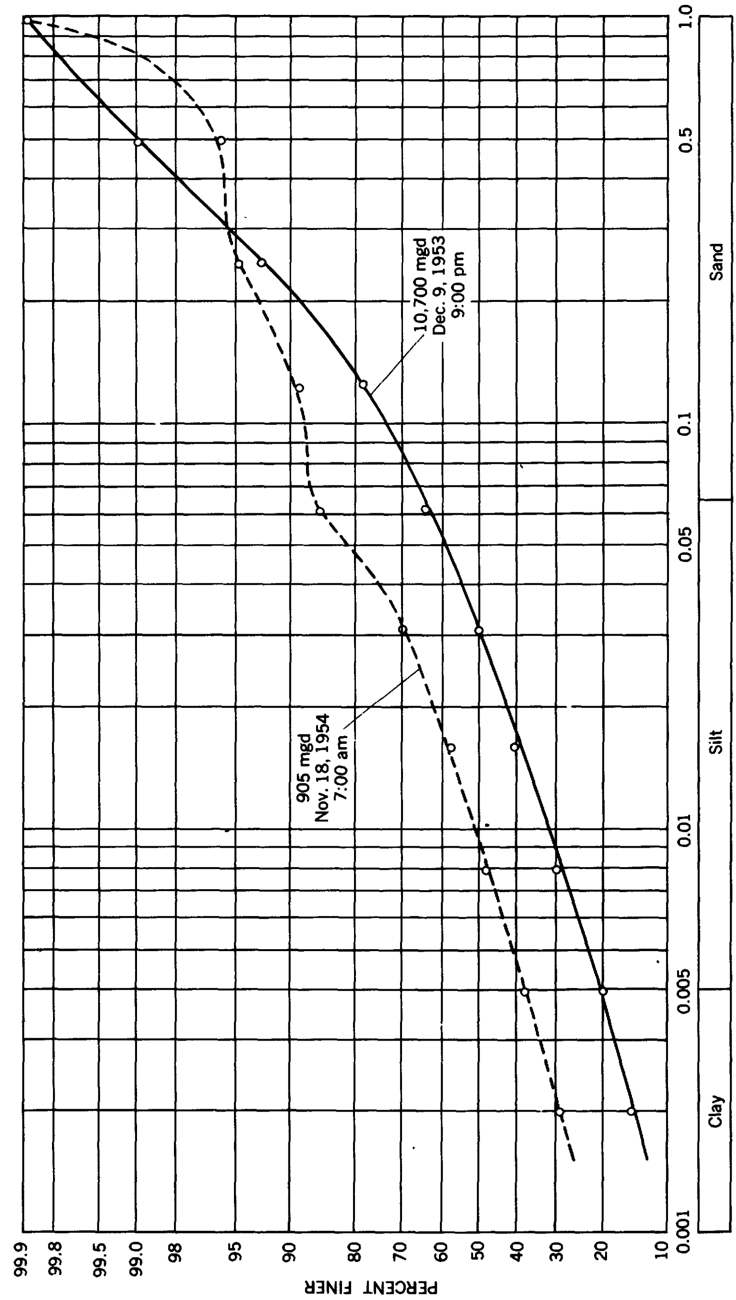

FIGURE 28.—Particle-size distribution of suspended-sediment samples analyzed in dispersion medium, Green River near Palmer.

TABLE 8.—*Particle-size analyses of suspended-sediment, depth-integrated samples for Green River near Palmer, Wash., 1950–55*

[Methods of analysis: D, decantation; P, pipette; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; M, mechanically dispersed; V, visual accumulation tube]

Date	Time	Water discharge (mgd)	Suspended sediment													Methods of analysis
			Concentration of sample (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
					0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	
1950																
Oct. 10	8:30 a.m.	1,950	92	3,400	11	20	32	58	-----	82	93	97	-----	-----	-----	SDWCM
Nov. 3	9:00 a.m.	1,360	12	433	21	33	50	72	-----	91	-----	-----	-----	-----	-----	SDWCM
Nov. 22	9:30 a.m.	3,810	124	4,670	10	21	32	65	-----	83	95	98	-----	-----	-----	SDWCM
Nov. 22	8:30 p.m.	5,170	102	3,810	10	19	33	61	-----	84	94	99	-----	-----	-----	SDWCM
1951																
Feb. 9	10:45 p.m.	9,050	666	-----	-----	-----	-----	-----	-----	49	66	83	94	-----	-----	S
Dec. 21	10:00 p.m.	1,230	26	-----	-----	-----	-----	-----	-----	63	82	92	96	-----	-----	S
1952																
Jan. 30	12:30 p.m.	840	25	-----	-----	-----	-----	-----	-----	68	83	92	97	-----	-----	S
Feb. 4	12:00 p.m.	3,360	-----	-----	-----	-----	-----	-----	-----	56	77	89	97	-----	-----	S
1953																
Dec. 9	3:00 a.m.	2,390	81	490	19	23	29	44	47	63	74	87	100	-----	-----	VPWCM
Dec. 9	9:00 p.m.	10,700	690	4,710	15	20	30	41	50	65	79	93	99	100	-----	VPWCM
Dec. 10	3:00 a.m.	7,890	428	2,600	13	20	30	43	53	67	79	90	99	100	-----	VPWCM
1954																
Dec. 31	6:00 a.m.	3,360	172	1,390	14	19	26	35	44	56	65	78	99	100	-----	VBWCM
Dec. 31	3:30 p.m.	3,300	96	781	15	20	26	32	40	55	64	76	100	-----	-----	VBWCM
1955																
Feb. 7	8:30 a.m.	2,360	93	430	12	14	19	29	36	47	61	82	100	-----	-----	VPWCM
Feb. 8	9:00 a.m.	8,530	784	3,730	10	14	21	28	37	46	58	74	88	100	-----	VPWCM
Feb. 8	3:00 p.m.	6,390	403	2,390	15	20	28	36	46	59	72	87	97	100	-----	VPWCM

The temperature of Green River water exceeded 42° F about 50 percent of the period 1950–55 (fig. 29). The maximum daily water temperature recorded by city employees at the purification plant on the Green River was 60°F.

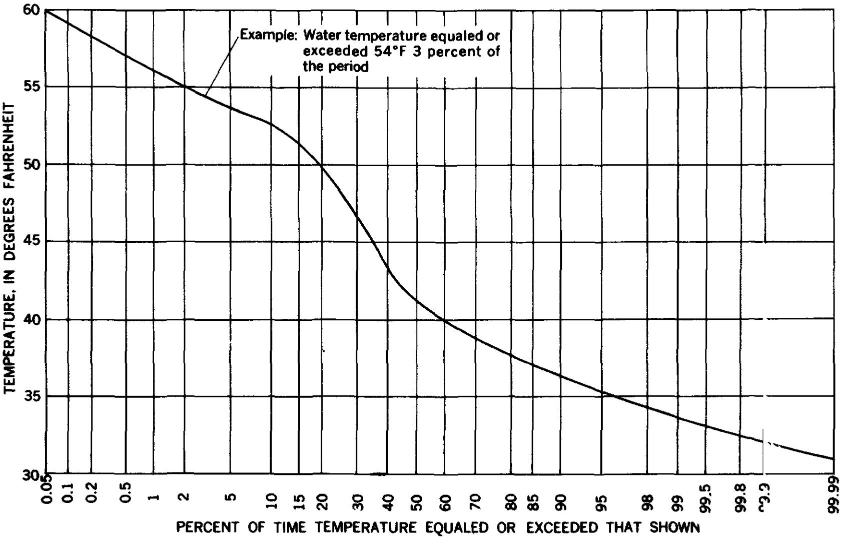

FIGURE 29.—Cumulative frequency curve of water temperature, Green River near Palmer, 1950–55.

The city of Tacoma, in cooperation with Forest Service personnel and private landowners, keeps constant check to prevent pollution. In winter, the weather prohibits extensive patrolling in the area.

CARBON RIVER

The Carbon River rises in the Carbon and Russell Glaciers on the northwestern slopes of Mount Rainier and flows northwestward through rugged mountainous country for the greater part of its length to enter the Puyallup River 2½ miles below Orting.

The average flow at a site 1¼ miles northwest of Fairfax during water years 1930–54 was 266 mgd (412 cfs) (station 22, pl. 1; table 12). The lowest daily flow during the periods April 1, 1910, to March 3, 1913, and April 1, 1929, to March 31, 1954, was 26 mgd. Low-flow frequency data are given in table 5, draft-storage data are given in table 6, and flow-duration data are given in table 4. The 1954 water-year hydrograph of daily flow and the maximum and minimum daily flows that have been recorded on each day of the year are given on plate 4.

Good dam sites are located 9 miles and 15½ miles upstream from the mouth. The site farthest upstream is at Fairfax Bridge, a little more than a mile downstream from the gaging station. Plan and profile maps showing these sites have been published by the Geological Survey (1953).

The chemical quality of Carbon River water is almost constant, even though the discharge may vary sixfold. The river water is softer and lower in dissolved solids than water in the Puyallup River to which the Carbon River is tributary. The sediment discharge for 9 measurements made during the water year 1955 ranged from less than 1 ton per day to 1,150 tons per day (table 18). Examination of a sample collected July 20, 1955, revealed that the suspended material was silty sand and was coaser grained than sediment transported by the Puyallup River.

SOUTH PRAIRIE CREEK

South Prairie Creek is tributary to the Carbon River, about 2 miles east of Orting. The upper part of the Creek basin is rugged and mountainous but the lower part is relatively flat. A small part of the flow is diverted for domestic use and is the primary source of water for the town of Buckley.

The average flow of South Prairie Creek at South Prairie during the water years 1950–54 was 160 mgd (247 cfs), and the lowest daily flow during the same period was 16 mgd (25 cfs). The 1954 water-year hydrograph of daily flow and the maximum and minimum daily flows that have been recorded on each day of the year are given on plate 4. Flow-duration data (table 4) and low-flow frequency data (table 5) have been computed by correlation with longer records for nearby gaging stations by a regional analysis of low flow; records for the standard period April 1, 1930, to March 31, 1954, were used. The draft-storage data (table 6) are based on flow during the period of record. Ordinarily a 5-year period is too short to be reliable for use in working out the details of a water-supply project; however, storage requirements based on records for water years 1950–54 are considered to be more reliable than those based on most 5-year records because of the drought of 1952. According to local streamflow records, this drought was one of the most severe since the early part of the present century.

South Prairie Creek is similar to other headwater streams in the Cascade Range in that its water is low in dissolved solids, soft, and of the bicarbonate type. A low-flow sample collected Sept. 1, 1955, contained 70 ppm dissolved solids, whereas a peak-flow sample on Feb. 9, 1955, contained 43 ppm; this difference is more pronounced than that noted in water from other streams. The sediment discharge for 9 measurements made during the water year 1955 ranged from less than 1 ton per day to 256 tons per day; the greater sediment discharge coincided with the maximum flow for the water year (table 18). During much of the year the creek water is practically clear.

WHITE RIVER

The White River is the largest tributary of the Puyallup River and drains an area larger than the remainder of the Puyallup River basin. The White River rises in the glaciers on the northern slope of Mount Rainier, and the Greenwater River, a major tributary, rises on the western slope of the Cascade Range. The White River flows westward and enters the Puyallup River a mile east of the city of Puyallup (pl. 1).

In 1942 the Corps of Engineers completed Mud Mountain Dam, a rock-filled structure across the White River about 5 miles southeast of Buckley. The drainage area above this dam is 400 square miles. Mud Mountain Reservoir has a capacity of 106,000 acre-feet between elevation 895 feet (invert of lower outlet tunnel) and elevation 1,215 feet (spillway crest). This reservoir is used for flood control; storage is dissipated as soon after a flood as possible without creating damaging flows downstream, so that its maximum capacity will be available for any later flood. Low flows are not affected appreciably by the reservoir because during most years it is empty at times.

The average flow of the White River at the gaging station three-fourths of a mile upstream from the Greenwater River is 533 mgd (825 cfs), and the average flow near Buckley is 895 mgd (1,384 cfs). The Greenwater River has an average flow of 131 mgd (203 cfs) 1 mile upstream from its mouth. The flows of the White River above Greenwater and of the Greenwater River are not affected by regulation or diversions. Information on the flows of the White and the Greenwater Rivers are given in tables 4, 13, and 14.

Flow-duration data for White River near Buckley (table 4) were compiled for the period since completion of Mud Mountain Reservoir and for the 25-year standard period, water years 1930–54. Data for the standard period were computed by using records for White River at Greenwater and for Carbon River near Fairfax; the existence and operation of Mud Mountain Reservoir during the standard period in the same manner as for the period 1944–54 was assumed hypothetically. The low-flow frequency data (table 5) are based on this same assumption. The minimum 1-day flow near Buckley is not shown in table 5 because of regulation by Mud Mountain Reservoir.

Water from the White River has practically the same chemical quality as that from the Greenwater River. Both waters are soft, low in dissolved minerals, and of the bicarbonate type; they have nearly identical concentrations of mineral constituents throughout a wide range in discharge.

White River is a glacial stream, heavily laden with sand and silt. Nine measurements of suspended-sediment discharge were made at Greenwater during the 1955 water year. The largest discharge observed at Greenwater was 13,600 tons per day. On 3 other days the discharge exceeded 2,500 tons per day (table 18). The sediment of the sample collected June 8, 1955, for determination of particle size contained 58 percent sand, 33 percent silt, and 9 percent clay. Sediment is deposited in Mud Mountain Reservoir; therefore, sediment loads near Buckley are much smaller than the sum of loads in the White River at Greenwater and in the Greenwater River. The sediment discharge measured near Buckley was 3,360 tons per day on June 10, 1955, whereas on June 8 at the upper station it was 13,600 tons per day. Furthermore, at the Buckley station the June 10 sample contained 16 percent sand, 37 percent silt, and 47 percent clay—much finer sediment than that measured upstream.

The Greenwater River is not of glacial origin and is practically sediment free much of the time. The sediment discharge for 3 of the 9 measurements made in the water year 1955 was less than 1 ton per day. The maximum sediment discharge, 277 tons per day, was measured February 8, 1955. Information on the pollution or need of pollution control in the White River basin is not available.

GROUND WATER IN THE BUCKLEY UPLAND

The principal aquifers in the Buckley Upland are coarse alluvium of Recent age, outwash sand and gravel of Vashon age, and sand and gravel of pre-Vashon age (pl. 2); the outwash includes the best aquifers. Alluvial deposits along the White and Green Rivers are coarse and permeable and, where saturated, they are generally capable of yielding large supplies of water. Alluvial deposits along the Carbon River and South Prairie Creek at most places are coarse and yield moderately large quantities of water.

Recharge to aquifers beneath the Buckley Upland comes from precipitation on the surface of the upland. However, on that part of the upland lying between the White River and South Priarie Creek valleys, considerable recharge apparently occurs along the flume that brings White River water across the upland for storage in Lake Tapps. Ground water south of the flume moves southward and discharges into South Prairie Creek, and ground water north of the flume moves northward and discharges into the White River. As the flume generally lies within a mile of the White River valley, the ground-water divide extending across the upland is close to the White River valley.

Meager information on two springs and a well 250 feet deep suggests that ground water in the upland is soft and low in dissolved-solids content. Information on the prevalence of iron in subsurface supplies is not available.

NORTHEAST TACOMA UPLAND

The Northeast Tacoma Upland is a rapidly growing rural residential area bounded by Puget Sound on the west, the Stuck River valley on the east, and the Puyallup River valley on the south. The upland extends northward beyond the border of the Tacoma area (see pl. 2). The Northeast Tacoma Upland is similar to other uplands in the area, being till mantled and rising to elevations of about 300 to 500 feet above sea level. Many small lakes and ponds and small bodies of recessional outwash rest upon the till mantle, especially along the eastern edge of the upland. The chief use of water in the Northeast Tacoma Upland is for rural supplies. Ground water is available in the area, and some water may be obtained from small streams. Water from the Puyallup, Stuck, and Green Rivers is available to the upland although the streams lie outside the area. The water supply available from these streams is described on pages 34, 42, and 46.

SURFACE WATER

Hylebos Creek is the largest and only gaged stream (station 40, pl. 1) draining that part of the Northeast Tacoma Upland within the Tacoma area. The creek heads in sec. 19, T. 21 N., R. 4 E., and enters Puget Sound through Hylebos Waterway, a dredged channel about 2 miles long that skirts the northeast edge of the Tideflats.

Fragmentary records of flow during 1950 and 1951 indicate that the flow of Hylebos Creek has been as low as 4.4 mgd (6.8 cfs). Analytical data show that, at least in 1926, the water was of very good chemical quality although concentrations of dissolved solids were higher than in any other surface water for which quality data are available.

GROUND WATER

The most productive aquifers on the upland are the outwash deposits of sand and gravel (pl. 2). The underlying unconsolidated deposits yield small to moderate supplies; the older semiconsolidated sediments have yielded only small supplies.

Around the margins of the upland the outwash deposits are generally drained and do not serve as aquifers. In these marginal areas, aquifers are chiefly sand or sand and gravel strata in the pre-Vashon unconsolidated deposits. Near the center of the upland, the outwash deposits generally are saturated, at least in their lower part, and serve as aquifers. Well *F* (pl. 3), which was drilled to a depth of 500 feet, taps water from outwash between 64 and 74 feet and has a drawndown of about 25 feet while being pumped at 300 gpm. A few other wells on the upland also obtain water from outwash at relatively shallow depths.

Most aquifers in the pre-Vashon unconsolidated deposits consist of sand or gravel strata interbedded with sand and clay. They are generally only a few tens of feet thick and usually lie at depths of 200 to 400 feet. As the upland is surrounded by deep valleys, permeable strata in the upper part of the pre-Vashon unconsolidated deposits are partially drained near the edges of the upland. At places this results in low heads in the confined aquifers that underlie the outwash deposits. For example, in well *C* some water was reported in outwash deposits from 44 to 47 feet below land surface, but after the well was completed at 463 feet, the water level was 258 feet below the surface, far below the outwash deposits.

A few of the deep wells on the upland have been drilled into the older semiconsolidated deposits. These wells have generally yielded only small supplies. Well *F* penetrated clay from 138 to 500 feet; well *G* penetrated chiefly sand, silt, and clay from 85 to 720 feet; well *H* along the southern margin of the upland, penetrated only fine-grained material from 72 to 540 feet. All three wells probably tapped pre-Vashon semiconsolidated materials below 400–450 feet. These deep wells show that the semiconsolidated deposits beneath the Northeast Tacoma Upland do not everywhere contain aquifers.

About 48 square miles of the Northeast Tacoma Upland is within the Tacoma area. Assuming the normal rainfall on the area to be 38 inches, the total amount falling on the upland would be about 97,000 acre-feet.

In view of the smaller overall area and the proportionally greater extent of the till mantle in the Northeast Tacoma Upland in comparison with that of the Tacoma Upland, it is estimated that the amount of recharge here is 30 to 50 percent of the precipitation on the area. This gives a possible recharge of 30,000 to 45,000 acre-feet annually.

Ground water moves outward from the center of the upland and discharges in springs along its edge. Ground water is also discharged through wells on the upland, but this discharge is proportionally very small.

Well *E* (pl. 3), 125 feet deep, taps outwash of the Vashon glaciation and produces water of satisfactory quality. Data on quality of ground water in the Northeast Tacoma Upland are few, but water from wells *E* and *F* suggest that ground-water supplies in this region meet quality requirements for domestic and industrial use.

NISQUALLY RIVER VALLEY

The Nisqually River Valley borders the Tacoma Upland along the southwest corner (pl. 2). The lower valley, which terminates in a delta somewhat similar to the Tideflats at Tacoma, has not been developed industrially but is a potential industrial area having good rail, highway, and sea communication. The valley is also a possible source of water for the Tacoma Upland. The river and the alluvium along the river are sources of water of good quality.

NISQUALLY RIVER

The Nisqually River rises in a glacier on Mount Rainier and flows about 80 miles westward to enter Puget Sound between Tacoma and Olympia. The flow in the lower reaches of the river is regulated by Alder Reservoir and by the city of Tacoma dam at La Grande. The Yelm Irrigation District canal has diverted as much as 45 mgd (70 cfs) during irrigation seasons. This canal was abandoned sometime after 1950 and is no longer in use. The Centralia power canal diverts as much as 407 mgd (630 cfs) for generation of power.

The average flow of the Nisqually River at a site 7.4 miles southeast of McKenna (station 11, pl. 1) was 1,117 mgd (1,728 cfs) during water years 1942–54, and the lowest daily flow was 114 mgd. Water diverted around the gage in the Yelm Irrigation District canal is not included in these amounts. The hydrograph for 1954 and hydrographs showing the maximum and minimum flows for each day in the year are shown on plate 4. Duration data and low-flow frequency data are not given for this station because the flow is affected by regulation and diversion.

The average flow of the Nisqually River at McKenna (station 13, pl. 1) for water years 1948–54 was 1,040 mgd (1,610 cfs) and the lowest daily flow was 37 mgd. The flow at McKenna was also affected by diversion past the gage in the Yelm Irrigation District canal. Because the Centralia power canal diverts water past the gage at McKenna, the flow there is less than the flow at the station 7.4 miles upstream.

Nisqually River water contains small concentrations of soluble salts throughout a wide range in flow. Samples of the river water near McKenna collected at times when the Nisqually River was either above or below average discharge show almost identical chemical quality. The chemical quality of the water was about the same on February 9, 1955, at a flow of 2,190 mgd (3,390 cfs) as it was on September 1 when the flow was 626 mgd. At high stages the Nisqually River has moderate color. The river water is low in content of dissolved solids, which consist principally of calcium bicarbonate. These characteristics are common to fresh water in regions where rainfall is heavy. Except for turbidity and occasional color, the water is suitable for most uses.

The turbidity of the Nisqually River which exists throughout the year, creates problems in operation of powerplants above McKenna. The turbidity, characteristic glacial streams, is due to debris from the Nisqually Glacier. Large quantities of clay, silt, sand, and gravel are deposited in impounding areas behind diversion dams as well as in canals and forebays. Sediment-laden water, furthermore, scours and corrodes turbine blades and linings. Random water samples from the Nisqually River near McKenna from November 1954 to September 1955 show that more than 1,000 tons of suspended sediment may be transported by the river in 1 day (see table 18). Near McKenna, sediment in suspension is finely divided; a sample collected July 25, 1955, was chiefly clay, for 75 percent of the material was finer than 0.004 mm in diameter.

Apparently no serious pollution exists in the Nisqually River. Food-processing industries in the Yelm area produce some organic wastes which are treated before disposal.

GROUND WATER IN THE NISQUALLY RIVER FLOOD PLAIN

The flood plain along the lower reaches of the Nisqually River is underlain by silt, sand, and gravel deposits, including both Recent alluvium and outwash of Vashon age. At most places the coarse-grained strata in these deposits are capable of yielding moderately large supplies of ground water.

Only a few wells have been developed on the lower Nisqually River flood plain. Wells *GG* and *HH* (pl. 3) are probably representative of the ground-water conditions in the area. These wells tap water from a sand and gravel aquifer at approximately 100 feet. One well was tested upon completion and had a drawdown of only 6.8 feet after 45 minutes pumping at a rate of 810 gpm; the other was reported to have a flow of 250 gpm when completed in February 1953.

Whether or not permeable aquifers occur beneath the shallow alluvial and outwash aquifers is not known for certain because there are no deep wells on the flood plain. However, at places the alluvial and outwash deposits may extend to depths of 150 to 200 feet. The underlying material is probably composed chiefly of clay, silt, and sand, containing some permeable sand or gravel aquifers The permeability of these deeper aquifers is most likely lower than that of the overlying alluvial and outwash aquifers; yet the water in the deeper aquifers may be of better quality, at least so far as dissolved iron is concerned.

Water levels in wells obtaining water from the shallow aquifers are near the land surface. As there are no deep wells, the head of the water in deeper aquifers is not known, but it would be expected that it would be above the water table and that many of the deeper wells would flow at the surface.

A sample collected November 16, 1955, from a well (*HH*, pl. 3) 120 feet deep, is probably representative of ground water in the lower Nisqually River valley. Water from this well is soft and of moderate dissolved-solids content; it meets the irrigation-supply requirements of electrical conductivity, sodium-adsorption ratio, and concentration of boron.

PUBLIC WATER-SUPPLY SYSTEMS

Residents of the Tacoma area are served soft water of very low dissolved-solids content. Most systems in the area supply water of better quality than is required to meet the standards of the U.S. Public Health Service for potable water that may be used by common carriers in interstate commerce.

More than 90 percent of all systems in the Tacoma area and almost 50 percent of the population depend on ground water as a source of supply. All communities using surface water have standby connections to wells which augment stream supply during peak demands and emergencies. Ground water may be substituted entirely during short periods when rivers are at flood stage and turbidity of the stream water is objectionable.

TACOMA

The Green River is the principal source of water supply for the city of Tacoma, and wells are an auxiliary source. Water is diverted from the Green River about 25 miles east of Tacoma. Intake gates at the north end of the diversion dam admit water from the Green River through a short tunnel into a small settling basin. From the settling basin the water flows into McMillin Reservoir, about 8 miles southeast of Tacoma. This transmission line, which is 26.6 miles long, can deliver a continuous flow of 73 mgd.

McMillin Reservoir, capacity 110 million gallons, provides transmission storage. To meet peak demands at times when lawns are being sprinkled, water can be drawn from this reservoir at a rate in excess of 105 mgd. Two additional reservoirs with a total storage capacity of 150 million gallons were placed in operation during 1957. The distribution system originally was designed to make maximum use of direct gravity supply in place of large static storage. Approximately 90 percent of the annual supply is derived from the Green River gravity system and 10 percent from the South Tacoma well system. The auxiliary well system has a capacity of 62.2 mgd. The average use of water during 1955 was 52.3 mgd, and the peak demand for 24 hours has reached 92.8 mgd. For short periods when many lawns are being sprinkled the peak rate has exceeded 119 mgd.

The average per capita use of water in Tacoma in 1955 was 317 gallons per day. About one-third of the water is used by domestic consumers, one-third by a pulp mill, and the remaining one-third by commercial and industrial consumers.

The auxiliary well system of Tacoma consists of 13 wells with a total capacity of 43,200 gpm; well locations and capacities are listed as follows:

City well	Designation on pl. 3	Location	Capacity (gpm)
1A	*QQ*	S. 63d and Cedar	3, 080
2A	*M*	S. 35th and Windom	1, 150
2B	*JJ*	S. 35th and Windom	3, 400
3A	*O*	S. 78th and Warner	3, 650
4A	*KK*	S. 39th and Adams	1, 450
5A	*PP*	S. 54th and Clement	4, 500
6A	*LL*	S. 43d and S. Tacoma Way	3, 770
7A	*MM*	S. 74th and Clement	920
8A	*RR*	S. 67th and Clement	3, 890
9A	*N*	S. 36th and Lawrence	6, 000
10A	SS	S. 76th and Clement	1, 000
11A	S	S. 43d and S. Tacoma Way	9, 340
Tideflats	*NN*	Seattle-Intertie-Taylor Way	1, 050
Total capacity			43, 200

Water is distributed through five service levels: Low, Middle, North End, High, and Northeast Tacoma. The McMillin Reservoir now serves as the static storage for High service. Facilities for storage of 312.6 million gallons of finished water are available and consist of 9 reservoirs and 5 standpipes as follows:

Type of storage	Location	Capacity (gallons)
Reservoirs:		
McMillin	8 miles SE. of Tacoma	110, 000, 000
McMillin No. 2	8 miles SE. of Tacoma	100, 000, 000
Portland Avenue	E. 38th and Portland Ave	50, 000, 000
North End	N. 31st and Shirley	25, 000, 000
Alaska Street North	S. 20th and Wilkeson	7, 500, 000
Alaska Street South	S. 20th and Wilkeson	3, 500, 000
Hood Street	S. 30th and I Street	13, 000, 000
South Tacoma	S. 62d and Clement	500, 000
Indian Hill	Circle Dr. and Bow Rd	500, 000
Standpipes:		
J Street	S. 20th and J Sts	295, 000
North End	N. 31st and Shirley	1, 200, 000
Fletcher Heights	S. 10th and Tyler	612, 000
Bismark	E. 64th and McKinley	371, 000
Northeast Tacoma	33d St. and 49th Ave. NE	96, 000
All facilities		312, 600, 000

A substantial part of the water from the city's purification plant is used in pulp manufacture. Specifications for the manufacture of white paper state that turbidity of the process water must not exceed 5 ppm, and for the manufacture of brown paper, 10 ppm. Because of this requirement, water from the gravity line is bypassed to the Puyallup River when turbidities exceed 5 ppm. A spillway is necessary because the upper transmission line operates continuously, and no facilities other than natural settlement in McMillin Reservoir exist for clarification of the water for domestic and industrial use.

The chemical quality of selected sources of Tacoma's public water supply is given in figure 30. Water in McMillin Reservoir reaches a maximum temperature of 59° F in July and August. A minimum temperature of 36° F has been recorded in January, as shown in the following table.

Temperature extremes of water in McMillin Reservoir, in degrees Fahrenheit

[Furnished by City of Tacoma]

Month	Maximum temperature	Minimum temperature
January	37.0	36. 0
February	40.0	38. 5
March	40.5	39. 5
April	44.0	41. 0
May	48.0	44. 5
June	52.0	49. 0
July	59.0	55. 0
August	59.0	56. 0
September	56.0	53. 5
October	51.5	50. 0
November	43.5	42. 0
December	40.0	39. 0

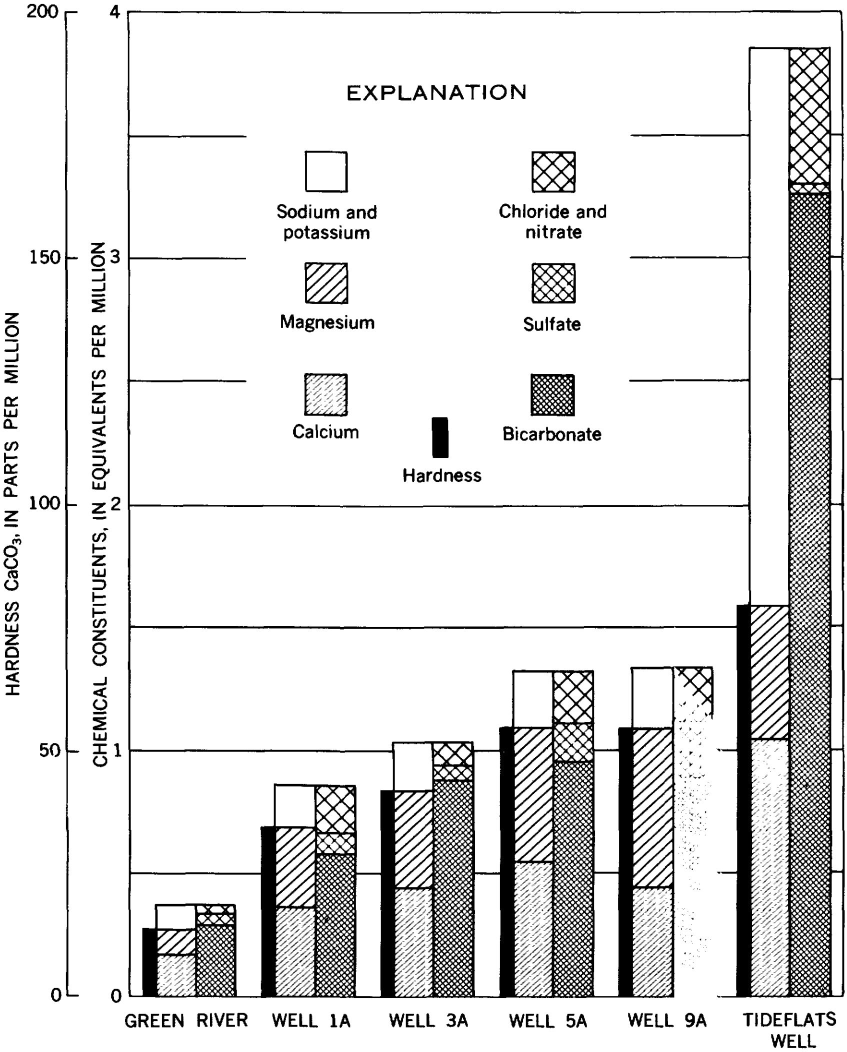

FIGURE 30.—Chemical quality of selected sources of water used for Tacoma public supply system.

OTHER SYSTEMS

Data on 29 smaller public water-supply systems in the Tacoma area are compiled and summarized in table 9. Of these 29 systems, 10 serve communities of 5,000 or more people. Most of the smaller communities in the Tacoma area deliver 90 percent or more of their water output to domestic and commercial consumers

The city of Auburn uses five hydraulic rams to pump water into the municipal reservoir. By taking advantage of the kinetic energy that produces water hammer, these rams, in operation since 1925, pump water at a cost estimated as one-tenth that of equivalent electric power. The five rams are connected to a 3-mile, 24-inch woodstave pipeline discharging 6 mgd and are operated three at a time with two rams in standby. According to B. C. Gosney, Auburn water superintendent, the hydraulic rams use about 75 percent of the water supplied to them to pump the remaining 25 percent into the city mains. Each ram can pump 200 gpm or 0.288 mgd against a pressure of 75 pounds per square inch with a uniform power head of 41 feet. On this basis, five rams at full capacity can pump about 1.4 mgd, or approximately one-fourth of the available supply.

USE OF WATER

Public water-supply systems in the Tacoma area serve more than 290,000 people. In 1955 the use of water averaged 70.1 mgd, of which 50.1 mgd came from streams. Wells and springs supplied 20 mgd—almost 30 percent of the average daily use. In addition to those industries in the Tacoma area which are supplied with water from public systems, chiefly the city of Tacoma system, many industries have their own private supplies.

Self-supplied water from surface sources within the Tacoma area amounts to about 20 mgd. About one-third of this amount is obtained from Hylebos Waterway, the dredged channel connecting Hylebos Creek with Commencement Bay. This water is saline and is used for cooling purposes. The remaining two-thirds is used principally for washing gravel, virtually a nonconsumptive use.

Within the Tacoma area about 50 industrial plants obtain water from some 75 wells, which range in depth from 60 to 1,500 feet. Ground-water appropriations in 1955 for industrial use, as listed by the State from wells only, total 25,672 acre-feet per year (22.9 mgd). Although some of the industries may not use the total quantity appropriated, a few probably use more; in addition, the small to moderate amounts of water used by some industries are not covered by water rights. Total industrial use from wells is probably about 30,000 acre-feet per year (about 27 mgd). Most of the larger users of ground water are listed in table 10. Industrial use of water from springs is probably not more than a few thousand acre-feet per year, much less than that from wells.

The Tacoma area includes a large share of the populated parts of Pierce County, and a small rural area of King County. On the basis of the 1950 census, it is estimated that the rural population within the Tacoma area is about 75,000. Many of the rural homes are supplied with water from public supply systems; the remainder, repre-

TABLE 9.—*Summary of information on principal water-supply systems, Tacoma area, 1955*

[Data from U.S. Public Health Service, Washington State Department of Health, U.S. Geological Survey]

Public Supply	Population served (estimated)	Ownership	Source of supply	Treatment	Finished water storage (gallons)	Estimated average use (gpd)	Estimated peak demand (gpd)	Average daily per capita consumption (gallons)	Division of use (percent) Domestic	Division of use (percent) Other	Other areas served	Remarks
Alderton	500	Private	Springs	None	12,100	100,000	150,000	200	98	2	McMillan	
Auburn	7,500	Municipal	Coal Creek Spring and several small springs.	do	3,500,000	1,500,000	2,500,000	200	90	10	U.S. Army General and Ordnance Depots.	Chlorination proposed.
Bonney Lake	400	do	Wells and Victor Falls Springs.	do	220,000	20,000	30,000	50	100	0		Springs are principal source of supply.
Browns Point	1,500	Private	Wells	do	410,000	160,000	220,000	107	100	0		Community served by two water companies.
Buckley	1,500	Municipal	South Prairie Creek.	Chlorination	527,000	142,500	262,000	95	95	5		Rainier State School well supplements supply during peak demand.
Dash Point	1,000	Private	Wells	None	125,000	108,000	153,000	108	100	0		
Day Island	500	do	do	do	20,000	130,000	270,000	260	100	0		Winter use averages 86,400 gpd; summer, 270,000 gpd.
Du Pont	400	Municipal	do	do	100,000	40,000	60,000	100	100	0		
Enumclaw	5,000	do	City and Water Crest Springs.	do	1,250,000	600,000	900,000	120	95	5		Copper sulfate used to control algae.
Fircrest	2,500	do	Wells	do	200,000	253,000	390,000	101	95	5		
Fort Lewis	35,000	Federal	Sequalitchew Spring and wells.	Chlorination	5,325,000	4,500,000	10,000,000	129	90	10	Madigan General Hospital, Mount Rainier Army Ordnance Depot, and U.S. Veterans Hospital.	Spring yields 14.4 mgd.
Kapowsin	500	Private	Spring	None	8,000	40,000	60,000	80	100	0		

King Co. Dist. No. 64.	1,500	Water district.	Wells	do	400,000	60,000	120,000	40	90	10		
Lake Center	2,500	do	do	Chlorination	100,000	300,000	550,000	120	85	15		
Lakewood	20,000	do	do	do	2,050,000	1,700,000	2,300,000	185	100	0	Tillicum and U.S. Naval Supply Depot.	
McChord Field	6,000	Federal	do	do	525,000	800,000	1,200,000	133	100	0		
Milton	5,000	Municipal	do	None	375,000	555,000	830,000	111	100	0		
Mountain View	2,400	Private	Springs and well	do	30,000	192,000	240,000	80	98	2	Edgewood	
Orting	1,600	Municipal	do	do	316,000	166,000	240,000	104	95	5		Well used during peak demand.
Parkland	5,500	Private	Wells	do	650,000	415,000	788,000	75	90	10		
Puyallup	12,000	Municipal	Springs and wells	do	6,000,000	2,500,000	3,200,000	208	95	5	North Puyallup	Water not metered in 1955.
Rainier State School.	1,800	State	South Prairie Creek and well.	Chlorination	3,000,000	180,000	290,000	100	100	0		Well used during peak demand.
South Prairie	250	Private	Springs and well	None	46,000	20,000	40,000	80	100	0		
Southeast Tacoma.	5,000	do	Wells	do	250,000	500,000	750,000	100	98	2		
Steilacoom	1,300	Municipal	Springs and wells	do	388,000	260,000	390,000	200	98	2		Well 1 aerated for removal of hydrogen sulfide.
Sumner	3,000	do	Springs	do	1,000,000	750,000	1,000,000	250	80	20		
Tacoma	165,000	do	Green River and wells.	Chlorination and ammonia.	312,574,000	52,340,000	89,050,000	317	32	68	Tacoma fringe area and along the supply line from Green River.	Wells used as auxiliary supply.
University Place	5,000	Private	Wells and spring	None	300,000	500,000	750,000	100	100	0		
Western State Hospital.	3,900	State	do	do	900,000	1,170,000	1,700,000	300	100	0		
Woodland	1,600	Water district.	Well	do	None	128,000	160,000	80	100	0		

senting probably not more than 12,000 to 15,000 families, obtain domestic water from individual wells or springs, or by diversion from small streams. A partial well inventory in the Tacoma area indicated that about 75 percent of these domestic supplies are from wells, about 20 percent are from springs, and only about 5 percent are from streams. Each rural family probably uses 180 to 225 gpd, or 0.2–0.25 acre-foot annually, for domestic purposes. As an additional 100 to 150 acre-feet per year is used for the livestock population of the area, the total rural demand is about 2,500 to 4,000 acre-feet per year (2.2–3.6 mgd).

Irrigation in Pierce County increased greatly in the period 1944–49. According to U.S. Census Bureau reports, there were 87 irrigated farms in the county in 1944 and 246 by 1949, an increase of 280 percent. In 1954 there were 247 irrigated farms.

TABLE 10.—*Industrial use of ground water in the Tacoma area*

Industry	Wells		Approximate quantity of water pumped	
	Number	Depth (feet)	Acre-feet per year	Million gallons per day
Cammerano Bros	1	146	320	0.29
Carstens Packing Co	2	452–705	300	.27
City Ice Co., Puyallup	1	252	100	.09
Columbia Power Co	1	80	320	.29
Container Corp	2	175–220	480	.43
Farmers Union Berry Cooperative, Puyallup	1	285	330	.29
Fibreboard Products, Inc	2	462–575	2,200	2.00
Flett Dairy	2	60–90	410	.36
Heidelberg Brewing Co	2	247–677	2,800	2.5
Hooker Electrochemical Co	1		1,500	1.3
I. E. duPont deNemours & Co	4	265–331	2,700	2.4
Kaiser Aluminum & Chemical Corp	3	824–950	2,800	2.50
Medosweet Dairies, Inc	1	275	250	.22
National Soap Co	1	435	13	.01
Northern Pacific Ry	1	196	230	.21
Northwest Door	1	600	400	.35
Pioneer Sand and Gravel Co	1	1,020	2,400	2.2
St. Paul & Tacoma Lumber Co	1	1,501	920	.82
Silver Springs Brewing Co	1	618	94	.08
Standard Brands, Inc	3	168–572	2,100	1.8
United Concrete Pipe Co	1	107	480	.42
Valley Packing Co., Puyallup	1	315	400	.35
West Tacoma Newsprint Co	2	548–1,172	4,700	4.2
Total			26,200	23.4

At the end of 1955, permits and certificates for the appropriation of surface water for irrigation totaled approximately 50 mgd for use on about 7,700 acres in Pierce County and the part of King County shown on plate 1. The average annual use probably does not exceed 20 mgd (31 cfs).

Use of ground water for irrigation increased more rapidly after 1945 than use of surface water. The great increase in use of ground water has been due to the development of portable irrigation systems, the wide availability of cheap electrical power, and the increased value of the agricultural products which made intensive cultivation practices economically feasible.

The rapid increase in use of ground water is shown by certificates of appropriation issued by the State Department of Conservation, Division of Water Resources. The State ground-water code, which was enacted in 1945, provided for certificates to be issued upon declaration of use for wells already constructed and in use. Only 21 certificates were issued on declaration of irrigation use in Pierce County as of 1945, whereas 89 certificates were issued upon applications made during the period 1945–56. In addition, several dozen applications were pending or were in the permit stage at the end of 1956. The approximate magnitude of appropriated ground water for irrigation in the Tacoma area is shown in figure 31. By 1955, the

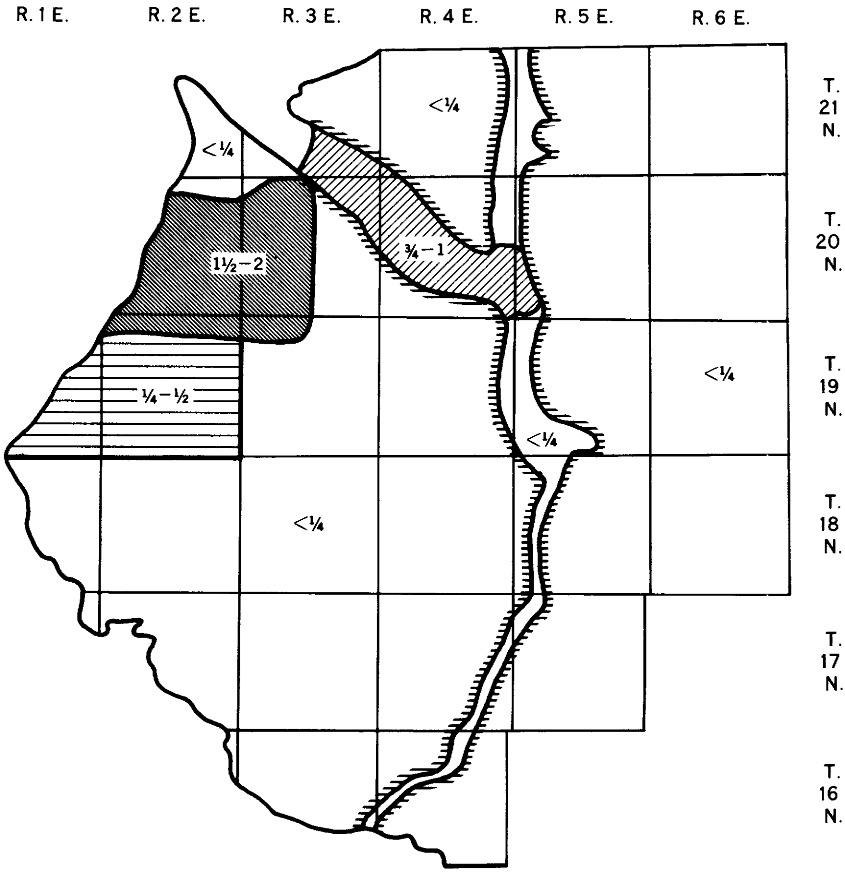

FIGURE 31.—Approximate magnitude of ground water appropriated for irrigation in the Tacoma, Wash., area, in acre-feet per acre per year (data from State Department of Conservation).

total quantity of ground water appropriated for irrigation in Pierce County was more than 3,000 acre-feet per year (average 2.7 mgd). Probably not all farmers use the total amount of water appropriated; on the other hand, there is some use that is not covered by water rights. The 1950 census report shows that 82 enterprises irrigated 992 acres from wells in 1949, and 22 enterprises irrigated 466 acres from springs. Thirteen enterprises irrigating 252 acres used both surface and ground water. Acreage in Pierce County irrigated by ground water in 1955 probably was 2,500 acres, and total quantity of ground water used for irrigation probably was between 3,000 and 4,000 acre-feet (2.7–3.6 mgd).

POTENTIAL ADDITIONAL WATER SUPPLIES

The overall national water use is expected to almost double between the years 1950 and 1975. As the population growth rate in the Pacific Northwest is greater than the national average, the water needs could more than double in the Tacoma area in that time. Some of the expected increase in use is anticipated from a rising standard of living, which calls for household appliances, such as automatic washers, garbage disposers, and water-cooled air conditioners, that require more water.

The greatest percentage expansion in water use throughout the Nation is expected to be in industry. Metal production and fabrication, oil refining, and pulp and paper manufacture are a few of the industries that use large quantities of water. Some plants at tidewater use saline water for cooling.

The runoff into Puget Sound from the streams in the Tacoma area averages 4,100 mgd. However, much of this runoff is unsuited for some uses because heavy loads of sediment of glacial origin are carried at times by certain streams in the area. Some of this sediment is extremely small in diameter and requires very long periods of settling for clarification to take place. In fact, samples of water containing suspended materials of glacial origin have remained turbid even after standing for several months. Hence, the detention time required for a unit volume of water containing glacially-derived sediment to flow through a sedimentation basin could be excessive for all except the most noncritical uses.

The heaviest water demand in the Tacoma area takes place during the period June-August, when temperatures are highest. Fortunately, the period of maximum demand does not quite coincide with the period of lowest streamflows. An examination of plate 4 indicates that the most critical periods of low flow of the Green River near

Palmer (above the city of Tacoma water-supply intake) may be expected in late August and September.

The dependable municipal supply from the Green River will be increased by the Eagle Gorge project now under construction. The project is expected to assure a flow of at least 136 mgd past the gaging station on Green River near Palmer, whereas the minimum of record is 52 mgd. The city of Tacoma has on file water rights on the Green River for 258 mgd (400 cfs) and has made application for an additional water right of 97 mgd (150 cfs).

The potential additional exploitation of surface waters in the Tacoma area is limited for some streams by the amount of water already appropriated. Table 11 gives the average discharge for selected gaging stations, shown on plate 1, and the approximate surface-water appropriations in the drainage basins above those stations. Appropriations are listed only for the area shown on plate 1 and do not include rights such as those for power and other uses in the Nisqually River basin south of Pierce County.

TABLE 11.—*Discharge at selected gaging stations and approximate surface-water rights, in million gallons per day*

[Data on surface-water appropriations from State Department of Conservation. Appropriations for parts of drainage areas lying outside bounds of map on plate 1 are not included. Some appropriations are nonconsumptive.]

Gaging station	Discharge		Surface water appropriated
	Average through 1954	Minimum daily, October 1952	
Nisqually River near National	488	115	0.6
Nisqually River at LaGrande	870	356	1.9
Ohop Creek near Eatonville	42.1	4.6	1.3
Nisqually River near McKenna	1,117	297	5.2
Nisqually River at McKenna	1,041	118	7.1
Kapowsin Creek near Kapowsin	31.3	1.2	52
Puyallup River near Orting	450	80	452
Carbon River near Fairfax	266	58	.01
South Prairie Creek at South Prairie	160	19	1.9
Puyallup River at Alderton	1,027	194	498
Greenwater River at Greenwater	131	20	.01
White River near Buckley	895	195	3.9
Stuck River near Sumner	398	31	21
Puyallup River at Puyallup	2,109	341	517
Green River near Lester	276	16	.13
Green River near Palmer	690	65	258

Following is a list (based on information furnished by the State Departments of Conservation, of Fisheries, and of Game) of streams in the Tacoma area that are closed to further appropriation or are restricted in use during low-flow periods:

- Big Soos Creek
- Boise Creek [1]
- Burns Creek
- Chambers Creek
- Clover Creek
- Fennel Creek
- Green River [1]
- Hylebos Creek
- Jenkins Creek
- Lacamas Creek
- Leach Creek
- Little Soos Creek
- Mashel River
- Mill Creek
- Milwaukee Ditch [1]
- Muck Creek
- Newaukum Creek
- Ohop Creek (trib. to Nisqually River) [1]
- Sequalichew Creek
- Voights Creek [1]
- Wapato Creek
- White-Stuck Rivers [1]

[1] Restricted during low-flow periods only.

The average annual rate of ground-water recharge from precipitation on the Tacoma Upland is estimated at 360,000 to 440,000 acre-feet, or 0.9 to 1.1 mgd per square mile. Some of this recharge goes into shallow perched or semiperched aquifers and could not be recovered economically in large quantities. A considerable part of the area is included in the Fort Lewis Military Reservation and is closed to general ground-water development. However, large ground-water withdrawals close to the boundaries of the reservation might effectively utilize at least some of the recharge that occurs within the reservation. Thus, the potential economically feasible withdrawal from the Tacoma upland may be 200,000 to 300,000 acre-feet annually; this is roughly 0.5 to 0.75 mgd per square mile. Because of the lenticularity of the aquifers and the lateral changes in permeability, the withdrawal from a single pumping center would be only a small part of the total quantity available. Nevertheless, there probably are several places on the Tacoma upland where supplies of 20 to 25 mgd could be withdrawn continuously.

The rates of recharge from precipitation per square mile are believed to be considerably less for the other subareas than for the Tacoma Upland, primarily because much of the potential recharge from that source is rejected in those smaller subareas. However, the total potential ground-water supply of the approximately 550-square-mile area probably exceeds 550 mgd (about 600,000 acre-feet per year), though probably not more than one-half to two-thirds of this quantity could be recovered economically. Although the installed capacity of all wells and developed springs in the area totals approximately 170 mgd (260 cfs), ground-water use at present is not more than 52 mgd. Therefore, a great deal of ground water is available for future development and use.

An important potential source of ground-water supply in addition to recharge by precipitation is induced infiltration, which occurs when ground water is pumped from aquifers that are adjacent to and freely connected with a surface-water supply such as a stream or a lake. Highly permeable aquifers may thus yield many times the amount of water that would be available through recharge from precipitation alone. Generally, the chief advantages of induced infiltration as a source of supply are that a filter plant is not needed and that the water supplied by the pumps has a more uniform temperature than does the surface water itself, though it may be expected to fluctuate more than normal ground water, which usually varies only a few degrees during the year. A further advantage at some locations is the storage afforded by the aquifer, which may be sufficient to carry through a period of low streamflow. However, one disadvantage of induced infiltration is that the streamflow ultimately is reduced by the amount of water withdrawn that does not return to the aquifer or the stream, and surface-water rights have to be considered. Some of the requisites for successful induced infiltration are: (a) a source of surface water of sufficient quantity to supply the wells, (b) permeable aquifers adjacent to and in hydraulic contact with the surface-water body, and (c) sufficient aquifer depth to permit establishment of a hydraulic gradient from the stream to the wells.

Induced infiltration seems to be the most feasible means of domestic utilization of water from glacial rivers in the Tacoma area. Water taken directly from a stream carrying suspended glacial flour or sediment, can be treated for this use, but the cost of such treatment probably would be considerably higher than that of pumping from wells located near a river, where natural filtration would occur.

The flood plain of the Puyallup River appears to offer the best possibility for utilization of water supplies through induced infiltration. The streamflow is ample, and the velocity is sufficient to keep the channel free of silt. Available well records indicate that sand-and-gravel aquifers underlie the flood plain at shallow to moderate depths. These records further indicate that favorable locations for wells might be found adjacent to the river from a few miles above Orting to a few miles downstream from Puyallup. Test wells and aquifer tests would be required to locate the best sites and to determine the quantities of water that could be pumped. However, the general character and permeability of aquifers in the Tacoma area, indicate that individual sites which would yield tens of millions of gallons a day could be found. The 15-mile reach of flood plain along the Puyallup River might yield several hundred million gallons of water a day.

In considering a large-scale program of ground-water development in the lower part of the Puyallup River valley, and particularly in the Tideflats area at the mouth of the valley, some attention should be given to the ever-present threat of salt-water encroachment into the aquifers. Heavy withdrawals, allowed to proceed without a constant check on static and pumping water levels and on water salinity, could result in the partial recharge of these aquifers from Puget Sound. Once encroachment has started, complete flushing of saline water may be accomplished only by virtually complete cessation of pumping from the contaminated aquifers. For a heavily industrialized area, dependent on ground water, this might be an impossibility. Therefore, measures should be taken to detect and then to prevent salt-water encroachment.

WATER LAWS

Water laws of the State of Washington are based on the doctrine of appropriation for beneficial use, provided that there is no infringement of any riparian rights existing as of June 7, 1917, the date of establishment of the State water code for surface waters. The Supervisor of Water Resources acting under the Director of the Department of Conservation allocates surface and ground water in Washington. His responsibilities include review of applications and issuance of permits for use of surface and ground water. Applications for surface water are also submitted to the Departments of Fisheries and of Game for review and recommendation. The law of 1939 requires that a flow of water sufficient to support game- and food-fish populations be maintained at all times in the streams of the State. The Supervisor of Water Resources may refuse to issue a permit for use which, in the opinion of the directors of the fisheries and game departments, might lower the flow of water in any stream below that necessary to support adequately the food- and game-fish populations in the stream.

Laws applicable to the withdrawal and use of underground water are generally the same as those pertaining to surface water. However, as stated in State of Washington Surface and Ground Water Codes, Division of Water Resources, 1952, "* * * to the extent that any underground water is part of or tributary to the source of any surface stream or lake, or that the withdrawal of ground water may affect the flow of any surface water, the right of an appropriator and owner of surface water shall be superior to any subsequent right hereby authorized to be acquired in ground water." All natural ground water and all artificial ground water that has been abandoned or forfeited are declared to be public ground water and to belong to the public and to be subject to appropriation for beneficial use.

Permits are also required for appropriation of public ground water by withdrawal except "* * * for stock watering purposes, or for watering of a lawn or of a noncommercial garden not exceeding one-half acre in area, or for single or group domestic uses, or for an industrial purpose, in an amount not exceeding 5,000 gallons a day * * *." Withdrawal of ground water, whether or not under written permit, shall be made for economical beneficial use. Ground-water rights may be declared to be abandoned if withdrawals have been discontinued for a period of 5 years.

Upon the request of 10 or more owners of real property abutting on a meandered lake, through a petition to the superior court of the county in which the lake is located, the Supervisor of Water Resources may be directed to regulate the outflow therefrom for the purpose of fixing the water level in the interest of flood control. This section of the water laws does not apply to any meandered lake or reservoir used for the storage of water for irrigation or other beneficial purpose or to lakes navigable from the sea.

Other State agencies that exercise control over waters of the State are the Pollution Control Commission and the Departments of Health and of Agriculture. The Pollution Control Commission has jurisdiction over control and prevention of pollution of streams, lakes, ponds, inland waters, salt waters, water courses, and other surface and underground waters of the State.

The Federal Government, through the Corps of Engineers, Seattle District, operates flood-control projects in the Puyallup-White River basins and is constructing a dam at Eagle Gorge on the Green River. The Corps of Engineers also has jurisdiction over the navigable tidal waterways of the Puyallup and the Duwamish Rivers.

DEFINITIONS OF TERMS AND ABBREVIATIONS

An *acre-foot* is the quantity of water required to cover an acre to a depth of 1 foot and is equivalent to 43,560 cubic feet.

An *aquifer* is a rock formation or stratum that will yield water in sufficient quantity to be useful as a source of supply. An *artesian aquifer* is an aquifer confined between relatively impermeable rocks and containing water under sufficient pressure to rise above the bottom of the upper confining bed. The *piezometric surface* is an imaginary surface defined by the levels to which water will rise in cased wells. It may be not only above the water table but above the land surface, and at such places, wells obtaining water from the confined aquifer will flow at the surface.

The *coefficient of transmissibility* is a measure of the ability of an aquifer to transmit water. It is defined as the number of gallons of water, at the prevailing water temperature, that will move in 1 day through a section of the aquifer 1 mile wide which has a height equal to the saturated thickness of the aquifer, under a hydraulic gradient of 1 foot per mile. Methods for determining the coefficient of transmissibility have been described by Theis (1935), Wenzel (1942), Cooper and Jacob (1946), Ferris (1948), Brown (1953), and many others.

One *cubic foot per second* is the rate of discharge of a stream whose channel is 1 square foot in cross-sectional area and whose average velocity is 1 foot per second. It is equal to 448.8 gpm or 723.97 acre-feet per year.

Cubic feet per second per square mile is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly in time and area.

A *draft storage curve* shows the amount of storage required to maintain a specific rate of regulated outflow. The storage quantities shown in this report do not include the amount required to replace evaporation, transpiration, and seepage losses from the reservoir.

Drawdown is the lowering of the water level in an aquifer, as measured in a well, caused by pumping or natural flow.

Equivalents per million is a measure of the concentration of dissolved solids in water, expressed in terms of their reacting value. It is the number of unit equivalent weights of an ion contained in 1 million unit weights of the water. An equivalent weight is exactly equal in reacting value to one-half the atomic weight of oxygen (8.000 grams).

A *flood-stage frequency curve* shows the average interval of time between flood stages reaching various elevations above mean sea level. The curves in this report represent the frequency of all floods rising above a base level.

A *flood-duration curve* is a curve showing the cumulative frequency of daily discharges, prepared by summing all daily discharges in order of magnitude and plotting against the percentage of time that the daily discharge equaled or exceeded a given amount.

Glacial outwash is the material deposited by melt-water streams discharging from the front of a glacier. The materials deposited during the advance of the glacier are "advance outwash" and materials deposited during the recession are "recessional outwash." At many places the recessional outwash is separated from the underlying advance outwash by a layer of till.

A *low-flow frequency curve* shows the expected average recurrence interval of annual low flow for periods of 1 day, 7 days, 30 days, or for some other consecutive period. *Annual low flow* is the lowest flow occurring in any year. Low-flow frequency curves in this report are computed using a regional analysis and a climatic year beginning April 1 and ending March 31. The stations used in the regional analysis for the 24-year period April 1, 1930, to March 31, 1954, were Greenwater River at Greenwater, White River at Greenwater, Carbon River near Fairfax, Puyallup River at Puyallup, and Skykomish River near Gold Bar.

Mgd is an abbreviation for million gallons per day. 1 cfs=0.646 mgd.

Outflow is the combined surface and subsurface flow out of a drainage area.

Parts per million is the number of unit weights of a substance in a million weights of solution (chemical), or it is one million times the ratio of the weight of sediment to the weight of water-sediment mixture (stream discharge).

Perched ground water is water collected in a zone of saturation above the regional water table and separated from it by a zone of aeration. The downward percolation of perched water is impeded by a stratum of hardpan or clay. The surface of the perched ground water is a *perched water table.*

Runoff is the discharge of water in surface streams. Current usage associates runoff with natural sources and effects, excluding those of artificial storage, diversions, and the like.

Semiperched ground water is water in or above materials of relatively low permeability, having a substantially higher head than ground water in adjacent, more permeable material from which it is not separated, however, by any unsaturated material. Semiperched water belongs to the same zone of saturation as the water in the adjacent, more permeable material and, therefore, where it occurs there is only one water table.

Specific capacity is the yield of a well per unit of drawdown, generally expressed as gallons per minute per foot of drawdown. It is dependent not only on the hydraulic properties of the aquifer, but on the size, construction, and development of the well, and on the length of time and rate of pumping.

Water year is a period of 1 year ending on September 30.

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BASIC DATA

TABLE 12.—*Age and water-bearing characteristics of aquifers in the Tacoma area*

Period	Epoch	Rock unit				Aquifer	
		Name		Composition	Thickness (feet)	Name	Composition and water-bearing characteristics
Sedimentary rocks							
Quaternary	Recent	Alluvium		Sand, silt, clay, gravel, shells.	0–600+	Recent alluvium (shown on pl. 2 only where 200 feet or more thick).	Sand and silt yield small to moderate supplies of water; sand and gravel along the White and Green Rivers yield moderate to large supplies where saturated; other saturated sand, silt, and gravel deposits yield moderate to moderately large supplies. Underlain by deposits of Vashon or pre-Vashon age.
	Pleistocene	Vashon drift	Recessional outwash.	Gravel, sand.	0–200+	(Not shown separately on pl. 2 from advance outwash.)	Coarse sand and gravel deposited by melt-water streams. Where deposits extend below the water table, they form very important aquifers. Unit includes small bodies perched on till, some of which yield water.
			Till	Clay, silt, sand, gravel, boulders.	0–60+	Till of the Vashon glaciation	Unsorted mixture of clay, silt, sand, gravel, and boulders forming a thin layer over a large part of upland areas; where sufficiently thick will yield small supplies. Underlain generally by advance outwash.
			Advance outwash	Sand, gravel.	5–100	Outwash deposits (advance and recessional) of the Vashon glaciation.	Chiefly outwash sand and gravel of Vashon age, overlain at many places by till; generally yield moderate to large supplies of water. Outwash deposits beneath uplands immediately adjacent to deep valleys are readily drained, and therefore generally do not yield water. Underlain by pre-Vashon unconsolidated deposits or older semiconsolidated sediments.
		Pre-Vashon unconsolidated deposits.		Silt, sand, gravel, clay, peat.	>1,000(?)	Pre-Vashon unconsolidated deposits.	Aquifers are sand and gravel; generally yield small to moderate supplies but at some places yield large supplies. Overlain at most places by deposits of Vashon or Recent age. Underlain by semiconsolidated or consolidated rocks.

Quaternary to Tertiary	Pleistocene to Pliocene		Clay, silt, sand, cemented gravel.	10–1,000(?)	Older semiconsolidated sedimentary deposits.	Sandy parts generally yield small supplies; where sands are deep, large available drawdown may permit developing large supplies by pumping from great depths. Underlain by consolidated sedimentary or volcanic rocks.
Tertiary	Eocene	Puget group.	Sandstone, shale, coal, conglomerate.	10,000+	Consolidated sedimentary rocks.	Sandstone and shale yield negligible to small supplies.
Igneous rocks						
Tertiary	Post-Eocene	Pyroxene andesite			Volcanic rocks.	Volcanic rocks generally yield no water or negligible supplies in Puget Sound lowland.

TABLE 13.—*Summary of streamflow data at gaging stations in operation on Sept. 30, 1954*

Gaging station		Drainage area (square miles)	Elevation of gage (feet above mean sea level)	Period of record	Average flow		Maximum flow		
No. (pl. 1)	Stream and location				Quantity (mgd)	Years	Quantity (cfs)	Gage height (feet)	Date
11	Nisqually River near McKenna	445	373.6	Aug. 1941 to Sept. 1954	1,117	13	17,700	11.37	2-11-51
13	Nisqually River at McKenna	517	275	Oct. 1947 to Sept. 1954	[2] 1,040	7	[2] 16,900	11.30	2-11-51
17	Chambers Creek below Leach Creek	104	100	Dec. 1937 to Sept. 1940 July 1943 to Sept. 1954	72	13	661		2-11-51
20	Kapowsin Creek near Kapowsin	23	561	June 1927 to Oct. 1932 Oct. 1941 to Sept. 1954	31.3	18	605	5.69	12-12-46
21	Puyallup River near Orting	172	357.5	Sept. 1931 to Sept. 1954	450	23			12-..-33
22	Carbon River near Fairfax	78.9	1,212.6	Nov. 1910 to July 1912 Mar. 1929 to Sept. 1954	266	25	11,000	10.2	12-9-33
24	South Prairie Creek at South Prairie	78.6	430	June 1949 to Sept. 1954	160	5	5,470	8.84	12-9-53
27	Puyallup River at Alderton	438	0	Oct. 1914 to Feb. 1927 Oct. 1943 to Sept. 1954	1,027	23	22,600	56.80	12-11-46
28	White River at Greenwater	216	1,725	Sept. 1911 to May 1912 Mar. 1929 to Sept. 1954	533	25	18,100	9.38	12-21-33
29	Greenwater River at Greenwater	73.9	1,725	Sept. 1911 to Aug. 1912 May 1929 to Sept. 1954	131	25	4,280	7.50	12-11-46
31	White River near Buckley	401	0	Oct. 1928 to Nov. 1933 Oct. 1938 to Sept. 1954	895	21	17,000	17.5	2-26-32
35	Stuck River near Sumner	[1] 470	0	Jan. 1945 to Sept. 1954	398	9	13,100	59.74	12-14-46
37	Puyallup River at Puyallup	948	0	May 1914 to Sept. 1954	2,109	40	57,000	31.0	12-10-33
47	Green River near Palmer	230	912.6	Oct. 1931 to Sept. 1954	690	23	23,200	19.95	12-11-46
58	Green River near Auburn	382	0	Aug. 1936 to Sept. 1954	833	18	22,000	68.16	12-11-46

[1] Excludes drainage area of Lake Tapps.
[2] Diversion around gage.

TABLE 14.—*Minimum daily flow, in million gallons per day*

Gaging station		Drainage area (sq mi)	Year beginning April 1																							
Number (pl. 1)	Name		1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
1	Nisqually River near Ashford	68.5					[2] 59	[2,3] 88																		
2	Nisqually River near National	133																								
3	Nisqually River near Alder	252																								
4	Alder Reservoir at Alder	286																								
5	La Grande Reservoir at La Grande	289																								
6	Tacoma Power Conduit near La Grande															[4]	[4]	[4]	[4]	[4]	[4]	[4]	[4]	[4]		
7	Nisqually River at La Grande	292	[2] 207	246		[2] 197	246																[2] 198	[2,3] 310	208	74
8	Mashel River near La Grande	80.7																								
9	Lynch Creek near Eatonville	16.3																								
10	Ohop Creek near Eatonville	35.5																						[2] 4.1	4.5	3.6
11	Nisqually River near McKenna	445																								
12	Tanwax Creek near McKenna	26.6																								
13	Nisqually River at McKenna	517																								
14	Muck Creek near Loveland	16.9																								
15	Clover Creek near Tillicum	70.3																								
16	Chambers Creek at Steilacoom Lake, near Steilacoom	78.4																								
17	Chambers Creek below Leach Creek near Steilacoom	104																								
18	Puyallup River near Electron	92.8			[2,3] 107	[3] 78	[3] 84	[3] 95	[3] 81	[3] 94	[3] 72	[3] 112	[3] 101	[3] 102	[3] 106	88	[3] 124	[3] 78	[2] 101	102	102	109	130	[3] 117	[3] 90	60
19	Puyallup River at Electron	131																								

See footnotes at end of table.

TABLE 14.—*Minimum daily flow, in million gallons per day*—Continued

Gaging station: Number (pl. 1)	Gaging station: Name	Drainage area (sq mi)	Year beginning April 1: 1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
20	Kapowsin Creek near Kapowsin	23 approx.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 3.2	1.6	2.3
21	Puyallup River near Orting	172	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
22	Carbon River near Fairfax	78.9	----	----	----	----	[2 3] 55	48	[2 3] 79	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	30
23	Gale Creek at Wilkeson	25.0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
24	South Prairie Creek at South Prairie	78.6	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
25	Voight Creek near Crocker	22.9	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
26	Fennel Creek near McMillin	12.5	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
27	Puyallup River at Alderton	438	----	----	----	----	----	----	----	----	[2 3] 252	252	282	278	341	221	326	297	234	222	147	175	[2] 309	----	----	----
28	White River at Greenwater	216	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 90
29	Greenwater River at Greenwater	73.9	----	----	----	----	----	[2] 24	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 18
30	Mud Mountain Reservoir near Buckley	400	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
31	White River near Buckley	401	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2 3] 200	143
32	White River flume near Buckley	----	----	----	----	----	----	----	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	----	----	----	----	----	----
33	Boise Creek near Enumclaw	9.58	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
34	White River at Buckley [1]	427	----	----	----	----	----	[2] 275	----	[3] 275	262	[3] 270	254	[2] 226	[2] 448	[2] 259	344	[3] 265	[2] 244	242	231	221	[2] 266	----	----	----
35	Stuck River near Sumner	470	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
36	Lake Tapps near Sumner	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
37	Puyallup River at Puyallup	948	----	----	----	----	----	----	----	----	827	[2] 769	[2] 724	[2] 562	711	[2] 834	1,054	950	[2] 827	[2] 853	808	672	[2] 944	[2] 1,054	[2] 801	[2] 265
38	Clark Creek at Puyallup	1.66	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
39	Wapato Creek near Tacoma	6.00	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
40	Hylebos Creek near Tacoma	5.40	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

41	Snow Creek near Lester	11.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	Friday Creek near Lester	4.55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
43	Green River near Lester	104	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	Smay Creek near Lester	8.71	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
45	Charley Creek near Eagle Gorge	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
46	Bear Creek near Eagle Gorge	4.25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
47	Green River near Palmer	230	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
48	Green River at Kanasket	240	--	--	--	--	--	[2] 85	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
49	Green River near Black Diamond	281	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
50	Newaukum Creek near Enumclaw	13.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
51	Newaukum Creek near Black Diamond	25.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
52	Burns Creek near Black Diamond	3.47	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
53	Big Soos Creek above Jenkins Creek, near Auburn	16.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
54	Jenkins Creek near Auburn	14.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
55	Covington Creek near Black Diamond	9.77	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
56	Covington Creek near Auburn	18.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
57	Big Soos Creek near Auburn	49.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
58	Green River near Auburn	382	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
59	North Fork Cedar River near Lester	8.81	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
60	South Fork Cedar River near Lester	6.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

See footnote at end of table.

TABLE 14.—*Minimum daily flow, in million gallons per day*—Continued

Gaging station		Drainage area (sq mi)	Year beginning April 1																							
Number (pl. 1)	Name		1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
1	Nisqually River near Ashford	68.5																								
2	Nisqually River near National	133													[2] 87	120	120	136	100	193	[3] 136	[3] 175	175	[3] 142	[3] 71	183
3	Nisqually River near Alder	252		[2] 184	184	291	123	102	[3] 97	175	142	163	131	178	111	171	[2] 185									
4	Alder Reservoir at Alder	286															(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	
5	La Grande Reservoir at La Grande	289																						(4)	(4)	
6	Tacoma Power Conduit near La Grande																									
7	Nisqually River at La Grande	292	[2] 121														[3] 3	[3] 53	290	235	[3] 110	[3] 204	251	268	132	284
8	Mashel River near La Grande	80.7											[2] 12	8.4	6.5	6.5	5.9	5.9	11	8.4	15	6.5	8.4	4.3	4.4	12
9	Lynch Creek near Eatonville	16.3																				[2] 2.8				
10	Ohop Creek near Eatonville	35.5	2.6	3.9										[2] 9.7	[2] 3.2	3.2	1.6	2.1	4.2	3.9	6.5	4.2	2.8	2.6	2.3	3.4
11	Nisqually River near McKenna	445												[2] 175	127	194	[3] 114	160	296	203	[3] 217	202	226	269	127	334
12	Tanwax Creek near McKenna	26.6															[2] 2.3	.8	.9	.8	1.6	.5	[2] .6			
13	Nisqually River at McKenna	517																		[2] 162	83	70	102	63	37	116
14	Muck Creek near Loveland	16.9																				[2] 1.4				
15	Clover Creek near Tillicum	70.3																				[2] 0	2.9	.5	0	1.0
16	Chambers Creek at Steilacoom Lake, near Steilacoom	78.4									[2] .5	.8	[2] 4.1													
17	Chambers Creek below Leach Creek near Steilacoom	104								[2,3] 124	31	26	[2] 24			[2] 28	23	26	30	34	45	24	37	31	20	25
18	Puyallup River near Electron	92.8	88	[3] 85	[3] 94	[2,3] 153											[2,3] 119	[3] 142	105	[3] 133	[3] 97	[2,3] 161				

19	Puyallup River at Electron	131																	[2] 142							
20	Kapowsin Creek near Kapowsin	23 Approx	1.0	2.2	[2] 1.7									[2] 6.1	1.5	2.5	1.9	.8	3.6	1.9	5.9	2.8	1.9	.6	1.2	2.6
21	Puyallup River near Orting	172		[2] 106	128	118	111	104	[3] 79	124	134	87	[3] 134	[3] 171	105	133	[3] 145	115	107	[3] 194	[3] 155	151	154	[3] 123	38	136
22	Carbon River near Fairfax	78.9	54	[3] 61	59	110	67	54	44	51	78	69	[3] 65	[3] 79	54	58	54	79	77	[3] 70	[3] 84	99	[3] 102	[3] 61	26	69
23	Gale Creek at Wilkeson	25.0																				[2] 4.5				
24	South Prairie Creek at South Prairie	78.6																				[2] 28	23	16	17	26
25	Voight Creek near Crocker	22.9																				[2] 4.9				
26	Fennel Creek near McMillin	12.5																				[2] 5.6				
27	Puyallup River at Alderton	438														[2] 313	228	301	248	310	[3] 365	322	324	319	97	222
28	White River at Greenwater	216	130	140	[2,3] 169	252	114	103	[3] 90	163	156	156	160	[3] 185	156	[3] 156	160	183	175	[3] 229	[3] 193	185	233	[3] 162	108	220
29	Greenwater River at Greenwater	73.9	[2] 17	19	19	34	16	20	16	26	19	19	18	23	20	21	18	21	25	24	37	24	30	23	[3] 18	26
30	Mud Mountain Reservoir near Buckley	400														(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
31	White River near Buckley	401	175	189	237	[2] 366					[2,3] 385	268	253	345	47	245	191	242	133	315	161	294	326	[3] 282	113	310
32	White River flume near Buckley																									
33	Boise Creek near Enumclaw	9.58																[2] 1.2	[2] 2.3							
34	White River at Buckley [1]	427																								
35	Stuck River near Sumner	470															[2,3] 59	40	30	34	45	35	40	44	23	45
36	Lake Tapps near Sumner																						(4)	(4)	(4)	
37	Puyallup River at Puyallup	948	[2] 417	455	750	989	452	323	414	507	737	637	704	737	549	573	556	724	548	628	[3] 543	543	627	[3] 535	259	500
38	Clark Creek at Puyallup	1.66																[2,3] 7.1	[3] 7.1	[3] 11	[2,3] 12					
39	Wapato Creek near Tacoma	6.00																				[2] 1.1				
40	Hylebos Creek near Tacoma																					[2] 5.3	[2] 4.4			
41	Snow Creek near Lester	11.9																[2] 6.3	3.0	4.5	5.8	4.6	4.4	2.6	1.9	2.8

See footnotes at end of table.

TABLE 14.—*Minimum daily flow, in million gallons per day*—Continued

Gaging station		Drainage area (sq mi)	Year beginning April 1																							
Number (pl. 1)	Name		1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
42	Friday Creek near Lester	4.55																[2] 3.5	1.4	1.8	2.7	.8	2.2	1.4	.8	1.6
43	Green River near Lester	104																[2] 39	22	23	28	25	28	18	14	21
44	Smay Creek near Lester	8.71																	[2] 4.0	5.8	5.4	5.4	6.2	4.5	2.7	4.5
45	Charley Creek near Eagle Gorge	11.0																	[2] 4.8	8.4	12	7.4	7.8	6.5	4.7	7.5
46	Bear Creek near Eagle Gorge	4.25																	[2] .3	.8	2.6	1.1	1.3	.5	.5	1.4
47	Green River near Palmer	230		[2] 119	91	65	52	69	72	74	57	71	65	79	69	69	83	69	81	100	103	90	100	72	63	81
48	Green River at Kanasket	240																								
49	Green River near Black Diamond	281										[2] 72	36	61	50	67	47	72	66	66	[2] 105					
50	Newaukum Creek near Enumclaw	13.4																[2] 4.8								
51	Newaukum Creek near Black Diamond	25.5															[2] 7.1	11	11	9.0	14	8.7	[2] 11		[2] 5.4	11
52	Burns Creek near Black Diamond	3.47																[2] 2.6								
53	Big Soos Creek above Jenkins Creek, near Auburn	16.3															[3] 3.3	[3] 3.4								
54	Jenkins Creek near Auburn	14.6															[2] 7.1	[2] 8.4								
55	Covington Creek near Black Diamond	9.77																							[2,3] 6.8	0
56	Covington Creek near Auburn	18.5															[2] 1.9	[2] 2.6								

57	Big Soos Creek near Auburn	49.4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 14	17	19	17	25	16	18	[2] 14	13	19
58	Green River near Auburn	382	----	----	----	----	----	----	[2] 110	110	81	94	73	94	96	79	94	106	123	107	167	102	115	62	52	94
59	North Fork Cedar River near Lester	8.81	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 7.1	6.5	5.4	5.8	7.8	7.4	8.4	5.5	3.5	5.8
60	South Fork Cedar River near Lester	6.00	----	----	----	----	----	----	----	----	----	----	----	----	----	----	[2] 3.2	2.1	1.9	2.5	3.7	3.1	4.0	1.7	1.3	2.3

[1] Minimum daily discharge for 1900, 420 mgd; for 1901, 317 mgd. Figures after 1913 include flow of White River flume.
[2] Incomplete year.
[3] Occurred outside the usual low-water period August to November.
[4] Reservoir records published.

TABLE 15.—*Chemical quality of stream waters*

[Analytical results in parts per million except as indicated]

Stream and location	Drainage area (square miles)	Date sample collected	Mean discharge (mgd)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per day	Dissolved solids: Tons per square mile	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C.)	pH	Color (in units on platinum: cobalt scale)
Nisqually River near McKenna.	445	Feb. 9, 1955	2,190	14	0.11	4.8	1.2	3.0	0.7	22	2.5	1.5	0.2	1.2	0.05	48	439	1.0	17	0	27	0.3	49.2	7.2	30
		Sept. 1	626	10	.02	4.8	1.0	2.8	.6	24	2.1	1.0	.1	.2	.05	47	123	.3	16	0	27	.3	47.9	7.1	0
Chambers Creek below Leach Creek near Steilacoom.	104	Feb. 18	96	15	.01	9.9	3.6	5.0	1.2	44	6.9	4.0	.1	4.7	.10	76	30	.3	40	4	21	.3	109	6.9	10
		Aug. 30	25	18	.00	10	5.2	5.7	1.0	51	7.4	5.0	.1	3.8	.04	84	8.8	.1	46	4	21	.4	124	7.1	0
Kapowsin Creek near Kapowsin.	23	Feb. 8	159	16	.08	3.4	1.1	3.0	.9	18	1.5	1.0	.3	1.6	.08	38	34	1.5	13	0	31	.4	42.7	6.6	40
		Sept. 1	4.1	13	.03	4.8	1.4	3.4	.9	28	.7	2.0	.2	.7	.01	41	.8	----	18	0	28	.4	53.0	6.7	25
Puyallup River near Orting	172	Feb. 8	2,090	13	.05	3.8	.9	2.3	.9	17	2.5	1.2	.3	1.6	.11	47	411	2.4	13	0	26	.3	39.9	6.6	40
		Aug. 31	323	9.7	.02	4.2	1.3	2.3	.6	16	7.4	1.0	.1	.2	.04	65	88	.5	16	3	23	.3	43.8	6.9	0
Puyallup River at Alderton	438	Feb. 9	2,710	12	.05	4.8	1.0	2.6	.8	20	3.0	1.0	.2	1.6	.14	46	520	1.2	16	0	25	.3	47.3	6.8	25
		Aug. 31	659	10	.03	5.6	1.6	3.0	.7	26	5.1	1.0	.1	.3	.01	57	157	.4	21	0	23	.3	58.7	7.2	0
Puyallup River near Sumner	----	Oct. 18, 1926	----	15	.13	8.3	2.7	3.3		35	8.6	1.6	----	.4	----	60	----	----	32	3	18	.3	----	----	----
Puyallup Run above Clark Creek at Puyallup.	----	Oct. 18	----	16	.09	7.8	2.3	3.5		31	10	1.8	----	.6	----	61	----	----	29	4	21	.3	----	----	----
Puyallup River at Puyallup	948	Feb. 9, 1955	5,710	13	.01	4.8	1.2	2.8	.9	20	4.7	1.2	.3	1.5	.04	47	1,120	1.2	17	1	25	.3	51.8	6.6	20
		Aug. 30	1,240	13	.02	6.0	1.4	4.0	1.4	26	6.7	2.0	.1	1.1	.01	55	285	.3	21	0	28	.4	66.7	6.3	0
Clear Creek at Tacoma	----	Oct. 18, 1926	----	32	.06	9.8	6.4	4.3		63	4.2	3.0	----	1.1	----	92	----	----	51	0	16	.3	----	----	----
Carbon River near Fairfax	78.9	Feb. 8, 1955	1,140	8.9	.00	3.2	.5	1.7	.6	12	1.5	.2	.2	1.6	.05	30	143	1.8	10	0	26	.2	29.8	6.6	10
		Sept. 1	191	7.1	.01	2.4	.3	1.8	.5	13	1.4	.5	.1	.4	.08	33	26	.3	7	0	33	.3	28.4	6.9	0
South Prairie Creek at South Prairie.	78.6	Feb. 9	583	11	.00	4.6	1.0	2.5	.7	18	4.5	1.2	.3	1.9	.05	43	105	1.3	16	1	25	.3	48.6	6.7	25
		Sept. 1	35	14	.00	11	2.9	5.8	.6	51	7.7	2.2	.1	.3	.02	70	10	.1	39	0	24	.4	106	7.3	0
White River at Greenwater	216	Feb. 8	1,960	13	.00	4.4	.8	2.3	.6	17	4.4	.5	.3	.9	.12	44	361	1.7	14	0	25	.3	42.5	6.9	25
		Aug. 30	467	14	.02	5.6	.9	3.9	.8	18	10	1.2	.1	.3	.11	62	121	.6	18	3	31	.4	58.3	7.0	0
White River near Buckley	401	Aug. 26, 1947	436	15	----	5.6	1.2	8.3		25	14	1.5	----	.3	----	58	106	.3	19	0	49	.9	61.0	----	----
		May 7, 1948	2,180	17	.05	7.2	1.0	3.7		26	7.1	.2	.1	.2	.01	45	409	1.0	22	0	27	.3	45.6	7.2	----
		Feb. 8, 1955	2,190	9.5	.07	3.2	.5	1.9	.7	12	3.8	1.0	.3	1.1	.12	42	384	1.0	10	0	27	.3	33.7	6.6	30
		Aug. 31	559	12	.03	5.4	.8	3.7	.8	20	8.8	1.5	.1	.4	.02	58	135	.3	17	1	31	.4	54.9	7.0	0
Greenwater River at Greenwater.	73.9	Feb. 8	743	14	.03	4.6	.5	2.5	.5	19	2.6	1.0	.3	.9	.08	43	134	1.8	14	0	28	.3	41.0	6.5	20
		Aug. 30	47	16	.00	6.7	1.2	4.3	.3	33	3.3	1.2	.0	.1	.02	50	9.8	.1	22	0	30	.4	61.4	7.5	0

Stuck River near Sumner	470	Oct. 20, 1926	-------	16	.09	6.7	1.9	3.4		24	9.8	1.4	----	.1	----	57	--------	----	25	5	23	.3	------	----	------
		Feb. 9, 1955	1,510	13	.07	4.4	1.0	2.5	.9	18	4.2	1.0	.3	1.8	.16	48	303	.6	15	0	25	.3	46.7	6.6	20
		Aug. 29	62	15	.02	9.3	2.0	4.5	1.0	38	9.1	1.8	.1	.5	.01	67	17	----	31	0	23	.3	87.9	7.2	0
Hylebos Creek near Tacoma	5.40	Oct. 20, 1926	-------	31	.14	9.6	7.5	4.6		66	4.8	2.4	----	.4	----	99	--------	----	55	1	15	.3	------	----	------
Green River at Hot Springs	--------	Feb. 1–Aug. 18, 1910.[1]	-------	17	.04	6.0	1.3	5.6		28	5.9	1.3	----	.1	----	55	--------	----	20	0	37	.5	------	----	------
Green River near Palmer	230	Jan. 13, 1938	1,070	11	.02	3.7	1.1	2.3	.5	17	2.1	1.2	.0	.1	----	32	143	.6	14	0	26	.3	------	----	------
		Aug. 25, 1947	100	16	----	6.4	1.0	3.7		28	3.1	1.5	----	.3	----	46	19	.1	20	0	29	.4	50.0	----	------
		May 7, 1948	2,150	17	.02	6.6	.9	1.6		22	3.8	.5	.1	.4	.01	40	360	1.6	20	2	15	.2	36.4	7.2	------
		Feb. 8, 1955	7,040	11	.01	3.4	.3	2.2	.3	13	2.1	1.0	.1	.9	.09	39	1,150	5.0	10	0	32	.3	32.7	6.2	0
		Sept. 2	157	12	.00	5.2	.7	3.1	.4	24	2.2	1.5	.1	.2	.02	40	26	.1	16	0	29	.3	48.7	6.9	0
Green River near Auburn	382	Feb. 9	4,320	11	.03	4.2	.8	2.7	.6	18	3.0	1.5	.3	1.3	.04	42	758	2.0	14	0	29	.3	43.4	6.7	20
		Aug. 31	197	15	.00	9.1	2.2	4.8	.4	44	4.6	2.2	.1	.6	.01	60	49	.1	32	0	24	.4	87.0	7.1	0

[1] Mean of 20 analyses.

TABLE 16.—*Chemical quality of water from selected wells*

[Analytical results in parts per million except as indicated]

Location of well or spring	Depth (feet)	Date sample collected	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color (in units on platinum-cobalt scale)
Puyallup River Valley																				
NE¼SE¼ sec. 4, T. 20 N., R. 3 E	705	Oct. 24, 1946	----	----	0.07	----	----	16		78	1.0	19	----	----	----	58	0	191	----	----
SE¼NW¼ sec. 24, T. 20 N., R. 4 E	572	Jan. 11, 1938	53	44	.14	18	6.3	59	4.3	222	1.8	13	0.0	0.0	255	71	0	----	----	----
NW¼NE¼ sec. 35, T. 21 N., R. 3 E	856	Feb. 1939 [1]	----	24	5.5	17	4.2	80		183	1.4	16	----	----	----	60	0	----	----	----
SE¼SW¼ sec. 36, T. 21 N., R. 3 E	824	June 1942 [1]	----	57	1.3	21	7.0	87		190	5.0	20	----	----	189	80	0	----	7.9	----
SW¼SE¼ sec. 26, T. 21 N., R 3 E	450	Feb. 6, 1930 [1]	----	46	4.1	11	10	146		230	0.5	92	----	----	----	69	0	----	----	----
SW¼SW¼ sec. 26, T. 21 N., R. 3 E	785	Dec. 29, 1944	----	39	1.5	21	6.6	53	2.2	199	1.6	17	.2	3.4	246	80	0	368	----	----
Tacoma Upland																				
NE¼NE¼ sec. 32, T. 18 N., R. 2 E	1,340	Oct. 10, 1955	51	24	0.84	15	7.7	5.9	1.5	91	5.1	3.0	0.0	1.4	106	69	0	166	7.3	0
SW¼NW¼ sec. 34, T. 18 N., R. 2 E	21	1946 [2]	----	14	----	5.0	5.0	----	----	38	2.0	9.0	----	----	51	32	1	----	6.6	----
NW¼SE¼ sec. 12, T. 19 N., R. 1 E	Spring	1946 [2]	----	15	----	9.0	4.0	----	----	47	2.0	10	----	----	69	41	3	----	7.7	----
SE¼SW¼ sec. 22, T. 19 N., R. 1 E	265	Feb. 1942 [3]	----	28	.04	15	8.8	----	----	----	44	20	----	----	142	74	----	----	8.0	----
NE¼SE¼ sec. 1, T. 19 N., R. 2 E	173	July 31, 1950 [4]	----	31	.1	9.3	5.8	9.3		71	5.8	6.3	----	----	103	47	0	----	7.7	----
Do	173	Dec. 23, 1955 [4]	----	52	.18	11	5.9	11		76	4.4	6.8	----	.0	98	53	0	----	7.5	0
NE¼NW¼ sec. 9, T. 19 N., R. 2 E	481	Nov. 4, 1938	52	51	2.8	10	6.4	16	2.2	101	.4	1.9	.2	.8	141	51	0	----	----	----
NE¼SW¼ sec. 10, T. 19 N., R. 2 E	638	Dec. 23, 1955 [4]	----	46	.06	7.9	5.9	14		77	2 6	6.8	----	.0	92	44	0	----	7.4	0
NE¼NE¼ sec. 12, T. 19 N., R. 2 E	141	Aug. 16, 1946 [5]	----	19	----	17	7.2	1.4		----	----	10	----	----	----	72	----	----	----	----
SW¼NE¼ sec. 13, T. 19 N., R. 2 E	200	Nov. 5, 1954	53	33	.06	11	5.5	6.5	1.7	62	6.6	3.5	.1	1.5	106	50	0	127	7.2	5
SW¼NE¼ sec. 13, T. 19 N., R. 2 E	298	Nov. 5, 1954	55	26	.02	13	5.9	5.1	1.6	60	8.1	4.0	.1	4.3	106	57	8	137	7.0	5
NW¼NE¼ sec. 14, T. 19 N., R. 2 E	110	Mar. 21, 1951 [4]	----	32	----	----	4.2	6.7		52	7.1	7.7	.0	.1	88	46	3	----	7.4	----
Do	110	Dec. 23, 1955 [4]	----	51	.34	13	5.1	6.6		59	8.7	7.5	----	.0	91	54	6	----	6.7	0
SE¼SE¼ sec. 16, T. 19 N., R. 2 E	224	Dec. 23, 1955 [4]	----	40	.08	8.7	5.3	12		68	4.1	6.8	----	.0	100	44	0	----	7.3	0
NW¼SW¼ sec. 18, T. 19 N., R. 2 E	550	Nov. 19, 1953	----	46	.08	7.6	5.0	7.8	1.7	66	2.0	1.6	.2	.2	99	40	0	110	7.8	3
NW¼NE¼ sec. 19, T. 19 N., R. 2 E	225	Sept. 13, 1954	53	32	.18	12	6.3	4.9	2.3	64	13	2.8	.1	.2	98	56	3	137	7.2	5
NW¼SE¼ sec. 19, T. 19 N., R. 2 E	1,000	Sept. 13, 1954	53	43	.29	6.4	4.4	4.2	.7	42	3.7	2.2	.1	.1	82	34	0	81.0	7.3	5
SE¼NW¼ sec. 19, T. 19 N., R. 2 E	229	Sept. 13, 1954	52	27	.60	12	6.2	4.7	1.1	66	3.5	3.2	.1	.2	88	55	1	118	7.1	10
SW¼SE¼ sec. 19, T. 19 N., R. 2 E	239	Sept. 13, 1954	54	31	.86	9.6	5.6	4.3	1.5	68	1.6	2.5	.1	.1	81	47	0	111	7.4	5
SW¼SE¼ sec. 19, T. 19 N., R. 2 E	Spring	Oct. 10, 1955	76	10	.01	9.1	2.9	5.0	1.0	44	5.4	3.0	.0	.4	57	35	0	95.3	6.8	0

SW¼ sec. 25, T. 19 N., R. 2 E	52	Oct. 10, 1955	51	21	.09	9.9	2.9	4.7	.8	54	3.9	3.0	.0	.3	73	37	0	103	6.7	0
SW¼NE¼ sec. 27, T. 19 N., R. 2 E	1,008	Sept. 13, 1954	54	48	1.0	9.0	5.3	6.3	.27	66	4.0	2.4	.2	.0	101	44	0	117	7.3	5
SW¼NE¼ sec. 34, T. 19 N., R. 2 E	36	Oct. 10, 1955	51	19	.02	12	3.3	5.4	1.0	40	13	4.5	.0	3.6	84	44	11	121	6.5	0
SW¼NE¼ sec. 9, T. 19 N., R. 3 E	367	June 29, 1946 [5]	----	20	1.3	6.6	4.0	7.5		41	5.9	6.5	----	----	85	33	0	----	6.8	----
NE¼SE¼ sec. 13, T. 20 N., R. 2 E	151	Nov. 4, 1952 [4]	----	22	.05	9.9	16	9.4		56	0	5.7	.2	4.4	105	63	17	----	7.5	0
NE¼NE¼ sec. 24, T. 20 N., R. 2 E	196	1946 [2]	----	22	2.0	9.0	4.0	----	----	64	0	10	----	----	70	43	0	----	7.2	----
SW¼SE¼ sec. 29, T. 20 N., R. 2 E	548	Oct. 1, 1938	51	45	.07	18	5.8	10	3.9	108	1.2	2.8	.0	.4	142	69	0	----	----	8
SW¼SE¼ sec. 29, T. 20 N., R. 2 E	854	Oct. 1, 1938	53	46	.07	12	6.2	7.6	1.6	84	2.1	2.2	.0	.0	121	55	0	----	----	4
NW¼NE¼ sec. 32, T. 20 N., R. 2 E	1,172	Oct. 1, 1938	54	50	.04	11	5.9	9.2	1.8	84	1.8	2.0	.0	.0	126	52	0	----	----	5
SW¼NW¼ sec. 33, T. 20 N., R. 2 E	Spring	Oct. 4, 1938	54	19	.01	8.4	3.4	5.0	1.4	46	4.1	3.0	.0	.5	66	35	0	----	----	0
SW¼NW¼ sec. 34, T. 20 N., R. 2 E	287	July 31, 1950 [4]	----	52	.1	8.4	5.8	8.4		62	5.6	5.8	----	----	113	45	0	----	7.6	0
Do	287	Dec. 23, 1955 [4]	----	45	.05	8.4	4.6	14		66	4.6	7.5	----	.0	110	40	0	----	7.2	0
SW¼NW¼ sec. 34, T. 20 N., R. 2 E	267	Dec. 23, 1955 [4]	----	51	.18	8.6	4.5	14		71	4.4	5.5	----	.0	95	40	0	----	7.3	0
NW¼NW¼ sec. 18, T. 20 N., R. 3 E	127	Apr. 21, 1952	50	31	.11	8.8	8.0	5.5	1.2	54	11	5.3	.1	4.3	100	55	11	131	7.3	3
SE¼NW¼ sec. 19, T. 20 N., R. 3 E	378	Jan. 4, 1939	----	28	.04	11	6.7	4.9	1.4	58	7.0	4.2	.3	4.9	94	55	7	----	7.1	----
SE¼SW¼ sec. 19, T. 20 N., R. 3 E	310	Jan. 4, 1939	48	24	.04	7.2	4.0	3.4	1.2	35	4.2	3.3	.0	6.0	70	34	5	----	----	----
SW¼SW¼ sec. 30, T. 20 N., R. 3 E	358	Jan. 4, 1939	----	26	.06	8.9	4.8	4.2	.9	54	2.8	2.6	.0	.9	78	42	0	----	----	----
SE¼NW¼ sec. 31, T. 20 N., R. 3 E	209	Dec. 30, 1950 [4]	----	29	.15	8.1	5.3	6.6		50	6.1	6.4	.0	.1	96	42	0	----	7.3	----
SE¼NW¼ sec. 31, T. 20 N., R. 3 E	158	Dec. 23, 1955 [4]	----	33	.04	9.6	5.8	9.0		62	4.8	8.2	----	.0	92	48	0	----	7.2	0
NE¼SE¼ sec. 32, T. 20 N., R. 4 E	Spring	Oct. 20, 1936	----	30	.04	9.4	6.4	3.9		61	3.4	2.0	----	.4	83	----	----	----	----	----
Buckley Upland																				
SE¼SE¼ sec. 2, T. 19 N., R. 6 E	250±	Aug. 16, 1946 [4]	----	27	----	25	5.4	6.1	----	64	----	3.6	----	----	----	85	33	----	----	----
NE¼SW¼ sec. 18, T. 19 N., R. 6 E	Spring	1946 [2]	----	15	----	8.0	2.0	----	----	39	0	9.0	----	----	55	31	0	----	7.8	----
SW¼SE¼ sec. 18, T. 20 N., R. 5 E	Spring	1944 [6]	----	19	----	14	5.0	6.0		73	0	5.0	----	----	96	55	0	----	----	----
Northeast Tacoma Upland																				
NE¼NW¼ sec. 29, T. 21 N., R. 4 E	125	Dec. 1948 [4]	----	30	.1	8.0	7.6	7.6		68	5.8	7.0	----	.0	92	51	0	----	7.2	----
NE¼NW¼ sec. 29, T. 21 N., R. 4 E	500	Feb. 13, 1950 [4]	----	50	----	8.4	7.7	9.9		84	1.7	2.5	----	.0	108	53	0	----	7.4	----
Lower Nisqually Valley																				
NE¼NE¼ sec. 18, T. 18 N., R. 1 E	120	Nov. 16, 1955	----	36	.24	12	5.7	6.4	2.1	75	2.9	4.5	0.1	0.4	107	53	0	139	6.9	5

[1] Analysis by Bennetts Chemical Laboratory, Inc., Tacoma, Wash.
[2] Analysis by Northern Pacific Railway, St. Paul, Minn.
[3] Analysis by E. I. duPont de Nemours and Company, Inc., Wilmington, Del.
[4] Analysis by Northwest Laboratories, Seattle, Wash.
[5] Analysis by Laucks Testing Laboratories, Inc., Seattle, Wash.
[6] Analysis by Chicago, Milwaukee, St. Paul, and Pacific Railroad, Chicago, Ill.

TABLE 17.—*Chemical quality of delivered water from selected public supply systems*

[Analytical results in parts per million except as indicated]

Public supply	Date sample collected	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color (in units on platinum-cobalt scale)
Auburn	Sept. 2, 1955	69	20	0.04	15	2.4	4.6	1.5	62	5.4	2.5	0.1	0.6	87	47	0	124	7.3	0
Enumclaw	Apr. 19, 1951 [1]		36	.21	10	2.1	1.5		49	1.8	8.4			80	35	0		7.4	
Fort Lewis:																			
Sequallitchew Spring.	Oct. 10, 1955	76	10	.01	9.1	2.9	5.0	1.0	44	5.4	3.0	.0	.4	57	35	0	95.3	6.8	0
Well 6	Oct. 10, 1955	51	24	.84	15	7.7	5.9	1.5	91	5.1	3.0	.0	1.4	106	69	0	166	7.3	0
Lake Center	Feb. 13, 1950 [2]		50	.00	8.4	7.7	9.9		84	1.7	2.5			108	53	0		7.4	
Lakewood	July 31, 1950 [2]		31	.10	9.3	5.8	9.3		71	5.8	6.3			103	47	0		7.7	
McChord Field	Nov. 5, 1954	54	41	.09	9.0	5.8	6.8	1.6	66	2.6	2.8	.1	.3	107	49	0	114	7.5	5
Parkland	June 29, 1946 [1]		20	1.3	6.6	4.0	5.9		41	5.9	6.5			85	33	0		6.8	
Puyallup	Jan. 11, 1938	46	30	.13	9.2	5.7	4.5	1.6	59	4.2	2.1	.0	.3	83	46	0			
Steilacoom	Sept. 9, 1953 [3]		36	.25					86					117				7.6	
Summit	May 19, 1955 [3]		28	.05					97		4.2			97	66	0		7.0	
Tacoma:																			
Green River supply.	Oct. 27, 1931		14	.05	5.0	1.2	2.7	.6	21	3.2	1.6		.2	39	17	0			
Do	Jan. 13, 1938	40	11	.02	3.7	1.1	2.3	.5	17	2.1	1.2	.0	.1	32	14	0			
Do	Oct. 4, 1948 [2]		26	.00	6.4	1.3	6.7		30	2.1	6.3	.0	.0	53	21	0		7.8	0
Well 1A	Oct. 27, 1931		25	.29	7.9	4.4	4.1	1.4	38	4.9	4.0		5.3	76	38	7			
Do	Jan. 4, 1939	48	24	.04	7.2	4.0	3.4	1.2	35	4.2	3.3	.0	6.0	70	34	5			
Well 2B [4]	Jan. 29, 1953 [3]		25	.11	26	20	46		67	0	97	.2	6.2	296	143	88		7.2	0
Do [5]	Feb. 4, 1953 [3]		26	.11	28	22	60		71	0	130	.1	6.2		162	104		7.3	0
Well 3A	Jan. 4, 1939		26	.06	8.9	4.8	4.2	.9	54	2.8	2.6	.0	.9	78	42	0			
Well 5A	Jan. 4, 1939		28	.04	11	6.7	4.9	1.4	58	7.0	4.2	.3	4.9	94	55	7			
Do	Oct. 4, 1948 [2]		27	.00	12	7.7	9.4		56	8.9	9.5	.0	17	115	61	15		7.1	0
Well 9A	Apr. 21, 1952	50	31	.11	8.8	8.0	5.5	1.2	54	11	5.3	.1	4.3	100	55	11	131	7.3	3
Do	Feb. 4, 1953 [3]		28	.17	8.1	7.9	17		53	0	5.4	.2	5.3	104	53	10		7.8	0
Well 11A	Nov. 4, 1952 [3]		22	.05	8.9	9.4	16		56	0	5.7	.2	4.4	105	63	17		7.5	0
Tide Flats well	Jan. 13, 1938	54	32	.05	16	6.1	51	2.4	188	1.5	12	.0	.0	215	65	0			
Do	Dec. 29, 1944		39	1.5	21	6.6	53	2.2	199	1.6	17	.2	3.4	246	80	0	368		
Do	Oct. 24, 1946			.04			48		209	0	15				88	0	346		
Do	Feb. 7, 1955 [3]		54	.25	14	5.5	79		229	.4	7.5	.9	.8	235	58	0		7.8	
Western State Hospital.	Oct. 4, 1938	54	19	.01	8.4	3.4	5.0	1.4	46	4.1	3.0	.0	.5	66	35	0			0

[1] Analysis by Laucks Testing Laboratories, Inc., Seattle, Wash.
[2] Analysis by Northwest Laboratories, Seattle, Wash.
[3] Analysis by Bennetts Chemical Laboratory, Inc., Tacoma, Wash.
[4] Before pumping.
[5] After pumping.

TABLE 18.—*Suspended-sediment discharge*

Date	Stream discharge (mgd)	Suspended sediment	
		Parts per million	Tons per day
Nisqually River near McKenna			
1954			
Nov. 9	1,500	13	81
Dec. 14	905	7	26
1955			
Jan. 18	1,580	8	53
Feb. 9	2,170	27	245
Mar. 17	1,350	10	56
Apr. 25	1,740	7	51
May 31	1,730	7	51
July 25	1,330	196	1,090
Sept 1	918	42	161
Kapowsin Creek near Kapowsin			
1954			
Nov. 3	14	3	<1
Dec. 15	28	2	<1
1955			
Jan. 18	37	5	<1
Feb. 8	183	13	10
Mar. 16	35	5	<1
Apr. 25	59	3	<1
May 27	22	5	<1
July 19	9.7	6	<1
Sept. 1	3.9	5	<1
Carbon River near Fairfax			
1954			
Nov. 2	103	5	2
Dec. 13	139	6	3
1955			
Jan 20	107	1	<1
Feb. 8	969	283	1,150
Mar. 18	77	5	2
Apr. 28	129	3	2
June 1	335	7	10
July 20	390	275	448
Sept. 1	184	179	138
Puyallup River at Alderton			
1954			
Oct. 29	638	10	27
Dec. 16	645	7	19
1955			
Jan. 19	588	11	27
Feb. 9	2,550	309	3,290
Mar. 16	530	9	20
Apr. 21	918	25	96
May 26	1,040	43	187
July 25	1,220	164	832
Aug. 31	672	296	831
Chambers Creek below Leach Creek, near Steilacoom			
1954			
Oct. 27	33	5	<1
Dec. 6	56	6	1
1955			
Jan. 19	85	10	4
Feb. 18	94	10	4
Mar. 14	88	7	3
Apr. 18	106	7	3
June 4	61	4	1
July 18	39	4	1
Aug. 30	25	7	<1
Puyallup River near Orting			
1954			
Nov. 3	255	85	91
Dec. 16	287	7	8
1955			
Jan. 17	280	14	16
Feb. 8	1,780	581	4,310
Mar. 16	217	5	5
Apr. 22	414	84	145
May 27	445	8	15
July 19	628	223	585
Aug. 31	337	448	631
South Prairie Creek at South Prairie			
1954			
Nov. 2	55	3	<1
Dec. 13	109	4	2
1955			
Jan. 17	103	4	2
Feb. 9	543	113	256
Mar. 16	94	2	1
Apr. 22	236	8	8
June 1	160	4	3
July 20	98	7	3
Sept. 1	34	10	1
White River at Greenwater			
1954			
Nov. 10	302	30	38
Dec. 9	309	16	21
1955			
Jan. 21	239	9	9
Feb. 8	1,960	751	6,140
Mar. 21	173	6	4
Apr. 27	284	13	15
June 8	2,730	1,190	13,600
July 22	924	654	2,530
Aug. 30	452	1,630	3,080

TABLE 18.—*Suspended-sediment discharge*—Continued

Date	Stream discharge (mgd)	Suspended sediment	
		Parts per million	Tons per day
Greenwater River at Greenwater			
1954			
Nov. 10	43	3	<1
Dec. 7	66	2	<1
1955			
Jan. 21	54	5	1
Feb. 8	840	79	277
Mar. 22	75	7	2
Apr. 27	87	17	6
June 8	724	64	194
July 22	147	15	9
Aug. 30	47	2	<1
Stuck River near Sumner			
1954			
Nov. 4	50	4	<1
Dec. 10	82	4	1
1955			
Jan. 20	82	5	2
Feb. 9	1,510	744	4,680
Mar. 15	88	4	1
Apr. 21	123	5	3
June 9	3,730	1,740	27,100
July 21	279	52	61
Aug. 29	62	25	6
Green River near Auburn			
1954			
Oct. 28	301	5	6
Dec. 10	517	7	15
1955			
Jan. 24	1,650	77	530
Feb. 8	4,250	1,210	21,500
Mar. 15	583	16	39
Apr. 20	969	12	49
June 2	1,360	23	131
July 21	547	11	25
Aug. 31	197	19	16

Date	Stream discharge (mgd)	Suspended sediment	
		Parts per million	Tons per day
White River near Buckley			
1954			
Oct. 28	435	10	20
Dec. 9	525	7	15
1955			
Jan. 21	427	9	16
Feb. 8	2,370	220	2,130
Mar. 18	392	8	13
Apr. 28	583	11	27
June 10	4,600	175	3,360
July 22	1,560	199	1,290
Aug. 31	566	1,270	3,000
Puyallup River at Puyallup			
1954			
Oct. 27	2,160	10	90
Dec. 6	2,440	20	204
1955			
Jan. 24	3,130	101	1,320
Feb. 9	5,570	290	6,870
Mar. 14	1,780	55	410
Apr. 19	2,360	13	128
May 31	3,440	148	2,130
July 18	3,800	284	4,510
Aug. 30	1,600	146	978

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