STATE OF WASHINGTON
Albert D. Rosellini, Governor

DEPARTMENT OF CONSERVATION
Earl Coe, Director

DIVISION OF WATER RESOURCES
Murray G. Walker, Supervisor

Water Supply Bulletin No. 12

Water Resources of the Nooksack River Basin

and Certain Adjacent Streams

with a contribution by the
UNITED STATES GEOLOGICAL SURVEY

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FOREWORD

This report represents initiation of a new but vitally needed service by the Division of Water Resources, for the people of the State of Washington. Not only will it permit the re-evaluation of our basic data programs, but it will enable us to administer the laws more intelligently and provide background material for planning the ultimate development of the waters in this area. The Nooksack River basin was chosen for the initial inventory report primarily because of its size and, secondarily, because of the availability of base maps and previous studies such as ground water, power, and flood control. Beginning such a study meant requesting a biennial budget increase to salary and operations money such that a staff of five technicians and one secretary could be added. Our request received endorsement of the governor and approval from the legislature for the 1959-1961 biennium. As a result, recruiting began in June of 1959 and the staff was finally completed as of June 16, 1960. Considerable time was spent in arriving at the contents and scope of the report and the experience gained in the mechanics of preparation will enable us to proceed on future studies at a much faster pace. Also, it should be noted that this report was limited to readily available information and data and no concerted attempt was made to expand or project the information, or to cover potential or future requirements or uses of the water supply.

Murray G. Walker
Supervisor
Division of Water Resources

CONTENTS

CONTENTS

CONTENTS

ILLUSTRATIONS

FIGURES

CONTENTS

PLATES

TABLES

CONTENTS

WATER RESOURCES OF THE NOOKSACK RIVER BASIN
AND
CERTAIN ADJACENT STREAMS

ABSTRACT

The quantity and quality of water within the Nooksack River basin is adequate to meet the area's municipal, industrial, agricultural, and domestic needs for many years to come. With a planned and orderly development, the basin has a water resource potential at least tenfold the present known demand. The Nooksack River system contains adequate dam and reservoir sites with capacities for 100 percent flood control and development of 123,200 kilowatts of firm power. These figures represent single purpose evaluations of each storage site and would necessarily require some refinement for multiple-purpose projects. Further study of each site will be required to determine the extent to which multiple uses would be compatible.

Water right permits and certificates place a low-flow demand of 255.26 cubic feet per second or 26.7 percent of the average low flow of the Nooksack River as gaged at Lynden (fig. 61). This figure includes 100 cubic feet per second for pollution abatement and fish passage purposes. There remain in the stream available for appropriation 700 cubic feet per second or approximately three times the present demand of record.

Approximately 90 percent of the total mean annual runoff of the Nooksack River system discharges into Georgia Strait without being put to beneficial use. Peak flows occur during water-surplus periods, October to May. With full development of storage sites in the upper Nooksack basin, flow characteristics of the Nooksack River and its major tributaries can be beneficially altered to bring flows more in line with periods of demand. Figure 62 shows the total mean annual water budget of the Nooksack River at Lynden to be 2,540,000 acre-feet. Of this, 282,400 acre-feet have been appropriated, leaving 2,257,600 acre-feet available. Major storage sites that have been studied have capacities for salvaging 1,150,000 acre-feet of this total, leaving 1,107,600 acre-feet of unsalvable water.

Many of the small but related streams discussed in the report have been entirely appropriated. Others are heavily appropriated but still have early and late irrigation water available. Additional water supplies for those areas will have to be developed from ground-water supplies, small storage projects, or a comprehensive river development program.

Rock systems in the Nooksack River basin range in age from Devonian to Recent with Tertiary sedimentary and pre-Tertiary metamorphic rocks predominating in the Eastern Upland and Pleistocene glacial sands and gravels and Recent alluvium being the chief materials of the Whatcom Basin. Tertiary and pre-Tertiary rocks in the study area produce only small amounts of ground water, and in most cases where production is obtained from those rocks, the water quality is poor.

Major production of ground water is restricted almost entirely to the glacial sands and gravels and river valley alluvium found in the Whatcom Basin and along valley floors of the Nooksack River and its three major forks. Wells produce from a few gallons per minute in areas of poor production to several hundred gallons per minute from the more permeable recessional outwash gravels of the Whatcom Basin. No complete quantitative figures are available for the study area. However, observation wells indicate that the maximum safe sustaining yields of the major aquifers have not been attained, and much additional development can be made utilizing that water source.

Geo-hydrologic and climatic conditions of the Nooksack River basin suggest that present naturally occurring water supplies can be materially increased by the application of artificial recharge and weather modification as those processes become better refined.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

This investigation was made by the Division of Water Resources of the Washington State Department of Conservation for the purpose of inventorying the water resources of the Nooksack River basin and certain adjacent streams. A section of the report was prepared by the U. S. Geological Survey.

The report was prepared under the general direction of Murray G. Walker, Supervisor, Division of Water Resources, and under the direct supervision of Robert H. Russell and Glen H. Fiedler. Contributing authors and their contributions in the order they appear are: climate and precipitation analysis by S. E. Shumway; geology and ground water by Dee Molenaar; surface water and hydrology by M. E. Garling; flood control by G. M. Hastings; water quality and reservoirs by E. R. Henken; and water use by W. R. Smith and E. R. Henken.

A section on basic streamflow data and history of floods was prepared by E. G. Bailey, U. S. Geological Survey.

The demand for additional water supplies to satisfy the ever-increasing requirements for domestic, municipal, industrial, and irrigation purposes within the State of Washington has resulted in the need for a thorough understanding of the occurrence and distribution of the State's total water resource. The 1959 session of the Washington State Legislature at the request of Mr. Earl Coe, Director, Department of Conservation, and Mr. Murray G. Walker, Supervisor, Division of Water Resources, provided funds for a start of an inventory of the State's water resources on a watershed basis. This report, "Water Resources of the Nooksack River Basin and Certain Adjacent Streams," covers the first watershed to be studied under this program.

Work was started on the Nooksack River basin study in July, 1959 and completed in September, 1960 and represents a total effort of approximately three man-years of time. The investigation required a complete compilation of existing data; an evaluation of previous works; geologic and hydrologic mapping of areas where existing data were incomplete or entirely lacking; and a thorough geo-hydrologic evaluation of ground-water occurrence, precipitation, and runoff patterns within the watershed and related areas.

The Nooksack River report is presented as an inventory of the water resources of the area designed to serve as a guide to assist municipalities, industry, and other public and private agencies in an orderly and complete development of the area's water resources. In presenting the material, the authors have tried to answer as completely and accurately as possible the following four question:

1. What is the total water budget (quantity and quality) of the area under investigation?
2. What is the present known demand against the total supply?
3. How much water is still available for appropriation and where are these supplies located?
4. How much additional water can be made available and how can streamflow patterns be improved by the application of artificial recharge, upstream storage, and weather modification practices?

LOCATION AND EXTENT OF AREA

The area under investigation includes a total of approximately 959 square miles, situated almost entirely in Whatcom County in the northwestern part of Washington State. It is bounded on the north by the Canadian border; on the west by Georgia Strait; and on the east by Mt. Baker, Mt. Shuksan, and the Skagit Range. The southern boundary consists of an irregular northwest-southeast trending line lying generally north of the City of Bellingham and Lake Whatcom. This line constitutes the hydrologic boundary of the Nooksack River drainage. Parts of four townships (36 N., Rges. 5, 6, 7, and 8 E.) lie within Skagit County.

Several small streams and three land areas closely related to the Nooksack River basin, but not actually within its watershed boundaries, are included in the discussion.

PREVIOUS INVESTIGATIONS

Although there were a number of early studies which include parts of the Nooksack River basin, none dealt specifically with the geo-hydrologic features of the area. Perhaps the first significant investigation was made by J Harlen Bretz (1910-13) in his study of the glaciation of the Puget Sound region. Bretz discussed the glacial drift of the Whatcom Basin. R. O. Helland (1941) discussed water utilization in the Nooksack River with emphasis on dam sites, reservoir capacities, and power potential. Erdman and Warren (1942) prepared a preliminary report on the geology of miscellaneous dam and tunnel sites in the upper basin of the Nooksack River system.

Much of the geology and ground-water hydrology of the Whatcom Basin was adopted from a cooperative report by the Geological Survey, Ground-Water Branch, and the Washington State Division of Water Resources. The report by Newcombe, Sceva, and Stromme (1949) discusses the ground-water resources of western Whatcom County.

The Corps of Engineers, U. S. Army, Office of the District Engineer, Seattle District (1952) prepared a review of reports on flood control of the Nooksack River. Bodhaine and Thomas (1960) of the Geological Survey reviewed the magnitude and frequency of floods in the State of Washington.

Streamflow hydrographs and flow-duration curves were prepared from stream gage records taken from the Division of Water Resources Water-Supply Bulletin No. 6 (1955) and related Geological Survey water-supply papers and miscellaneous streamflow records. Geology of the Nooksack River dam sites was adopted from a report in progress by Erdman and Bateman of the Geological Survey which describes the geology of dam sites at four utilization areas above Deming.

A number of reports which treated various phases of the Nooksack River basin, but not cited here, are included in the selected bibliography.

ACKNOWLEDGMENT

The writers wish to acknowledge assistance rendered by a number of agencies and individuals. James Pluntze, Washington State Department of Health; Ray Buswell, Whatcom County Health Department; L. B. Laird and J. F. Santos, Quality Branch U. S. Geological Survey for their assistance in matters pertaining to water quality. Earl L. Phillips of the U. S. Weather Bureau, R. D. Perry, W. S. Perry, and other weather station operators who were helpful in furnishing precipitation records and comment on climatology. Byron Mosier of the U. S. Soil Conservation Service and his staff were extremely helpful with land classification and water use matters. The assistance of Dale Rockey of the Whatcom County Highway Department is also graciously acknowledged.

Dr. Peter Misch, Professor, Department of Geology, University of Washington and the staff of the State of Washington Division of Mines and Geology were helpful in working out the geology for areas not yet studied in detail.

The assistance of Messrs. Fred Veach, A. A. Garrett, and Fred Johnson of the Geological Survey was appreciated.

A special note of gratitude is extended to Aileen Jacobs and Margaret Holland for their valuable assistance in editing and typing the report.

CHARACTERISTICS OF THE REGION

PHYSICAL DESCRIPTION

The area under discussion in this report, Nooksack River basin and certain adjacent streams, occupies a large part of northern and western Whatcom County in extreme northwestern Washington State. It extends from Bellingham north to the Canadian border and east to Mt. Baker, Mt. Shuksan and the Skagit Range and is bounded on the west by Georgia Strait.

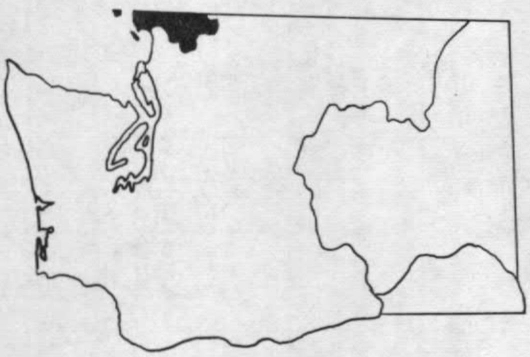


Figure 1. LOCATION MAP OF REPORT AREA

For convience in this report the area has been divided into two major physiographic provinces, those being: (1) The Whatcom Basin, or that part of the area lying west of the foothills of the Cascade Mountains and entirely within the Puget Trough of the Pacific Border physiographic province,[1] and (2) The Eastern Upland which includes those parts of the Cascade Mountains lying within the Nooksack and Sumas River Drainages.

SIZE OF AREA

Total area in the report includes 959 square miles within the United States and 51.0 square miles of contributing drainage area in Canada. This includes 4.9 square miles of Point Roberts, Eliza Island with 0.2 of a square mile, and Lummi Island with 9.2 square miles. Of the total area, all but 51.0 square miles in Canada and parts of four townships in north central Skagit County lie within Whatcom County.

1/ Fenneman, N. M., 1917, Physiographic division of the United States: Assoc. of Amer. Geographers Annals, v. 6, p. 95, pl. 1.

PHYSIOGRAPHY

The Whatcom Basin west of Lawrence is typical hummocky glacial topography with till-capped uplands overlooking broad river valleys. The valleys and uplands are interconnected by gentle slopes or terraces mantled with recessional outwash materials. The till-covered uplands, because of their resistance to erosion, stand out as dominant topographic features.

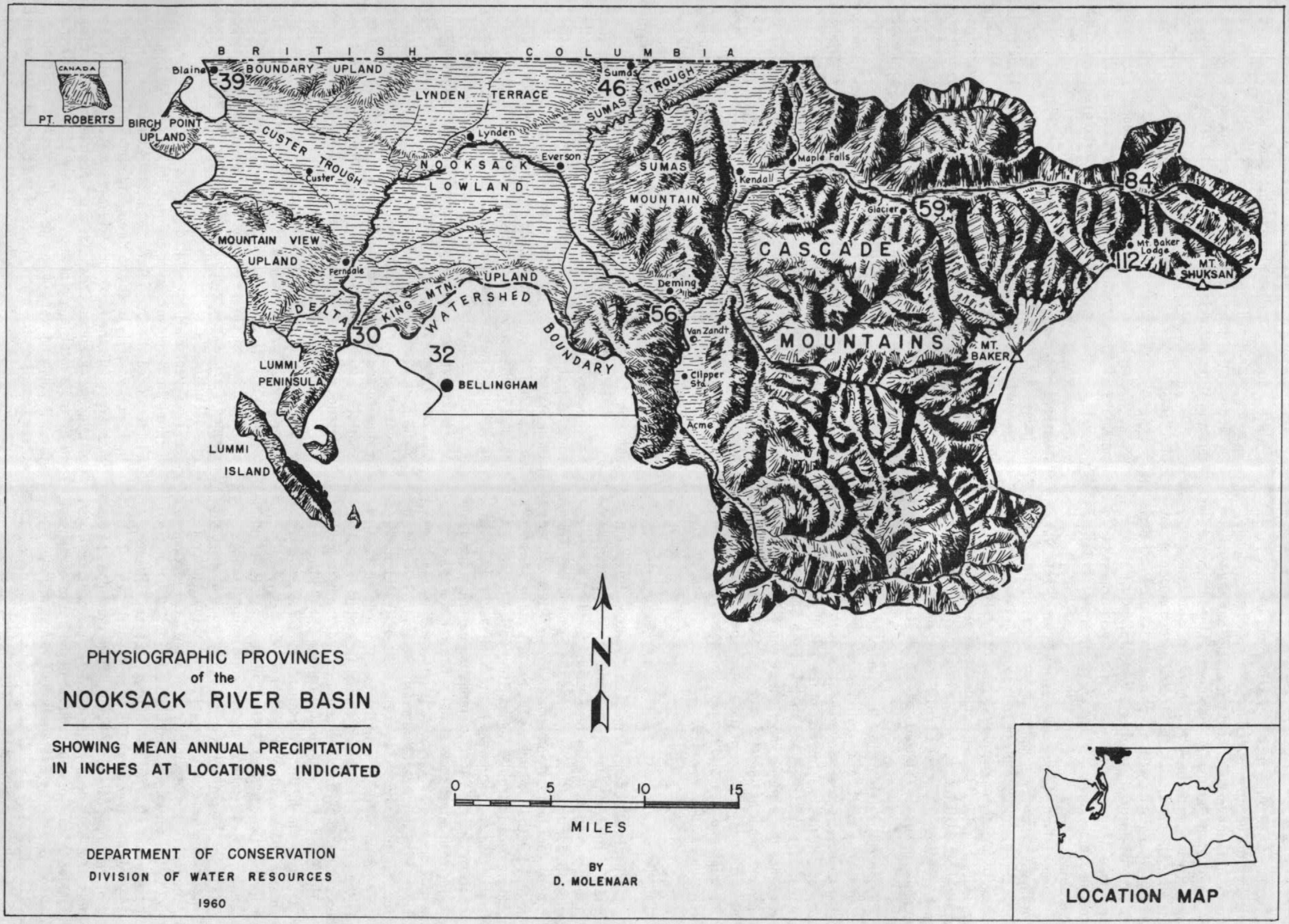
There are six significant upland or plateau areas within the Whatcom basin that warrant discussion (fig. 2). They are: (1) The small peninsular area southwest of Blaine, herein called the Birch Point Upland; (2) The large area extending eastward from Blaine and across the international boundary into Canada generally referred to as the Boundary Upland; (3) The Mountain View Upland west of Ferndale; (4) The King Mountain Upland extending north from Bellingham to the Nooksack River valley; (5) The Lummi Peninsula; and (6) Lummi Island. The inter-upland river basin lowlands constitute a seventh significant physiographic province. Point Roberts, a small peninsular projection of Canada, but a part of Whatcom County, is also discussed in the report.

Birch Point Upland, which is till-capped, comprises an area of about 4 square miles and is bounded on three sides by steep sea cliffs; Drayton Harbor on the north; Georgia Strait on the west; and Birch Bay on the south. The upland attains a maximum elevation of about 265 feet above sea level.

Mountain View Upland, west of Ferndale, is diamond shaped and embraces an area of about 42 square miles. It too is a till-capped rolling hilly surface and rises to an elevation of about 385 feet. This upland is bordered on the west by Georgia Strait where steep sea cliffs drop from the upland surface to the beach below. It is bordered on the north by the Custer Trough and on the east and south by the Nooksack River and Lummi River floodplains. Many large erratics found on the upland surface were ice rafted to the area from their source in Canada to the north. The relatively impermeable till surface supports several swamps and one small lake. The Mountain View Upland, like other low plateaus in the Whatcom Basin, was forested in its native state; but since has been logged and is now mostly cultivated. The land is dry during most of the summer and requires additional water for irrigation.

Boundary Upland, immediately east of Blaine, is about 10 miles long and 3 miles wide and is a part of a larger upland extending northward into Canada. Its surface rises to a maximum altitude of nearly 500 feet and is a smoothly rolling, stony till surface formerly forested but now cutover and partially taken by brush and second growth.

The rolling till surfaces of the King Mountain and Squalicum Mountain Uplands rise to the south from the Nooksack River valley to a maximum elevation of approximately 500 feet to where the till laps upon the slopes of the Cascade



BRITISH COLUMBIA
CANADA
PT. ROBERTS
Blaine
39
BOUNDARY UPLAND
LYNDEN TERRACE
Sumas
46
SUMAS TROUGH
BIRCH POINT UPLAND
CUSTER TROUGH
Custer
Lynden
NOOKSACK LOWLAND
Everson
SUMAS MOUNTAIN
Maple Falls
Kendall
84
Glacier
59
CASCADE
Mt. Baker Lodge
112
MT. SHUKSAN
MOUNTAIN VIEW UPLAND
Ferndale
KING MTN. UPLAND
WATERSHED BOUNDARY
Deming
56
DELTA
30
32
Van Zandt
MOUNTAINS
MT. BAKER
Clipper Sta.
LUMMI PENINSULA
BELLINGHAM
Acme
LUMMI ISLAND
N
PHYSIOGRAPHIC PROVINCES
of the
NOOKSACK RIVER BASIN
SHOWING MEAN ANNUAL PRECIPITATION
IN INCHES AT LOCATIONS INDICATED
0 5 10 15
MILES
DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES
1960
BY
D. MOLENAAR
LOCATION MAP

Figure 2.

foothills. Knobs of older rock of Tertiary age in places protrude through the unconsolidated materials. These uplands, too, consist of cutover brushland and cultivated farmland.

The Lummi Peninsula, a southern extension of the Nooksack River floodplain, was formerly an island whose connection to the mainland was affected by deposition of fine-grained deltaic deposits with a probable Nooksack River derivation. The peninsula is a relatively low rolling till-capped surface whose maximum elevation is slightly in excess of 100 feet above sea level. There are no perennial streams on the peninsula.

Lummi Island, lying southwest of Lummi Peninsula, is a northwest-southeast trending island about 9 miles long and about 1½ miles in width whose topography is an external expression of underlying geologic formations. The submountainous, heavily timbered southeastern part of the island averaging about 300 feet above sea level and reaching a maximum elevation in excess of 500 feet is underlain by resistant metamorphic and igneous rocks of the Leach River group.

The northwestern part of the island, in contrast to the rugged southern part, is a low rolling till-capped surface averaging about 150 feet above sea level with a maximum elevation of 360 feet. This part of the island is underlain by less resistant sandstone and shales of the Chuckanut formation. Since there are no important perennial streams on Lummi Island, most of the inhabitants have settled near the beaches of the northern part of the island where sufficient water for stock and domestic purposes can be obtained from relatively shallow drilled wells.

LOWLANDS

Lowlands or bottom lands of the Whatcom Basin consist largely of the Nooksack River floodplain and two branching lowlands known as the Custer Trough, trending northwest to Drayton Harbor and Birch Bay, and the Sumas River Trough, leading northward into Canada and the Fraser River drainage. Also included in the lowlands is the broad Lynden Terrace extending westward from the Sumas River valley to the Boundary Upland and southward to the Nooksack and Custer Trough bottom lands. These lowlands are generally flat lying and mantled with either recessional outwash materials of Vashon glaciers or glacial materials re-worked by the Nooksack River. These lowlands generally lie below 100 feet in elevation, but the Lynden Terrace rises to 150 feet or more.

The Sumas River, a misfit stream, occupies a valley used by the Fraser River during glacial time when it was crowded southward by the continental ice advancing from the north. The Sumas River, now a distributary of the Nooksack River, drains a sub-basin in Washington of 69.9 square miles in area, northward to the Fraser River.

East of the Whatcom Basin, the Nooksack River drainage occupies a west slope of the Cascade mountain range. Just west of Deming, where the Tertiary bedrock of the Cascades disappears beneath the glacial drift of the Whatcom Basin, the foothills rise abruptly from about 200 feet above sea level to the snowfields and glaciers of 9,127 foot high Mt. Shuksan and 10,778 foot high Mt. Baker. Glaciers and perennial ice cover about 11.3 square miles1/ or 1.1 percent of the Nooksack River basin. Here the slopes of the mountains have been deeply dissected by the Nooksack River and its major tributaries. In contrast to the old topography of the Whatcom Basin, the Eastern Upland is mature in the foothills, and to the east where higher elevations prevail, it becomes youthful with narrow, steep sided valleys. The valley floors of the three major forks of the Nooksack River are partially filled with glacial drift and Recent river alluvium.

1/ U. S. Geological Survey Quadrangle Maps.

DRAINAGE

As the last of the continental ice receded to the north, the Nooksack River and associated streams returned to courses generally occupied prior to the advance of the glaciers. The Nooksack River, whose drainage was temporarily diverted southward from Deming and Van Zandt to the Skagit River drainage, again flowed westerly to Everson, Ferndale, and into Lummi or Bellingham Bay. However, immediately prior to about 1860 the river discharged into Lummi Bay. The change to its present discharge into Bellingham Bay was originally caused by a log jam but was later made permanent by construction of a dam across the headwaters of the Lummi River. The present dendritic drainage pattern has remained more or less unchanged since the close of the Pleistocene (ice age) epoch about 10,000 to 15,000 years ago.

Genetically, the three forks of the Nooksack River are consequent streams; their courses being dictated by topography and natural land slope rather than by geologic structure or jointing and faulting.

The North Fork (above the confluence of the North Fork and Middle Fork) drains a total area of 292.9 square miles of which 4.9 square miles are in Canada. The North Fork heads on the north slopes of Mt. Shuksan and flows westerly for about 30 miles to where it courses southwesterly and joins the Middle Fork about 4 miles east of Deming. This tributary drains the west slopes of the Skagit Range and the north slopes of Mt. Shuksan and Mt. Baker and has a total length of approximately 40 miles.

The Middle Fork (above its confluence with the North Fork) heads on the south slopes of Mt. Baker and drains the southwest slopes of Mt. Baker and the northeast slopes of Twin Sisters Mountain. The Middle Fork drainage has an area of 101.2 square miles and courses northwesterly for about 17 miles to where it joins the main stem of the Nooksack about 4 miles east of Deming.

The South Fork drains the regions south and west of Mt. Baker and the western slopes of Twin Sisters Mountain. Mt. Baker does not actually contribute to this drainage. The South Fork heads on the southeast slopes of Twin Sisters Mountain and scribes a semicircular pattern eventually flowing northward and entering the Nooksack River at Deming. The South Fork has a total length of approximately 36 miles and a watershed of 181.6 square miles.

An area of about 69.9 square miles lying generally north and east of the town of Everson, is drained by the Sumas River which flows in a northeasterly direction and discharges into the Fraser River in Canada. The Sumas River receives runoff from the west slopes of Sumas Mountain, the east slopes of Lynden Terrace, and ground water discharging from contiguous alluvial materials.

Seven small but related streams drain the general area north of the Nooksack River and west of the town of Lynden. Fishtrap Creek heads in Canada north of Lynden and courses in a southwesterly direction through the town of Lynden and discharges into the Nooksack River about 4 miles southwest of Lynden. Fishtrap Creek has a drainage area of 30.6 square miles and a total length of approximately 13 miles. Bertrand Creek, lying just west of and generally parallel to Fishtrap Creek, heads on the north slopes of the Boundary Upland and discharges into the Nooksack River just below its confluence with Fishtrap Creek. Bertrand Creek, about 6 miles long, has a drainage area of 43.5 square miles. Dakota Creek drains the south slopes of the Boundary Upland and the northern part of the Custer Trough; it heads in the western half of Twp. 40 N., Rge. 2 E., and flows northwesterly and discharges into Drayton Harbor. Dakota Creek, approximately 9 miles long, has a watershed area of 28.3 square miles. Lying just south of and parallel to Dakota Creek, California Creek drains an area of 22.8 square miles of the southern half of the Custer Trough and the northeastern slopes of Mountain View Upland. California Creek has a total length of approximately 9 miles. Terrell Creek drains an area of 17.2 square miles of the western slopes of the Mountain View Upland. It heads in Terrell Lake and flows northwesterly for about 5 miles and discharges into Birch Bay. The Lummi River, once an outflow channel of the Nooksack River but now dyked off, drains the south slopes of Mountain View Upland and the lowland generally south of Ferndale and north of the Nooksack River drainage. The Lummi River courses southwesterly and empties into Lummi Bay. Tenmile Creek, about 10 miles in length, drains an area of 34.0 square miles of the north slopes of King Mountain and Squalicum Mountain. Tenmile Creek flows southwesterly and discharges into the Nooksack River just north of Ferndale.

All of the small related streams just discussed course across the glacial drift of the Whatcom Basin and are maintained primarily by ground-water discharge from the glacial material with the exception of periods of high precipitation when surface runoff contributes to their flow.

Silver Creek, a small stream of about 5 miles in length, drains an area of about 15.8 square miles of the northwest slopes of King Mountain Upland lying south and east across the Nooksack River from Ferndale.

The balance of the area under study, namely 172 square miles, is drained by ground-water discharge or small streams.

Point Roberts, Eliza Island, and Lummi Island are included in this report but do not support major surface streams and residents rely almost entirely upon springs, lakes, and ground water for water supplies.

VEGETATION

The Nooksack River basin originally was heavily forested except for small open meadows and marshes. Douglas fir, western hemlock, and western red cedar are the dominant forest trees. Cottonwoods are common along stream bottoms and Alder predominates in cutover and poorly drained areas. Birch, maple, dogwood, and willow are also commonly found. Underbrush is usually very thick. Most common shrubs are devils club, madrona, manzanita, Oregon grape, salal, cascara, rhododendron, huckleberry, and numerous types of thorny berry bushes. Ferns form a dense cover in open areas.

Most of the virgin timber has been cut except in the higher mountains and on national forest land. River bottoms and many of the lower benches have been brought under cultivation. Cutover areas not suitable for farm crops sustain a thick second growth of fir, cedar, and hemlock.

The western lowlands of the Whatcom basin are now a highly developed agricultural area. Much of the land is planted to hay, pasture, and other forage crops required to support the modern dairy industry.

CLIMATE

INTRODUCTION

In describing the climate of the Nooksack River basin, which is typical of all of western Washington, it would be difficult to overemphasize the importance of several unique, natural aspects which combine in bestowing on this land the distinction of being one of the earth's best watered regions.

Nowhere on the globe are the climatic controls of latitude, air mass source region, and topography more advantageously blended for the production of large quantities of high quality water.

The dominant control affecting the climate of this region results from its geographic position. Due to the tilt of the earth's axis relative to the plane of its annual circular journey around the sun, the northern and southern hemispheres are alternately exposed to excessive heating and cooling from solar radiation. Without the protective shield provided by the atmosphere, the equatorial regions bathed in solar radiation for twelve hours every day would become progressively hotter while the polar zones would be fluctuating every six months between torrid heat and bitter cold.

Fortunately, the atmosphere and in a similar way the oceans provide the medium by which these excesses of heat and cold can be distributed over the globe. History assures us this mechanism has been very effective in maintaining relatively constant, local mean annual temperatures all over the earth.

To maintain this temperature balance, enormous quantities of heat energy must be transported poleward by the air-ocean mediums. Governed by known physical laws this exchange is conducted in the atmosphere essentially by gigantic eddies of air, some of which are thousands of miles in diameter. Depending on the rotation of the eddy, configurations of air similar to mountains and valleys are formed above the surface of the earth. The "mountains," which rotate clockwise, are referred to as high pressure areas or anticyclones; the "valleys," with the opposite rotation, are called low pressure areas, cyclones, or storms.

One of the major eddies in the earth's atmospheric circulation is the Pacific High, so called for its semipermanent location over the Northeastern Pacific Ocean. In response to the seasonal fluctuations in solar energy, this mountain of air will migrate northward during the summer and recede slowly southward with the sun in the fall. It is this oscillatory movement that accounts for the dramatic seasonal change in climate experienced twice a year.

In the vicinity of the Aleutian Islands, another semipermanent feature of the atmospheric circulation occurs. Here nature favors the generation of somewhat smaller eddies which rotate counter-clockwise. These low pressure areas, once set in motion, usually drift eastward and are the storms experienced in this region.

Although somewhat fewer lows are generated during the summer months, it is the position of the Pacific High that dictates the frequency of storms entering this area. During the late spring, the northward extension of this vast mountain of air effectively diverts the storm track to higher and higher latitudes. After reaching maximum development, in July and August a gradual deterioration and southerly recession of this revolving air mountain permits the more numerous and active disturbances to batter the coast at increasingly lower latitudes. Because of the coincidence of maximum eddy development in the Aleutian area, with an unimpeded storm path, this region experiences an unusually wet winter season.

Because of two other permanent protective barriers to airflow from the east being provided by the Rocky Mountain Range and the less formidable but more immediately effective Cascade Mountain Range, western Washington climate is predominately maritime and is unprotected for a full 180° to the west. Practically all air masses entering this region have been subject to some modification by the Pacific Ocean. Since water bodies absorb and expend heat at considerably lower rates than do land masses, they exert a significant moderating effect on both winter and summer temperatures. The range of extreme temperatures in this region is as small as in any other similar latitude zone.

The foregoing climatological features are not uncommon to many regions on earth situated in temperate latitudes downwind from large expanses of water. However, it is the effect of the topographic control on western Washington climate and resultant hydrology that is distinctly unique.

It is the existence of the Cascade Range, a substantial north-south mountain barrier athwart the mean storm path, that fulfills the potential hydrologic capabilities of this climate. The configuration of these mountains and their stream valleys are particularly well adapted for the conversion of precipitation to a high quality water resource. All these valleys are oriented nearly parallel to the moisture laden wintertime airflow. Furthermore, these natural catchment basins are distinctive in that the valley floors maintain an unusually low gradient for a considerable distance into the mountains. Elevations of the valley floor of 2,000 feet at less than 10 miles from the watershed boundary crest are not uncommon. The importance of this abrupt rise in topography is twofold. In addition to the influence of the sudden orographic lifting, materially increasing the quantity of water precipitated from winter storms, these mountains are of principal importance in effecting a spectacular change in climate within the short horizontal distance of only a few miles.

As a natural consequence of the lower temperatures experienced in this mountain climate, practically all precipitation during the winter falls in the form of snow. Here, a delicate balance of temperature and precipitation results in one of the most distinctive manifestations of the character of this climate: the existence of large permanent ice fields and glaciers. For example, the Nooksack River basin alone contains almost as much glacier covered area as the combined total in the states of Oregon and California! Approximately eighty percent of the area of glacial ice in the forty-eight contiguous states is concentrated on the Olympic and Cascades Mountains in the State of Washington.

Although the reduction in temperature provided by the mountain environment is necessary to the development and perpetuation of glaciers, the essential difference with most mountainous areas of the world is the concomitant occurrence of extremely heavy precipitation during the winter (probably in excess of 200 inches of water equivalent in the most favorable areas). These enormous quantities of snow are protected from melt by a common and inherent ability to reflect solar energy. An additional immunity against wastage is provided by the unusual atmospheric environment in which these snow fields thrive. Swathed in air previously cooled and moistened over the Pacific Ocean and shielded from the desiccating effect of dry continental air masses, these snowfields are able to survive complete depletion. Because of the larger amount of precipitation at the higher elevations, the surplus of snow at the end of each year is gradually compressed into ice. Consequently, ice fields or glaciers build at the high elevations and, because of their own weight, flow downhill into the warmer zone to be melted.

The importance of these naturally controlled snow and ice reservoirs to the water resources of this basin cannot be overemphasized.

PERIOD OF STUDY

Weather is a very complex phenomenon. In order to reduce the extreme variability of meteorological data, it is necessary to incorporate as large a number of observations as possible. The period studied should be as long as the data will allow. From the mean tendencies revealed in records collected over comparable periods of time from several observation points, it is possible to gain some insight of the nature of the major regional climatic controls.

Since this study is directed toward an evaluation of the water resources of the Nooksack River basin, the hydrological records from that region were a prime factor in determining the length of the period.

Streamflow records were collected in the Nooksack River basin as early as the 1920's. However, it was not until the middle 1930's that permanent and continuous records were started. Generally, climatological data records from this region were well established by this time.

Fortunately, a period for study compatible with the available data was suggested for a beginning in the year 1934, following one of the particularly high precipitation years of record. Equally convenient was the re-occurrence of a similar year in 1959. This twenty-six year period affords a cyclic range of data for summation that will be least affected by antecedent conditions.

GENERAL CLIMATIC TRENDS

The Clearbrook climatological data station was selected to depict the general trend of precipitation distribution throughout the past 57 years. This excellent record was chosen because of the uninterrupted location of the instruments and the near perfect continuity of daily observations, particularly since July 1, 1919. It was at this time that Mr. R. D. Perry of Clearbrook, Washington, assumed the responsibility of reading climatological instruments every evening, 365 days a year for a period of over 32 years; after which his brother, Mr. William S. Perry, assumed these same duties such that the Perry family has to date contributed almost one-half of a century of their time to the maintenance of this climatological station.

Figure 3 represents the general trend of precipitation amounts in the lower Nooksack River basin as recorded at the Clearbrook station since 1903. Because of the year to year variability in precipitation amounts, it is sometimes advantageous to represent the cyclic patterns by a moving series of averages, each of ten consecutive year periods. For example, the period 1903-12 is characterized by one point on the graph and represents the average annual amount of moisture precipitated during that decade. The 1904-13 period and each succeeding ten year period are similarly computed and plotted as an ordinate quantity point above the abscissa year ending the decade. General conclusions can

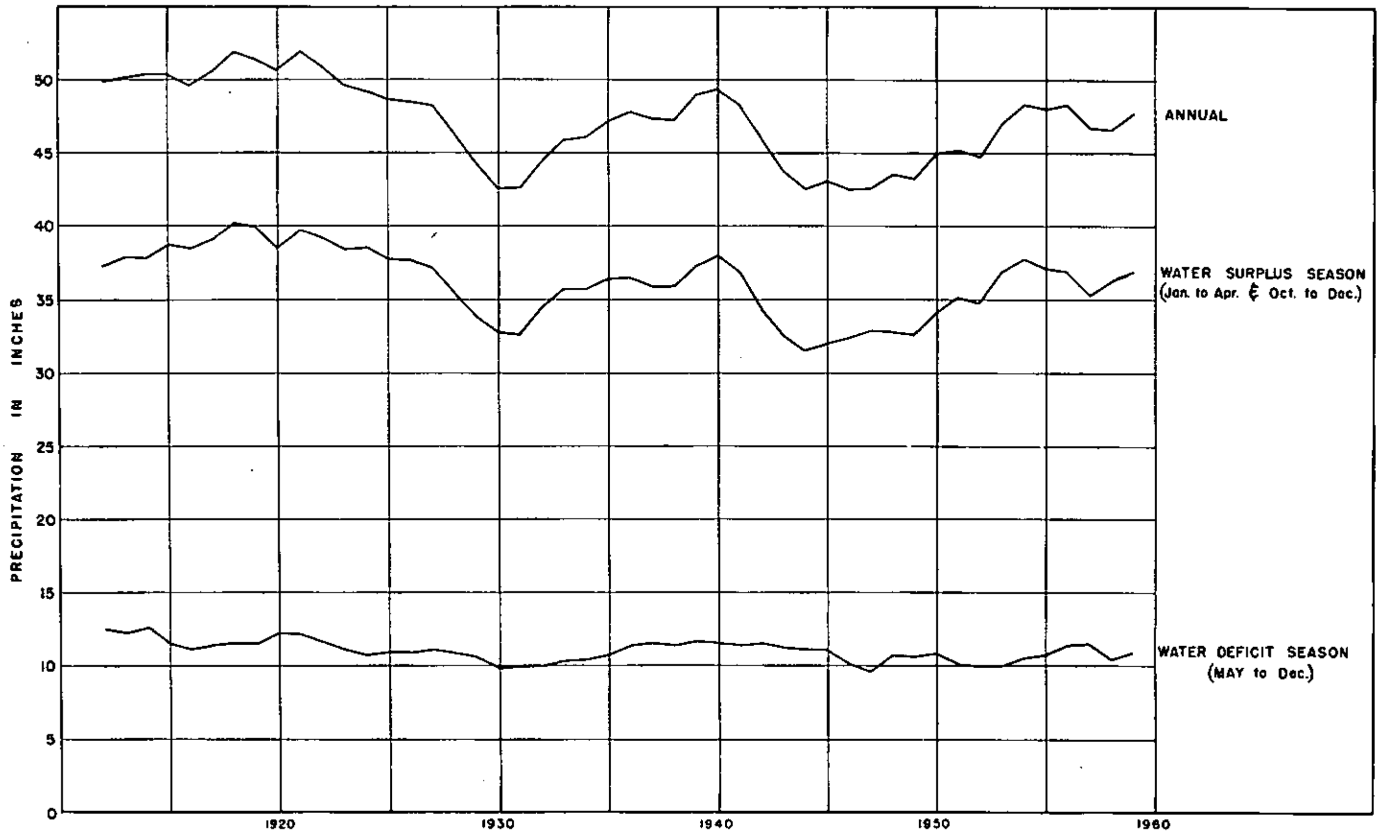


Figure 3. 10-YEAR MOVING AVERAGE PRECIPITATION AT CLEARBROOK STATION.

be deduced from this graph. Decadal data has been computed and curves are drawn for annual amounts and also for both the surplus and deficit seasons. The last two periods will be defined in subsequent paragraphs.

In general, the annual graph indicates three relatively wet periods of decreasing amplitude centered around 1920, 1940, and 1955 with intervening dry periods in the early 1930's and middle 1940's of similar amplitude but increasing duration. As would be expected, the surplus season, which represents over 76 percent of the average year's total precipitation of Clearbrook, closely parallels the annual curve. The curve of decadal means for the deficit season shows some departure from annual and surplus seasons, although there is generally close agreement. In these data the deficit period intervenes the surplus season and some interrelationship is inevitable. A cursory re-examination using data for concurrent seasons showed considerable more dispersion.

A comparison of the annual average for the 1903-59 period of record and the 1934-59 period selected for study shows the latter period to be deficient by 1.77 inches per year or about 3.75 percent below the longer term record. This percentage departure was slightly higher during the surplus season.

AVAILABLE DATA

The primary purpose of this examination of climatological data is to evaluate the areal precipitation distribution over the Nooksack River basin. In an area of only 1,010 square miles, but ranging from sea level to above 10,000 feet, a considerable variability of precipitation amounts in both time and space was expected.

To begin the examination, it was deemed advisable to divide the basin into elevation areas. Since stream gage data would be used intensively in this study, the watershed area above each stream gage was measured in 1,000 foot elevation intervals. These data revealed that the distribution of area with each 1,000 foot interval was essentially constant up to the 4,000 foot elevation constituting over three-quarters of the basin area. Ninety-nine percent of the basin is below 7,000 feet, and the residual 1 percent is distributed over rapidly diminishing 1,000 foot interval areas with less than one-tenth of 1 percent above 10,000 feet.

There are a total of five stations recording precipitation in the Nooksack River basin, three of which are below the 1,000 foot elevation contour. In addition, there are four stations in the United States and several in Canada adjacent to the basin which have been useful in this study. Unfortunately these, too, are all lowland stations. The remaining two stations are located near Shuksan at 2,030 feet and Mt. Baker Lodge, elevation 4,150 feet.

The station at Shuksan, attended by the State Highway Department, began continuous operation in 1956. The Mt. Baker Lodge record, while extending back prior to the study period, is riddled with missing data such that the period 1934-59 contains less than 50 percent of the total record and only 3 complete calendar years. Consequently, this study had available only a limited amount of actual data on precipitation above 1,000 feet elevation in this basin.

Figure 2 shows mean annual precipitation for the period of study at approximate locations of the recording stations. Due to the wide variation in amounts of precipitation with different exposures and changes in elevation and because of the obvious insufficiency of actual data, no attempt was made to delineate zones receiving equal amounts of precipitation.

Stream gage records contain valuable information regarding precipitation over the watershed area. However, due to the aforementioned unusually low gradient of the principal river valleys in the watershed area, gaging sites are located at relatively low elevations. For example, the stream gage above Cascade Creek on the North Fork of the Nooksack River, at the comparatively low elevation of 1,245 feet, measures only 13 percent of the Nooksack River drainage. Consequently, this record is the integrated sum of all runoff from an area ranging between elevations of 1,245 feet and the 10,778 foot summit of Mt. Baker, the highest point in the watershed. A more extreme situation exists at the gage near Wickersham on the South Fork of the Nooksack River. Here, the elevation of the gage is only 385 feet, yet it also samples a mere 13 percent of the total Nooksack River watershed.

Undoubtedly, the most serious problem confronting a thorough understanding of our available water resource is the effect of topography on precipitation. It is well known that the cooling resulting from forced ascent of moist air over mountain barriers increases condensation and the subsequent precipitation on the windward slopes. However, this orographic effect will vary from storm to storm and also with season. From the data available for examination, a quantitative evaluation of these phenomena in the Nooksack River basin was not possible. Lacking sufficient density of data in the Nooksack River basin, it was necessary to expand the field of investigation. Being bounded on the east by the data-barren Cascade Mountains, the periphery of investigation could be extended only to the south, west, and north. Included in the study but not shown are four stations in the Skagit River valley, one on the San Juan Islands, and four selected stations located in British Columbia. Thus, a total of seventeen climatological data stations distributed over an area of roughly 4,000 square miles have been examined.

With the period for study established as the 26-year interval of 1934 through 1959 inclusive, daily precipitation data for these seventeen stations were assembled. Missing data, which were negligible except for Glacier Ranger Station, were computed by means of the normal-ratio method of comparing similar periods of two adjacent stations to the station with the missing data.

Annual means were computed for the 26-year period and in addition similar means were computed for the surplus and deficit periods.

Whenever possible, graphs have been prepared with the time scale being along the horizontal axis (abscissa) and the element being compared with time being scaled along the vertical axis (ordinate). In graphing variates that are discontinuous in time such as precipitation, it is technically incorrect to join computed points with a continuous line. Actually, it is only the point on the line directly above the time interval noted on the abscissa that is significant. In most figures, the significant points on the line have been circled. After this word of caution, it is believed for the purposes of this study that the line joining the points depicts the essential variations more efficiently than the customary bar chart.

SURPLUS AND DEFICIT PERIODS

Besides being customary in most studies, it is quite useful to differentiate between seasonal precipitations. The year usually is divided into summer and winter halves. In the climate under study, however, the transition from wet, cool winters to warm, dry summers is quite naturally resolved by the concept of water utilization exemplified by the pseudo-climatic elements--surplus and deficit periods. As illustrated from mean values at Clearbrook station in Figure 8, almost without exception the surplus period begins each year in October. At the time of the autumnal equinox, the amount of solar radiation intercepted by the earth's surface at this latitude is decreasing at the maximum rate. Interconnected with the decrease of insolation is an abrupt change in the atmospheric circulation exhibited in the recession of the Pacific High to more southerly latitudes. Consequently, the number of moisture laden cyclonic storms crossing this area are rapidly increasing while the effects of evapotranspiration by solar energy are diminished, not only as a result of the shorter days, but also from the reflection of solar radiation by the increased cloud cover. For the remainder of the period, precipitation exceeds evaporation and the surplus moisture is expended as runoff.

The transition from the surplus to the deficit period is only slightly less persistant and usually occurs during late April or early May. At this time, the northward extension of the Pacific High results in fewer storms with diminishing precipitation. Simultaneously, the rapidly increasing length of the day and clearing skies cause evapotranspiration to become the dominant hydrologic factor. When evapotranspiration amounts exceed the supply of moisture contributed by precipitation, a deficit condition exists. This natural climatological division of the year, thus, defines the surplus period as October through April and the deficit period as the remaining five months, May through September.

PRECIPITATION

Precipitation patterns throughout the area under study exhibit a marked consistency in temporal distribution. Although total annual accumulations vary from 30 to possibly 200 inches, the monthly percentage contributions to the annual are remarkably similar. Therefore, to avoid a repetitious discussion, the Clearbrook location has been chosen as representative of the entire basin. Variations from this station, especially over the basin, are essentially those of quantity. Figure 4 shows graphically the mean monthly precipitation recorded at this station during the period 1934 to 1959, inclusive. The height of the line immediately above the months along the abscissa indicates the quantity of precipitation in inches as scaled vertically on the left. Similarly, the percent of the monthly contribution to the annual mean total is along the right margin. The solid line in figure 5 depicts the probability, in percent, of the occurrence of 0.01 inches of precipitation on any day during each month scaled along the left. The dashed line indicates the mean intensity in inches of water precipitated scaled along the right during each probable rainy day of the month. The latter data can be can be considered as an average rainfall rate at the Clearbrook location.

Less than 4 percent of the total mean annual precipitation falls in the form of snow at this station. The maximum snowfall occurs during January averaging about 6.5 inches in depth for the month. Snowfall is primarily limited to the months of November through March. Measurable amounts do occur in October and April, but these become insignificant when averaged over a long period of time. Precipitation from thunderstorms is insignificant. This area averages about five thunderstorm days per year, these occuring mostly during the

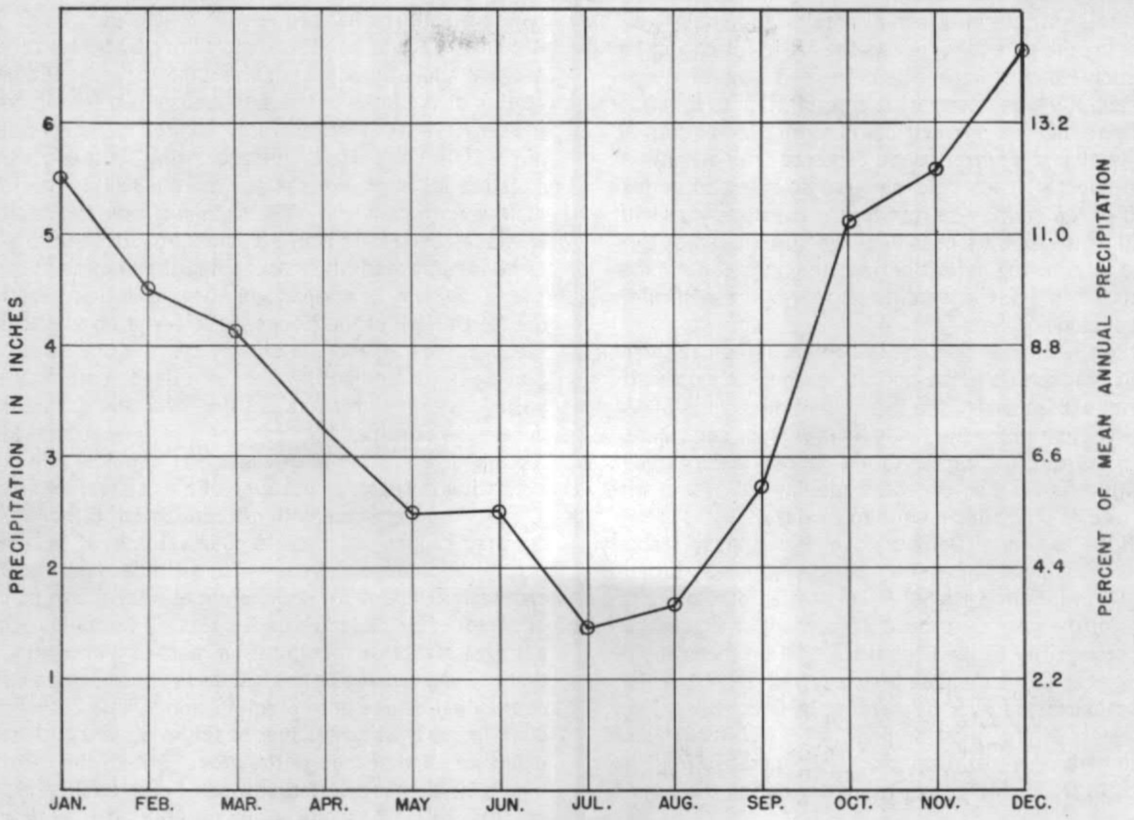


Figure 4. MEAN MONTHLY PRECIPITATION AT CLEARBROOK STATION.

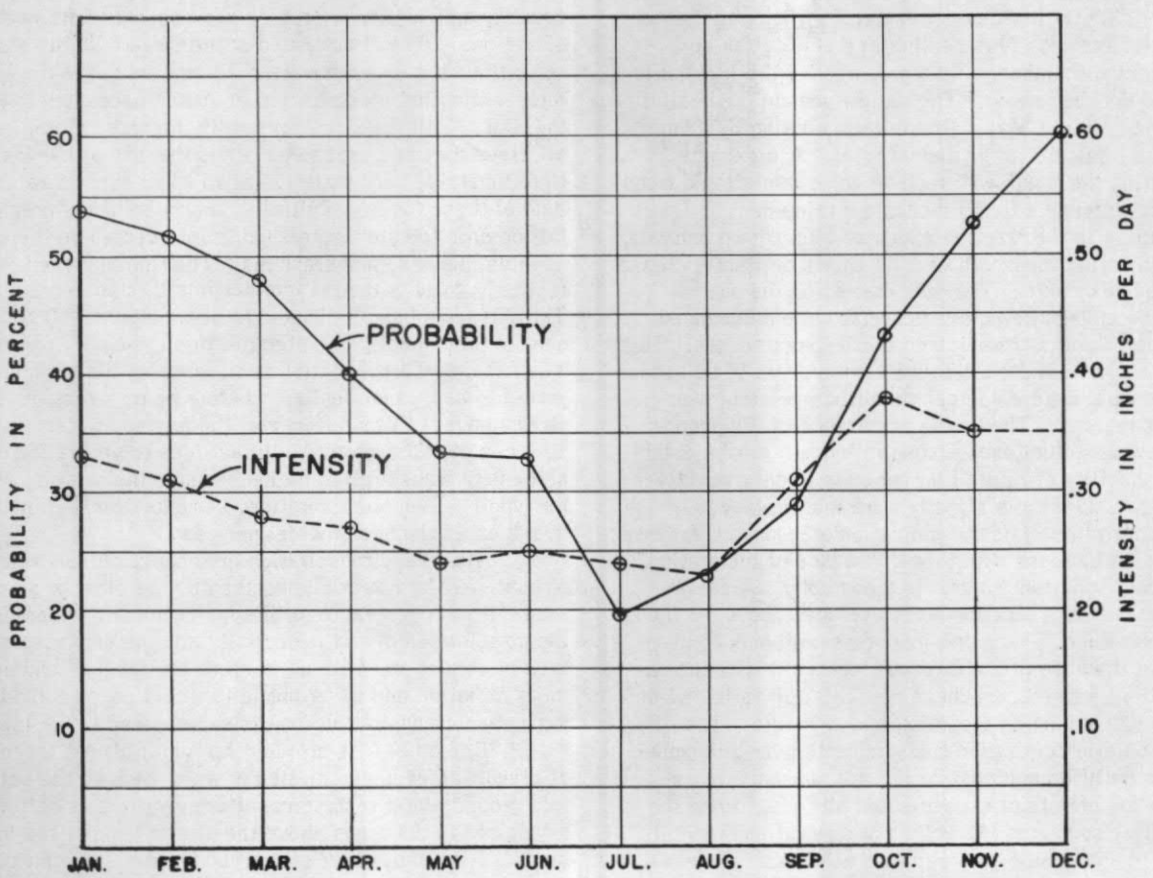


Figure 5. MEAN PROBABILITY AND INTENSITY OF PRECIPITATION AT CLEARBROOK STATION.

months of May through September.

Generally all compilations of precipitation data are published using the calendar year as the basis for comparison. Following such a procedure in this climate is somewhat cumbersome especially when comparing precipitation to runoff. Figure 4 shows that the symmetrical precipitation pattern at Clearbrook is almost a mirror image centered on the month of July. Consequently, each calendar year summary combines the last half of the surplus season for the previous year with the first half of the surplus season of the current year. Because of the intervening deficit period, the natural persistency that is known to exist in weather patterns is lost in this unnatural grouping.

At the Clearbrook station, 24 percent of the mean annual precipitation is recorded in the deficit season. Almost half of this amount occurs during the two transition months of May and September such that June, July, and August contribute only 12.3 percent to the annual total. During these three months precipitation can be expected one day out of four with an average rate of 0.25 inches per rainy day.

With the coming of October, cyclonic storms, steadily increasing in number and intensity, invade this area, hitherto blocked off by the Pacific High. Precipitation during the last three months of the year contribute 38 percent of the annual total. The probability of the Clearbrook station recording rainfall during the day increases from a low of 19.6 percent in July to a maximum of over 60 percent in December. The average intensity of precipitation per rainy day is a much more conservative parameter, exhibiting a slight increase from 0.24 inches to 0.35 inches per rainy day during the same period.

During the four following months, January, February, March, and April precipitation is essentially a reverse order reoccurrence of the September-December period, each month varying only slightly in intensity and probability from its corresponding reflection. This decline in precipitation occurrence, beginning in January, is a precursor of the inevitable return of the deficit season. The deficit season (generally) begins in the month of May. Precipitation during this month contributes 5½ percent to the annual total. Approximately ten days during the month will receive some rainfall and when combined, will average 0.25 inches per rainy day.

Contrary to the reaction expected from known controls, precipitation during the month of June shows a slight increase over the previous month. The perturbation on the smooth contour of the distribution curve becomes more pronounced when the short months are adjusted to 31-day amounts. This interesting anomaly in June precipitation appears to be associated with unusual meteorological conditions existent near mountainous regions. The timely occurrence of the phenomena with maximum actual evapotranspiration may not be coincidental. Probability of rainfall during June is only slightly less while the intensity is slightly more than in May.

Although there is some indication that annual amounts of precipitation increase with inland distance of the station, by far the most important control is topography. Areal precipitation on the Nooksack lowlands averages about 30 inches per year along Puget Sound and increases uniformly to near 50 inches at the base of the Cascade foothills. For the remainder of the basin the amount of precipitation varies within wide limits, depending on elevation and exposure. The paucity of actual precipitation measurements over this mountainous area nullifies any possibility of a quantitative assessment of the effects of exposure and altitude. From the data available, supported by records of streamflow from this area, some insight of the topographic mechanism is inferred.

As an example of the effect of exposure, a Canadian recording station located east of Vancouver, B. C., near Alouette Lake at an elevation of only 516 feet receives an average annual precipitation of 105 inches. Obviously, this station at the base of the extremely steep terrain north of the Fraser River is most favorably located to receive the maximum of precipitation. Here, the prevailing southerly winds slam moisture laden air masses against a mountain barrier perpendicular to the airflow. The sudden lifting and resultant cooling of these air masses cause a large proportion of this moisture to be precipitated while ascending the heights.

By way of comparison, Glacier Ranger Station well up the North Fork of the Nooksack River at an elevation of 937 feet receives an average of only 59.49 inches per year. This station is located on the floor of a deep, narrow, meandering valley, and any air mass passing over this station has already undergone considerable orographic modification. In spite of the higher elevation at this station, considerably less precipitation is recorded because of the unfavorable exposure.

In accordance with meteorological principles, which are also supported by ample observations, it is known that precipitation does increase with altitude. But due to the decrease in temperature with height and the progressive inability of air to retain moisture as it cools, it is obvious that at some optimum elevation precipitation reaches a maximum. From that point an increase in altitude is accompanied with a corresponding decrease in precipitation. This optimum elevation, even in the Nooksack River basin, will vary with storm type, exposure, and season of the year. Due to the insufficiency of high altitude observation stations in the basin and, in fact, over the entire Cascade Mountain area, it is practically impossible to determine if this optimum elevation would be above or is below the mean crest of the divide.

Streamflow data were used to supplement the lack of quantity and quality of precipitation observations in the higher elevations. Runoff computed at the stream gaging station was redistributed over each watershed studied to yield a figure representing net precipitation in inches necessary to produce the flow. This quantity represents the gross precipitation from all elevations and exposures minus the sum of the losses. Unfortunately, very little is known about the nature and magnitude of these losses. Initially, a portion of the precipitation falling on a forested watershed is intercepted on the canopy of needles, leaves, and branches. The rain and even more effectively snow is then evaporated from this vulnerable exposure. This loss has been estimated to be as high as 10 to 15 percent of the annual gross precipitation in heavily forested areas. The remaining precipitation upon reaching the ground is subjected to additional depletion before being measured at the stream gage. Evaporation from the ground, water, and snow surfaces plus the more significant loss to vegetation by the process of transpiration further reduces the quantity available for runoff. Evapotranspiration, computed for the lowland area, averages 25 inches of water per year.

The evapotranspiration process is closely related to the amount of solar radiation absorbed by the plant or ground surface. It is conceivable in this high mountain watershed that the combination of low reflectivity and the enormous surface area of conifer trees living in an environment of higher incident solar radiation and lower humidity would cause considerably more evapotranspiration than is experienced in the lowlands.

One other loss of potential runoff almost independent of climate is deep percolation of water through the soil profile into ground-water reservoirs. However, this is believed to be negligible in the areas above the stream gages used in this study. Also, any short term ground-water storage would be averaged out over the 26-year period examined.

To supplement the lack of direct information on the extent and magnitude of these losses, streamflow data have been of material assistance in this study. For example, the maximum mean precipitation in the basin at Mt. Baker Lodge, as adjusted to the 26-year period, is 112.11 inches. However, streamflow measurements from this area average 98.78 inches of runoff per year. Assuming an interception loss of 10 percent plus an evapotranspiration loss estimated conservatively at 30 inches per year, a total mean annual precipitation averageing 143 inches over the entire watershed would be required to produce this runoff. Since the elevation of the watershed above the Cascade Creek gage varies from 1,245 feet to 10,778 feet atop Mt. Baker and because of a knowledge of the increase in precipitation with altitude and exposure, it is reasonable to expect a precipitation maximum in excess of 200 inches per year in the most favorable locations.

The effect of elevation on precipitation is not constant throughout the year. Figure 6 is a graphic representation of the extremes of the elevation effect. Mean monthly precipitation data from four stations varying in elevation from 64 to 4,150 feet were computed and plotted against elevation. Only the months of December and August have been selected for display, the other months being intermediate in character. During the colder months, which also represent the rainy season, the effect of elevation on precipitation is quite significant, increasing in December from 6.61 inches at Clearbrook to 16.99 inches at Mt. Baker Lodge. In August at these same two stations the effect is considerably less, increasing only from 1.65 to 2.93 inches.

Obviously, these mountains operate with uncanny efficiency for the production of a valuable water resource in this area: initially, by stimulating what would normally be only a modest amount of precipitation; secondly, by providing a climatic region in an otherwise temperate zone capable of converting this augmented rainfall into snow, an environment also particularly well adapted for the retention of large quantities of water in the solid form but with a sensitive release mechanism operated in conformity with water demand; finally, the magnitude of the orographic influence on precipitation is in phase with the optimum time--that is, during periods of large amounts of precipitation, this effect is maximum and throughout the summer months, when practically all precipitation is lost to evapotranspiration, the effect is negligible.

Perhaps the culmination of all the intricate built-in mechanisms operating to maximize runoff from this area is the natural immunity of snow covered areas to significant evaporation losses. A snow surface can never attain a temperature above 32° F, the temperature of melting ice. The ability of air to absorb water and retain these vapors is primarily a function of temperature. For example, air at a temperature of 50° F is capable of holding twice as much water as air at 32° F and almost nine times more than air at 14° F. Usually, in this climate during the period when sufficient solar energy is available for appreciable melt, the temperature of the air is

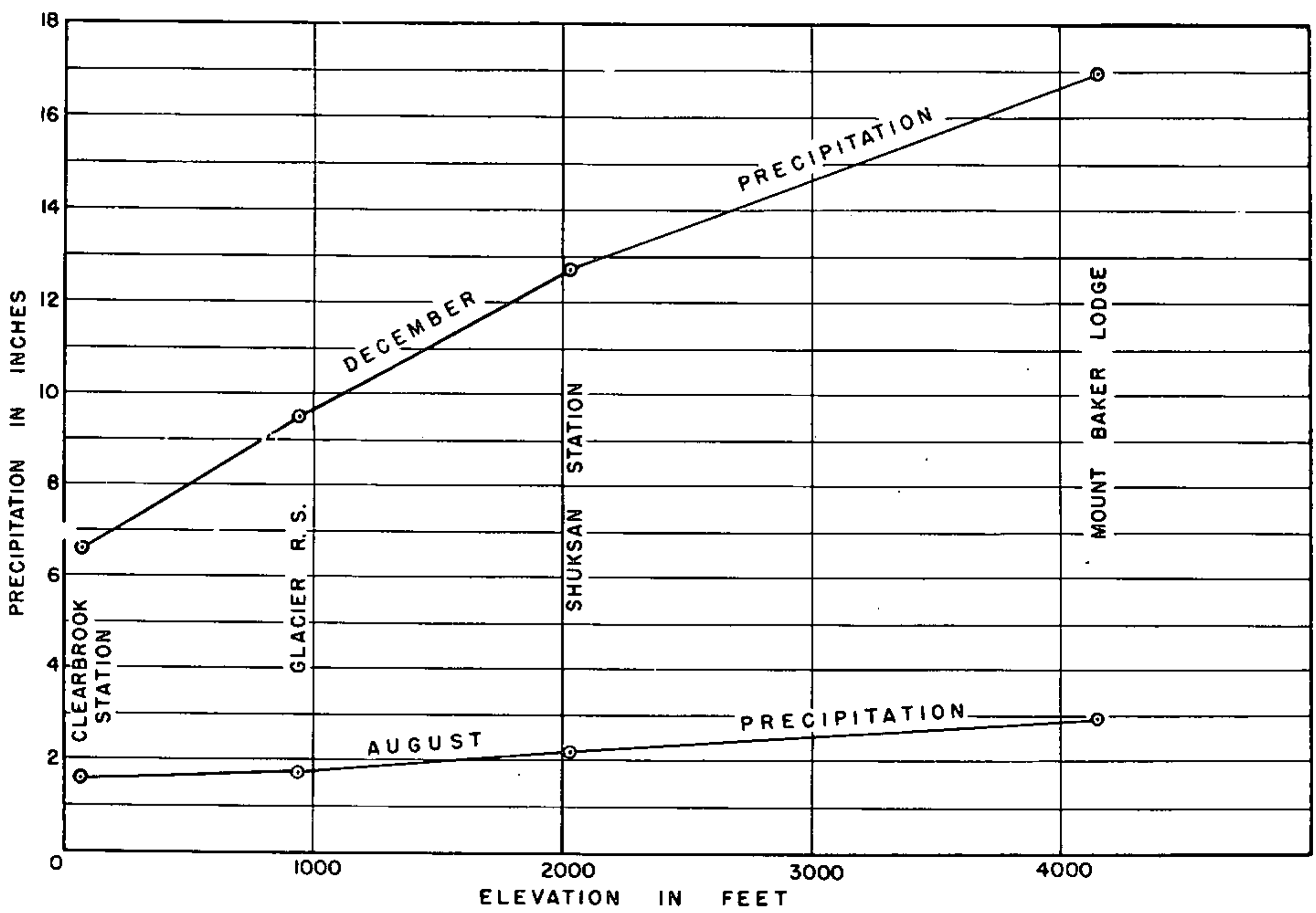


Figure 6. COMPARISON OF ELEVATION EFFECT ON SUMMER AND WINTER PRECIPITATION.

above freezing. Upon contact with the snow its temperature and associated water holding capacity are reduced and evaporation is inhibited. Actually, the snow has a slight affinity for the vapor if all other factors are equal. Research observations in this climate indicate that the amount of water lost to evaporation from snow surfaces is replaced in almost equal volume by the reverse process of condensation.

Additional conservation of potential runoff from snow covered areas can be attributed to an almost complete utilization of summer rain falling on the pack, whereas precipitation falling on bare ground at high altitudes during the summer is evaporated or transpired almost in entirety.

EFFECT OF TOPOGRAPHY ON RUNOFF

An examination of the records from the gage on the North Fork of the Nooksack River above Cascade Creek yields an average net precipitation, measured as runoff, equal to 98.78 inches annually. The area-elevation data computed from the watershed above this gage, which is at an elevation of 1,245 feet, are shown in the following table in the second column.

Runoff records measured at the gage on the South Fork of the Nooksack River near Wickersham, at an elevation of 38 feet, yield average net precipitation equal to 97.21 inches per year. Area elevation figures are shown in column 3 of this table.

Elevation Interval	Above Cascade Creek	Near Wickersham
0 to 1000 ft	0% of total area	8.0% of total area
1000 to 2000 "	3.3% "	19.5% "
2000 to 3000 "	16.4% "	28.1% "
3000 to 4000 "	22.4% "	32.5% "
4000 to 5000 "	29.4% "	10.7% "
5000 to 6000 "	20.8% "	1.1% "
6000 to 7000 "	6.2% "	.1% "
7000 to 8000 "	1.2% "	0 "
Above 8000 "	.3% "	0 "

Although these two areas are practically identical in size, the South Fork watershed is considerably lower in elevation. Despite a lower elevation, this watershed is much more favorably exposed to the direction of the prevailing rain-bearing winds. Also, there are no appreciable barriers to the flow of air from the southwest. Consequently, this basin, elevation for elevation, receives more precipitation than the North Fork watershed although the total runoff is practically the same.

It is indeed fortunate that measurements from these two areas are available for comparison, not only to demonstrate the effect of exposure on precipitation, but for yielding dramatic statistics on the value of the mountain snowpack reservoirs to the water resources of the region. In figure 7, the mean monthly hydrograph for these streams is drawn for comparison.

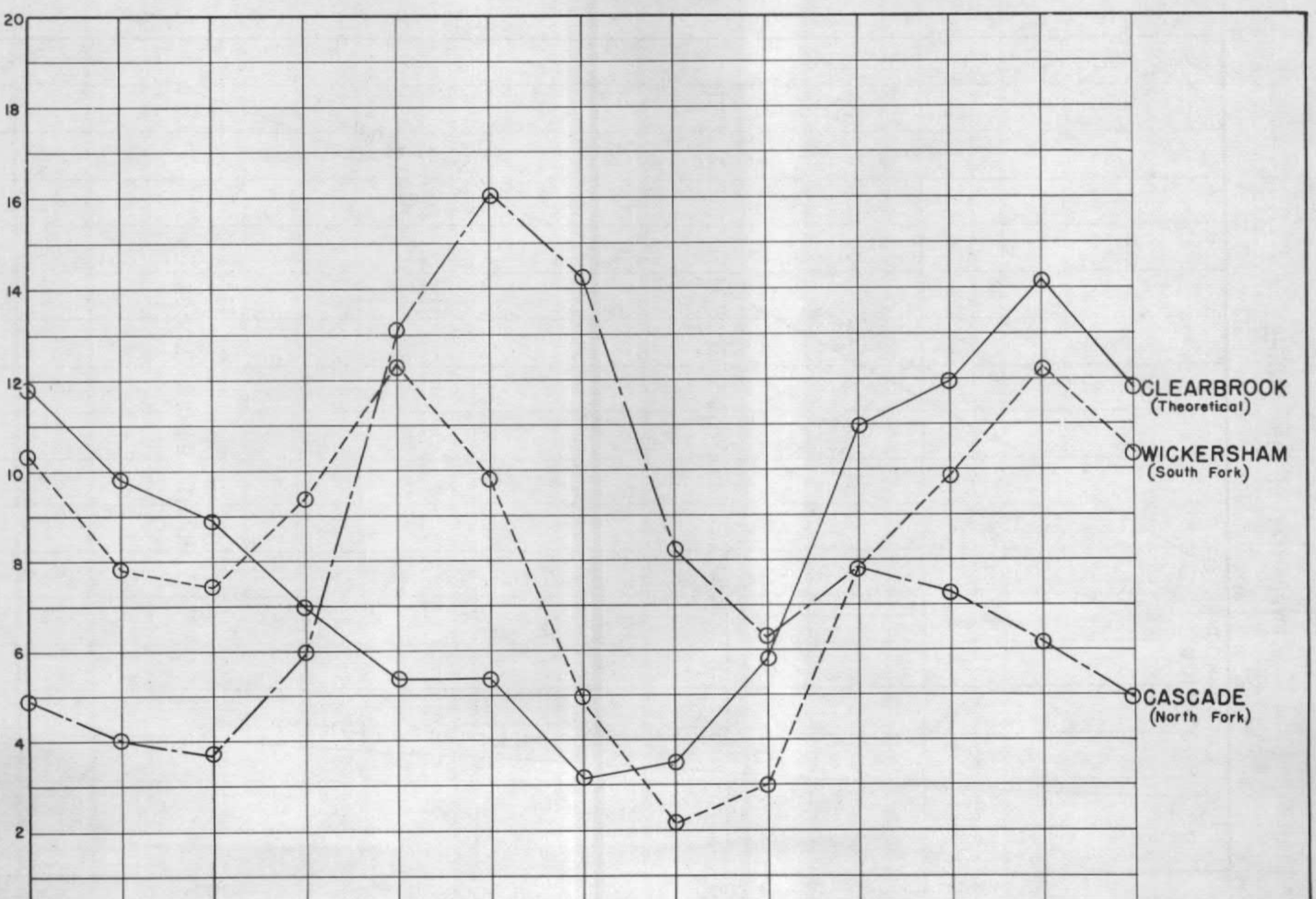


Figure 7. COMPARISON OF RUNOFF ON NORTH AND SOUTH FORKS OF NOOKSACK RIVER.

Because of the close relationships between rainfall and runoff in this region, the quantity of precipitation recorded at Clearbrook has been adjusted to equal the runoff from these two areas. Theoretically, this would represent the monthly distribution of runoff from a watershed devoid of losses or delayed recessional flows.

These monthly distribution curves are presented merely to show qualitatively the effect of topography on climate and runoff. As would be expected, runoff from both areas fall below the hypothetical precipitation curve during the colder months of the year indicating storage of water in the snowpack. The lower elevation and more favorable exposure results in streamflow from the South Fork being almost twice that of the North Fork during most of the winter months. With the warmer temperatures experienced during April, depletion of the snowpack combined with a higher incidence of precipitation in the form of rain over both basins cause streamflows to rise. These effects continue on into May. At this time runoff exceeds precipitation, indicating that depletion and ablation of the snowpack are becoming dominant contributors.

Tabulated below for the months of May through September in column 2 are the differences of runoff between the North and South Forks. Column 3 is a conversion of this runoff in acre-feet to the runoff in inches from a 27-square mile area.

Month	Runoff in Acre-Feet	Runoff in Inches
May	3,195 acre-feet	2 inches
June	33,746 "	23 "
July	51,584 "	36 "
August	33,613 "	23 "
September	18,038 "	13 "
Total	140,176 acre-feet	97 inches

The data involved in the area-elevation figures tabulated on page 14 were computed from a total area of a little over 100 square miles. Consequently, these figures can be considered, interchangeably, either as percentages or as total area in square miles. For example, 28.2 percent of the area on the North Fork is above 5,000 feet. This is approximately 28 square miles. Similarly, only 1 square mile is above this elevation on the South Fork watershed. Fortunately, for ease in comparison of these two streamflows, no permanent ice fields exist on the South Fork watershed.

If the runoff characteristics of the two streams were similar at all elevations below 5,000 feet, the excess flows in the foregoing tabulation could be attributed to the large difference in the area above 5,000 feet on these two streams. The North Fork has approximately 27 square miles more watershed above the 5,000 foot elevation than does the South Fork.

Actually because of the concentration of area over the lower elevation and the more favorable exposure to solar radiation on the South Fork, the comparison is somewhat biased in favor of the contention suggested in the last paragraph. However, these elevation and exposure effects would be expected to become less important as the summer season progresses.

After May the value of the high altitude watershed becomes conspicuous. Referring again to figure 7, at a time when precipitation is rapidly decreasing and runoff on the South Fork has reached its peak, streamflow on the North Fork is still rising.

During the same five-month deficit period when the Clearbrook station is recording only 24 percent of its mean annual precipitation, the North Fork produces 59 percent of its mean annual runoff. Actually, the contribution of the deficit period precipitation to the total at the higher elevations is probably only 10 to 15 percent.

The benefits derived from these climatically controlled glacier and snow field reservoirs on the North Fork are threefold. Obviously, a mean annual retention of 140,176 acre-feet of water for release during the season of maximum demand is extremely valuable to this region. In addition, the glaciers on the North Fork, estimated to cover 6.2 square miles of the watershed, are inherently capable of effecting cyclic storage. During periods of above normal precipitation and below normal temperatures, usually associated with years of water surplus, these glaciers grow in volume, storing water for inevitable return of a dry cycle. Finally, the water stored in glaciers and snow fields is withdrawn during the season of high runoff which results in a reduction of the downstream flood potential.

EVAPOTRANSPIRATION

Climatologists and ecologists working independently have come to realize the close association between the processes of evaporation and transpiration. The primary source of energy required for both of these processes is solar radiation. In most problems involving a water budget, these two consumptive withdrawals, evaporation (directly from the water-bearing surface) and transpiration (indirectly through the structures of plants), are usually combined. Hence, the term "evapotranspiration."

One of the most widely used methods of computing evapotranspiration was developed by Dr. C. W. Thornthwaite. Simply stated, Dr. Thornthwaite reasoned that the dissipation of solar energy was distributed among three primary heat consumers. A portion is expended in heating the air. The residual is expended either in heating the ground or is available for evapotranspiration. Although the magnitude of these three processes vary with wide limits, the ratio of the portion absorbed by each consumer is fairly constant. Therefore, the temperature of the air becomes an efficient indicator of the potential evapotranspiration. Using lysimeters, a device wherein plants are grown under known conditions of solar radiation, temperature, and moisture, Dr. Thornthwaite has derived an empirical formula based on temperature and latitude or length of possible duration of sunshine. Although there are more exact and sophisticated methods using actual measurements of solar radiation, wind movement, and humidity data, the Thornthwaite method, requiring only the conventional and readily available climatological data, is one of the most practical tools for evaluating evapotranspiration.

Figure 8 is a graphic representation of the water budget at the Clearbrook station compiled with this method. The coordinates are: months of the year along the abscissa and inches of water along the ordinate. The solid line denotes mean monthly precipitation, the dashed line mean monthly potential evapotranspiration, and the dotted line actual evaporation.

Beginning in January, which is really the middle of the surplus season, precipitation exceeds evapotranspiration by more than five inches. This surplus condition normally persists until mid-May, at which time the declining precipitation is just sufficient to meet the rising evaporatranspiration demands. This point marks the beginning of the deficit season.

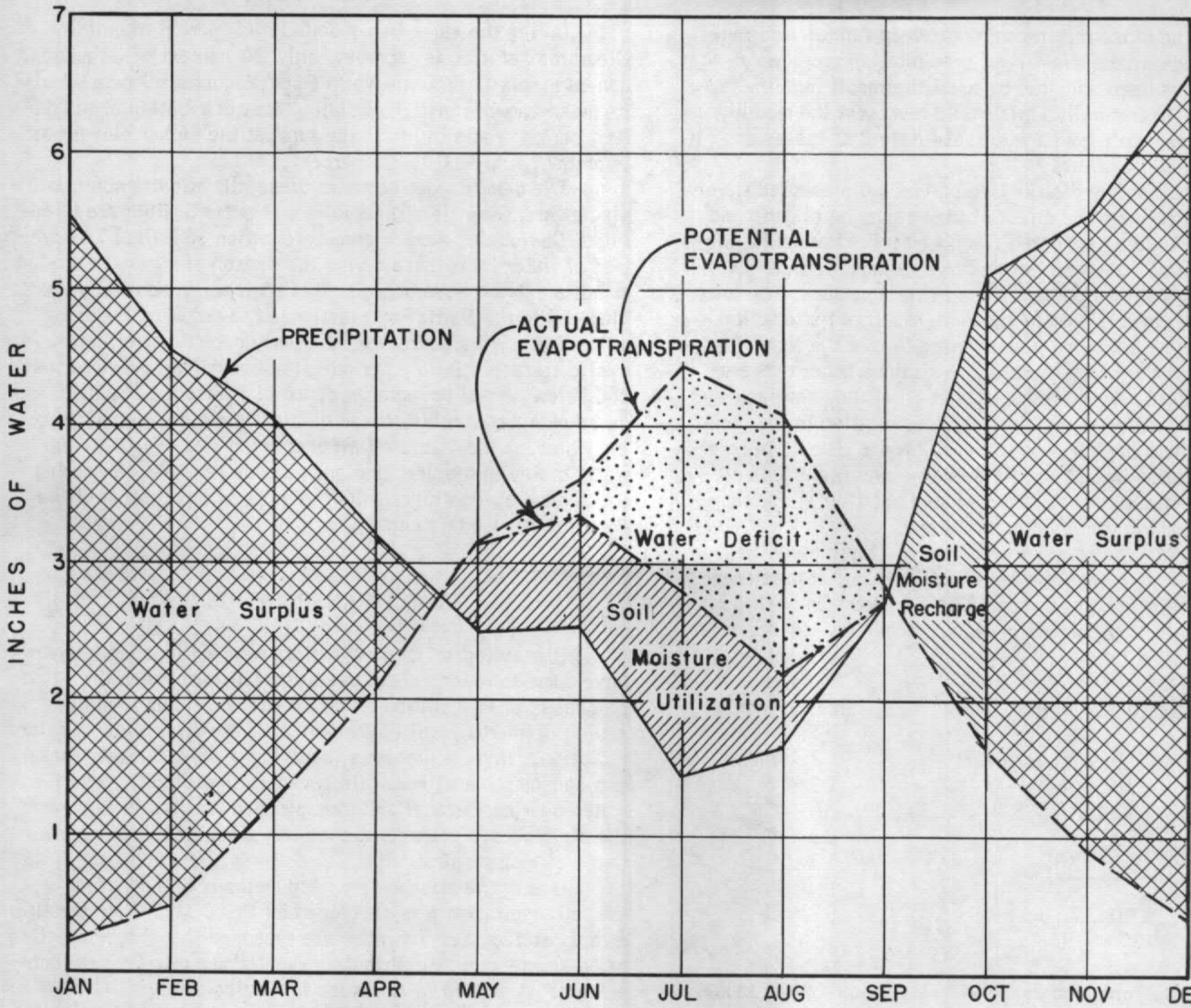


Figure 8. MEAN ANNUAL WATER BUDGET AT CLEARBROOK STATION.

Throughout the remainder of this season, evapotranspiration is the dominant hydrologic factor with a potential for evaporating 18.18 inches of water. Precipitation during this same 5 month period equals only 10.83 inches.

All through the surplus season and for a short time after the beginning of the deficit season the evapotranspiration rate is equal to the potential. Thereafter, since precipition is inadequate, the actual evapotranspiration is less than the potential. During this period there is a depletion of the water stored in the soil. At Clearbrook this field capacity is estimated to be 4 inches of water. As the deficit season progresses, increasingly higher potentials are required to evaporate the same quantity of water. For example, in September an evapotranspiration potential of 0.14 inches is required to evaporate only 0.02 inches of moisture from the desiccated soil profile.

Early in October the southward migration of the rain-bearing storm track signifies the end of the deficit season. Simultaneously, decreasing daily duration of sunshine accompanied by lower air temperatures cause a rapid reduction in the evapotranspiration potential. Precipitation once again is in excess. For a short interval this excess is utilized in recharging the depleted soil profile. Usually the ground becomes saturated by the end of October and further contributions of precipitation, less the now negligible evapotranspiration requirements, are expended as runoff.

In applying this principle to agriculture and especially to the needs for application of supplemental water, the concept of soil moisture can be neglected. Obviously for optimum plant growth and maximum irrigation efficiency, the soil profile should be maintained at or near field capacity throughout the growing season. Therefore, at the beginning of the deficit season supplemental water, just sufficient to meet the difference of the evaporation potential minus the precipitation, should be applied to the plant for optimum growth. Additional water is required to compensate for the efficiency of the irrigation system.

This graph illustrates a very important and somewhat insidious feature of Puget Sound climate. All during the winter the abundance of rainfall is most impressive. Although there is a pronounced decline in precipitation beginning after the first of the year, the ground remains saturated until late April or early May. Since temperatures are relatively high even during the coldest month, averaging 35.2°F during January at Clearbrook station, a luxuriant shallow-rooted vegetation is developed. The deficit in May, requiring only 0.66 inches of water to maintain complete saturation, represents a negligible draft on the soil profile. Even as late as June precipitation is only slightly below water demands. But after the first of July there is an abrupt change in growing

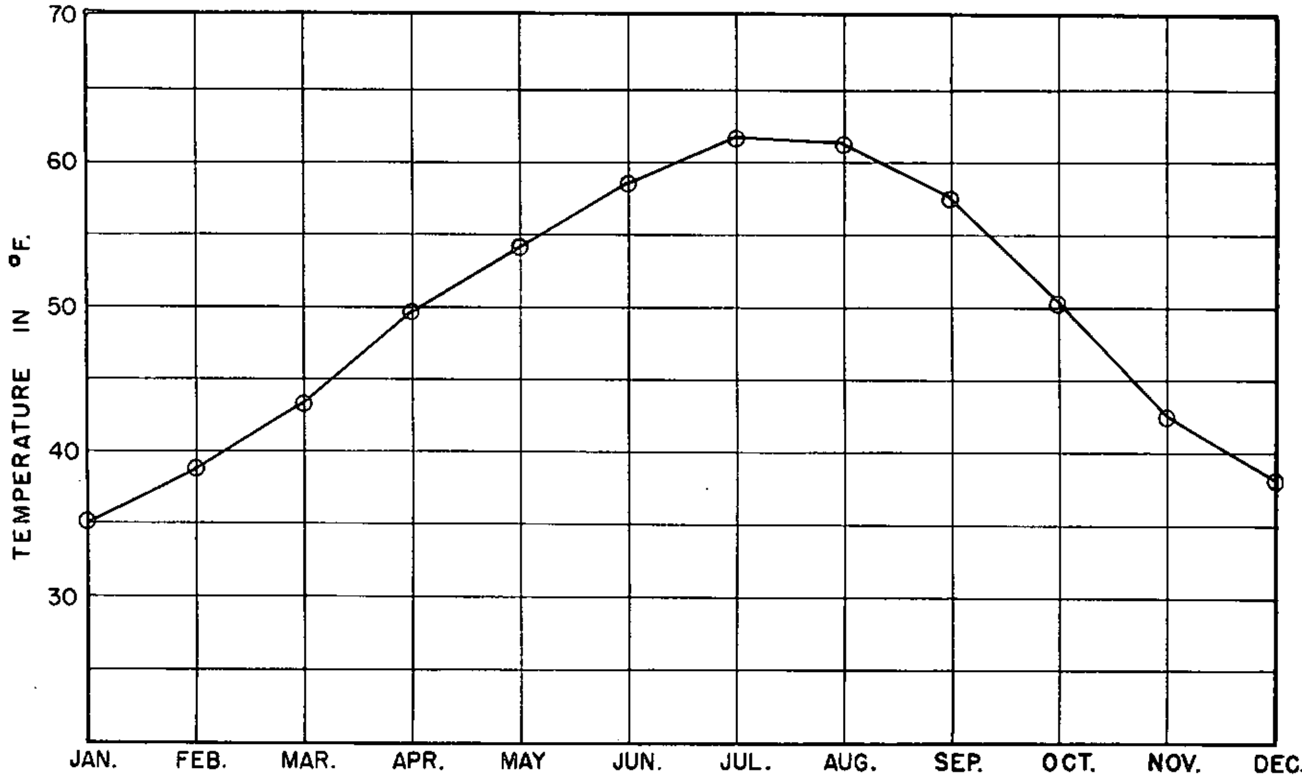


Figure 9. MEAN MONTHLY TEMPERATURE AT CLEARBROOK STATION.

conditions. A decrease in precipitation also affords a maximum of clear skies, which causes the evaporation potential to rise sharply. Quite suddenly in the midst of an environment of plenty a moisture deficient situation occurs. The moisture stored in the soil has been depleted to ineffectiveness and plant growth without supplemental irrigation is left to wither and die. Since this feature of the climate is a persistent annual occurrence, the practice of irrigation in this region of relatively high annual precipitation has proven to be practical.

TEMPERATURE

The graph of the mean monthly temperature recorded at Clearbrook shown in figure 9 is typical of temperature throughout the Nooksack basin lowlands. Maximum mean temperatures occur in July with slightly lower temperatures during August. Minimum temperatures occur in January. The mean annual temperature of the coldest month recorded at any station in the lower basin is above freezing.

The distribution of temperature throughout the year reflects the moderating influence of the ocean on the climate. Winters are particularly mild and summers are relatively cool for this latitude. Mean ocean temperatures at the mouth of the Strait of Juan de Fuca range from a warm 45°F in January to a cool 53° F in July!

The mean maximum temperature at Clearbrook is 75.8° F in both July and August and the absolute maximum for this station is 102° F which occurred in July. The mean minimum temperature is 29.5° F and occurs in January. The absolute minimum recorded was -4° F and occurred also in January. This decidedly low range in extremes of only 106° F is indicative of a maritime type climate. The average frost-free season at Clearbrook is the 148 days between May 5th and September 30th.

Cold weather at Clearbrook usually results from a spillover of an air mass originating over the extremely cold land surfaces in the Arctic. The Fraser River Gorge extending through the Cascade Range aids in conducting sporadic outbreaks of this cold Canadian air during the winter. The effect is generally confined to the Nooksack valley and is respectfully referred to as a "Northeaster."

ECONOMICS OF THE REGION

The economy of the Nooksack River area is based primarily on agriculture with intensive farming of relatively small farms. The area has an estimated population of 33,000 for a population density of 34 people per square mile which compares with a state-wide average of 41 people per square mile. When the unpopulated mountainous area is not considered, the density increases to 87 people per square mile, which is very high for an agricultural area. There are six incorporated cities, all located within the western half of the basin and all with populations of less than 3,000.

CITIES AND TOWNS

BLAINE

Blaine is situated in the extreme northwest corner of the basin, which is the most northwesterly portion of the 48 contiguous states. Blaine merits its title "The International City" and is famous for its "Peace Arch" and surrounding International Park dedicated as a monument to the peace which has existed between the United States and Canada.

The present city of Blaine was originally called

Semiahmoo and was a thriving community during the Fraser River gold rush of 1859. Its name later was changed to Concord and shortly after was platted as Blaine in 1884. Although the gold rush was a passing thing, Blaine continued to grow due to its location on Drayton Harbor. Abundant fishing, an excellent harbor, and fertile tidelands helped to attract settlers, and for many years Blaine was the largest city within the study area. Following incorporation on May 20, 1890, Blaine had grown to 2,289 persons by 1910. Blaine continued to thrive as long as fishing and logging prospered, but with the decline of these industries in the thirties Blaine also declined reaching a low in population of 1,524 in 1940. More recently, Blaine has participated in tourist trade and again is growing with a population of 1,800 in 1959. Blaine is the second largest city in the basin with three fish canneries and fish receiving stations being its major commercial industries. Blaine's harbor has been improved in recent years, and its present facilities are adequate to have 101 commercial boats and 160 pleasure and gill-net craft.

The ever increasing tourist trade and present trend of people moving to waterfront areas are contributing factors in Blaine's continued growth. Blaine serves as a trading center for many farmers in the region in addition to the numerous resorts. Point Roberts is closely associated with Blaine since the latter is the nearest major American trading center.

EVERSON

Everson is a small trading community located on the Nooksack River in the heart of the basin's richest agricultural land. Everson originated when the old Bellingham Bay and British Columbia Railroad established a depot there in 1891. Everson was incorporated on May 4, 1929, and has enjoyed a consistent growth to its present population of 420.

One large fruit and vegetable cannery contributes considerably to the economy in the area by providing both employment and a cash market for agricultural crops. Formerly a milk processing plant was located in Everson, but with the advent of bulk milk tanks on farms this has been closed. This building is now used by the Whatcom County Highway Department as a maintenance shop.

FERNDALE

Ferndale is located on the Nooksack River five miles above its mouth. Prior to 1877 a large log jam blocked the river at the present site of Ferndale, and at that time this area was officially called Jam. Ferndale, like Everson, has enjoyed a consistent but not spectacular growth since its incorporation in March 19, 1907, and presently has a population of 1,405.

Fruit orchards were established in the area at an early date, and at one time, Ferndale boasted a cannery in addition to three sawmills and one shingle mill. At the turn of the century, Ferndale was largely a lumber center; but as the forests were depleted, agriculture became prominent. Present industries include a large berry and vegetable frozen food processing plant that employs several hundred during the peak season, while just west of town is located the area's first refinery, which contributes a great deal to Ferndale's present growth.

LYNDEN

Lynden was incorporated on March 16, 1891, and is situated four miles from the Canadian border on the Lynden Terrace and Fishtrap Creek overlooking the Nooksack River. There were several shingle and sawmills in Lynden as long as timber was available in the area, but agriculture has always been the mainstay of the Lynden economy. At one time, bulb-growing was a major agricultural item, and the largest azalea business in the state is still located there. However, the dairy and poultry industries presently comprise the bulk of the area's agriculture. Located in the heart of the state's largest dairying region, Lynden has enjoyed a steady, consistent growth and now is the largest city in the study area with a population of 2,501. It is the major trading and service center for the county's farmers with the major farming implement and supply companies located there.

The dairy industry is centered at Lynden, with a large processing plant situated there. Lynden has progressed along with the major dairying changeover to bulk milk tanks on farms, and a Lynden firm manufactures automatic milk tank cleaners. Other industries include three seasonal frozen food processing plants which process strawberries, raspberries, blueberries, peas, corn, cauliflower, and other vegetables and fruits. Lynden's two parks are popular with tourists,and Canadians especially avail themselves of the excellent grounds and facilities for picnicking and general outdoor recreation.

NOOKSACK

Nooksack is a small residential community located east of Everson between the Nooksack and Sumas Rivers. The town was incorporated on December 6, 1912 and has always been associated with the lumber industry with one sawmill still located there. The decline of the lumber industry in this area, however, has had a negative effect on Nooksack, which has a present population of but 322.

SUMAS

The city of Sumas is located on the border just west of the Sumas River. Sumas was incorporated on June 18, 1891 and with many nearby mills and logging camps soon boomed to a population of over 2,000. Despite its excellent border location, Sumas declined in size to 647 in 1930 with the recession of the lumbering industry in the region. More recently, however, Sumas has depended on an agricultural economy, and its population has remained fairly constant, presently being 628.

Feed and grain processing is the main industry in Sumas as nearby dairy farms provide a ready market. It is also a major port of entry to Canada and is often described as the Gateway to the Caribou. Much tourist traffic does pass through Sumas, and the tourist trade will no doubt increase and contribute more to the future growth of Sumas.

AGRICULTURE

As the timber in the lower valleys was logged, it became apparent that the soil was rich and excellent for agricultural purposes. Gradually agriculture replaced lumbering in the lower valley and despite many changes is today the number one industry in this area. Ignoring the Class 10 soils which are not suitable for farming, there are approximately 245,000 acres in the basin. Of this about 160,000 acres or two-thirds of it is Class 2 or better, composing one of the larger good soil areas of western Washington. The bulk of this farming area extends from Ferndale to Everson and Sumas with Lynden in the center. Because of this strategic location, Lynden has grown to become the trading and processing center for agricultural Whatcom County.

The average farm size is relatively small, being but 58.7 acres in 1959 as compared with a state-wide farm of 363.9 acres. This average includes part-time and residential farms, so the size of an average commercial farm is somewhat larger. The location, climate, and soil lend themselves well to the intensive-type farming necessary for a successful operation on the small farms found here.

Previous cash products such as sugar beets and flower bulbs have been largely discontinued. The county's present crops are tabulated in table 1 and show that peas, potatoes, and strawberries predominate. Although these figures are for the entire county, they accurately reflect the study area where most of the agricultural land is found. Whatcom County leads the state in strawberry production and also leads both the State and nation in the production of White Rose Certified Seed Potatoes.

Dairying and poultry-raising, which involve considerable labor and are suited to smaller farms, are the basis of the area's agriculture. After leading the state for many years in poultry products, Whatcom County has dropped to second place although still producing 17.3 percent of the state's entire egg production and 7.6 percent of the state's chickens, including broilers. Whatcom County is, however, the state's number one producer of dairy products, and the dairying industry is continuing to expand with hay and pasture being the major crops in the county. In the ten years from 1949 to 1959, Whatcom County increased its percentage of the state's dairy production from 14 to 16.1 percent. In contrast to previous years when most of the milk was used for processing into butter, cheese, and condensed milk--increasing quantities of milk are being hauled in bulk tanks for the fresh milk market. Fresh milk from the basin enters the Puget Sound-Washington marketing area and now appears in Seattle homes and markets. The growth of the fresh milk market together with the continued demand for ice-cream, cheese, and other dairy products assures the prosperity and future growth of this rich dairy industry.

Due to the intensive type of farming practiced there, the region has become one of the leaders in developing new and improved methods of farming. The area's farms are above the state average in utilizing labor-saving devices. Agriculture is well mechanized and farming not only is more productive but is becoming an easier and more comfortable way of life.

AGRICULTURAL PRODUCTS PROCESSING

The processing of agricultural products is another major industry particularly during the summer months. Numerous fruits and vegetables are processed in season at the plants in Everson, Ferndale, and Lynden. A large milk processing plant in Lynden provides stable year-round employment as do the several mills which grind and distribute cattle feed throughout the basin.

MANUFACTURING

Manufacturing contributes only a small portion to the economy of the basin. General Petroleum's refinery west of Ferndale is the major industry. Its crude oil is imported both by trans- Canada oil pipeline and by ship. This refinery is located west of Ferndale and has contributed a great deal to that town's economy. Other industries include a Lynden firm that manufactures bulk milk tank cleaners, but for the most part manufacturing is small and of local importance only.

NATURAL RESOURCES

LUMBERING

At one time the economy of the entire Nooksack River area was closely tied to lumbering and shingle industries. As the valleys were logged and cleared for agriculture, lumbering lost its dominant economic hold on the region although it still

Table 1. PRODUCTION OF CASH CROPS IN WHATCOM COUNTY

Crop	1957 Acreage	1957 Yield (tons)	1958 Acreage	1958 Yield (tons)	1958 State Rank	% State Total	1959 Estimated Acreage	1959 Estimated Yield (tons)
Beans	450	2,700	290	2,190	2	19.0	270	1,350
Carrots	90	1,220	90	1,280	6	6.7	135	3,550
Peas (processing)	2,600	5,090	2,400	4,980	6	5.6	3,000	5,440
Potatoes (commercial and seed)	2,350	23,500	2,570	21,170	7	4.0	2,250	29,000
Broccoli	40	120	20	70	6	1.8	110	440
Cauliflower	90	630	100	920	5	10.5	0	0
Cucumbers	90	360	90	540	8	4.7	0	0
Strawberries	1,400	3,920	1,350	3,965	1	20.3	1,000	3,500
Red Raspberries	300	790	300	720	4	9.4	300	900
Blackberries	60	120	40	120	4	3.5	15	60
Blueberries	50	75	50	80	5	5.7	55	130

is very important. Logging is especially important in the Eastern Upland where the mountainous terrain supports much virgin timber and important stands of second growth. The Mt. Baker National Forest occupies a large portion of this area and continuing reforestation and fire prevention programs are insuring a supply of timber for the future. In the lower basin, marginal farms are being planted with conifer primarily for Christmas tree purposes.

FISHING

When Whatcom County was first settled, the fisheries resources seemed unlimited. Thousands of cases of fish were canned every year and shipped to other regions. However, when fish traps were outlawed, the fishing industry suffered a setback and now much of the fish processed in the area is shipped in from Canadian and Alaskan waters. Purse seiners, gill-net, and reef-net fishermen still fish near Lummi Island and Point Roberts, but on the whole the commercial fishing influence on the area is declining.

Boundary Bay, near Point Roberts, is the best producer of Dungeness crabs in the inland waters of the state.

The best port of the basin and one of the best small boat harbors in the state is located at Blaine. Although no sharp increase in commercial boats is likely, pleasure craft are increasing and using the improved facilities more each year.

MINERAL RESOURCES

The Nooksack River basin has a variety of mineral resources. Coal, refractory clay, sand, gravel, and peat are all found in the Whatcom Basin, while limestone, quartz, gold, copper, chromite, olivine, and Shuksan building stone are found in the Eastern Upland. However, present economic conditions have not been conducive for the development of these resources, although potentially they could be of major importance. The chromite deposit, though apparently small, should be further investigated as it is the largest deposit in the state. An olivine deposit in the Twin Sisters Mountain is one of the largest in the United States and could be more completely developed. Extensive drilling for oil and gas has been conducted, and although there has been no commercial production, a minor gas field located west of Custer has produced small quantities for local home use.

RECREATION

The tourist trade appears to hold an important key to the future of the Nooksack River basin. This scenically situated area contains seaside resorts catering to fishing and boating enthusiasts, excellent fresh-water streams and lakes, and rugged mountains, in which is located at Heather Meadows one of America's most beautiful year-round skiing centers. Its strategic location makes it readily accessible to Canadians seeking a vacation or summer and winter sports. Also, increased numbers of residents from the populous lower Puget Sound areas of Seattle and Tacoma are taking advantage of the recreation facilities of the area.

GEOLOGY AND GROUND-WATER RESOURCES

GEOLOGY OF THE REGION

GEOLOGIC HISTORY

The oldest rocks known to exist in the Nooksack River basin occur in the mountainous portions of the Eastern Upland. Here, rocks dating back as far as Devonian age have been identified by fossil evidence. Although this report does not attempt detailed differentiation of rocks of pre-Tertiary age, a brief resume' of the earlier geologic history of this region is outlined for general interest. See "Geologic Map of the Nooksack River Basin" (pl. 1).

PALEOZOIC-MESOZOIC ERAS

The wide variety of rock types and degrees of metamorphism give clear evidence of a complex structural history. During middle through late Paleozoic time, the area covered by this report was under water--a western marginal portion of a vast arcuate seaway know as the Cordilleran Geosyncline which extended generally through the Pacific states from Mexico to Canada. Into this slowly subsiding structural trough was deposited a thick sequence of lime-marl, clay, and andesitic lava flows. Subsequent folding, uplift, and intense deformation of the earth's crust during early and middle Mesozoic time (Triassic and Jurassic Nevadian orogeny) resulted in low-grade metamorphism of these sediments and volcanics to form the crystalline limestones, phyllites, and greenstones now found throughout the mountainous portions of the Nooksack River basin. From late Jurassic through late Cretaceous time, portions of the area were again depressed and invaded by seas to allow deposition of the marine sediments known as the Nooksack formation.

TERTIARY PERIOD

From late Cretaceous to early Tertiary (Eocene) time, large scale thrust faulting resulted in the older Paleozoic rocks being forced over younger rocks, and some granite was intruded locally in the upper watershed area (Nooksack cirque on Mt. Shuksan at the head of the North Fork Nooksack River). The intrusion of a large dunite body also occurred during Eocene time to form the rocks of the Twins Sisters Mountain. Along with deformation in the mountains, a widespread and thick deposition of continental sands, clays, and conglomerates occurred across a coastal plain extending along the western margins of the uplift area. These sediments of late Cretaceous to early Eocene age were then uplifted to form what is now known as the Chuckanut formation composed predominately of sandstones and shales. Today these are found in the foothills of the Cascade Mountains east of the Whatcom Basin, near the surface along the southern margins of the Whatcom Basin from Bellingham to Deming, and in the northern portion of Lummi Island. From late Eocene to Miocene time, the range was subject to further uplift and erosion of the earlier rocks with accompanying extrusion and deposition of the Hannegan volcanics (primarily ash beds) in the Hannegan Pass-Ruth Mountain area of the upper North Fork Nooksack River valley. During Pliocene time, the first north-south uplift affected the earlier northwest-southeast structural trend of the range and the present Cascade Mountain Range and Olympic Mountains were born with accompanying downwarp of the Puget Trough lying between. During the late period of this uplift in late Pliocene to early Pleistocene time, igneous activity occurred along the range to form numerous volcanic cones, with Mt. Baker forming on the eastern boundary of the present Nooksack River watershed. The lowland of the Whatcom Basin became well dissected by streams draining the adjacent mountains, and a very uneven, hilly topography was developed on the Tertiary and older rocks west of the Cascade Range.

QUATERNARY PERIOD

Pleistocene epoch.

Early in the Pleistocene epoch (Ice Age) erosion reduced the newly formed Cascade Range to a stage of mature dissection. River valleys were cut into the mountain flanks and rock waste from the mountains was carried to the Puget Trough where it was deposited, partially filling lowland valleys cut into the Tertiary bedrock. Structural evidence indicates that the Whatcom Basin was formed as the south half of a structural downwarp which extends northward to include the Fraser delta, and that the early Pleistocene deposits filled this basin to depths of at least 560 feet below present sea level, as recorded in well 40/1E-4J1 east of Blaine. See "Geologic Cross Sections of the Lower Nooksack River Basin" (pl. 2).

During middle to late Pleistocene time, climatic changes brought on the growth of vast continental ice sheets which covered most of Canada, Alaska, and the northern fringes of the United States. A mass of ice moved southward into the Puget Trough from the piedmont glacier between Vancouver Island and the Canadian Coast Range and in its earliest stages caused blockage of existing waterways to the extent of forming vast temporary lakes. Into these lakes fine silts and clays were deposited by both the streams issuing from the ice front and from existing streams carrying material from the adjacent mountains. Although the early history of Puget Sound glaciation is vague owing to much of the deposits lying at or below present sea level and having been covered by later glacial deposits, the earliest glaciation is referred to generally as the Admiralty, with the Admiralty clay being the predominate member of these materials. The exact nature of the depositional environment of these clays is not known; some claim that it was pre-glacially deposited into a large fresh-water lake, with some local encroachment of marine waters; others attribute its formation strictly to glacial drift origin. This report does not attempt to present a detailed discussion of the two theories, but will accept the Admiralty clay as of early glacial origin.

The deposition of the Admiralty clay ended abruptly.

The lake into which it was deposited was drained and a stream system developed across the top of the Admiralty. Deep canyons were quickly eroded and reached headward to the hard rocks of the mountain slopes. The Whatcom Basin presented a deeply eroded surface at the beginning of the latest and largest period of glacial advance, known as the Vashon glacial epoch.

During Vashon glaciation, the Puget Trough was occupied by ice as far south as Tenino in southern Thurston County, with probable thicknesses of 3,000 to 5,000 feet, as judged by glacially deposited boulders found at corresponding elevations on adjacent mountain slopes. Thick ice tongues also extended down local Cascade Mountain valleys to join the large Vashon glacier. Numerous temporary lakes were formed where drainages were blocked, and river courses were forced into new channels by the advancing ice mass. The Fraser River in British Columbia was probably forced southward to join the Nooksack River across the Whatcom Basin. In turn, the Nooksack and other streams were diverted southward along the advancing ice margin. As the ice moved southward in the Puget Trough, it pushed up the then existing Nooksack River gorge, at that time located in the present day Custer Trough southeast of Blaine, and it forced the river to seek a new outlet. The river probably flowed temporarily south of the Birch Point Upland, then down the present outlet of the Lummi River, then was gradually forced eastward to where its course through the foothills was completely blocked. Here, in combination with the flow from the north of the diverted Fraser River, a north-south valley was initially cut which permitted the trapped rivers to escape to the Skagit drainage south of Wickersham. As the ice pushed into the foothills and followed these new river channels, the valleys were deepened further and widened by glacial erosion. At the height of its activity the Vashon glacier eventually filled the entire Puget Trough, with one huge lobe pushing westward to the Pacific Ocean through the area now known as the Strait of Juan de Fuca. With a gradual warming of the climate, the ice mass began melting and its front gradually receded northward. The final waning of the "Ice Age," as recently as 14,000 years ago by latest calculations, brought the disappearance of the glacier from the Puget Trough. Sea water invaded the deeply eroded trough and formed the present-day inlets of Puget Sound. Local valley and mountain glaciers receded into the range where today they now occupy only the upper cirques and slopes of the higher peaks.

Recent.

The Vashon glaciated surface of Pleistocene time has been modified but little by erosion during Recent time. As the ice left the Whatcom Basin and adjacent lowland areas, the Nooksack and Fraser Rivers returned to flow again across these lowlands in new courses determined by topography left by the recessional outwash of the ice sheet. In the upper mountain valleys the Nooksack River cut into the recessional materials and carried the re-worked sediments to the lowlands, depositing these gravels, sands, and silts across the broad flood plain.[5] The coarser sands and gravels were deposited just beyond the valley mouths, while the finer, lighter sands and silts were carred downstream to become the growing deltaic deposits. The lower course of the Nooksack River below Ferndale was probably an estuary, and the Lummi Peninsula was then an island. Alluvial deposits have since filled the embayment, producing a near-sea level plain that transformed the island into a peninsula. Owing to a slight topographic rise or natural levee separating the Nooksack River from the base of the west slope of Sumas Mountain, drainage from this slope formed the headwaters of the Sumas River which flowed northward in a flat, meandering course to join the Fraser River in British Columbia. The valley now occupied by Kendall Creek was abandoned by the Fraser River and is today of minor importance to the surface-water flow of the Nooksack River basin, most of the precipitation here disappearing quickly into the gravelly valley fill.

The recession of the Vashon glacier and subsequent adjustment of the drainage to its new environment were succeeded by a short period of adjustment to topography and climate before man entered the scene to find the earth materials, topography, soils, vegetation, and drainage as they are today.

DESCRIPTION OF ROCK UNITS

PRE-TERTIARY METAMORPHIC ROCKS

Briefly, these rocks which predominate in the mountainous upper watershed area include the Paleozoic sediments and volcanic flows which were metamorphosed during mid-Mesozoic time to form shales, argillites, slates, phyllites, schists, greenstones, greenschists, and amphibolites. These dense, compact rocks, being primarily impermeable to either retention or transmission of ground water except through occasional joint and fracture zones, owe their importance to the watershed principally by virtue of their permitting precipitation to be quickly drained off to surface streams for rapid measurement in downstream gaging stations. Although some precipitation is lost through interception by the dense vegetal cover and forest growth, with resultant direct evaporation, or is lost through evapotranspiration, most of the water reaching the soil mantling the bedrock eventually finds its way to the rivers through seepage and springs. It is estimated that approximately 70 percent of the total precipitation falling in the mountains will reach the gaging station at Deming, below the confluence of the North, Middle, and South Forks of the Nooksack River.

The pre-Tertiary metamorphic rocks are also exposed in a few places in the foothills. Sumas Mountain, although covered by varying thicknesses of glacial deposits, shows outcrops of a dark green peridotite at the surface of the west slope. Vedder Mountain east of Sumas is also composed essentially of pre-Tertiary metamorphic rocks, mostly argillites and graywacke sandstones, with minor amounts of greenstone. Other pre-Tertiary rocks in the report area occur in the mountainous southern half of Lummi Island where, according to McLellan 1/, dark colored and usually thin-bedded argillite, graywacke, slate, grit, and conglomerate of the Leech River group of late Paleozoic age occur. The northern tip of the island has a small outcrop of Eagle Cliff ellipsoidal porphyrite which shows a semi-andesitic texture 2/.

TERTIARY ROCKS

So far as is known, the Chuckanut formation of Eocene age forms the bedrock beneath the unconsolidated Pleistocene deposits throughout the Whatcom Basin. This is a thick sequence of sandstones, shales, and conglomerates of continental type, fresh-water deposition. Interbedded in these

1/ McLellan, R. D. 1927, The geology of the San Juan Islands: Univ. of Wash. Publ. in Geology, vol. 2, p. 109.

2/ Ibid., p. 147.

sediments are abundant plant remains and some coal seams that have been mined for many years in the Bellingham area.

These sandstones, shales, and conglomerates are folded into broad, open folds that trend generally northwest-southeast. Prior to burial beneath the Pleistocene deposits of the Whatcom Basin, the folds of the Tertiary had been cut and bevelled by erosion. The exposed knobs and probably the buried surface consist mostly of subdued strike ridges connected by intervening gentler slopes. Records of several drill holes in the Birch Bay district show a relief of as much as 200 feet per mile on the buried surface of the Tertiary bedrock. This surface descends generally northward from the southern and eastern margins of the basin, to where it attains its maximum depth below sea level just north of the international boundary. The Blaine city well (40/1E-4J1) which penetrates to 560 feet below sea level in Pleistocene materials, does not reach Tertiary rocks (pl. 2).

On Lummi Island the Chuckanut formation rocks consist of cross-bedded and poorly consolidated arkosic sandstones and conglomerates which trend northwesterly, occupying the bottom of a distorted syncline in the northern half of the island.1/

Although of little importance to the water resources of the Nooksack River basin, a few areas of Tertiary igneous rock occur in the mountainous upper watershed area. These include the intrusive, locally serpentinized, dunite mass of Twin Sisters Mountain; the intrusive granitic mass occupying the Nooksack cirque on Mt. Shuksan at the headwaters of the North Fork Nooksack River and the extrusive Hannegan volcanics occurring as well-layered ash beds in the Hannegan Pass-Ruth Mountain area.

QUATERNARY DEPOSITS

Pre-Vashon Pleistocene Deposits.

The oldest known deposits of Pleistocene age can be seen in very few places, and are believed to form the core of the principal low plateaus or upland areas. These materials are exposed in the sea cliffs along the west side of the Mountain View Upland (in the SE¼SW¼ of Sec. 20, Twp. 39 N., Rge. 1 E.) and consist primarily of well-bedded clays having silt or fine sand partings. These clays may include those of the Admiralty drift which have been identified more definitely farther south in the Puget Sound basin. A similar section of these early Pleistocene deposits is exposed in the sea cliff 2½ miles southeast of Marietta (in the SW¼NW¼ of Sec. 23, Twp. 38 N., Rge. 2 E.) where interbedded clays and fine sands are found. Aside from the above described exposures, pre-Vashon deposits are known only from subsurface exploration, mostly by drilling for ground water, and by oil and gas test wells.

Vashon Advance Outwash.

There is an irregular thickness of cross-bedded sands and gravels beneath the till which caps the upland areas in the Whatcom Basin, particularly noticeable in the sea cliffs on the west and on the east slopes of the Mountain View Upland, on the Boundary Upland, and on the north slopes of the King Mountain Upland. These current-laid deposits belong to the advance outwash of the Vashon glacier and were laid down by the numerous streams issuing from the advancing ice front. Elsewhere in the basin, the outwash layer seems to consist of finer materials (sands, silts, and clays) deposited in ponded water.

Vashon Till.

As a massively compact mixture of clay, silt, sand, and pebbly gravel with occasional cobbles and boulders, the Vashon till was laid down as a ground moraine beneath the advancing ice sheet. It is bluish gray in color except near the surface or along joints where it is stained a yellow-red color. The till ranges from a few feet to 50 feet or more in thickness. It extends from the edge of the recessional outwash materials and alluvial deposits of the river valleys over the uplands and up the mountain slopes that bound the Whatcom Basin. The till is a hard, distinctive stratum commonly known locally as "hardpan." The till averages about 20 feet in thickness which is not as great as in Snohomish County, 75 miles to the south, where a thickness of 50 feet is about average.

Vashon Recessional Outwash.

These deposits of the Vashon Glacier consist of sand and gravel and some finer materials, laid down primarily as fluviatile deposits by streams flowing from the melting and retreating ice front. The Lynden Terrace, Custer Trough, and the broad area that extends northward from the King Mountain Upland to the flood plain of the Nooksack River contain the most extensive deposits of the recessional outwash found in the report area. The extensive terrace lands formed by these recessional outwash deposits are now some of the finest agricultural lands in the county. Within the mountainous portion of the Nooksack River basin, the present-day streams have cut into and reworked these deposits, carrying the materials to lower valley bottoms for deposition as alluvium.

Recent Alluvium.

After the recessional materials had been laid down and the rivers again were permitted to flow across this broad lowland area, the Nooksack River excavated its floor to the newer and lower sea level of today. It reworked much of the recessional outwash material, mixing it with river silt and forming a flood plain deposit that mantles the lower level cut in the recessional outwash deposits. These Recent deposits of silt, sand, and gravel along the river channel and stream beds, and mud and peat deposits in swampy depressions are being referred to as Recent alluvium.

SOILS

The following general outline of the soils of the Nooksack River basin is adapted almost completely from the Soil Conservation Service report by E. N. Poulson and R. D. Flannery, "Soil Survey of Whatcom County, Washington" Series 1941, No. 7. For a more detailed description of local soil types and conditions, the reader is referred to the more comprehensive report.

Owing to the characteristics of heterogeneous underlying glacial and stream deposits throughout the Whatcom Basin, and to extreme variations in both surface and internal

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1/ Ibid., p. 136.

drainage, perhaps nowhere else in the Puget Sound basin is there such a great diversity of soil types.

However, owing to the occurrence of aggregates or granules hard and durable in water, most of the soils are friable, easy to dig unless very stony, and vegetation grows rapidly on all of them. Because of the combination of water-stable granules and rapid plant growth, erosion is not a serious factor in soil management, and steep road banks are not marred by deep rills and erosion gullies common in finer soils of poor permeability. Though leached by frequent rainfall, the soils here retain considerable inherent mineral fertility. All have acid surface soil and most have a less acid lower subsoil or substratum, which indicates a more healthful condition than if the acidity increased with depth. The soils respond well to fertilization and to good farming practices.

About 60 percent of the Whatcom Basin consists of uplands and terraces from which all the virgin timber has been removed, and large areas of this land are farmed. Highly fertile soils of the alluvial bottoms cover most of the remaining area. A considerable acreage, however, is covered by organic soils, which occur in basins and depressions in all parts of the Whatcom Basin. Practically all stream bottom and organic soils are cultivated.

Excluding differences in the lay of the land, the soils of both the uplands and terraces fall naturally into three classes of drainage, namely, well or moderately well drained (including some with excessive drainage), imperfectly drained, and poorly drained. Each of these groups is readily distinguished by surface color, which has resulted largely from the degree of leaching, oxidation, and incorporation of organic residues.

The well or moderately-well drained soils are yellowish brown when wet. They are strongly acid, and most of them have a friable, mellow, water-stable granular silty surface soil, though sandy and gravelly textures are not uncommon. The soils are fairly low in nitrogen but not necessarily so in other plant nutrients. Application of lime alone does not benefit them significantly, but plants respond well to additions of phosphate or phosphate and lime. The subsoils and substrata vary from dense tight clay to open droughty gravelly material. Soils developed from clay till have a strongly rolling or knobbymorainic relief and are generally free from surface stone and gravel, though a few gravelly areas do occur in some. Even on the steepest slopes the dense native vegetation and the water-stable granular surface soil promote rapid infiltration. Runoff is therefore small and erosion insignificant. On incorrectly cultivated steep hillsides, however, the silty surface soil becomes thin and the clay subsoil, when exposed, is more readily susceptible to accelerated erosion.

The imperfectly-drained soils occupy smooth areas in association with those better drained. Slower surface drainage and retarded internal water movement have promoted a more luxuriant vegetation, and larger quantities of organic residues have become incorporated in the surface soil. The organic material, together with retarded oxidation, has created darker soils. The surface soil is weak brown when dry and dusty brown when wet, and the subsoil is pale brown and usually mottled with iron stain. Iron concentration occurs in some soils as accretions and cementations, and ironpans are common. Being less leached the imperfectly-drained soils are generally less acid, have a higher mineral fertility, and retain more moisture than those better drained. This moisture relation is especially important because of the dry summers. These soils generally respond well to the same treatment as that given better-drained soils.

The soils of stream bottom lands are largely fine textured, deep, dark, and of high fertility. The highly organic ones are dark brown or nearly black, whereas those with lesser quantities of organic matter are brownish gray to light brownish gray or somewhat grayish olive. Stream bottom land soils are inherently fertile and have a plentiful supply of moisture. Moisture is commonly excessive where natural or artificial drainage is ineffective or incomplete.

The poorly-drained soils of the uplands and terraces occupy nearly level basins and depressions and, not uncommonly, seepy areas on smooth steep slopes. Soils having this drainage support a luxuriant vegetation, including many deciduous trees, underbrush, and a ground-cover of water-tolerant herbs and grasses. The conditions of drainage and vegetation have created a brownish-gray rather highly organic surface soil and a pale-brown discolored subsoil highly stained with rusty iron. In some soils iron cementations occur as fragments and plates, and dense ironpans are common. These soils have a higher inherent fertility than the associated better drained ones, but they are wet and cold in spring; even where drains are installed they may be suited to only a limited number of crops. The drains now used are largely open ditches. If tile were employed, a greater diversity of crops probably could be grown.

The organic soils are widely scattered in old lake basins, in depressions, on steep slopes, and in low bottom lands of streams. Large areas, often many square miles in extent, occupy old abandoned stream channels and areas adjacent to subsiding lakes. Peats and mucks of varied origin and composition are included. Organic soils form an important agricultural acreage and are highly productive when fertilized and properly drained. Moss peat growing on undrained uncultivated areas has a limited agricultural value, but is dug and sold for commercial use.

The first settlers recognized the value of bottom and upland depression soils, including the organic ones. Their fertility and supply of moisture were appreciated and, as indicated by the density of farm population, these soils are still the most extensively used. Lands of the stream bottoms were from the first readily accessible by water but those of upland depressions and other less favorable locations were difficult to reach and largely unavailable until the lands were logged. These natural factors, together with greater ease of clearing, made expansion on the bottoms more rapid than elsewhere and now little bottom land is uncleared. Railroads and the main arterial highways usually follow the easy grade of the stream valleys or terrace flats these soils occupy, and though power and telephone lines often have more direct courses, they naturally are directed to the more populated areas.

In the early period of settlement most of the stream bottom land was cleared and farmed to meet the growing demand for agricultural products brought about by the rapid expansion of lumbering and other industries. There was not enough stream bottom land to keep pace with industrial development, however, and soils of the upland depressions and wet terrace flats, including the organic soils, came into use after they were logged. Expansion to these soils was later followed by movement to less desirable ones of the uplands and terraces, especially where additional acreage was needed to increase farm units to desirable size.

Many of the soils of the uplands and terraces having naturally imperfect or poor drainage have become highly productive. Those that retain moisture well and do not waterlog at any time are now important fruit-producing soils because of their freedom from frosts.

The more droughty gravelly soil types have been largely abandoned because they do not retain enough moisture to mature crops satisfactorily. The early settlers frequently sought home sites around industrial or logging centers regardless of the kind of soil. Most logging operations have now moved to the more mountainous interior, but many people still remain on their farm holdings or retain them as a place for part-time employment. In many of the less desirable of these areas occupants change frequently, as the clearings are small and a patch type of part-time farming is practiced.

GROUND WATER

WELL-NUMBERING SYSTEM

In this report, the U. S. Geological Survey's well-numbering system is used, whereby wells and springs are designated by symbols that indicate their respective locations according to the official rectangular public land survey. For example, in the symbol 40/2-27J1, the part preceding the hyphen indicates successively the township and range (Twp. 40 N., Rge. 2 E.) north and east of the Willamette base line and meridian. Because the report area lies almost entirely within the northeast quadrant of the Willamette base line and meridian, the letters indicating the directions, north and east, are omitted, but the letter "W" is included when the range lies west of the Willamette meridian. The first number following the hyphen indicates the section (Sec. 27) and the letter (J) gives the 40-acre subdivision of the section, as shown in figure 10.

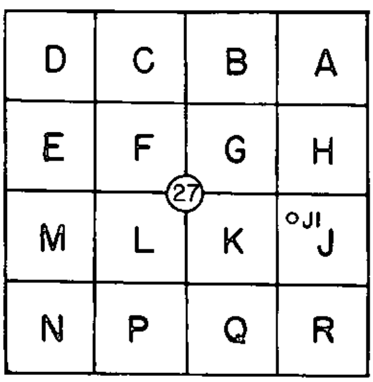


Figure 10.

The last number is the serial number of the well in the particular 40-acre tract. Thus well 40/2-27J1 is the first well listed in the NE¼SE¼ of Sec. 27, Twp. 40 N., Rge. 3 E.

GENERAL CONDITIONS OF GROUND-WATER OCCURRENCE

PERCHED GROUND WATER

The shallow soil-zone wells located on the till-covered uplands of the Whatcom Basin tap water that is held up or "perched" above the regional water table. Impervious clay layers near the surface of some terraces, such as the low outwash terrace just east of the Nooksack River opposite Ferndale, may cause a similar perching effect. Beneath the uplands, clay layers within the otherwise pervious sand and gravel bedsmay also perch small bodies of ground water at a position above the regional water table.

UNCONFINED GROUND WATER

In areas of the Nooksack River basin where only permeable materials exist, such as in the recessional outwash and Recent alluvial deposits of the lowlands, there is but one water table and all wells drilled in these unconsolidated materials will obtain unconfined ground water when the water table is penetrated. The majority of wells in the report area obtain water under unconfined ground-water conditions.

CONFINED GROUND WATER

Confined, or "artesian" ground water occurs under pressure and head due to its passage beneath an impermeable stratum which prevents its upward movement to the level of the point of inflow. Water encountered by a well penetrating the overlying confining layer will rise in the well casing to that piezometric surface. Although popular usage of the term "artesian well" usually implies one that flows at the surface, the term commonly accepted by hydrologists refers to ground water beneath a confining stratum that will rise in a well above the level at which it was encountered, whether or not it reaches ground surface. In the Whatcom Basin the principal known areas of flowing artesian wells are the Anderson Creek area north of Squalicum Mountain (well 39/4E-31Q1), the east slope of the Mountain View Upland area near Ferndale (well 30/2E-30K1), and the south slope of the Boundary Upland east of Blaine (well 41/1E-31Q1). The presence of these known areas of flowing wells suggests that other areas probably exist but have not yet been discovered.

OCCURRENCE OF GROUND WATER WITHIN STRATIGRAPHIC UNITS

PRE-TERTIARY METAMORPHIC ROCKS

The metamorphic rocks (principally slates, schists, and greenstones) that comprise the bedrock of the Eastern Upland and the southern half of Lummi Island do not contain pores or openings other than small joint cracks and shear zones common to hard rocks and consequently normally carry ground water only irregularly and in small quantities. No wells are known to obtain water from these rocks in the report area and the dense, tight character of these rocks makes them unlikely sources of substantial quantities of ground water.

TERTIARY ROCKS

The Tertiary sedimentary shales, sandstones, and conglomerates which are exposed in the Cascade foothills carry small quantities of fresh ground water in a few places where the pore space permits and where adequate recharge and drainage have flushed out the saline and other highly mineralized water commonly found in these rocks. The yields are low, normally a few gallons a minute for domestic use only. These sandstone and conglomerate materials are rather poorly sorted, quite well cemented, and irregularly and discontinuously stratified, all of which characteristics help to account for their lack of permeability. In fact, drilling records show that in many cases the meager supplies of water obtained from the Tertiary rocks have come from the "broken shale" members of the formation. During the well canvass only a few wells were found obtaining water from the Tertiary rocks; these are at fairly high altitudes, where downward flushing of the strata

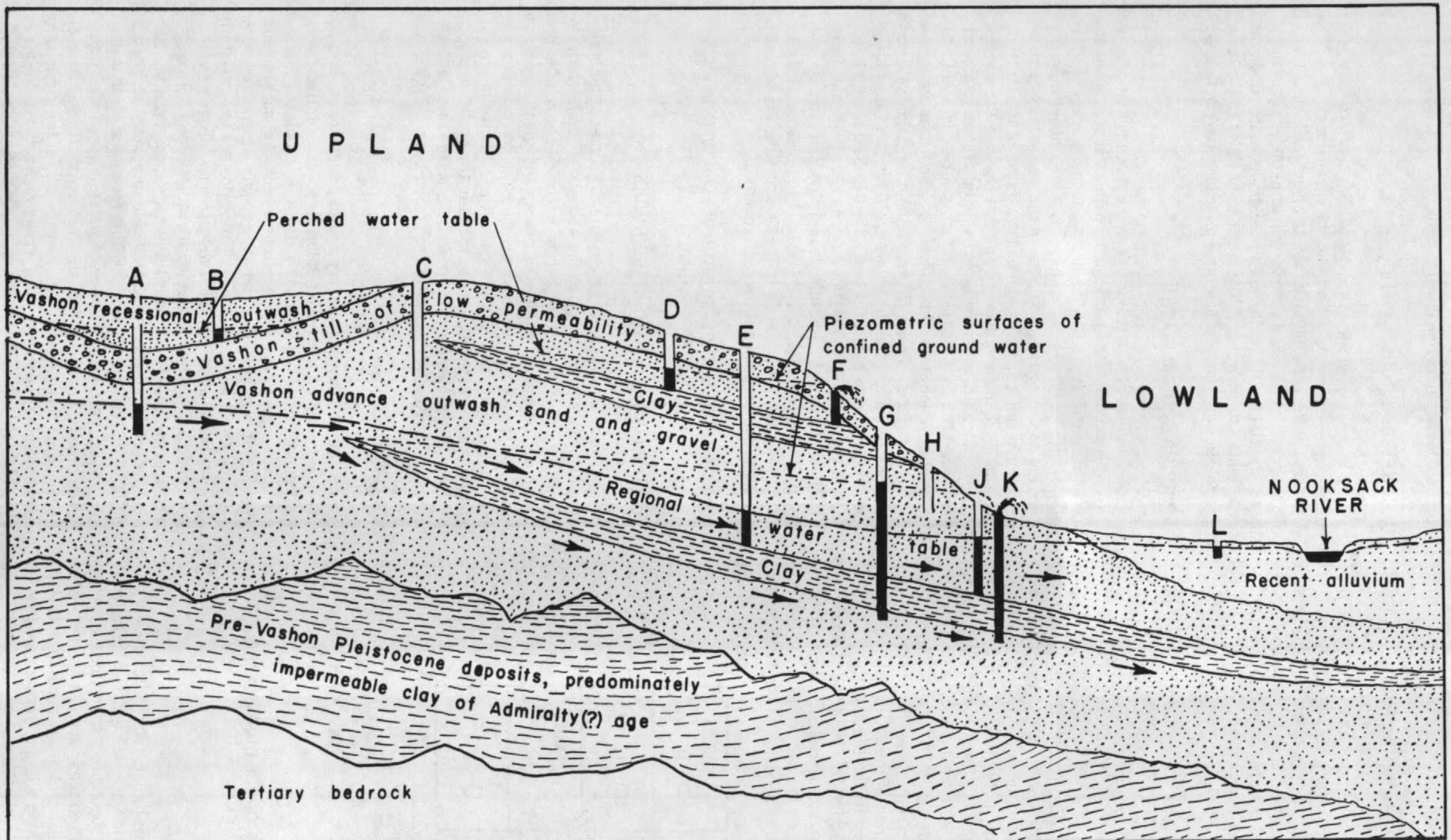


Figure 11. GENERAL CONDITIONS OF GROUND-WATER OCCURRENCE WITHIN THE LOWER NOOKSACK RIVER BASIN.
Vertical scale exaggerated. Arrows indicate direction of ground-water movement.

Well A yields unconfined water from below the regional water table; well B yields perched water from a water body perched on glacial till; at well C water was not encountered owing to insufficient depth; well D yields perched water from water body perched on clay zone; well E yields unconfined water from below the regional water table; well F yields confined perched ground water and flows because land surface is lower than the head developed on the water body as a result of the presence of the till cover; well G yields confined water from water body confined by clay zone; at well H water was not encountered owing to insufficient depth; well J yields unconfined water from below the regional water table: well K yields confined ground water and flows because the land surface is below the piezometric surface; and well L yields unconfined ground water from alluvial materials lying below the regional water table adjacent to the river.

by percolating fresh water could be expected to be most vigorous. Of those wells on the lower ground obtaining water from the Tertiary rocks, essentially all produce saline or mineral-charged water. Investigated reports of large flows or large potential yields from these rocks, such as rumors originating in oil test drilling, all proved to be unfounded.

QUATERNARY DEPOSITS

As will be noted in plate 2, the major water-bearing materials found within the Nooksack River basin are the river and glacier-deposited silts, sands, and gravels of Quaternary age. These materials are among those deposited inthe following sequence: (1) Pre-Vashon Pleistocene deposits, predominately river-laid silts, sands, and gravels (and including lower clay members of possibly Admiralty age) which preceded the advance of the large ice sheet from the north; (2) Vashon advance outwash, or silts, sands, and gravels laid down by streams issuing from the front of the advancing ice sheet; (3) Vashon till, or the hard, compacted, and relatively impervious layer of unsorted sands, clays, and gravels laid down beneath the advancing ice mass; (4) Vashon recessional outwash, or the water-laid sands, silts, clays, and gravels deposited by streams issuing from the melting and retreating ice front; and (5) Recent alluvium, or the sands, clays, and silts deposited along the flood plain by the present-day streams and rivers of the Nooksack River basin. The foregoing deposits are discussed separately below.

Pre-Vashon Pleistocene Deposits.

Beneath the Mountain View Upland fresh ground water has been obtained from sand and gravel layers in stratified deposits. These deposits probably do not crop out at the surface. Well logs show this material to form the core of the upland, lying beneath the Vashon advance outwash and Vashon till "hardpan" which caps the upland. Separation from the overlying Vashon advance deposits is frequently difficult, since both are composed of similar sedimentary materials. Data obtained for deeper wells from drillers' logs show frequently a sticky blue clay and compact silt layer or "hardpan" lying beneath the Vashon advance deposits which have served to mark the upper members of the pre-Vashon glacial deposits. Some observers have related the blue clay to that of the pre-Vashon, Admiralty drift, material. The pre-Vashon sediments extend downward to the underlying consolidated Tertiary sediments. The water is largely unconfined and occurs in a body whose upper surface has the shape of a broad dome with local high "mounds" (see water table contours on pl. 3). The water-bearing sand and gravel beds of this formation are thin and wells penetrating these materials are of low average yield.

In the Boundary Upland these deeper Quaternary materials are known only from the log of one well (40/1E-4J1) east of Blaine. The large amount of gravel reported for this well may be deceptive since the rotary drilling methods used have frequently given inaccurate records on gravel content elsewhere in the Puget Sound area.

Water encountered in these Pleistocene strata is generally fresh except along the west side of the Mountain View Upland, where considerable saline water has been found. Owing to the capping of impervious Vashon till and upper clay layers, little water can recharge these aquifers beneath the upland by downward percolation from the surface, although some ground-water recharge must so occur, probably through lateral seepage from areas where the till capping is either thin or absent.

The strata beneath the Mountain View Upland has been thoroughly tested and yields found to be low, but those beneath the Boundary and Birch Point Uplands remain largely untested to date.

Vashon Advance Outwash.

Immediately beneath the till capping the Boundary Upland is a thick zone of clean, water-washed, irregularly bedded gravel and coarse sand that crops out around the steep slopes southeast of Blaine. Similar gravel zones are encountered beneath the till in the northeast side of Mountain View Upland, in the area northward from King Mountain to Laurel, and in the small hilly area just west of Sumas. These deposits are advance outwash of the Vashon glacier. Except for a few isolated clay deposits within this material, porous and permeable clean sands and gravels predominate and, below the local water table, they carry large volumes of ground water. Yields of 200 to 400 gallons per minute from 10 to 12-inch cased wells are common in these areas. The evident sources of recharge water for these aquifers is precipitation on the upland above, the water entering the sand and gravel where the till capping is thin or absent. The ground water in these areas has established natural gradients toward points of exit. Larabee Springs (39/2-36D1) and Crystal Springs, half a mile to the north, are natural discharge points for the advance outwash aquifer near the base of the north slope of King Mountain Upland. The city of Sumas springs (41/4-33H1) probably are supplied in part by the gravel aquifer beneath the till. Springs at 40/1-11F1 and 40/2-8N1 and numerous creek sources drain the advance outwash beneath the south slopes of the Boundary Upland, and several small springs probably drain the equivalent zone on the northeast slopes of the Mountain View Upland. The gradient of the water table toward Larabee Spring is but 5 feet or so per mile, and the substantial discharge of the spring is indicative of the high permeability of these advance outwash sands and gravels.

In some places (such as at well 39/1-26B1) this advance outwash gravel lies above the water table; in other places it is penetrated far below the local water table in such a position that the overlying till cap serves as a confining layer and flowing artesian wells are obtained (41/1-31Q1 and 39/2-30K1). These advance outwash gravels and sands are widely used sources of ground-water supply for people living on the lower parts of the upland areas and are among the most satisfactory sources so far developed in the Nooksack River basin.

Vashon Till.

The till or "hardpan" deposited by the Vashon ice mass is largely impermeable and causes much of the precipitation to run off or to be captured as perched water in small local depressions where the till is overlain by permeable surficial sediments. However, occasional sand and gravel streaks within the till provide small supplies of ground water for domestic and stock purposes, and in many upland areas are the most common sources for rural domestic supply. In places these gravel and sand streaks within the till afford a year-round domestic supply, but the great majority of these wells dug into the till run dry in the summer. Sometimes deepening of an inadequate well affords more storage space and occasionally opens up gravel and sand streaks that let in more water, but in some cases well deepening results in perforation of the till capping and loss of water into lower pervious materials.

The Vashon till caps the uplands already mentioned, also the Lummi Peninsula, the northern half of Lummi Island, and the greater part of Point Roberts. Varying thicknesses of till and associated glacial deposits also fill depressions and mantle slopes of the Cascade foothills; since these are usually well dissected by erosion and drained of ground water by lateral percolation to lower areas and occur in heavily forested or recently logged off uninhabited portions of the watershed, these deposits are of little value as sources of water supply.

Vashon Recessional Outwash.

The greater portion of the Whatcom Basin, from the Cascade foothills westward, and excluding the till-capped upland areas already mentioned, is covered by sands, silts, and gravels deposited by outwash streams of the retreating Vashon glacier. This material forms the Lynden Terrace and Custer Trough, lines the Nooksack River floodplain, and extends far up the three principal tributary valleys of the Nooksack River as primarily valley fill material.

This outwash carries unconfined ground water at rather shallow depth. Much of the area has an insufficient slope for good drainage and in many localities the ground water stands at drainage-ditch level. In the higher area, extending from north of Lynden toward Sumas, the outwash is generally coarser-grained and composed largely of sand and gravel, as compared to the clay, silt, and sand along the Nooksack valley below Ferndale and to similar materials in the Custer Trough and Sumas valley. Much of the ground water of the outwash terraces flows from springs along the river escarpment or is now led off by drainage ditches. In many places water levels in wells show a harmonious rise and fall with the rainfall cycle and with the level of marginal drainage creeks.

Wells obtain large yields when properly constructed in these recessional outwash materials, but many of the present developments are shallow driven, drilled, or dug wells barely penetrating the water table. However, it is from the dug wells in the recessional outwash materials that the major groundwater supplies are obtained for irrigation in the Whatcom Basin.

Some wells tapping recessional outwash materials yield water high in iron content which must be treated to make it satisfactory for household domestic use. Beneath much of the lower part of the outwash-terrace area, deeply drilled wells have encountered saline ground water and some wells flow at land surface. Notable among these is the Kenneth Vander-Griend well (40/3-28M1). Drilled to a depth of 375 feet in 1910, the well originally flowed 50 to 60 gallons per minute before partial plugging reduced the flow to the present 3 gallons per minute. Chemical analysis of this well discloses a chloride content of approximately 4,500 parts per million and a hardness of 1,500 parts per million (tab. 39). It is quite probable that this recessional outwash material was deposited into sea water which then stood 50 to 60 feet above present sea level, resulting in saline water being trapped at depth and not being entirely flushed out by later fresh ground-water movement.

Recent Alluvium.

Along the present flood plain of the Nooksack River and the broad trough occupied by the Sumas River, the recessional outwash materials have been cut to a newer, lower level, over which the present rivers spread during flood periods and have lain down thin deposits of Recent alluvium. These clays, silts, and sands are saturated with water to about river level, the unconfined ground-water level here fluctuating with the rise and fall of the river and with seasonal rainfall cycles. During the winter and spring, the ground water table adjacent to the river drops slightly toward the river and intersects the river level, while during the dry summer months, the water table may occasionally drop slightly away from the river, with river water seeping laterally to charge the adjacent ground-water reservoirs. Ground water from the alluvium is developed for domestic and industrial supplies by shallow driven, drilled, and dug wells. Much of the water contains an excessive amount of iron, and gaseous odors are present in some well water. Zones of iron-rich water seem to occur along the Nooksack River flood plain between Lynden and Deming. The fineness of the material probably accounts for the slow movement and consequent oxidation of the ferrous materials within these sediments.

THE WATER TABLE

The regional water table in the Nooksack River basin is shown in plate 3. The contour lines show the general shape and elevation above sea level of the water table. The elevations were derived from water-level information on wells located throughout the report area. Unfortunately, well development in some upland areas was too sparse to supply data necessary for inclusion of these within the contoured area.

WHATCOM BASIN AREA

As the map shows, the general configuration of the water table approximates the land surface, with the water table higher in the upland areas, particularly noticeable in the Mountain View Upland, where local low "mounds" occur beneath points of surface recharge. In terrace lands, such as those north of Lynden, the water table lies near the surface and slopes toward the streams and drainage ditches or toward springs or lateral escarpments. The lowest level of the regional water table is commonly along the major streams, with the water table beneath the Nooksack River flood plain being in general balance with the river into which the ground water escapes by effluent seepage. The water table slopes toward the stream and downstream in conformity with stream gradient. In the large trough followed northward by the Sumas River the regional water table slopes northward toward the Fraser River in British Columbia. Local depressions of the water table occur adjacent to the Tenmile and Fourmile Creek watershed, indicating that ground water here is effluent to the creeks.

UPPER NOOKSACK RIVER VALLEYS

The water table in the flat-bottomed lower portions of the three major tributary valleys of the Nooksack River, where highly permeable sands, silts, and gravels occur along the river channel, generally follows the river level. The ground water here is effluent to the rivers and the water table rises slightly as it leaves the river and approaches the steeper valley sides. Since most needs for domestic and stock supplies have been satisfied here by shallow dug wells and driven sandpoints and there has been little demand for irrigation from ground water, very little information has yet been obtained on the water-bearing characteristics of the deeper sediments filling these valleys; however, there is no reason to doubt the water-producing capabilities of these deeper, probably well-saturated zones below river level. Only the Kendall Creek valley appears rather limited in ground-water supply, with most of the few scattered wells penetrating 75 to 125 feet of dry gravels before unconfined ground water is encountered. This valley, owing its origin to a temporary diversion of glacial marginal rivers (Fraser River and/or Nooksack River) and deepened by glacial ice scouring, has today only the annual precipitation and the meager surface flow of Kendall Creek to recharge the ground-water reservoir.

AREAS OF GROUND-WATER RECHARGE

Natural recharge to the ground-water reservoirs in the Nooksack River basin is primarily by direct precipitation and inasmuch as the annual rainfall is moderately heavy (fig. 2), recharge of most aquifers, especially those located within the recessional outwash sands and gravels and Recent alluvium where the permeable zone extends to the ground surface, is in excess of the present rate of withdrawal. In those upland areas capped by Vashon till or extensive impermeable clay layers, ground-water recharge by direct precipitation is less effective and much of the rainfall drains off in surface streams and ditches. The aquifers lying beneath the till must be recharged either by water seeping through occasional permeable sand and gravel beds within the till, or by lateral ground-water movement from areas directly adjoining the till-mantled area. Minor amounts of recharge of aquifers adjacent to major stream channels may occur locally as a result of lateral seepage from the stream itself particularly during the summer months.

The principal areas of ground-water recharge by direct precipitation upon the land surface are those shown in plate 1 as underlain by Vashon recessional outwash and Recent alluvium. These include the broad lowlands of the Whatcom Basin such as the Custer Trough, Sumas Trough, Nooksack Lowland, and Lynden Terrace areas, also the floors of the upper tributary valleys of the Nooksack River.

Areas recharged by small openings in the till capping or by indirect lateral ground-water movement include the Mountain View Upland, the Boundary Upland, the Birch Point Upland, and the King Mountain Upland.

The deeper zones of confined (artesian) ground water are recharged by lateral movement of ground water beneath confining layers from areas of higher elevation. Although no detailed and controlled studies have been made of the direction of movement or rate of flow of these deeper ground waters, some conjecture has been made over the possibility that considerable recharge of the deeper aquifers north of Lynden and beneath the Boundary Upland originates from water percolating through extensive gravel beds lying north of the international boundary.

AREAS OF GROUND-WATER DISCHARGE

Natural discharge of the aquifers in the Nooksack River basin is made by movement either laterally into natural spring zones, lakes, stream and river depressions, or by vertical percolation between aquifers.

As shown by water table contours on plate 3, the regional ground water table is at its lowest elevations along the main channels of the Nooksack River, the Sumas Trough, and the Custer Trough, with minor flextures occuring in the Wiser Lake drainage and the Tenmile Creek-Fourmile Creek drainage. These lows represent the local "base level" for the water table, toward which all ground-water flow is naturally directed by gravity. Where the water table intersects the ground surface, such as in stream headwaters and at spring zones along the lower slopes of the uplands, and along the major stream escarpments, the ground water is discharged and becomes part of the surface-water supply of the basin. Countless springs occur throughout the basin, some representing discharge from unconfined ground water seeping laterally through sands and gravels underlain by impervious strata of till or clay as in spring 39/4-4N1 on the west slopes of Sumas Mountain and the Town of Sumas springs 41/4-33N2 (pl. 2). Others, representing discharge under artesian conditions where an aquifer under a confining stratum intersects the land surface, include Larabee Springs (39/2-36D1) on the north slopes of King Mountain Upland, and springs 40/1-11F1 and 40/2-8N2 on the south slopes of Boundary Upland.

WELL YIELDS

Plate 3 shows generally the distribution of ground-water yields within the report area. The information for determination of well yields was obtained from pump test data supplied by drillers and from pumping information received orally during the well canvass.

AREAS OF HIGH YIELD

The areas of high ground-water yield (200-500 gallons per minute) coincide closely with those areas underlain by Vashon Recessional outwash and Recent alluvium, the broad lowlands and flood plains of the Nooksack Lowland and Sumas Trough. Here the sedimentary materials are highly pervious and are open to recharge by direct precipitation, by lateral seepage from adjacent uplands, and at times from the rivers themselves. These are areas of extensive agricultural development, with available ground water contributing to summer irrigation demands. Recorded water rights (tab. 47) indicate that more land is irrigated from ground water than from surface-water sources in these lowland areas. The greatest withdrawal here is made from shallow dug wells of 36-inch diameter developed in the sands and gravels near the surface, most wells ranging in depth from 10 to 15 feet and with water levels very near the surface. Since yields of 100 to 200 gallons per minute are reported with only 2 to 3 feet of drawdown, it can be assumed that yields in excess of 500 gallons per minute may be obtained from wells designed to permit 5 to 10 feet of available drawdown. Although some areas report high iron content which makes the water unsuitable for domestic use, there appears to be no deficiency in supply for irrigation.

Some areas underlain by Vashon recessional outwash and Recent alluvium supply only moderate quantities (50 to 200 gallons per minute) of ground water. Owing to the fineness of some of the sands, and the inclusion of interbeds of fine silts and clay, some of the lowland areas do not readily yield water in quantity unless the wells are adequately developed and properly screened. As the map shows, areas of moderate yield include the delta lowland of the Nooksack and Lummi Rivers south of Ferndale, the lower portion of the Custer Trough west of Custer, the lower fringes of the bordering upland areas, and the lower portions of the upper three major tributary valleys of the Nooksack River.

AREAS OF LOW YIELD

Areas generally deficient in ground-water supply include the following: (1) Parts of the Mountain View Upland, especially toward the western side; (2) Parts of the Boundary

Upland, notably the higher portion; (3) Birch Point Upland; (4) The King Mountain Upland; (5) Portions of the upper three major tributary valleys of the Nooksack River, including the Kendall Creek valley; (6) Lummi Peninsula; (7) Lummi Island; and (8) Point Roberts.

Mountain View Upland.

On the Mountain View Upland the shallow wells in the till are the chief sources of farmstead domestic supply. These wells frequently go dry in the summer or early fall. Some deeper wells (39/1-29B2) have encountered largely non-water-bearing clayey section beneath the till before entering dry Tertiary bedrock. Tabulation of wells drilled in the western Mountain View Upland shows that ground-water yields are small and water-bearing zones are generally weak, in spite of rumors that large water-bearing zones are encountered at depth in the Standard-Ferndale No. 1 oil test well. The available ground water will sustain domestic needs only, and the conclusion must be drawn that ground water for sustained irrigation or similar uses is not available on the western two-thirds of the upland. Water for irrigation and other uses could possibly be obtained from surface-water sources by developing local lakes and swampy depressions into reservoirs where natural surface water could be stored for irrigation purposes, such storage possibly being supplemented by pumping from the Nooksack River at Ferndale.

Boundary Upland.

The Boundary Upland in its highest portions three miles east of Blaine is an area where ground water may be difficult to obtain, although the situation may be largely due to lack of exploratory drilling beneath the till mantle. Most water in this sparsely populated area comes from shallow wells dug into the till, or from surface runoff reservoirs.

Birch Point Upland.

The Birch Point Upland is also thickly mantled with till. Shallow wells dug into the thin recessional outwash covering the till capture some water for domestic supply but these are unreliable during the summer months. Deeper wells (40/1W-22G1) penetrate 100 to 110 feet of till and hard clay before a thin bed of water-bearing sand is encountered.

King Mountain Upland.

On the north slopes of King Mountain Upland eastward to Squalicum Mountain, the Tertiary bedrock underlies the till, both yielding meager water supplies. Here there is little hope for future development of ground-water supplies, and frequently domestic ground-water supplies must be supplemented by rainfall storage in cisterns during the rainy season, or by development of surface-water sources from springs and small intermittent streams.

Upper Tributary Valleys.

Ground-water supplies in the upper tributary valleys diminishes as the valleys narrow and the bedrock approaches the surface. Coarse gravels and sands adjacent to the major river channels offer the only ground-water supply for local use, with most of the water for domestic and group domestic supplies coming from hillside springs and small reservoirs. The broad valley north of Kendall has a doubtful supply of ground water, generally unconfined but deep beneath the thick gravels filling the valley.

The Lummi Peninsula.

This peninsula was studied in some detail by the U. S. Geological Survey in the spring of 1956 and the following general observations were made at that time.

Vashon recessional outwash sands and gravels mantle the northern end of the upland to depths of 2 to 30 feet, the east and west margins of the peninsula, and scattered areas in the interior of the upland. The greater portion of the upland is underlain near the surface by pebbly clay till to depths of 2 to 75 feet, under which is an undetermined thickness of Vashon advance outwash sands and gravels. The upland is drained by numerous intermittent streams discharging into Lummi Bay on the west and Bellingham Bay on the east. Ground-water supplies are derived either from upper perched aquifers of sands which are thin and discontinuous, and located high on the interior portions of the upland and along the eastern bench extending from Fish Point to Lummi School, or from a lower aquifer beneath the till mantle, from Fish Point south to Portage and near Gooseberry Point and Neptune Beach. Numerous springs also issue along the base of the bench from Fish Point north to Lummi School.

Well yields are generally poor on Lummi Peninsula, averaging 1 to 5 gallons per minute on the upland. The present well withdrawal on the peninsula totals only about 25 acre-feet a year, an average continuous withdrawal of only 15 gallons per minute. Recharge to the upper aquifers is principally by direct precipitation on the land surface, the lower aquifers being supplied by percolation and lateral seepage. The aquifers discharge into springs and swampy areas. Of 22 wells measured on the peninsula, depths ranged from 7 to 22 feet, with water levels averaging less than 5 feet from the surface and with an annual fluctuation averaging 5 to 10 feet.

The most favorable location for development of a ground-water supply on the peninsula is along the beach on the east side (in the sandy bench running from Lummi School south to Fish Point) in 2 to 30 feet of fine- to medium-grained sands having water levels 5 to 20 feet below the land surface. From Fish Point south to Portage a lower aquifer of sand and gravel offers possibilities although wells would have to be extended just below sea level; any deeper penetration may encounter saline water. In the upland portion of the peninsula water must be obtained either from the perched sands or wells must be drilled through the underlying Vashon till to just below sea level.

Lummi Island.

Located off the southern end of Lummi Peninsula, Lummi Island is divided into two geologically different portions. The southern, heavily-forested, mountainous half of the island is composed entirely of pre-Tertiary rocks, primarily greenstones, which are essentially impervious to water. The only water found here lies in occasional local sand and gravel depressions in the bedrock; otherwise water is limited to surface streams and small ponds.

The northern portion of the island is of a more gently rolling topography, dotted by small farms and with seasonal tourist resorts located along the shore bluffs and beaches. From Village Point to Migley Point on the northwest shore, water is obtained principally from wells drilled to sea level in the glacially-deposited sands and gravels, with occasional perched zones supplying water (5 to 15 gallons per minute) to shallow dug wells. Since the Tertiary Chuckanut sandstone lies near the surface in the hilly northern quarter of the island, ground water is sparse except where occasional depressions in the underlying sandstone have been filled by recessional outwash sands and gravels. Occasional springs and marshy areas found on the upper slopes of the north half of Lummi Island indicate the presence of water in these materials. Along the east shore from Migley Point to Sunrise Cove water may be found either in these pervious materials lying above the sandstone, or occasionally in minor amounts within fracture zones in the sandstone bedrock. Along the shore at Legoe Bay, and also at Lummi Point, water is obtained from shallow sandpoint wells near sea level. Tidal fluctuations control the water levels in these wells and occasionally saline water is encountered. A synclinal structural feature was observed in the sandstone lying across the northern portion of the island.1/ Exploratory drilling within this basin may encounter some quantities of water in the bedrock, although the overlying sediments must be considered as the principal aquifers on the island. The uneven erosional surface of the Tertiary sandstone is indicated by the great local variations in thickness of these glacial deposits.

Ground water on the island is limited to domestic and stock supply, with the average yield being but 5 to 10 gallons per minute. According to driller Livermore, the highest producing well on the island is that of F. Granger, in the NE¼SE¼ of Sec. 5, Twp. 37 N., Rge. 1 E., which was tested at 17 gallons per minute at the time of drilling.

Habitation is limited primarily to the shoreline around the north half of Lummi Island, with a few small farms and homesteads located inland. Most of the shoreline homes are occupied during the summer months only, the principal economy of the island being based on the summer tourist trade and offshore fisheries recources. Some speculation is being made on development of view property on the mountainous south half of the island, depending upon approval and construction of a proposed bridge linking the island to the mainland. Presumably here the water supply will come from development of surface springs and streams which reportedly flow the year around.

Point Roberts.

Point Roberts, as referred to in this report, is about 2 miles long and 2½ miles wide and includes the entire American portion of the peninsular extension of the Fraser River delta across the international boundary. Primarily of summer resort economy, with a summertime population of 500 to 600 families as compared to a winter population of 75 to 100 families, Point Roberts is reached from Blaine by road through British Columbia.

The highest elevation of Point Roberts is 235 feet above sea level and is located in the east central portion of the upland area. From here the land surface drops rapidly to the east and northeast where a steep, eroded sea bluff of bedded clean sands rises 100 to 200 feet above Boundary Bay. To the west and southwest of the upland the land slopes more gradually, the southwest half mile of Point Roberts being only slightly above sea level. Along the north mile of the west shoreline a bluff rises 100 to 140 feet above the Georgia Strait.

Owing to the problem of limited community water supply, Whatcom County Water District No. 4 initiated ground-water studies here through the services of Howard J. Harstad and Associates, consulting engineers, and Richard J. Rongey, engineering geologist. These preliminary studies, made from a well canvass of the area and electric resistivity tests, presented the following general geologic information.

In the upland areas, Point Roberts is for the most part mantled by 5 to 20 feet of Vashon till and some gravel, under which is an extensive layer of bedded sands and silts. The sand varies from medium to fine and the silt is very fine, approaching clay in appearance. These layers of sands and clays are generally uniform and almost horizontal, with a slight slope generally to the southwest. The ground-water supply is essentially limited to the following aquifers: (1) Perched ground water lying in gravel pockets on top of the till mantle; (2) An aquifer composed of pervious sand layers beneath the till and above a generally impervious hard silt layer at or near sea level; and (3) A shallow aquifer in the dune sands along the west shore of the southwest point.

As a result of these studies, three wells were drilled by the Harold O. Meyer Drilling Company, two of these being located on the highest upland area, within the W½NE¼ of Sec. 2, Twp. 40 N., Rge. 3 W., a third being located near South Beach, in the SW¼SW¼ of Sec. 2. Of these wells, the two on the upland produced 40 gallons per minute and 85 gallons per minute respectively, both obtaining water from the lower aquifer, with the water table being about 80 feet above sea level. The driller's log gives the following information: till: 0-22 feet; sand, gravel, and clay: 22-110 feet; coarse water-bearing sand: 130-136 feet. One of these two wells was drilled to 433 feet, with "hard rock" being reached at 365 feet, and Tertiary sandstone being struck at 388 feet. The well located near South Beach was drilled to a depth of 150 feet and produced about 30 gallons per minute in the initial test. These three wells should provide an adequate supply for the area's present needs, although further drilling or well development may be necessary for full summertime demands.

ESTIMATE OF WATER AVAILABLE FOR FUTURE USE

EXISTING SOURCES

The foregoing discussion of the geologic and hydrologic occurrence of ground water within the report area shows that an abundant supply of ground water exists in most of the lowland areas for all present domestic, agricultural, and industrial needs. Although treatment of iron-bearing waters is necessary for household and industrial uses in a few areas, there appears to be no lack in quantity of water for all purposes and there are no indications that future demands cannot be met for some time to come. As may be seen in figure 12, hydrographs of several observation wells show that over many years natural recharge exceeds annual withdrawals, and no decline has been noticed in the general level of the water table.

In other areas, however, notably in the uplands underlain by till, the water supply for present demands has been insufficient and some hardship has been experienced during the summer months when shallow domestic and stock-supply wells go dry. Drilling for the deeper aquifers is expensive for single household domestic supply, and in many cases local water associations have been formed among neighborhood groups for the purpose of distributing the cost of drilling deep community supply wells. In these upland areas, development of future residential areas will depend largely upon the availability of water, either through the extension of water mains

1/ Ibid., p. 136.

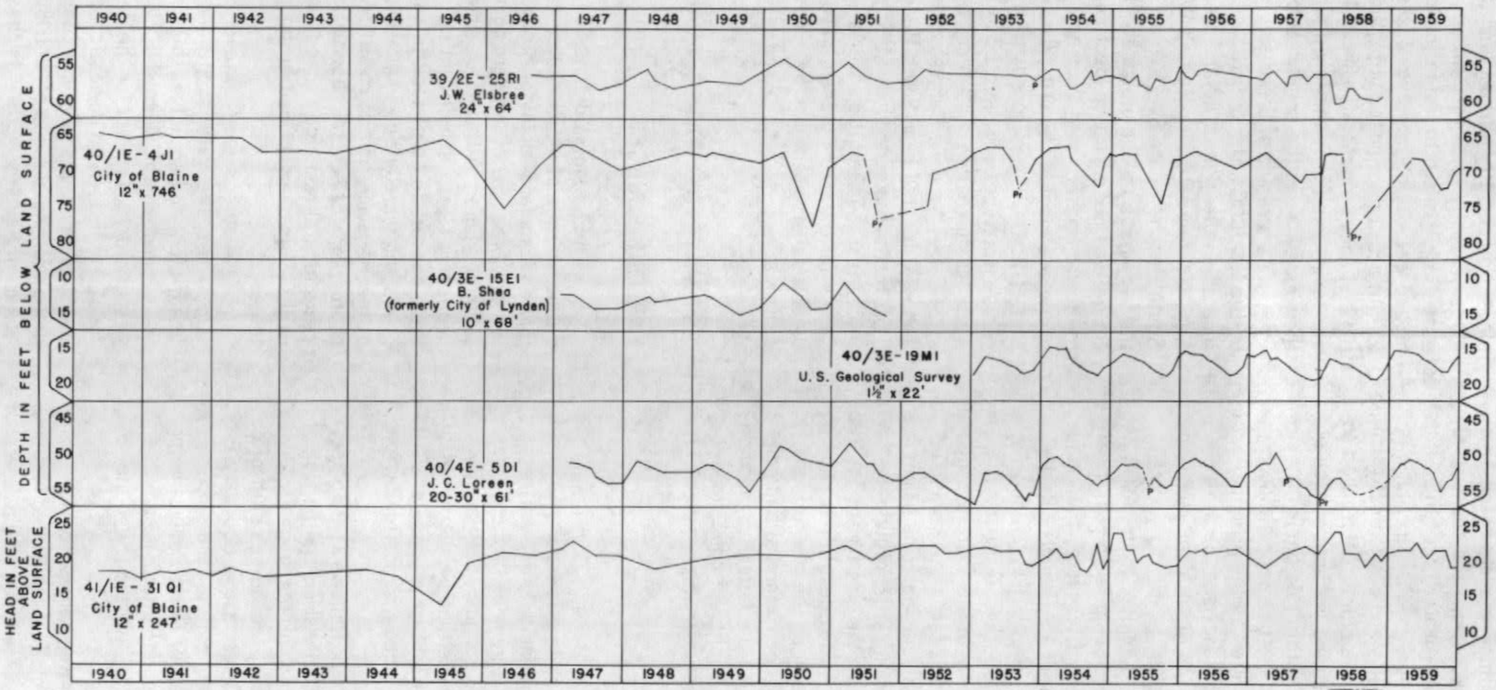


Figure 12. WATER LEVEL FLUCTUATIONS IN OBSERVATION WELLS, LOWER NOOKSACK RIVER BASIN.

from wells now tapping high-producing aquifers, or by deepening and further developing the pumping facilities of wells now barely penetrating the water-bearing materials.

ARTIFICIAL RECHARGE

To date the only artificial recharge within the Nooksack River basin has been through downward percolation of waters incidental to irrigation. However, should future water requirements necessitate artificial recharge of underground reservoirs, it may be worth noting here those areas that may be suitable.

The till-mantled upland areas, because of geologic limitations and topographic expression, do not lend themselves to artificial recharge except on a very local basis where small amounts of water may be added to closed basins supporting perched water bodies. Most of the uplands lack adequate sources of water for recharge purposes.

The ground-water reservoirs most suitable for recharge are those which have a basin-like structure, wherein water may be added without immediately draining off to bordering spring zones and river or lake escarpments. Along the Nooksack River lowland, the sand and gravel aquifers in the Recent alluvium and Vashon recessional outwash may be adaptable to recharge at times when excessive pumping or summer drought conditions cause the water table to fall below the river level. Under these circumstances, it would be conceivable to conduct water spreading operations by ditch or pipeline from the river to adjacent areas underlain by permeable, water-receptive sands and gravels.

SURFACE-WATER RESOURCES

INTRODUCTION

Although ground water represents by far the more abundant source of fresh water on earth, in the past man has gone primarily to the rivers, lakes, and streams to take care of his major needs. It has been estimated that 75 percent of all municipal and irrigation supplies, 90 percent of all industrial supplies, and virtually all of the water to generate hydroelectric power comes from the surface waters of our nation. It is quite evident from this that surface waters represent one of our most valuable water resources, and it is, therefore, imperative that they be developed in the most beneficial manner possible. This objective cannot be accomplished unless the extent and nature of this resource is first adequately determined. In the following pages, surface waters in the Nooksack River basin and certain adjacent small streams are inventoried and analyzed with this purpose in mind.

STREAMFLOW CHARACTERISTICS

Contrary to general belief, streamflow is a variable and continuously changing phenomenon. The variations are a direct result of many complex meteorological, physiographic, and geologic factors within a watershed and can best be shown by means of a streamflow hydrograph. Hydrographs of various streams in the Nooksack River basin are presented in figures 13 through 16 and provide good illustrations of this instability.

The fluctuations depicted by a hydrograph can usually be attributed to three rather distinct types of runoff. These are: direct runoff or water that drains from the land immediately after a storm; sub-surface storm runoff in which water is diverted to the stream before penetrating to the regional water table; and ground-water runoff which is a constant contributor as long as the water table slopes down toward the stream and remains in contact with its bed. Although ground-water runoff is usually more continuous throughout a year, the major portion of annual runoff produced by most streams is derived from direct runoff of rainfall and snowmelt.

Flow from direct runoff causes the sharp, abrupt flood peaks on a hydrograph. As storm or snowmelt waters reach a stream, the discharge past a gaging station increases rapidly until a maximum is reached. The flow then drops off and recedes at a progressively slower rate until all direct runoff has been drained from the land. At this time ground water and subsurface storm runoff are the only contributors, and a distinct decrease is noticed in the recession rate. After sub-surface storm runoff subsides, the rate of recession is again reduced and ground water becomes the sole contributor. In general, this process is repeated after every storm, but if natural or artificial storage exists in a basin, the individual contributors may become obscure and the shape of a hydrograph may change considerably as varying quantities of water are alternately accumulated and released throughout a year.

Provided no rain occurs and there are no tributary springs in a basin, streamflow will cease when the water table recedes below the channel bed. Streams that exhibit this characteristic are fairly common in the Nooksack River area and are described as being intermittent. Most of the streams are perennial and flow through the year, while a few in high mountain areas have no baseflow at all and carry surface runoff only. These latter "ephemeral" streams flow only when there is sufficient precipitation or snowmelt to produce runoff.

In addition to the individual fluctuations produced by storms, all three of the above stream types are subject to pronounced seasonal, annual, and long-term variations. Figures 23, 27, 31, 35, 39, 43, and 47 illustrate by means of bar graphs the monthly range in flows that have occurred in several streams in the report area. For example, the graph of the South Fork near Wickersham shows monthly runoff for December as small as 30,740 acre-feet (1952) and as large as 135,300 acre-feet (1934), which is a ratio of maximum to minimum of about 4 to 1. The ratio of maximum to minimum monthly runoff for August for this same record is about 6 to 1. These large differences are not unusual for most streams in this area and other similar comparisons would probably show even greater variations. Another type of stream variation with respect to time may be seen in figure 20, which shows by graphic representation the annual discharge for the South Fork of the Nooksack River over its entire 26-year period of record. Here it is found that the annual runoff varies from 67 percent of the average in 1944 to 126 percent in 1950. As brought out in the chapter on climate, there are indications that precipitation and streamflow vary in cycles over long periods of time. This type of variation along with annual variations, as they apply to the Nooksack area, will be discussed further in the section on streamflow analysis.

Despite the many unpredictable fluctuations in discharge, each stream will ordinarily exhibit its own consistent flow pattern from one year to the next. These patterns or trends for the most part are controlled by seasonal variations in precipitation and storage characteristics within the watershed. On some watersheds almost all precipitation runs off immediately after a storm, while on others it may be stored for months and even years in the form of snow and perennial ice. Storage in marshes, lakes, and reservoirs also influences the flow and provides regulation in many areas.

In the Nooksack River region there are three rather distinct regimes of streamflow caused by various combinations of the above factors in conjunction with other differences in environments. For example, streams which head at the glaciers of Mt. Baker and adjacent peaks have a characteristic high-water period early each summer, a well-sustained flow during late summer and early fall, and a low-water period during winter. The high-water period in spring and early summer represents water coming out of storage in the form of snowmelt from large packs accumulated during winter months. The sustained late summer flow is maintained for the most part by melt water from glaciers and high snow fields, while the low period during winter is the result of freezing temperatures which prevent accumulating snows from melting and running off. This runoff pattern is well expressed by the bar graph showing monthly

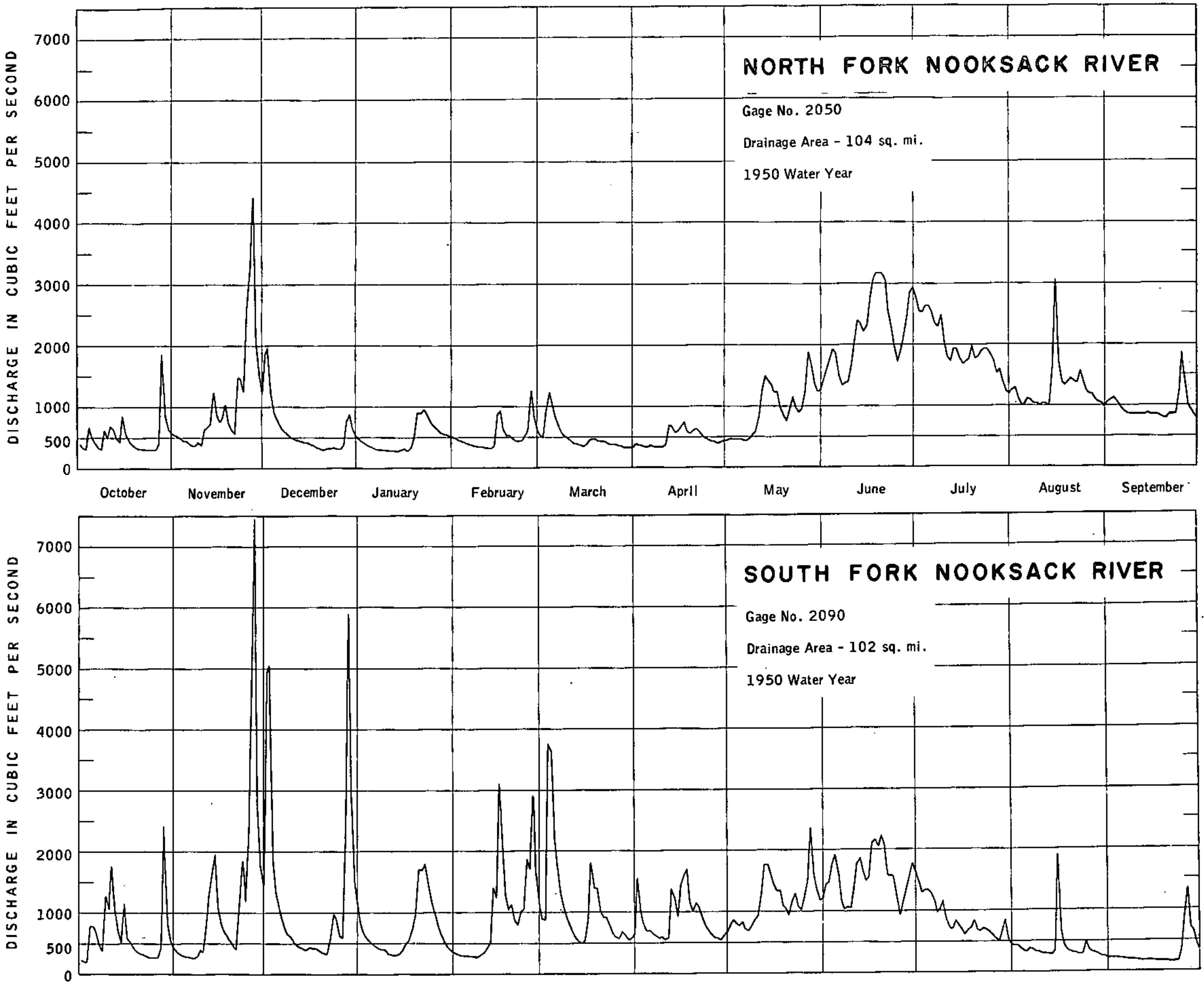


Figure 13. Streamflow Hydrographs of North Fork and South Fork Nooksack River.

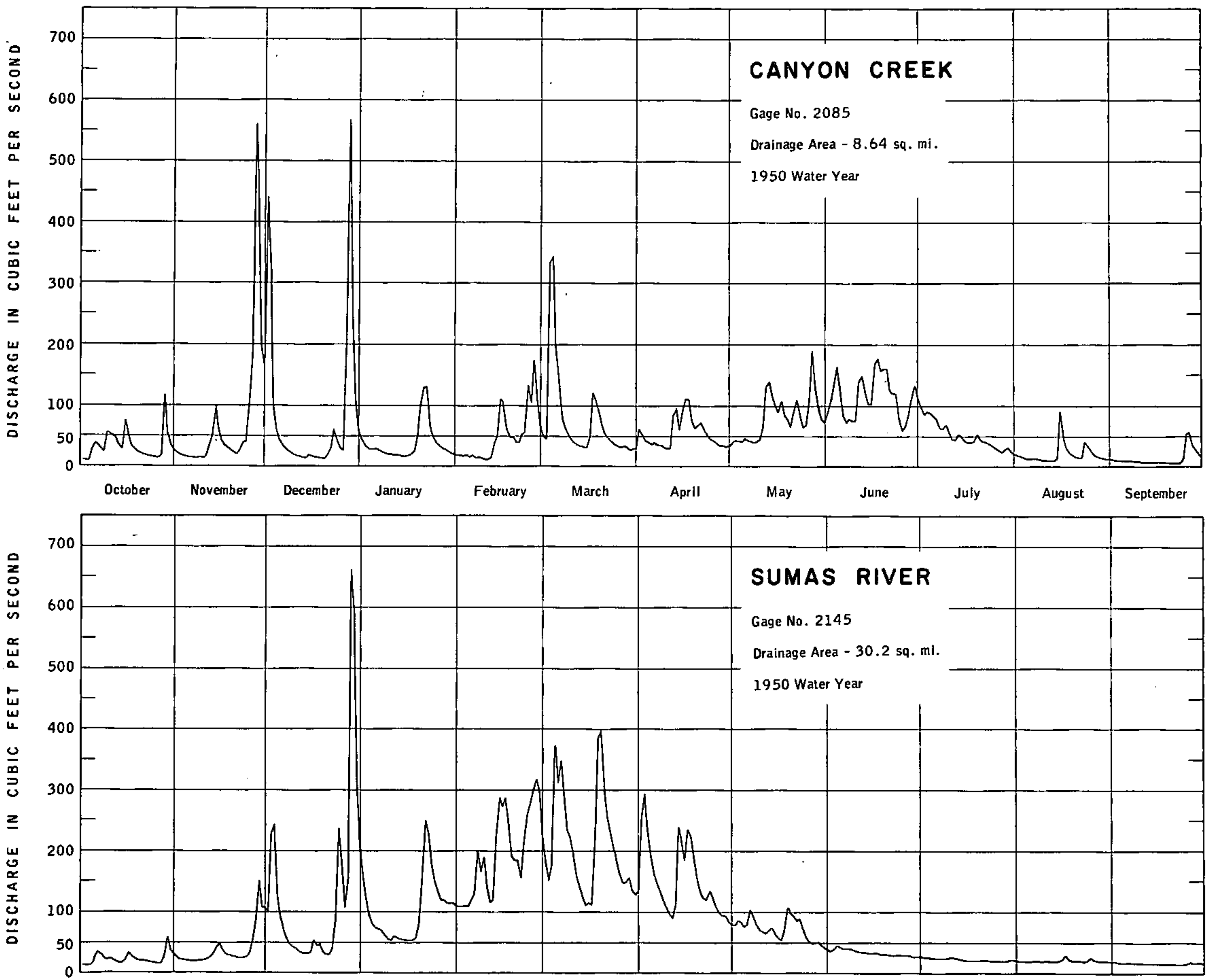


Figure 14. Streamflow Hydrographs of Canyon Creek and Sumas River.

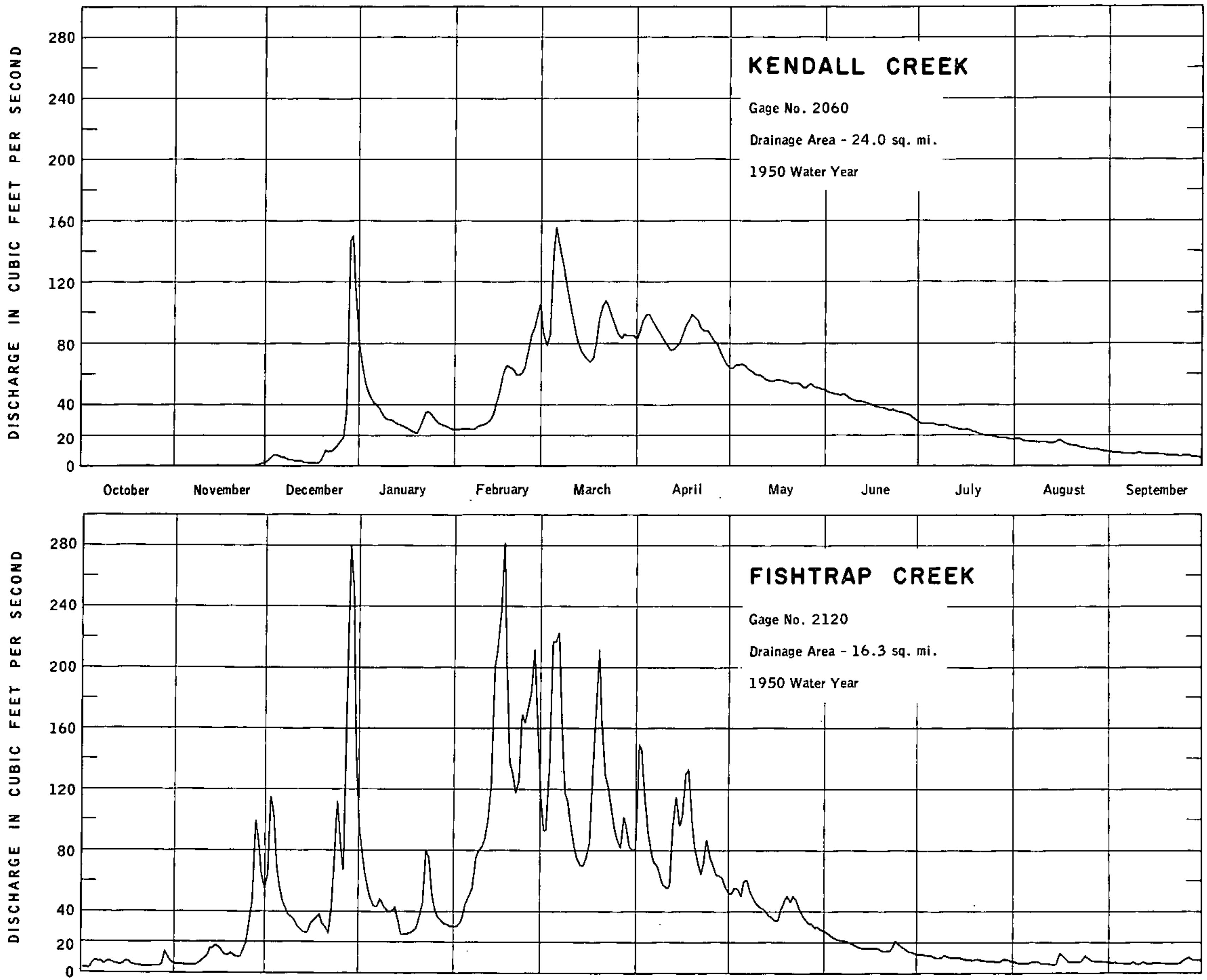


Figure 15. Streamflow Hydrographs of Kendall and Fishtrap Creeks.

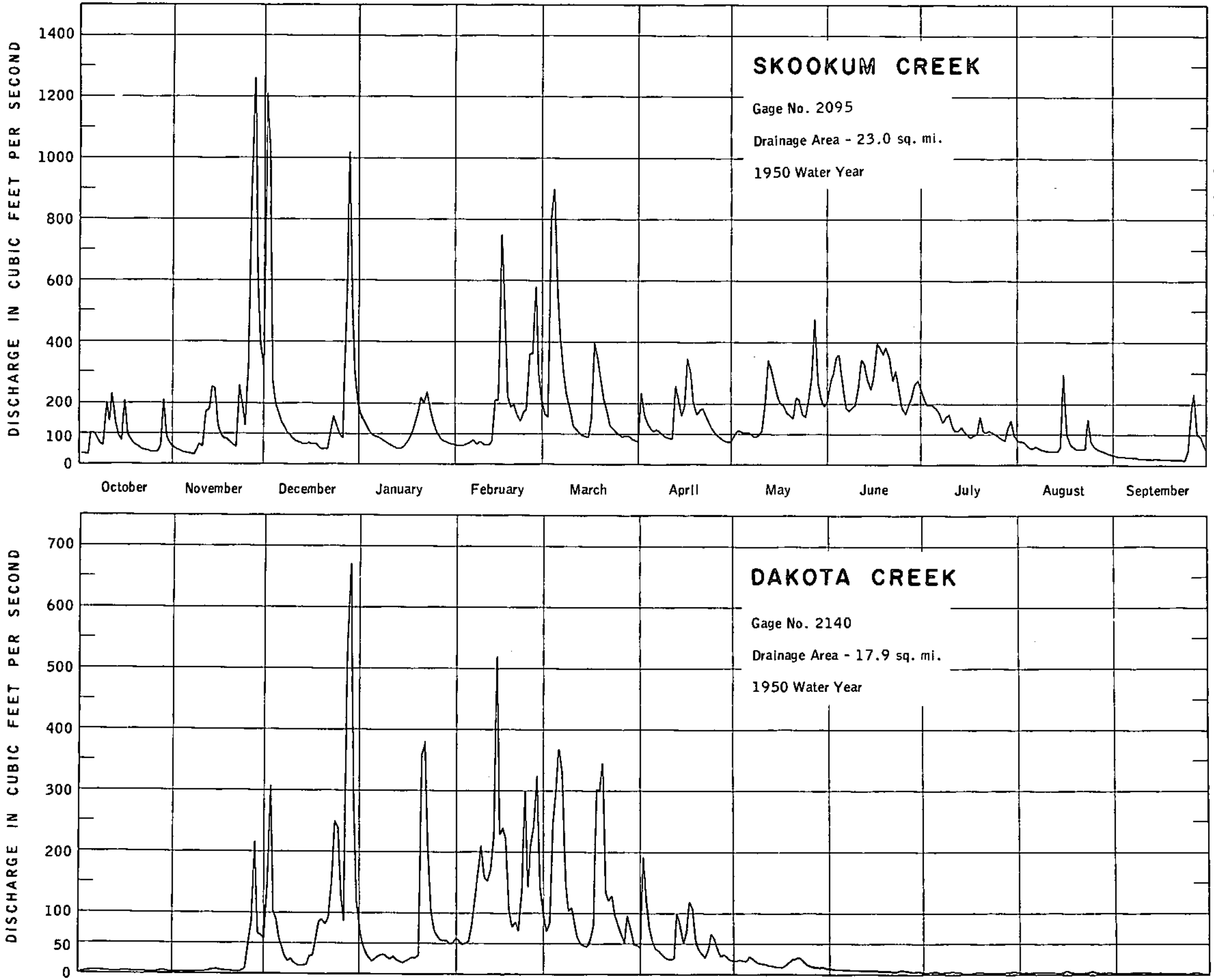


Figure 16. Streamflow Hydrographs of Skookum and Dakota Creeks.

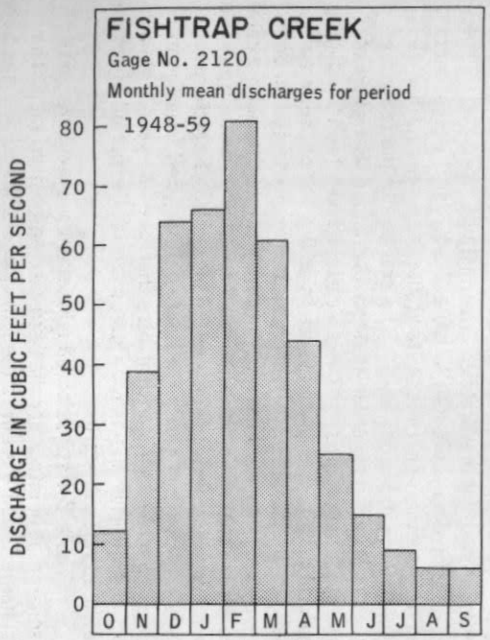


Figure 17.

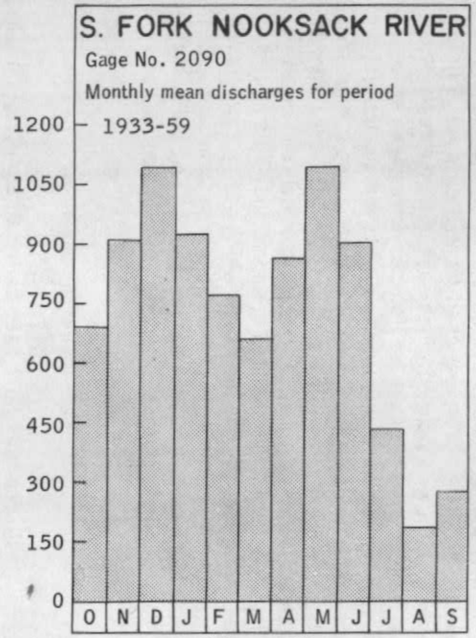


Figure 18.

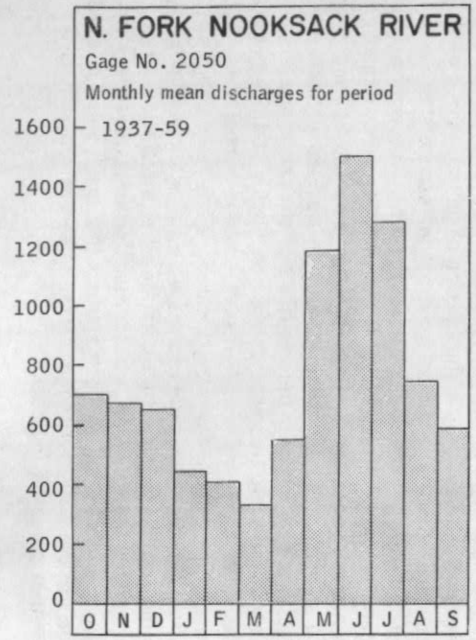


Figure 19.

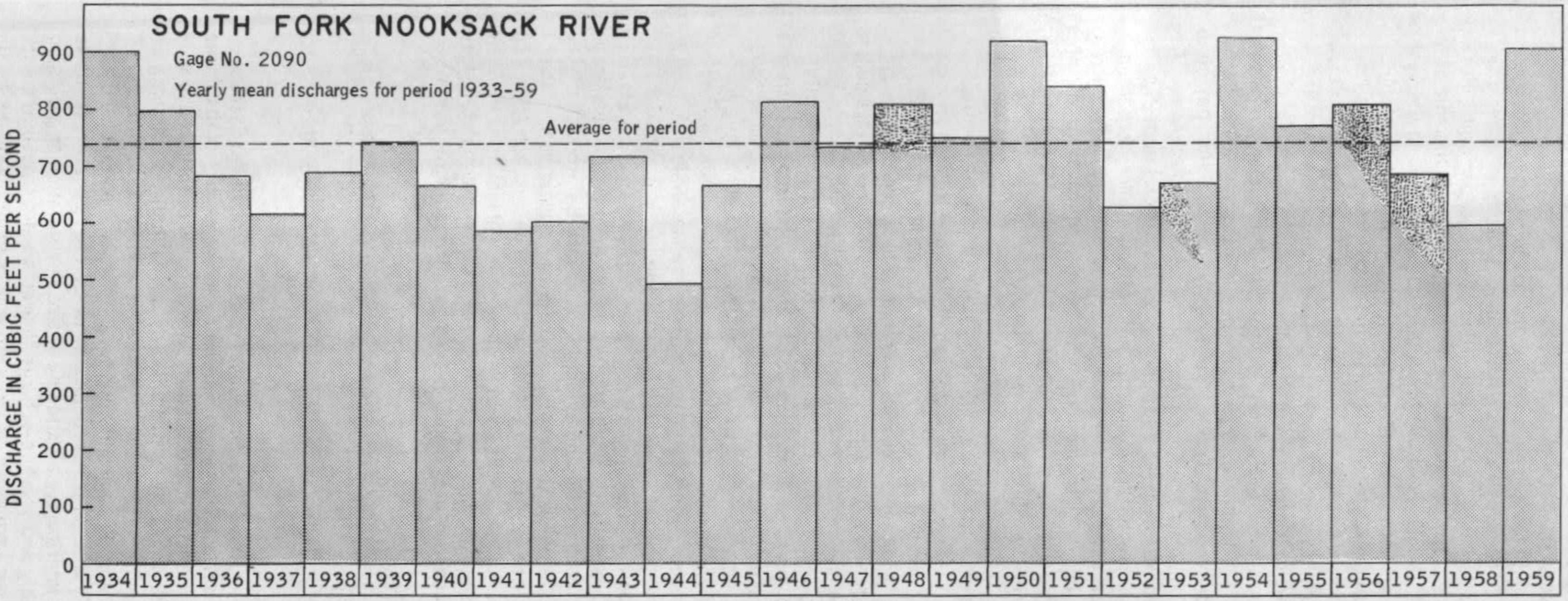


Figure 20.

mean discharges of the North Fork of the Nooksack River below Cascade Creek (fig. 19).

In the second category are streams that originate in mountainous areas where winter precipitation at higher altitudes is largely in the form of snow, and at lower altitudes is rain. In this environment, a large portion of the annual runoff occurs during winter, but is followed later in the year by a second high-water period derived from melting of accumulated winter snows. The low-water period occurs late in summer and early fall because these watersheds lie below the elevation necessary to sustain perennial snow and ice. An illustration of this type of streamflow is shown in figure 18 by the South Fork of the Nooksack River near Wickersham.

The third category includes streams whose basins lie largely at low altitudes. Some winter precipitation may be in the form of snow, but in general the snow is short-lived. Annual runoff of these streams follows the general pattern of annual precipitation with the period of maximum discharges occurring from October to February and then gradually decreasing along with the precipitation trend to minimum flows during August and September. Streams which follow this typical regimen are illustrated by Fishtrap Creek (fig. 17).

Certain generalizations about the characteristics of a watershed can also be made by again studying streamflow hydrographs. If flow increases of various streams are analyzed during a period when runoff occurs immediately after a storm and is not stored or appreciably detained in any way from reaching the stream channel, it will be noted that peaks on the hydrographs vary between those that are extremely sharp and short in duration and those that are rather indistinct and flat. The sharp peaks are characteristic of streams in steep, rugged topography usually underlain by impervious, consolidated rocks, while hydrographs that show only low extended rises are associated with mature topography and permeable, unconsolidated sub-surface materials. A good illustration of the former condition can be seen from the hydrograph of Skookum Creek near Wickersham (fig. 16. This stream displays extremely variable flows and its watershed is characterized by rugged and rocky terrain with a relatively thin soil mantle. A striking example of the latter condition is shown in the Kendall Creek hydrograph (fig. 15). Although this basin contains several low mountains, the major portion adjacent to the main stream is almost completely level and consists of permeable, unconsolidated glacial deposits.

BASIC STREAMFLOW DATA

(By E. G. Bailey, U. S. Geological Survey)

Basic streamflow data consist of records of streamflow collected at gaging stations and the results of discharge measurements made at other sites. The streamflow data collected at gaging stations usually are published as records of daily discharge in cubic feet per second (cfs) ; as monthly discharge in cubic feet per second and in acre-feet; and as yearly discharge. In addition, where the flow at a station is not significantly affected by upstream regulation or diversion, monthly and yearly discharge figures are also given in cubic feet per second per square mile and as depth in inches for the drainage basin. Discharge measurements made at sites other than at gaging stations are made by current meter or by indirect methods that utilize the slope indicated by high-water marks and data on the size, shape, and roughness of channels or of bridge and culvert openings.

Streamflow data have been collected at 23 gaging stations in or adjacent to the Nooksack River basin; many of these stations have only a short period of record. Some of these short-term records were from reconnaissance stations operated early in the development of the area to determine the general pattern of streamflow. Other short-term records, in more recent years, are from gaging stations operated during low-flow summer seasons in conjunction with a series of measurements made to inventory the low flows of streams in the area. A few of the short-term records are from gaging stations that were moved to other sites after a short period of operation showed them to be unfavorably located. Five years or more of continuous daily discharge records were collected at 8 of the gaging stations. Streamflow data for all of the stations are summarized in this report. In addition, continuous records of daily discharge for 7 of these stations that are 5 years or more in length are analyzed and presented in several ways as described in the following pages.

BAR CHART OF GAGING STATION RECORDS

All gaging stations that have been operated in the report area are listed in the bar chart located on page 41, together with the years during which each station was operated. The stations in each basin are listed in downstream order. Thus, proceeding in a downstream direction along the main stem, all stations on a tributary that enter above a main-stem station are listed before that station. If a tributary enters between two main-stem stations, it is listed between them. Tributary streams are indicated by indention. This downstream order and system of indention show which gaging stations are on tributaries between any two stations on a main stem. Each station has been assigned a number that can be used to locate the station on the surface-water maps (pls. 4 and 5).

SUMMARY OF DATA

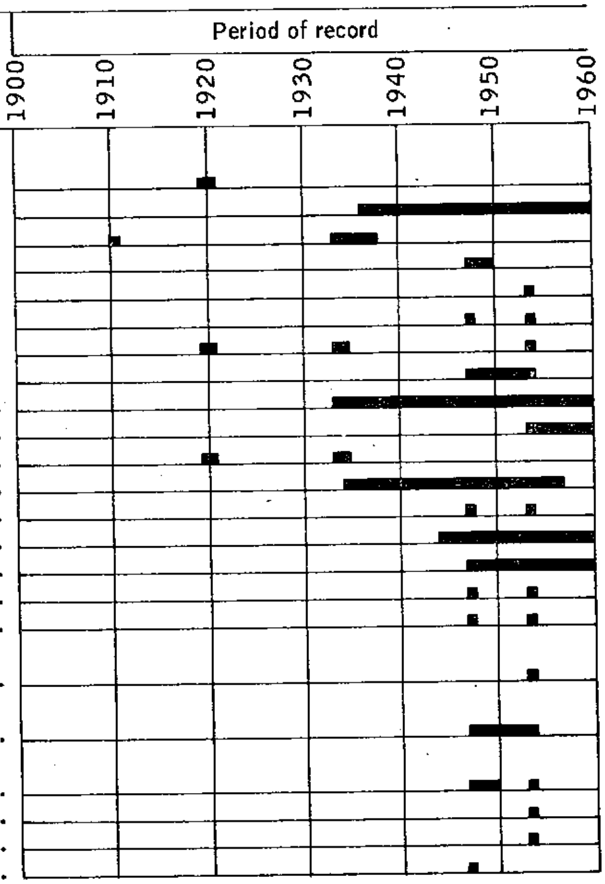
Basic data that have been collected at gaging stations and at miscellaneous discharge measurement points in the report area are summarized in tables 2 and 3. More detailed data for each station will generally be found in water-supply papers published by the U. S. Geological Survey or in bulletins published by the State of Washington.

The data presented in table 2 are, for the most part, self-explanatory; only those items that may need further explanation are described here. The stations in the table are listed in downstream order as described under "Bar chart of gaging station records." The elevation shown for each gaging station is the approximate elevation of the bed of the stream above mean sea level. Discharge data are presented on both annual and seasonal bases. The ratios relate the mean annual and mean seasonal discharges for the period of record to those for a long-term period (see section on "Ratio of discharge," p. 41). Maximum discharge figures are omitted from the extremes columns for records of less than one full year. Maximum and minimum discharge figures are for the period of record indicated at each station.

Table 3 lists selected miscellaneous measurements of discharge at points other than stream-gaging stations. The discharge listed therein is the minimum discharge that has been measured at each site; it is not necessarily the minimum discharge that has occurred in the past or that can be expected to occur in the future. In almost every case, however, each discharge listed approximates the minimum flow at that point during the low-water season in which the measurement was made. When evaluated such measurements are helpful in

Figure 21. BAR CHART OF GAGING STATION RECORDS.

Map no.	Gaging station or stream name
	Nooksack River basin:
2045	Nooksack River at Excelsior
2050	Nooksack River below Cascade Creek, near Glacier
2055	Nooksack River near Glacier
2060	..Kendall Creek at Kendall
2065	..Kendall Creek near mouth, at Kendall
2070	..Coal Creek near Kendall
2080	..Middle Fork Nooksack River near Deming
2085	....Canyon Creek at Kulshan
2090	..South Fork Nooksack near Wickersham
2095	....Skookum Creek near Wickersham
2100	..South Fork Nooksack River at Saxon Bridge
2105	Nooksack River at Deming
2100	..Anderson Creek at Goshen
2115	Nooksack River near Lynden
2120	..Fishtrap Creek at Lynden
2125	..Bertrand Creek near Lynden
2130	..Tenmile Creek near Ferndale
	California Creek basin:
2135	California Creek near Custer
	Dakota Creek basin:
2140	Dakota Creek near Blaine
	Sumas River basin:
2145	Sumas River near Sumas
2150	..Johnson Creek at Sumas
2154	..Saar Creek at Rock Road, near Sumas
2155	..Saar Creek near Sumas



appraising the overall water supply and in determining the potential low flow at the places where they were made. At some sites, several measurements have been made in addition to those reported herein; the results of these additional measurements are contained in the U. S. Geological Survey water-supply papers (WSP) listed in the column headed "Publication."

RATIO OF DISCHARGE

The natural flow of streams varies from day to day and from year to year. Therefore, to evaluate the potential runoff of a stream, the relationship of the known discharge of record to that for a long-term period must be determined. The procedure used to estimate this relationship was to compute the ratio of each annual mean discharge of a long-term record to the average of all the annual mean discharges at the same station. In addition, ratios were computed to show the relation of the seasonal July to September mean discharge of each year to the average of all the seasonal discharges.

The index station used for computing these ratios is South Fork Nooksack River near Wickersham. This station has the longest period of continuous record (water years 1934 to 1959) of any station in the report area. With the possible exception of the glacier-fed streams, the annual and seasonal (July to September) runoff patterns for most streams in the area compare favorably with those for South Fork Nooksack River. Glacier streams usually have runoff characteristics which preclude the application of ratios without adjustment for other factors.

Tables included herein show ratios of both annual discharge and seasonal discharge each year to the average for 1934-59. In each table the ratio figure of 1.00 represents a discharge equal to the average for the base period, 1934-59. For example, the discharge ratio of 1.26 for the water year 1950 means that the discharge for 1950 was 126 percent of the average discharge for the 26-year base period; similarly, the average ratio of 0.88 for the 4-year period 1940-43 means that the average annual discharge for that period was 88 percent of the average discharge for the base period. Ratio figures for years 1910 to 1933 were estimated on the basis of long-term records of streams outside the Nooksack River basin.

The basic streamflow data from 7 of the stations listed in table 2 are summarized and presented in this section to demonstrate the streamflow characteristics and to provide a basis for further study. These gaging stations, each of which has 5 years or more of continuous record, are listed below.

Map no.	Gaging station
2050	Nooksack River below Cascade Creek, near Glacier
2085	Canyon Creek near Kulshan
2090	South Fork Nooksack River near Wickersham
2095	Skookum Creek near Wickersham
2115	Nooksack River near Lynden
2120	Fishtrap Creek at Lynden
2140	Dakota Creek near Blaine

Table 2. Summary of Gaging Station Streamflow Records.

Sta. No.	Name	Location	Drain. Area (sq mi)	Elev. (ft above m.s.l.)	Period of Record	Annual discharge (water year ending			
						Maximum		Minimum	
						Acre-feet	Year	Acre-feet	Year
	NOOKSACK RIVER BASIN								
2045	Nooksack River at Excelsior	Sec.31, T.40N., R.8E., ½ mile downstream from Wells Creek.	95.7	1,320	1920-21	-	-	-	-
2050	Nooksack River below Cascade Creek, near Glacier	NW¼ sec.1, T.39N., R.7E., ¼ mile downstream from Cascade Creek.	104	1,245	1937-	689,200	1950	392,400	1944
2055	Nooksack River near Glacier	NE¼ sec.2, T.39N., R.6E., 600 ft downstream from Canyon Creek.	192	720	1911, 1933-38	1,042,000	1934	709,000	1937
2060	Kendall Creek at Kendall	NW¼ sec.34, T.40N., R.5E., 1½ miles upstream from mouth.	24.0	430	1948-50	25,610	1950	15,720	1949
2065	Kendall Creek near mouth, at Kendall	NE¼ sec.3, T.39N., R.5E., 3/4 mile upstream from mouth.	29.2	410	1954	-	-	-	-
2070	Coal Creek near Kendall	NW¼NW¼ sec.10, T.39N., R.5E., ¼ mile upstream from mouth.	4.7	400	1948, 1954	-	-	-	-
2080	Middle Fork Nooksack River near Deming	NW¼ sec.13, T.38N., R.5E., ¼ mile downstream from Heislers Creek.	72.8	590	1920-21, 1934-35, 1954	481,000	1921	355,100	1935
2085	Canyon Creek at Kulshan	SE¼SE¼ sec.27, T.39N., R.5E., ¼ mile upstream from mouth.	8.64	350	1948-54	45,770	1951	28,180	1952
2090	South Fork Nooksack River near Wickersham	SW¼ sec.26, T.37N., R.5E., 3/4 mile upstream from Skookum Creek.	102	385	1933-	675,300	1954	353,900	1944
2095	Skookum Creek near Wickersham	NE¼ sec.27, T.37N., R.5E., 500 ft upstream from mouth.	23.0	400	1948-	118,800	1954	75,910	1958
2100	South Fork Nooksack River at Saxon Bridge	SE¼ sec.21, T.37N., R.5E., 1½ miles downstream from Skookum Creek.	129	350	1920-21, 1933-34	-	-	-	-
2105	Nooksack River at Deming	Sec. 6, T.38N., R.5E., 800 ft downstream from South Fork.	582	204	1935-57	3,144,000	1954	1,617,000	1944
2110	Anderson Creek at Goshen	E½ sec.19, T.39N., R.4E., ½ mile upstream from mouth.	12.9	145	1948, 1954	-	-	-	-
2115	Nooksack River near Lynden	NE¼NE¼ sec.36, T.40N., R.2E., 1½ miles upstream from Fishtrap Creek.	646	24	1944-	3,308,600	1959	2,099,860	1958
2120	Fishtrap Creek at Lynden	On north line sec.16, T.40N., R.3E., 1 mile north of Lynden.	16.3	110	1948-	37,740	1951	16,110	1958
2125	Bertrand Creek near Lynden	SE¼ sec.27, T.40N., R.2E., 3/4 mile upstream from mouth.	38.5	35	1948, 1954	-	-	-	-
2130	Tenmile Creek near Ferndale	NE¼SW¼ sec.22, T.39N., R.2E., 100 ft downstream from county bridge.	25.8	20	1948, 1954	-	-	-	-
	COASTAL AREA BASINS								
	California Creek Basin								
2135	California Creek near Custer	SE¼SE¼ sec.27, T.40N., R.1E., at Porter Road crossing.	11.0	15	1954	-	-	-	-

September 30)		Seasonal discharge (July to September)						Extremes of discharge			
Mean	Annual ratio	Maximum		Minimum		Mean	Season ratio	Maximum (cfs)	Date	Minimum (cfs)	Date
Acre-feet		Acre-feet	Year	Acre-feet	Year	Acre-feet					
576,000 (1 year)	1.26	-	-	-	-	177,900 (1 season)	1.35	4,650	Oct. 4, 1920	186	Feb. 5-9, 1921
545,900 (22 years)	1.00	253,920	1950	112,210	1958	159,000 (22 seasons)	1.03	10,300	Nov. 26, 1949	73	Feb. 16, 1949
830,900 (5 years)	1.00	315,200	1911	164,620	1936	212,520 (6 seasons)	0.79	9,400	Oct. 28, 1937	130	Oct. 17, 1934
20,660 (2 years)	1.14	2,750	1950	707	1949	1,440 (3 seasons)	1.48	162	Dec. 29, 1949	0	Sept. 10 to Nov. 26, 1949
-	-	-	-	-	-	3,340 (1 season)	2.01	-	-	5.7	Oct. 16, 18, 31, 1954
-	-	1,700	1954	1,280	1948	1,490 (2 seasons)	1.64	-	-	0.7	Aug. 13, 1948
418,000 (2 years)	1.17	109,420	1954	58,690	1935	82,700 (4 seasons)	1.28	-	-	127	Apr. 9, 1935
37,890 (5 years)	1.04	7,130	1954	841	1951	4,240 (7 seasons)	1.27	-	-	1.0	Sept. 15-24, 1951
529,200 (26 years)	1.00	109,590	1954	18,290	1940	54,450 (26 seasons)	1.00	19,300	Nov. 3, 1955	66	Oct. 9, 1940, Sept. 11-13, 1944
97,740 (11 years)	1.06	19,220	1954	6,050	1951	12,970 (12 seasons)	1.23	3,050	Nov. 27 or Dec. 1, 1949	17	Feb. 9, 10, 1949
743,300 (1 year)	1.23	147,000	1933	54,610	1934	104,900 (3 seasons)	1.43	13,100	Feb. 11, 1921	111	Sept. 4, 1934
2,350,000 (22 years)	0.98	670,400	1954	254,160	1940	411,800 (22 seasons)	1.00	43,200	Feb. 10, 1951	502	Nov. 29, 1952
-	-	616	1948	551	1954	584 (2 seasons)	1.64	-	-	0.3	Aug. 1-3, 9-15, 1954
2,698,000 (15 years)	1.05	679,800	1954	321,260	1951	472,580 (15 seasons)	1.16	46,200	Feb. 10, 1951	595	Nov. 30, 1952
25,560 (11 years)	1.06	1,690	1959	589	1958	1,240 (12 seasons)	1.23	550	Feb. 11, 1951	0.4	Sept. 10, 1949
-	-	2,970	1954	2,820	1948	2,900 (2 seasons)	1.64	-	-	7.6	Aug. 12, 1954
-	-	1,530	1948	1,480	1954	1,500 (2 seasons)	1.64	-	-	3.2	Aug. 2, 1954
-	-	-	-	-	-	264 (1 season)	2.01	-	-	0.8	Aug. 10-15, 1954

Table 2. Summary of Gaging Station Streamflow Records. (Continued)

Sta. No.	Name	Location	Drain Area (sq mi)	Elev. (ft above m.s.l.)	Period of Record	Annual discharge (water year ending			
						Maximum		Minimum	
						Acre-feet	Year	Acre-feet	Year
	Dakota Creek Basin								
2140	Dakota Creek near Blaine	NW¼SW¼ sec.14, T.40N., R.1E., 50 ft above county bridge, 3½ miles upstream from mouth.	17.9	20	1948-54	35,900	1950	13,240	1952
	SUMAS RIVER BASIN								
2145	Sumas River near Sumas	NE¼ sec.11, T.40N., R.4E., at road crossing, 1½ miles south of Sumas.	30.2	40	1948-50, 1954	61,020	1950	44,400	1949
2150	Johnson Creek at Sumas	SW¼ sec.35, T.41N., R.4E., 1 mile upstream from mouth.	20.4	35	1954	-	-	-	-
2154	Saar Creek at Rock Road, near Sumas	On north line sec.6, T.40N., R.5E., 3/4 mile upstream from international boundary.	9.43	30	1954	-	-	-	-
2155	Saar Creek near Sumas	E½ sec.31, T.41N., R.5E., ¼ mile upstream from international boundary.	10.0	30	1948	-	-	-	-

September 30)		Seasonal discharge (July to September)						Extremes of discharge			
Mean	Annual ratio	Maximum		Minimum		Mean	Season ratio	Maximum (cfs)	Date	Minimum (cfs)	Date
Acre-feet		Acre-feet	Year	Acre-feet	Year	Acre-feet					
23,000 (5 years)	1.04	630	1948	279	1951	459 (7 seasons)	1.27	669	Dec. 27, 1949	0.1	Aug. 11, 1950, Sept. 22, 1952
52,710 (2 years)	1.14	4,910	1954	3,630	1950	4,220 (4 seasons)	1.62	800	Dec. 28, 1949	13.5	Sept. 27 to Oct. 4, 1949
-	-	-	-	-	-	3,740 (1 season)	2.01	-	-	17	Oct. 3-7, 1954
-	-	-	-	-	-	818 (1 season)	2.01	-	-	0.6	Aug. 12, 1954
-	-	-	-	-	-	864 (1 season)	1.27	-	-	0.9	Aug. 13, 1948

Table 3. Miscellaneous Low Flow Discharge Measurements.

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	NOOKSACK RIVER DRAINAGE BASIN					
NS1	Nooksack River	Sec.32, T.40N., R.8E., at Puget Sound Power and Light Co. gaging station, 1½ miles above Wells Creek.	67.6	767	612	Sept. 13, 1934
NS2	Lookout Creek	SE¼ sec.35, T.40N., R.7E., at Mt. Baker Highway crossing, 4 miles east of Glacier.	1.06	1122, 1346	0.52	Sept. 29, 1954
NS3	Unnamed stream (tributary to Nooksack River)	NW¼ sec.2, T.39N., R.7E., at Mt. Baker Highway crossing, 3½ miles east of Glacier.	0.20	1122, 1346	0.22	Sept. 22, 1948
NS4	Deer Horn Creek	SW¼ sec.34, T.40N., R.7E., at Mt. Baker Highway crossing, 2½ miles east of Glacier.	0.72	1122, 1346	0.34	Sept. 8, 1954
NS5	Coal Creek	SW¼ sec.33, T.40N., R.7E., at Mt. Baker Highway crossing, 2 miles east of Glacier.	0.73	1122, 1346	0.10	Sept. 8, 1954
NS6	Glacier Creek	NE¼ sec.7, T.39N., R.7E., at Mt. Baker Highway crossing, at Glacier.	32.1	512, 1346	111	Sept. 29, 1954
NS7	Gallop Creek	NE¼ sec.7, T.39N., R.7E., at Mt. Baker Highway crossing at Glacier.	2.11	1122, 1346	5.26	Sept. 29, 1954
NS8	Cornell Creek	SE¼ sec.1, T.39N., R.6E., at Mt. Baker Highway crossing, 1 mile west of Glacier.	5.28	1122, 1346	1.54	Sept. 29, 1954
NS9	Canyon Creek	NW¼ sec.35, T.40N., R.6E., 300 ft above mouth and 2 miles northwest of Glacier.	30.9	1122, 1346	87.9	Sept. 29, 1954
NS10	Unnamed stream (tributary to Nooksack River)	NE¼ sec.34, T.40N., R6E., at Mt. Baker Highway crossing, 3 miles northwest of Glacier.	0.70	1122, 1346	0.04	Sept. 9, 1954
NS11	Unnamed stream (tributary to Nooksack River)	SW¼ sec.27, T.40N., R.6E., at Mt. Baker Highway crossing, 4 miles northwest of Glacier.	0.28	1122, 1346	0.48	Sept. 29, 1954
NS12	Unnamed stream (tributary to Nooksack River)	SW¼ sec.27, T.40N., R.6E., at Mt. Baker Highway crossing, 4½ miles northwest of Glacier.	0.25	1122	0.10	Sept. 22, 1948
NS13	Boulder Creek	NW¼SE¼ sec.28, T.40N., R.6E., at Mt. Baker Highway crossing, 2 miles east of Maple Falls.	7.96	1122, 1346	15.8	Sept. 9, 1948
NS14	Maple Creek	South line sec.30, T.40N., R.6E., at Mt. Baker Highway crossing at Maple Falls.	10.1	1122, 1152, 1346	0.79	Aug. 17, 1948
NS15	Unnamed stream (tributary to Kendall Creek)	NW¼ sec.36, T.40N., R.5E., at Mt. Baker Highway crossing, 1¼ miles east of Kendall.	1.27	1122	2.86	Sept. 22, 1948
2065	Kendall Creek	NE¼ sec.3, T.39N., R.5E., at former gaging station, ½ mile above mouth, and 3/4 mile south of Kendall.	29.2	1346, 1566	3.23	Aug. 21, 1958
NS16	Racehorse Creek	N½ sec.10, T.39N., R.5E., at logging road crossing 3½ miles norh of Kulshan.	11.0	1346	8	Sept. 14, 1954
2070	Coal Creek	NW¼NW¼ sec.10, T.39N., R.5E., at former gaging station, ¼ mile above mouth.	4.57	1122, 1346, 1396, 1446, 1566, 1636	0.20	Sept. 8, 1956
NS17	Unnamed stream (tributary to Nooksack River)	NE¼ sec.9, T.39N., R.5E., at Mt. Baker Highway crossing, 2½ miles south of Kendall.	0.23	1122	0	Summer 1948
NS18	Unnamed stream (tributary to Nooksack River)	NW¼ sec.27, T.39N., R.5E., at mouth, 1 mile north of Kulshan.	3.09	1396	53.4	Oct. 6, 1954

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	NOOKSACK RIVER DRAINAGE BASIN (continued)					
NS19	Bells Creek	SE¼ sec.21, T.39N., R.5E., at Mt. Baker Highway crossing, 1½ miles northwest of Kulshan.	4.15	1122, 1152, 1346, 1396, 1446, 1566, 1636	0.20	Sept. 8, 1956
NS20	Nooksack River	West line sec.27, T.39N., R.5E., at highway bridge, ½ mile above Middle Fork, and 1 mile west of Kulshan.	293	1122, 1346	1640	Sept. 15, 1954
NS21	Middle Fork Nooksack River	SW¼ sec.30, T.38N., R.7E., 1/8 mile above Deming ranger station.	24.5	312	212	Oct. 11, 1910
NS22	Middle Fork Nooksack River	NW¼ sec.21, T.38N., R.6E., 100 ft above Clearwater Creek and 6 miles southeast of Kulshan.	46.4	1396	132	Oct. 6, 1954
NS23	Clearwater Creek	NW¼ sec.21, T.38N., R.6E., at mouth, 6 miles southeast of Kulshan.	21.1	1346, 1396	29.8	Oct. 6, 1954
NS24	Falls Creek	N½ sec.20, T.38N., R.6E., at mouth, 5½ miles southeast of Kulshan.	0.75	1396	0.83	Oct. 6, 1954
NS25	Unnamed stream (tributary to Heislers Creek)	W½ sec.13, T.38N., R.5E., at mouth, 4 miles southeast of Kulshan.	0.45	1396	0.24	Oct. 6, 1954
NS26	Heislers Creek	W½ sec.13, T.38N., R.5E., at mouth, 4 miles southeast of Kulshan.	1.70	1346, 1396	0.69	Oct. 6, 1954
NS27	Porter Creek	SE¼ sec.11, T.38N., R.5E., at road crossing 3 miles southeast of Kulshan.	4.23	1346, 1396, 1636	0.59	Sept. 12, 1959
NS28	Unnamed stream (tributary to Middle Fork Nooksack River)	Center of sec.2, T.38N., R.5E., at Mosquito Lake road crossing, 1 3/4 miles southeast of Kulshan.	0.46	1396	0	Oct. 6, 1954
NS29	Unnamed creek (tributary to Middle Fork Nooksack River)	NW¼ sec.35, T.39N., R.5E., at road crossing 1 mile south of Kulshan.	1.21	1396	2.15	Oct. 6, 1954
NS30	Nooksack River	SE¼ sec.6, T.38N., R.5E., at railroad trestle just above South Fork and 1 mile southeast of Deming.	400	1122, 1346	2200	July 23, 1948
NS31	South Fork Nooksack River	Sec.21, T.36N., R.6E., ¼ mile above Lyman Timber Co. railroad bridge.	65.6	752	135	Sept. 10, 1933
NS32	Cavanaugh Creek	NW¼ sec.1, T.36N., R.5E., at logging road crossing 4½ miles east of Wickersham.	9.68	1346	12.4	Sept. 30, 1954
NS33	Unnamed stream (tributary to South Fork Nooksack River)	SE¼ sec.35, T.37N., R.5E., at logging road crossing 4 miles east of Wickersham.	0.58	1346	0	Sept. 30, 1954
NS34	South Fork Nooksack River	Sec.35, T.37N., R.5E., 1,000 ft above Edfro Creek.	100	752	135	Sept. 13, 1933
NS35	Edfro Creek	NE¼ sec.35, T.37N., R.5E., at logging road crossing 4 miles east of Wickersham.	2.18	1346	1.68	Sept. 30, 1954
NS36	Hutchinson Creek	NW¼ sec.2, T.37N., R.5E., at road crossing, 3 miles east of Acme.	10.8	1122, 1346	7.53	Sept. 8, 1954
NS37	Jones Creek	North line sec.7, T.37N., R.5E., at road crossing at Acme.	2.31	1122, 1346	0.01	Sept. 21, 1948
NS38	Unnamed stream (tributary to South Fork Nooksack River)	West line sec.5, T.37N., R.5E., at road crossing ½ mile north of Acme.	1.04	1122, 1152, 1346	2.14	Sept. 21, 1948

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	NOOKSACK RIVER DRAINAGE BASIN (continued)					
NS39	McCarty Creek	NW¼ sec.6, T.37N., R.5E., at road crossing, 3/4 mile northwest of Acme.	1.64	1122, 1346	0.73	Sept. 10, 1954
NS40	Black Slough	NW¼ sec.17, T.38N., R.5E., at road crossing, ½ mile south of VanZandt.	6.94	1122, 1152, 1346	0	Aug., 20, 1949 Sept. 9, 1954
NS41	Nooksack River	Sec.28, T.39N., R.4E., at Nugent's bridge.	594	312, 792	1600	Feb. 14, 1911
NS42	McCauley Creek	W½ sec.26, T.39N., R.4E., at Mt. Baker Highway crossing, 1 mile northwest of Deming.	3.66	1346, 1396	0.62	Oct. 1, 1954
NS43	Smith Creek	West line sec.22, T.39N., R.4E., at highway crossing, ½ mile southeast of Lawrence.	10.3	1346, 1396	0.37	Aug. 19, 1948
NS44	Anderson Creek	SE¼ sec.6, T.38N., R.4E., at Mt. Baker Highway crossing, 3 miles south of Goshen.	7.25	1122, 1152, 1346, 1396 1446, 1636	0.10	Aug. 8, 1956
2110	Anderson Creek	NE¼ sec.19, T.39N., R.4E., at former gaging station at Goshen, ½ mile above mouth.	12.9	1122, 1152, 1346, 1396, 1446, 1636	0.19	Sept. 7, 1956 Aug. 10, 1959
NS45	Kamm Ditch	NW¼ sec.14, T.40N., R.3E., at Lynden-Sumas Road crossing, 2½ miles northeast of Lynden.	0.66	1346, 1396	0.70	Oct. 1, 1954
NS46	Kamm Ditch	Center S½ sec.15, T.40N., R.3E., at road crossing 80 ft north of Milwaukee Railroad tracks, 1½ miles east of Lynden.	2.73	1346, 1396	2.92	Oct. 1, 1954
NS47	Mormon Ditch	N½ sec.22, T.40N., R.3E., at Norwood Road crossing, 1½ miles east of Lynden.	2.30	1346	0.21	Sept. 14, 1954
NS48	Stickney Slough	SE¼ sec.20, T.40N., R.3E., at Lynden, 500 ft above mouth.	7.88	1346	5.81	Sept. 14, 1954
NS49	Scott Ditch	SE¼ sec.29, T.40N., R.3E., at Hannegan Road crossing, 1 mile south of Lynden.	8.03	1122, 1152, 1346, 1396	3.41	Oct. 1, 1954
NS50	Unnamed stream (tributary to Nooksack River)	Center E½ sec.36, T.40N., R.2E., 500 ft west of Meridian Road and 2¼ miles southwest of Lynden.	0.86	1346	0.24	Sept. 14, 1954
NS51	East Branch Double Ditch Creek	NE¼ sec.31, T.41N., R.3E., at international boundary, 4 miles north of Lynden.	*	962, 982, 1122, 1152, 1346, 1396	1.42	Oct. 12, 1942
NS52	East Branch Double Ditch Creek	South line sec.7, T.40N., R.3E., at Blaine-Sumas Road crossing, 1 mile northwest of Lynden.	*	1122, 1346, 1396	2.52	Oct. 1, 1954
NS53	West Branch Double Ditch Creek	NW¼ sec.31, T.41N., R.3E., at international boundary, 4 miles north of Lynden.	*	962, 982, 1122, 1152, 1346, 1396	3.05	Aug. 23, 1955
NS54	West Branch Double Ditch Creek	South line sec.7, T.40N., R.3E., at Blaine-Sumas Road crossing, 1 mile northwest of Lynden.	*	1122, 1346, 1396	2.22	Sept. 10, 1954
NS55	Double Ditch Creek	NE¼ sec.19, T.40N., R.3E., just below confluence of branches, at Lynden.	4.11	962, 982	3.52	Oct. 12, 1942

*Drainage areas are indeterminant

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	NOOKSACK RIVER DRAINAGE BASIN (continued)					
NS56	Fishtrap Creek	NE¼ sec.25, T.40N., R.2E., at highway crossing, 1 mile southwest of Lynden.	28.5	962, 982, 1122, 1152, 1346, 1396, 1636	4.85	Aug. 18, 1958
NS57	Fishtrap Creek	SW¼ sec.35, T.40N., R.2E., at mouth.	30.6	1346	15.1	Sept. 11, 1954
NS58	Bertrand Creek	SE¼ sec.11, T.40N., R.2E., at Blaine-Sumas Road crossing, 2½ miles northwest of Lynden.	26.9	1122, 1346, 1396, 1636	2.65	Aug. 8, 1956
NS59	Unnamed stream (tributary to Bertrand Creek)	NW¼ sec.18, T.40N., R.3E., at Lynden-Sumas Road crossing, 1½ miles northwest of Lynden.	1.06	1122, 1152, 1346, 1396	0.02	Oct. 1, 1954
NS60	Bertrand Creek	North line sec.27, T.40N., R.2E., at Birch Bay-Lynden Road crossing, 3½ miles west of Lynden.	33.8	982, 1012, 1346, 1396	8.96	Oct. 12, 1943
NS61	Bellingar Ditch	NE¼NE¼ sec.5, T.39N., R.3E., at Hannegan Road crossing, 3 miles south of Lynden.	0.47	1346	0.05	Sept. 14, 1954
NS62	Wiser Lake Creek	SW¼ sec.3, T.39N., R.2E., ½ mile above mouth and 3 miles northeast of Ferndale.	6.23	962, 982, 1152, 1346, 1396, 1566, 1636	1.04	Aug. 18, 1958
NS63	Unnamed stream (tributary to Tenmile Creek)	N½ sec.27, T.39N., R.3E., at Starry Road crossing, 3½ miles southeast of Laurel.	0.71	1346	0	Sept. 14, 29, 1954
NS64	Tenmile Creek	NE¼ sec.18, T.39N., R.3E., at road crossing, 1 mile northeast of Laurel.	10.1	1122, 1152, 1346, 1396, 1446, 1566, 1636	0.69	Aug. 18, 1958
NS65	Tenmile Creek	East line sec.13, T.39N., R.2E., at State Highway crossing 3/4 mile north of Laurel.	12.1	962, 982	1.36	Aug. 17, 1942
NS66	Unnamed stream (tributary to Green Lake)	North line sec.10, T.39N., R.3E., at Pole Road crossing, 4 miles southeast of Lynden.	0.31	1346	0.88	Sept. 14, 1954
NS67	Fourmile Creek	West line sec.9, T.39N., R.3E., at Hannegan Road crossing, 4½ miles south of Lynden.	8.30	1346	1.53	Sept. 14, 1954
NS68	Fourmile Creek	W½ sec.18, T.39N., R.3E., at road crossing, 1 mile north of Laurel.	10.0	1122, 1152, 1346	2.30	Oct. 1, 1954
NS69	Fourmile Creek	SE¼ sec.13, T.39N., R.2E., at State Highway crossing, 3/4 mile north of Laurel.	10.6	962, 982	2.19	Oct. 12, 1942
2130	Tenmile Creek	NE¼SW¼ sec.22, T.39N., R.2E., at former gaging station site near Ferndale.	25.7	1122, 1152, 1216, 1396, 1446, 1566	1.64	Aug. 18, 1958
NS70	Larrabee Springs	NW¼NW¼ sec.36, T.39N., R.2E., 100 ft below source, 2 miles southwest of Laurel.	0.07	982, 1122, 1152, 1182, 1346, 1396, 1446, 1636	0.31	Sept. 7, 1956

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	NOOKSACK RIVER DRAINAGE BASIN (continued)					
NS71	Deer Creek	NE¼ sec.27, T.39N., R.2E., at road crossing, 2 miles east of Ferndale.	6.45	982, 1152, 1346, 1396, 1446, 1566, 1636	0.82	Aug. 18, 1958
NS72	Barrett Lake Outlet	SE¼ sec.20, T.39N., R.2E., at road crossing, 1 mile east of Ferndale.	33.9	1346	9.67	Sept. 10, 1954
	COASTAL AREA BASINS					
	Silver Creek Basin					
SL1	Silver Creek	SE¼ sec.34, T.39N., R.2E., at Sunset Road crossing, 1½ miles east of Brennan.	7.59	1122, 1152, 1346	0.10	Sept. 9, 1954
	Terrell Creek Basin					
TR1	Terrell Creek	Center sec.9, T.39N., R.1E., at Kickerville.	5.93	982, 1346	0	July 23, 1943, Sept. 30, 1954
TR2	Fingalson Creek	South line sec.3, T.39N., R.1E., at road crossing, 4 miles northwest of Ferndale.	0.84	1122, 1346	0	Sept. 20, 1948, Sept. 9, 1954
TR3	Terrell Creek	East line sec.6, T.39N., R.1E., at road crossing, 6 miles south of Blaine.	8.29	1346, 1396, 1446, 1566 1636	0	Sept. 30, 1954, Aug. 7, Sept. 6, 1956, Aug. 19, 1958
TR4	Terrell Creek	West line sec.6, T.39N., R.1E., at road crossing, 6 miles south of Blaine.	12.4	1122, 1346	0	Sept. 20, 1948
	California Creek Basin					
2135	California Creek	SE¼SE¼ sec.27, T.40N., R.1E., at Porter Road crossing, at gaging station site.	11.0	962, 982, 1346, 1566	0.33	Aug. 19, 1958
CL1	California Creek	SE¼ sec.21, T.40N., R.1E., at road crossing, 4 miles southeast of Blaine.	18.1	1122, 1152, 1346, 1636	1.19	Sept. 30, 1954
	Dakota Creek Basin					
DK1	North Fork Dakota Creek	SE¼SE¼ sec.14, T.40N., R.1E., at road crossing, 5 miles southeast of Blaine.	7.90	1122, 1152, 1346, 1396, 1446, 1566, 1636	0.56	Aug. 7, 1956
DK2	South Fork Dakota Creek	SE¼SE¼ sec.14, T.40N., R.1E., at road crossing, 5 miles southeast of Blaine.	7.67	1122, 1152, 1346	0.47	Aug. 16, 1949
DK3	Haynie Creek	SE¼ sec.10, T.40N., R.1E., at road crossing, 4 miles east of Blaine.	1.73	1122, 1346	0.27	Sept. 30, 1954
DK4	Unnamed stream (tributary to Dakota Creek)	SE¼ sec.9, T.40N., R.1E., at road crossing, 2 miles east of Blaine.	1.61	1122, 1346	0.38	Sept. 10. 1954
DK5	Unnamed stream (tributary to Dakota Creek)	About center W½ sec.9, T.40N., R.1E., at road crossing, 2 miles east of Blaine.	1.26	1122, 1346	0.08	Sept. 10, 1954
DK6	Spooner Creek	South line sec.5, T.40N., R.1E., at road crossing, 1½ miles east of Blaine.	1.43	1122, 1346	0.04	Sept. 10, 1954

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	SUMAS RIVER BASIN					
SM1	Sumas River	SE¼ sec.16, T.39N., R.4E., at road crossing, ½ mile north of Lawrence.	1.79	1092, 1346	0	Sept. 4, 1947, Sept. 9, Oct. 1, 1954
SM2	Sumas River	West line sec.9, T.39N., R.4E., at road crossing, 2 miles north of Lawrence.	3.47	1122, 1346	0	Sept. 20, 1948, Sept. 9, Oct. 1, 1954
SM3	Dale Creek	North line sec.9, T.39N., R.4E., at road crossing, 2½ miles southeast of Nooksack.	1.49	1092, 1122, 1346, 1396, 1446, 1566, 1636	0	Sept. 4, 1947
SM4	Goodwin Ditch	SW¼ sec.33, T.40N., R.4E., at road crossing, 1 mile southeast of Nooksack.	3.05	1092, 1122, 1346, 1396, 1446, 1636	2.59	Sept. 4, 1947
SM5	Sumas River	South line NE¼ sec.32, T.40N., R. 4E., at farm bridge, 1 mile southeast of Nooksack.	8.38	1092	9.19	Sept. 4, 1947
SM6	Swift Creek	NW¼ sec.33, T.40N., R.4E., at road crossing, 3/4 mile east of Nooksack.	3.12	1092, 1122, 1346, 1396 1446, 1636	0	Aug. 11, 1959
SM7	Sumas River	South line sec.29, T.40N., R.4E., at road crossing at Nooksack.	15.0	1122, 1152, 1346, 1446, 1566	6.82	Aug. 21, 1958
SM8	Breckenridge Creek	East line sec.28, T.40N., R.4E., at Goodwin Road crossing, 1½ miles east of Nooksack.	5.37	1092, 1122, 1152, 1346, 1396, 1446, 1566, 1636	0.27	Aug. 21, 1958
SM9	Kinney Creek	NW¼ sec.22, T.40N., R.4E., at road crossing, 3 miles south of Sumas.	1.89	1092, 1122, 1346, 1396	0.12	Sept. 20, 1948
2145	Sumas River	NE¼ sec.11, T.40N., R.4E., at former gaging station site, near Sumas.	30.2	1122, 1152, 1182, 1216, 1346, 1396, 1446, 1566, 1636	7.96	Aug. 19, 1958
SM10	Bone Creek	South line sec.3, T.40N., R.4E., at road crossing, 1 mile southwest of Sumas.	1.23	1092, 1346	0	Sept. 5, 1947, Sept. 9, Oct. 1, 1954
SM11	Bone Creek	NW¼ sec.2, T.40N., R.4E., at road crossing at Sumas.	2.56	1122, 1346	0.10	Sept. 9, Oct. 1, 1954
SM12	Sumas River	South line sec.35, T.41N., R.4E., at road crossing, ½ mile east of Sumas.	33.6	1092	12.5	Sept. 5, 1947
SM13	Johnson Creek	South line sec.8, T.40N., R.4E., at road crossing, 1 mile south of Clearbrook.	5.87	1092, 1122, 1346	0	Sept. 5, 1947, Sept. 21, 1948, Sept. 10, 1954
SM14	Squaw Creek	South line sec.12, T.40N., R.3E., at road crossing, 2 miles southwest of Clearbrook.	1.92	1122, 1346, 1396	0.73	Oct. 1, 1954
SM15	Unnamed stream (tributary to Squaw Creek)	SW¼SW¼ sec.7, T.40N., R.4E., at Lynden-Sumas Road crossing, 1¼ miles southwest of Clearbrook.	0.40	1346	0.31	Sept. 14, 1954

Table 3. Miscellaneous Low Flow Discharge Measurements. (Continued)

Map No.	Stream	Location	Drain. area (sq mi)	Publication (WSP)	Minimum discharge measured	
					Cfs	Date
	SUMAS RIVER BASIN (continued)					
SM16	Squaw Creek	South line sec.7, T.40N., R.4E., at road crossing, 1½ miles southwest of Clearbrook.	3.53	1122, 1346, 1396	1.08	Oct. 1, 1954
SM17	Squaw Creek	West line sec.8, T.40N., R.4E., at road crossing, 3/4 mile south of Clearbrook.	3.80	1092, 1346 1396	0.81	Sept. 5, 1947
SM18	Pangborn Creek	SW¼ sec.5, T.40N., R.4E., at road crossing at Clearbrook.	3.02	1092, 1122, 1346, 1396, 1466, 1566, 1636	1.53	Sept. 5, 1947
SM19	Johnson Creek	South line sec.5, T.40N., R.4E., at road crossing, ¼ mile east of Clear-brook.	13.7	1122	8.31	July 21, 1948
SM20	Johnson Creek	South line sec.34, T.41N., R.4E., at Front Street crossing at Sumas.	17.4	1092	10.7	Sept. 5, 1947
2150	Johnson Creek	SE¼ sec.34, T.41N., R.4E., at Sumas Avenue crossing, at former gaging station site at Sumas.	20.4	1122, 1152, 1346, 1396, 1446, 1566	8.22	Aug. 24, 1955
SM21	Saar Creek	Center sec.12, T.40N., R.4E., at mouth of canyon, 1½ miles southeast of Sumas.	7.46	1122, 1152, 1346, 1396	1.89	Aug. 17, 1949
2155	Saar Creek	North line sec.6, T.40N., R.5E., at Rock Road crossing, at former gaging station site.	10.0	1346, 1396 1566, 1636	0	Aug. 19, 1958

Table 4. Ratio of annual discharge for South Fork Nooksack River.

Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio
1910	*1.18	1920	*0.93	1930	*0.67	1940	0.91	1950	1.26
1911	*0.91	1921	*1.26	1931	*0.75	1941	0.80	1951	1.15
1912	*0.98	1922	*0.89	1932	*1.10	1942	0.82	1952	0.86
1913	*1.11	1923	*0.93	1933	*1.41	1943	0.98	1953	0.92
1914	*0.98	1924	*0.89	1934	1.23	1944	0.67	1954	1.28
1915	*0.61	1925	*1.08	1935	1.08	1945	0.91	1955	1.06
1916	*1.19	1926	*0.69	1936	0.93	1946	1.12	1956	1.11
1917	*1.04	1927	*0.97	1937	0.84	1947	1.00	1957	0.94
1918	*1.25	1928	*1.14	1938	0.94	1948	1.11	1958	0.82
1919	*1.13	1929	*0.72	1939	1.01	1949	1.02	1959	1.25

*Based on long-term records for nearby streams.

Table 5. Ratio of seasonal (July to September) discharge for South Fork Nooksack River.

Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio
1910	*1.44	1920	*1.20	1930	*0.46	1940	0.34	1950	1.68
1911	*0.97	1921	*1.35	1931	*0.50	1941	1.08	1951	0.52
1912	*1.01	1922	*0.69	1932	*0.96	1942	0.58	1952	0.75
1913	*1.78	1923	*0.86	1933	*2.12	1943	1.02	1953	1.19
1914	*0.73	1924	*0.53	1934	0.81	1944	0.71	1954	2.01
1915	*0.36	1925	*0.60	1935	0.96	1945	0.80	1955	1.68
1916	*1.75	1926	*0.38	1936	0.79	1946	0.98	1956	1.32
1917	*2.08	1927	*1.16	1937	0.79	1947	0.85	1957	0.69
1918	*0.78	1928	*0.56	1938	0.44	1948	1.27	1958	0.51
1919	*1.06	1929	*0.66	1939	1.10	1949	1.50	1959	1.65

*Based on long-term records for nearby streams.

The data are shown in tabular and graphical form as (1) maximum and minimum daily discharge hydrographs, (2) maximum, minimum, and average monthly discharge bar graphs, and (3) flow-duration curves. The three forms of presentation are discussed briefly below and are followed by the graphical and tabular expressions of the data.

MAXIMUM-MINIMUM DAILY HYDROGRAPHS

The hydrographs of maximum and minimum daily discharge shown on pages 54 through 66 are based on the maximum and minimum daily discharge for each date of the year throughout the period of record. The extremes of discharge thus plotted delineate a band within the boundaries of which every past daily discharge of record would lie if plotted. The hydrographs can be used to appraise the extremes of discharge to be expected throughout the year but do not define a record of continuous flow or typify the actual record for any individual year. The hydrographs approach the category of flow-duration graphs inasmuch as the minimum daily discharge hydrograph presents daily mean discharges that have been equaled or exceeded 100 percent of the time, while the maximum daily discharge hydrograph presents daily mean discharges that have not been exceeded at any time during the period of record. The discharge figures used for preparing these hydrographs are tabulated on pages 68-74.

MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE BAR GRAPHS

The bar graphs shown on pages 54-66 and based on data listed on pages 75-78 are similar to the maximum-minimum hydrographs in that they show the maximum monthly discharge, the minimum monthly discharge, and the average of all the monthly discharges of record. These graphs appraise a stream's potential in more summarized form than do the daily maximum and minimum data.

FLOW-DURATION CURVES

Flow-duration curves show the percentage of time that specified discharges were equaled or exceeded during a given period.[1] Such curves are used to analyze the availability and variability of streamflow and to investigate problems of water supply, power development, waste disposal, and administration of water rights. A flow-duration curve for the entire period of record in itself does not show a chronological sequence of flow, but the curves for each month of the year as shown on pages 55 through 67 provide a substitute for the chronologic sequence of events. Such curves tend to define the frequency of occurrence of discharge at any given time of the year.

1/ Searcy, J. K. 1959, Flow duration curves manual of hydrology, pt. 2 of low flow techniques: U. S. Geol. Survey Water-Supply Paper 1542-A.

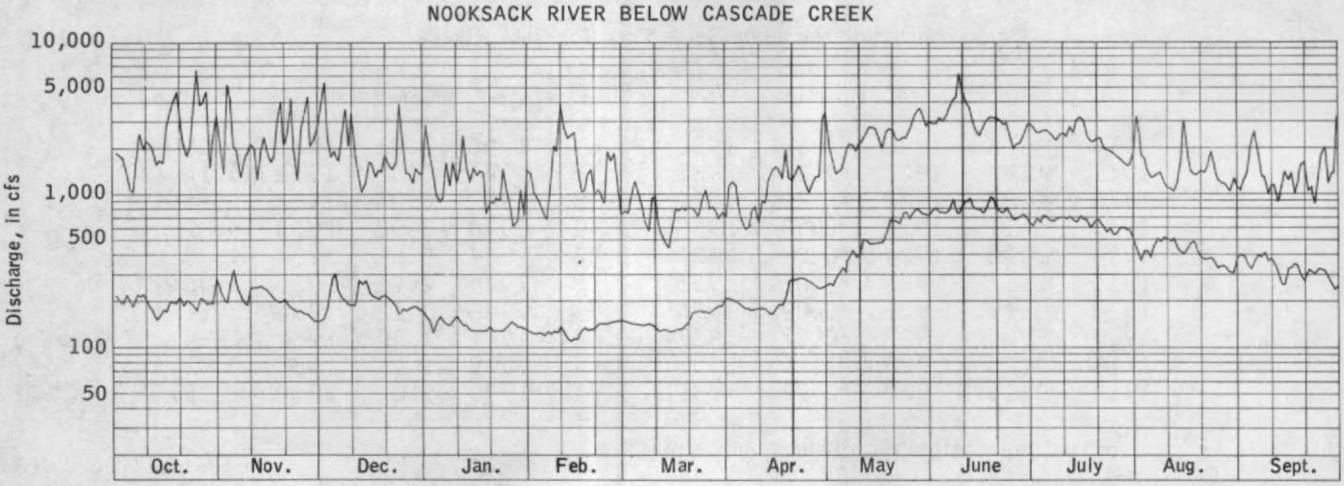


Figure 22. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1947-59.

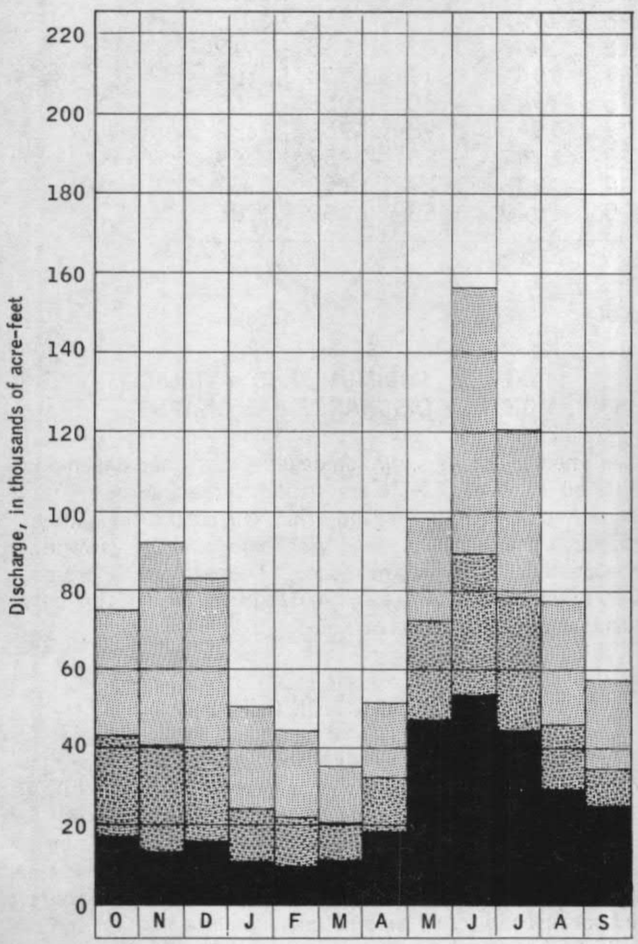


Figure 23. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1947-59.

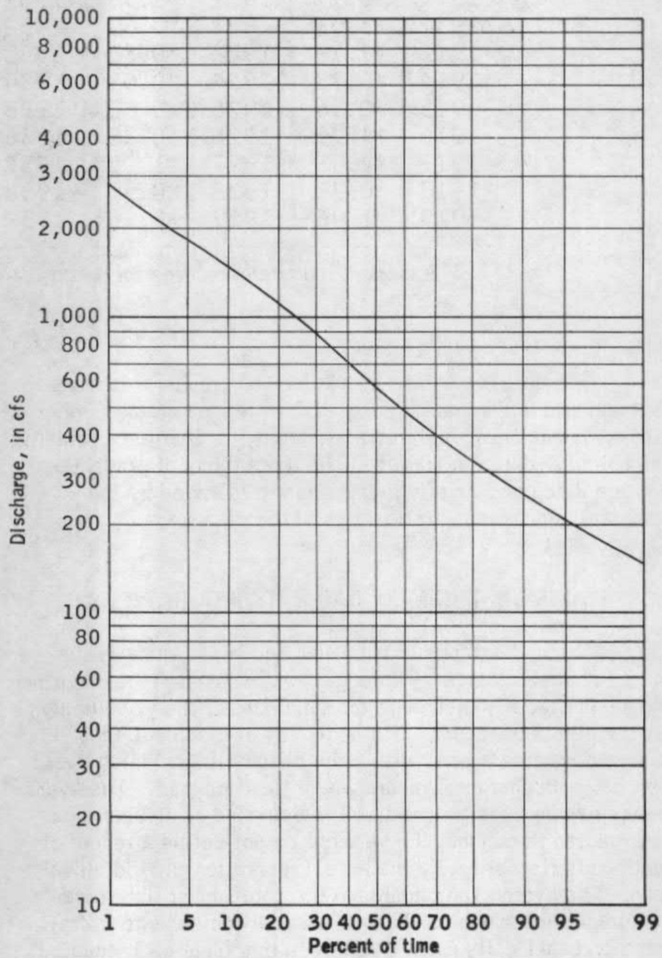


Figure 24. FLOW-DURATION CURVE FOR THE PERIOD 1938-59.

NOOKSACK RIVER BELOW CASCADE CREEK

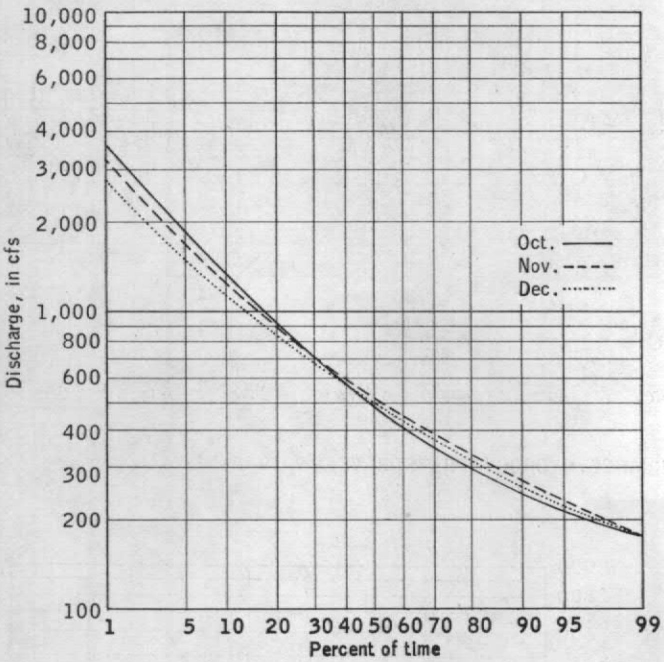


Figure 25a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1938-59.

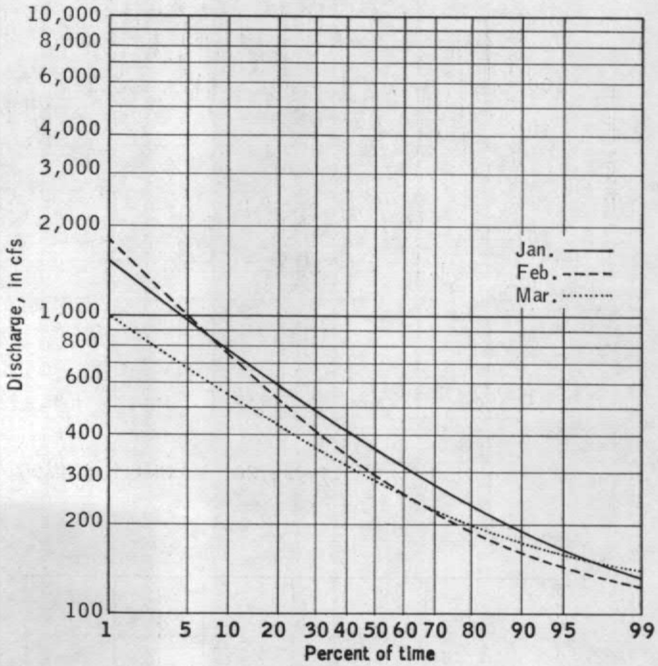


Figure 25b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1938-59.

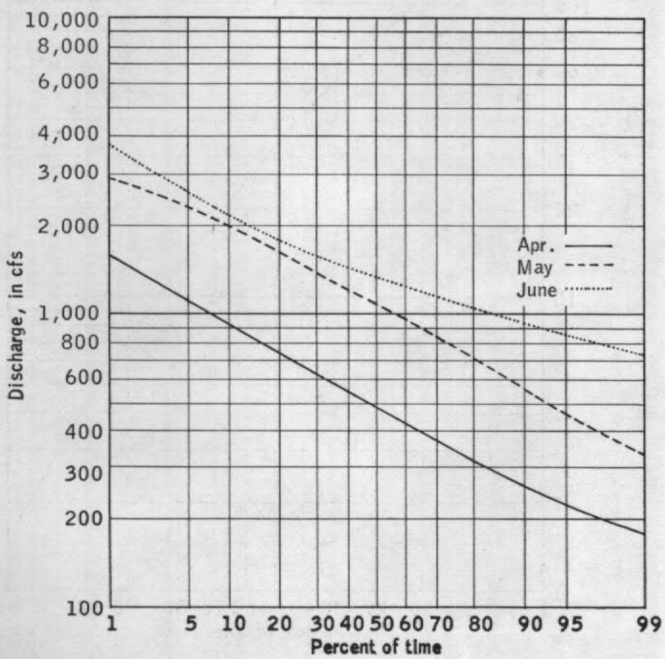


Figure 25c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1938-59.

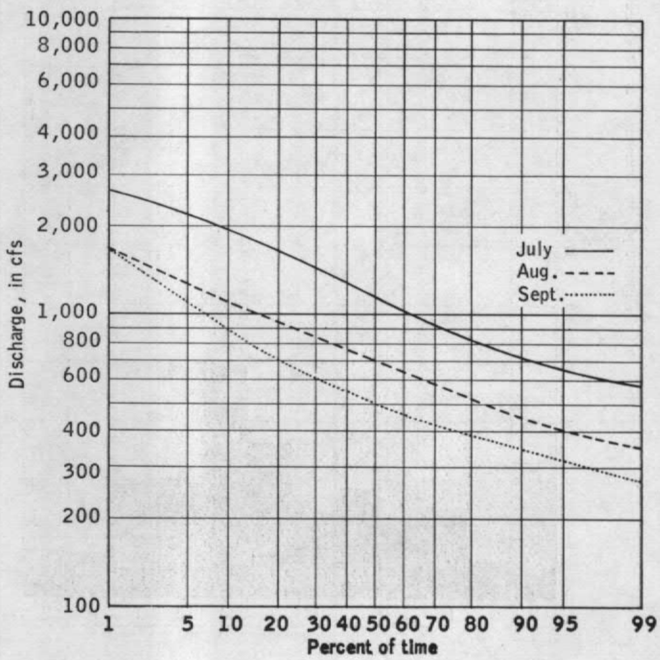


Figure 25d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1938-59.

CANYON CREEK AT KULSHAN

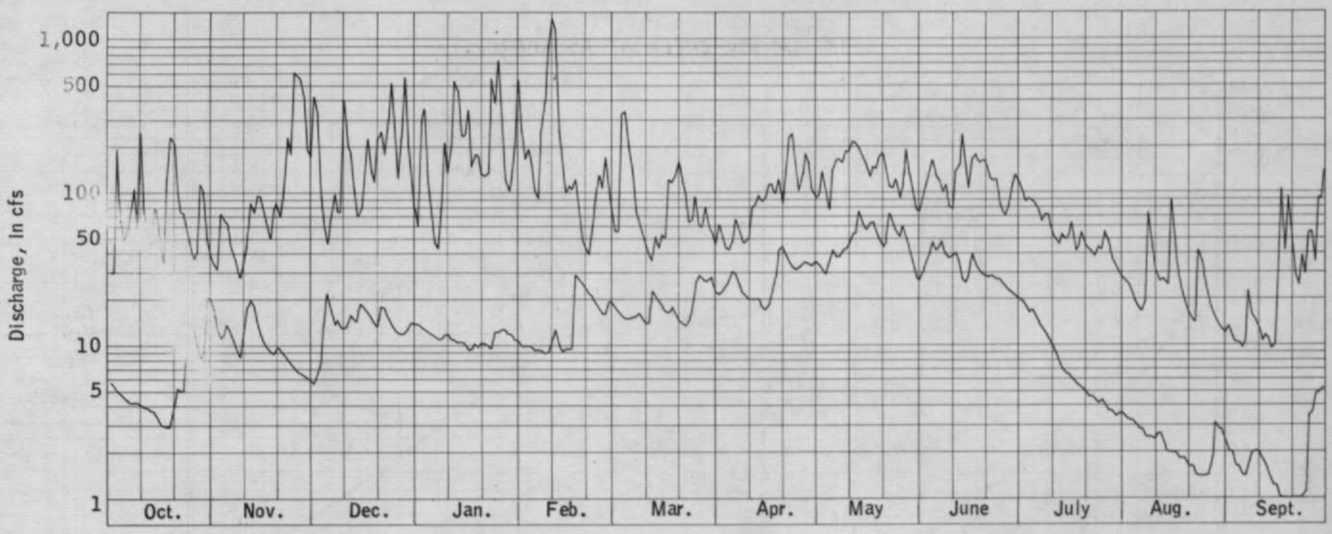


Figure 26. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1948-54.

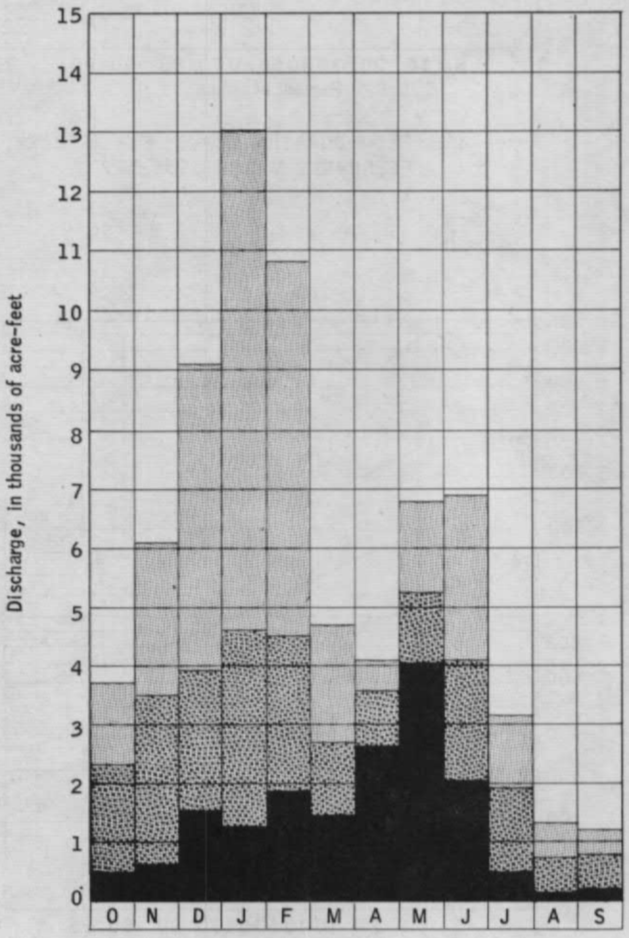


Figure 27. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1948-54.

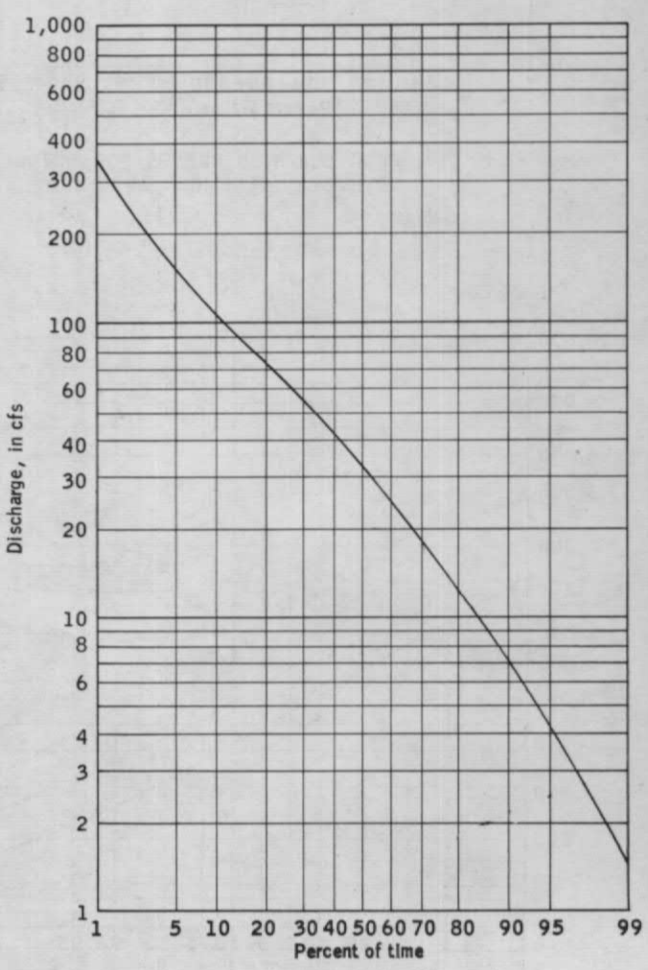


Figure 28. FLOW-DURATION CURVE FOR THE PERIOD 1949-53.

CANYON CREEK AT KULSHAN

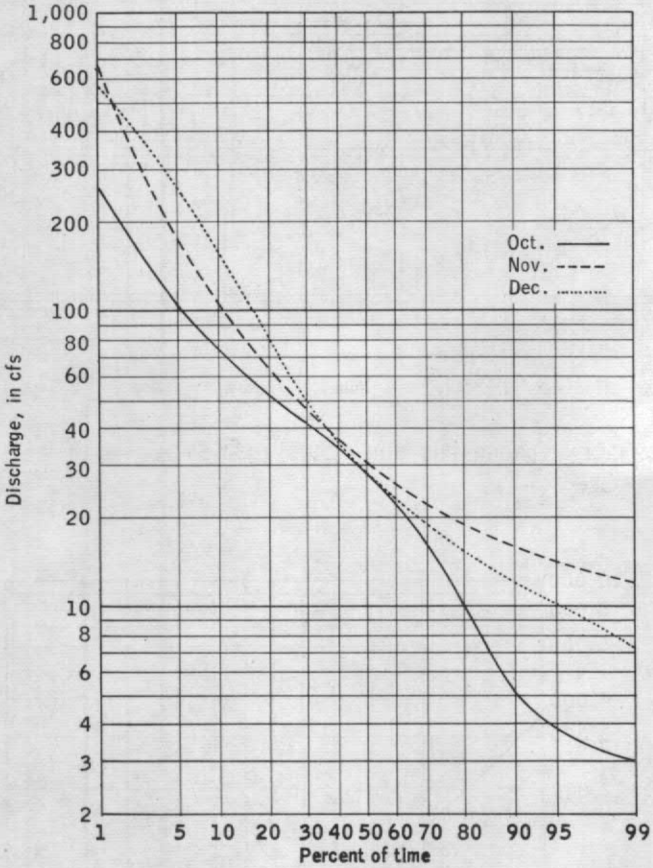


Figure 29a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1949-53.

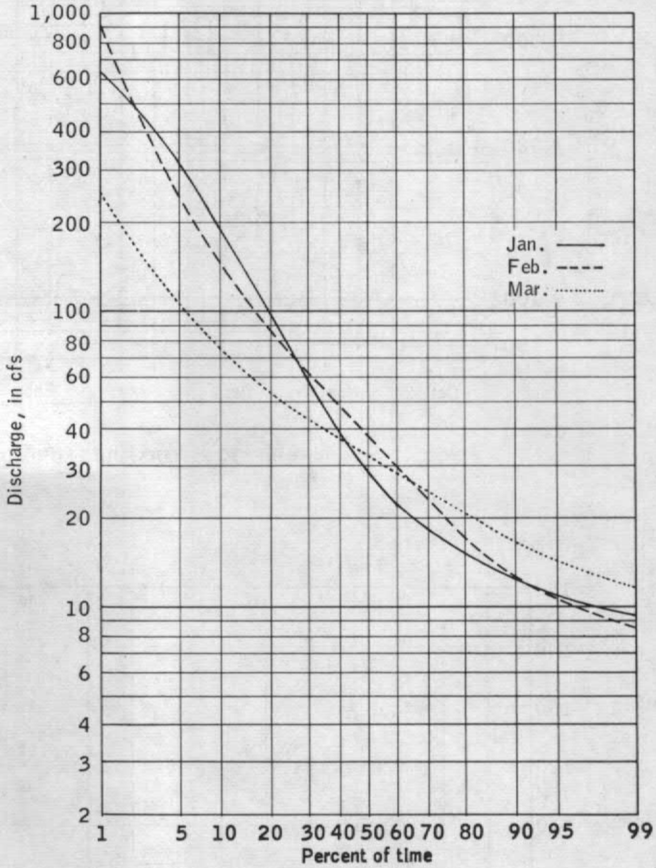


Figure 29b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1949-53.

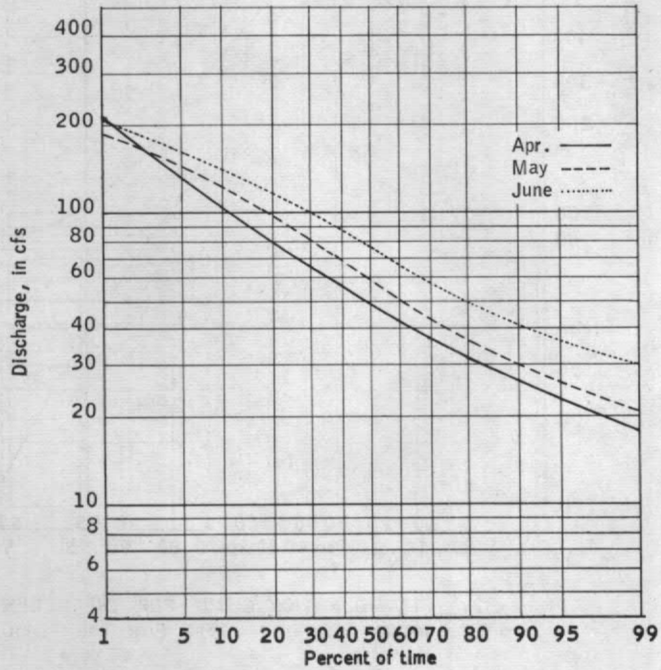


Figure 29c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1949-53.

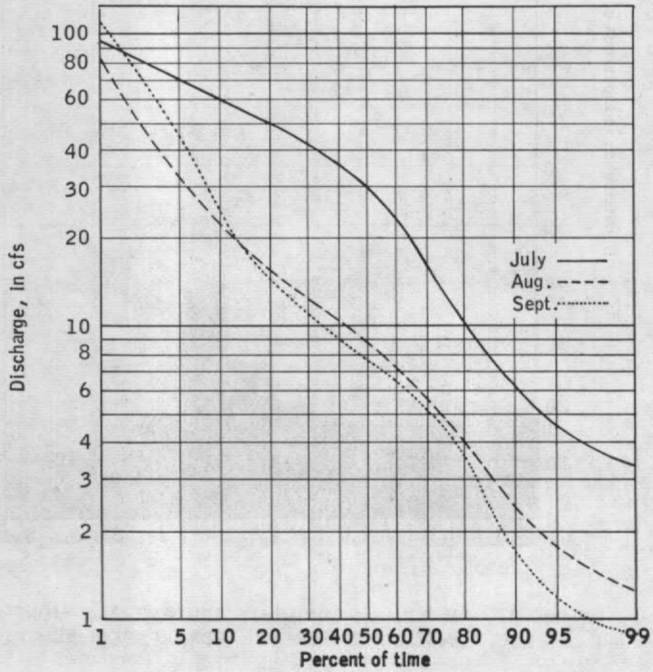


Figure 29d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1949-53.

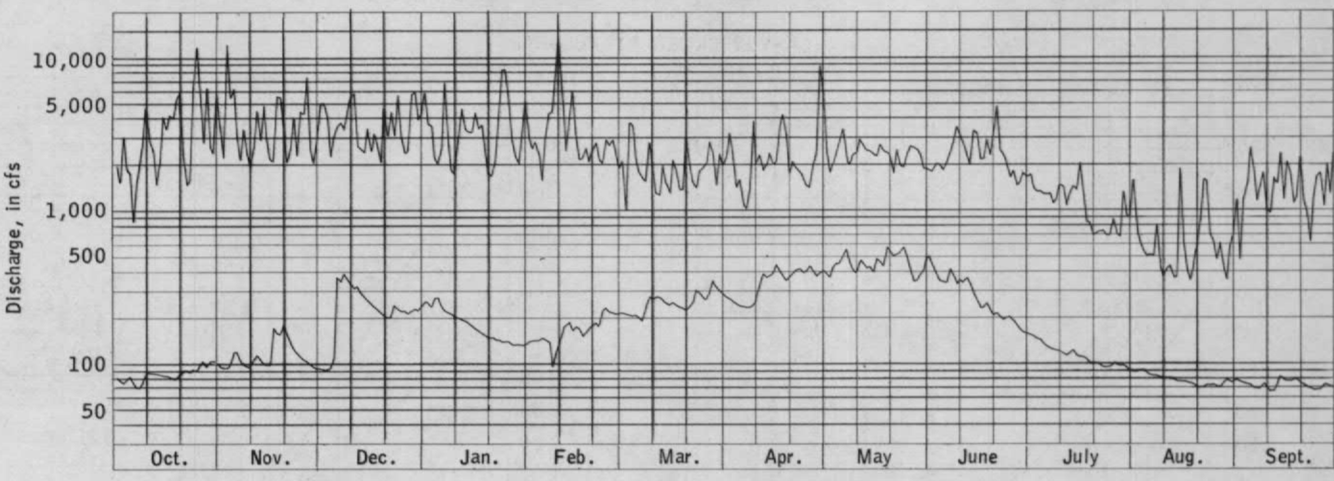


Figure 30. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1934-59.

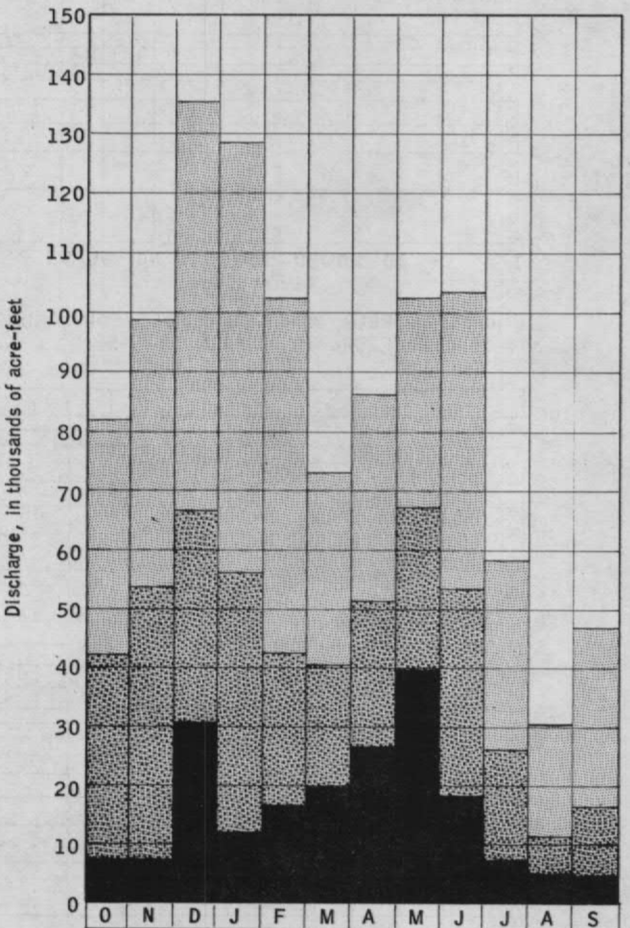


Figure 31. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1934-59.

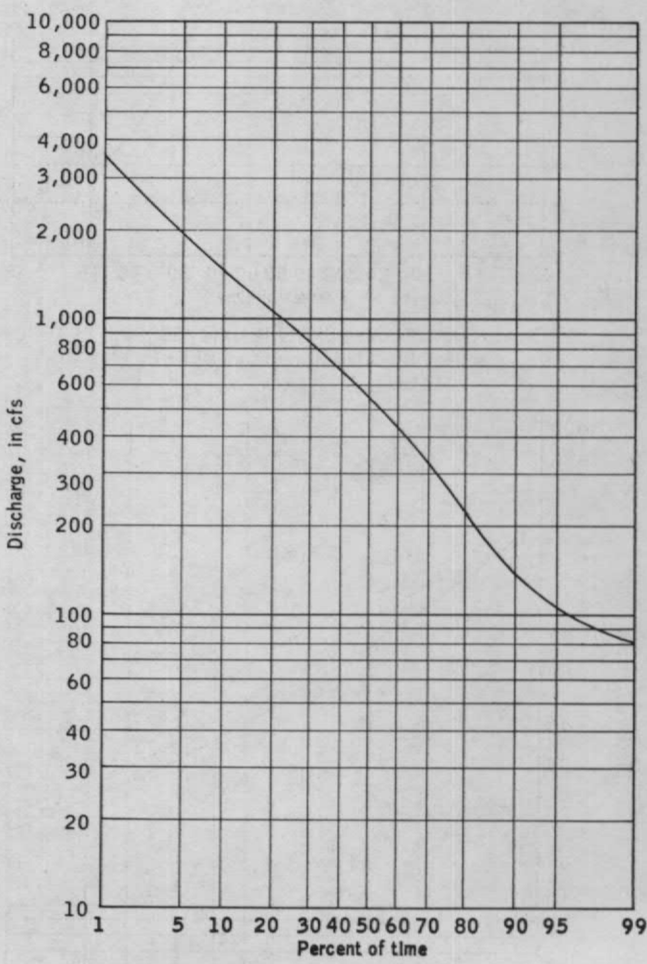


Figure 32. FLOW-DURATION CURVE FOR THE PERIOD 1935-59.

SOUTH FORK NOOKSACK RIVER NEAR WICKERSHAM

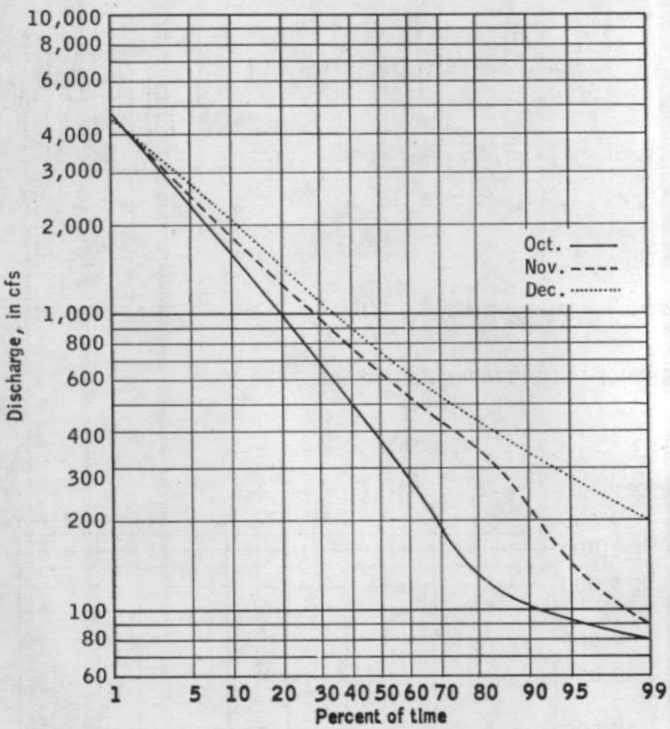


Figure 33a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1935-59.

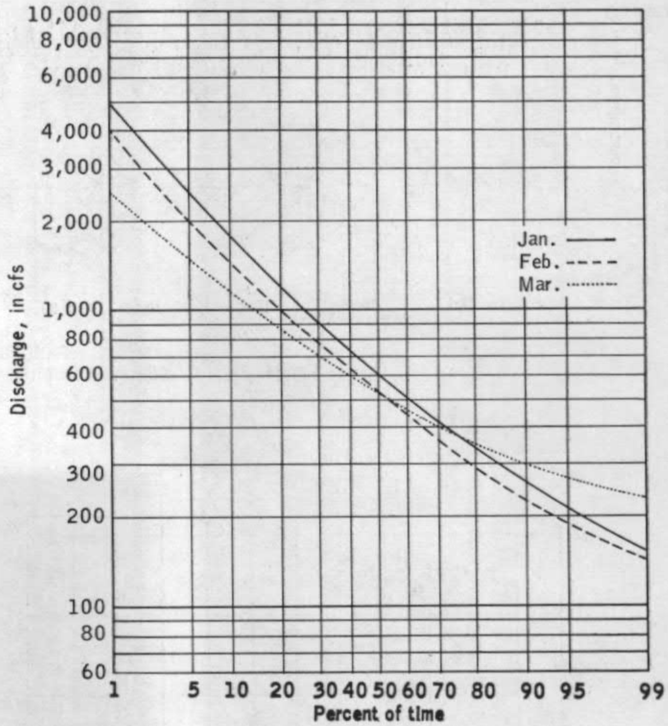


Figure 33b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1935-59.

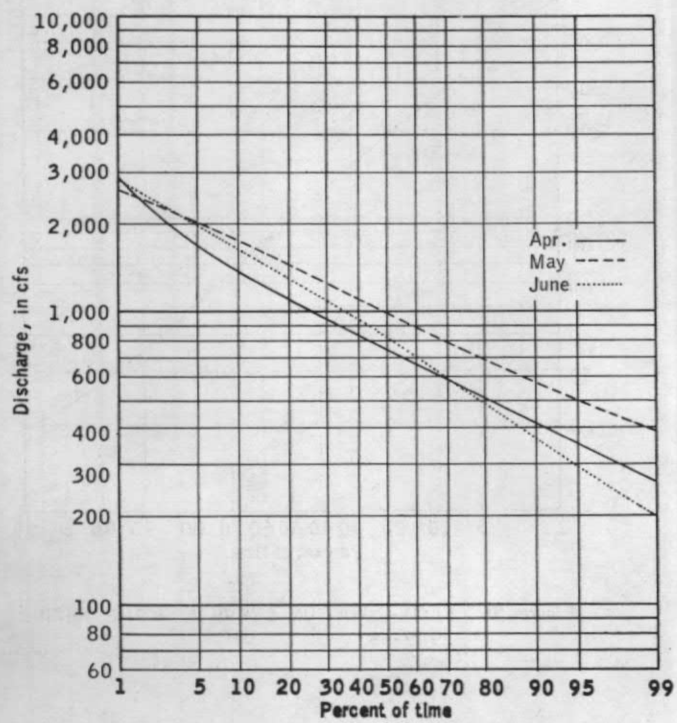


Figure 33c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1935-59.

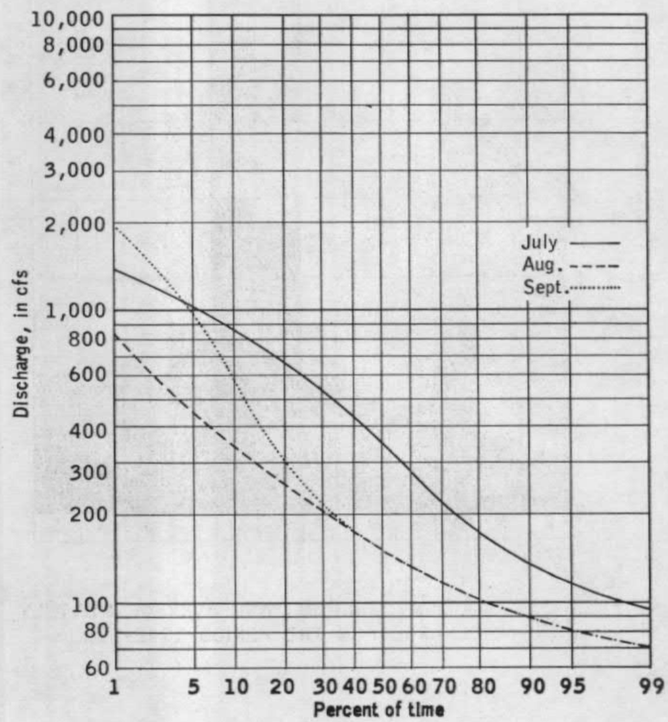


Figure 33d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1935-59.

SKOOKUM CREEK NEAR WICKERSHAM

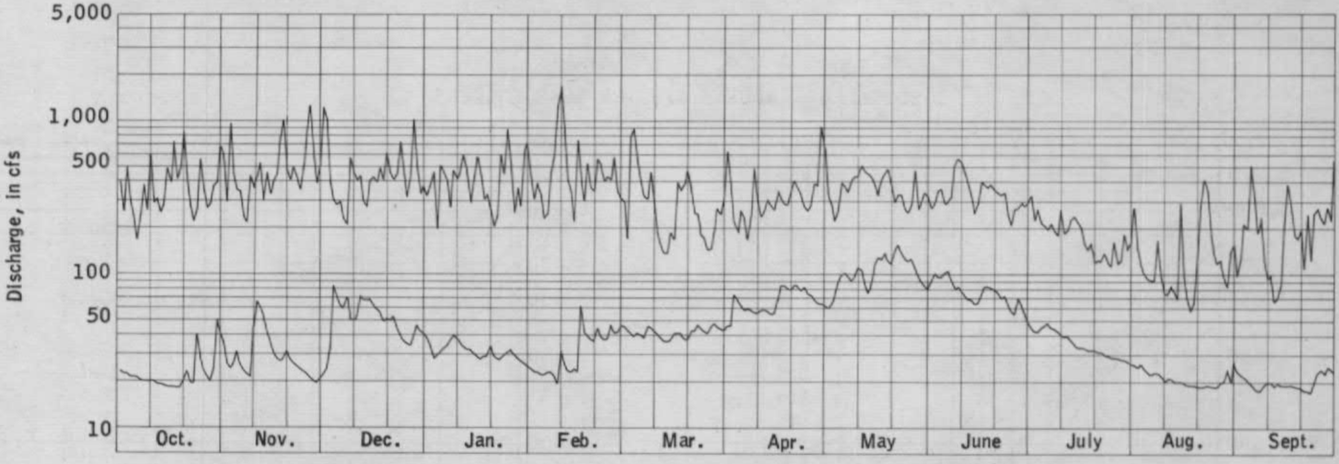


Figure 34. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1948-59.

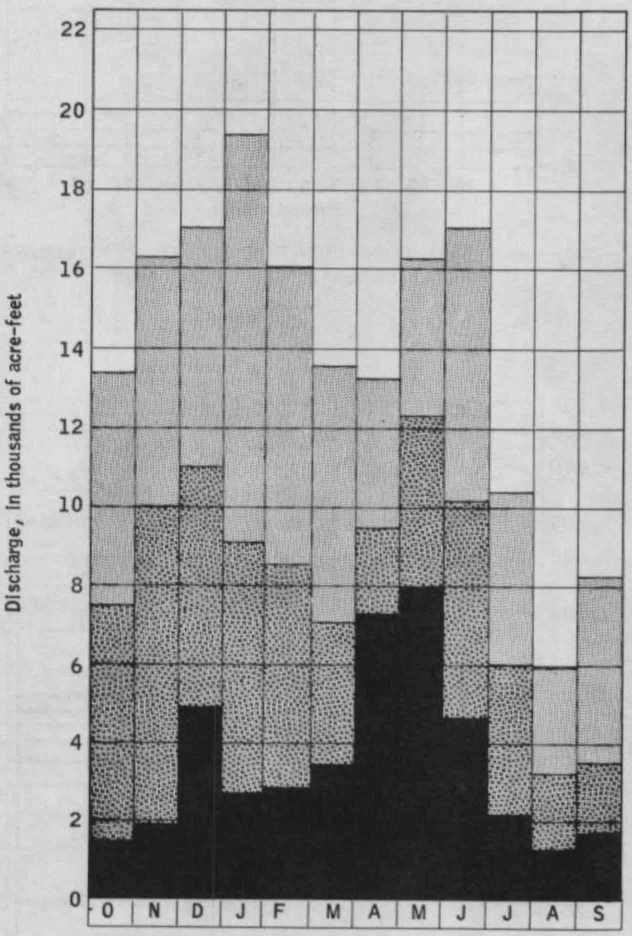


Figure 35. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1948-59.

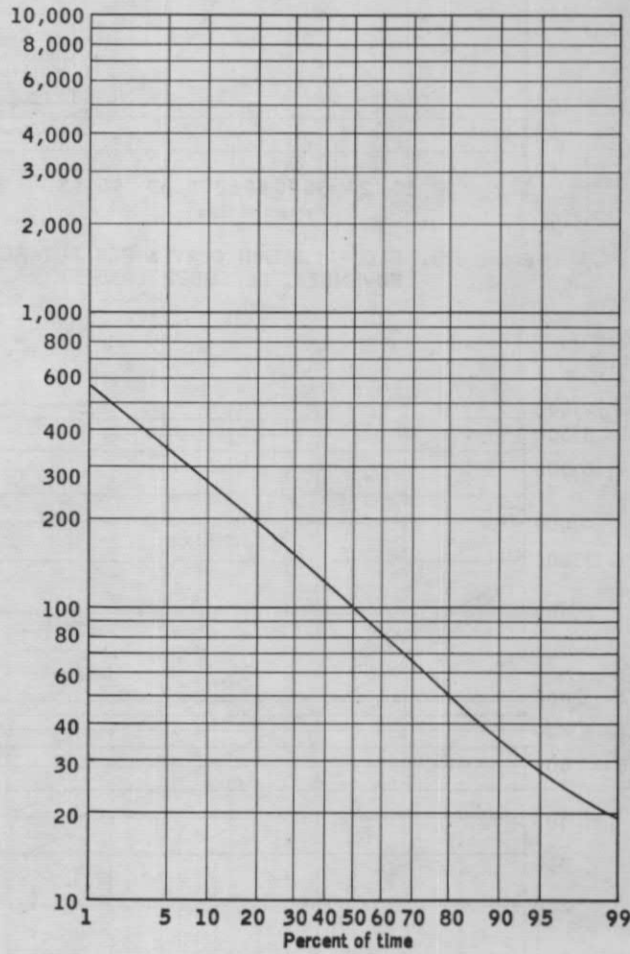


Figure 36. FLOW-DURATION CURVE FOR THE PERIOD 1949-59.

SKOOKUM CREEK NEAR WICKERSHAM

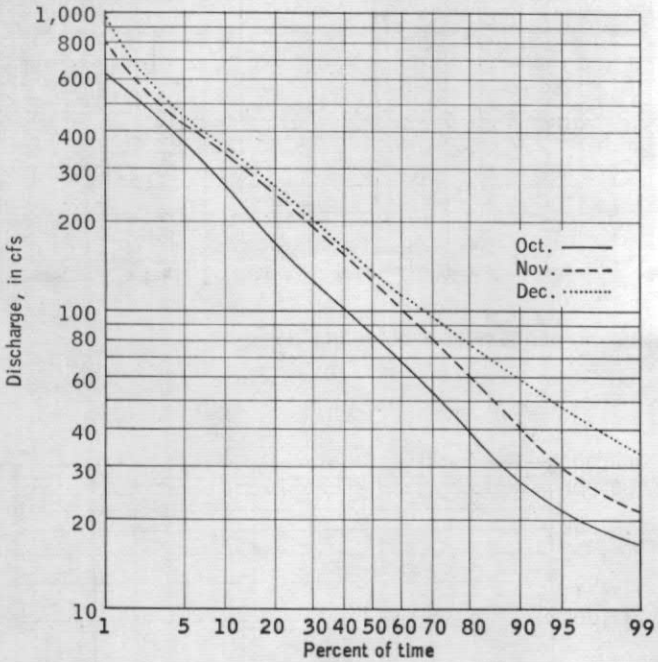


Figure 37a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1949-59.

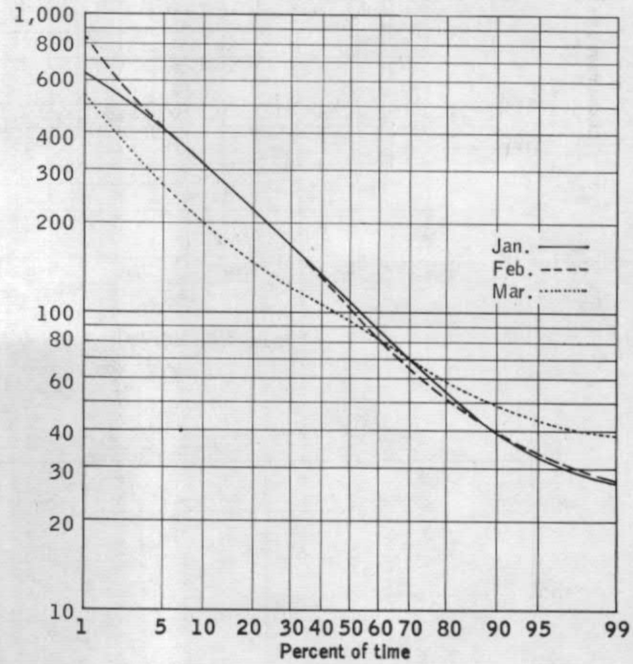


Figure 37b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1949-59.

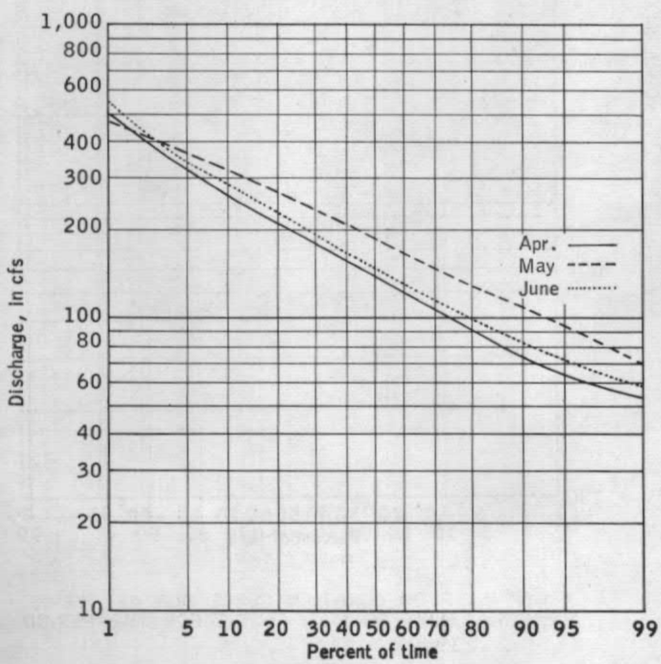


Figure 37c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1949-59.

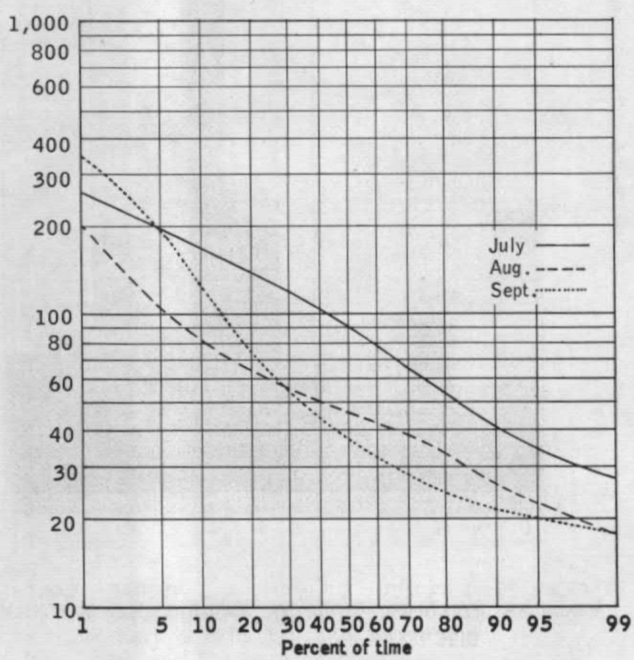


Figure 37d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1949-59.

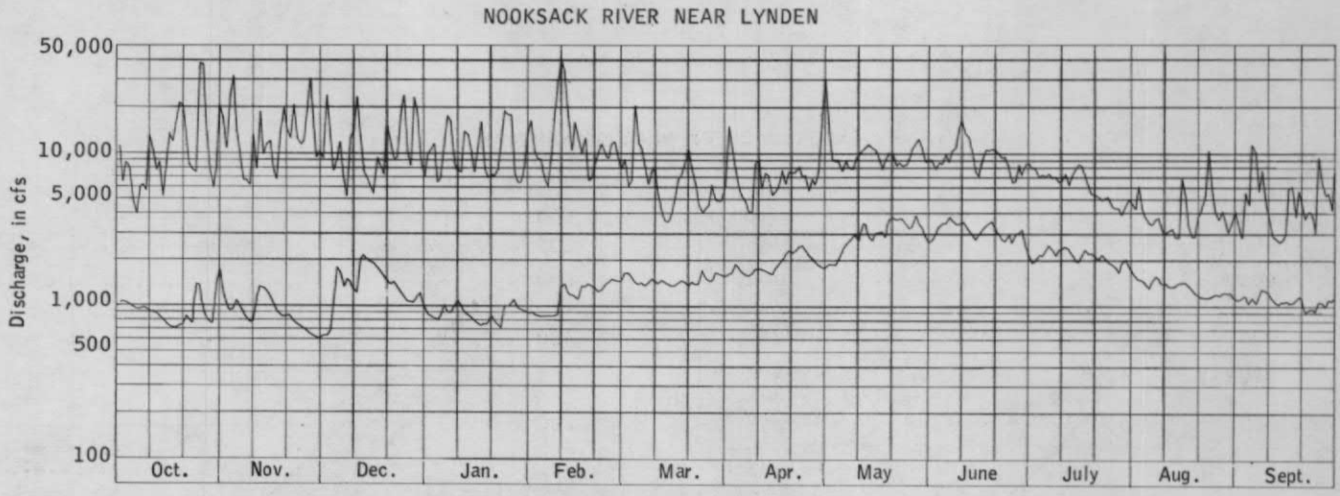


Figure 38. MAXIMIM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1944-59.

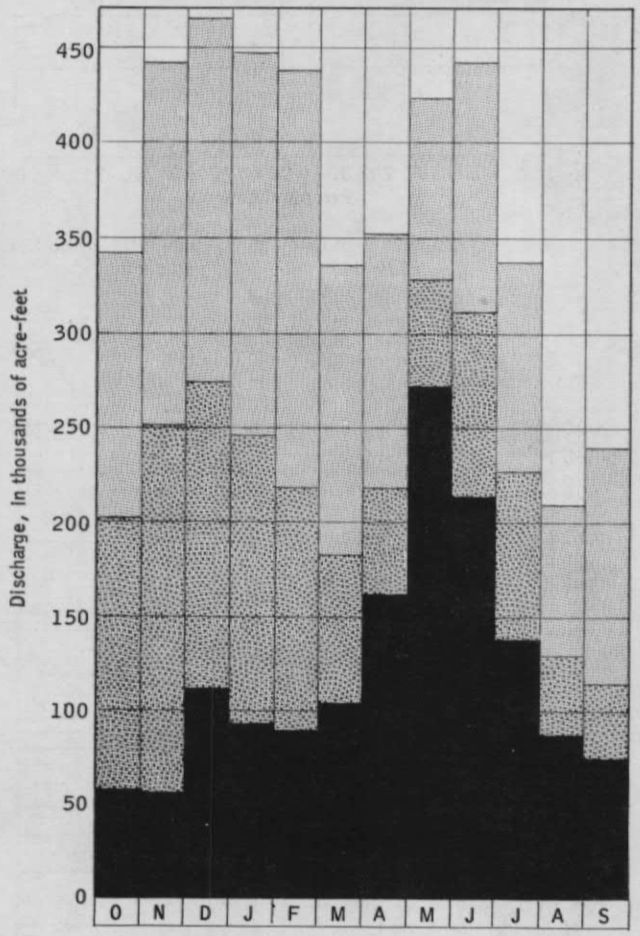


Figure 39. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1944-59.

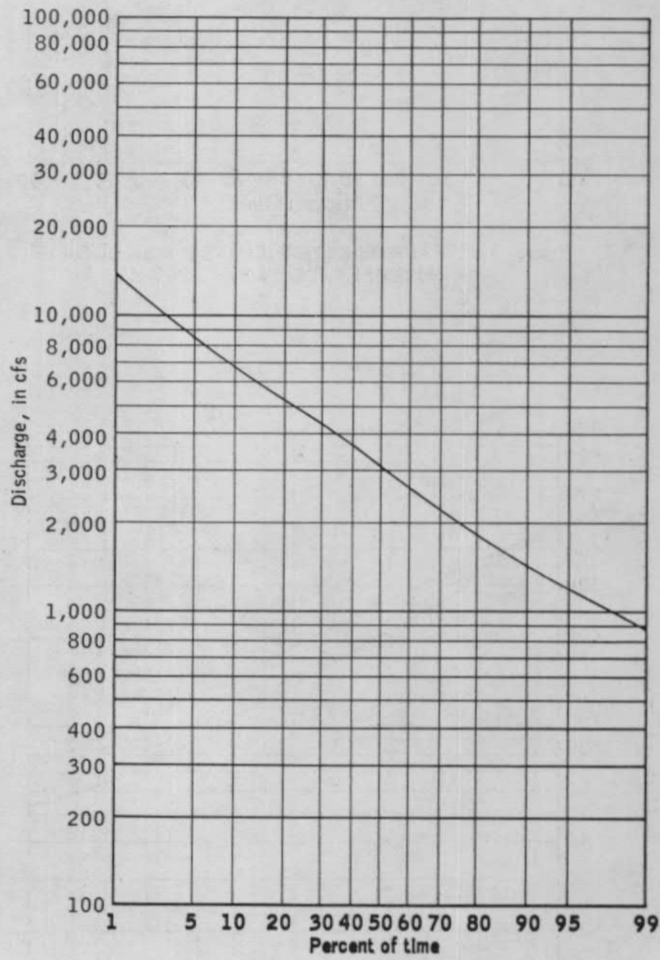


Figure 40. FLOW-DURATION CURVE FOR THE PERIOD 1946-59.

NOOKSACK RIVER NEAR LYNDEN

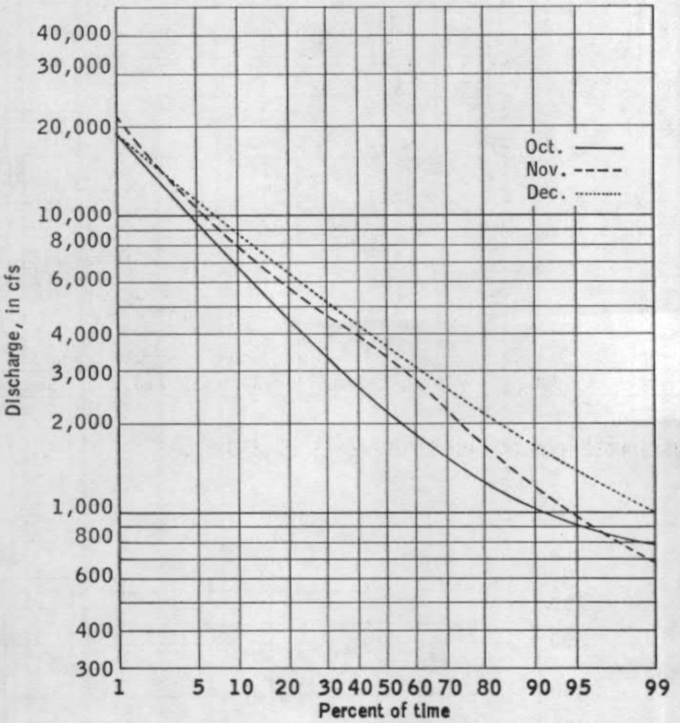


Figure 41a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1946-59.

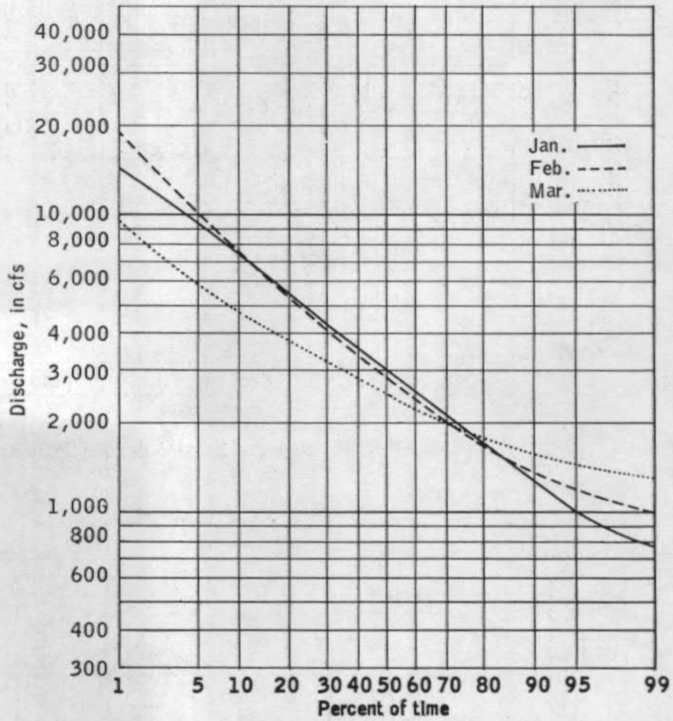


Figure 41b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1946-59.

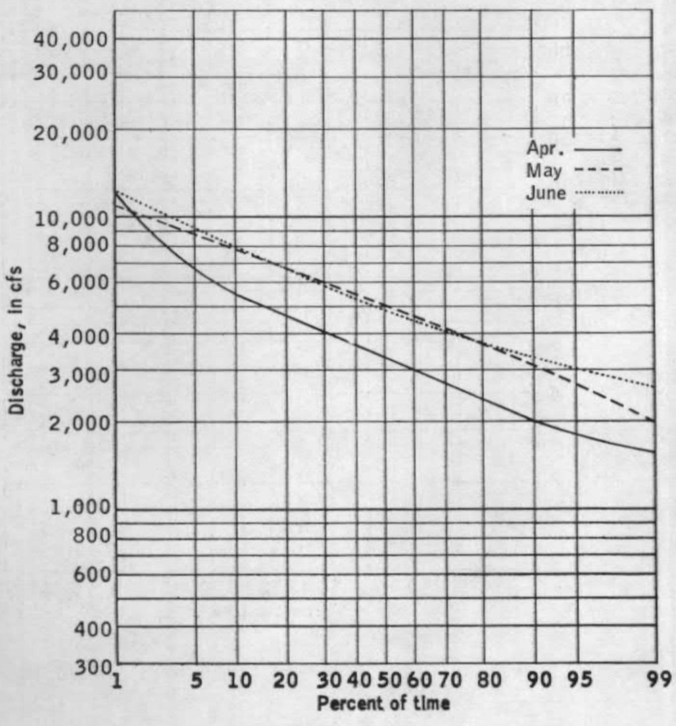


Figure 41c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1946-59.

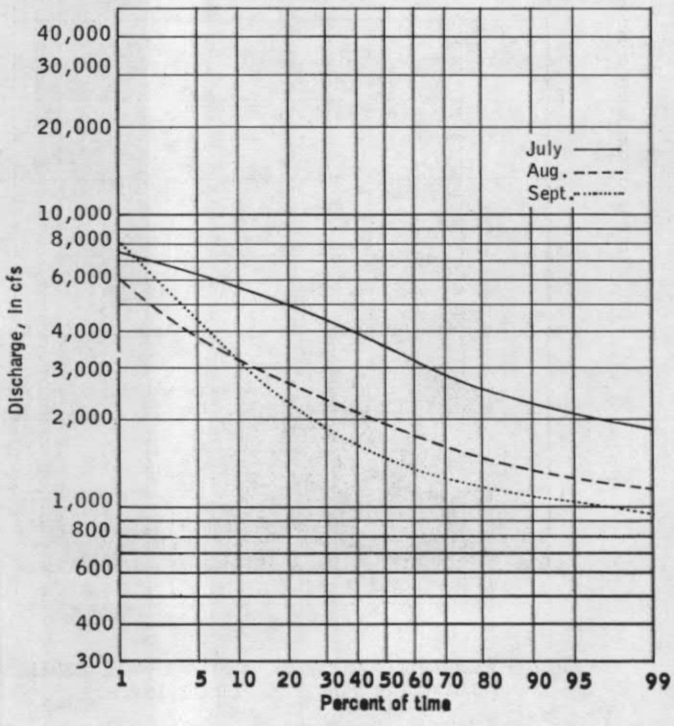


Figure 41d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1946-59.

FISHTRAP CREEK AT LYNDEN

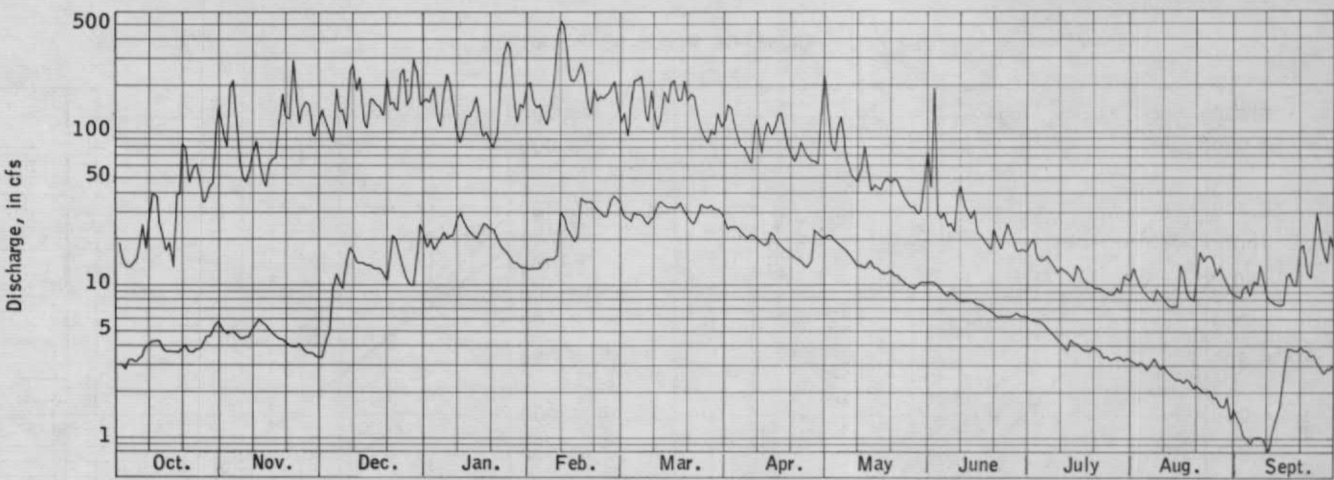


Figure 42. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1948-59.

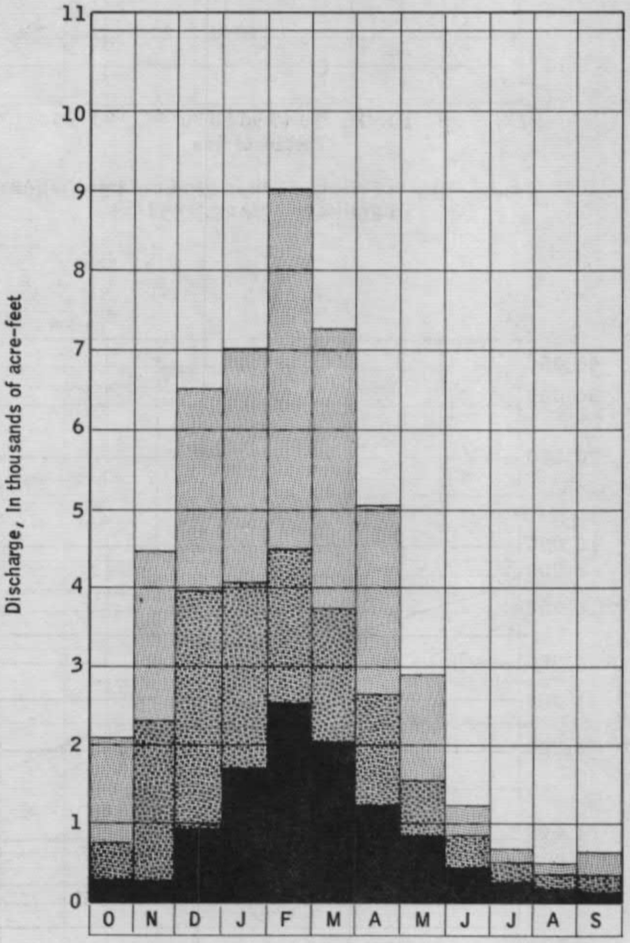


Figure 43. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1948-54.

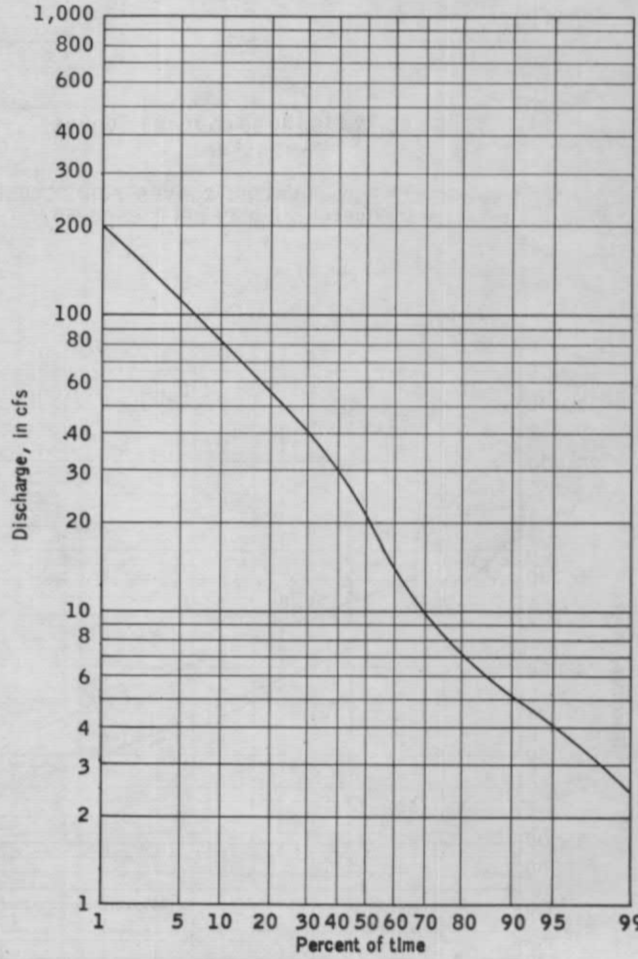


Figure 44. FLOW-DURATION CURVE FOR THE PERIOD 1949-59.

FISHTRAP CREEK AT LYNDEN

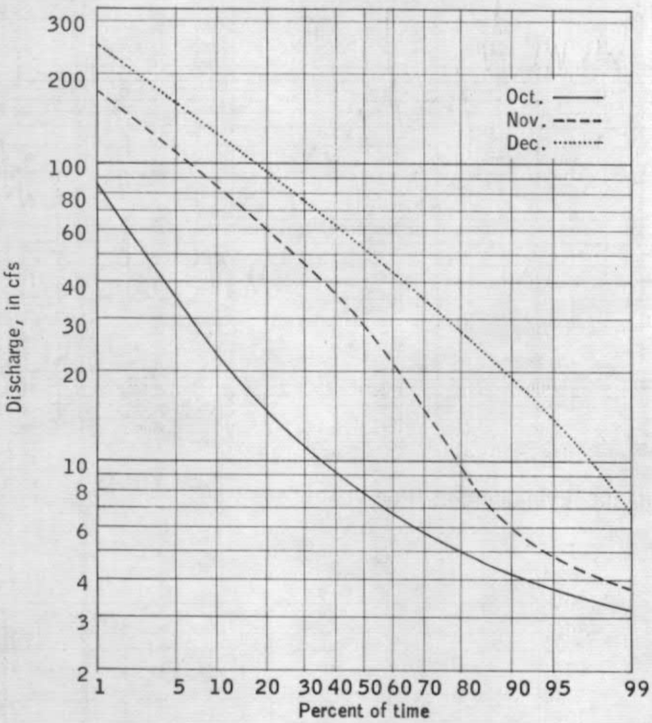


Figure 45a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1949-59.

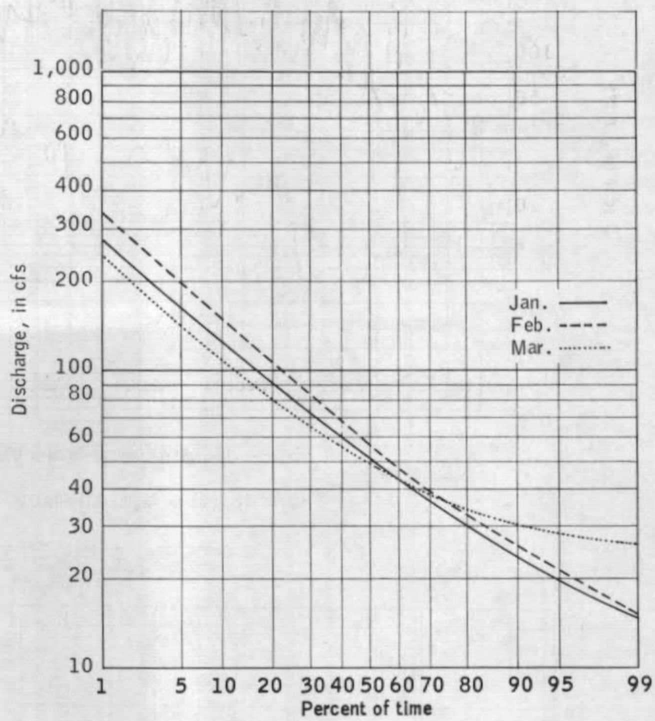


Figure 45b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1949-59.

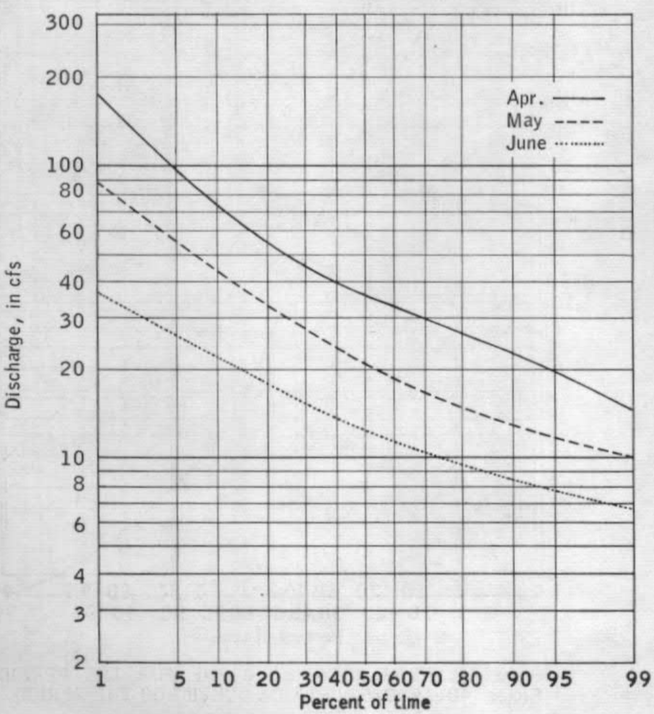


Figure 45c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1949-59.

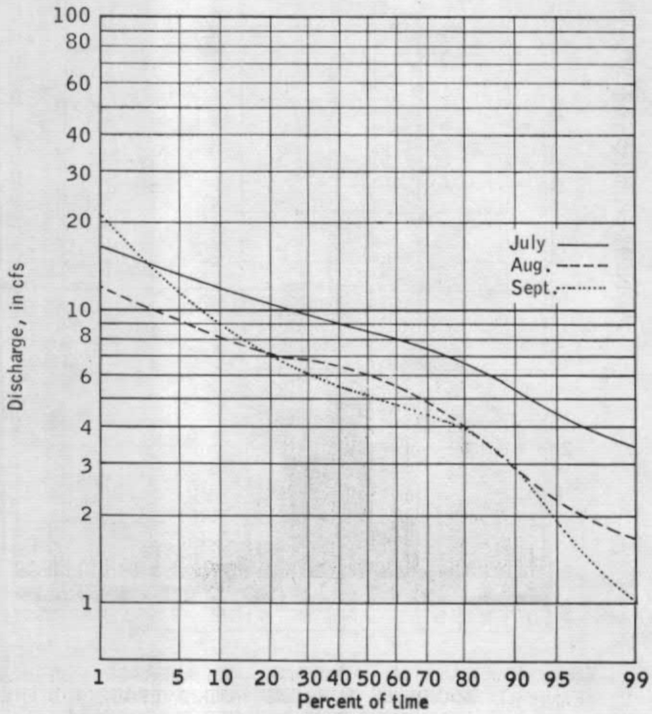


Figure 45d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1949-59.

DAKOTA CREEK NEAR BLAINE

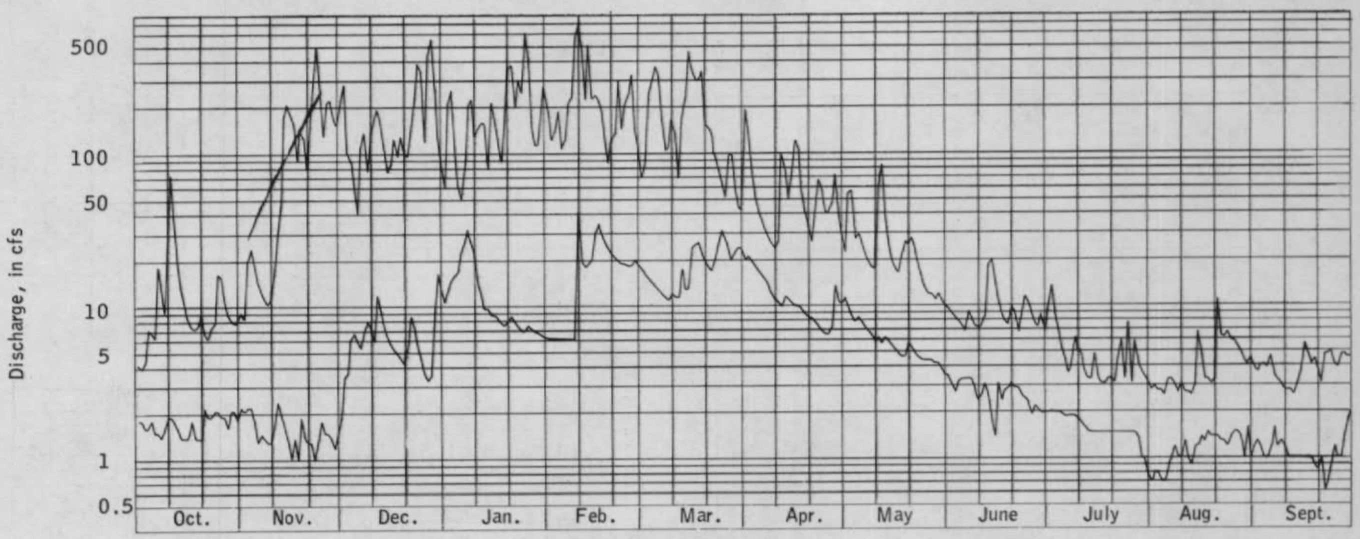


Figure 46. MAXIMUM-MINIMUM DISCHARGE HYDROGRAPHS FOR YEARS 1948-54.

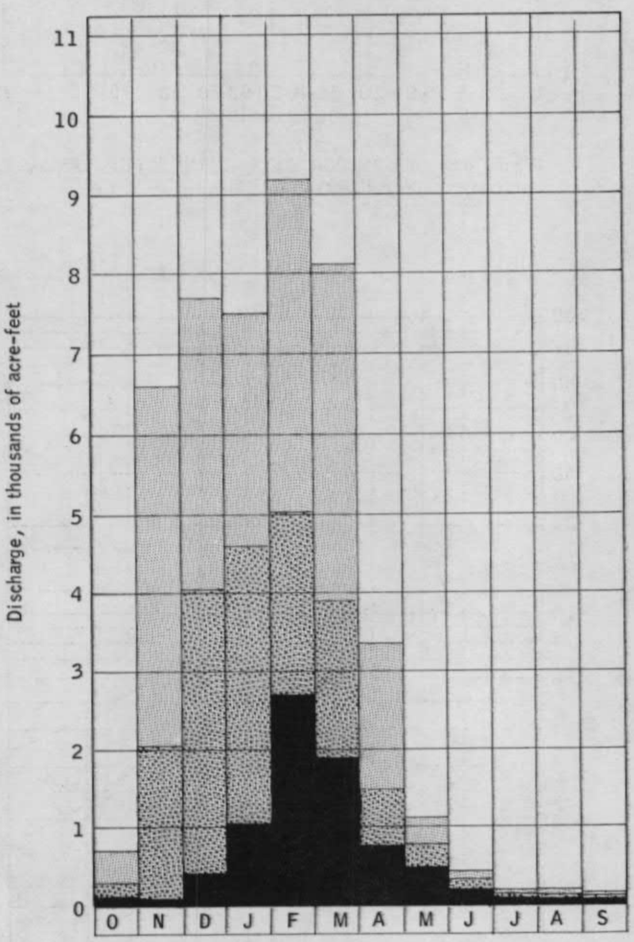


Figure 47. MAXIMUM, MINIMUM, AND AVERAGE MONTHLY DISCHARGE FOR THE PERIOD 1948-54.

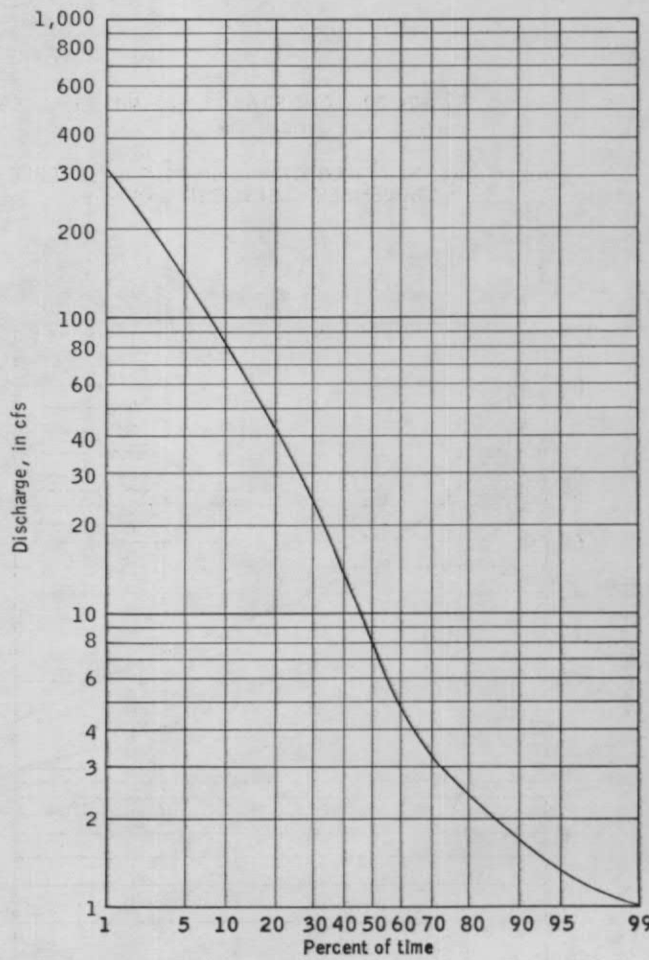


Figure 48. FLOW-DURATION CURVE FOR THE PERIOD 1945-53.

DAKOTA CREEK NEAR BLAINE

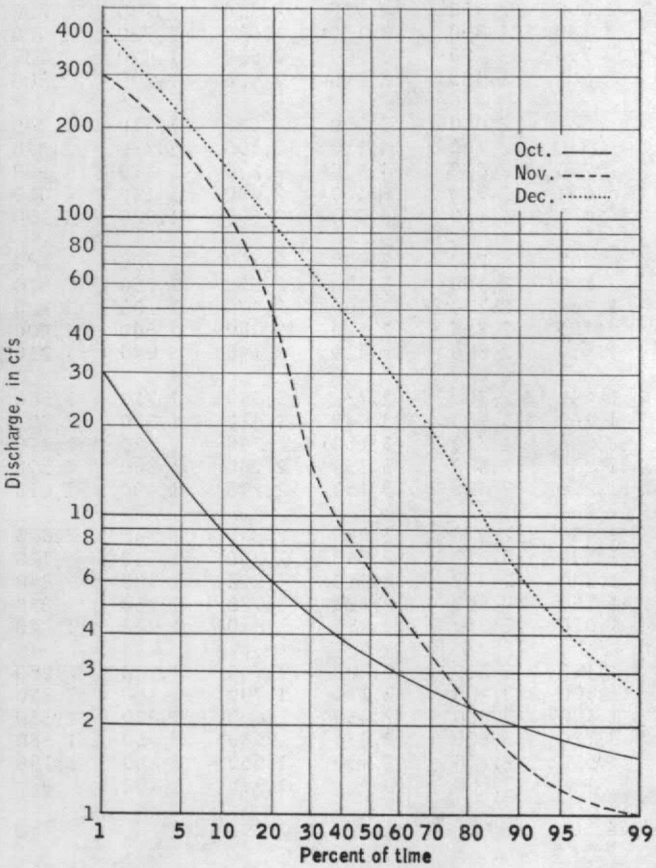


Figure 49a. FLOW-DURATION CURVES FOR OCTOBER, NOVEMBER, DECEMBER 1945-53.

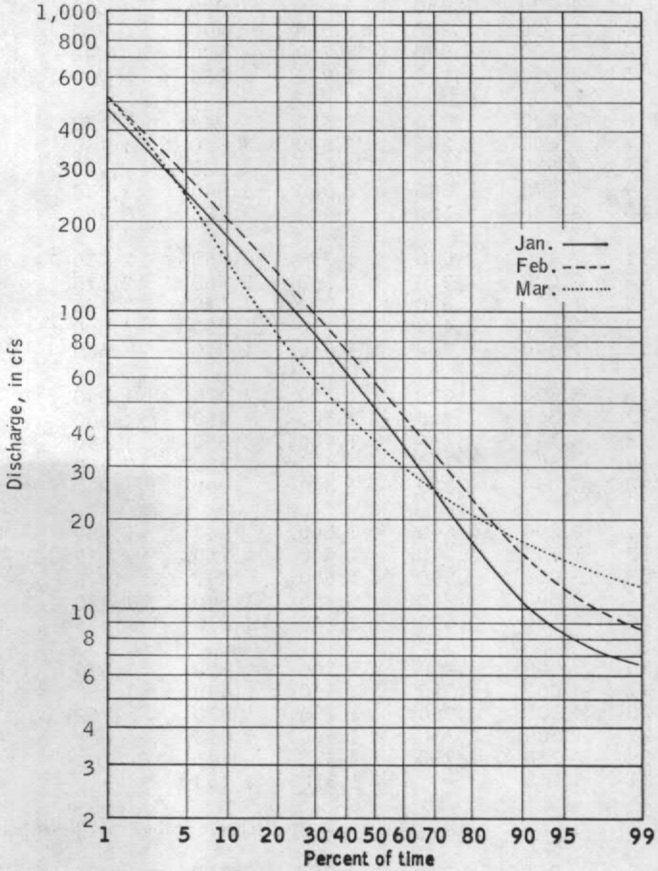


Figure 49b. FLOW-DURATION CURVES FOR JANUARY, FEBRUARY, MARCH 1945-53.

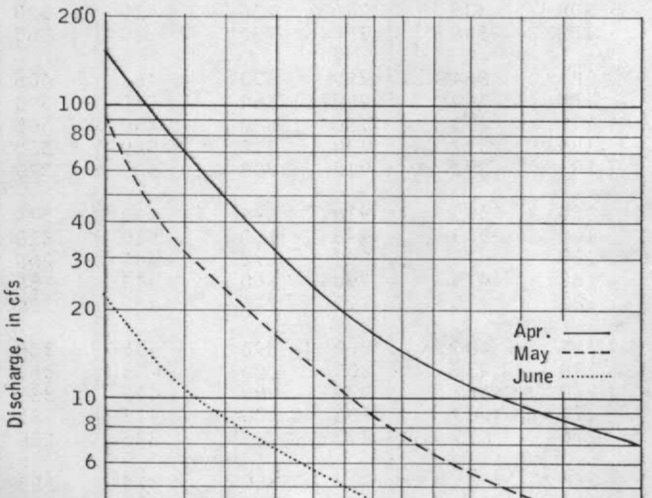


Figure 49c. FLOW-DURATION CURVES FOR APRIL, MAY, JUNE 1945-53.

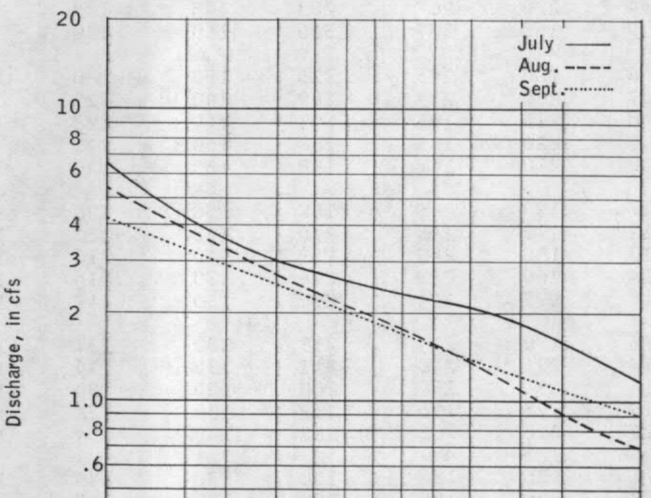


Figure 49d. FLOW-DURATION CURVES FOR JULY, AUGUST, SEPTEMBER 1945-53.

Table 6. Maximum - minimum daily discharge records, Nooksack River below Cascade Creek.

Maximum daily discharge of Nooksack River below Cascade Creek, near Glacier, for years 1947-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	1,830	2,040	3,810	2,900	1,400	776	1,170	2,020	2,900	2,730	3,280	1,050
2	1,800	1,350	5,400	1,820	1,030	760	1,200	1,750	2,900	2,530	1,780	1,230
3	1,730	5,260	2,550	1,400	954	922	1,140	1,350	3,150	2,530	1,720	1,400
4	1,900	4,040	1,750	990	842	1,220	790	1,400	3,000	2,630	1,420	2,130
5	1,080	2,060	1,950	884	720	990	660	1,480	3,250	2,630	1,290	2,580
6	1,020	1,920	1,650	944	680	820	584	2,000	3,650	2,530	1,310	1,940
7	1,660	1,290	2,500	1,610	1,100	655	610	2,100	4,150	2,330	1,330	1,310
8	2,530	1,650	3,650	1,120	2,080	574	790	2,080	4,300	2,290	1,370	1,300
9	1,970	1,840	2,060	1,640	1,880	940	831	1,920	6,100	2,480	1,180	1,000
10	2,930	2,100	3,400	1,180	3,940	979	610	2,120	4,580	2,500	1,080	1,150
11	2,100	2,000	1,790	1,450	2,730	650	909	2,240	3,970	2,390	1,080	1,140
12	2,000	1,250	1,360	2,460	2,310	535	880	2,490	3,650	2,750	1,050	870
13	1,570	1,850	1,020	1,570	2,450	485	1,260	2,750	2,900	2,470	1,180	1,100
14	1,680	2,400	1,150	1,200	2,550	445	1,450	2,750	2,520	3,080	1,580	1,400
15	1,600	1,980	1,640	1,510	1,500	588	1,510	2,680	2,420	3,140	3,040	1,210
16	2,800	1,620	1,590	1,330	1,040	810	1,440	2,300	2,730	3,040	1,710	1,380
17	3,360	1,740	1,300	1,450	1,060	790	1,260	1,960	3,040	2,410	1,390	995
18	4,100	3,190	1,460	1,390	1,390	820	2,000	2,570	3,150	2,240	1,320	1,170
19	4,800	4,120	1,400	730	1,480	790	1,280	2,680	3,150	2,180	1,360	1,590
20	3,850	2,020	1,800	900	970	816	1,220	2,680	3,150	2,290	1,430	1,610
21	2,250	2,640	1,540	880	1,080	820	1,400	2,270	3,040	2,320	1,390	1,050
22	1,750	4,270	1,470	950	1,010	790	1,540	2,250	2,840	1,990	1,510	1,120
23	2,050	1,830	1,600	897	876	710	1,340	2,370	2,910	1,920	1,900	848
24	3,500	1,240	3,980	1,500	1,920	930	1,150	2,350	2,220	1,920	1,360	1,280
25	6,600	2,630	2,240	1,010	1,670	1,090	1,010	2,550	1,980	1,840	1,220	1,840
26	3,800	3,260	1,360	850	1,850	800	1,120	3,000	2,100	1,730	1,180	2,030
27	4,000	4,390	1,360	620	1,080	830	1,300	3,400	2,110	1,700	1,180	1,190
28	4,800	2,060	1,150	670	752	780	1,300	3,650	2,430	1,600	1,080	1,380
29	1,500	2,250	1,500	1,090	-	690	3,120	3,300	2,830	1,530	1,050	1,380
30	2,230	2,750	1,370	725	-	770	3,620	2,760	2,930	1,560	1,260	3,190
31	3,120	-	1,350	1,450	-	670	-	3,050	-	1,910	1,100	-

Minimum daily discharge of Nooksack River below Cascade Creek, near Glacier, for years 1947-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	215	234	150	160	128	150	210	261	792	620	420	400
2	198	209	155	151	125	148	208	255	820	700	360	390
3	190	198	190	125	125	148	203	286	760	650	430	340
4	220	267	283	145	125	145	200	305	760	730	430	320
5	198	317	306	160	120	142	188	336	750	730	380	365
6	180	243	226	150	128	142	180	354	790	670	460	405
7	220	214	209	140	123	142	180	389	924	660	510	390
8	215	193	201	140	128	146	179	433	750	680	490	405
9	220	185	188	150	125	143	180	392	730	710	520	365
10	210	245	188	160	139	136	180	392	910	705	505	379
11	180	245	188	150	125	129	180	505	910	695	490	344
12	170	245	276	140	112	131	180	505	948	710	510	310
13	150	250	259	140	110	131	168	475	831	670	440	255
14	160	243	276	130	114	129	168	475	790	660	415	255
15	175	234	230	130	114	129	182	475	790	725	410	330
16	170	214	219	130	131	131	192	480	760	690	435	330
17	201	206	211	130	134	131	190	485	805	680	485	350
18	196	198	208	130	130	131	210	560	970	600	490	335
19	193	196	219	130	132	141	276	680	935	630	425	285
20	210	203	219	140	134	146	276	675	790	710	385	270
21	175	188	208	130	145	170	280	675	760	660	375	323
22	204	180	200	130	145	172	286	650	750	600	375	313
23	195	175	176	130	145	174	286	760	820	560	380	306
24	188	170	164	130	145	170	273	760	750	600	375	323
25	171	170	180	140	150	172	264	670	670	540	325	320
26	210	165	173	150	150	169	261	760	680	560	340	314
27	206	165	180	145	150	174	249	805	710	615	340	283
28	188	155	185	137	151	181	246	775	730	605	310	255
29	195	150	183	137	-	188	249	740	708	585	308	238
30	192	150	173	134	-	185	255	740	637	580	308	255
31	283	-	173	131	-	212	-	715	-	500	396	-

Table 7. Maximum - minimum daily discharge records, Canyon Creek near Kulshan.

Maximum daily discharge of Canyon Creek at Kulshan, for years 1948-54

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	30	34	440	60	266	56	63	95	91	128	26	42
2	30	31	325	290	165	55	53	140	112	112	25	43
3	197	74	100	359	198	336	43	101	139	91	29	62
4	74	67	60	119	154	345	42	74	164	89	29	50
5	48	64	46	66	103	199	47	141	130	85	22	40
6	55	45	71	47	91	142	68	161	120	78	19.5	34
7	76	40	100	60	266	80	58	165	98	79	19	29
8	106	32	76	73	404	64	46	157	111	73	74	25
9	68	28	75	212	1,030	54	47	185	80	71	44	23
10	246	36	400	135	1,400	46	50	185	77	71	31	21
11	82	48	255	202	1,200	40	82	213	139	62	26	19.5
12	56	86	175	553	300	36	85	210	150	52	27	17.5
13	44	74	104	475	150	52	97	198	242	54	26	15.5
14	80	98	70	230	100	43	87	176	138	63	25	15
15	76	95	73	239	112	54	93	159	116	61	91	19.5
16	48	74	120	351	106	50	112	126	168	63	50	34
17	34	74	232	148	127	122	112	149	178	56	31	106
18	131	179	145	179	84	108	97	141	158	48	23	46
19	228	339	108	176	51	130	122	172	161	54	19.5	95
20	210	89	224	132	42	170	85	180	161	45	76	57
21	113	69	255	130	39	120	138	143	124	42	92	40
22	73	104	175	132	54	100	234	110	120	41	178	89
23	73	234	279	571	90	63	242	104	120	38	280	68
24	57	176	526	351	134	66	144	123	84	44	90	46
25	45	621	295	750	106	95	100	90	77	42	62	54
26	36	586	122	328	175	61	122	106	90	56	63	56
27	41	559	204	122	106	58	180	192	99	46	75	35
28	117	438	568	100	64	82	155	129	112	37	56	91
29	88	195	241	128	-	61	103	95	132	33	44	91
30	52	164	117	190	-	53	92	78	115	30	43	141
31	40	-	78	563	-	43	-	75	-	28	54	-

Minimum daily discharge of Canyon Creek at Kulshan, for years 1948-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	5.6	17	5.6	14	10	17.5	23	34	29	19.5	3.4	2.0
2	5.4	13	6.4	13.5	10	16.5	24	30	34	18	3.2	2.0
3	5.0	11	7.6	13	10	15.5	25	29	38	16.5	3.2	1.6
4	4.8	11.5	14	12.5	9.8	15	26	36	47	17	3.1	1.6
5	4.6	14	22	12	9.5	15	31	42	42	15.5	2.8	1.4
6	4.4	12.5	16.5	11.5	9.5	15.5	29	37	44	14	2.8	1.4
7	4.2	10.5	13.5	11	9.5	15.5	26	38	48	13	2.5	1.6
8	4.2	9.1	15	11	9	16.5	22	41	39	12	2.5	2.0
9	4.2	8.2	13	12	9	15.5	21	42	37	11	2.5	2.0
10	4.0	12	13	12	11	14	20	44	38	10	2.4	2.0
11	3.9	17.5	13.5	11	13	14	20	53	40	9	2.6	1.8
12	3.9	20	16	11	10	23	20	55	34	7.6	2.5	1.6
13	3.7	18	15	10.5	9.2	22	20	77	27	7.0	2.0	1.4
14	3.7	14.5	14.5	10.5	9.6	19.5	17.5	64	26	6.5	2.0	1.2
15	3.4	12	19	10.5	9.6	18	17	56	29	6.5	2.0	1.2
16	3.0	10.5	17.5	9.5	9.6	16.5	18.5	63	40	6.2	2.0	1.0
17	3.0	9.7	16.5	9.5	30	16.5	23	64	34	5.6	1.8	1.0
18	2.9	9.1	15.5	10.5	27	18	28	60	31	5.4	1.8	1.0
19	2.9	8.8	14	10	25	16	42	48	29	5.2	1.8	1.0
20	3.7	9.7	13	10.5	24	14.5	45	43	28	5.0	1.6	1.0
21	5.2	9.4	18	10.5	22	14	39	49	28	4.6	1.6	1.0
22	5.0	8.8	17.5	10	21	13.5	35	72	28	4.6	1.4	1.0
23	5.0	8.2	15.5	9.5	19	14.5	32	63	27	4.4	1.4	1.0
24	15	7.6	14	12.5	17.5	17	31	55	27	4.2	1.4	1.2
25	14	7.3	13	12.5	16	27	32	51	26	4.4	1.4	3.4
26	13	6.8	12	13	16	29	33	59	24	4.0	1.4	3.6
27	9.7	6.6	12	13	19.5	28	35	50	23	3.7	1.8	4.8
28	8.2	6.4	12	12	19.5	26	34	42	22	3.7	3.1	4.8
29	8.5	6.2	13	12	-	27	33	34	21	3.4	2.8	5.2
30	20	6.0	14.5	11	-	28	35	28	20	3.6	2.8	5.2
31	22	-	14	11	-	24	-	27	-	3.6	2.4	-

Table 8. Maximum - minimum daily discharge records, South Fork Nooksack River near Wickersham.

Maximum daily discharge of South Fork Nooksack River near Wickersham, for years 1934-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	1,980	3,480	4,920	6,000	3,100	2,130	2,180	2,450	1,800	1,750	1,590	1,170
2	1,520	2,200	5,040	3,600	2,530	1,000	3,220	1,750	1,890	1,390	791	468
3	2,990	11,700	4,060	3,630	2,830	3,760	2,220	2,040	2,030	1,330	612	1,210
4	1,840	5,350	2,210	2,230	2,380	3,640	1,390	2,440	1,930	1,330	534	1,500
5	1,750	6,360	3,060	2,000	1,580	2,170	1,610	2,960	1,800	1,280	507	2,560
6	842	3,200	3,590	2,520	3,150	1,760	1,100	3,430	2,090	1,280	512	1,850
7	1,500	2,120	3,710	6,980	4,380	1,640	1,020	2,050	2,330	1,300	490	1,160
8	1,960	3,460	3,330	2,660	4,490	1,540	1,380	2,020	2,760	1,100	814	1,470
9	2,620	2,320	4,460	1,850	8,680	2,840	3,890	2,310	3,520	1,160	420	1,780
10	4,560	1,900	5,710	1,710	12,700	1,960	2,030	2,310	3,020	1,470	358	1,010
11	2,820	2,560	5,890	2,800	6,140	1,300	2,300	2,960	2,730	1,450	417	945
12	2,530	4,540	2,640	4,670	2,440	1,260	1,800	2,670	2,300	1,070	436	1,640
13	1,470	2,880	2,560	3,450	3,940	1,990	1,990	2,490	1,930	1,310	359	1,490
14	2,060	4,970	2,390	3,260	6,340	1,520	2,380	2,430	3,300	1,430	362	2,390
15	4,120	2,820	3,430	3,220	3,100	1,300	2,000	2,310	3,230	1,350	1,890	1,170
16	3,390	2,160	2,420	4,490	2,160	2,160	2,040	2,240	2,110	2,070	642	2,100
17	4,230	2,050	3,140	3,410	2,200	1,810	3,570	2,720	2,170	1,340	410	1,780
18	3,960	5,480	2,660	3,660	2,610	1,380	4,270	2,430	2,940	833	344	1,120
19	5,400	5,540	2,020	2,350	2,040	1,380	3,170	2,390	2,280	833	465	1,240
20	5,860	3,770	4,600	1,760	2,520	3,000	1,700	2,240	3,430	680	551	2,720
21	2,280	2,060	3,050	1,680	2,810	2,190	2,090	1,750	4,870	704	850	1,160
22	1,480	2,540	4,530	2,000	2,140	1,520	1,900	2,530	2,420	722	1,610	945
23	1,560	4,140	3,040	4,240	2,020	1,400	1,800	1,970	2,300	722	1,580	620
24	6,290	2,250	5,740	8,240	3,000	1,820	1,650	1,900	2,060	680	680	1,220
25	11,600	4,520	2,960	8,550	2,630	1,850	1,440	2,330	1,640	674	627	1,630
26	5,570	4,230	2,320	5,260	2,990	2,000	1,410	2,640	1,810	890	471	1,720
27	2,760	7,450	2,420	2,830	2,300	2,850	1,980	2,580	1,470	686	613	1,040
28	6,350	2,680	5,880	2,290	1,900	2,360	2,320	2,850	1,540	661	413	2,030
29	2,590	2,020	6,060	1,990	-	1,440	8,900	2,280	1,760	1,320	349	1,290
30	2,340	2,840	3,880	3,270	-	2,320	6,060	1,850	1,640	904	584	2,360
31	5,900	-	4,480	5,310	-	1,910	-	1,860	-	896	696	

Minimum daily discharge of South Fork Nooksack River near Wickersham, for years 1934-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	80	95	93	256	140	212	274	390	498	156	89	79
2	77	93	91	249	145	209	266	363	413	153	89	76
3	74	93	93	232	145	209	254	430	372	147	90	75
4	78	95	93	270	145	206	243	450	342	145	102	73
5	82	120	110	270	150	206	239	446	342	134	86	73
6	75	120	368	235	145	197	235	501	335	129	84	71
7	70	105	347	220	140	190	232	559	415	127	85	70
8	69	98	390	215	95	236	232	446	376	124	83	68
9	77	95	345	210	120	274	240	394	329	122	82	74
10	88	93	335	200	135	262	256	390	355	119	80	67
11	87	107	311	200	165	273	327	472	338	117	80	66
12	86	115	315	195	180	270	382	446	368	114	81	66
13	86	107	288	190	188	263	363	422	329	119	79	76
14	85	100	274	185	165	248	372	432	282	122	77	82
15	84	98	260	175	175	245	387	390	260	112	77	78
16	84	98	249	170	170	250	445	481	228	110	77	77
17	82	172	239	165	150	240	404	471	230	110	75	77
18	80	159	226	160	160	236	368	435	248	107	75	80
19	80	154	219	155	170	230	350	573	216	100	73	78
20	86	186	206	150	180	222	359	523	206	100	71	74
21	90	156	200	150	186	232	386	501	212	100	71	72
22	91	137	203	145	176	249	408	519	200	98	70	70
23	88	123	242	145	224	307	413	525	194	94	72	69
24	92	115	230	140	231	295	390	574	203	94	72	67
25	90	112	220	140	219	269	404	491	203	94	72	67
26	97	105	220	140	216	261	432	390	190	100	70	67
27	104	103	212	135	212	288	410	340	175	99	70	73
28	94	98	216	135	216	348	368	347	164	97	76	73
29	103	95	229	135	-	318	385	381	161	97	79	72
30	103	93	222	135	-	298	410	404	158	93	76	74
31	100	-	239	135	-	286	-	494	-	91	76	-

Table 9. Maximum - minimum daily discharge records, Skookum Creek near Wickersham.

Maximum daily discharge of Skookum Creek near Wickersham, for years 1948-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	391	592	1,210	317	444	302	634	328	268	324	275	97
2	252	290	1,020	382	304	170	368	290	296	221	150	127
3	487	956	400	460	392	800	220	220	352	264	112	212
4	291	450	300	195	325	900	182	258	358	212	98	199
5	239	343	280	511	226	550	258	391	283	207	92	510
6	164	346	296	464	246	400	235	373	299	197	91	311
7	238	233	228	403	469	314	168	343	318	212	91	182
8	372	212	207	269	579	308	240	414	517	191	168	234
9	257	440	567	471	1,280	468	494	434	562	179	94	127
10	597	354	474	413	1,690	296	296	434	542	264	74	94
11	287	420	408	467	862	181	235	508	464	183	74	99
12	306	525	434	593	400	154	260	476	397	195	85	67
13	246	298	296	467	346	136	307	448	318	224	77	69
14	274	454	271	290	218	136	282	434	248	236	69	84
15	486	325	409	438	750	184	259	394	285	219	294	218
16	387	403	430	586	400	166	349	323	400	202	97	390
17	718	442	394	436	301	400	304	411	385	157	69	264
18	411	780	490	304	526	350	282	445	361	142	57	179
19	480	1,010	411	331	366	381	285	480	385	160	66	171
20	840	419	620	260	349	486	335	380	352	119	138	193
21	401	407	450	203	560	360	405	294	340	122	285	110
22	280	491	408	290	519	246	362	329	329	121	416	248
23	214	422	445	600	394	245	329	329	338	138	351	122
24	260	355	730	450	434	178	271	259	243	121	177	252
25	549	403	460	890	401	172	260	253	209	113	134	269
26	350	883	311	500	582	142	274	285	269	164	117	235
27	264	1,260	440	250	350	145	388	478	269	118	122	212
28	282	582	1,020	362	260	187	378	263	296	121	93	274
29	368	385	495	276	-	268	928	300	279	181	82	225
30	387	521	329	527	-	242	660	341	285	144	141	574
31	682	-	371	755	-	328	-	323	-	162	157	-

Minimum daily discharge of Skookum Creek near Wickersham, for years 1948-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	23	35	22	38	24	46	46	60	91	44	26	23
2	22	26	24	34	23	44	46	63	101	42	25	22
3	22	24	33	28	23	41	73	69	96	42	26	21
4	21	26	84	30	22	39	67	88	96	45	24	20
5	21	31	70	31	22	41	62	100	102	46	23	19
6	21	25	61	33	23	40	58	102	105	48	22	18.5
7	20	23	59	34	23	38	59	96	90	45	23	17.5
8	20	22	71	37	22	46	58	91	80	44	23	17.5
9	20	21	50	40	19	45	56	96	82	42	22	19
10	20	45	50	38	32	44	55	111	78	40	20	20
11	20	66	51	35	26	41	58	106	72	39	21	20
12	19	61	72	33	23	38	58	84	68	39	21	18.5
13	19	53	67	32	23	36	57	74	68	37	20	19.5
14	18.5	42	67	32	24	36	55	83	64	35	20	19
15	18.5	37	68	30	23	37	56	116	65	33	20	19
16	18	30	63	29	62	41	67	128	73	33	20	19
17	18	28	58	28	41	41	84	126	83	33	19	19
18	18	27	57	29	40	41	85	139	83	32	19	18.5
19	18	28	49	29	37	38	81	121	82	32	19	18.5
20	20	31	51	35	36	37	79	118	78	32	18.5	18
21	23	27	50	29	40	43	85	144	77	31	18.5	17.5
22	19	26	53	28	38	43	84	155	70	31	18.5	17.5
23	19	25	44	28	37	47	78	136	72	30	19	17
24	40	24	40	30	38	44	82	128	65	30	18.5	20
25	28	23	36	31	47	42	74	121	57	29	18.5	23
26	23	22	35	32	41	41	73	123	54	29	18.5	24
27	21	21	34	30	42	46	68	111	70	29	20	22
28	19.5	20	39	28	46	47	64	99	64	28	20	25
29	24	19.5	46	27	-	45	64	88	54	28	24	24
30	50	21	42	26	-	44	63	84	49	27	20	23
31	43	-	41	25	-	43	-	80	-	26	26	-

Table 10. Maximum - minimum daily discharge records, Nooksack River near Lynden.

Maximum daily discharge of Nooksack River near Lynden, for years 1944-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	11,000	16,500	9,120	10,000	16,500	9,180	15,000	14,600	9,000	7,930	8,450	3,250
2	6,350	10,600	23,800	10,600	10,000	6,000	14,800	9,110	7,750	7,990	6,080	2,780
3	8,630	24,100	13,500	11,700	9,140	6,460	7,830	8,700	8,700	6,820	4,290	5,520
4	7,950	31,400	7,570	6,340	9,050	20,100	6,050	8,700	8,480	7,180	3,810	4,520
5	5,040	14,000	8,860	6,810	7,080	11,700	5,180	7,570	9,790	7,000	3,420	11,300
6	3,900	9,370	11,800	11,600	6,020	10,800	4,870	8,800	8,700	7,290	3,400	10,100
7	5,920	6,450	6,770	17,300	9,470	7,740	4,080	7,970	10,400	6,830	3,690	5,590
8	6,040	6,610	5,150	16,300	17,600	6,120	4,050	7,880	10,800	6,870	3,760	7,880
9	5,450	6,020	12,600	8,560	27,700	7,720	8,620	9,080	14,900	6,460	3,130	4,870
10	12,900	13,000	13,700	7,860	39,000	8,180	9,040	9,840	16,200	6,540	2,890	3,880
11	10,200	7,700	22,300	7,410	34,600	5,250	5,670	10,400	13,200	7,380	3,010	2,970
12	7,650	18,800	11,500	14,100	18,800	4,030	7,390	11,000	12,200	6,010	3,130	2,730
13	8,960	9,620	7,630	13,200	10,200	3,510	7,030	11,200	10,100	7,020	2,780	2,610
14	5,140	11,500	6,820	10,200	16,000	3,500	5,200	10,600	7,550	7,970	2,780	2,680
15	8,710	12,000	6,080	7,390	12,900	3,900	5,540	10,200	7,000	8,530	7,000	2,900
16	13,600	7,940	5,300	10,900	9,970	5,000	5,950	9,270	9,100	8,150	5,210	6,000
17	11,700	6,580	9,450	16,000	12,700	6,640	7,740	7,680	10,800	7,180	3,390	6,600
18	16,400	13,700	8,320	7,940	6,510	7,180	6,200	9,160	10,300	5,850	2,810	3,800
19	21,300	20,000	7,070	6,900	6,770	8,200	7,560	9,910	10,600	5,250	2,860	5,700
20	20,000	14,500	15,100	7,200	8,400	10,400	7,390	9,870	10,600	5,220	3,810	4,600
21	13,400	12,100	12,000	7,000	10,000	8,000	7,560	8,200	9,710	5,150	4,250	3,640
22	8,330	20,700	8,900	7,600	11,500	6,340	8,140	8,600	9,250	4,830	5,360	4,110
23	7,600	12,500	9,300	12,100	10,000	4,600	6,970	8,140	9,340	4,970	10,300	4,020
24	7,370	11,200	17,800	18,900	9,050	4,020	7,030	8,300	8,060	5,050	5,740	2,940
25	38,700	11,700	23,900	17,600	11,600	4,260	5,520	8,800	6,390	4,580	4,160	9,270
26	38,100	18,800	10,100	17,800	11,900	4,590	6,680	10,600	6,510	4,300	3,630	6,420
27	13,700	30,900	8,120	7,360	9,560	6,340	6,180	11,600	8,510	4,320	4,160	5,300
28	7,750	15,800	23,600	6,250	6,680	4,880	7,600	12,200	7,160	3,900	3,500	5,540
29	5,680	9,180	18,400	6,400	-	4,800	17,200	10,600	8,500	4,440	3,010	4,200
30	8,010	10,300	9,120	8,060	-	4,830	31,700	8,700	8,700	5,000	3,500	7,250
31	20,400	-	6,120	12,800	-	6,040	-	9,130	-	4,650	4,300	-

Minimum daily discharge of Nooksack River near Lynden, for years 1944-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	1,040	1,230	625	890	900	1,660	1,620	1,860	2,700	1,900	1,570	1,100
2	1,050	1,030	630	850	880	1,620	1,630	1,830	2,860	1,920	1,490	1,130
3	1,020	908	678	830	860	1,530	1,880	1,830	3,270	2,140	1,490	1,160
4	980	926	945	810	860	1,410	1,780	2,000	3,420	2,110	1,420	1,020
5	976	1,080	1,770	850	850	1,380	1,640	2,300	3,420	2,300	1,300	1,120
6	928	984	1,610	1,000	850	1,400	1,590	2,500	3,760	2,500	1,470	1,010
7	938	900	1,310	900	850	1,380	1,570	2,660	3,630	2,320	1,560	1,170
8	962	816	1,500	900	850	1,410	1,600	2,760	3,390	2,100	1,520	1,300
9	944	772	1,400	1,000	880	1,500	1,720	2,990	3,390	2,300	1,410	1,280
10	902	780	1,260	1,100	1,340	1,450	1,720	2,660	3,510	2,360	1,420	1,230
11	908	1,080	1,200	1,000	1,400	1,400	1,710	3,500	3,280	2,410	1,340	1,130
12	890	1,340	1,940	900	1,200	1,480	1,680	3,340	3,060	2,400	1,340	1,040
13	848	1,300	2,110	860	1,180	1,440	1,640	2,770	2,840	2,150	1,370	1,010
14	778	1,240	2,030	840	1,150	1,400	1,600	2,670	2,660	1,940	1,410	1,070
15	739	1,130	1,920	800	1,100	1,360	1,760	3,010	2,880	1,940	1,410	1,050
16	712	1,020	1,880	760	1,340	1,360	1,850	3,010	3,130	2,100	1,410	1,050
17	706	926	1,790	740	1,320	1,410	2,000	3,010	3,340	2,320	1,380	1,050
18	706	866	1,660	760	1,390	1,460	2,150	2,780	3,440	2,160	1,340	1,070
19	739	838	1,580	760	1,370	1,430	2,310	3,630	3,520	2,160	1,240	1,160
20	728	849	1,450	880	1,310	1,390	2,230	3,760	3,170	2,070	1,180	1,100
21	849	866	1,390	800	1,240	1,430	2,290	3,630	2,900	2,000	1,150	900
22	783	800	1,420	740	1,260	1,380	2,440	3,630	2,660	2,130	1,120	950
23	750	756	1,310	720	1,390	1,400	2,500	3,700	2,650	2,020	1,120	952
24	1,380	739	1,220	1,000	1,410	1,710	2,350	3,430	2,990	1,890	1,150	925
25	1,340	706	1,140	1,000	1,490	1,510	2,140	3,190	2,590	1,840	1,180	1,070
26	956	684	1,070	1,050	1,480	1,470	2,040	3,270	2,920	1,720	1,160	1,060
27	810	656	1,050	1,100	1,450	1,470	1,940	3,900	3,010	1,640	1,200	980
28	756	635	1,050	970	1,490	1,650	1,820	3,390	3,130	1,940	1,200	1,100
29	750	615	1,150	950	-	1,610	1,780	3,150	2,460	2,010	1,200	1,080
30	1,350	605	1,200	930	-	1,600	1,780	2,810	2,110	1,730	1,150	1,150
31	1,710	-	1,000	900	-	1,570	-	2,600	-	1,570	1,100	-

Table 11. Maximum - minimum daily discharge records, Fishtrap Creek at Lynden.

Maximum daily discharge of Fishtrap Creek at Lynden, for years 1948-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	18.5	107	139	164	207	132	150	136	44	19	13	8.4
2	14.5	80	115	154	153	93	146	87	195	20	11	8.2
3	13	195	102	200	145	142	112	73	30	15	9.8	9.6
4	13	214	86	126	150	217	95	97	27	14.5	8.9	9.9
5	13.5	113	190	109	121	217	80	125	30	14.5	8.4	8.4
6	14.5	66	136	176	110	223	80	80	24	15.5	8.1	10.5
7	19	50	139	240	151	160	70	61	25	14.5	7.9	10
8	25	47	104	194	213	118	62	52	22	13.5	9.4	13.5
9	17	54	252	140	417	188	108	50	38	12	8.6	10.5
10	29	74	278	104	533	145	127	46	44	13	8.1	8.6
11	39	89	184	85	499	102	72	56	34	12.5	7.6	7.8
12	38	62	226	106	302	125	96	80	30	12	7.1	7.6
13	26	55	127	129	211	180	115	55	27	11.5	7.1	7.4
14	20	44	106	126	212	154	96	41	31	10.5	7.1	7.3
15	16.5	61	164	140	235	206	102	45	22	13.5	13.5	7.4
16	19	67	162	170	282	216	130	43	21	12	11.5	11.5
17	13	67	151	115	246	159	134	42	19.5	10.5	8.8	12
18	39	121	145	94	164	160	102	48	18.5	10	8.1	9.8
19	39	179	127	100	130	212	82	50	17	10	7.9	9.8
20	82	125	233	89	194	160	72	46	23	9.8	11.5	17
21	80	121	151	79	159	174	64	50	19	9.5	16.0	18
22	46	298	155	97	169	169	72	48	17	9.5	14.0	12
23	60	170	138	208	164	126	87	41	21	9.2	15.5	11
24	61	115	241	327	174	104	75	37	25	8.9	15.5	17
25	51	145	257	390	184	92	70	34	22	8.7	14.5	30
26	34	157	149	348	212	85	64	32	19	8.9	11.5	21
27	35	152	167	158	160	102	64	32	16.5	9.5	13	17
28	44	96	300	116	115	96	62	29	17	9.0	11.5	14
29	46	94	250	154	-	134	132	30	17	11.5	9.9	21
30	102	121	150	144	-	109	235	53	16.5	11	9.0	17
31	153	-	159	202	-	118	-	74	-	10.5	8.7	-

Minimum daily discharge of Fishtrap Creek at Lynden, for years 1948-59

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	3.0	5.0	3.4	17.5	13	28	23	21	10.5	6.0	3.1	1.3
2	3.0	4.8	4.2	20	14	27	24	21	10.5	6.0	3.0	1.2
3	2.8	5.0	5.0	17	14	26	24	20	10	5.8	3.1	1.0
4	3.2	5.0	9.7	18	14	30	24	19	9.2	5.8	3.0	1.0
5	3.2	4.8	12	20	14.5	29	22	18	8.9	5.6	2.8	0.9
6	3.1	4.5	10.5	22	15	29	21	17.5	8.6	5.1	3.8	1.0
7	3.3	4.5	9.4	20	15	28	20	16	8.9	5.0	3.3	1.0
8	3.4	4.6	14	21	15	25	21	15.5	8.6	4.6	3.0	1.0
9	4.0	4.6	17.5	21	15.5	27	21	14	8.3	4.4	2.8	1.0
10	4.1	5.2	16	28	30	28	20	13.5	8.0	4.1	3.0	0.8
11	4.3	5.6	14	30	28	34	19	13.5	8.0	4.0	2.7	0.9
12	4.3	6.0	14	25	23	35	18	13	8.0	3.7	2.6	1.2
13	4.3	5.6	14	23	21	34	18.5	13.5	8.0	4.4	2.5	0.9
14	3.8	5.4	13.5	22	19	32	22	14.5	7.8	4.1	2.4	1.6
15	3.6	5.0	13.5	21	21	32	21	13	7.5	4.1	2.4	2.4
16	3.6	4.8	13	20	37	32	19	13	7.5	3.8	2.3	3.8
17	3.6	4.6	13	23	35	32	18	12	7.2	3.7	2.4	3.8
18	3.6	4.4	13	25	35	34	17	12	7.0	3.7	2.3	3.7
19	3.6	4.4	12	24	35	31	16.5	12	7.0	3.7	2.1	3.7
20	3.8	4.2	10.5	23	33	28	16	12.5	6.5	4.0	2.2	3.9
21	4.0	4.0	15	23	31	26	15.5	11.5	6.2	3.8	2.1	3.7
22	3.6	4.0	21	20	30	25	15	11.5	6.2	3.7	2.0	3.7
23	3.6	4.0	19.5	18	28	28	14.5	11	6.2	3.3	2.0	3.4
24	3.8	4.1	15	17	28	34	13.5	10.5	6.2	3.4	2.0	3.5
25	3.8	3.8	13	16	36	32	13	10	6.2	3.2	1.8	3.0
26	4.0	3.6	11	15	38	32	14	9.8	6.5	3.3	1.8	2.8
27	4.6	3.6	10	14	36	33	23	9.5	6.5	3.4	1.6	2.6
28	4.6	3.6	10	14	32	31	22	9.8	6.2	3.4	1.6	2.8
29	5.0	3.4	16	13	-	31	21	10.5	6.2	3.2	2.0	2.8
30	5.6	3.4	25	13	-	30	20	10.5	6.2	3.3	1.3	3.0
31	5.8	-	22	13	-	28	-	10.5	-	3.2	1.6	-

Table 12. Maximum - minimum daily discharge records, Dakota Creek near Blaine.

Maximum daily discharge of Dakota Creek near Blaine, for years 1948-54

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	4.2	9.2	220	59	186	70	192	22	9.6	9.9	2.8	3.9
2	3.9	8.4	281	218	120	83	128	107	8.8	12.5	3.0	3.6
3	4.4	20	100	262	142	244	77	57	8.4	8.9	2.8	4.1
4	7.2	24	90	100	189	295	52	27	8.1	6.6	2.8	4.1
5	6.8	18.5	58	61	106	368	40	30	7.4	5.3	2.6	3.9
6	6.2	14.5	41	50	123	328	38	26	6.8	4.5	3.3	4.6
7	18.5	13	108	80	210	156	32	22	9.2	3.6	3.3	7.0
8	13	11.5	136	201	230	104	28	20	8.4	4.4	3.1	3.2
9	9.2	10.5	77	228	587	108	25	17.5	7.2	6.2	2.7	3.1
10	24	11	127	130	717	180	24	17.5	7.2	5.2	3.1	2.8
11	73	16.5	159	148	521	134	26	62	7.2	4.9	2.7	2.8
12	33	30	192	159	223	68	100	84	8.4	3.7	2.7	2.8
13	18	45	164	158	519	173	80	38	18.5	3.3	2.6	2.6
14	13.5	173	108	79	228	230	49	25	20	3.3	2.9	3.1
15	10.5	210	75	218	240	474	72	20	14	4.8	6.8	3.7
16	8.4	182	83	169	220	344	120	17.5	11	3.3	4.9	5.7
17	7.4	156	124	112	190	303	108	16.5	8.7	3.1	3.3	4.9
18	7.2	90	95	88	115	300	55	21	7.9	3.1	3.3	4.1
19	7.4	140	129	163	86	345	40	26	7.5	3.3	3.1	4.5
20	9.2	128	100	360	121	156	34	25	9.9	3.3	3.2	3.7
21	6.8	80	97	380	135	148	26	28	8.9	3.1	11.0	3.1
22	6.2	152	141	200	298	128	42	24	6.6	4.6	6.4	4.8
23	7.4	280	233	307	144	94	67	18.5	8.9	5.9	6.2	4.8
24	7.8	500	388	249	210	76	58	15	11.5	3.3	6.7	5.1
25	16.5	250	345	601	242	63	40	13	10.5	7.8	5.9	4.1
26	16	130	116	386	325	51	40	12	8.7	3.1	5.9	3.9
27	11	215	444	148	144	97	46	12	7.5	5.9	5.3	4.8
28	9.2	220	574	112	100	98	73	11	7.2	4.3	5.1	4.8
29	8.1	170	269	113	-	55	38	12	8.8	3.7	4.3	4.6
30	7.8	150	124	201	-	47	28	10.5	6.5	3.4	4.1	4.6
31	8.1	-	83	260	-	44	-	10	-	3.2	4.6	-

Minimum daily discharge of Dakota Creek near Blaine, for years 1948-54

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	1.8	2.2	1.9	10.5	6.2	17.5	20	11.5	3.5	2	0.7	1.2
2	1.8	2.1	3.5	13	6.2	16	21	9.6	3.1	2	0.8	1.3
3	1.6	2.2	3.7	15	6.2	15	19.5	8.4	2.7	2	0.8	1.2
4	1.6	2.2	6.2	16	6.1	14.5	18.5	7.8	3.2	2	0.7	1.0
5	1.8	1.8	6.8	17	6.2	13.5	17	8.4	3.3	2	0.7	1.0
6	1.5	1.3	5.9	23	6.2	13	16	8.1	3.3	1.9	0.9	1.2
7	1.5	1.5	5.4	26	6.1	12	15	7.2	3.3	1.9	1.0	1.6
8	1.4	1.4	7.2	32	6	11.5	14	6.8	3.3	1.9	1.2	1.2
9	1.6	1.3	8.1	27	6	11	12	6.5	2.9	1.9	1.0	1.3
10	1.9	1.3	7.4	23	45	12	11	5.9	2.4	1.8	1.0	1.2
11	1.9	1.8	5.9	14	20	11.5	10.5	6.2	2.6	1.7	1.3	1.0
12	1.8	2.4	12	12	18	11.5	10	5.6	3.1	1.6	1.0	1.0
13	1.6	1.9	9.2	9.6	19	17.5	11.5	6.2	2.6	1.5	0.9	1.0
14	1.4	1.6	7.4	9.6	20	13	11	5.9	1.8	1.5	1.2	1.0
15	1.4	1.3	6.2	8.8	30	13	10.5	5.4	1.4	1.5	1.2	1.0
16	1.4	1.0	5.6	8.8	35	24	10	5.2	3.1	1.5	1.4	1.0
17	1.8	1.4	5.2	8.4	30	25	10	4.9	2.4	1.5	1.3	1.0
18	1.4	1.0	4.9	7.8	26	26	9.6	4.6	2.8	1.5	1.5	1.0
19	1.4	1.9	4.6	7.5	24	23	8.8	4.6	2.9	1.5	1.4	0.9
20	1.4	1.4	4.2	8	22	20	8.4	5.6	3.1	1.5	1.4	0.8
21	2.2	1.3	5.6	8.7	21	18	8.4	5.4	2.9	1.5	1.4	1.0
22	1.9	1.3	8.8	8	20	17	7.8	4.9	2.9	1.5	1.3	0.6
23	1.9	1.0	7.2	7.5	19	20	7.2	4.6	2.6	1.5	1.3	0.7
24	2.1	1.3	5.6	7	19	26	6.8	4.4	2.5	1.5	1.2	0.9
25	2.1	1.8	4.6	7	18.5	31	6.5	4.4	2.4	1.5	1.4	1.2
26	1.9	1.5	3.7	7.5	18.5	28	6.5	4.4	1.9	1.5	1.5	1.0
27	1.9	1.5	3.3	7.2	20	24	7.2	4.4	2.2	1.5	1.5	1.0
28	1.6	1.4	3.5	7	18.5	19.5	13.5	4.2	2.1	1.4	1.4	1.4
29	2.1	1.2	8.8	6.8	-	22	10.5	4.2	2.0	1.0	1.0	1.8
30	2.1	1.5	16.5	6.6	-	24	10.5	3.9	2.0	1.0	1.6	2.1
31	1.8	-	13	6.4	-	24	-	3.5	-	0.8	1.0	-

Table 13. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1938-59. Nooksack River below Cascade Creek.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	74,980	92,420	83,240	50,840	43,960	34,990	51,420	98,650	156,300	120,200	77,510	57,190
Minimum	16,910	12,880	15,830	10,940	9,510	11,710	18,560	46,980	53,150	44,570	29,090	24,860
Average	43,300	40,300	39,660	24,050	22,300	20,300	32,560	72,600	89,110	78,700	45,600	34,760

Table 14. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1938-59. Nooksack River below Cascade Creek.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	3,600	1,900	1,400	950	700	580	480	400	340	290	240	215	180
November	3,200	1,700	1,250	900	720	600	520	450	390	330	270	230	180
December	2,700	1,500	1,150	850	680	580	500	430	370	310	250	220	180
January	1,550	980	780	580	480	410	360	310	270	230	190	165	135
February	1,800	1,000	740	520	410	340	290	250	220	190	165	145	125
March	1,000	660	540	420	360	310	280	250	220	200	180	160	140
April	1,600	1,100	920	740	620	540	480	420	370	320	260	230	180
May	2,900	2,300	2,000	1,600	1,400	1,200	1,100	960	840	700	560	450	330
June	3,700	2,600	2,200	1,800	1,600	1,450	1,350	1,250	1,150	1,050	920	840	720
July	2,700	2,200	1,950	1,650	1,450	1,300	1,150	1,020	920	820	720	660	580
August	1,700	1,300	1,100	940	830	750	700	630	580	520	450	410	350
September	1,700	1,100	900	700	610	550	500	460	430	390	350	320	270
Period	2,800	1,850	1,500	1,120	880	700	580	480	390	320	240	200	150

Table 15. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1949-53. Canyon Creek at Kulshan.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	3,720	6,110	9,140	13,020	10,830	4,710	4,110	6,760	6,910	3,150	1,290	1,210
Minimum	474	638	1,540	1,230	1,870	1,460	2,630	4,030	2,020	510	139	197
Average	2,330	3,510	3,920	4,610	4,500	2,690	3,550	5,260	4,090	1,940	720	779

Table 16. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1949-53. Canyon Creek at Kulshan.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	260	102	72	52	42	35	28	23	17.5	10	5.0	3.8	3.0
November	660	180	102	64	47	37	31	26	22	19	16	14.3	12
December	580	270	165	82	51	36	28	23	19.5	16	12	10	7.2
January	640	320	190	100	58	38	28	22	18.5	15.5	12.5	11	9.3
February	900	240	140	87	64	49	39	30	24	17.5	12.5	10.5	8.5
March	260	106	75	54	44	38	33	28	25	21	17	15	12
April	215	133	105	80	66	56	49	43	37	32	27	23	18.5
May	190	150	125	98	80	68	58	50	43	36	30	26	21
June	210	170	145	120	100	86	74	65	57	49	41	36	30
July	95	70	60	50	42	36	30	23	16.5	11	6.4	4.5	3.4
August	88	33	23	16	12.5	10.2	8.8	7.4	5.8	4.1	2.4	1.8	1.3
September	115	46	25	14.5	11	9.0	7.5	6.5	5.2	3.6	1.7	1.2	0.9
Period	360	150	105	74	55	42	33	25	18	12.5	7.0	4.3	1.5

Table 17. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1934-59.
South Fork Nooksack River near Wickersham.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	82,200	98,780	135,300	128,600	102,600	72,980	86,640	102,500	103,500	58,370	30,790	47,060
Minimum	7,460	7,520	30,740	11,910	16,590	19,910	26,940	39,830	18,340	7,570	5,010	4,840
Average	42,280	54,060	66,850	56,480	42,640	40,540	51,360	67,270	53,740	26,480	11,660	16,320

Table 18. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1953-59.
South Fork Nooksack River near Wickersham.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	4,700	2,250	1,550	970	680	500	360	265	185	125	102	94	80
November	4,700	2,500	1,800	1,250	950	770	630	520	420	330	220	140	90
December	4,600	2,750	2,050	1,420	1,100	880	740	610	510	420	330	270	200
January	5,000	2,500	1,750	1,200	900	720	600	490	405	330	255	210	150
February	4,000	1,950	1,400	990	770	625	520	430	355	285	220	185	140
March	2,400	1,500	1,150	860	700	600	520	450	400	345	290	260	220
April	2,800	1,650	1,400	1,100	960	840	750	660	580	500	410	350	265
May	2,600	2,050	1,750	1,450	1,250	1,100	1,000	900	800	700	580	500	390
June	2,800	2,000	1,650	1,300	1,100	950	810	700	580	470	360	290	200
July	1,350	1,020	850	650	520	420	340	270	220	175	130	115	95
August	800	435	325	240	200	170	150	130	115	102	88	80	70
September	1,900	980	560	320	230	180	150	130	115	100	86	78	70
Period	3,500	1,900	1,470	1,050	840	670	540	430	320	220	135	105	80

Table 19. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1949-59.
Skookum Creek near Wickersham.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	13,360	16,290	17,050	19,390	16,020	13,550	13,220	16,280	17,040	10,400	5,940	8,240
Minimum	1,530	1,890	4,930	2,710	2,850	3,430	7,290	7,960	4,650	2,180	1,300	1,710
Average	7,530	10,020	10,960	9,110	8,530	7,090	9,510	12,300	10,140	5,980	3,220	3,540

Table 20. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1949-59.
Skookum Creek near Wickersham.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	620	370	270	170	130	100	84	69	54	39	26	21	17
November	800	420	340	250	195	155	125	100	80	60	40	29	21
December	950	440	350	260	205	165	135	115	95	75	58	47	33
January	640	420	310	220	170	140	110	90	71	54	39	32	26
February	850	420	310	220	170	130	100	82	65	52	40	34	27
March	540	270	200	150	125	110	95	82	70	57	48	43	38
April	500	310	255	210	180	160	140	125	105	90	74	64	53
May	480	360	310	260	230	205	185	165	150	130	110	95	70
June	540	340	280	230	195	170	150	130	115	98	81	72	58
July	260	195	170	140	120	105	91	78	65	52	40	34	27
August	200	105	82	64	55	50	46	42	38	33	25	22	18
September	350	200	125	74	55	44	37	32	28	24	21	20	18
Period	580	340	265	195	155	125	100	84	66	50	35	27	19.5

Table 21. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1945-59.
Nooksack River near Lynden.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	341,600	443,500	464,800	447,400	437,500	335,700	351,700	423,400	441,900	338,200	209,900	240,100
Minimum	57,940	56,650	111,100	92,930	90,210	104,200	161,500	272,000	213,000	137,600	86,820	74,870
Average	201,950	250,680	274,110	246,290	217,890	182,200	217,650	328,840	311,480	226,960	130,360	115,270

Table 22. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1946-59.
Nooksack River near Lynden.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	19,000	9,500	6,700	4,500	3,400	2,700	2,200	1,850	1,520	1,270	1,030	900	770
November	21,000	10,800	7,800	5,700	4,600	4,000	3,400	2,800	2,200	1,700	1,250	950	680
December	19,000	11,300	8,800	6,400	5,200	4,300	3,600	3,100	2,600	2,150	1,700	1,400	1,000
January	15,000	9,500	7,300	5,400	4,300	3,600	3,000	2,600	2,200	1,800	1,300	1,000	780
February	19,000	10,000	7,500	5,300	4,100	3,300	2,800	2,360	2,000	1,660	1,360	1,200	1,000
March	9,500	5,800	4,700	3,800	3,200	2,800	2,500	2,200	2,000	1,750	1,550	1,450	1,320
April	12,500	6,600	5,400	4,600	4,100	3,700	3,300	3,000	2,700	2,400	2,000	1,850	1,600
May	11,000	8,800	7,700	6,600	6,000	5,400	5,000	4,600	4,200	3,700	3,100	2,650	2,000
June	12,500	9,300	8,000	6,600	5,800	5,300	4,800	4,400	4,100	3,700	3,300	3,000	2,600
July	7,600	6,400	5,800	5,000	4,400	3,900	3,500	3,100	2,800	2,500	2,200	2,050	1,850
August	6,000	3,700	3,100	2,600	2,300	2,100	1,900	1,800	1,650	1,500	1,350	1,280	1,150
September	8,000	4,300	3,200	2,300	1,900	1,650	1,500	1,350	1,280	1,190	1,100	1,040	950
Period	14,000	8,400	6,600	5,100	4,300	3,700	3,100	2,600	2,200	1,800	1,400	1,180	870

Table 23. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1949-59.
Fishtrap Creek at Lynden.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	2,090	4,460	6,510	7,010	9,010	7,260	5,050	2,910	1,240	680	510	660
Minimum	270	270	930	1,710	2,530	2,030	1,230	850	450	260	160	140
Average	770	2,310	3,950	4,060	4,490	3,730	2,650	1,550	860	520	360	340

Table 24. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1949-59.
Fishtrap Creek at Lynden.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	88	37	24	15.5	11.7	9.4	7.8	6.7	5.8	5.1	4.3	3.8	3.2
November	180	110	85	60	46	36	28	21	15	9.8	5.8	4.7	3.7
December	250	160	125	93	75	62	51	43	35	27	19	14	6.6
January	280	170	130	92	74	61	51	43	36	30	24	20	15
February	340	200	150	110	85	70	56	47	40	33	26	22	16
March	240	140	110	80	65	56	49	43	38	34	30	28	26
April	180	95	72	54	46	40	36	33	30	27	23	20	15
May	88	55	43	33	28	24	21	19	17	15	13	11.8	10
June	37	26.5	22	18	16	14	13	11.7	10.6	9.5	8.3	7.6	6.7
July	17	13.4	12	10.5	9.6	9.0	8.4	7.9	7.4	6.6	5.4	4.3	3.4
August	12	9.0	8.0	7.1	6.8	6.4	6.0	5.6	4.9	4.2	2.9	2.3	1.7
September	21	11.6	9.0	7.0	6.1	5.5	5.1	4.7	4.4	3.9	3.0	1.9	1.0
Period	200	110	82	55	40	30	21	14	10	7.2	5.2	4.1	2.4

Table 25. Maximum, minimum, and average of the monthly discharges, in acre-feet, for the period 1949-53. Dakota Creek near Blaine.

	October	November	December	January	February	March	April	May	June	July	August	September
Maximum	760	6,610	7,720	7,460	9,200	8,120	3,350	1,090	440	200	210	140
Minimum	110	90	400	1,030	2,710	1,880	759	490	200	100	90	80
Average	310	2,030	4,140	4,600	5,040	3,910	1,480	770	310	160	130	120

Table 26. Discharge, in cubic feet per second, equaled or exceeded for specified percent of time--1945-53. Dakota Creek near Blaine.

	Percent of time												
	1	5	10	20	30	40	50	60	70	80	90	95	99
October	30	13	9.0	6.0	4.7	3.8	3.4	3.0	2.6	2.3	2.0	1.8	1.6
November	300	180	115	50	15	9.0	6.5	4.7	3.5	2.4	1.5	1.2	1.0
December	430	220	150	95	67	50	37	27	20	12	6.2	4.2	2.5
January	480	250	180	115	85	62	47	35	25	17	10.5	8.2	6.5
February	540	280	200	130	95	73	56	44	33	24	16	12	8.5
March	540	250	150	82	58	44	36	30	25	22	17.5	15	12
April	155	70	48	32	24	20	17	15	13	11	9.3	8.4	7.0
May	90	31	23	17	13	10.5	8.6	7.4	6.4	5.5	4.6	4.1	3.5
June	22	10.5	8.3	6.6	5.7	5.0	4.5	4.0	3.5	3.1	2.6	2.2	1.7
July	6.5	4.2	3.6	3.0	2.8	2.6	2.4	2.3	2.2	2.1	1.9	1.6	1.2
August	5.3	3.8	3.3	2.7	2.3	2.1	1.9	1.8	1.6	1.4	1.1	0.9	0.7
September	4.2	3.3	2.9	2.5	2.2	2.0	1.9	1.7	1.5	1.4	1.2	1.1	0.9
Period	320	140	85	42	24	14	7.8	4.7	3.2	2.4	1.7	1.3	1.0

RUNOFF MAP

Meteorological data for the study area indicates that the years 1934 through 1959 contain a complete climatic cycle. Most reliable precipitation and streamflow records available for the report were also obtained during this period, therefore, all streamflow studies were based on data obtained during that time. All precipitation and continuous stream gage records were first adjusted so they would be representative of this 26-year period. This was accomplished through use of the discharge ratios described in the preceding section on basic data and by methods discussed in the section on climate. Mean annual evapotranspiration losses as computed by the Thornthwaite procedure were then applied to precipitation data in order to estimate values of runoff.

Drainage areas contributing flow to each gage were studied to determine the effects of certain environmental factors on precipitation and runoff. Of all variables involved, elevation appears to have the greatest influence, but its effect is not consistent from one region to another. This inconsistency results from various modifying factors such as average land slope, basin orientation with respect to prevailing winds and storm paths, the influence of nearby mountains to shield the basin from storms, time of year, types of vegetative cover, and a multitude of other variables too numerous to mention. It is an impossible task to determine what effect each of the many variables would have upon precipitation and runoff in any one area, but a close approximation can be obtained by studying the more important ones. This was done, and the resulting information then used to construct a map showing runoff isopleths or lines of equal runoff (pl. 6). These lines are similar to isohyetal lines on a precipitation map, and in like manner can be used to estimate total mean annual runoff from any part of the report area. It should be stressed, however, that they represent average conditions that have occurred over a period of 26 years and it does not mean that this same amount and distribution of runoff will occur during every water year.

It also must be pointed out that this map most likely contains discrepancies caused by the scarcity and inherent inadequacies of the basic data used in its construction. The regions of greatest doubt are above 7,000 feet near the summit of Twin Sisters Mountain, Mt. Baker, and Mt. Shuksan; and short dashed lines are used in these areas to indicate the higher degree of uncertainty.

STREAMFLOW ANALYSIS AND EVALUATION

All basic streamflow data in the report area were compiled by the U. S. Geological Survey and summarized in tables 2 and 3. Although basic data is the primary source of information, in many instances it does not present a true picture of average conditions over a long period of time. It, therefore, becomes essential to analyze and interpret basic information so that meaningful conclusions can be drawn.

In the Nooksack River area, major streams were broken-down into their most important tributaries and then evaluated in order to gain such information. Surface-water maps of Whatcom Basin and the Eastern Upland, which provide easy reference to all the streams, are enclosed at the end of this report (pls. 4 and 5). To avoid confusion every stream in the analysis was evaluated in its entirety above its confluence with another tributary or stream.

In order to locate any particular point of confluence, a system of numbering was developed. Beginning with zero at the mouth, or where a stream flows across the international border, each primary tributary confluence with the main stream was numbered consecutively in an upstream direction. Using the primary confluence number as a base, a similar consecutive numbering system was then applied to the branches of each primary tributary to indicate secondary points of confluence and so on until every confluence point was numbered. In all cases each additional number was separated from the other base numbers by a colon and the order of magnitude of any tributary is then determined by merely counting these groups of numbers. It should be noted that several streams shown on the Whatcom Basin surface-water map have junctions but do not have confluence numbers. Those junctions usually represent large diversion ditches or effluent streams and consequently cannot be considered as points of confluence.

A detailed summary of the surface-water analysis is presented in table 27. Although this streamflow study was generally quite comprehensive, it was necessary to omit certain areas near the coast because they were affected by tidal action. Several small streams and tributaries inland were also omitted from the discussion because of their relative unimportance, but runoff in these areas can easily be estimated through use of the runoff map described previously. In all cases, every stream in the table is referred to both by name and confluence number and all streamflow information refers to the stream system and drainage area contributing flow above the point of confluence.

All drainage areas listed in the table are within the United States unless otherwise indicated and refer only to surface drainage areas as established by topographic divides. Baseflow contributions may or may not originate from this same area depending mainly upon local geology within and adjacent to the basin. If ground water exists under water table conditionsrather than being confined, the area contributing baseflow is to a large extent controlled by the position of the groundwater or phreatic divide.

Scientific exploration in the field of hydrology has not yet found an accurate way to predict streamflow in advance without relying upon a statistical analysis of events that have occurred in the past. This leads to a discussion of streamflow in terms of maximum, minimum, and mean flows and their corresponding probabilities of occurrence. Most streamflow records in the Nooksack area are of insufficient duration to warrant good probability studies. However, a great amount of knowledge is still provided by determining maximum, minimum, and mean values from past records. Estimates of the total mean annual runoff adjusted for the past 26-year period are presented in table 27 in terms of acre-feet and inches of water on the basin. If a comparison is made, it will be seen that these figures compare favorably with those on the runoff map.

The last two columns in table 27 represent estimates of low flow and the probable times of the year they can be expected to occur. If streamflow hydrographs of a particular gage are examined, it is evident that the lowest flows are seldom identical from year to year. Over a period of time, however, it can be seen that annual low flows will generally approximate the same order of magnitude each year. Estimated values in the table were, therefore, presented in round numbers to reasonably approximate these magnitudes and are not intended to represent the absolute lowest flows that have occurred unless the stream actually dries up. In most cases, these figures can also be interpreted to mean flows that can be expected in equal magnitude or less from 1 to 5 percent of the time during any one year.

Table 27. Streamflow Evaluation.

Confluence Number	Name of Stream Above Confluence	Surface Drainage Area	Estimated Mean Annual Runoff From Drainage Area		Estimated Average Low Flow and Usual Periods of Occurrence	
		Square Miles	Inches	Acre Feet	Second Feet	Months
		NOOKSACK RIVER DRAINAGE BASIN				
		North Fork Nooksack River				
55	North Fork Nooksack River	70.1	99	370,000	120	Feb., Mar., Sept., Oct.
55	Wells Creek	24.2	101	131,000	30	Feb., Mar., Sept., Oct.
47	Glacier Creek	32.2	85	146,000	40	Feb., Mar., Sept., Oct.
42	North Fork Nooksack River	161.5	86	740,000	210	Feb., Mar., Sept., Oct.
42	Canyon Creek	30.9	75	123,000	15	Feb., Mar., Sept., Oct.
38	Boulder Creek	8.6	77	35,400	2	Sept., Oct., Nov.
35	Maple Creek	11.0	60	35,200	2	Sept., Oct., Nov.
31	Kendall Creek	30.0, * 25.1	49	78,500	4	Sept., Oct., Nov.
30	North Fork Nooksack River	263.7, *258.7	77	1,080,000	260	Jan., Feb., Aug., Sept.
30	Coal Creek	4.6	59	14,300	0.5	Aug., Sept.
29	Racehorse Creek	11.1	74	43,600	3	Aug., Sept.
27	Bells Creek	5.0	57	15,100	0.5	Aug., Sept.
26	North Fork Nooksack River	292.9, *288.0	76	1,190,000	290	Jan., Feb., Aug., Sept.
		Middle Fork Nooksack River				
26:10	Middle Fork Nooksack River	46.4	88	218,000	120	Feb., Sept., Oct.
26:10	Clearwater Creek	21.2	83	94,000	20	Feb., Sept., Oct.
26:4	Porter Creek	4.7	75	19,000	0.5	Aug., Sept., Oct.
26:1	Canyon Creek	8.8	78	36,400	4	Aug., Sept., Oct.
26	Middle Fork Nooksack River	101.2	80	432,000	170	Feb., Aug., Sept., Oct.
		Nooksack River				
23	Nooksack River	400.2, *395.3	77	1,630,000	500	Jan., Feb., Sept., Oct.
		South Fork Nooksack River				
23:37	South Fork Nooksack River	50.2	105	281,000	40	Aug., Sept., Oct.
23:37	Howard Creek	7.5	103	41,500	5	Aug., Sept., Oct.
23:22	Cavanaugh Creek	9.7	98	50,500	6	Aug., Sept., Oct.
23:19	South Fork Nooksack River	103.4	97	535,000	90	Aug., Sept., Oct.
23:19	Skookum Creek	23.0	75	92,300	25	Feb., Mar., Sept., Oct.
23:14	Hutchinson Creek	14.7	64	50,000	8	Aug., Sept., Oct.
23:4	Black Slough	6.9	51	18,700	0	Aug., Sept., Oct.
23	South Fork Nooksack River	181.6	81	785,000	180	Aug., Sept., Oct.
		Nooksack River				
22	Nooksack River	584.2, *579.3	78	2,430,000	750	Jan., Feb., Sept., Oct.
		Smith Creek				
19	Smith Creek	10.6	51	28,800	0.3	July, Aug., Sept.
		Anderson Creek				
18:3	Anderson Creek	2.0	50	5,400	0.1	July, Aug., Sept.
18:3	North Unnamed Stream	3.5	51	9,400	0.1	July, Aug., Sept.
18	Anderson Creek	14.3	36	27,800	0.2	July, Aug., Sept.
		Stickney Slough				
17:2	Kamm Ditch	4.3	23	5,200	3	Aug., Sept., Oct.
17:2	Mormon Ditch	2.5	21	2,900	0.2	Aug., Sept., Oct.
17	Stickney Slough	7.9	22	9,200	5	Aug., Sept., Oct.
		Scott Ditch				
16:3	Scott Ditch	3.2	21	3,700	1.5	Aug., Sept.
16:3	Elder Ditch	2.7	19	2,100	1.5	Aug., Sept.
16	Scott Ditch	9.8	20	9,700	4	Aug., Sept.

* Portion of Drainage Area in the United States.

Table 27. Streamflow Evaluation. (Continued)

Confluence Number	Name of Stream Above Confluence	Surface Drainage Area Square Miles	Estimated Mean Annual Runoff From Drainage Area Inches	Acre Feet	Estimated Average Low Flow and Usual Periods of Occurrence Second Feet	Months
		NOOKSACK RIVER DRAINAGE BASIN				
		Nooksack River				
15	Nooksack River	645.6, *640.7	74	2,540,000	930	Jan., Feb., Sept., Oct.
		Fishtrap Creek				
14:4	Fishtrap Creek	16.5, *4.0	28	24,300	4	Aug., Sept., Oct.
14:4	Bender Ditch	2.1, *1.4	23	2,500	0.4	Aug., Sept., Oct.
14:3	Depot Ditch	3.7, *3.1	23	4,500	0.8	Aug., Sept., Oct.
14:2	Benson Ditch	1.0	22	1,100	0.2	Aug., Sept., Oct.
14:1:2	Double Ditch	**2.7	26	3,700	5	Aug., Sept., Oct.
14:1	Double Ditch	4.3, *1.6	23	5,300	3.5	Aug., Sept., Oct.
14	Fishtrap Creek	30.6, *14.1	26	43,000	10	Aug., Sept., Oct.
		Bertrand Creek				
13:6	Bertrand Creek	22.2, *2.4	26	30,800	5	Aug., Sept., Oct.
13:6	Van Ditch	4.4, *1.5	25	5,900	0.7	Aug., Sept., Oct.
13:4	McClelland Creek	2.5	23	3,200	0.4	Aug., Sept., Oct.
13:2	North Unnamed Stream	3.8	22	4,500	0.6	Aug., Sept., Oct.
13:1	Duffner Ditch	4.3, *4.1	21	4,800	1	Aug., Sept., Oct.
13	Bertrand Creek	43.5, *20.5	24	56,000	9	Aug., Sept., Oct.
		Schneider Ditch				
10	Schneider Ditch	5.1	15	4,100	0.5	Aug., Sept.
		Wiser Lake Creek				
9:3	Wiser Lake Creek (Wiser Lake Outlet)	3.7	17	3,300	1.5	Aug., Sept.
9	Wiser Lake Creek (Cougar Creek)	7.0	15	5,800	1.8	Aug., Sept.
		Nooksack River				
2	Nooksack River	743.8, *699.5	67	2,650,000	1000	Jan., Feb., Sept., Oct.
		Tenmile Creek				
2:16	Tenmile Creek	4.4	21	5,000	0.3	Aug., Sept.
2:16	East Unnamed Stream	2.2	21	2,400	0.2	Aug., Sept.
2:10	Tenmile Creek	12.1	19	12,300	1	Aug., Sept.
2:10:1	Fourmile Creek (Green Lake Outlet)	7.1	21	8,600	1	Aug., Sept.
2:10	Fourmile Creek	10.6	19	11,600	1.5	Aug., Sept.
2:4	Tenmile Creek	25.8	19	26,200	3	Aug., Sept.
2:3:5	Deer Creek	3.5	20	3,700	0.3	Aug., Sept.
2:3	Deer Creek	6.8	17	6,200	1	Aug., Sept.
2	Tenmile Creek	34.0	18	33,400	5	Aug., Sept.
		Nooksack River				
0	Nooksack River	781.2, *736.9	64	2,690,000	1050	Jan., Feb., Sept., Oct.
		COASTAL AREA DRAINAGE BASINS				
		Dakota Creek				
13	North Fork Dakota Creek	7.9, *7.5	26	11,000	0.9	Aug., Sept.
13	South Fork Dakota Creek	9.0	22	10,500	0.7	Aug., Sept.
11	Dakota Creek	18.0, *17.5	23	22,200	1.6	Aug., Sept.
11	Haynie Creek	3.0	25	4,100	0.5	Aug., Sept.
4:1	East Unnamed Stream	1.7	25	2,200	0.4	Aug., Sept.
4:1	North Unnamed Stream	1.3	23	1,600	0.2	Aug., Sept.
2	Spooner Creek	1.6	22	1,900	0.1	Aug., Sept.
0	Dakota Creek	28.3, *27.8	23	34,400	3	Aug., Sept.

*Portion of Drainage Area in the United States.
**Total Drainage Area in Canada.

Table 27. Streamflow Evaluation. (Continued)

Confluence Number	Name of Stream Above Confluence	Surface Drainage Area	Estimated Mean Annual Runoff From Drainage Area		Estimated Average Low Flow and Usual Periods of Occurrence	
		Square Miles	Inches	Acre Feet	Second Feet	Months
	COASTAL AREA DRAINAGE BASINS					
	California Creek					
12	California Creek	8.4	17	7,600	0.6	Aug., Sept.
12	East Unnamed Stream	2.6	15	2,100	0.2	Aug., Sept.
10	East Unnamed Stream	1.3	14	900	0.1	Aug., Sept.
9:1	Campbell Ditch	1.6	15	1,200	0.2	Aug., Sept.
9:1	West Unnamed Stream	2.0	14	1,400	0.1	Aug., Sept.
4	North Unnamed Stream	1.8	13	1,200	0.1	Aug., Sept.
0	California Creek	22.8	15	18,000	1.5	Aug., Sept.
	Terrell Creek					
13	Butler Ditch	2.1	18	2,000	0	Aug., Sept.
13	Terrell Lake Outlet	2.8	16	2,400	0	Aug., Sept.
12	Fingalson Creek	1.6	20	1,700	0	Aug., Sept.
6	South Unnamed Stream	2.2	15	1,700	0	Aug., Sept.
5	Terrell Creek	12.5	16	10,700	0	Aug., Sept.
5	South Unnamed Stream	0.9	15	700	0	Aug., Sept.
2	East Unnamed Stream	0.9	14	600	0	Aug., Sept.
1:2	East Unnamed Stream	1.4	14	1,100	0	Aug., Sept.
0	Terrell Creek	17.2	15	14,000	0	Aug., Sept.
	Lummi River and Delta Tributaries					
1	Schell Ditch	2.2	17	2,000	0.2	Aug., Sept.
9	West Unnamed Stream	1.4	16	1,100	0	Aug., Sept.
9	North Unnamed Stream	2.0	19	2,000	0	Aug., Sept.
8	East Unnamed Stream	1.1	18	1,100	0	Aug., Sept.
7	East Unnamed Stream	1.2	15	1,000	0.1	Aug., Sept.
4	North Unnamed Stream	9.5	16	8,000	0.2	Aug., Sept.
	Silver Creek					
11	Andreason Ditch	3.3	17	3,000	0.5	Aug., Sept.
11	Bear Creek	4.2	15	3,300	0.1	Aug., Sept.
6	Tennant Lake Creek	2.6	12	1,600	0	Aug., Sept.
3	East Unnamed Stream	0.9	10	500	0	Aug., Sept.
0	Silver	15.8	14	11,500	0.6	Aug., Sept.
	SUMAS RIVER DRAINAGE BASIN					
	Sumas River					
7	Dale Creek	1.5	45	3,600	0.2	Aug., Sept.
6	Goodwin Creek	3.3	34	5,900	3	Aug., Sept.
5	Sumas River	11.7	35	21,900	7	Aug., Sept.
5	Swift Creek	3.2	46	7,800	0.1	Aug., Sept.
4	Breckenridge Creek	7.5	42	16,700	0.6	Aug., Sept.
3	Kinney Creek	2.1	30	3,300	0.1	Aug., Sept.
1	Sumas River	34.2	35	63,200	12.5	Aug., Sept.
	Johnson Creek					
1:8	Johnson Creek	6.0	23	7,500	2	Aug., Sept.
1:8	Squaw Creek	3.8	23	4,800	1	Aug., Sept.
1:6	Pangborn Creek	3.3	25	4,400	2.8	Aug., Sept.
1:1	West Unnamed Stream	2.6, *1.4	27	3,800	1.5	Aug., Sept.
1	Johnson Creek	20.7, *19.6	24	26,900	12	Aug., Sept.
	Sumas River					
0	Sumas River	55.8, *54.6	31	91,300	25	Aug., Sept.

*Portion of Drainage Area in the United States.

Table 27. Streamflow Evaluation. (Continued)

Confluence Number	Name of Stream Above Confluence	Surface Drainage Area	Estimated Mean Annual Runoff From Drainage Area		Estimated Average Low Flow and Usual Periods of Occurrence	
		Square Miles	Inches	Acre Feet	Second Feet	Months
		SUMAS RIVER DRAINAGE BASIN				
		Saar Creek				
0	Saar Creek	10.1	41	22,000	0.2	Aug., Sept.
		Mud Slough				
0	Mud Slough (Arnold Slough in Canada)	3.3, *3.2	32	5,600	1	Aug., Sept.

*Portion of Drainage Area in the United States.

Table 28. Existing Lakes and Reservoirs in the Report Area.*

Location** Township	Range	Section	Name	Approximate elevation above sea level in feet	Approximate area in acres	Drainage
T36N	R7E	4	Three Lakes (Lake No. 1)	4,000	1	South Fork Nooksack River
			(Lake No. 2)	4,000	1	South Fork Nooksack River
			(Lake No. 3)	4,000	4	South Fork Nooksack River
		5	Heart Lake	4,050	15	South Fork Nooksack River
		5	Unnamed Lake	4,300	6.5	South Fork Nooksack River
		5	Unnamed Lake	4,650	1.5	South Fork Nooksack River
		6	Unnamed Lake	4,000	4.5	South Fork Nooksack River
		9	Bear Lake	3,550	4	South Fork Nooksack River
		12	Springsteen Lake	3,550	19.2	South Fork Nooksack River
T37N	R5E	7	Marona Millpond	350	2.5	South Fork Nooksack River
		16	Unnamed Lake	300	10	South Fork Nooksack River
		22	Ferguson Ponds		10	South Fork Nooksack River
		35	Athearns Ponds	450	5	South Fork Nooksack River
T37N	R6E	24	Unnamed Lake	5,200	5	South Fork Nooksack River
		34	Unnamed Lake	4,075	1.5	South Fork Nooksack River
T37N	R7E	7	Unnamed Lake	4,450	3	Middle Fork Nooksack River
		8	Hildebrand Lake	3,450	0.7	Middle Fork Nooksack River
		8	Wiseman Lake	4,250	18.6	Middle Fork Nooksack River
		9	Elbow Lake	3,400	5	South Fork Nooksack River
		9	Unnamed Lake	3,400	1.5	South Fork Nooksack River
		9	Dorreen Lake	3,380	1	South Fork Nooksack River
T37N	R8E	32	Tuckway Lake	3,850	1.5	South Fork Nooksack River
T38N	R1E	5	Unnamed Lake	10	1.5	Georgia Strait
T38N	R2E	4	Unnamed Lake	120	1.5	Silver Creek
		9(O.L.)	Lost Lake	140	3	Silver Creek
		10	Unnamed Lake	145	2	Silver Creek
		11	Taylor Pond	120	1	Silver Creek
T38N	R5E	6	Mud Lake	250	0.3	Nooksack River
		9	Williams Lake	350	3.5	South Fork Nooksack River
		9	Unnamed Lake	450	1	South Fork Nooksack River
		23	Unnamed Lake	690	1	Middle Fork Nooksack River
		23	Mosquitoe Lake	690	7	Middle Fork Nooksack River
		23	Unnamed Lake	720	1	Middle Fork Nooksack River
		23	Jorgensen Lake	690	12	Middle Fork Nooksack River
		23	Unnamed Lake	690	1	Middle Fork Nooksack River
T38N	R6E	35	Unnamed Lake	3,750	1	Middle Fork Nooksack River
T38N	R7E	21	Unnamed Lake	5,700	1	Middle Fork Nooksack River
		27	Hann Lake	5,100	0.5	Middle Fork Nooksack River
		27	Unnamed Lake	5,100	2.5	Middle Fork Nooksack River
		35	Mazama Lake	5,150	0.5	Middle Fork Nooksack River
T39N	R1W	1	Med-O-Land Reservoir	15	3.8	Terrell Creek
T39N	R1E	2	Unnamed Lake	70	1	California Creek
		4	Smrekar Reservoir	180	3	Terrell Creek
		6	Heide Pond	20	1.5	Terrell Creek
		16(O.L.)	Terrell Lake	212	438	Terrell Creek
		21	Unnamed Pond	212	1.8	Terrell Creek
		24	Nubgaard Reservoir "A"	280	11.5	Lummi River
T39N	R2E	3	Unnamed Lake	25	2.5	Nooksack River
		4	Unnamed Lake	45	1	Schneider Ditch
		4	Keefe Lake	25	4	Schneider Ditch
		7	Potts Pond	70	0.5	California Creek
		9	Unnamed Lake	25	1	Nooksack River
		10(O.L.)	Unnamed Lake	30	3.5	Wiser Lake Creek
		15	Unnamed Lake	60	1.5	Nooksack River
		21(O.L.)	Unnamed Lake	20	1.5	Nooksack River
		21(O.L.)	Barrett Lake	20	40	Tenmile Creek
		32(O.L.)	Tennant Lake	15	43	Silver Creek
		32	Unnamed Lake	20	1	Silver Creek
		33	Unnamed Lake	20	1	Silver Creek
		33	Brennan Pond	15	11.7	Silver Creek
T39N	R3E	4	Fountain Lake	70	14	Scott Ditch
		6	Wiser Lake	50	123	Wiser Lake Creek
		9(O.L.)	Green Lake	74	19.5	Tenmile Creek
		13	Fazon Lake	128	33	Tenmile Creek
		27	Unnamed Lake	285	1.5	Tenmile Creek
T39N	R4E	9	Unnamed Lake	100	5	Sumas River
		28	Unnamed Lake	230	1	Nooksack River
T39N	R6E	9	Three Small Unnamed Lakes	4,200	3	North Fork Nooksack River
		30(O.L.)	Canyon Lake	2,250	45	Middle Fork Nooksack River
T39N	R8E	4	Pinus Lake	2,450	1.5	North Fork Nooksack River
		13	Unnamed Lake	5,000	5	North Fork Nooksack River
		23	Arbuthnot Lake	4,800	5	North Fork Nooksack River
		23	Hayes Lake	4,800	13	North Fork Nooksack River
		23	Mazama Lake	4,800	0.8	North Fork Nooksack River
		24	Iceberg Lake	4,800	36.6	North Fork Nooksack River

Table 28. Existing Lakes and Reservoirs in the Report Area.* (Continued)

Location** Township	Range	Section	Name	Approximate elevation above sea level in feet	Approximate area in acres	Drainage
T39N	R9E	17	Picture Lake	4,100	3	North Fork Nooksack River
		17	Highwood Lake	4,100	2	North Fork Nooksack River
		18	Terminal Lake	4,240	0.3	North Fork Nooksack River
		19	Lower Bagley Lake	4,200	11	North Fork Nooksack River
		19	Upper Bagley Lake	4,240	9	North Fork Nooksack River
		19	Austin Pass Lake	4,450	0.8	North Fork Nooksack River
		23	Price Lake	3,895	40	North Fork Nooksack River
T40N	R3W	9	Unnamed Lake	10	1.2	Georgia Strait
T40N	R1E	4	Blaine Reservoir	140	1.5	Dakota Creek
		5	Olason Reservoir	70	1	Dakota Creek
		14	Unnamed Lake	60	1	Dakota Creek
		24	Leland Pond	45	0.7	Dakota Creek
T40N	R2E	8	Unnamed Lake	130	1	Dakota Creek
		27	Unnamed Lake	50	3.5	Bertrand Creek
		27	Willey Lake	50	4	Schneider Ditch
		34	Harksell Lake	25	0.3	Schneider Ditch
T40N	R3E	1	Pangborn Lake	130	30	Johnson Creek
		20	Lynden Juvenile Pond	100	0.5	Fishtrap Creek
T40N	R5E	6	Unnamed Lake	50	1.5	Mud Slough
		7	Anderson Lake	500	2.5	Mud Slough
		10	Unnamed Lake	500	1	North Fork Nooksack River
		27(O.L.)	Kendall Lake	490	12	North Fork Nooksack River
		31	Lost Lake	2,850	4.4	Sumas River
T40N	R6E	7(O.L.)	Silver Lake	780	184	North Fork Nooksack River
		12	Bald Lake	4,400	2.5	North Fork Nooksack River
T40N	R7E	13	Church Lake (Upper Bear Paw Mt. Lake)	5,150	4	North Fork Nooksack River
		13	(Lower Bear Paw Mt. Lake)	4,450	6.5	North Fork Nooksack River
		23	Whistler Lake	5,575	2.5	North Fork Nooksack River
		27	Kidney Lake No. 1	5,500	0.6	North Fork Nooksack River
			Kidney Lake No. 2	5,500	0.9	North Fork Nooksack River
T40N	R8E	20	Canyon Lake	4,775	2	North Fork Nooksack River
T40N	R9E	16	Twin Lakes (Upper Twin Lake)	5,200	17	North Fork Nooksack River
			(Lower Twin Lake)	5,180	20	North Fork Nooksack River
T41N	R3E	36	Unnamed Lake	152	1	Judson and Laxton Lakes
T41N	R4E	31	Judson Lake	152	112	Judson and Laxton Lakes
		33	Van Valkenberg Pond	50	1	Johnson Creek

* Tabulation includes unnamed lakes one acre or more in surface area and all known named lakes.

** The major portion of a lake or reservoir lies in the township, range, and section listed unless followed by "(O.L.)" which indicates the outlet location.

All low flow estimates were based upon partial or miscellaneous measurements and continuous stream gage records taken in this area by the U. S. Geological Survey. In some cases the estimates were determined from many observations, while in others from only meager information. Certain values in the tabulation can, therefore, be given greater confidence than others depending upon the quantity and quality of data used.

Unfortunately no data were ever collected at the time of these low flow measurements to determine how much upstream diversion or consumptive use was being made of waters in the stream. In most cases, it is impossible to state whether or not low flow measurements and subsequent estimate of the average low flow are affected by such use. Owing to the fact, however, that most low flows occur during the summer when irrigation withdrawals are at a peak, it is quite probable that many measurements were affected by upstream use up to the limit of water rights in the area.

NORTH FORK NOOKSACK RIVER

The North Fork of the Nooksack River originates from East Nooksack Glacier near the base of 9,000 foot high Mt. Shuksan and flows through a rocky, heavily wooded canyon which gradually flattens out into a relatively low valley. From here the river flows in a westerly and eventually southerly direction, picking up many small tributaries, until it meets the Middle Fork where the two become the main stem of the Nooksack River. Many major tributaries such as Wells Creek and Glacier Creek also originate from snow fields and glaciers and similarly follow steep, rocky courses in their upper reaches.

Above its confluence with the Middle Fork, the North Fork drains an area of about 293 square miles and contains elevations from less than 300 feet to more than 10,000 feet above mean sea level datum. Large variations in precipitation are associated with these extreme elevation differences, but the extent of this variability and its distribution is not well-defined by the existing gage network in the basin. With the exception of the station at Mt. Baker Lodge, all precipitation stations are situated at low elevations in the sheltered, deep, narrow North Fork canyon and obviously do not receive samples that are representative of higher areas. (fig. 2).

Snowpack data has been collected in this watershed since 1957 when a snow survey course was established on top of 4,300 foot high Panorama Dome just above Mt. Baker Lodge. Several other courses exist across the divide in the Baker River drainage, but none of these have a longer period of record than the Panorama course and at most can only infer what conditions would be like in the Nooksack River watershed.

Continuous daily discharge records have been collected on the North Fork below Wells, Cascade, and Canyon Creeks; at two locations on Kendall Creek near Kendall; and on Coal Creek. Of these, the station below Cascade Creek has the longest period of record and offers the most reliable hydrologic information. Information provided by the other gages is relatively meager and though certain tendencies are indicated, these records are generally of insufficient duration to indicate long-time trends. Based on these data and various miscellaneous measurements, annual runoff produced by the North Fork was estimated to average about 76 inches or somewhat more than one million acre-feet. This far exceeds that of either the Middle or South Fork and is usually about equal to their combined runoff.

Hydrographs of the North Fork taken below Cascade Creek show a highly variable pattern throughout the year, but two rather distinct low flow periods are indicated. One of these periods generally occurs during the months of January and February and the other later on in August and September. The more pronounced low flows usually occur during the cold winter season when most high elevation streams are frozen and precipitation is accumulating on the basin in the form of snow. During this time of the year the average of minimum daily discharges recorded at the gage below Cascade Creek was about 180 cubic feet per second. No low flow measurements were ever made on the North Fork just above its confluence with the Middle Fork, but based on an analysis of tributary contributions, the average low flow at this point should be around 290 cubic feet per second.

Approximately one-third of the North Fork's total annual flow originates from the watersheds of Wells, Glacier, and Canyon Creeks. Glacier Creek and Wells Creek together drain almost one-half of the area on the slopes of Mt. Baker and produce the greatest amount of runoff per unit area with the exception of a few small streams farther east that originate on the slopes adjacent to Mt. Shuksan. A comparison of the area-distribution with elevation in the Wells and Glacier Creek watersheds shows that Wells Creek has a higher mean basin elevation than Glacier Creek. Wells Creek basin, therefore, receives more precipitation and produces more runoff per unit area than Glacier Creek basin even though its exposure and orientation are somewhat less favorable. The watersheds of Canyon Creek and Glacier Creek are similar in size, but a greater percentage of the Canyon Creek watershed is distributed at lower elevations thereby producing considerably less precipitation and runoff.

It is difficult to accurately predict low summer flows for these three streams, but it is safe to assume that Canyon Creek will be the lowest because there are no permanent snow and ice fields in this watershed. Glacier Creek basin, like its name implies, contains the larger amount of permanent ice and is generally much better exposed to melting than the Wells Creek watershed. This, in combination with its greater drainage area, produces the largest low flow of the three. Low flows on these streams during winter months are even more difficult to predict and depend mainly on the extent of freezing within the basin, which is in turn primarily a function of elevation. On this basis, the Wells Creek flow should drop most and that of Canyon Creek least.

Boulder and Maple Creeks drain areas on the north side of the North Fork of the Nooksack River, but produce less runoff per unit area than other basins farther upstream primarily because of the lower mean elevation of their watersheds. Boulder Creek basin is considerably higher and more favorably situated than the Maple Creek watershed, resulting in somewhat greater annual runoff even though its drainage area is significantly smaller.

Low flows on these and other nearby streams almost always occur in late summer or early fall with actual time of occurrence and magnitude depending primarily upon the intensity, frequency, and duration of summer storms in the area. The probability of summer precipitation and consequent runoff occurring in these areas is somewhat greater than in the flat Whatcom Basin region, but small intramontane valleys like these are not geologically suited to accumulate large quantities of ground water. Consequently, there is little storage to maintain baseflow after direct storm runoff has passed. As a result many small streams in the area not heading in perennial ice fields become intermittent during this time of the year. Maple Creek is an exception as it has some ground-water storage and discharge from Silver Lake to maintain its baseflow. Although streamflow measurements of Kendall Creek record an approximate annual runoff of only 20 inches, in reality the contribution of this stream is probably considerably greater. Permeable glacial deposits on the floor of this valley absorb much of the runoff and this does not reappear at the surface until it has reached the lower end of the basin beyond the point where the stream was gaged. This is evident from the fact that perennial surface streams are nonexistent in the upper portion of the flat Columbia Valley but appear in the lower part just before joining the North Fork. Hydrographs of Kendall Creek also indicate that direct runoff contributes very little to its total flow. These graphs show none of the sharp, high peaks characteristic of direct runoff but show a rather smooth, continuing curve typical of baseflow conditions. The lowest flows on Kendall Creek also occur in late summer, but because of the rather steady ground-water contribution, these flows are more consistent from year to year than those of neighboring streams.

Other small tributaries of some importance near the lower end of the North Fork are Coal, Racehorse, and Bells Creeks. These streams, because of their low elevations, are primarily rain-fed; but at times during winter months, relatively small amounts of snow will accumulate on the upper parts of their watersheds. Very little factual information is available on the flow characteristics of these streams, but based on their hydrologic location, they are probably quite similar to Canyon Creek on the Middle Fork near Kulshan (see figs. 14, 26, 27, 28, and 29).

The most outstanding feature of hydrology in the watershed of the North Fork of the Nooksack River is the large amount of natural storage occurring throughout regions of high elevation in the form of snow and perennial ice. Snow fields that build up during winter blanketing most of this area release their waters gradually as temperatures increase in spring and early summer, thus providing a major part of streamflow from March through July. Glacial melt occurs somewhat later after most of the snow cover has dissipated and continues on throughout summer and fall. Both of these large reservoirs, therefore, serve as natural runoff regulators by storing precipitation when it is most abundant and releasing it again during the growing season when it is most needed. This can be proven by the total difference in runoff between the South and North Forks of the Nooksack River during the summer period. At this time, for equal size drainage areas, the glacial-fed North Fork produces approximately 140,000 acre-feet more than the South Fork.

Smaller amounts of natural surface storage also exist in the North Fork watershed in numerous small lakes, but most of these are located in remote areas and mainly provide recreational value. For convenience, all available data on these lakes and others in the report area are listed in table 28.

MIDDLE FORK NOOKSACK RIVER

The Middle Fork of the Nooksack River heads at the end of the Deming Glacier located on the southwest slopes of Mt. Baker and falls sharply to the main river valley a short distance below. Here, it makes an abrupt turn and flows in a northwesterly direction to its confluence with the North Fork near the settlement of Kulshan. Topography of the Middle Fork area has generally the same features that characterize the the North Fork basin. The terrain varies from high glaciated peaks surrounded by lower densely timbered mountains to narrow gravel-mantled stream valleys.

The Middle Fork basin occupies more than 100 square miles or about one-eighth of the total area drained by the Nooksack River system, and it exhibits a range in elevation from 300 feet above sea level to 10,778 foot high Mt. Baker. Most of the drainage area lies on the northeast side of the main stem where there is a generally favorable southwest exposure. This exposure causes the northeast side of the watershed to intercept larger quantities of precipitation than the opposite side, which lies in a rain shadow behind Bowman Mountain, Twin Sisters Mountain, and the Sisters Divide. Probably the heaviest precipitation in the study area falls on Mt. Baker's southwest slopes near the Middle Fork headwaters, but no actual records exist to prove this. The only information to substantiate this assumption is provided by a storage gage located in Schriebers Meadow just across the divide in the Baker River drainage. Although the gage is situated at the relatively low elevation of 3,400 feet, during the first year and one month of operation, from August, 1958, to September, 1959, 184 inches of precipitation were recorded. Actually no precipitation records of any kind are available from points within the Middle Fork basin itself, and other than the gage just mentioned, the nearest precipitation station is in the town of Deming. As indicated on the Physiographic Province Map showing mean annual precipitation (fig. 2), this station has measured an average of 56 inches per year.

Continuous stream gage information on the Middle Fork proper is limited to a little more than two years of records taken about fourteen years apart at a site situated about half a mile above the Heislers Creek confluence. In contrast to this, there are five consecutive years of record available on Canyon Creek near Kulshan. These records are rated as good, and provide a reliable indication of runoff conditions in this and similar nearby basins. Various miscellaneous measurements made throughout the basin are also available from the U. S. Geological Survey, but their use is limited to estimating low flows. Based on all available data, the Middle Fork's mean annual runoff has been estimated to be over 400,000 acre-feet, which is equivalent to about 80 inches of water over the entire basin.

Low flow characteristics of the Middle Fork, similar to those of the North Fork, exhibit two well-defined periods during late summer and winter. In the upper reaches the more pronounced low flows occur coincident with freezing temperatures, while in summer glacial firn melt usually maintains higher flows. In contrast to this, it is difficult to predict which season will produce the lowest flows along lower reaches of the main river as there is no perennial ice to feed major tributaries in this area and the region is not subject to prolonged periods of freezing during winter. These factors produce a counterbalancing effect that maintains flow reasonably well throughout crucial periods, and as a result, it is estimated that the flow above the Middle Fork's confluence with the North Fork under present conditions will seldom be less than 170 second feet. In the future, however, when the city of Bellingham begins to divert water from this fork into Lake Whatcom to amplify its existing municipal water supply, this figure will be altered considerably.

Owing to the unbalanced drainage area distribution in this watershed, most major tributaries are located in the northern part of the basin. Of these Clearwater Creek, which joins the main stem a little more than a mile above Heislers Ranch, is by far the largest. This stream drains more than one-fifth of the Middle Fork basin and has an estimated average annual discharge close to 100,000 acre-feet. As the name implies, its waters are basically free of turbidity, being derived entirely from snowmelt and rain with no glacier melt contribution. Records for this stream are too meager to arrive at a well-defined conclusion, but its location infers that the lowest flows most often occur during the dry summer period. On the other hand, a prolonged cold spell during winter could very easily produce the minimum flow, but the probability of such an occurrence is less likely because much of the basin lies at relatively low elevations.

The comparatively long record on Canyon Creek shows a pattern of high flows during the months of December, January, and February, which is the result of extended winter precipitation falling mainly in the form of rain. Another peak is apparent in May or June when the small snowpack that has accumulated at higher elevations melts and runs off. After this peak has receded, a single low flow period follows in August and September. In addition to Canyon Creek, the pattern just described is characteristic of other small streams, such as Porter and Heislers Creeks near the lower end of the basin, and for the most part it also applies to Racehorse, Coal, and Bells Creeks, which are similarly situated at the lower end of the North Fork basin. Annual runoff from most of these streams is relatively small, but on a unit area basis those having an unobstructed southwest exposure usually produce somewhat larger amounts.

Snow and ice fields again represent the most important forms of natural surface storage in the Middle Fork basin. As in the case of the North Fork, snowpacks accumulate in winter over a major portion of the watershed, but glacial ice is more limited, being confined to the slopes of Mt. Baker and the north side of Twin Sisters Mountain. Many lakes in the region also provide some natural storage and data for these are listed in table 28.

SOUTH FORK NOOKSACK RIVER

The South Fork of the Nooksack River has its source on the high slopes south and east of Sister Divide and Twin Sisters Mountain. As it descends to the valley below, its course describes a large clockwise spiral arc until it eventually joins the main stem of the Nooksack River immediately above the town of Deming. For the most part, the terrain found in the South Fork's 180 square miles of drainage area is comparable in ruggedness to that of the North and Middle Forks, but elevations are somewhat lower, ranging between 200 and 7,000 feet.

As in the case of the Middle Fork, most of the area and all of the major tributaries lie on the north side of the river. This side also exhibits higher elevations, which have a tendency to induce a more pronounced orographic effect on storms than that produced by the opposite side. As a result of these factors and the generally advantageous southwest exposure, the South Fork watershed appears to receive precipitation comparable to the other two major forks in spite of its lower mean elevation.

Continuous streamflow records are presently obtained at only two points within the South Fork watershed, but both of these stations are rated as good and provide some of the most reliable information available in the Nooksack River basin. The better of the two is the gage on the South Fork itself, situated near the town of Wickersham and about three-quarters of a mile upstream from Skookum Creek. This gage has been in operation since 1933, and exhibits a longer record than any other streamflow station in the report area. The period of record, in fact, was long enough to encompass the 26-year period upon which studies in this report are based and, therefore, was employed as an indicator to estimate conditions in other parts of the Nooksack area where fewer and shorter records have been collected. The second gage is located on Skookum Creek a short distance above its confluence with the South Fork. This station was initiated in 1948, and although its record does not extend over as long a period as the South Fork gage, it still represents one of the more useful records in the area covered by this report. In addition fragmentary records were obtained on the South Fork at Saxon Bridge about a mile below Skookum Creek, and a few miscellaneous measurements were made at various points within the area.

Nearly 30 percent of the Nooksack River's total annual discharge is derived from that part of the basin drained by the South Fork. The actual amount approaches 800,000 acre-feet, which if evenly distributed, would amount to more than 80 inches of water on the basin. Low flows show up on the South Fork during the same two periods that are characteristic of the other two forks, but the lowest flows practically always occur toward the end of summer or early in fall because of the lack of perennial ice in this basin. Low flows during winter are usually less extreme because a smaller percentage of this basin is subject to freezing temperatures. Based on available data the estimated low flow for the South Fork at its confluence with the main river is 180 cubic feet per second.

Tributaries of the South Fork are for the most part small with the exception of Skookum Creek, which heads on the southwest slopes of Twin Sisters Mountain and discharges into the South Fork about four miles above Acme. Its short length of run combined with its relatively high and low elevations gives it one of the steepest gradients of the streams studied.

Although Skookum Creek appears to have its catchment area advantageously located to derive maximum benefits from precipitation, in reality its runoff is considerably less than might be expected. Close scrutinization shows that the main feature of the basin is a steep, narrow canyon which protects much of the lower valley from direct contact with storms. The only part with good orientation and exposure is the southwest slopes of Twin Sisters Mountain, which represents only a small percentage of the entire area. The overall result is that Skookum Creek produces an average of only 75 inches of runoff annually, while similarly located adjacent tributaries contribute amounts equal to or greater than 100 inches. In spite of this, the large watershed of Skookum Creek produces better than 90,000 acre-feet of annual runoff, which by far surpasses that of any other tributary in the South Fork basin.

The low flow estimate of 25 cubic feet per second for Skookum Creek is considered to be one of the more reliable figures in the streamflow evaluation table and represents an average of actual measurements taken over a period of 12 years. Although glaciers exist on Twin Sisters Mountain, Skookum Creek receives none of its low flow from this source as the entire ice area is situated on the north side of the mountain and drains into the Middle Fork system.

Hutchinson, Cavanaugh, and Howard Creeks are other tributaries worthy of mention, but each produces only about half as much runoff as Skookum Creek. Very little data was available to estimate low flows and annual runoff for these and other small tributaries in the South Fork basin.

Winter snowpacks that pile up in high altitudes represent the South Fork's main form of natural storage. Many small natural lakes are also found in this basin, but they add little to the total amount of storage. Reference is made to table 28 for more complete information on their location and size.

SMITH CREEK

Smith Creek is a small stream that starts near the summit of Sumas Mountain and flows in a southerly direction to the Nooksack River valley just west of the gap at Deming. Here it makes an abrupt turn to the northwest and parallels the Nooksack River, finally flowing into it just south of Lawrence.

Two distinct physiographic features are noted in this watershed. The upper portion, situated on Sumas Mountain, has a moderate slope near the source and gradually becomes steeper as the stream approaches the valley. This area at one time was heavily timbered but more recently has been logged off and now is covered by smaller second growth trees and brush. The lower part of the basin along the foot of the mountain is moderately flat with a gentle downstream slope toward the main Nooksack River.

Smith Creek drains an area of 10.6 square miles and its watershed includes elevations from 3,300 feet near the summit of Sumas Mountain to about 120 feet where it joins the Nooksack River. Squalicum Mountain and the range of mountains across the Nooksack River to the south have a tendency to block some of the effectiveness of oncoming storms, but this is offset somewhat by the favorable southwest exposure and high mean elevation of the basin, resulting in a moderately high annual precipitation.

No continuous streamflow records have been collected on Smith Creek, but based on a few miscellaneous measurements and runoff information from nearby watersheds, it is estimated that Smith Creek produces an average annual runoff of 29,000 acre-feet and experiences a low flow of about 0.3 of a cubic foot per second. Except for small amounts of snow, a few stagnant sloughs near the Nooksack River, and limited ground-water reservoir areas, there is very little natural or artificial storage in the basin.

ANDERSON CREEK

Originating near the crest of an unnamed mountain lying east of Squalicum and south of Sumas Mountains, Anderson Creek cascades down in a northwesterly direction over a falls and through a steep gorge, finally emerging at the eastern end of the King Mountain Upland. From here it makes a turn to the north and falls at a greatly reduced gradient until it reaches a large oxbow bend on the Nooksack River about four miles away. Along its course of travel it is joined by a few small intermittent drainage courses, but in reality, it has only one significant tributary. This is an unnamed branch that feeds into it from the south as the main stream enters a broad valley immediately east of Squalicum Mountain.

Anderson Creek has a total drainage area of 14.3 square miles and contains elevations that range from 115 feet to 3,080 feet above sea level. Topographically, terrain along the upper reaches greatly resembles that of Sumas Mountain and, in a like manner, most of the area has been logged off and is now covered with slash and second growth. Some farming is carried out in the lower part of the basin, but similar to the upper areas, second growth represents the most prevalent type of foliage.

No actual measured precipitation data are available from within this watershed, but the mean annual values of 56 inches at Deming and 46 inches at Clearbrook probably are somewhat indicative of amounts received in the lowland region. Precipitation on the basin's upper half in all probability is considerably higher, but owing to its northwest exposure and the presence of Squalicum Mountain, quantities here should be somewhat less than those experienced by areas of like elevation on Sumas Mountain.

Continuous streamflow records were obtained during two summer seasons on Anderson Creek near the settlement of Goshen and are of some value in estimating its low flow characteristics, but they are of too short a duration to be of much value in determining the total average annual runoff. A value of 36 inches or 27,800 acre-feet was, therefore, estimated with the aid of hydrologic relationships and measured quantities from similar nearby watersheds.

Other than one or two small isolated swamp areas near the stream's headwaters, no surface storage of consequence exists in the basin. Much of the lower area geology is comprised of readily drained recessional outwash material, which, when combined with the meager amount of surface storage, produces extremely low flows during critical summer months.

STICKNEY SLOUGH

The two major tributaries of Stickney Slough, Mormon Ditch and Kamm Ditch, originate in an area of hilly parallel ridges about three miles east of Lynden and from there flow in westerly and southwesterly directions respectively until they reach a swampy area about one mile east of Lynden. Here they join to form Stickney Slough which continues on to the west as far as the city limits of Lynden and then turns south, flowing for about half a mile through an abandoned oxbow depression, to the Nooksack River. Contrary to other basins thus far discussed, the terrain and most soils in this and surrounding areas are excellent from an agricultural standpoint, but a generally high water table makes it necessary to drain the land before it can be effectively farmed.

The eight square mile watershed of this system contains very low elevations, ranging from 40 to 140 feet above mean sea level, indicating that orographic influence has very little effect on precipitation falling on the basin. Climatalogical data obtained nearby at Clearbrook shows a total mean annual precipitation of nearly 46 inches, but considering values at other stations in the vicinity, mean annual precipitation on the Stickney Slough basin is probably a little less.

Although streamflow data is limited to a few spot measurements, one can imply from the high water table condition and numerous springs, that streamflow in this basin is quite stable throughout the year. Based on precipitation, evapotranspiration, and streamflow data obtained in nearby areas, the mean annual runoff from the Stickney Slough watershed was estimated to be 9,200 acre-feet or about 22 inches over the basin, and because of the large ground-water contribution, its flow should seldom recede below 5 cubic feet per second. Although both aforementioned tributaries receive most of their flow from ground water effluent, Kamm Ditch also receives a large amount from several large springs located near the escarpment at the edge of the Lynden Terrace. This branch drains more than half of the total basin and by far contributes the most significant amount of runoff.

Other than swamp land, the Stickney Slough region has practically no surface-water storage. Natural storage in the form of snow is negligible because of generally warm temperatures, and only one small spring pond located immediately east of Lynden exists in the area.

SCOTT DITCH

Scott Ditch originates just west of Strandell and flows nearly due west for about five miles until it reaches the

Nooksack River just above the Guide Meridian Highway bridge. Approximately half-way along its course it is joined from the south by Elder Ditch, the outlet stream of Fountain Lake. Bellingar Ditch, an intermittent cross connection into the Wiser Lake Creek drainage, joins Scott Ditch a short distance farther downstream. All remaining tributaries in this network are rather insignificant and consist primarily of small individual farm drainages.

A large percentage of this stream's flow is derived from springs in the hilly area just south of Strandell. Although not entirely obvious, these springs probably originate from the outflow of Lake Fazon, which lies about three miles farther south. During periods of high rainfall, overflow from this lake drains for about a mile along a course to the north and then suddenly stops and ponds in a densely wooded area. Here sizeable quantities of water obviously filter into the ground as there is no apparent surface outlet,and most likely, most of this recharges the springs above Strandell.

All of the 9.8 square miles in the Scott Ditch watershed are mantled by the rich alluvium found in the Nooksack Lowlands, and like the Stickney Slough area, this soil is excellent for farming when the water table is controlled by proper drainage methods. The region between Scott Ditch and the Nooksack River levee is relatively flat, but farther south the land begins to rise somewhat reaching a maximum elevation of about 125 feet. This extremely low relief exerts little influence on passing air masses, and from records taken at nearby stations, precipitation on an average varies from about 30 inches in the western portion of the basin to 40 inches in the east.

An estimated annual runoff of 9,700 acre-feet or 20 inches of water over the basin is based mainly on records obtained in surrounding areas. Like other primarily ground-water fed streams, Scott Ditch has a rather consistent flow pattern throughout the year, but discharge is higher than normal during late fall and winter and at its lowest in August and September. Miscellaneous measurements taken near the stream's confluence with the Nooksack River substantiate this trend and indicate an average minimum discharge of about 4 cubic feet per second. There is little natural surface storage in this watershed except for some water in Fountain Lake at the source of Elder Ditch.

FISHTRAP CREEK

Fishtrap Creek and its neighbor to the west, Bertrand Creek, differ from all other streams in the report area because more than half of their watersheds lie across the border in Canada. Small headwater tributaries of Fishtrap Creek start in Canada in two perched marshy areas and thereafter combine to form the main stem, which then continues on in a southwesterly direction into the United States,picking up other tributaries from the north along its way until it reaches the Nooksack River about three miles southwest of Lynden. Except for a few high mounds near the source, the major topographic feature of the basin is a nearly flat plain that slopes gently to the south. This flat area encompasses most of the Lynden Terrace and consists primarily of permeable glacial outwash material, while the higher areas are covered by relatively watertight glacial till or hardpan, creating swampy perched water-table conditions. In addition to the above deposits, a small portion of the basin southwest of Lynden lies in recent alluvial deposits characteristic of the Nooksack lowlands.

It is difficult to accurately determine the exact amount of surface area drained by a flat basin such as this, but recent large scale topographic maps indicate the total watershed of Fishtrap Creek to be about 30.6 square miles and the drainage area contributing to Stream Gage No. 2120 to be 16.3 square miles. In comparison, this latter figure appears in older U. S. Geological Survey publications as 24.1 square miles, but was based on maps printed in 1908.

Elevations within the basin vary from about 25 feet near the stream's confluence with the Nooksack River to about 475 feet in Canada near the headwaters. This moderate relief has little orographic influence on moving air masses, but there is a general tendency for precipitation on the lowlands to increase as one approaches the high mountains north and east of the Whatcom Basin. For example, an average annual precipitation of 46 inches has been recorded at Clearbrook while Canadian stations to the north and east at Abbotsford and Chilliwack have recorded 63 and 64 inches of precipitation respectively. Unfortunately there are no precipitation data from within Fishtrap Creek basin itself, but it appears from the neighboring stations that this region receives an average of about 46 inches per year.

Fishtrap Creek has several years of continuous streamflow record and this provides the best indicator of runoff quantities in the lower basin. Nearly 28 inches of water runs off annually from the area above this gage and the estimated runoff for the entire basin is about 26 inches or 43,000 acre-feet. Fishtrap Creek receives a major portion of its flow from ground-water runoff, but during periods of intense precipitation, the streamflow hydrograph also shows peaks characteristic of direct surface runoff. Throughout dry periods in summer the sizable ground-water contribution adequately maintains flow and it is estimated that the low flow of the stream where it enters the Nooksack River should seldom be less than 10 cubic feet per second.

A series of parallel north-south ditches situated between Lynden and the Canadian border at half-mile intervals make up the major tributary system of this stream. This intricate drainage network was developed to improve the land for farming by lowering the high water table that existed in the region. Of all the tributaries, Double Ditch is largest, originating in Canada from the same marshy area that is the source of Fishtrap Creek and joining the main stream just below Lynden. Double Ditch aquired its name from the fact that it is divided at the international border and then flows in the ditches along both sides of Double Ditch Road. About half a mile below the border, the west branch of Double Ditch divides once more and about one cubic foot per second of its flow is diverted into Bertrand Creek basin. The three remaining major tributaries, Benson, Depot, and Bender Ditches located at half-mile intervals in that order to the east of Double Ditch, are all considerably shorter and do not extend appreciably into Canada. Based primarily on its percentage of the total area, Double Ditch contributes roughly one-eighth of Fishtrap Creek's total runoff and the combined flow of the other three major tributaries provides about one-fifth of the total.

Like other streams in the area discussed previously, surface storage is practically non-existent in Fishtrap Creek basin and the small amounts present are confined to the marshy areas in Canada. Much of this area, however, has been recently ditched and reclaimed for use as farm land. These improvements have resulted in a general increase in flows farther downstream and at times the additional discharge has caused the capacity of certain ditches on the American side to be exceeded. Laxton and Judson Lakes near the border store sizable volumes of water, but they are isolated and appear to have no direct surface outlet into this or any other drainage system. There is evidence, however, that Laxton Lake may contribute to Fishtrap Creek and Judson Lake to Pangborn Creek by subsurface means, and this in effect would create additional storage in the area.

BERTRAND CREEK

The area drained by Bertrand Creek lies adjacent to and west of Fishtrap Creek basin and extends as far into Canada. Small intermittent upstream tributaries start near Aldergrove in the lower, eastern part of the Boundary Upland and flow west for about three miles paralleling the Trans-Canada Highway. The main stream then turns south near swamp lands at the headwaters of Campbell Creek and continues on in this general direction into the State of Washington. About a mile south of the border it emerges from the Boundary Upland hills and flows out onto the western part of the Lynden Terrace. After meandering over this shelf for about five miles, the stream drops into the Nooksack Lowlands and shortly thereafter reaches the river about a half mile below the point where Fishtrap Creek empties into the Nooksack River.

Bertrand Creek basin has a drainage area of 43.5 square miles and contains elevations ranging from 25 feet in the south to 450 feet in the north. Precipitation is not recorded within the basin itself, but as indicated by nearby stations, it appears to increase with higher elevations. The upper portion of the watershed is situated about midway between Langley Prairie and Abbotsford, and these stations record mean annual precipitation of 60 and 63 inches respectively. There are no stations in or near the lower half of the basin, but judging from records at Blaine, Bellingham, and Clearbrook, this region receives around 40 inches per year.

A geological comparison of the Bertrand and Fishtrap Creek watersheds indicates that less precipitation infiltrates in the Bertrand Creek basin because more of the area is capped with the impervious Boundary Upland glacial till. As a result, this watershed produces more direct surface runoff and less ground-water runoff than Fishtrap Creek basin. During dry periods the lack of ground water causes tributaries on the Boundary Upland to recede rapidly to very low flows, but farther south in the glacial outwash region, increasing ground-water inflow makes streamflow more uniform and reliable.

Tables 2 and 3 show that basic streamflow data in the basin is comprised of several scattered miscellaneous measurements and two periods of seasonal record on the main stem. It is difficult to draw meaningful conclusions about total annual runoff from short duration records such as these, so data from Fishtrap and Dakota Creeks were also employed in the analysis. The results of this study are listed in table 27 and show that Bertrand Creek basin produces a mean annual runoff of about 24 inches or 56,000 acre-feet. Using data described above, the low flow of this stream system just prior to its junction with the Nooksack River is about 9 cubic feet per second.

Most tributaries to this stream flow in natural channels in their upper reaches, but ditching and drainage improvements have been undertaken in the lower basin to reduce soil moisture and improve farming. At one time East Guide Meridian Ditch flowed into Fishtrap Creek about a mile west of Lynden, but more recently this ditch has been diverted to prevent excessive flooding in the area and now joins Bertrand Creek by way of Duffner Ditch near the lower end. West Guide Meridian Ditch, which receives additional flow from the west branch of Double Ditch, has also been diverted into Bertrand Creek, but it enters about three miles farther upstream. The watershed of Van Ditch lies mainly in Canada, and because of its size and location, this tributary most likely produces a greater runoff than any of the others. The Duffner Ditch drainage area is next in size followed by the watershed of the unnamed stream north of confluence no. 13:2, but both are of equal importance as far as total runoff is concerned.

Little natural surface storage exists in the watershed other than that found in one or two small marsh areas and several small lakes and ponds. The most significant of these are the 3.5 acre lake on the unnamed tributary just north of stream confluence number 13:2 and a smaller pond half a mile north of the Blaine-Sumas Road on McClelland Creek.

SCHNEIDER DITCH

Schneider Ditch is a small stream but worthy of discussion because its waters are quite heavily appropriated, and it is located in an extensive agricultural area. Tributary headwater ditches of this stream start in a marshy area near the center of the Custer Trough and feed into the main channel which flows in a general southeasterly direction. About a quarter of a mile from the Nooksack River it makes an abrupt turn south and flows into Keefe Lake. Flow from the outlet of this lake then discharges into the river a short distance away. The Schneider Ditch watershed, lying in part of the relatively low Custer Trough and Nooksack Lowlands, is underlain with porous and permeable alluvium and glacial outwash material suitable for storing sizeable quantities of ground water. This ground-water reserve sustains the flow of Schneider Ditch during dry periods and provides much of its total annual runoff.

The surface area of this basin is approximately 5.1 square miles, and elevations range from about 15 feet to 75 feet above mean sea level. The area lies in the lee of the Mountain View Upland and this, combined with low elevations, reduces its ability to intercept precipitation. No climatological data is available in the watershed, but precipitation is estimated to average about 30 to 35 inches per year.

Based primarily on measurements of nearby streams, Schneider Ditch should experience an average annual runoff of about 15 inches or 4,100 acre-feet and an annual low flow of about one half a cubic foot per second.

Surface water in the basin is stored primarily in two lakes. Willey Lake in the northern part is isolated without an outlet, but based on topography, it lies within the Schneider Ditch drainage area. Keefe Lake, mentioned previously, is in the southern part of the basin and is merely an elongated enlargement of Schneider Ditch.

WISER LAKE CREEK

Wiser Lake Creek, or Cougar Creek as it is sometimes called, drains a narrow, poorly-defined area lying between the Scott Ditch and Tenmile Creek systems. The portion above Wiser Lake, called Bellingar Ditch, connects with Scott Ditch during high water periods, but its usual direction of flow is toward the west. Wiser Lake itself covers an area of 123 acres and lies on both sides of the Guide Meridian Road about one mile south of the Nooksack River. Its outlet, Wiser Lake Creek, flows from the west end of the lake in a southwesterly direction for approximately three miles and finally reaches the Nooksack River about three miles above Ferndale. Other than the main stream, there are only two tributary water courses of importance in this system. One originates from a spring and flows for about a mile discharging into the head end of Wiser Lake, and the other starts in the West Ditch along Aldrich Road and flows due north for nearly a mile to Wiser Lake Creek.

As shown on the Geologic Map (pl. 1), recessional outwash deposits and a small amount of alluvium near the lower end of the basin make up the surface geology of this area. In contrast to the featureless terrain of the Lynden Terrace, this watershed is quite hilly and irregular, ranging in elevation from 15 to 100 feet above mean sea level.

Basic streamflow data for this system consist of only a few miscellaneous measurements; consequently, all estimates presented in table 27 were developed from general relationships applicable in the lower part of the report area. The mean annual runoff and low flow found for the stream was about 15 inches or 5,800 acre-feet and 1.8 cubic feet per second respectively. As in most other small low elevation basins, the distribution of precipitation producing this runoff should be quite uniform and is estimated to average around 35 inches per year.

Wiser Lake, having a relatively large area, provides ample storage and regulates roughly one-half the runoff from this basin. An enlargement of Wiser Lake Creek near its confluence with the Nooksack River also furnishes a certain amount of water retention, but the amount is small in comparison to that provided by Wiser Lake.

TENMILE CREEK

Tenmile Creek and its two major tributaries, Fourmile and Deer Creeks, drain a major portion of the Whatcom Basin lying south of the Nooksack River and extending nearly to the towns of Strandell and Goshen in the east and Ferndale in the west. The small headwater tributaries of Tenmile Creek start in the eastern part of the King Mountain Upland just south of Fazon Lake and join to form the main stem which in turn flows in a northwesterly direction through a narrow gorge until it approaches the settlement of Tenmile. Here it describes an arc to the southwest picking up Fourmile Creek just past the Guide Meridian Road. After bearing in this general direction for nearly three miles, the main stream enters Barrett Lake. This mile-long marshy enlargement of the stream is actually an artificial reservoir caused by a beaver dam at the lower end. Deer Creek, the other main tributary, joins the drainage system from the southeast near the midpoint of Barrett Lake. About half a mile beyond Barrett Lake and just above the U. S. Highway 99 bridge at Ferndale, Tenmile Creek ultimately flows into the Nooksack River.

Most higher elevation land lying in the southeastern half of the basin is an extension of the King Mountain Upland being composed primarily of glacial till or "hardpan" with a few outcrops of older tertiary sediments. This area is less fit for farming than the remaining northwest part of the basin, and a good share of it is forested mainly with second growth deciduous trees. Large portions of the upstream bottom land in this area and the entire northwestern half of the basin are covered with the same type of pervious glacial outwash material found in most other parts of the Nooksack Lowlands. Fourmile Creek and lower reaches of Tenmile and Deer Creeks flow in this section of the basin, and as indicated previously, this flatter terrain is excellent for agriculture. The watershed extends over an area of about 34.0 square miles, and exhibits elevations between 10 and 370 feet above mean sea level.

There are no high, abrupt obstructions within the area to produce an orographic effect on atmospheric flow; consequently, precipitation over the basin is probably quite uniform. Climatological data have never been collected within this basin, but using information obtained at Bellingham, Deming, and Clearbrook, it appears that total precipitation in any average year amounts to about 30 inches near the western end of the basin to 40 inches in the eastern part.

Despite the magnitude and importance of this watershed, streamflow data are limited to two summer seasons of continuous record and a few miscellaneous measurements taken at various locations. Using these data in conjunction with other records from nearby streams, the estimated total annual runoff for Tenmile Creek is 18 inches or 33,400 acre-feet, and the annual low flow, 5 cubic feet per second.

As mentioned in the discussion of Scott Ditch, Fazon Lake lies in the surface drainage area of the Fourmile Creek system. In reality, however, flow from its outlet ponds and disappears into the ground near the poorly-defined divide between these two watersheds, and until a thorough investigation is made, it must be assumed that a portion of the water drains into both basins. This subterranean flow apparently shows up in seepage springs above Strandell in the Scott Ditch drainage, and it is also quite possible that it contributes to the ditches above Green Lake that flow into Fourmile Creek.

The above two lakes and Barrett Lake provide most of the useable surface storage in the Tenmile Creek watershed. Some use is presently being made of waters in all three of these lakes, but their supplies still remain practically undeveloped; consequently, they should furnish ideal sources for future needs. Other information about these lakes can be obtained from table 28. In addition to these main sources, smaller quantities of water are also stored artificially in farm ponds and ditches.

DAKOTA CREEK

Dakota Creek, situated in the far northwestern corner of the report area, is one of four major streams along the coast independent of the Nooksack River drainage system. The North Fork, its major branch, originates about half a mile south of the international border near the summit of the Boundary Uplands and from there flows southwesterly into the Custer Trough to a point about two miles north of Custer where it joins the smaller South Fork. The South Fork's source is near Bertrand Creek at the eastern end of the trough, and its main stem flows with very little deviation in a northwesterly direction to the North Fork confluence. From here Dakota Creek proper continues in the same northwesterly direction, picking up several large tributaries from the north along its course and eventually discharges into Drayton Harbor just south of Blaine.

This drainage system covers 28.3 square miles and extends a short distance into Canada, but not nearly as far as the basins of Bertrand and Fishtrap Creeks. Elevations vary from sea level to about 540 feet and this moderate difference, combined with the east-west orientation of the uplands, produces some orographic precipitation on the watershed. Blaine receives only 39 inches annually, but to the north and farther inland, stations at Langley Prairie and Aldergrove report 58 and 62 inches respectively. The latter two stations are situated considerably lower than the highest elevations found in the Boundary Upland and it would, therefore, be reasonable to expect at least equal and possibly greater amounts in the northern part of Dakota Creek basin. The Custer Trough portion, being much lower and partially in the lee of the Mountain View Upland, in all probability receives precipitation in amounts comparable to or less than that of Blaine. A little more than five years of streamflow record were obtained on Dakota Creek from that part of the basin contributing flow above Haynie Road. This road crosses the main stem more than three miles upstream from the mouth, and as a result, nearly one-half of the total runoff was never measured because it entered below the gage site.

It is impossible to obtain complete coverage by a single gage in streams like this, however, as measurements taken farther downstream would be affected by tidal action. Using these records and information provided by miscellaneous measurements on the major tributaries, the mean annual runoff and low flow estimated for Dakota Creek at its mouth is 23 inches or 34,400 acre-feet and about 3 cubic feet per second. Like Bertrand Creek many smaller tributaries in the upland regions become dry in summer, and though baseflow is maintained quite well in the Custer Trough farming area, large appropriations here obviously have an adverse effect on low flows.

The old five million gallon reservoir used in the past by the city of Blaine for their water supply and a few small farm ponds contain most of the surface storage in this basin. As in the rest of Whatcom Basin, only about 3 to 4 percent of the total precipitation falls as snow and this is very short-lived providing no useful storage.

CALIFORNIA CREEK

California Creek, like Dakota Creek, flows nearly northwest and discharges directly into Drayton Harbor. Most headwater tributaries on the southwest side of the basin flow from the summit of the Mountain View Upland to the main stream near the base of these hills, while a complex interconnecting system of ditches drains part of the Custer Trough on the opposite side of the basin.

The watershed of California Creek covers about 22.8 square miles and elevations within the area range from sea level to over 360 feet. A slight rain shadow is produced by the Mountain View Uplands over the lowland part of this basin, and as a result, it receives somewhat less total precipitation than the two adjacent basins to the north and south. Following the precipitation trend, runoff is also reduced somewhat and overall is estimated to be about 15 inches or 18,000 acre-feet annually. Low flows, however, as indicated by one seasonal record and several miscellaneous measurements, are not as severely affected by the lower precipitation and should average approximately 1.5 cubic feet per second at the mouth.

Some time ago efforts were made to drain most of the original marsh land and improve it for farming, so at present the only useable storage in the area is contained in a few small lakes and ponds.

TERRELL CREEK

Terrell Creek and its tributaries drain an irregular-shaped section of the Mountain View Upland situated roughly between the settlement of Mountain View and Birch Bay. For all practical purposes, the source of this stream is Terrell Lake. Flow from this large, marshy body of water is controlled by a small dam at its outlet, and the quantity spilled has considerable influence on total flows farther downstream. From the lake outlet, the stream meanders in a northwesterly direction, and after about two miles, is joined by Fingalson Creek from the east. Shortly thereafter the main stem turns west and flows as far as Point Whitehorn Road on the shore of Birch Bay. Here it again turns abruptly and runs parallel with this road in a northeasterly direction for about two miles to its mouth in Birch Bay.

Except for a few isolated patches, this basin is capped with hardpan, making ground water very scarce. As a result, nearly all streamflow is derived from surface runoff while baseflow is practically non-existent. Miscellaneous measurements taken in the region substantiate this and show that the streams dry up completely every summer.

The terrain, like that exhibited in California Creek basin, varies in elevation from sea level to over 360 feet, but in this case the mean basin elevation is somewhat higher and the entire area unobstructed to the southwest resulting in greater amounts of precipitation and runoff from certain portions of the watershed. Terrell Creek is completely void of useable hydrologic data, and one can only infer from similar nearby areas the quantities that can be expected here. Considering all available relationships and information, precipitation should average between 30 and 35 inches and mean annual runoff from the watershed should be about 15 inches or 14,000 acre-feet.

Terrell Lake, which has the largest surface area of any lake included in the report, retains a sizable percentage of the annual runoff and helps to regulate downstream discharges during the dry summer seaon. Low flows are also aided by the fact that little use is made of the surface waters in this basin except for two diversions from small reservoirs near the lower end.

LUMMI RIVER

Prior to 1860 the Nooksack River discharged into Lummi Bay by way of the channel presently used by the Lummi River. During that year a log jam blocked the Nooksack River and diverted it to a small stream that flowed into Bellingham Bay and since then the stream remaining in the Nooksack River's old channel has been called the Lummi or Red River.

For all practical purposes, the Lummi River has only two major tributaries, but a maze of independent small streams and ditches also flow into its complex delta region. In addition to these tributaries, a continuous supply of fresh water is diverted into the Lummi River proper from the Nooksack River by means of an interconnecting culvert; consequently, the Lummi River is actually a distributary of the main river. It would be comparatively easy to measure this incoming amount, but nearly impossible to determine the total output at the lower end of the Lummi River owing to the complex tidal action that takes place there. No attempt was, therefore, made to analyze the main stem itself, but instead, all efforts were concentrated on the major tributaries, which are either situated above high tide level or sealed off from this action by flap gates and dikes. In general, these streams drain the Mountain View Upland's southeastern slopes, and because ground water is lacking, most of them become completely dry during summer seasons. On the other hand, in lower areas of recessional outwash and alluvium, ground water is abundant and stream channels remain completely filled throughout the year.

Individual estimated amounts of mean annual runoff produced by each important tributary are listed in the evaluation table, but in general, an average for the area is around 17 inches. Precipitation data collected at Marietta, a few miles to the southeast, indicates that an average of 30 inches per year falls on the delta region, but if upland tributary areas are included, this figure should be an inch or two more. As indicated above, a considerable amount of water is stored in the lowland sloughs and ditches, but this water is rather stagnant and, though it has not been sampled for quality, is probably quite brackish.

SILVER CREEK

Silver Creek and its major tributaries, Bear Creek, Andreason Ditch, and Tennant Lake Creek, drain a small watershed just northeast of the Nooksack Delta and northwest of Bellingham. Its headwaters originate on northwest slopes of the King Mountain Upland and gradually turn to the southwest into the Nooksack River's alluvial trough. After passing through an extensive marshy region in the trough, the stream empties into Bellingham Bay near the town of Marietta.

The basin occupies 15.8 square miles and contains terrain ranging in elevation from sea level to about 350 feet. This moderate relief does not have an appreciable effect on precipitation, but some variation is evident as indicated by gages at Marietta and the Bellingham Agricultural Experiment Station. These gages are situated about four miles apart, and in this short distance mean annual precipiation varies from nearly 30 inches to about 32.5 inches. Based on these quantities of precipitation and various streamflow records, the mean annual runoff for Silver Creek was estimated to be about 14 inches, or an equivalent total volume of 11,500 acre-feet.

Like streams originating on the Mountain View Upland, very little ground water is present to feed the upper tributaries in this system, and as a result, many of them dry up during summer months. Larabee Springs on the divide between the Fourmile Creek watershed and this basin flows into both drainages and by itself sustains most of the flow in the main stream during dry periods. Other than a few marshes, Brennen Pond and Tennant Lake furnish most of the surface storage for the system, and these bodies of water together with contributions from ground water help to amplify low flows along lower reaches of this stream.

SUMAS RIVER

Sumas River basin is an important agricultural area situated in the transition region between the Whatcom Basin and Cascade Mountains. Sumas Mountain occupies the high eastern half of the watershed and Sumas Trough the low western part containing elevations just slightly above mean sea level. With the exception of the Johnson Creek system, all major tributaries originate near the summit of Sumas Mountain and descend abruptly to the west onto the lowland where they are intercepted by the main stem. The river itself starts on the southwest side of the mountain and, after cascading to the lowland, turns sharply and flows in a northerly direction along the base of the mountain. In this reach, the stream is located less than half a mile from the Nooksack River, and in past years, flood waters of the Nooksack River have spilled over this low narrow divide into the Sumas Valley. From here the stream meanders northward away from the Nooksack River, and past the city of Nooksack, it turns northeast toward the city of Sumas. Johnson Creek, which drains the northwestern part of the Sumas Trough and part of the Lynden Terrace, joins the river just east of Sumas and from there the main river crosses the border and flows in a northeasterly direction into the Vedder Canal near its confluence with the Fraser River.

In the Canadian portion of the Sumas Trough elevations are exceedingly low with some areas actually being below sea level. Dikes were, therefore, necessary to confine the river in this region to prevent it from flooding the low valley and a dam was constructed near the lower end to keep the Vedder from backing up into the channel of the Sumas. Also, at times when the stage of the Vedder and Fraser are higher than the Sumas, it becomes necessary to pump water from the Sumas over this dam to prevent it from backing up and spilling over the dikes.

Except for a small strip of hardpan along the base of Sumas Mountain, most of the material in the Sumas valley consists of recessional outwash and recently deposited river alluvium. The ground-water supply map (pl. 3) indicates that these latter mentioned deposits are quite highly productive; therefore, streams toward the lower end of the basin receive a considerable contribution from ground water and exhibit sizable baseflows. As a result of the relative positioning of these lowland deposits, several tributary streams flow down from the mountain and cross the strip of hardpan but disappear into the ground when outwash is reached.

The total area contributing flow to the Sumas River where it crosses the United States-Canadian border is 55.8 square miles, of which the Johnson Creek portion is 20.7 square miles. Portions of these above areas are situated in Canada and they produce runoff that drains into the United States and then returns to Canada by way of the Sumas River. Also, the above figures do not include the entire Sumas basin area on the United States side of the border because a small part of this drains across the border and reaches the river on the Canadian side.

Elevations range from about 30 feet at the lower end of the Sumas Trough to more than 3,300 feet on top of Sumas Mountain. Although this difference in elevation is only moderate in comparison to other parts of the report area, no major obstructions exist to the west, and as a result, passing air masses receive most of their initial orographic lift from Sumas Mountain, causing large quantities of vaporized moisture to condense and precipitate out in the process. Unfortunately, there are no records to prove just how much precipitation actually falls at various places on this mountain, but based on experiments in other regions and measured streamflow quantities, it can be inferred that the annual average precipitation around the summit should be near 100 inches. Clearbrook lies in the middle of the lower basin, and its average annual precipitation of 46 inches should be fairly representative of most of the lowland area.

A multitude of miscellaneous streamflow measurements have been taken in this region and, combined with four seasonal records on the main river, provide a fairly reliable basis upon which to estimate minimum flows. Based on this information, the average low flow of the Sumas River to be expected at the border should be about 25 cubic feet per second, and of this, Johnson Creek would probably contribute about 12 cubic feet per second. Two complete years of continuous streamflow data are available on this stream, and using these in conjunction with more reliable records from nearby streams as a control, the total mean annual runoff of the Sumas River where it crosses the border was estimated to be about 91,000 acre-feet or an equivalent of 31 inches of water over the entire watershed above this point. Continuous streamflow data have never been collected on Johnson Creek, but it is estimated that this tributary contributes a little less than one-third of the above total.

In a prior section it was mentioned that Judson and Laxton Lakes near the border appear topographically to be independent of this drainage basin, but several springs lie just southwest of Judson Lake and it seems quite possible that their flow originates from this source. Pangborn Lake, a shallow marshy body of water about a mile southwest of Judson Lake, gets some of its water from these springs and represents the only surface storage actually within the Sumas River drainage system.

SAAR CREEK

Saar Creek originates in Paradise Valley on the north side of Sumas Mountain and flows north for about three miles to the pass between Sumas and Vedder Mountains. Here it turns west, and after a mile or so, drops into the Sumas Trough. Once in the lowland, it flows northeasterly across the trough and joins the Sumas River about three miles north of the international border in Canada. Mud Slough, its major tributary, starts in Anderson Lake near the southwest end of Vedder Mountain and from there flows onto the lowland joining Saar Creek in Canada by way of Arnold Slough.

When the glaciers receded, sizable deposits were left behind to mantle Paradise Valley. This material being quite permeable and porous has a sizable ground-water storage capacity, and as a result, there are many marshy springs in the area which help to maintain flow during dry periods. Farther down in the pass between the two mountains, the stream's banks have been diked to alleviate flooding and in this reach little ground water is contributed to the total flow. In the Sumas Trough the gradient flattens out and once more its flow is increased by ground water stored in the alluvium.

Based on miscellaneous measurements and two summer seasons of continuous streamflow record taken at two different locations on this stream, the average low flow was estimated to be about 0.2 of a cubic foot per second. Annual runoff has never been measured on this stream, but by extending relationships from nearby basins, the mean annual runoff is estimated to be about 22,000 acre-feet or 41 inches.

FLOODS IN THE NOOKSACK RIVER BASIN

(By E. G. Bailey, U. S. Geological Survey)

Floods generally result from acts of nature and cannot be eliminated. However, within limits of economic feasibility, they can be controlled by reducing their destructive forces or by providing protection against them. A flood is defined as a condition that prevails when the waters of a stream exceed the capacity of the channel and overflow the adjacent flood plains.

HISTORY OF FLOODS

There is relatively little recorded information on the occurrence of floods in the Nooksack River basin. The principal source of information about floods during the early days of settlement by white men is from accounts of the pioneers of the region, of whom a few are still alive. Newspaper accounts and records from the railroads, during the early years of the 20th century, also serve as sources of information prior to the beginning of systematic stream gaging in the area.

In a field investigation by the U. S. Geological Survey the earliest evidence found of a major flood in the Nooksack River basin refers to a flood that occurred "about 1893." There is reason to believe that the year was 1894 because the flooding in this basin in that year would have been concurrent with major floods in many other river basins of the region.

Other notable destructive floods on the Nooksack River are reported to have occurred in 1909, 1917, 1921, 1932, and 1935. Few data have been found that can be used for computing peak discharges for these floods. However, comparison of the available information with the records of nearby rivers indicates that the flood of 1909 on the Nooksack River had the greatest magnitude of any flood since the valley was settled.

Correlation of known floods on this river with those in adjacent basins brings forth interesting speculation in regard to the occurrence of earlier floods than those now identified. Studies by Stewart and Bodhaine 1/ of floods in the Skagit River basin, based on Indian accounts, high-water marks, and other physical evidence, provide authentic information on major floods in that basin as early as about 1815 and indicate that the flood of 1815 had a higher peak discharge than any flood that has occurred since. Records of runoff in the Northwest coastal region show that floods in one basin usually are paralleled by excessively high flows in adjacent basins even though the relative magnitude of peak flows varies to some extent from basin to basin. Thus, floods of outstanding magnitude may have occurred in the Nooksack River basin in about 1815 and 1856, and were probably higher than any occurring since, including the flood of 1909.

Records of stage and discharge have been collected at various points on the Nooksack River since October 1933. From this date until 1959 the flood of greatest magnitude was that of February 10, 1951. The peak discharge at that time was 43,200 cubic feet per second at the Deming gaging station. From eye-witness account there is reason to believe that the peak discharge of the 1909 flood exceeded that of 1951.

The annual peak discharges of the Nooksack River at the Deming gaging station from 1936 to 1959 are listed in table 29; their lack of regularity may be seen by inspecting figure 50. The magnitude and frequency of floods are discussed in more detail in the following pages.

ORIGIN AND CHARACTER OF FLOODS

Floods in the area of the report occur during the fall, winter, and spring seasons. The fall and winter floods result primarily from rainfall sometimes augmented by snowmelt; whereas, spring floods usually result from snowmelt frequently supplemented by warm spring rains. Winter floods are characterized by peaks of relatively high magnitude and short duration. Almost without exception the most destructive floods in this region are of this type. Spring floods almost always have rounded peaks of longer duration.

The highest momentary peak discharge in a water year has been used as the significant flood characteristic for analysis in this report. Hereafter this peak discharge will be referred to as the "annual flood," although not every yearly peak discharge is of flood proportion. Also, the term "annual flood" does not imply that there may be only one flood of major importance each year; other peak flows occurring within

1/ Stewart, J. E., and Bodhaine, G. L., 1960, Floods in the Skagit River basin: U. S. Geol. Survey Water-Supply Paper 1527 (in press).

Table 29. Momentary maximum discharge, in cubic feet per second, of Nooksack River at Deming.

Water year	Maximum discharge	Date	Water year	Maximum discharge	Date
1936	12,100	May 4, 1937	1948	31,400	Oct. 19, 1947
1937	20,100	Dec. 22, 1936	1949	(c)	Feb. 17, 1949
1938	33,200	Oct. 28, 1937	1950	36,500	Nov. 27, 1949
1939	23,000	Jan. 1, 1939	1951	43,200	Feb. 10, 1951
1940	14,200	Dec. 15, 1939	1952	14,200	Jan. 30, 1952
1941	15,000	Jan. 18, 1941	1953	22,700	Jan. 31, 1953
1942	15,800	(a)	1954	24,900	Oct. 31, 1953
1943	17,200	Jan. 15, 1943	1955	23,300	Nov. 19, 1954
1944	23,300	Dec. 3, 1943	1956	38,500	Nov. 3, 1955
1945	28,800	Jan. 7, 1945	1957	27,500	Oct. 20, 1956
1946	38,000	(b)	1958	22,000	Jan. 16, 1958
1947	29,900	Oct. 25, 1946	1959	31,100	Apr. 15, 1959

a Dec. 2, 1941 and June 15, 1942.
b About Oct. 25, 1945
c Maximum discharge not determined; maximum discharge at the Lynden station was 17,500 cfs.

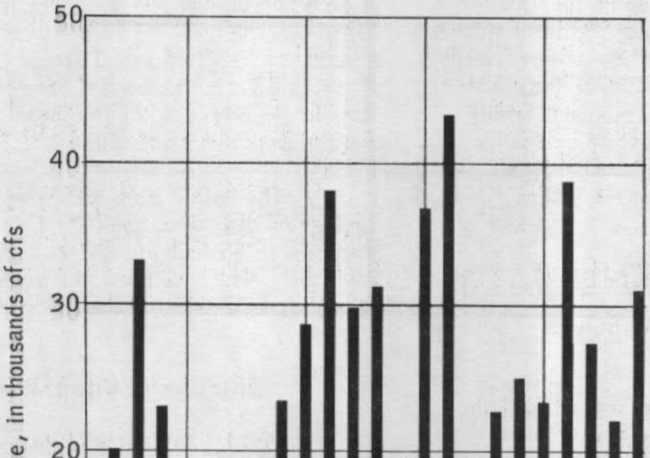


Figure 50. Maximum annual discharge of Nooksack River at Deming during the years 1936-59.

Figure 51. Magnitude and recurrence interval of annual floods, Nooksack River at Deming

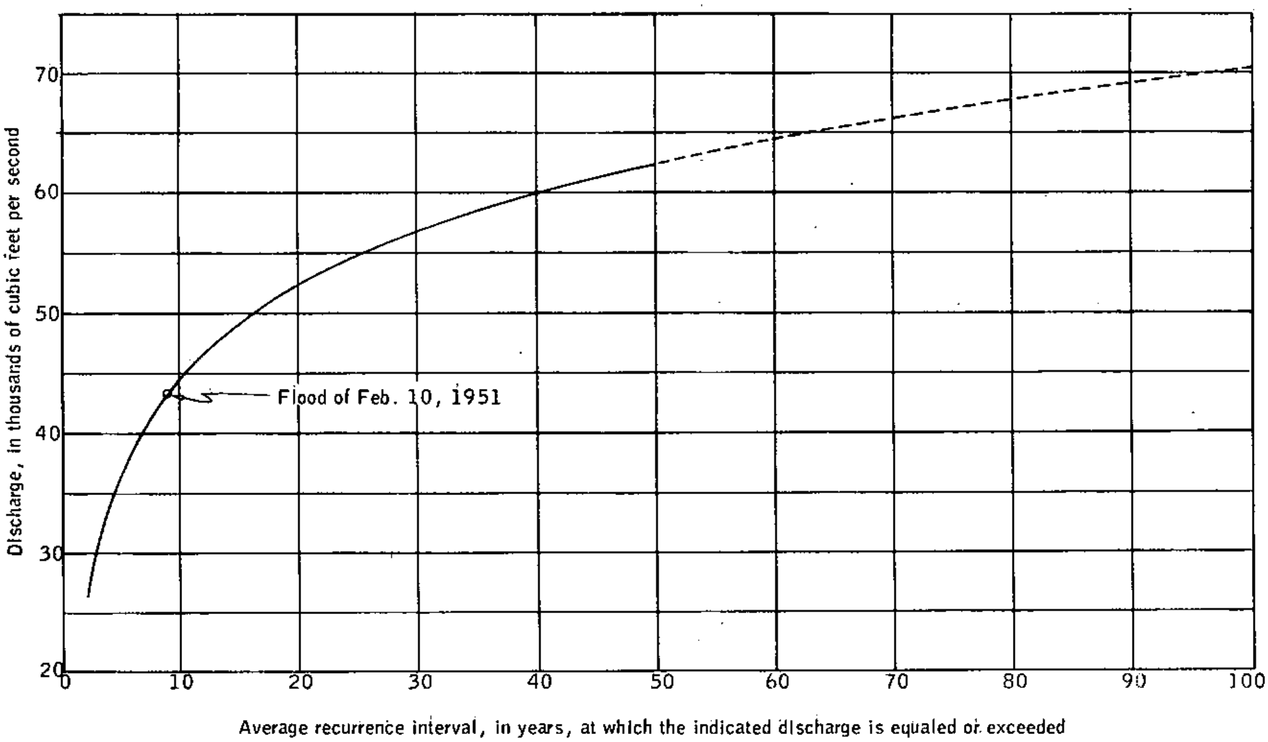
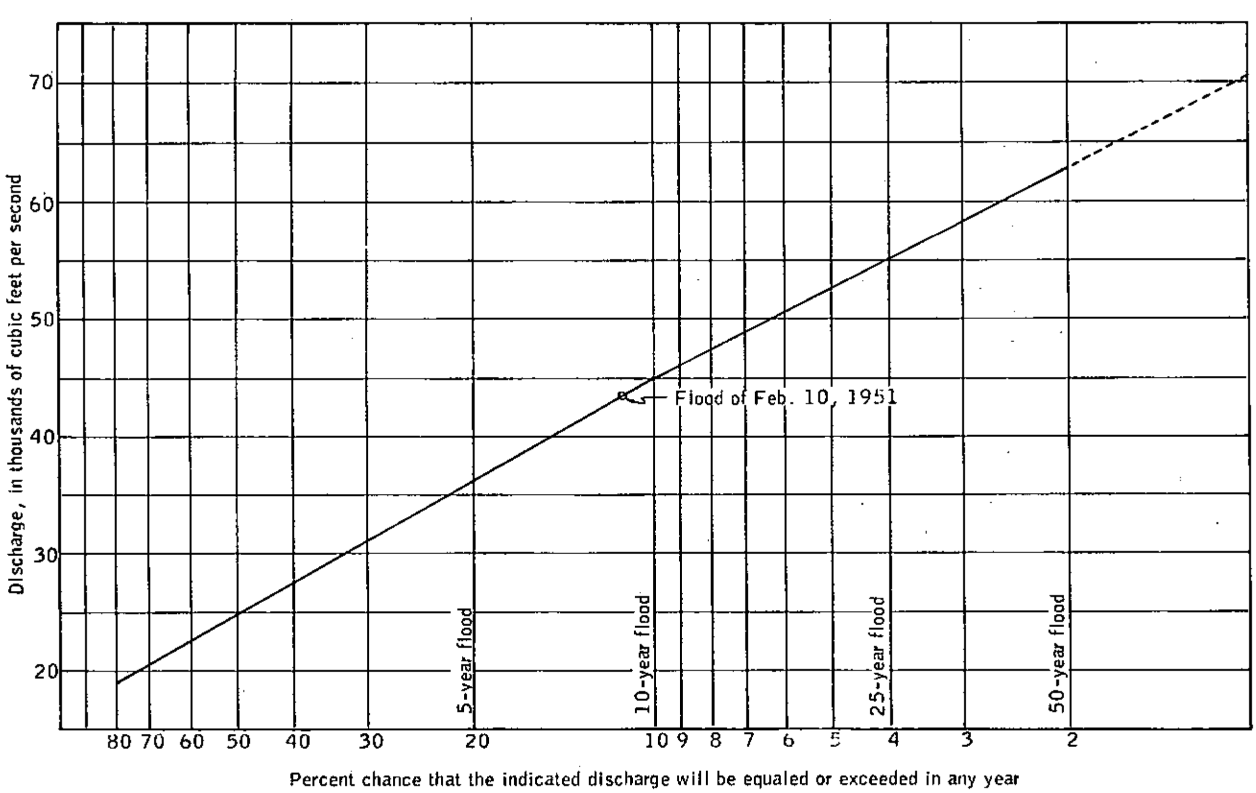


Figure 52. Magnitude and percent chance of annual floods, Nooksack River at Deming.



the same water year sometimes have but slightly less magnitude than the "annual flood."

In the Nooksack River basin the "annual floods" occur predominately during the period October to February. It may be of interest to note that during the last 24 years, and for the known 5 floods of earlier years for which there is valid information, an "annual flood" has occurred only 3 times outside the October-February period--one each during April, May, and June. The distribution of the 29 "annual floods" of record according to their occurrence by months is shown in the following table:

Table 30. Monthly "Annual Flood" Occurrences.

Month	Number of occurrences	Month	Number of occurrences
October	5	February	3
November	4	March	0
December	6	April	1
January	8	May	1
		June	1

MAGNITUDE AND FREQUENCY OF FLOODFLOWS

The method of analysis used herein to estimate the magnitude and frequency of floods is the same as that currently used by the U. S. Geological Survey 1/ in other areas. The conclusions drawn from the analysis are derived from streamflow data collected at various gaging stations in the general area during the 46-year base period 1912-57. The flood records used include those of the Nooksack River basin and those from adjacent river basins that the study showed to have similar basin characteristics. Although the graphs in this report have been extrapolated to provide estimates of magnitudes of floods up to a 100-year recurrence interval, they are based on observation only up to the 50-year recurrence interval.

The flood-frequency data are presented by two graphs. In figure 51 the graph sets forth the average recurrence interval at which a flood of a given magnitude may be equaled or exceeded. For example, the flood of February 10, 1951, at Deming, which had a peak discharge of 43,200 cubic feet per second, can be expected to be equaled or exceeded on an average of once in 9 years. In figure 52 the flood-frequency data presented in figure 51 have been converted to probability of occurrence; instead of showing the magnitude of a flood in relation to the average recurrence interval, it is shown in terms of chance of occurrence in any year. For example, the graph shows that the flood of February 1951 has a chance of about 11 to 12 percent of occurring in any one year.

Estimates of flood frequency are based on the assumption that events of the future will have the same average frequency as events that were experienced in the past. It is well to note, however, that although the probable average frequency of a flood of given size can be estimated, the time of its next occurrence cannot be predicted. For example, a flood of 50-year magnitude may be expected to occur twice in 100 years, but it is possible for two 50-year floods to occur in consecutive years. Therefore, flood-frequency data can be used in the design of flood-control projects, such as dikes, levees, and storage dams, and in the design of bridge and culvert openings, but cannot be used to forecast the time when a flood will occur.

1/ Dalrymple, Tate, 1960, Flood-frequency analyses, pt. 3 of Manual of hydrology: U. S. Geol. Survey Water-Supply Paper 1543-A, p. 1-80.

FLOOD AND DRAINAGE CONTROL IN THE NOOKSACK RIVER BASIN

(By G. M. Hastings, Division of Flood Control)

The widespread floods of December 1933 and January 1934 focused the general public's attention on flood control, and with the near disastrous conditions resulting again from the January 1935 floods, the 1935 Washington State Legislature replied to the demands and desires of the people by its enactment of several flood control laws. These laws related to the following: (1) flood control district organization, authorizing counties to levy a one-mill river improvement tax; (2) establishing flood control zones with the state assuming full regulatory control over all waters; (3) establishing a state policy for flood control and cooperation with all local and federal agencies; and (4) carrying out state participation with local municipal corporations in flood control maintenance subject to flood conditions. In the enactment of these laws the 1935 Legislature declared "it is the purpose of the state in the exercise of its sovereign and police powers, and in the interests of public welfare, to establish a state policy for the control of floods to the extent practicable and by economically feasible methods" and stated that "the prevention and alleviation of flood damages is a matter of public concern as affecting the health, safety, and general welfare of the state."

To carry out such a policy, the Division of Flood Control was created within the Department of Conservation. Pursuant to the 1935 Flood Control Zone Act, sixteen major rivers were designated flood control zones, the Nooksack River being Zone No. 8 (see pl. 7). Within these sixteen zones no improvement, public or private, shall be constructed, reconstructed, modified, nor shall any such improvement which was constructed, reconstructed or modified after March 22, 1935, be maintained or operated without a written permit from the supervisor of flood control. The supervisor may examine, approve, or reject all plans for new construction or for reconstruction or modification of existing improvements. Any improvement operated or maintained within a zone in violation of any order of the supervisor shall be presumed to be a public nuisance and may be abated. The supervisor assumes no jurisdiction over structural designs but is solely concerned with the probable effect of proposed works and structures on the safe passage of flood waters, their probable influence on the regimen of streams and bodies of water, and with any adverse effect such proposed works and structures may have upon the security of life, health, and property.

When state funds are available, any municipal corporations (towns, cities, and counties) and diking, drainage, irrigation, flood control, and soil conservation districts subject to flood conditions may receive financial assistance from the state in the cost of proposed flood control maintenance projects, normally on a 40 percent state fund basis. Such projects shall be for the purpose of maintaining and restoring normal, stable stream-channel alignment and capacity; for carrying off flood waters with a minimum of bank erosion damage or overflow on adjacent lands and property; and for restoring, maintaining, and repairing natural conditions, works, and structures for the maintenance of such conditions.

As stated previously in the section on flood history, origin, and magnitude, there are no records for flood discharges, stages, and damages prior to 1935 for the Nooksack River basin. Severe floods have been recorded as occurring in January 1935, October 1945, November 1949, and February 1951. Such floods inundate much of the cultivated lowlands of the Nooksack valley and portions of the towns of Everson, Ferndale, and Marietta. In addition, a portion of the flood waters overtop the low divide between the Nooksack and Sumas valleys near Everson and aggravate flood conditions in the Sumas basin, both in the United States and Canada. In their "Review of Reports on Flood Control of Nooksack River," April 25, 1952, the Corps of Engineers reported that the amount of land flooded and the depth to which it is flooded depend not only on the crest discharge, but also on the duration of the flood, local failures of levees, and formation of ice and drift jams. The 1935 flood is the only flood for which there is complete information available concerning the area inundated and the use of that area. That flood, although its crest discharge has been exceeded three times in the past seventeen years, is believed to have flooded a larger area than did the subsequent higher-crested floods. Of the 17,200 acres flooded in the valley in 1935, about 8,944 acres were in pasture and forage cropland, 3,612 acres were in grain cropland, 3,784 acres were in swamp and brushland, and the remaining 860 acres included fruit and specialty cropland and portions of Ferndale, Everson, and Marietta. Within the flood zone were tracks of the Northern Pacific Railway and the Chicago, Milwaukee, St. Paul and Pacific Railroad and several miles of state and county roads. Damage to buildings in 1935 is unknown, but during the 1951 flood, major damage occurred to 450 homes, 350 farm buildings, and 150 other types of buildings and affected 450 families. No lives have been lost as a direct result of floods in the Nooksack River basin. Plate 7 shows the boundaries of the Nooksack Flood Control Zone No. 8, established pursuant to Chapter 159, Laws of 1935, and the area that was theoretically inundated by the flood of February 1951, the maximum discharge of record. The entire shaded area was not actually inundated in 1951 but, on the basis of that flood stage and accompanying surface water gradient, similar recurring floods could inundate several portions or all of the area by a progressive combination of (1) bank and dike failures; (2) time of crest duration; and (3) ice and drift formation and their locations. During a particular flood of such magnitude all lands, property, and people are subject to damage and inundation within this theoretical flood area.

Floods in the Nooksack River basin result in damage to lands through bank and sheet erosion, through deposition of sand, gravel, and debris, and through spreading of weed seeds. Damage also occurs to crops, to farm and urban buildings and their contents, to roads, to railroads and utilities, and to dikes and bank protective works. The average annual damages, based on 1951 conditions and prices, were estimated by the Corps of Engineers to be $246,300 including $23,900 in the Sumas River basin. In addition to this tangible damage appraisal there are certain intangible flood damages which cannot be reduced to a monetary basis, such as endangering lives and pollution of wells and municipal water supplies. Fear of floods no doubt retards economic growth and causes some land to be utilized at less than its full economic potential.

No reasonable estimate can be made on the total cost of flood control work performed in the Nooksack River basin since its habitation. There are no records showing the value of flood control works constructed by individual landowners over the years. However, between 1935 and 1940 the Works Progress Administration constructed flood control improvements at more than 20 locations costing $378,000 and consisting of brush revetments, shear cable, snagging, and diking. During the period 1935 to 1960 the Corps of Engineers have expended $216,000 in snagging, repairing, and strengthening of dikes, stabilization of banks, and restoration of the Lummi Channel intake works. From March 1943 to September 1960 the state, through the Division of Flood Control, has participated in the cost of flood control maintenance projects in the Nooksack Basin. This maintenance involved pile and timber groins and shear walls (which have given way to rock riprap in recent years), channel rectification, dike repair, and debris removal on an estimated 150 projects. State funds expended amount to $488,954 with total project costs amounting to approximately $1,250,000. The other participating agencies are Drainage District No. 1 (Fishtrap Creek), Drainage District No. 2 (Schneider Ditch), Drainage Improvement District No. 15 (Saar Creek), Macauley Creek Flood Control District (Macauley and Smith Creeks), and Whatcom County Soil Conservation District, Whatcom County and Corps of Engineers (entire Nooksack River basin). The WPA, Corps of Engineers, and state expenditures do not represent the total cost of flood control works and improvements constructed in the basin, since from time to time when state funds were not available, local authorities proceeded with needed work with 100 percent local funds and no complete record of these local efforts is available. However, a conservative estimate of the total funds expended on flood control in the Nooksack basin since 1935 approaches $2,000,000.

On January 31, 1946, Congress requested the Corps of Engineers to review their 1942 report on flood control of the Nooksack River for the purpose of determining whether or not a federal flood control project would be economically feasible, the 1942 report being unfavorable. By their review report of April 25, 1952, in compliance therewith, the Corps of Engineers considered and carefully investigated all possible methods of reducing flood damages in the Nooksack River basin (channel improvement, diversion, diking, and storage) and determined costs and resulting benefits, based on a standard project flood of 125,000 cubic feet per second. This standard project flood was considered by the Corps of Engineers to be the maximum flood that could reasonably be expected to occur. The conclusions of their report are presented in table 31.

The benefit-cost ratios indicated that no federal projects could be justified under the then existing state-of-basin development. The review summarized further, however, that small levee and revetment projects would from time to time become justified and that continuing efforts of local interests could most efficiently provide for such projects.

It is fully appreciated and understood that a federal project must provide for complete protection, that is, standard project flood of 125,000 cubic feet per second (Corps of Engineers estimate). The maximum flood of record at Deming as reported by the Corps of Engineers had a discharge of 44,500 cubic feet per second (February 1951) and a recurrance interval of approximately nine years. By extrapolating their curve representing recorded maximum flood discharges it is shown that a flood of 65,000 cubic feet per second at Deming is likely to occur once every 100 years.

It is believed by state and Whatcom County officials

Table 31. Flood Control Cost-Benefit Ratio--Nooksack River.

Project	Annual Costs	Annual benefits	Benefit-cost ratio
Channel improvements:			
Dredging at mouth (annual maintenance) ---	$ 65,000	$ 49,000	0.8
Diversion:			
To Lake Whatcom ---	685,000	250,000	0.4
To Samish River ---	245,000	125,000	0.5
To Lummi River ---	26,900	16,500	0.6
Levees:			
Right bank below Ferndale ---	23,600	11,500	0.5
Left bank at Marietta ---	1,700	1,100	0.6
Left bank, Ferndale to Marietta ---	26,400	10,000	0.4
Right bank, Lynden to Everson ---		over $240 per acre	
Left bank, Everson to Ferndale ---		over $300 per acre	
Right bank, Everson to Lawrence ---	27,400	15,000	0.5
Storage:			
Edfro Creek site			
74,000 acre-feet ---	568,000	245,000	0.4
36,000 acre-feet ---	451,000	123,000	0.3
Wells Creek site			
46,000 acre-feet ---	550,000	165,000	0.3
Deming site			
120,000 acre-feet ---	837,000	262,000	0.3
35,000 acre-feet ---	507,000	125,000	0.2

and Nooksack River basin residents that the standard project flood sights should be lowered to a more realistic level, possibly that of a fifty year flood. In light of the present economic level of development in the basin and corresponding damages likely to accrue ($246,300 annually), a lower standard project flood would decrease project costs accordingly and cause benefit-cost ratios to improve and become economically feasible. By this thesis it is acknowledged that complete protection might not be achieved, but at the price of the present extreme vulnerability of the basin, accomplishment of a lesser, calculated degree of protection may be justified and at a risk the local interest can well afford and are willing to assume. Preparation for such reappraisal and determination of benefit and costs are being made by the state and a review of the 1952 Corps' reports has been authorized. It is hoped that the results of these combined cooperative reviews and studies may be available within the next two to three years.

WATER DEVELOPMENT SITES

INTRODUCTION

Three basic types of water development projects are suitable to the report area. These include the major reservoir storage sites and power diversion sites of the upper basin, and the minor storage sites of the lower basin. The approximate site locations and maximum inundation areas are shown on plate 8.

Considerable geologic work has been done on the four major areas of development although additional study would be required to determine in more detail the feasibility of these sites to the uses proposed. The smaller storage sites have been examined in only a precursory manner, while diversion sites are based largely on estimations following field studies.

Earthquakes must be considered in the design of any storage or diversion project as western Washington is an area of considerable seismic activity. Most of the earthquake shocks have been of low to moderate intensity, but a few have been severe. A large majority of them have originated in or near Puget Sound. Between the years 1856 and 1934, twenty-one earthquakes were recorded for northwest Washington that were probably felt in the Nooksack River basin, six of these having their epicenters within the basin. From review of past earthquake activity in the basin, it is evident that a dam and its appurtenant structures will be subject to numerous earthquakes mostly of low intensity but occasionally reaching an intensity of VI to VII on the modified Mercalli scale, causing moderate damage. In general, earthquakes will be more severe in the lower parts of the basin than in the upper parts. On the seismic map of the United States, the U. S. Coast and Geodetic Survey has placed the lower basin and the downstream portions of the upper basin in zone 3, subject to major damage. The Maple Falls, Edfro Creek, and all sites farther west are included in this zone. The remainder of the basin is placed in zone 2, subject to minor damage.

MAJOR DAM AND RESERVOIR SITES

This discussion is based on several government reports which are listed in the bibliography. These reports discuss four major water utilization areas in the basin which include the Nooksack River Utilization Area at Deming, the North Fork River Utilization Area, the Maple Falls River Utilization Area, and the South Fork River Utilization Area. The North Fork area includes as alternates the Shuksan and North Fork dam sites while the South Fork area includes as alternates the Skookum and Edfro Creek dam sites. The four major areas are all accessible by hard surfaced all-weather highways with the exception of the South Fork area and the Wells Creek portion of the North Fork area which are reached by gravelled logging roads.

Table 32 shows the estimated power available at the major reservoir and diversion sites. With the exception of Maple Falls, all the major sites are considered multipurpose and, therefore, power development may be sacrificed in order to utilize more water for irrigation, municipal supply, and other uses. Varying amounts of power are available at each site depending upon the following factors: location of powerhouse, which dam is selected where alternates are available, and, in the case of the Deming site, what large diversions occur upstream. It is estimated that a maximum of 70,800 kilowatts could be developed at these sites. However, when other uses are considered the estimated 70,800 kilowatts for 99.9 percent of the time may well be much greater than any feasible development from the major sites. On the other hand, Nooksack basin plants could be coordinated on an interbasin basis under a program of hydraulic and electrical integration and thus sharply increase the amount of firm power output. Likewise, the expanding electrical integration program may eliminate the need for storage dams for power purposes on the Nooksack River and develop more firm power with river run plants.

NOOKSACK RIVER UTILIZATION AREA AT DEMING

This is perhaps the most controversial of the major dam sites in the basin as this site would flood the villages of Acme, Clipper, Comar, Standard, and Van Zandt, together with 3,000 acres of rich farm land and an additional four to five thousand acres of land that could be brought under cultivation. Extensive railroad and highway relocation would also be required. The site is located on the main Nooksack River three-quarters of a mile upstream from Deming at about river mile 36.8 on the Corps of Engineer's river survey map. It would tap the greatest drainage area of any site in the basin, 582 square miles, and also provide the largest amount of storage, as much as 500,000 acre-feet.

Above Deming the watershed is made up of many precipitous high mountains interlaced by a network of narrow canyons. This region encompasses 77 percent of the total area drained by the Nooksack River system and produces more than 90 percent of the basin's total runoff.

Based on streamflow records at Deming, an average of 2,400,000 acre-feet of water passes the site annually. Owing to dissimilar runoff patterns, peak flows do not occur on the three forks of the Nooksack River simultaneously. However, major flooding occurs on the main stream of the river usually during heavy precipitation periods in the late fall or in the spring when runoff from snowmelt is accompanied by moderate precipitation. To provide adequate storage capacity for flood control purposes it would be necessary to maintain a reduced reservoir level during periods of potential flooding. The required reservoir level regulation would to some extent decrease the maximum possible power generation at the Deming site.

At the Deming site, the valley is constricted by a ridge of rock and glacial debris extending southward from the right valley wall. Two pre-glacial river channels now filled with drift cut this ridge. The exact dam location has not been selected since further geologic determinations will be required. Existing studies indicate the minimum dam section location to be in the E½ of Sec. 6, Twp. 38 N., Rge. 5 E., between the bedrock left wall and the small bedrock ridge on the right bank. However, before this axis can be considered, certain problems of leakage through glacial deposits, bedrock of the ridge, and the two pre-glacial stream channels must be resolved. Test pits, exploratory drilling, and laboratory permeability tests must be conducted to assess these problems.

An alternate axis is located about 2,800 feet downstream where bedrock is encountered about 140 feet below the stream bed. The right abutment of this site is superior to that of the former in that it abuts against the broad upper portion of the ridge extending southward from the right valley wall. Thus the danger of instability and leakage through the long narrow portion of the ridge is eliminated and the buried pre-glacial channel is not a problem. The chief disadvantage of this site is the greater cross sectional area of the valley and correspondingly larger dam required.

The maximum reservoir level at the Deming site is limited to an elevation of 320 feet because the divide between the South Fork valley and the Samish River is only 322 feet above sea level. This would permit a dam 113 feet high storing slightly under 500,000 acre-feet and inundating 9,800 acres of land. Storage could be increased with construction of a dam on the ridge between the South Fork and Samish River valleys. However, this would probably not be required since a storage capacity of 500,000 acre-feet of water would insure almost complete flood protection for the lower basin. Figure 53 shows the various capacities for dams of different sizes at this site based on Helland's report. The U. S. Army Corps of Engineers' standard project flood is 125,000 cubic feet per second and would require total storage of 420,000 acre-feet. There is no record of a flood of this magnitude having occurred in the Nooksack River basin and the probability of such a flood ever occurring is unlikely.

Flood control storage and subsequent water use

Table 32. Estimated Power Available, Nooksack River Basin.

Site	Stream	Drainage Basin sq miles*	Mean Effective Head	Natural Flow Available (cfs) 50% time	90% time	99.9% time
				POWER DEVELOPMENT AT		
Deming	Nooksack River	582	100 feet	*3,000	1,400	660
Deming (with Edfro Diversion to Skagit River)	Nooksack River	582	100 feet	*2,460	1,270	590
Shuksan - powerhouse upstream	North Fork Nooksack River & Wells Creek	85	220 feet	* 520	300	90
powerhouse downstream	North Fork Nooksack River & Wells Creek	85	605 feet	* 520	300	90
North Fork	North Fork Nooksack River & Wells Creek	88	*600 feet	* 520	300	90
Maple Falls - powerhouse below dam	North Fork Nooksack River	226	100 feet	900	400	150
powerhouse downstream	North Fork Nooksack River	226	200 feet	900	400	150
Edfro Creek - Lyman Powerhouse	South Fork Nooksack River	100	550 feet	* 530	135	60
South Fork Powerhouse	South Fork Nooksack River	100	340 feet	* 530	135	60
Skookum Creek - Lyman Powerhouse	South Fork Nooksack River	103	*550 feet	* 540	140	60
South Fork Powerhouse	South Fork Nooksack River	103	*340 feet	* 540	140	60
				POWER DEVELOPMENT AT		
Swamp Creek	Swamp & Ruth Creeks	14	*833 feet	90	90	10
Glacier	North Fork, Nooksack River, Deer Horn, Lookout, Coal, & Canyon Creeks		920 feet	700	300	110
Warnick	North Fork Nooksack River	190	160 feet	800	370	140
Glacier Creek	Glacier, Falls, Coal, Deep, Davis, Little, Gallop, Cornell, & West Cornell Creeks		1,300 feet	180	75	25
Clearwater Creek	Middle Fork Nooksack River, Wallace, Warm, & Clearwater Creeks	44	720 feet	200	110	60
Wanlick Creek	South Fork Nooksack River, Howard Creek	37	900 feet	200	40	25

* Figures determined by Division of Water Resources

Kilowatts Available Without Regulation			Regulated Flow Available (cfs)		Kilowatts Available Regulated Flow	
50% time	90% time	99.9% time	50% time	99.9% time	50% time	99.9% time
MAJOR RESERVOIR SITES						
20,300	9,400	4,400		2,600		17,600
16,600	8,600	4,000		1,950		13,200
7,700	4,400	1,300	650	600	9,600	8,900
21,300	12,300	3,700	650	600	26,600	24,500
21,100	12,200	3,600	650	600	26,400	24,400
6,000	2,700	1,000	950	660	6,400	4,400
12,100	5,400	2,000	950	660	12,800	8,900
19,700	5,000	2,200		650		24,200
12,200	3,100	1,400		650		15,000
20,100	5,200	2,200		650		24,200
12,400	3,200	1,400		650		15,000
DIVERSION SITES						
5,100	2,200	500	No Regulation			
43,600	18,700	6,800	700	615	43,600	38,300
8,600	4,000	1,500	850	650	9,200	7,000
15,800	6,600	2,200	No Regulation			
9,700	5,300	2,900	No Regulation			
12,200	2,400	1,500	No Regulation			

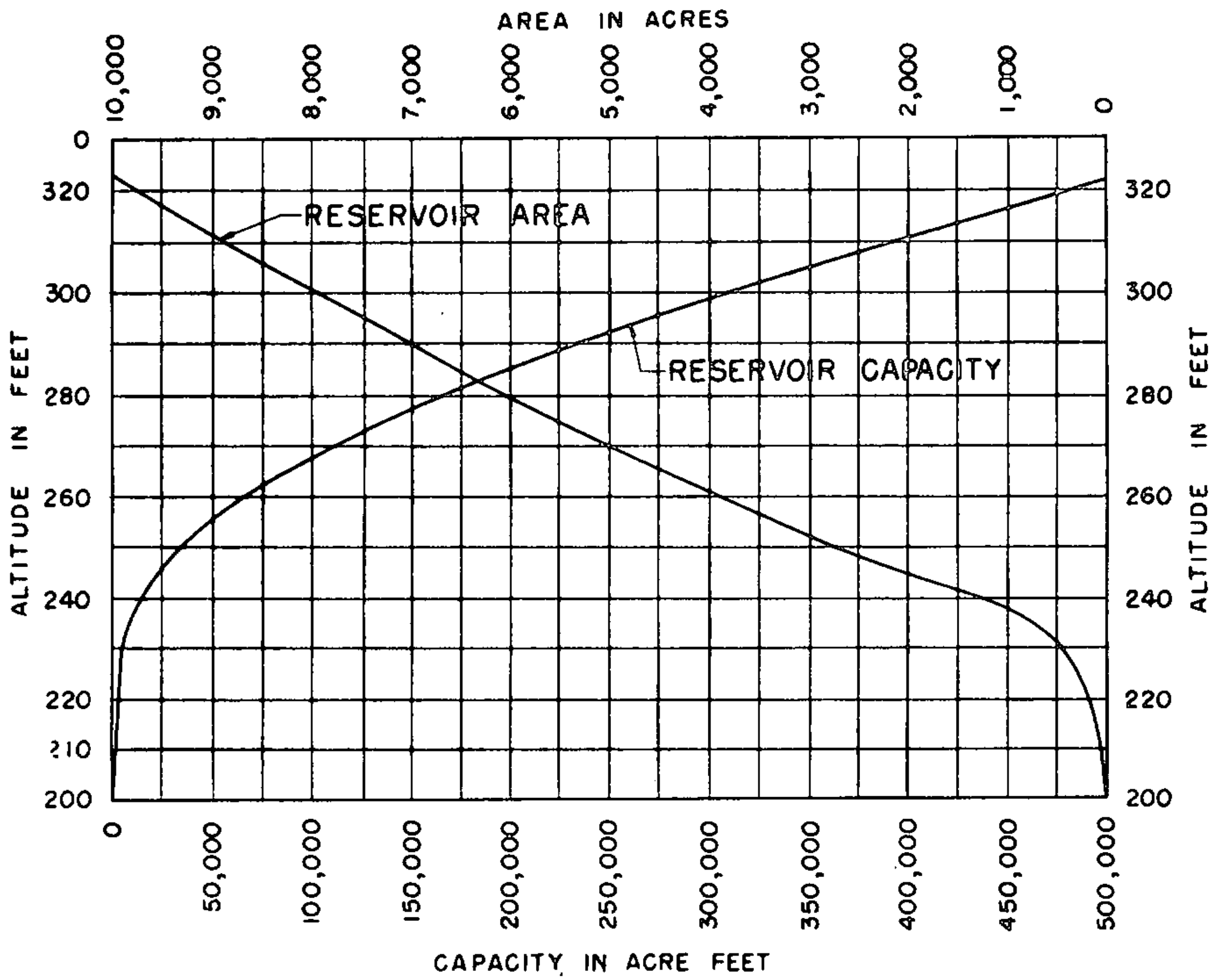


Figure 53. RESERVOIR AREA AND CAPACITY CURVES, DEMING DAM SITE.

are the primary justifications for a dam at the Deming site. Some power could be generated at the site although use of the reservoir for flood control purposes would reduce power generation.

Helland assumed use of this reservoir primarily for power purposes, with a large dam providing 450,000 acre-feet of useable storage. After allowing for evaporation losses, an average controlled flow of 2,600 cubic feet per second would be available 99.9 percent of the time, providing a power potential of 17,600 kilowatts. However, development of power on the South Fork at the Edfro or Skookum Creek sites with diversion to the Skagit basin for power purposes would reduce the available flow at Deming to 1,950 cubic feet per second for 99.9 percent of the time, thereby reducing the power potential to 13,200 kilowatts.

Irrigation, public supply, or other consumptive demands must be evident before further consideration could be given to construction of a dam at the Deming site.

Smaller structures primarily for flood control purposes have also been considered at this location by the Corps of Engineers and cost, storage, and benefit estimates have been made for reservoirs with 252 foot and 274 foot pool levels. These figures are presented in table 31 of the Flood Control Section of this report. Any dam constructed here would require fish passage facilities to insure continuation of the Nooksack River as a spawning area for anadromous fish.

NORTH FORK RIVER UTILIZATION AREA

There are three possible storage sites in the area of Nooksack Falls, but the two on the North Fork of the Nooksack are alternates and only one could be built. Power would be a primary purpose here with flood control also being important. Ideal development would divert water from the Wells Creek project to whichever reservoir is constructed on the North Fork. Development of the North Fork or Shuksan sites, together with Wells Creek site is essential for effective power development farther downstream on the North Fork.

Shuksan Dam Site.

This dam site is located in Sec. 34, Twp. 40 N., Rge. 8 E.W.M., (unsurveyed) at river elevation 1,890 in a reach of the North Fork valley that is partly filled with intra-valley bedrock hills. Bedrock is exposed in the bed of the North Fork at the dam site, and no buried channels bypass

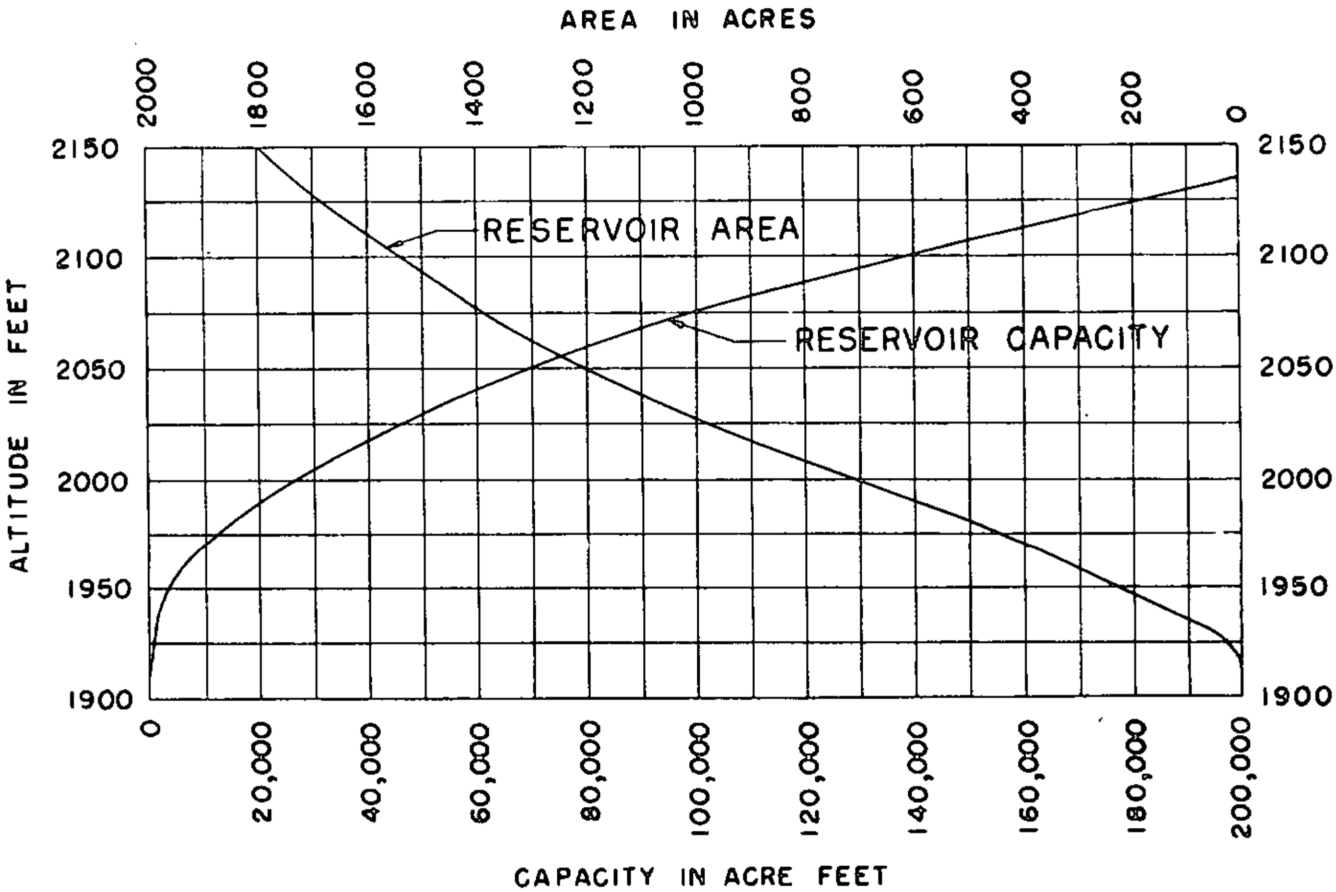


Figure 54. RESERVOIR AREA AND CAPACITY CURVES, SHUKSAN DAM SITE.

the site. The foundation and both abutments are underlain by greenstone which is adequate to support any type of dam of the required height. A possible spillway site is located in a small valley on the left abutment, and a possible site for an outlet works tunnel is located 300 feet south of the river.

Recommendations for further geologic study include exploration of the foundation and both abutments by drilling and field permeability tests, exploration of the area of crushed rock downstream from the dam site by drilling to obtain data to evaluate its effect on the dam site, exploration of the contact zone behind the left abutment by drilling and field permeability tests, and examination of gravel deposits that may be used for concrete aggregate to determine possible deleterious effects of greenstone pebbles on concrete.

Excluding any additional contributions from Wells Creek, the North Fork above this point drains approximately 64 square miles and produces an annual runoff of about 340,000 acre-feet. Streamflow patterns in this area are very erratic but, similar to that at Deming, rather consistent high flow periods occur in fall and spring. The high altitude and lower temperatures cause the lowest flows to occur mostly in winter. Another less pronounced low flow period occurs after most of the snowpack has melted in late summer, but here again glacial melt plays a prominent part in maintaining flow.

A reservoir level at 2,052 feet would provide annual equalization of the flow in the North Fork, while a level of 2,073 feet would equalize both Wells Creek and the North Fork. However, a reservoir level of 2, 130 feet with a dam height of 215 to 245 feet would be desirable for both power and storage purposes. Such a structure would store 200,000 acre-feet of which 110,000 acre-feet would accomplish flow equalization for power purposes while the additional 90,000 acre-feet would be available for flood-control purposes. Assuming a 5-day flood, 90,000 acre-feet would provide considerable flood relief by containing 9,000 cubic feet per second for the flood period. Figure 54 shows the various capacities for different height dams at the Shuksan site based on Helland's study.

There are two potential powerhouse locations here. An upstream site is available just below the dam at altitude 1,858 and would have a mean head of 220 feet. Allowing for evaporation, an estimated minimum controlled flow of 600 cubic feet per second would be available for a potential capacity of 8,900 kilowatts for 99.9 percent of the time. An alternative powerhouse site is below Nooksack Falls, about 3 miles downstream from the dam. This plan would provide about 605 feet of available head and be capable of generating 24,500 kilowatts for 99.9 percent of the time and, with a minimum flow of 650 cubic feet per second for 50 percent of the time, could generate 26,600 kilowatts.

North Fork Dam Site.

This site is an alternate dam location to the Shuksan site and is located 1½ miles downstream from the Shuksan

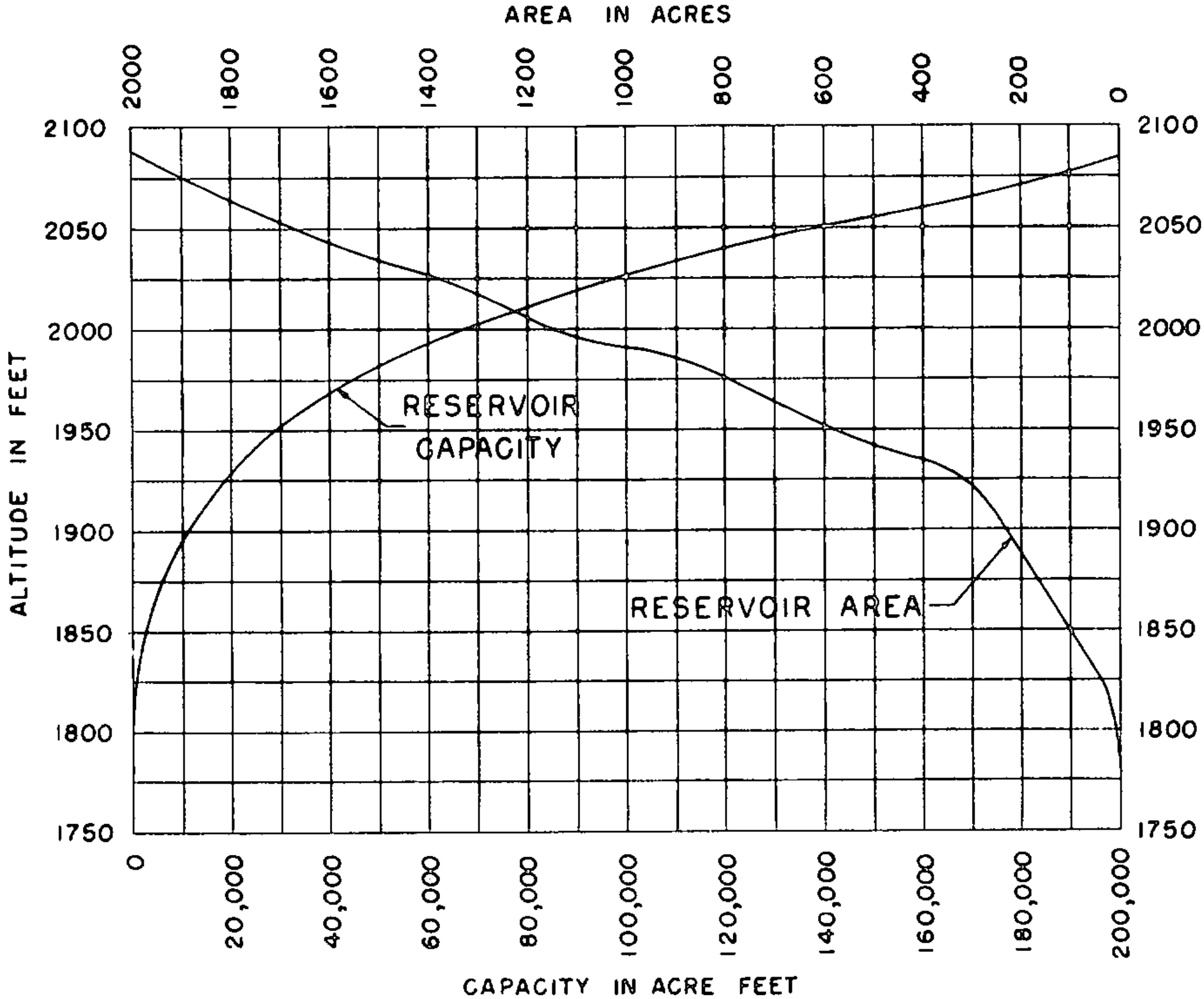


Figure 55. RESERVOIR AREA AND CAPACITY CURVES, NORTH FORK DAM SITE.

location. Drainage basin and flow characteristics here are similar to that at Shuksan, and complete development would also be dependent upon diversion of Wells Creek into the reservoir. Two potential dam axes were studied here. These are about three-quarters of a mile upstream from Nooksack Falls and 900 feet apart, being 66.3 and 66.7 miles above the mouth of the Nooksack River. Both sites are in Sec. 32, Twp. 40 N., Rge. 8 E.W.M. The lower of these two sites offers better foundation conditions although the presence of a permeable lava-argillite contact at altitude 2,000 feet means that any dam higher than 260 feet would be subject to possible leakage problems. A dam of this height could store but 67,500 acre-feet and from the standpoint of storage would be inferior to that at the Shuksan dam site. However, further geologic exploration may reveal that the problem of this permeable zone is not as serious as it appears and that a higher structure may be feasible.

The fundamental defect of the upper site is the strong probability of a buried valley beneath the lava flows in the left bank and the further possibility that the lower lava flow rests upon thick deposits of highly permeable fluviatile or glacio-fluviatile materials. The extent of this contingency can be determined only by further geological investigations. A pool elevation of 2,080 feet would be highly desirable and provide 193,800 acre-feet of storage and, together with the Wells Creek flow, would provide a minimum flow of about 600 cubic feet per second and a 50 percent flow of 650 cubic feet per second. A gross head of about 550 feet would be available by constructing only one mile of conduits and locating the powerhouse below Nooksack Falls.

A high dam at the North Fork site would provide flood control storage virtually identical with the Shuksan site, while available power would be slightly less. The area-capacity curves in figure 55, based on Helland's report, show the various capacities for different dams at the North Fork site.

Wells Creek Dam Site.

This is primarily a power project and, as pointed out in the preceding discussion of the Shuksan and North Fork dam sites, the Wells Creek site could best be developed in conjunction with either of the former. The dam site is located about 2.2 miles above the confluence of Wells Creek and the North Fork.

Above the dam site, Wells Creek drains about 21 square miles of Mt. Baker's north slopes, the estimated runoff from this area in an average year being about 115,000 acre-feet. No streamflow figures have ever been collected on this stream, but a similarity of terrain and topography indicates it would have streamflow characteristics similar to the Nooksack River at the North Fork and Shuksan sites.

Geologic conditions at this site appear favorable for dam construction. However, before construction is contemplated, preliminary studies should include determination of the boundaries of the greenstone mass in which the site is situated, chemical studies of the natural solubility of the rock, and various physical tests on the fresh and treated rock.

If the water impounded in the Wells Creek reservoir is diverted into either the Shuksan or North Fork reservoirs, as has been proposed, a conduit or tunnel will be required. A tunnel to either reservoir would follow the same route, and it is probable that the tunnel would pass through greenstone and argillite and would be approximately 8,000 feet in length. If an open conduit were used it would be about 22,000 feet in length to the Shuksan reservoir and about 13,750 feet in length to the North Fork reservoir and would traverse rugged terrain in places.

This site has a unique hazard potential in the possibility that Mt. Baker should again become active. Although all the sites on the North and South Forks of the Nooksack River are within range of heavy ash fall, the Wells Creek site is also within possible range of lava flows. A violent or prolonged period of volcanic activity would be expected to produce mud-flows and floods effects of which might be harmful in the river valleys far distant from the mountain.

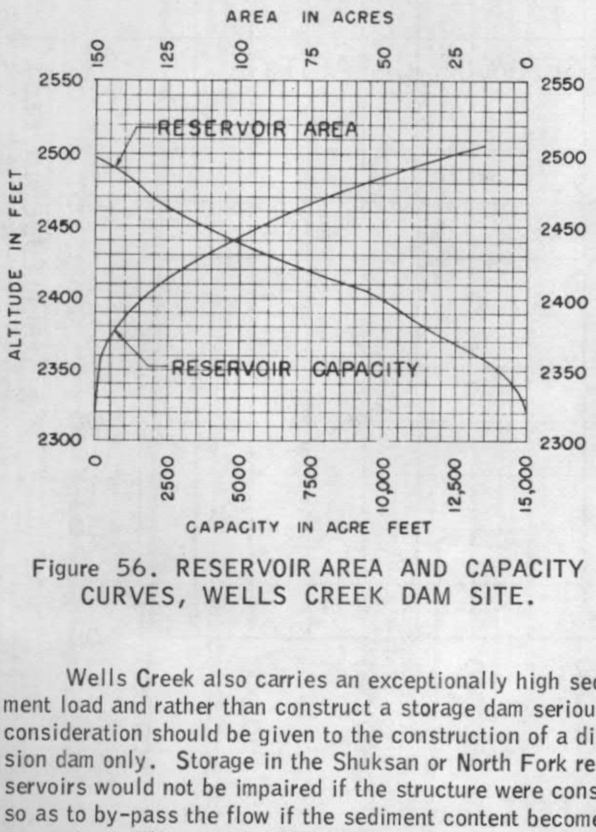


Figure 56. RESERVOIR AREA AND CAPACITY CURVES, WELLS CREEK DAM SITE.

Wells Creek also carries an exceptionally high sediment load and rather than construct a storage dam serious consideration should be given to the construction of a diversion dam only. Storage in the Shuksan or North Fork reservoirs would not be impaired if the structure were constructed so as to by-pass the flow if the sediment content becomes excessive. This would allow almost complete utilization of the flow of Wells Creek through the storage facilities in the larger reservoirs. An area-capacity curve for the Wells Creek site (fig. 56), based on Helland's studies, shows the the small amount of storage available here, hence very little storage would be lost by constructing only a diversion dam. The power available at this site is included in the discussion of the North Fork and Shuksan development.

MAPLE FALLS RIVER UTILIZATION AREA

This proposed dam site is in a narrow, rock-walled gorge within Sec. 31, Twp. 40 N., Rge. 6 E.W.M., on the North Fork of the Nooksack River immediately below the confluence with Maple Creek. Power development would be the sole purpose for a dam at this site as reservoir storage would be negligible. Thus, stream regulation would have to depend on upstream structures such as the Shuksan or North Fork projects.

At this site the North Fork cuts a gorge in a course that has been superimposed upon the south bank of the pre-glacial valley. The pre-glacial valley is wider and deeper than the present valley and is partly filled with unconsolidated glacial deposits and alluvium. Rock in the foundation and both abutments consists of coarse, clastic conglomerates with interbedded sandstones and siltstones. Bearing capacity of this rock would be sufficient to withstand the loads imposed by either a masonry or an earthfill dam.

Chief defects of this site are: first, the possibility of excessive seepage loss from the reservoir through the unconsolidated sediments filling the pre-glacial channel, and second, the permeability of the rock making up the foundation and abutments of the dam site. Again, further exploration and test drilling is necessary to determine the rock profile in the right abutment and permeability of rock in the foundation with respect to controlling of seepage by grouting.

The highest apparent reservoir level at this site would be 590 feet requiring a dam of 95 feet above the stream bed and 105 to 110 feet above the rock foundation. This would provide about 6,000 acre-feet of useable storage.

With a regulated low flow of 660 cubic feet per second for 99.9 percent of the time and 950 cubic feet per second for 50 percent of the time, there would be 4,000 kilowatts available 99.9 percent of the time and 5,800 kilowatts 50 percent of the time if the powerhouse is located directly below the structure. Planning should also include studies of an alternative powerhouse location directly above the backwater from the proposed Deming dam at elevation 320 feet in Sec. 22, Twp. 39 N., Rge. 5 E.W.M., which would require a conduit of five miles in length. This location of the powerhouse would increase the effective head to 200 feet, and the available power would be increased by 120 percent.

SOUTH FORK RIVER UTILIZATION AREA

Skookum Creek and Edfro Creek are two alternate dam sites in the South Fork River Utilization Area. Power and flood control would be the primary purposes for either of these dams although future municipal, industrial, and irrigation requirements also offer reason for development. Construction of a dam in this area presently appears more favorable than in any of the preceding areas discussed.

Skookum Creek Dam Site.

This site is located on the South Fork of the Nooksack River just above the confluence of Skookum Creek.

The 103 square mile watershed above this site is considerably lower in elevation than that of the Shuksan or North Fork projects, but it lies in an area more favorably situated for precipitation and thereby receives comparable amounts of runoff per unit area. Excellent streamflow records are available immediately upstream from this location and indicate that this drainage area produces an average annual runoff volume of 535,000 acre-feet.

Owing to the absence of glaciers, however, streamflow characteristics are somewhat different than those of the North Fork. Here there is a definite tendency for the lowest flows to occur during the late summer after the snow pack has completely ablated, while the highest flows appear to be in fall and early winter followed by a lower peak period during the spring snowmelt season.

No geologic or engineering information is available on this site. However, field examinations indicate that a slightly larger dam structure would impound somewhat more water than the Edfro Creek dam site. Reservoir height, power and storage figures for Edfro Creek are, therefore, typical for this site. Some authorities feel that the Skookum Creek site may be superior to the Edfro Creek site; the Division of Water Resources, therefore, advocates a thorough study of both sites before a final selection is made.

Edfro Creek Dam Site.

This damsite is located on the South Fork of the Nooksack River, 2,000 feet above Edfro Creek. The drainage and flow characteristics are virtually identical with those at the Skookum Creek site with the only difference being that the flow of Edfro Creek itself would by-pass this site. Figure 57 gives the various capacities for the different size dams at this site as determined by Helland.

Suitable foundation conditions are probably too deep, being about 165 feet below river level, to consider excavation to bedrock for the foundation of a rigid dam. Although the valley fill has a complex arrangement, it might be possible to site

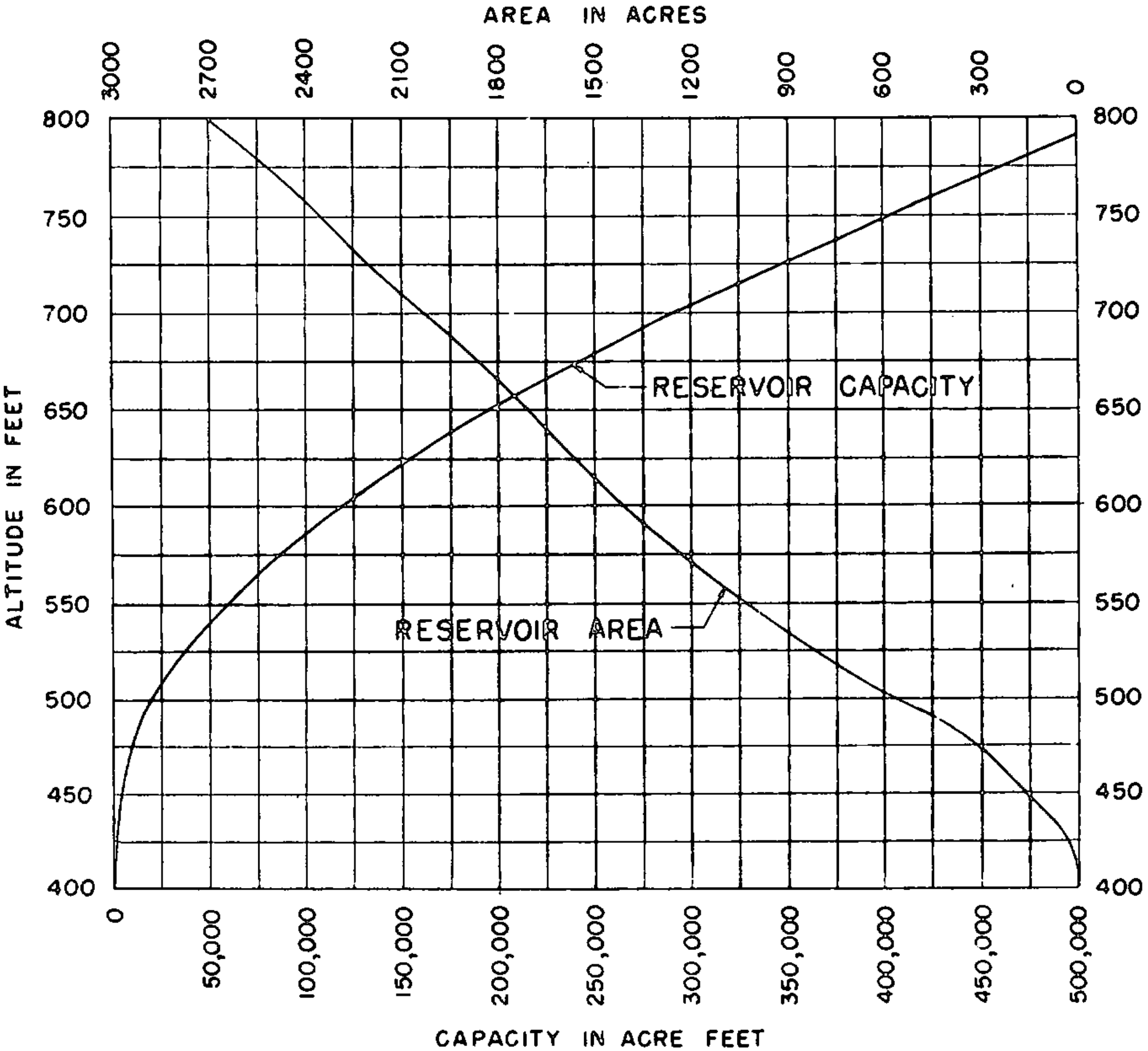


Figure 57. RESERVOIR AREA AND CAPACITY CURVES, EDFRO CREEK DAM SITE.

a flexible dam upon a silty middle layer which is about 35 feet below the river and about 100 feet in thickness. The lower layer of the fill should be disturbed as little as possible, and boreholes should be properly plugged before abandonment. A dam at this site could stand about 400 feet above river level and possibly 450 feet above the foundation. Since valley width increases rapidly above altitude 800 feet at the dam site, this elevation may mark the economic limit of a high dam for both power and flood control.

The record of discharge for this site shows that a storage capacity of 300,000 acre-feet would enable equalization of flow permitting a constant release of 650 cubic feet per second after allowance for evaporation loss, and this much storage would enable a somewhat greater release in most years. Helland proposes to develop the power of the South Fork by diversion to the Skagit River near Lyman. Assuming diversion at an altitude of 620 feet, a dam 220 feet high would be required to raise the water to the tunnel intake. Thus, a 370 foot high dam with spillway at 770 feet elevation, would be required to provide 300,000 acre-feet of live storage. Total capacity of the reservoir would be 450,000 acre-feet. An additional 30 feet of height could be used for flood storage providing over 100,000 acre-feet for this purpose. The Corps of Engineers also discuss reservoir elevations at 562 and 521 feet and estimate flood prevention by such storage.

The Lyman power development would require a tunnel originating in Sec. 20, Twp. 36 N., Rge. 6 E.W.M., and terminating in Sec. 32. From there the water would be conveyed by a penstock to the powerhouse at elevation 60 feet at or near Lyman. After allowing for head losses, an estimated mean effective head of about 550 feet would be available at the turbine, with a corresponding power output of about 24,000 kilowatts 99.9 percent of the time.

An alternate plan would be to install the powerhouse directly below the dam. However, net power output would be 40 percent less due to only about 340 feet of head being available. With construction of the Deming dam, however, this loss would be offset by an additional 4,400 kilowatts produced at downstream plants.

MINOR DAM AND RESERVOIR SITES

There are thirteen smaller dam sites in the basin which are tabulated in table 33. These sites are all much smaller than those discussed in the preceding section, but are larger than normal farm pond size. The information and site locations on plate 8, "Water Development Projects," is included to show where possible storage may be available and further studies warranted.

All the information concerning these sites is based on

Table 33. Potential Minor Storage Projects, Nooksack River Basin.

Reservoir Name	Stream	Approximate Dam Location Sec. Twp. Rge.	Estimated Storage Acre-feet	Inundated Area Acres	Estimated Available Runoff Acre-feet	Remarks
Anderson Creek	Anderson Creek	W½8-38N-4E	3,800	85	15,000	
Barrett Lake	Tenmile Creek	SW¼21-39N-2E	1,100	110	33,400	
California Creek	California Creek	E½18-40N-1E	1,400	120	18,000	Conversion of tidal area to fresh water lake.
Dakota Creek	Dakota Creek	E½7-40N-1E	4,500	210	34,400	Conversion of tidal area to fresh water lake.
Deer Creek	Deer Creek	N½30 or 29-39N-3E	2,500	210	3,000	
Green Lake	Fourmile Creek	NE¼9-39N-3E	130	45	8,600	Regulation & development of existing lake.
Kelly Road	Unnamed tributary of Anderson Creek	NE¼5-38N-4E	700	480	1,500	
Lake Terrell	Terrell Creek	N½16-39N-1E	3,000	600	2,400	Raising & regulation of existing lake for water use downstream.
Maple Creek	Maple Creek	19&30-40N-6E	18,000	750	30,000	No known use at present.
Markworth Road	Unnamed Stream	NW¼10-40N-2E	700	30	800	
Tenmile Creek	Tenmile Creek	22 or 26-39N-3E	8,750	580	7,400	Suitable for partial or complete development dependent upon demand.
Saar Creek	Saar Creek	12&13-40N-5E	11,000	230	15,000	
Upper Bertrand	Unnamed tributary of Bertrand Creek	NE¼3-40N-2E	1,600	100	1,000	

estimates following precursory field examinations to determine whether a site actually existed. No geological reconnaissance has been done to ascertain the geological feasibility of any of the sites. However, runoff estimations are based on the same assumptions predicating the streamflow analysis section of this report and, thus, are quite accurate. In all cases, sufficient water is available to merit inclusion of these sites as possible storage reservoirs. However, reservoir capacities are calculated from available U.S. Geological Survey topographic maps, and because of the absence of refined contour intervals, certain estimates may be somewhat inaccurate.

The largest site included here is the Maple Creek site which is probably the least likely to be constructed as it would flood considerable farmland without producing significant downstream benefits.

The Green Lake and Lake Terrell sites would provide for effective lake control and additional storage with subsequent downstream summer use of the water in areas deficient of irrigation water.

The Saar Creek reservoir could provide some relief from flash floods on the flat valley below as well as permitting an increase in the summer flow, and thereby making additional water available for appropriation.

The Anderson Creek, Deer Creek, Kelly Road, Markworth Road, Tenmile Creek, and the Upper Bertrand sites would all store winter and spring runoff for later summer consumption. Some of these sites may also offer recreational or lakefront possibilities.

The Barrett Lake, California Creek, and Dakota Creek sites would all entail channel storage almost exclusively but such reservoirs would greatly enhance the value of associated lakefront property. This water could also be utilized for irrigation, but because of their locations only adjacent farms would benefit.

Undoubtedly additional sites exist but are not included in this report as this is but a brief resume' of the smaller sites that have come to the attention of the authors.

DIVERSIONS

In addition to the major reservoir and storage sites, there are also numerous diversion locations in the basin. The majority of these would be for power diversions and are presently undeveloped as they require storage water to achieve effective utilization. All the diversion sites discussed are shown on plate 8.

EXISTING POWER DIVERSIONS

The only major power plant presently existing within the basin is the Puget Sound Power and Light Company's Excelsior plant directly below Nooksack Falls on the North Fork of the Nooksack River. The diversion dam itself is located directly above the falls. Constructed in 1906, the dam is about 10 feet high and 72 feet long. The Puget Sound Power and Light Company claims 328 cubic feet per second at the site, utilizing an elevation drop of 228 feet for a theoretical horsepower development of 8,953. However, the rated capacity of the installed waterwheels is 3,200 horsepower and the generators 1,875 horsepower, with a useable head of about 210 feet. Thus, in actual practice probably not more than 125 cubic feet per second is effectively utilized for the production of power.

A smaller power diversion was made on Lower Bagley Lake by the Mt. Baker Lodge during the 1930's. This power project has since been abandoned due to weather difficulties, but the diversion dam still exists and raises the lake level about 8 feet.

UNDEVELOPED POWER DIVERSION SITES

R. O. Helland's report, "Water Utilization in the Nooksack River," 1941 and revised in 1954, discusses seven areas for power diversion development in the basin and was the major reference for the potential power diversion discussion. These seven sites are all similar in that they have no storage themselves, but rather rely on diversion structures to intercept the flow of one or more streams and transport this water in a canal or flume until sufficient volume and head is available for power development. The construction of either the Shuksan or North Fork dams would enhance the available power from diversions on the North Fork by making a much higher base flow available, and thus the reservoir project is an integral part of any diversion development in the basin. Only six of the seven sites discussed by Helland are mentioned here and shown on the Reservoir Map as the city of Bellingham's Middle Fork diversion has now made the seventh site unfeasible. No geologic or structural engineering studies have been made to determine the feasibility for such diversion dam construction.

The estimated power potentialities of these developments are all listed in table 32 on pages 102 and 103.

Swamp Creek Power Site.

The Swamp Creek power site would utilize the flow of Swamp and Ruth Creeks, diverting both at about 3,020 foot level. The powerhouse would be located just above the Shuksan Dam reservoir near the mouth of Swamp Creek.

Glacier Power Site.

This site would be located in the SE¼NW¼ of Sec. 6, Twp. 39 N., Rge. 7 E.W.M. The water would be obtained from the Lower Excelsior diversion on the North Fork at elevation 1,800 feet and the diversion canal would also pick up the flow of Deer Horn, Lookout, and Coal Creeks while providing an effective head of 920 feet. The Canyon Creek flow could also be diverted in Sec. 19, Twp. 40 N., Rge. 7 E.W.M., and carried by canal to the same forebay, thus contributing to the available power at the Glacier power site. The amount of power available from this site would be dependent upon the development of storage facilities at either the North Fork or Shuksan reservoir sites.

Warnick Power Site.

The North Fork could again be diverted at the Upper Warnick diversion in the SE¼NW¼ of Sec. 1, Twp. 39 N., Rge. 6 E.W.M., at elevation 773 feet, using a 47 foot high dam to back water up to the Glacier powerhouse. Just above the tailwaters of the Maple Falls reservoir, 3.5 miles of canal would carry the water to the powerhouse in the NW¼SE¼ of Sec. 29, Twp. 40 N., Rge. 6 E.W.M., at elevation 600 feet. This would provide an effective head of about 160 feet, but like the Glacier powerhouse, would be extremely dependent upon a Shuksan or North Fork reservoir for most effective development.

Glacier Creek Power Site.

This power development would require the diversion of Glacier Creek at elevation 2,500 feet in the SW¼SW¼ of Sec. 34, Twp. 39 N., Rge. 7 E.W.M., and carry water to the center of Sec. 17, gaining the flows of Falls, Coal, and Deep Creeks on the way. Diversions on Little and Davis Creeks would also contribute substantially to the flow. Also, Gallup, Cornell, and West Cornell Creeks should be considered as contributors to this project even though they are not shown on the map. Consideration should also be given to utilizing the Glacier powerhouse, thus avoiding the necessity of constructing an additional powerhouse.

Clearwater Creek Power Site.

This is the only remaining power site on the Middle Fork of the Nooksack River since Bellingham's proposed diversion of up to 250 cubic feet per second in Sec. 19, Twp.38 N., Rge. 6 E.W.M., will make others impossible. The Clearwater site would utilize the Middle Fork through the Upper Middle Fork diversion just below the mouth of Green Creek at elevation 2,000 feet. This flow would be carried to a point in Sec. 21, Twp. 38 N., Rge. 6 E.W.M., gaining the flows of Wallace and Warm Creeks enroute, and discharging through a powerhouse at elevation 1,180 feet just above the mouth of Clearwater Creek. Clearwater Creek itself would be diverted at about the 2,000 foot level, just below Rocky Creek in Sec. 2, Twp. 38 N., Rge. 6 E.W.M., and its flow carried to the same penstock. This would provide development of water from a 44 square mile drainage area.

Wanlick Creek Power Site.

The diversion of the South Fork of the Nooksack River just below the mouth of Wanlick Creek at elevation 1,820 feet would provide considerable seasonal power by carrying the water to a powerhouse in Sec. 22, Twp. 36 N., Rge. 6 E.W.M., at the tailwaters of the Edfro or Skookum Creek reservoirs on the South Fork. The flow of Howard Creek could also be gained on the way. There is no feasible storage here, so any power obtained would be dependent upon natural flow.

MISCELLANEOUS DIVERSIONS

City of Bellingham.

This diversion of the Middle Fork is located in Sec. 19, Twp. 38 N., Rge. 6 E.W. M., and is by far the largest single consumptive diversion in the basin. An 18-foot diversion structure is presently under construction to divert water into Mirror Lake by pipe and canal and thence into Lake Whatcom.

F. Baker.

The F. Baker diversion is a private project on Lummi Island that prevents water from flowing directly down a cliff and into Puget Sound by diverting it in the opposite direction toward the north part of the island where it is used for irrigation, emergency power production, and domestic supply. Additional water is available here and more complete development and use of this water is being contemplated.

WATER QUALITY

Water in its natural state is never completely pure. Even rain gathers impurities as it falls through the atmosphere. Man has learned from experience that good quality water is conducive to good health and accordingly has attempted to obtain water of a high quality and has fancied himself as knowing good water from bad merely by its appearance. Water's appearance, however, can be deceiving and stagnant swamp water may be of good quality and safe to drink while, ironically, a sparkling stream may carry disease-causing organisms.

Of all the future water problems relating to distribution, variability, supply, and quality, those associated with quality appear to be the most troublesome. As man's activities degrade the water in various ways, people have increasing difficulty differentiating between naturally poor water and contaminated water. Although in many parts of the nation water has always been of poor quality, the ground water and surface water in the Nooksack River basin is of excellent quality and available in large quantities. This quality, however, must be protected and in order to be preserved, the present quality must first be determined.

Quality data pertaining to ground water were collected by the U. S. Geological Survey in 1949 and the Division of Water Resources in 1960. In addition, limited privately analyzed data are available. The necessary background for obtaining quality information for surface water was begun in July, 1959, when the U. S. Geological Survey in cooperation with the Pollution Control Commission, State Health Department, and Division of Water Resources established a quality sampling station for the Nooksack River at Nugent's Bridge near Lawrence. This station is part of the state-wide network to collect basic data on the quality of Washington's water. Daily samples have been collected here since September 1, 1959; and the analysis of these samples, together with additional spot or grab samples by the U. S. Geological Survey, the State Pollution Control Commission, the Division of Water Resources, and private corporations, comprises the technical data predicating this chapter. The State Health Department provided background information, and the Whatcom County Department of Public Health assisted in the collection of data as well as providing data of past years' quality.

It is important to remember that a quality analysis indicates only what the condition is at a specific time and, thus, should be used in conjunction with a sanitary survey if accurate information is sought to resolve a specific problem. There are five types of quality tests commonly used to analyze water. These are the bacteriological, chemical, physical, sanitary, and biological tests that are discussed on the following pages.

STANDARDS

Certain standards of quality have been established for hygienic, aesthetic, and industrial purposes. There are almost as many standards as there are uses of water, so of necessity, only the most common and widely accepted are discussed here.

Table 34 summarizes the U. S. Public Health Service's bacteriological requirements which are used by the State of Washington, Department of Health, and are commonly accepted throughout the United States as the standard for potable water for public supplies.

Table 34. U. S. Public Health Service Drinking Water Standards for Bacteriological Quality.

Sample size	Number of test portions per sample	Maximum % of portions showing coliform bacteria	Maximum % or samples showing 3 or more portions positive per month
50 ml	5	10	5% (when 20 or more samples per month) 1 sample (when less than 20 per month)
500 ml	5	60	20% (when 5 or more samples per month) 1 sample (when less than 5 per month)

Table 35. U. S. Public Health Service Drinking Water Standards for Chemical Quality.

CONSTITUENT	MAXIMUM ALLOWABLE CONCENTRATION parts per million	
	Mandatory	Recommended
Arsenic	0.05	
Hexavalent Chromium	0.05	
Fluoride	1.5	
Lead	0.1	
Selenium	0.05	
Chloride		250.0
Copper		3.0
Iron & Manganese (total)		0.3
Magnesium		125.0
Phenolic Compounds		0.001
Sulfate		250.0
Zinc		15.0
Total Solids		500 (1000 permitted if better not available)

The U. S. Public Health Service has also established chemical standards for potable water which are listed in table 35. Following recent concern through the nation regarding

Table 36. Suggested Water Quality Tolerances.

(Allowable limits in parts per million. Source of Data: E. W. Moore, (1940) Journal New England Water Works Association, Volume 54. Potable water conforming to U. S. Public Health Service standards is necessary. Iron as Fe limit given, applies to both iron alone and the sum of iron and manganese)

Industry or use	Turbidity	Color	Hardness as $CaCO_3$	Iron as Fe	Manganese as Mn	Total solids	Alkalinity as $CaCO_3$	Odor and taste	Hydrogen sulfide	Health requirement
Air conditioning				0.5	0.5			Low	1	
Baking	10	10		0.2	0.2			Low	0.2	Potable
Boiler feed										
Brewing:										
Light beer	10			0.1	0.1	500	75	Low	0.2	Potable
Dark beer	10			0.1	0.1	1,000	150	Low	0.2	Potable
Canning:										
Legumes	10		25 -75	0.2	0.2			Low	1	Potable
General	10			0.2	0.2			Low	1	Potable
Carbonated beverages	2	10	250	(0.2) (0.3)	0.2	850	50-100	Low	0.2	Potable
Confectionery				0.2	0.2	100		Low	0.2	Potable
Cooling	50		50	0.5	0.5			Low	5	
Food: General	10			0.2	0.2			Low		Potable
Ice	5	5		0.2	0.2			Low		Potable
Laundering			50	0.2	0.2					
Plastics, clear, uncolored	2	2		0.2	0.02	200				
Paper and pulp:										
Groundwood	50	20	180	1.0	0.5					
Kraft pulp	25	15	100	0.2	0.1	300				
Soda and sulfite	15	10	100	0.1	0.05	200				
High-grade light papers	5	5	50	0.1	0.05	200				
Rayon (viscose):										
Pulp production	5	5	8	0.05	0.03	100	Total 50; hydroxide 8			
Manufacture	0.3		55	0	0					
Tanning	20	10-100	50-135	0.2	0.2		Total 135; hydroxide 8			
Textiles: General	5	20		0.25	0.25					
Dyeing	5	5-20		0.25	0.25	200				
Wool scouring		70		1.0	1.0					
Cotton bandage	5	5		0.2	0.2			Low		

excessive nitrates in water, the State Department of Health has adopted a concentration of 10 parts per million of nitrogen in the form of nitrate or a total of 44.2 parts per million nitrate as a recommended maximum since no nitrate limitation has, as yet, been adopted by the Public Health Service. The State Department of Health conducts further investigations when greater concentrations of nitrogen than this are found.

In addition to these hygienic requirements, many industries have further restrictions concerning their use of water. Suggested water quality tolerances for several industries are listed in table 36 and exemplify the difficulty of obtaining suitable water for all uses. Because of these varying tolerances no one supply can be suitable for all uses.

Physical standards for potable water have been established by the U. S. Public Health Service and are outlined in table 37. Several physical tolerances for various industries are listed in table 36.

Table 37. U. S. Public Health Service Drinking Water Standards for Physical Quality.

Property	Requirements
Turbidity	10 ppm (maximum)
Color	20 ppm (maximum)
Taste	Not objectionable
Odor	Not objectionable

Although both the sanitary and biological tests of water are very important, no generally accepted standards have been established for a determination of their quality and, therefore, each situation must be considered individually.

PRESENT QUALITY

BACTERIOLOGICAL

The primary purposes for bacteriological testing are to determine whether water is safe for human consumption and delineate areas of pathogenic contamination. The test is used to determine the presence of coliform bacteria such as Escherichia coli, and a positive sample is one in which these bacteria are present. The coliform bacteria themselves do not cause illness in concentrations commonly found in drinking water. However, they are indicative of contamination and their presence in appreciable numbers indicates that the water contains diluted human wastes or sewage and likely carries disease-causing organisms and is, therefore, not safe for human consumption without adequate treatment.

Table 38 contains the bacteriological results of three years of tests for municipal and community domestic water systems in the study area which were tested during 1957, 1958, and 1959. Comparison of table 38 with table 34 indicates whether a system corresponds to the Public Health Service requirements for approved supplies. However, additional factors such as sampling frequency and a sanitary survey must be considered before approving any supply for public use. All cities should collect at least one bacteriological sample per month, and the Whatcom County Health Department has adopted a policy of trying to collect at least one sample per year from every community supply. Sources indicating contamination are, of course, sampled more frequently.

Table 38 shows that many of the water associations have not maintained a recommended sampling frequency of at least one sample per year. The large number of positive samples for the systems utilizing surface supplies also accentuates the need for continuous chlorination of these supplies. Essentially, however, the basin's water is of excellent quality from a bacteriological standpoint and, with a minimum of treatment, is suitable for domestic supplies.

CHEMICAL

A chemical analysis, often called a mineral test, is used to determine the inorganic or mineral constituents of water. In making this analysis the chemist tests for arsenic, boron, carbonate, bicarbonate, calcium, chloride, copper, fluoride, iron, lead, magnesium, manganese, nitrate, potassium, silica, sodium, sulfate, and zinc. The analysis also includes determinations of alkalinity, hardness, pH, radioactivity, and the specific electrical conductance.

GROUND WATER

The ground waters of the Nooksack River basin are relatively low in dissolved solids although they are more highly mineralized than the surface waters. They are generally of good quality, although ground water of poor quality does occur in small areas of generally good quality water. The quality in most cases depends mainly upon the geologic mode of occurrence. The majority of waters can be classified as calcium-magnesium-bicarbonate type. However, sodium bicarbonate, sodium sulfate, sodium chloride, and mixed-type waters are also present. In studying the mineral content of the ground water, relatively complete chemical analyses were made on twenty-five representative wells located throughout the Whatcom Basin (tab. 39). In addition, analyses of the city of Everson well (40/3-36H1), the city of Blaine spring (40/1-3M1) and artesian well (41/1-31Q1) were furnished by city water department officials.

Hardness.

Of the field hardness determinations, the greatest found in the Nooksack River basin was 1,500 parts per million from an artesian well owned by K. VanderGriend (40/3-28M). This well, drilled in 1910 to a depth of 375 feet, apparently obtains saline water from the Tertiary and/or early Pleistocene marine sediments which underlie the younger glacial deposits in the Whatcom Basin. The softest water with a hardness of 36 parts per million (Northwood Springs, 40/3-15H1) comes from recessional outwash gravels overlying Vashon till. Of 246 wells and springs tested for hardness by the U. S. Geological Survey, 31 percent had soft water, 39 percent had slightly hard water, 27 percent had moderately hard water, and 3 percent had very hard water. Wells in the Vashon till yielded slightly hard to moderately hard water. Wells in the recessional outwash yielded soft to slightly hard water. Water from the shallow wells in the Recent alluvium of the Nooksack and Sumas River flood plains differs somewhat in hardness from place to place and at various depths, in many wells the hardness being but 60 to 80 parts per million, while others ran as high as 175 parts per million with the average hardness being about 150 parts per million. Table 39 shows the hardness expressed as calcium carbonate in parts per million by weight for twenty-five wells in the report area.

Table 38. Bacteriological Water Sample Record of Municipal and Community Water Systems in the Nooksack River Report Area--1957, 1958, 1959.*

System	Number of samples submitted			Number of 10 ml portions			Number of positive portions			Percentage of portions positive			Number of samples, 3 or more tubes positive			Percentage of samples, 3 or more tubes positive		
	57	58	59	57	58	59	57	58	59	57	58	59	57	58	59	57	58	59
Acme	0	5	4	0	25	20	--	9	4	--	36.0	20.0	--	2	0	--	40.0	0
Aldergrove Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Bakerview Water Association	0	0	2	0	0	10	--	--	4	--	--	40.0	--	--	0	--	--	0
Bell-Bay-Jackson Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Blaine	8	2	3	40	10	15	4	1	5	10.0	10.0	33.3	1	0	0	12.4	0	0
Custer Water Association	1	2	1	5	10	5	0	0	0	0	0	0	0	0	0	0	0	0
Delta Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Deming	2	4	1	10	20	5	9	1	0	90.0	5.0	0	2	0	0	100.0	0	0
Everson	7	3	5	35	15	25	1	1	0	2.9	6.7	0	0	0	0	0	0	0
Ferndale	4	3	1	20	15	5	0	0	0	0	0	0	0	0	0	0	0	0
Fertile Meadows Water Association			1			5			0			0			0			0
Glacier	1	6	4	5	30	20	3	4	0	60.0	13.3	0	1	1	0	100.0	67.7	0
Gooseberry Point Water Association	0	2	1	0	10	5	--	2	0	--	20.0	0	--	0	0	--	0	0
Guide Meridian Water Ass'n.	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
"H" Street Road Water Association	1	1	1	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
Lake Terrell Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Laurel Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Lynden	13	11	12	65	55	60	0	0	0	0	0	0	0	0	0	0	0	0
Maple Falls	5	4	4	25	20	20	15	2	1	60.0	10.0	5.0	3	0	0	60.0	0	0
Meadowdale Water Association	0	1	0	0	5	0	--	0	--	--	0	--	--	0	--	--	0	--
Mt. Baker Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Neptune Beach Water Association	1	0	1	5	0	5	1	--	0	20.0	--	0	0	--	0	0	--	0
North Star Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Northwest Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Northwood Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Old Settlers' Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Orchard Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Pleasant Valley Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Skookumchuck Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Smith Road Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Sumas	7	7	8	35	35	40	13	3	2	37.2	8.6	5.0	3	1	0	42.9	14.3	0
Sunrise Cove Water System	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Thornton Road Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Victor Water Association	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0
Whalen Utilities	0	0	1	0	0	5	--	--	0	--	--	0	--	--	0	--	--	0

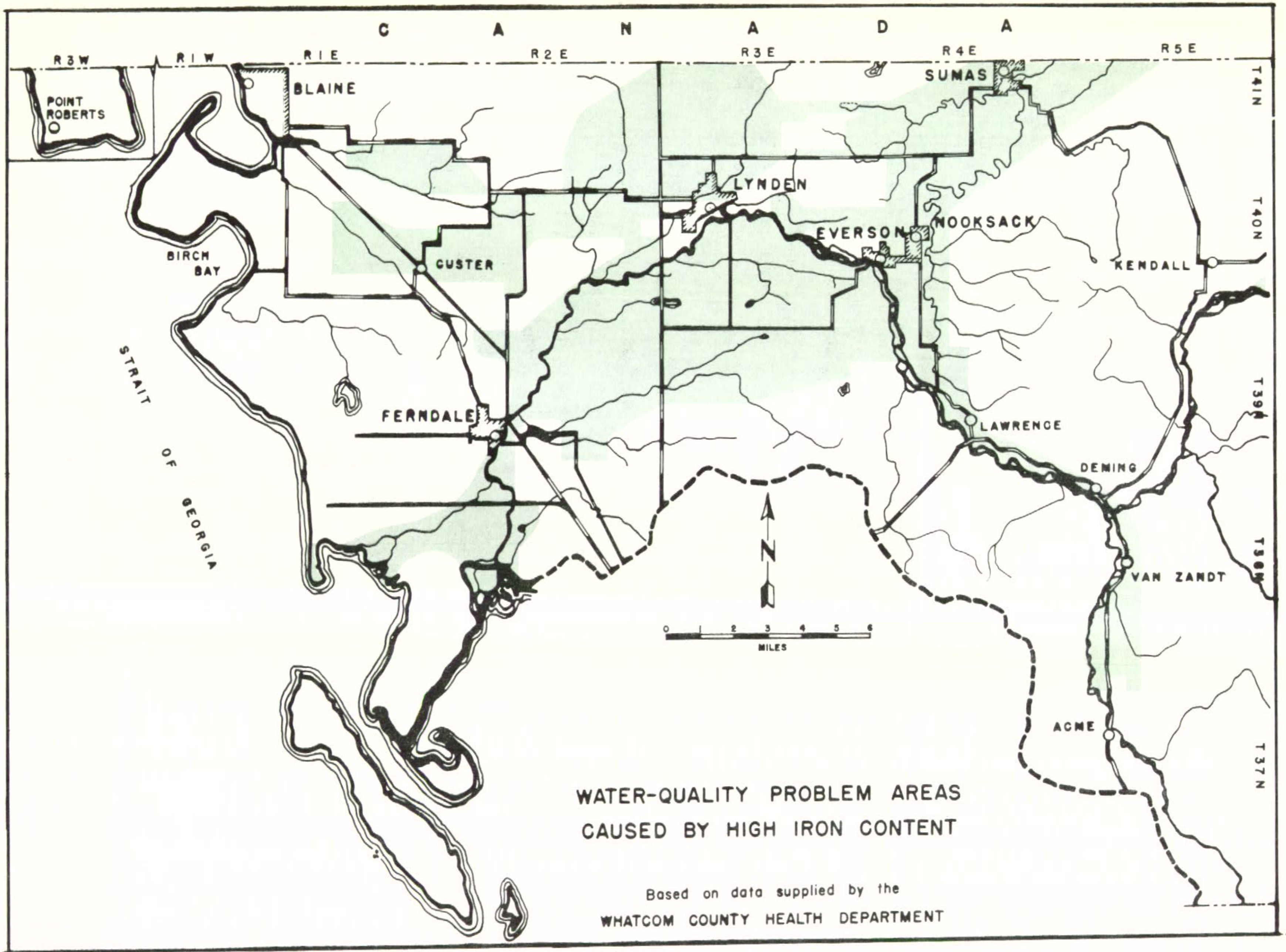
* Data for this table supplied by the Whatcom County Department of Public Health.

Table 39. Chemical Analyses of Ground Waters in Nooksack River Basin.
All analyses were made by U. S. Geological Survey, except for City of Blaine and Custer Water Association, analyzed by Northwest Laboratories.

(F) : pH reading made in field during collection of sample.
(L) : pH reading made in laboratory within a few days of collection date.

Well Location	Owner or Tenant	Description of Well and Aquifer	Date of Collection
38/1E-4D1	Neptune Beach Water Assn.	143'x8"; aquifer 133'to143' in advance sands, gravels.	3/1/60
38/5E-2Q	Emma Bodtke	18' dug well; aquifer in alluvial sands, gravels.	3/2/60
38/5E-29D	Tony Fresla	16'x36"; aquifer in recessional sands, gravels.	3/2/60
39/1E-2R1	Custer Water Assn.	50'x10"; 38' blue clay, then sand and gravel aquifer.	9/30/59
39/2E-19Q	Town of Ferndale	2 wells, 157' & 160'; aquifer in advance sands, gravels.	3/1/60
39/2E-36D1	C. V. Wilder	Spring. Water-table discharge from sub-till gravels.	4/7/49
39/3E-10H1	Emma McMillan	20' dug well.	3/1/60
39/3E-18D	Meridian Water Assn.	24'x36"; aquifer in recessional sands.	3/1/60
39/4E-27E	Henry Diercks	Drilled well (only information given).	3/2/60
39/4E-32P	Otto Sehrt	179' deep; aquifer in advance sands, gravels.	3/2/60
39/4E-34C	Don Haaland	100' deep; area underlain by till, Tertiary bedrock	3/2/60
39/5E-3F1	Joe Zender	44'x6"; aquifer in recessional sands, gravels.	3/2/60
40/1E-3M1	City of Blaine	Spring. Discharge from sub-till gravels.	4/7/49
40/2E-8D	B. McPhail	Well.	3/1/60
40/2E-25A1	J. Crabtree	Well.	3/1/60
40/3E-9R1	Delta Water Assn.	2 wells: 30' & 37'; aquifer in recessional sands, gravels.	3/1/60
40/3E-15H1	Northwood Springs	Springs.	3/1/60
40/3E-28M	K. Vander Griend	375'x3"; drilled 1910 with artesian flow of 50 gpm, later plugging reduced flow to 3 gpm; salt-water aquifer probably in marine Tertiary and/or early Pleistocene sediments.	3/1/60
40/3E-36H1	City of Everson	30' dug well; aquifer is gravel in alluvium.	4/8/49
40/4E-9A	Andrew Hento	15' dug well; aquifer in recessional sands, gravels.	3/2/60
40/4E-10D1	John Brayard	84' driven well; aquifer is gravel in alluvium.	4/8/49
40/4E-33E	James Rorabaugh	Well.	3/1/60
40/5E-9Q1	Kelley's Store	102'x4"; aquifer in recessional sands, gravels.	3/2/60
41/1E-31Q1	City of Blaine	247'x12" artesian well; aquifer in advance sands, gravels.	3/2/60
41/4E-33N2	City of Sumas	Spring; aquifer is recessional sand, gravel lying on till stratum, some water from confined gravel beneath till.	3/1/60

Parts per Million															
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 at 180° C	Hardness as $CaCO_3$	Electrical Conductivity (micromhos at 25°C)	pH	Temperature °F
23	.07	31	22	20		218		14.0	.3		226	167	415	8.1(L) 7.2(F)	46
	.01	10	3.6			37					82	40	135	6.4(L) 6.2(F)	
	3.4	16	21	3.6		160		3.5	.1		162	128	255	7.4(L) 6.8(F)	
22	2.4	14.9	7.0	15.3		94.5	8.1	14.0			106	50-100		6.7(L)	
	.56	42	19	116		291		121.0			480	184	811	8.2(L) 7.0(F)	50
19	.04	23	10	18	3.0	124	8.6	22.0	.2	2.0	167	98	296	7.3(L)	
	.07	13	2.1			39					85	41	122	6.5(L) 6.1(F)	
22	.28	16	7.8	12		47	12.0	14.0	.2	32.0	132	72	218	6.9(L) 6.5(F)	
	.09	11	7.7			55			.1		86	59	133	6.8(L) 6.9(F)	
	.28	17	11			470		8.0		0	450	86	706	8.1(L) 7.6(F)	
32	.12	27	9.9	41		235		6.5		0	238	108	372	8.0(L) 7.8(F)	
	.06	26	4.6			105					118	84	188	8.2(L)	
24	.01	12	6.5	5.8	2.0	78	6.7	3.3	.2	.1	90	57	133	7.3(L)	
	.06	37	13			188		4.0			190	146	346	7.5(L) 7.0(F)	
	.23	13	3.2	3.7		44		4.0			82	46	120	6.6(L) 6.4(F)	
	.01	14	3.1			30	10.0	6.0	.1	9.8	83	48	131	6.8(L) 6.6(F)	
	.03	10	2.7			33					76	36	98	6.9(L)	42
		180	250			120		4500				1500	14,500	7.5(L)	
19	.01	28	12	21	2.2	44	12.0	84	.2	5.6	215	119	388	6.6(L)	
	4.2	7	18			120	1.4	3.0		.8		90	195	7.1(L)	
48	.42	14	17	13	2.8	138	1.6	14.0	.2	.2	175	105	245	6.8(L)	
	.54	14	19			130					152	114	290	6.7(L) 6.5(F)	
	.06	18	5.5			74					92	68	152	7.2(L) 7.0(F)	
29.6	.05	12.3	7.1	18		100.8	8.2	5.5		.01	137	60		7.9	
13	0.00	23	4.6	14		82	14.0	5.0			111	76	173	8.1(L) 7.7(F)	



WATER-QUALITY PROBLEM AREAS CAUSED BY HIGH IRON CONTENT

Based on data supplied by the WHATCOM COUNTY HEALTH DEPARTMENT

Figure 58.

Salinity.

The small amount of ground water in the Tertiary rocks is saline or brackish, except on the mountain slopes or other places where good circulation has apparently flushed out these waters. In some places, the unconsolidated deposits overlying the Tertiary bedrock have received some saline waters from the bedrock below. The unconsolidated pre-Vashon Pleistocene deposits beneath the Mountain View and Boundary Uplands appear to contain fresh water of low chloride content even when lying as much as several hundred feet below present sea level. In deep wells that approach Tertiary bedrock or early Pleistocene marine sediments, some saline water may be encountered; other wells penetrating aquifers which are poorly supplied by fresh ground-water recharge may experience sea water encroachment if overpumped.

The principal zone of saline water lies at a depth of 100 feet or more beneath the lowlands of the Nooksack and Sumas River flood plains and the Custer Trough. Chloride content as high as 4,500 parts per million (K. VanderGriend well, 40/3-28M) has been found there. Possibly the advance and recessional outwash deposits of the Vashon glaciation were laid down in these lowlands under marine or brackish water conditions and the connate saline water has not been flushed out.

Gaseous Impurities.

Numerous wells drilled in the area where glacial materials cap the bevelled coal-bearing Tertiary rocks have struck pockets of natural gas, and in some cases water is being confined under pressure along with gas accumulation. Well 39/2-28H1 was reported to have tapped confined water that shot 100 to 150 feet into the air by gas pressure. Other wells in this area east of Ferndale produce methane gas. Well 39/4-33C1, three-quarters of a mile south of Cedarville, was reported to have had a gas explosion in the pump house when the pump was turned on. The chief constituent of the gas is methane, which was probably generated in the organic matter of the underlying Tertiary rocks. Where strata of the Tertiary rocks are bevelled, the gas may be free to move up into the overlying Pleistocene deposits, where it becomes trapped by confining clay members until encountered by wells.

A few of the wells were reported to obtain water having the odor of hydrogen sulfide gas. Such occurrence may be due to peat or swamp deposits near the aquifer.

Iron.

Iron is by far the most common objectionable constituent of ground water in the Whatcom Basin. Its occurrence is confined almost entirely to the areas of recessional outwash and Recent alluvium, the greatest concentrations being in the Recent alluvial deposits of the Sumas River flat.

Since 75 to 90 percent of the total iron present is oxidized and precipitated on contact with air, the iron is probably largely in the form of ferrous bicarbonate, $Fe(HCO_3)_2$ and likely derived from action of carbon dioxide and vegetal acids on ferric oxide and other iron compounds in the rocks, the vegetal matter possibly consisting largely of peat beds.

The chemical analysis of the iron-bearing water from well 40/4-10D1 shows the presence of manganese in a concentration of 0.42 parts per million. Manganese is often associated with iron-bearing water and may be present throughout the iron-bearing waters of this area.

Nitrate.

The Meridian Water Association's well (39/3-18D) shows a relatively high nitrate value of 32 parts per million. When nitrate is present in amounts greater than 44 parts per million, the supply is not satisfactory for public use as it can cause a circulatory disorder (metheglobinemia) in infants under six months of age.

SURFACE WATER

The chemical quality of the basin's surface water is very good and suitable for most uses, with the exception of the high iron content of the Nooksack River at Ferndale. Table 40 lists the surface water quality analyses with respective station numbers corresponding to those on plates 4 and 5.

Iron.

The presence of iron in water is often confused with hardness. Although iron does act like calcium as a hardness constituent, the iron quantity is normally so small in relation to the other hardness constituents that it can be considered insignificant.

Part of the iron in surface water is obtained from ground water discharging to streams as discussed on preceding pages; in addition, iron is a constituent of the chlorophyll of green leaves and high concentrations of iron are found in swamp waters and in low lying ponds with deficient drainage. This iron is in organic combination until worked over by bacteria during decomposition processes in many places forming deposits of bog iron. There are numerous such deposits in the basin which likely contribute much to the high iron content found at Ferndale.

Most of the information regarding iron in surface water was collected and analyzed by the General Petroleum Corporation at Ferndale. Their results show iron in quantities ranging from 0.11 to 0.8 parts per million, which is exceptionally high for a mountain-fed stream such as the Nooksack River. Only two other iron analyses have been made of surface water in the basin. They showed 0.11 parts per million in the Nooksack River at Deming and 0.03 parts per million at Northwood Springs, east of Lynden. The lack of iron analyses on the forks of the Nooksack River and lower tributaries make it impossible to accurately locate the source of the high iron concentration at Ferndale. It is assumed, however, that the majority of the iron leaches from bog iron deposits in the Lynden, Lawrence, and Van Zandt areas. The Whatcom County Health Department has found iron problems to be prevalent throughout much of the lower basin (fig. 58). Visual examinations of the streams in this area show red precipitates along the banks of lowland streams which tend to support this theory. Ground-water analyses by the U. S. Geological Survey discussed in preceding pages also indicate iron problem areas in this vicinity. In addition the one quality sample collected at Deming shows a substantially lower iron content than that at Ferndale. Thus, although there is no absolute proof that the high iron content at Ferndale originates in the lower basin, all indications seem to bear this out.

CHARACTERISTICS AND TREATMENT OF IRON

The effects and treatment of iron in water are similar regardless of whether the supply is surface or ground water. Iron is undesirable in domestic supplies since it stains plumbing fixtures, cooking utensils, and clothing when

Table 40. Surface-water Quality Analyses, Nooksack River Basin, in parts per million.

Place of Collection	Station No.	Date of Collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
Nooksack River at Deming	NS10	9-22-47	9.4	--	13	3.7	(0.5)		37
Nooksack River at Deming	NS10	6-18-48	7.6	0.11	12	2.3	(.0)		32
Nooksack River at Lynden	NS16	6-30-47	8.2	--	12	3.2	(0.2)		37
Nooksack River at Ferndale	NS21	12-24-52	10	0.11	13	5.0	3.2	0.6	46
Nooksack River at Ferndale*	NS21	2-25-53	7.0	0.3	12	6.0	5.0	1.0	51
Nooksack River at Ferndale*	NS21	3-25-53	12	0.8	8.0	3.0	3.0	1.0	42
Nooksack River at Ferndale*	NS21	4-23-53	11	0.8	7.0	3.0	5.0	1.0	37
Nooksack River at Ferndale*	NS21	5-25-53	16	0.7	10	3.0	2.0	1.0	38
Nooksack River at Ferndale*	NS21	6-53	19	0.5	11	3.0	2.0	1.0	42
Nooksack River at Ferndale*	NS21	7-22-53	20	0.8	10	3.0	3.0	1.0	42
Nooksack River at Ferndale*	NS21	9-10-53	28	0.3	10	5.0	2.0	1.0	42
Nooksack River at Ferndale*	NS21	9-30-53	11	0.5	10	4.0	3.0	1.0	41
Nooksack River at Ferndale*	NS21	10-29-53	15	0.3	14	2.0	2.0	1.0	46
Nooksack River at Ferndale*	NS21	12-9-53	20	0.8	6.0	4.0	5.0	2.0	42
Nooksack River at Ferndale*	NS21	2-1-54	26	0.5	10	6.0	3.0	1.0	44
Nooksack River at Lawrence	2107	7-15-59	5.9	--	8.0	1.2	0.9	0.5	24
Nooksack River at Lawrence	2107	8-20-59	8.6	--	12	1.2	1.5	0.9	34
Nooksack River at Lawrence	2107	9-1-4-59	8.5	--	11	2.3	1.7	0.6	36
Nooksack River at Lawrence	2107	9-5-10-59	7.2	--	8.0	1.5	1.4	1.2	27
Nooksack River at Lawrence	2107	9-11-24-59	8.0	--	10	2.1	1.6	0.5	34
Nooksack River at Lawrence	2107	9-25-30-59	7.5	--	10	1.3	1.4	0.5	32
Nooksack River at Lawrence	2107	10-1-8-59	9.7	--	12	2.4	1.7	0.4	40
Nooksack River at Lawrence	2107	10-9-16-59	7.9	--	11	0.8	1.3	0.4	31
Nooksack River at Lawrence	2107	11-17-31-- 11-1-4-59	8.9	--	9.5	2.5	1.4	0.4	36
Nooksack River at Lawrence	2107	11-5-17-59	9.2	--	11	2.9	1.7	0.4	41
Nooksack River at Lawrence	2107	11-18-29-59	7.8	--	8.0	1.9	1.3	0.7	29
Nooksack River at Lawrence	2107	11-30, 12-1-10-59	9.8	--	11	2.1	1.6	0.3	39
Nooksack River at Lawrence	2107	12-11-14-59	8.8	--	8.5	2.5	1.5	0.5	35
Nooksack River at Lawrence	2107	12-15-17-59	8.4	--	7.0	1.7	1.2	0.6	28
Nooksack River at Lawrence	2107	12-18-31-59	9.3	--	9.5	3.1	1.5	0.4	40
Nooksack River at Lawrence	2107	1-1-13-60	10	--	12	3.4	2.0	0.5	46
North Fork at Shuksan	NS1	12-16-59	6.3				--		19
North Fork near Glacier	NS2	12-16-59	--				1.0		26
Glacier Creek at Glacier	NS3	12-16-59	--				1.9		28
Canyon Creek near Glacier	NS4	12-16-59	--				--		32
Maple Creek near Kendall	NS5	12-16-59	--				1.5		41
Middle Fork Nooksack River near VanZandt	NS7	12-16-59	--				--		21
Skookum Creek near Wickersham	NS8	12-16-59	--				--		21
South Fork Nooksack River near Saxon Bridge	NS9	12-16-59	--				--		24
Nooksack River at Deming	NS10	12-16-59	--				--		27
Nooksack River at Everson	NS12	12-16-59	--				--		29
Anderson Creek at Goshen	NS11	12-16-59	--				--		21
Nooksack River near Lynden	NS16	12-16-59	8.7				--		28
Fishtrap Creek below Lynden	NS17	12-16-59	--				3.5		24
Bertrand Creek at Willeys Road Crossing	NS18	12-16-59	--				2.6		16
Nooksack River at Ferndale	NS21	12-16-59	--				--		27
Silver Creek at Slater Road	SL1	3-2-60	--				--		93
Tenmile Creek at Guide Meridian	NS19	3-2-60	--				--		
Fourmile Creek at Guide Meridian	NS20	3-2-60	--				--		
Scott Ditch at Hannegan Road	NS15	3-2-60	--				--		
Northwood Springs	NS14	3-2-60	--	0.03	10	2.7	--		33
Harvey Creek at Blaine-Sumas Road	NS13	3-2-60							
Kendall Creek at Kendall Highway	NS6	3-2-60							
Terrell Creek at Kickerville Road	TR1	3-2-60							
California Creek at Birch Bay Lynden Road	CL1	3-2-60							33
South Fork Dakota Creek at Custer School Road	DK2	3-2-60							
North Fork Dakota Creek at Custer School Road	DK1	3-2-60							25
Sumas River at Rock Road	SM1	3-2-60					11		116
Saar Creek at Rock Road	SM4	3-2-60							
Johnson Creek at Main St., Sumas	SM3	3-2-60					4.6		61
Pangborn Creek at Clearbrook Road	SM2	3-2-60							

* Analyses by Mobil Oil Company Laboratories Department

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids: Parts per million	Dissolved Solids: Tons per acre-foot	Dissolved Solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Color	Specific conductance (micromhos at 25°C)	pH
0	16	1.0	--	0.3	--	62	0.08	214	48	--	100	--
0	11	0.5	0.3	0.4	--	46	0.06	671	40	--	67	7.6
0	11	0.9	--	0.3	--	54	0.07	493	43	--	79	--
0	16	3.8	0.1	--	0.04	80	0.11	160	--	--	121	7.4
0	14	5.0	0.1	--	0.1	87	0.12	441	56	--	119	7.4
0	9.0	3.0	0.1	--	0.1	62	0.08	720	33	--	79	7.0
0	17	3.0	0.1	--	0.1	76	0.10	1315	33	--	66	8.1
0	17	3.0	0.1	--	0.1	84	0.11	725	38	--	79	7.5
0	15	2.0	0.1	--	0.1	85	0.12	990	39	--	82	7.3
0	13	5.0	0.1	--	0.1	80	0.11	670	38	--	100	7.4
0	23	2.0	0.1	--	0.1	100	0.14	364	48	--	138	8.1
0	24	3.0	0.1	--	0.1	70	0.10	1340	45	--	92	7.7
0	15	6.0	0.2	--	0.1	73	0.10	831	45	--	82	7.8
0	21	6.0	0.5	--	0.1	87	0.12	2940	33	--	77	7.3
0	20	5.0	0.1	--	0.2	94	0.13	761	51	--	94	7.4
0	6.9	0.2	0.2	0.1	--	38	0.05	420	25	15	58	7.0
0	13	0.8	0.2	0.1	--	51	0.07	233	35	5	86	7.3
0	13	.0	0.2	0.3	--	55	0.07	313	37	10	89	7.3
0	6.3	0.5	0.3	0.4	--	43	0.06	843	26	20	61	7.0
0	9.3	0.8	0.2	0.3	--	53	0.07	395	34	20	81	7.3
0	7.0	0.5	0.2	0.4	--	49	0.07	749	30	25	71	7.3
0	11	.0	0.1	.0	--	61	0.08	338	40	5	93	7.7
0	7.7	0.5	0.1	0.2	--	52	0.07	685	31	20	72	7.3
0	8.8	0.5	0.1	0.2	--	55	0.07	659	34	15	81	7.4
0	9.5	0.8	0.1	0.2	--	60	0.08	398	40	5	93	7.4
0	5.7	0.5	0.1	0.4	--	50	0.07	859	28	20	66	7.3
0	8.3	0.8	0.1	0.6	--	52	0.07	469	36	5	90	7.3
0	7.1	0.5	0.1	0.5	--	50	0.07	719	31	20	78	7.3
0	5.4	0.2	0.1	0.8	--	46	0.06	1748	24	35	61	7.7
0	7.1	0.8	0.1	0.7	--	53	0.07	566	36	5	85	7.8
0	9.1	1.0	0.1	0.7	--	61	0.08	308	38	5	105	7.7
		--	--	0.4					16		40	7.5
		--	0.5	--					29		69	7.5
		.0	--	--					27		68	7.4
		--	--	--					27		64	7.4
		--	0.1	1.7					41		93	7.4
		--	--	0.3					--		48	7.3
		--	--	--					--		42	7.2
		--	--	--					21		48	7.4
		--	--	--					25		61	7.2
		--	--	--					--		61	7.3
		1.0	--	1.8					18		54	6.8
		.0	--	0.8					--		63	7.2
		--	0.5	3.8					43		116	6.6
		--	--	3.2					24		71	6.6
		--	0.1	1.0					27		65	7.0
0		22							90		267	7.2
		11							84		231	7.0
									62		176	6.9
		27		3.6							253	6.7
0						76			36		98	6.9
			0.1						50		133	7.2
									70		157	7.7
		5.0	0.1						23		75	6.8
0									74		281	6.7
		24	0.2						51		207	7.8
0		10							24		96	6.9
0		15							102		217	7.6
											101	7.1
0		5.2							62		150	7.1
		3.8							46		119	7.1

Table 41. Processes of Iron and Manganese Removal.*

Treatment or Processes	Oxidation Required	Character of Water	Equipment Required	pH Range Required	Chemicals Required	Remarks
Aeration Sedimentation Sand filtration	Yes	Iron alone in absence of appreciable concentrations of organic matter	Aeration, settling basin, sand filter	Over 6.5	None	Easily operated. No chemical control required.
Aeration, contact oxidat'on, sedimentation, sand filtration	Yes	Iron and manganese loosely bound to organic matter, but no excessive carbon dioxide or organic acid content	Contact aerator of coke, gravel, or crushed pyrolusite, settling basin, and sand filter	Over 6.5	None	Double pumping required. Easily controlled.
Aeration, contact filtration	Yes	Iron and manganese bound to organic matter, but no excessive organic acid content	Aerator and filter bed of manganese coated sand, "Birm," crushed pyrolusite ore, or manganese zeolite	Over 6.5±	None	Double pumping required unless air compressor, or "sniffler valve" is used to force air into water. Limited air supply adequate. Easily controlled.
Contact filtration	Yes, but not by aeration	Iron and manganese bound to organic matter, but no excessive carbon dioxide or organic acid content	Filter fed of manganese coated sand, "Birm,"crushed pyrolusite ore, or manganese zeolite	Over 6.5	Filter bed reactivated or oxidized at intervals with chlorine or sodium permanganate	Single pumping. Aeration not required.
Aeration, chlorination, sedimentation, sand filtration	Yes	Iron and manganese loosely bound to organic matter	Aerator and chlorinator or chlorinator alone, settling basin and sand filter	7.0 to 8.0	Chlorine	Required chlorine dose reduced by previous aeration but chlorination alone permits single pumping.
Aeration, lime treatment, sedimentation, sand filtration	Yes	Iron and manganese in combination with organic matter, and organic acids	Effective aerator, lime feeder mixing basin, settling basin, sand filter	8.5 to 9.6	Lime	pH control required.
Aeration, coagulation and lime treatment, sedimentation, sand filtration	Yes	Colored, turbid, surface water containing iron and manganese combined with organic matter	Conventional rapid sand filtration plant	8.5 to 9.6	Lime and ferric chloride or ferric sulfate, or chlorinated copperas, or lime and copperas	Complete laboratory control required
Zeolite softening	No	Well water devoid of oxygen, and containing less than about 1.5 to 2.0 ppm iron and manganese	Conventional sodium zeolite unit, with manganese zeolite unit or equivalent for treatment of bypassed water	Over 6.5±	None added continuously but bed is regenerated at intervals with salt solution	Only soluble ferrous and manganous compounds can be removed by base exchange, so aeration or double pumping is not required.
Lime treatment, sedimentation, sand filtration	No	Soft well water devoid of oxygen containing iron as ferrous bicarbonate	Lime feeder, enclosed mixing and settling tanks and pressure filter	8.0 to 8.5	Lime	Precipitation of iron in absence of oxygen occurs at lower pH than otherwise. Absence of oxygen minimizes or prevents corrosion. Double pumping not required.

* Cox, C. R. 1952, Water supply control: New York State Dept. of Health, Bull. 22, p. 159-160.

Table 42. Sanitary analysis of Nooksack River at Lawrence Quality Station.

Collection		Temperature °C.	Coliform Organisms MPN*	Dissolved Oxygen	
Date	Time			ppm	Saturation
7-15-59	0800	11.5	91	10.7	96.0%
8-20-59	0630	12.0	230	9.8	90.5%
9-29-59	0715	9.0	36	10.9	94.0%
10-21-59	0710	9.8	23	11.6	101.9%
11-19-59	0700	5.0	91	11.6	90.6%
12-22-59	0720	3.2	230	12.2	91.0%
1-20-60	1810	2.0	150	13.4	96.8%
2-17-60	0700	3.2	230	12.5	93.2%

* Most probable number of coliform organisms per 100 milliliters of the sample analyzed.

present in concentrations of about 0.3 parts per million or greater. It is also undesirable in industries such as paper manufacturing where clear water is essential for a quality product (tab. 36).

Iron may also cause tastes and odor through the growth of iron-forming bacteria such as Crenothrix and Leptothrix. These bacteria grow in pipes carrying water devoid of oxygen and with as little as 0.1 parts per million of iron in solution. These organisms secrete iron and deposit ferric hydroxide as well as oxidizing ferrous to ferric iron which precipitates ferric hydrate which causes the discoloration and staining. Small gray or brownish flakes or masses of stringy or fluffy growths in water indicate the presence of iron bacteria. Additional iron problems can be caused by corrosive waters which attack iron pipe and house plumbing resulting in red water problems.

Treatment for removal of iron is necessary for many ground-water supplies in the basin as well as some surface waters. The commonly used methods for removal of iron from water are outlined in table 41.

Iron-forming bacteria can present an additional treatment problem which is most effectively handled through complete iron removal and chlorination to kill the bacteria and clear up the system.

PHYSICAL

The physical characteristics of water are those generally noticed by the casual observer. Temperature, color, turbidity, taste, and odor are usually determined in a standard physical analysis.

COLOR

The only physical test conducted in the basin was the color test, and the results of this analysis are listed in table 40. Color in untreated water usually comes from organic compounds in suspension leached from decaying or decomposed vegetation. A colored turbidity, such as caused by red clay, is sometimes described as apparent color. The samples taken from the Nooksack River ranged from 5 to 35 parts per million and comparison of these results with the standard in table 37 indicates that color removal is necessary for municipal water use.

Coagulation, settling and rapid sand filtration reduces the color in water to less than 5 parts per million, while slow sand filters should remove about 40 percent of the color.

SANITARY

A sanitary analysis determines the water characteristics which are of sanitary or pollution significance. This analysis is usually made in connection with a sanitary survey to explain the significance of the analysis and to locate pollution sources, unless the test is being made only to gather background information, as is presently the case in the lower Nooksack River basin. This analysis includes tests for the number of coliform organisms present, dissolved oxygen, biochemical oxygen demand, oxygen consumed from chromic acid, nitrogen in its various forms, and total organic constituents. Usually the total and suspended solids are also determined in a sanitary analysis. Although all the above tests are important, only the bacteria and dissolved oxygen content have been determined in the Nooksack River basin. These samples were all collected by the Pollution Control Commission at the permanent quality station located near Lawrence, and are tabulated in table 42. These sample results indicate that the water is quite free of pollution as evidenced by the low concentration of coliform organisms present and the high percentage of dissolved oxygen.

BIOLOGICAL

No biological tests have been conducted in the study area for no special problems have occurred to warrant such tests.

POLLUTION AND DEGRADATION

Water quality deteriorates through the influence of irrigation return water as well as contamination and pollution by industrial wastes, sanitary sewage, and refuse. Although the Division of Water Resources has certain responsibilities

Table 43. Industrial Waste Facilities in the Nooksack Report Area Based on Data Supplied By Washington State Pollution Control Commission.

Company	Location	Type of Wastes	Average Daily Flow Gallons	Maximum Daily Flow Gallons	Treatment	Waste Recipient	Permit Issued From	Permit Issued To
Alaska Packers Association	Blaine	Fish by-products and cooling		283,000	Solids collection, screened and submerged outfall	Boundary Bay	7-26-57	7-26-62
Blaine Fish Products Co.	Blaine	Miscellaneous and cooling		50,000	Grease traps	Semiahmoo Bay	8-6-56	8-6-61
Carnation Company	Ferndale	Milk products	90,000	150,000	Septic tank	Nooksack River	8-24-55	8-24-60
DeJong Packing Company	Lynden	Slaughtering	1,600	1,600	Good housekeeping, grease trap, septic tank, drainfield, gravel bed	Fishtrap Creek	5-25-56	5-25-61
Farmers Meat Company	Sumas	Meat Packing		2,000	Good housekeeping, grease trap, septic tank, drainfield,	Sumas River	6-26-56	6-26-61
General Petroleum	Ferndale	Petroleum		1,000,000	Distillation and stripping, emulsion breaking, neutralization, chemical oxidation, filtration, septic tank for sanitary	Georgia Strait	7-25-55	7-25-60
Iverson Canning Company	Point Roberts	Fish canning				Puget Sound		
C.S. Kale Canning Company	Everson	Canning and cooling			Screen and lagoons, none for cooling	Nooksack River	12-30-55	12-30-60
Kelley, Farquhar and Company	Ferndale	Canning and cooling	348,000	1,000,000	Screened, city sewers	Nooksack River	6-28-57	6-28-62
Kratzig Meat Company	Laurel	Slaughtering	800	1,200	Good housekeeping, septic tank, drainfield	Subsurface to Tenmile Creek	11-28-55	11-28-60
Lynden Berry Growers Ass'n.	Lynden	Canning and cooling		40,000	Screened, city sewer	Nooksack River	7-12-57	7-12-62
Lynden Dairy Products Co.	Lynden	Milk products	100,000	200,000	Good housekeeping	Nooksack River	4-23-56	4-23-61
Lynden Frozen Foods, Inc.	Lynden	Canning and cooling		180,000	Screened and city sewer (storm)	Stickney Slough	6-28-57	6-28-62
Minute Maid Corp.	Lynden	Canning and cooling		20,000	Screened and city sewer	Nooksack River	1-26-56	1-26-61
Nelbra Packing Company	Point Roberts	Fish canning				Puget Sound		
Point Roberts Fisheries	Point Roberts	Fish canning				Puget Sound		
Sumas Dairy Products Co.	Sumas	Milk products		15,000	Septic tanks	Sumas River	5-14-56	5-14-61
Western Condensing Company	Lynden	Milk products and cooling		150,000	Good housekeeping	Nooksack River and cooling Fishtrap Cr.	6-7-56	6-7-61
Whatcom Builders Supply Company	Ferndale	Sand and gravel	8,000	140,000	Lagoon, 2 day retention	Tributary of Nooksack River	6-8-56	6-8-61
Whatcom Builders Supply Company	Lynden	Sand and gravel	24,000	100,000	Lagoon, seepage to river	Nooksack River	8-12-57	8-12-62
Whatcom County Dairymens' Ass'n.	Lynden	Milk products and cooling	180,000	340,000	Good housekeeping	Nooksack River and cooling Fishtrap Cr.	6-4-56	6-4-61
Whiz Fish Products Company	Blaine	Fish by-products		4,000	Solids collection, screened outfall	Drayton Harbor	5-21-56	5-21-61

Table 44. Municipal Waste Facilities in the Nooksack Report Area Based on Data Supplied by the Washington State Department of Health.

City or Sewer District	Type of Sewer System	Average Daily Flow Gallons	Treatment Facilities: Designed For: Population Equivalent	Treatment Facilities: Designed For: Average Daily Flow Gallons	Treatment Facilities: Type	Waste Recipient	Population Served
Blaine	Separate				None	Drayton Harbor	1,000
Everson	Separate				Individual septic tanks, effluent collected by municipal sewers.	Nooksack & Sumas Rivers	300
Ferndale	Separate		800		28,500 gallon septic tank, gas chlorination with contact tank, open sludge beds.	Nooksack River	1,000
Lynden	Separate	250,000	2,000	450,000	Screened (bar rack), mechanical settling tanks, rotary distributor trickling filter, gas chlorination, covered digester, open sludge beds.	Nooksack River	2,000
Sumas	Combined				Private septic tanks, effluent collected by municipal sewers.	Sumas River	500
Whatcom County Hospital	Separate		300	30,000	Screened, Imhoff Tank, rotary distributor trickling filter, settling tank, gas chlorination and open sludge beds.	Silver Creek.	300

for protecting the quality of Washington's waters, that phase of water resource administration is generally under the authority of the Washington State Department of Health and the Pollution Control Commission. The State Department of Health has authority outlined in their rules and regulations to prohibit pollution affecting domestic water supplies or which otherwise endangers the health and well-being of the people.

Under the state's pollution control program, plans and specifications of waste disposal facilites are processed by the Pollution Control Commission working in cooperation with the State Department of Health. By working with industries prior to the actual beginning of construction, these agencies are able to recommend necessary alterations and modifications and, thus, avoid excessive future expense for changing waste treatment facilities.

Since inauguration of the pollution permit system in 1955, nineteen industries have been licensed in the study area, all in the Whatcom Basin. Those industries are tabulated in table 43, together with existing industries not as yet covered under the permit program. This information was obtained from the files of the Pollution Control Commission.

Municipal, community, and institutional sewerage systems are listed in table 44. Information for those systems, which are not covered under a permit system, was submitted by the State Department of Health, who assists cities in developing sewerage systems.

The two tables cited above include only the major known sources of man-made pollution in the study area. There exists, of course, considerable natural and animal pollution, particularly on smaller streams of the watersheds.

WATER USE

There was an upsurge of water utilization and development throughout western Washington during World War II and the following years. This was primarily due to the increases in water demands for manufacturing, municipal use, power, and irrigation. The increased water use and demand has also been sharply felt in the Nooksack River basin with current and anticipated conflict of interest emphasized on the smaller streams. The greatest increase within the study area, however, was for irrigation purposes.

WATER RIGHTS AND WATER LAW

Since the water use discussion which follows is based primarily on the water right records of the Division of Water Resources, it is only proper to first present a brief description of the evolution of our Washington State Water Code and the manner in which water rights are established.

Under Article XXI of our State Constitution, it is provided that water for irrigation, mining, and manufacturing, shall be deemed a public use. The procedure for appropriating these public waters was provided soon thereafter under Chapter CXLII, Session Laws of 1891. Under this statute, rights to the use of the surface waters of the state could be acquired by posting a notice in writing at a conspicuous place at the point of intended diversion, and filing a copy of the notice with the county auditor of the county in which the notice was posted. Through compliance with the specific provisions of this act and the development and use of the waters in question, rights were established with a date of priority which related to the date of the posting of the notice. However, this procedure proved to be inadequate since no supervisory agency had been created to assure compliance with the provisions of the act. Therefore, numerous filings were made whereby the notice was posted at the intended point of diversion and a copy was filed with the local auditor but no actual diversion was made. Thus, the appropriation was never consummated and the actual right never established. However, due to the lack of records, it was not known, without considerable investigation and litigation, as to which filings had actually been perfected.

Through the years many conflicts arose over rights to the use of public waters and in about 1913 the governor was petitioned to compile a water code for the state. As a result, a commission was formed which drafted a code of some 44 sections which was passed into law by the legislature as Chapter 117, Laws of 1917.

Chapter 117, Laws of 1917, became effective June 6, 1917, and has become known as the Surface Water Code. This code extended the concept of rights by appropriation by declaring that subject to existing rights, all waters within the state belong to the public and any right thereto, or to the use thereof, could only be acquired by appropriation for a beneficial use as provided in the act. Although the code provided that as between appropriations the first in time shall be the first in right, it further declared that nothing in the act shall lessen, enlarge, or modify the rights of riparian owners existing as of June 6, 1917, or any right however acquired, existing as of that date. The act created the office of Hydraulic Engineer to administer these laws and the basic concept of the laws has not been changed through the 43 years of their existence. However, the office of the Hydraulic Engineer has, by law, become a division of the Department of Conservation and the duties of administration now fall upon the Supervisor, Division of Water Resources, of that department.

Since the code recognized rights which existed at the time it became effective, a procedure was established whereby the extent and priority of said rights could be determined. This procedure involves the adjudication of all rights on a certain stream or water course through a hearing in the superior court of the county in which the majorpart of the stream is located. Normally, the supervisor of the Division of Water Resources acts as referee, conducting the hearing and taking evidence for the court. Upon conclusion of the hearing a report is prepared by the referee whereby a schedule of rights is presented, setting forth the priority and extent of the rights of each claimant. If adopted by the court, this report then becomes a decree in the case and title to all rights on the stream are determined. It should be noted that this action is only required to establish the validity and extent of rights claimed by use prior to 1917.

Where an appropriation is to be initiated after June 6, 1917, the code provides that application must be made to the supervisor for a permit to make the appropriation and that no use or diversion of water shall be made until a permit has been issued. Applications to appropriate public waters must be submitted on forms supplied by the supervisor. When received in the office of the supervisor, the date and time of receipt is endorsed thereon and this date establishes the priority of the application. After office review of the application, a notice for publication is prepared and forwarded to the applicant together with instructions for publication. It is a statutory requirement that this notice appear once a week for two consecutive weeks in a newspaper of general circulation published in the county, or counties, in which the storage or diversion is to be made. A period of thirty days from last date of publication is then provided as a protest period during which formal objections to the approval of the application may be recorded. At this time, notice of the application is also forwarded to the State Department of Fisheries and the State Department of Game and no formal action on the application is taken until such time as the recommendations of those departments are received. Following due notice to the public, a field investigation is conducted by a representative of the Division of Water Resources to determine what water, if any, is available for appropriation and to determine to what beneficial use or uses it can be applied. After full review of the application, written findings of fact are prepared concerning all aspects of the application. If it is found that there is water available for appropriation in the proposed source of supply, and that the proposed use will not conflict with existing rights, or, threaten to prove detrimental to the public interest having due regard to the highest feasible development of the use of the waters belonging to the public, the application may be approved.

Approval of the application and issuance of permit constitutes authority for the commencement of actual construction work which will lead to use of the waters in question. For small projects it is normally specified that construction shall be started within one year from the date of issuance of permit, shall be completed in the second year, and full beneficial use of the waters shall be made in the third year. If in good faith, this schedule cannot be met, extensions of time are granted upon request. This permit may be considered as an agreement between the permittee and the supervisor for the development and use of the waters in accordance with the terms of the permit. Once the water has been put to beneficial use, the permittee may acquire the final certificate of water right. However, since it is a fundamental concept of our water laws that an appropriation does not extend in a legal sense to any water except as it is used beneficially, the final certificate of water right issues only for that quantity of water actually used and for the purposes to which the water has been beneficially applied within the maximum limits set by the permit. Should a permittee fail to comply with the conditions of the permit, he is notified by registered mail that he has sixty days in which to show cause why his permit should not be cancelled. If the permittee does not show cause, the permit is cancelled without further notice.

With issuance of the final certificate of water right, processing of the application and permit is completed. Through the certificate, title to the waters in question is acquired and the actual water right is perfected. The right acquired by this appropriation becomes an appurtenance to the property described therein as the place of use with the date of priority relating to the original date of filing of the application in the office of the supervisor. Since no provision exists in the present surface water code for the revoking of such certificates, perpetual rights are established.

Whenever storage of water is contemplated, either within the stream channel or adjacent thereto, a storage permit may be required. Normally such a permit is to be obtained whenever the dam or dike will store water to a depth of ten feet or more at its deepest point, or ten acre-feet or more of water will be retained. Furthermore, the surface-water code provides that whenever it is proposed to construct any dam or controlling works for the storage of ten acre-feet or more of water, detail plans and specifications of the structure must be submitted to the supervisor for his examination and approval as to safety before construction is started. The supervisor requires that such plans and specifications be prepared by a properly qualified registered professional engineer and carry his signature and seal. Applications for reservoir permit must be made on forms supplied by the supervisor and the procedure for processing of such applications is the same as described under applications for appropriation permit.

Since development and use of public ground waters of the state took place at a slower rate than the surface waters, the need for regulatory control evolved at a later date. However, with improvement of drilling techniques and the expansion of the industrial, municipal and irrigation requirements of the state, the need for laws relating to the appropriation and use of ground water became evident. Therefore, in 1945 the Association of Washington Cities sponsored and assisted in drafting legislation which is now referred to as the Washington State Ground-Water Code.

The laws relating to ground water supplement the surface-water code of the state and were enacted for the purpose of extending the application of the surface-water statutes to the appropriation of ground waters for beneficial use. Thus, the laws are administered by the Division of Water Resources and the appropriation procedure is essentially the same. Basically, the law provides that no withdrawal of public ground waters shall be begun, nor shall any well or works for such withdrawal be constructed unless an application to appropriate such waters has been made to the supervisor and a permit has been granted by him. However, it is further provided that for any withdrawal of public ground waters for stock water purposes, or for watering of a lawn, or of a non-commercial garden not exceeding one-half acre in area, or for single or group domestic uses, or for an industrial purpose, and in an amount not exceeding 5,000 gallons per day, a permit is not required from the supervisor. Applications may be submitted for these purposes if any person or agency wishes to record the well and the use made thereof.

In much the same manner as the surface-water code of 1917, the ground-water code recognizes existing rights established by development and use of ground waters prior to the effective date of the code, June 6, 1945. However, the ground-water code differed in that a declaratory period was provided whereby wells developed prior to 1945 could be recorded. The code provided that any person claiming a vested right for the withdrawal of public ground waters by virtue of prior beneficial use, could within three years after June 6, 1945, receive from the supervisor a certificate of ground-water right to that effect, upon declaration by the claimant in a form prescribed by the supervisor. This declaratory period was subsequently extended for a period of two years such that a total of five years was allowed in which a certificate could be acquired under declarations of claim.

In the review of all records concerning water rights established in the Nooksack River basin, the miscellaneous water right records of the Whatcom County Auditor's office were consulted. It was found that approximately 219 filings had been recorded in that office during the 21-year period from 1897 to 1917. The majority of these filings were in the form provided by the Laws of 1891, whereby notices of appropriation were to be posted at the intended point of diversion. Since these records do not disclose as to whether the appropriation was actually consummated, a field check was made during the summer of 1960 to determine if diversions and use were being made of the water at that time. Supporting evidence which indicated that development had taken place and that water had actually been used was found in less than 5 percent of the recordings. However, adjudication proceedings would be required to establish the extent and validity of any claim to rights under the recordings in the Whatcom County Auditor's office.

It is probable that many instances occur in the basin where diversions were initiated prior to June 6, 1917, and no recording was made with the local county auditor. However, since the 1917 act recognized all existing rights, the courts have subsequently held that if water was diverted and applied to a beneficial use prior to 1917, and the use has been continuous through the years, the use has ripened into a valid right regardless if a recording was made with the auditor. Again, adjudication proceedings would be required to quiet title to such claim to vested rights.

In the consideration of all vested rights, continuity of use is important. If it is found through adjudication proceedings or quiet title action that a long period of non-use has taken place, the courts may rule that the right has been abandoned. However, our laws do not provide for a statutory period which constitutes abandonment and each instance of non-use must therefore be considered individually.

Table 45. Surface-water Use By Drainage Basin.

Drainage Basin	Total Number of Valid Filings	Number of Irrigation Filings	Irrigation Acreage	Irrigation Quantity (cfs)	Public & Domestic Quantity (cfs)	Other Consumptive Quantity (cfs)	Non-consumptive Quantity (cfs)	Total Appropriated Quantity (cfs)
Main Nooksack River*	25	23	946.5	9.415	5.01	5.00	0	19.425
Tenmile Creek	45	43	1,064.0	12.605	0.065	0.04	0.69	13.40
Unnamed Tributary of Nooksack River	1	1	70.0	0.67	0	0	0	0.67
Wiser Lake Creek	12	12	528.0	4.03	0.02	0	0	4.05
Schneider Ditch	8	8	371.0	2.91	0	0	0	2.91
Bertrand Creek	16	16	645.0	6.51	0.03	0	0	6.54
Fishtrap Creek*	14	12	427.0	4.32	0	6.55	0	10.87
Scott Ditch	13	13	617.5	6.08	0	0	0	6.08
Stickney Slough	10	9	206.0	2.00	0.01	0.03	0	2.04
Anderson Creek	8	4	106.1	1.061	0.08	1.10	0	2.241
Smith Creek	5	5	63.0	0.48	0.02	0	0	0.50
South Fork Nooksack River	13	7	215.0	1.99	50.07	0	2.75	54.81
Middle Fork Nooksack River	2	0	0	0	250.0	0.10	0	250.10
North Fork Nooksack River	22	3	105.5	1.06	1.75	0	8.02	10.83
Willey Lake	3	3	160.0	1.29	0.01	0	0	1.30
Unnamed Slough	2	2	110.0	1.10	0	0	0	1.10
Lake Fazon	4	4	130.0	1.23	0.01	0	0	1.24
Unnamed Brook	2	2	75.0	0.77	0.01	0	0	0.78
Germans Creek	2	1	26.0	0.26	0.025	0	0	0.285
Dakota Creek	12	11	245.0	2.57	0.04	0	0	2.61
California Creek	9	7	197.0	1.47	0.01	0	0	1.48
Unnamed to Salt Water	6	3	88.0	0.80	0.04	0.02	0.30	1.16
Terrell Creek	5	3	100.0	1.00	0	0	0	1.00
Lummi (Red) River	5	5	335.0	3.35	0	0	0	3.35
Silver Creek	19	12	307.0	2.82	0.155	0.046	0.005	3.026
Lummi Island	7	1	200.0	2.00	1.145	0.005	0.21	3.36
Sumas River	19	19	583.5	5.69	0	0	0	5.69
Saar Creek	2	0	0	0	0.03	0.97	0.52	1.52
Sumas Drainage Ditch	1	1	29.0	0.29	0	0	0	0.29
Johnson Creek	22	20	683.0	6.65	3.13	0	0	9.78
Kinney Creek	1	1	25.0	0.25	0	0	0	0.25
Breckenridge Creek	3	3	95.0	0.55	0	0	0	0.55
Swift Creek	1	1	40.0	0.40	0.01	0	0	0.41
Goodwin Creek	4	4	140.5	1.19	0.01	0	0	1.20
Judson Lake	3	3	150.0	1.50	0	0	0	1.50
Total*	325	261	9,067.6	88.311	311.68	13.861	12.495	426.347

*Duplication - therefore sum does not equal total

WATER APPROPRIATION

Compilation of records of the Division of Water Resources reveals that 733 active filings exist in the basin in the form of applications, permits, and certificates. Of this total, 325 surface-water filings are recorded for a total appropriation of 426.347 cubic feet per second and 448 ground-water filings exist for a total appropriation of 77,767 gallons per minute or, 172.82 cubic feet per second. Total quantities appropriated from surface-water sources from the various sub-basins in the area are tabulated by use in table 45. Also, the comparative amounts of surface water authorized for various uses in the basin is descriptively shown in figure 59.

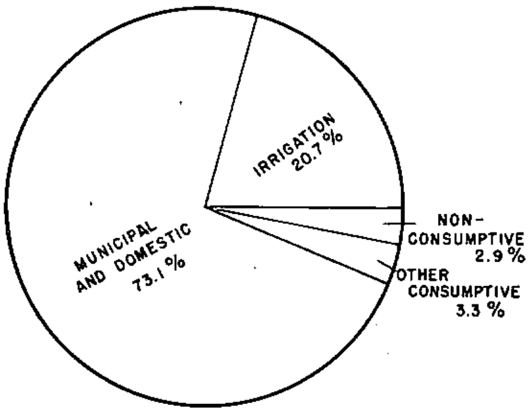


Figure 59. AUTHORIZED SURFACE WATER USE IN STUDY AREA.
426.347 cfs = 100%

Since the city Bellingham's authorized 300 second foot diversion has not been initiated to date, a more accurate portrayal of the present surface-water use is indicated by figure 60.

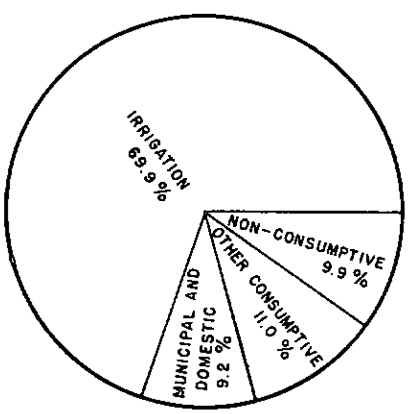


Figure 60. ACTUAL SURFACE WATER USE IN STUDY AREA.
126.347 cfs = 100%

Figures 61 and 62 show the actual charge against the Nooksack River and its tributaries above Lynden based on authorized water rights. Figure 61 is based on an average low flow of 955.26 cubic feet per second at the Lynden gage and shows the proportions of this low flow which have been appropriated. The figures take actual tributary flows into consideration; for example, the city of Bellingham could not utilize the full extent of its 250 cubic feet per second permit on the Middle Fork during low flows periods since this quantity would not be available.

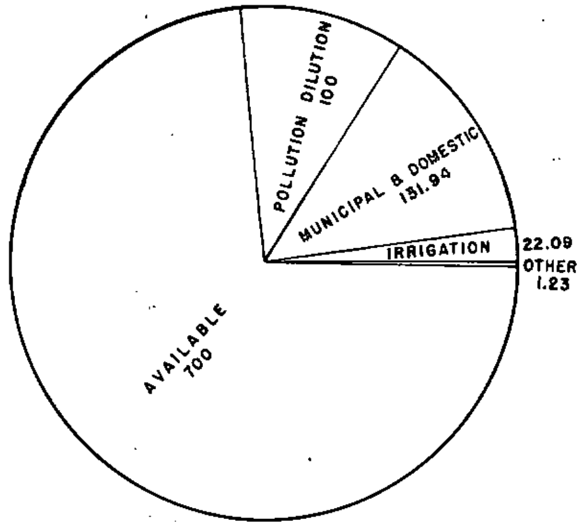


Figure 61. CURRENT WATER DEMANDS AND POTENTIAL AVAILABLE SUPPLY ON NOOKSACK RIVER, BASED ON MEAN LOW FLOW IN CUBIC FEET PER SECOND AT LYNDEN.

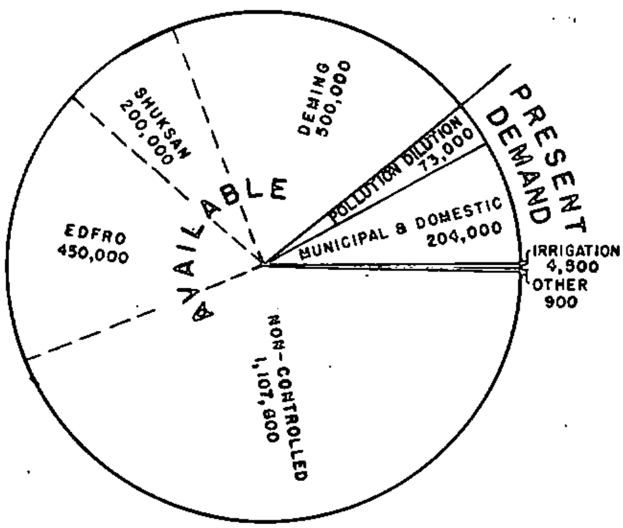


Figure 62. PRESENT DEMAND AND POTENTIAL STORAGE AT MAJOR RESERVOIR SITES STUDIED, BASED ON MEAN ANNUAL RUN-OFF IN ACRE-FEET AT LYNDEN.

Table 46. Community and Municipal Water Systems, Nooksack River Report Area, Based on Data Supplied by the State of Washington Department of Health and Whatcom County Health Department.

City or Water District	1959 Population Connected Population*	Year Operation Started Present Supply Present Treatment Plant	Ownership	No. of Services No. of meters	Sources of Supply
Acme	200 280	1945 --	Municipal	55 0	Jones Creek
Birch Bay	-- 2,400		Private	500 500	Blaine
Blaine	1,800 2,000	1929 1910	Municipal	670 670	6 artesian wells, 1 drilled well
Custer	350 300	1956 --	Municipal	80 80	2 wells
Delta Water Association	-- 310	1954 --	Municipal	102 102	Dug well
Deming	132 132	1906	Private	55 0	Springs
Everson	420 1,000	1936	Municipal	311 0	2 wells
Ferndale	1,405 1,500	1955 --	Municipal	700 600	5 wells
Glacier	100 100	 --	Private	35 0	Gallup Creek and 1 spring
Lynden	2,501 2,927	1910 1951	Municipal	1,144 1,050	Nooksack River
Meadowdale Water Association	-- 150	1958	Municipal	52 42	1 well
Meridian Water Association	-- 100	1954	Municipal	31 31	Dug well
Mt. Baker Water Association	-- 175	1955 --	Municipal	46 46	1 well
Neptune Beach Water Association	-- 100		Municipal	33 33	2 drilled wells
Nooksack	325 350	1955	Municipal	118 116	City of Sumas
Northwest Water Association	-- 275	1956	Municipal	70 70	2 wells
Old Settlers Water Association	-- 140	1956	Municipal	42 42	2 drilled wells
Point Roberts	-- 550	1937	Private	170 0	2 springs, 1 well
Skookumchuck Water Association	-- 210	1954	Municipal	74 74	Dug well
Sumas	628 1,270	-- --	Municipal	442 303	Springs

*Estimated population served by city or water district

Safe Yield: Surface Supply / Sub-surface Supply GPD	Treatment Plant Capacity / Average Daily Usage GPD	Treatment	Laboratory Control	Distribution Storage: Non-gravity / Gravity Gallons	Improvements Needed
600,000	--	None	None	--	Underground source, transmission, treatment
	15,000	--		15,000	
		None	None		
360,000	--	None	None	1,000,000	Transmission, treatment
640,000	250,000	--			
--	40,000	None	None	40,000	None
280,000					
--	--	None	None	100,000	--
80,000	50,000	--			
--	--	None	None	--	Surface source, distribution system, elevated storage
100,000	50,000			30,000	
--	--	None	None	--	Underground source
504,000	140,000			50,000	
--	--	None	None	--	Distribution system
3,300,000	450,000			565,000	
75,000	--	None	None	--	Underground source, treatment, distribution system, elevated storage
--				1,000	
5,000,000	3,000,000	Purification-alum, lime, chlorine gas, rapid gravity sand filters, slow mechanical mixing, open sedimentation basin	Complete	--	Pumping, ground storage
	653,000			300,000	
--	--	None	None	3,000	Elevated storage
--	--			--	
--	--	None	None	1,000	--
50,000	--			--	
--	--	None	None	--	None
90,000	11,000			36,000	
--	--	None	None	--	--
80,000	9,000			18,000	
--	--	None	None	--	None
--	31,000			100,000	
--	--	None	None	30,000	None
25,000	14,000			--	
--		None	None	750	
28,000				25,000	
116,000	--	None	None	15,000	Surface source, treatment, distribution system, elevated storage
72,000	--			--	
--	--	None	None	3,000	
430,000	42,000			--	
1,440,000	--	None	None	150,000	Surface source, treatment, distribution system
--	120,000			230,000	

Table 47. Acreage covered by Ground- and Surface-water Irrigation in the Nooksack River Report Area.

Area Basin	Ground Water	Surface Water	Total Irrigation
Main Nooksack River (Including Unnamed Slough, Unnamed Tributary, and Unnamed Brook)	636.00	1,201.5*	1,837.5*
Tenmile Creek (including Lake Fazon)	1,563.75	1,194.0	2,757.75
Wiser Lake Creek	856.50	528.0	1,384.50
Schneider Ditch (including Willey Lake)	346.00	531.0	877.00
Bertrand Creek	2,103.00	645.0	2,748.00
Fishtrap Creek	1,416.00	427.0*	1,843.00*
Scott Ditch	325.50	617.5	943.00
Stickney Slough	703.00	206.0	909.00
Anderson Creek	47.00	106.1	153.10
Smith Creek	149.17	63.0	212.17
South Fork Nooksack River	130.00	215.0	345.00
Middle Fork Nooksack River	0	0	0
North Fork Nooksack River	93.60	105.5	199.10
Germans Creek	0	26.0	26.00
Dakota Creek	500.06	245.0	745.06
California Creek	522.00	197.0	719.00
Unnamed to Salt Water	10.00	88.0	98.00
Terrell Creek	5.00	100.0	105.00
Lummi (Red) River	110.00	335.0	445.00
Silver Creek	174.00	307.0	481.00
Lummi Island	2.50	200.0	202.50
Sumas River (including Sumas Drainage Ditch and Saar, Kinney, Breckenridge, Swift, and Goodwin Creeks)	1,408.00	913.0	2,321.00
Johnson Creek	1,017.50	683.0	1,700.50
Judson (Boundary) Lake	190.00	150.0	340.00
SUB-TOTAL	12,308.58	9,067.6	
		GRAND TOTAL	21,376.18

* Duplication - therefore sum does not equal total.

In comparison, figure 62 is based on the total annual runoff at Lynden and shows the small amount (11.1 percent) of the total that actually is appropriated, including 73,000 acre-feet (2.9 percent) for estimated pollution dilution. Of the 2,540,000 acre-feet flowing past the Lynden gage annually, 282,400 acre-feet are demanded by present uses, including pollution dilution; 1,150,000 acre-feet could be stored at the three sites shown in figure 62, while 1,107,600 is classified as non-controlled. Because of the Nooksack River's streamflow characteristics, however, a major portion of this 1,107,600 acre-feet could be used through efficient control of the three storage sites.

As these figures show, the bulk of the appropriated water is for municipal water systems. Table 46 gives additional facts concerning these community and municipal water systems; figure 63 shows the areal extent of the report area served by these systems.

Irrigation is the next largest authorized use and the largest present use within the study area. Table 47 lists the acreage covered under existing ground-water and surface-water rights for each major sub-basin within the study area. This table does not necessarily correspond with table 45 as some of the smaller basins have been included in larger ones for simplicity in table 47.

There are other smaller uses in the study area that are discussed in more detail under the specific sub-basins. There are also uses such as recreation and fish propagation which must be considered even though water rights are not always issued for these purposes.

The Division of Water Resources recognizes and respects the needs of fish and game for the use of surface waters. Several aspects are considered: water rights for fish propagation, for specific use in fishways, and for stream benefits for the support of its fishery. The Departments of Fisheries and Game were consulted to appraise the fishery value of various streams within the study area and information was provided as to the portions of streams utilized by salmon for spawning purposes. These areas are shown on plate 9.

Although only the known spawning and migration areas are shown in red on plate 9, these streams also benefit fingerlings by providing rearing areas which have suitable food supplies. The species vary in their length of residence in fresh-water streams prior to migration to the sea. This residence may be from three months to a year in time. The Department of Fisheries and the Department of Game have requested that the eight streams or drainages listed in table 48 be closed to further consumptive water right appropriations in the interest of protection to the fishery of these streams. This closure does not apply to domestic or stock water diversions. Occasionally, streams closed for the purposes stated above, may be reappraised and reopened to appropriation.

Table 48. Streams Closed to Further Appropriation.

NOOKSACK RIVER BASIN Bertrand Creek Drainage Fishtrap Creek Drainage Kamm Ditch--tributary Stickney Slough Wiser Lake Creek Drainage
COASTAL AREA BASINS California Creek Drainage Dakota Creek Drainage
SUMAS RIVER BASIN Clearbrook Creek--tributary Johnson Creek Elkins Creek--tributary Breckenridge Creek

Appropriation from these streams may be permitted with certain low flow provisions and diversions will be restricted to periods when the flow of the streams exceed those established flows. An additional four streams are subjected to low flow restrictions in the specific locations outlined in table 49. Streams not listed in either tables 48 or 49 are still subject to appropriation.

Table 49. Streams Available for Appropriation, Subject to Designated Low-flow Restrictions.

NOOKSACK RIVER BASIN Deer Creek - minimum flow--1.5 cfs directly above its confluence with Tenmile Creek. Fourmile Creek - minimum flow--1.0 cfs from stream crossing at north section line of Sec. 17, Twp. 39 N., Rge. 3 E.W.M., upstream to Green Lake. minimum flow--1.5 cfs from above crossing, downstream to its confluence with Tenmile Creek. Tenmile Creek - minimum flow--4.5 cfs directly above its confluence with Fourmile Creek. minimum flow--6.0 cfs from Fourmile Creek, downstream to Deer Creek. minimum flow--7.5 cfs from Deer Creek to Nooksack River.
SUMAS RIVER BASIN Breckenridge Creek - minimum flow--2.0 cfs June 1 to October 1 at center line of Sec. 24, Twp. 40 N., Rge. 4 E. minimum flow--3.0 cfs October 1 to June 1 at center line of Sec. 24, Twp. 40 N., Rge. 4 E.

The considerations of these departments are to utilize to the full capacity the available water of these streams for the full potential fishery value. This is tendered in consideration of the known existing uses of water and with full appreciation of all benefits to be derived from these waters.

The following paragraphs deal with present water use in the specific sub-basins within the report area. These discussions are based on tables 45 and 47 and appendices A and B are intended to present only a brief resume' of use by basin. More detailed facts and figures relating to low flows do not come under the scope of present use and have been discussed and tabulated in the section of this report dealing with streamflow analyses.

MAIN NOOKSACK RIVER

As figure 61 shows, there is an abundance of water available for appropriation in the Nooksack River since the main stem, which extends from the junction of the North and Middle Forks to its mouth at Marietta, has only 19.425 cubic feet per second appropriated. The two largest rights are for 5.00 cubic feet per second each, one being for manufacturing by General Petroleum Company and the other for municipal use by the city of Lynden. There is an additional domestic right for 0.01 of a cubic foot per second from the Nooksack River, but the balance of the 9.415 cubic feet per second that has been appropriated is used for the irrigation of 964.5 acres. There are 636.0 acres irrigated from ground-water sources in approximately the same area.

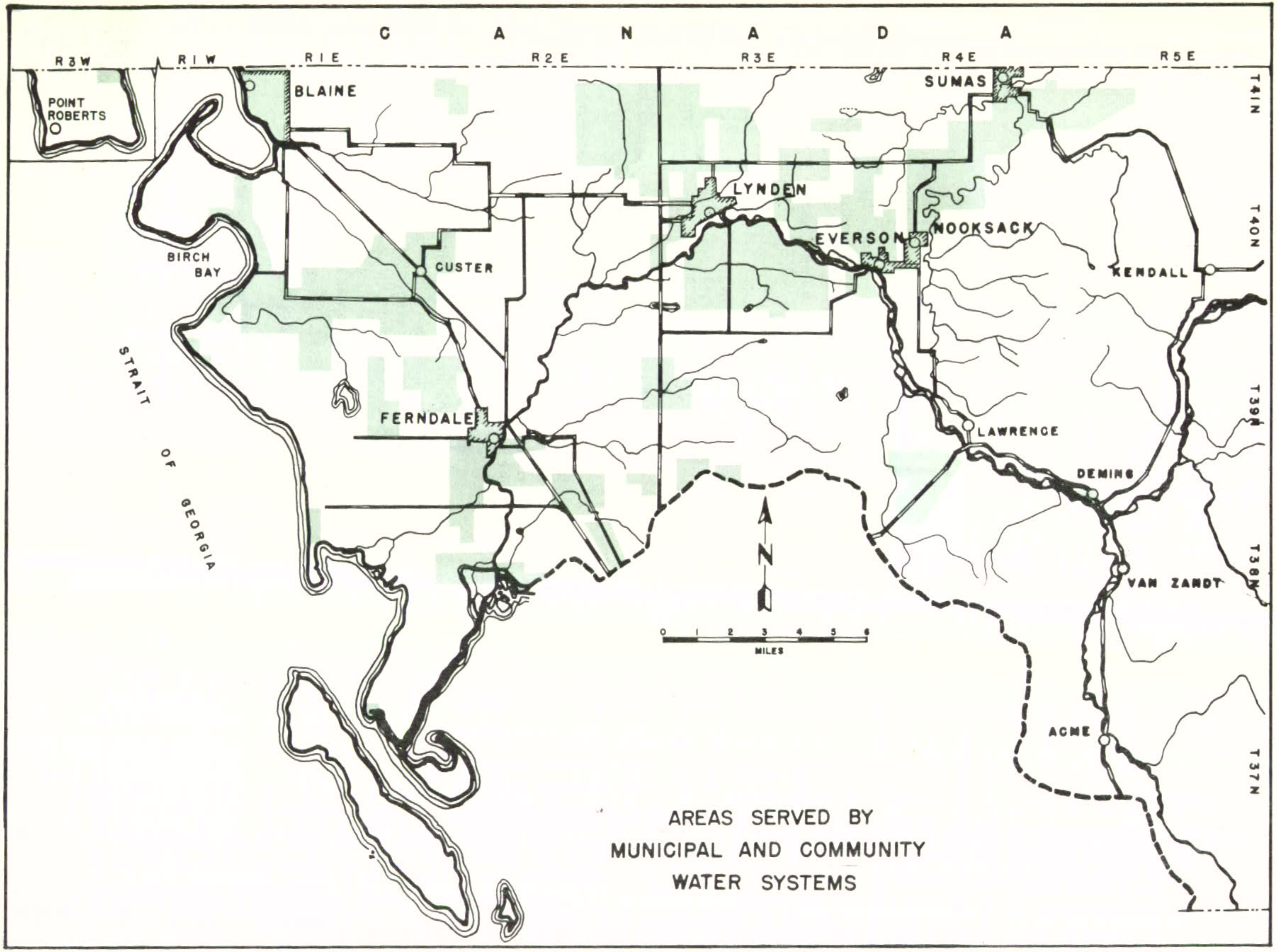

C A N A D A
R3W
R1W
R1E
R2E
R3E
R4E
R5E
T41N
T40N
T39N
T38N
T37N
POINT ROBERTS
BLAINE
BIRCH BAY
CUSTER
LYNDEN
SUMAS
EVERSON
NOOKSACK
KENDALL
FERNDALE
LAWRENCE
DEMING
VAN ZANDT
ACME
STRAIT OF GEORGIA
N
0 1 2 3 4 5 6
MILES
AREAS SERVED BY
MUNICIPAL AND COMMUNITY
WATER SYSTEMS

Figure 63.

TENMILE CREEK

This relatively small drainage basin of only 34 square miles has the largest amount of irrigation by surface water for any single basin in the study area. There have been 12.605 cubic feet per second appropriated here for the irrigation of 1,064.0 acres, while an additional 1,563.75 acres are irrigated from ground water. Seven of the 45 rights in this basin recognize a total domestic diversion of 0.065 of a cubic foot per second, and an additional 0.04 of a cubic foot per second is listed as other consumptive diversions for domestic garden irrigation. A non-consumptive diversion estimated at 0.69 of a cubic foot per second is used for fish propagation near Barrett Lake.

Due to the large number of diversions in this basin, extensive low-flow restrictions have been placed on the appropriation of additional water. These restrictions maintain streamflows for fish and game propagation and are outlined in detail in table 49. From a pactical viewpoint, these restrictions prevent additional diversion during low-flow periods except during extremely wet years. Water is, however, still available during the early portions of the irrigation season.

There are at least four possible storage sites in the Tenmile Creek basin which could augment the flow during low-flow periods. Development of the Barrett Lake, Deer Creek, Green Lake, and Tenmile Creek sites could provide water for the irrigation of much additional land. Table 33 on page 109 and plate 8 provide more detailed information concerning these sites.

UNNAMED TRIBUTARY OF THE NOOKSACK RIVER

This small unnamed stream, north of Tenmile Creek, is listed separately because the single water right from this stream does not affect any of the drainages other than the Nooksack itself. Very little is known about this drainage, and the one water right amounts to 0.67 of a cubic foot per second for the irrigation of 70 acres. All irrigation by ground water in this basin is included in the total for the Main Nooksack River.

WISER LAKE CREEK

This small stream and lake are heavily appropriated and for this reason is included in table 48 as being closed to further appropriation. The authorized diversion of 4.03 cubic feet per second is for the irrigation of 528 acres of land, while 856.5 acres is allowed under ground-water rights. An additional 0.02 of a cubic foot per second is specified for domestic uses which likely are garden and lawn irrigation.

SCHNEIDER DITCH

This small, heavily appropriated drainage ditch is used exclusively for irrigation purposes with 2.91 cubic feet per second being allowed for the irrigation of 371 acres. Ground-water irrigation here amounts to 346 acres which includes the Willey Lake drainage. Available water is dependent on ground-water discharge, but it appears that there is little water for appropriation during the low-flow period.

BERTRAND CREEK

The sixteen filings in the Bertrand Creek drainage are all for irrigation, although domestic supply is mentioned in three instances for a total of 0.03 of a cubic foot per second. The irrigation rights total 6.51 cubic feet per second for the irrigation of 645 acres. Ground water provides irrigation for an impressive 2,103 acres which makes this the largest ground-water irrigation basin in the study area.

Bertrand Creek has been closed for further appropriation due to its intrinsic value for recreation and fish propagation. Occasional rights are granted on intermittent tributaries, however, where such diversion will not affect the low flow of Bertrand Creek.

Development of the Markworth Road and Upper Bertrand storage sites could materially aid the flow in the respective tributaries on which they are located as well as providing additional flow in Bertrand Creek proper.

FISHTRAP CREEK

This stream roughly parallels Bertrand Creek, and like Bertrand Creek, is closed to further appropriation. Of the total appropriated quantity of 10.87 cubic feet per second, 4.32 cubic feet per second are authorized for the irrigation of 427 acres of land. This compares with 1,416 acres permitted under ground-water rights and exemplifies the availability of ground water in this and the Bertrand Creek area.

There are two large diversions in the basin. The older, from Fishtrap Creek, is the Whatcom County Dairymens' Association right for 1.55 cubic feet per second for fire protection and manufacturing. The Double Ditch Water Association has the other large right, 5.0 cubic feet per second from the Double Ditches to be used for domestic, stock, and garden irrigation. This area is now included in the Delta Water Association, so it is doubtful if more than a small part of this 5.0 cubic feet per second right is actually being diverted.

SCOTT DITCH

This drainage lies across the Nooksack River from Fishtrap Creek and insofar as surface water is concerned is used exclusively for irrigation. The flow is largely appropriated with 6.08 cubic feet per second being the authorized diversion for the irrigation of 617.5 acres. An additional 325.5 acres are covered under ground-water rights.

STICKNEY SLOUGH

This is a small basin with a relatively small amount of water being appropriated. Only 2.04 cubic feet per second have been appropriated with 2.00 cubic feet per second, the largest use being for the irrigation of 206 acres of land. Irrigation by ground water amounts to 703 acres and again reflects the excellent aquifers beneath the Lynden area. Domestic supply accounts for a diversion of 0.01 of a cubic foot per second while stock-water requirements account for the balance for 0.03 of a cubic foot per second.

Although the Kamm Ditch portion of this drainage is closed to further appropriation (tab. 48) the entire lower portion of the basin still appears to have an abundant supply of available water.

ANDERSON CREEK

As discussed in the streamflow section, the flows in this drainage are not as well sustained as those previously mentioned. Therefore, storage must be considered for any large use during low-flow periods. The two large potential storages here (tab. 33) could conserve about 4,500 acre-feet for use during the critical low-flow period. Plate 8 shows the location of these two sites, which are called Anderson Creek and Kelly Road reservoir sites.

With the limited surface water supply available, only 1.061 cubic feet per second have been appropriated for the irrigation of 106.1 acres. Irrigation by ground water is also very limited with only 47 acres being covered by present rights. Domestic supplies account for 0.08 of a cubic foot per second while a surprisingly large quantity of 1.10 cubic feet per second is claimed by the Glen Echo Coal Company for mining and power purposes. At present this organization has ceased operations, but use of the property has been transferred to the Whatcom-Skagit Rendering Company. Information from the Pollution Control Commission indicates that the rendering company is presently using up to 10,000 gallons per day, but this at most amounts to about 0.05 of a cubic foot per second and would have only a minor effect on the stream's total flow.

SMITH CREEK

This stream, like Anderson Creek, exhibits extremely variable flows; however, there are no storage sites known here to augment the low flow. Presently authorized surface-water use is very small with only 0.50 of a cubic foot per second being appropriated to date. Of this, 0.48 of a cubic foot per second is for the irrigation of 63 acres, while the remaining 0.02 of a cubic foot per second is for domestic supplies. Ground-water use, similarly, is quite small with only 149.17 acres authorized for irrigation.

SOUTH FORK NOOKSACK RIVER

This large stream and its tributaries are relatively untapped, insofar as surface-water use is concerned. The authorized diversions total 54.81 cubic feet per second, but 50 cubic feet per second of this is for municipal use by the city of Bellingham and is not yet being used. Furthermore, Bellingham is presently developing the Middle Fork and it is unlikely that the South Fork will beutilized for some time, if ever, under this permit. Of the remaining 4.81 cubic feet per second, 2.75 cubic feet per second are for non-consumptive use in millponds while 0.07 of a cubic foot per second is for domestic and community domestic supplies. Only 1.99 cubic feet per second have been appropriated for irrigation with 215 acres covered under seven rights. The extent of the irrigation by ground water in this entire basin is only 130 acres.

The development of any of the major reservoir sites on the South Fork as discussed in the reservoir section of this report would materially change the amount of water available from that source.

MIDDLE FORK NOOKSACK RIVER

Although 250.10 cubic feet per second have been authorized for diversion from the Middle Fork, present surface-water use is negligible since Bellingham has not yet completed its diversion dam and pipeline designed to take the 250 cubic feet per second authorized by permit, while the Chicago, Milwaukee, St. Paul and Pacific Railroad's right of 0.10 of a cubic foot per second from Canyon Creek is believed abandoned. There are no recorded rights for either ground or surface-water irrigation in the basin.

NORTH FORK NOOKSACK RIVER

This fork has the largest amount of present use of the three forks of the Nooksack River. Although only 93.6 acres are covered by ground-water rights, 22 valid surface-water filings are on record for a total appropriation of 10.83 cubic feet per second. Three of these rights are for irrigation with 1.06 cubic feet per second provided for 105.5 acres. Domestic and community domestic uses amount to 1.75 cubic feet per second with the largest right belonging to the Baptist General Convention for 1.00 cubic foot per second from an unnamed tributary of the North Fork.

A total of 8.02 cubic feet per second is recorded for non-consumptive purposes, the largest being 3.00 cubic feet per second for fish propagation from the North Fork near Kendall. Other large non-consumptive uses include 2.00 cubic feet per second from an unnamed stream for power for the State Department of Highways, and 0.80 of a cubic foot per second from Galena Creek by the Mt. Baker Ski Club for hydro-electric power. Private individuals hold rights to 2.08 cubic feet per second for power production in the Maple Creek drainage. It is quite doubtful whether many of these power rights are utilized at present. It is known that the Ski Club's diversion is inactive; it is entirely possible that the others are not used.

The largest use in the basin is that of Puget Sound Power and Light Company at its Nooksack Power Plant. This diversion is not recorded in the water-right tabulations as the company claims a vested right to the use of 328 cubic feet per second, of which 35 percent is presently developed.

Development of any of the major reservoir sites in the basin would materially affect the flow and make additional water available. There is also one smaller storage site on Maple Creek; however, this site would flood all the agricultural land in the area and there is no known use for this water that would make the project economically feasible.

WILLEY LAKE, UNNAMED SLOUGH, LAKE FAZON, UNNAMED BROOK

These small drainages are all included in larger drainages for purposes of the ground-water irrigation tabulation in table 47. All are small in area, but combined, they account for diversions amounting to 4.42 cubic feet per second with 4.39 cubic feet per second for irrigation and 0.03 of a cubic foot per second for domestic use.

GERMANS CREEK

This small stream disappears in gravelly soil in the Columbia valley. Despite the small size of its drainage, 0.285 of a cubic foot per second has been appropriated for the irrigation of 26 acres and for domestic purposes. There is no recorded ground-water irrigation in this drainage basin.

DAKOTA CREEK

This is one of the larger sub-basins in the study area, but the diversion of only 2.61 cubic feet per second is authorized. Of this 2.61 cubic feet per second, 0.04 of a cubic foot per second is for domestic use, while 2.57 second feet are used for the irrigation of 245 acres. Ground-water irrigation amounts to 500.06 acres.

The small total amount of diversions is partially due to the basin being closed to further appropriation because of the importance of the fishery resource.

Development of the one small storage site on Dakota Creek would not aid materially in flow stabilization. The development's primary purpose would be to reclaim the tidal zone of Dakota Creek by converting it into a fresh-water lake. A certain amount of water would be available for irrigation or other use, but the primary value would be aesthetic.

CALIFORNIA CREEK

This basin is similar to the Dakota Creek drainage in that it is also closed to further appropriation and has a storage site similar to that on Dakota Creek. The drainage is somewhat smaller, and only 1.48 cubic feet per second have been appropriated here. The irrigation of 197 acres accounts for the use of 1.47 cubic feet per second, the remaining 0.01 of a cubic foot per second is for domestic use. There are also 522 acres of authorized ground-water irrigation here.

UNNAMED TO SALT WATER

Several small streams and ditches are for simplicity combined under this heading. Total authorized irrigation in these drainages amounts to 10 acres from ground-water sources and 88 acres with 0.80 of a cubic foot per second from surface water.

Total surface-water diversions amount to 1.16 second feet. In addition to 0.80 of a cubic foot per second for irrigation, other consumptive uses amount to 0.06 of a cubic foot per second with 0.04 of a cubic foot per second being used for domestic supply and 0.02 of a cubic foot per second for stock-water purposes. The 0.03 of a cubic foot per second for non-consumptive purposes is from an unnamed spring and is used for fish propagation.

The amount of water still available for appropriation has not been determined and would require careful field investigations in each case.

TERRELL CREEK

This stream goes dry during the summer months so additional summer use is dependent upon storage. Other than private farm ponds, the only apparent storage site would be increased storage in Lake Terrell. The State Department of Game now holds a right to store 5,600 acre-feet here which is used for fish and wildlife propagation. Raising the outlet structure a few feet could increase the capacity 2,000 to 3,000 acre-feet which through controlled discharge could provide water for the irrigation of an additional 1,000 acres or more.

The total extent of ground-water irrigation in this drainage is only 5 acres which exemplifies the extreme ground-water shortage here. Total surface-water diversions amount to 1.00 cubic foot per second for the irrigation of 100 acres. Authorized storage amounts to 5,644 acre-feet with 5,600 of this being the State Department of Game's project and the balance of 44 acre-feet for two private reservoirs used primarily for irrigation.

LUMMI (RED) RIVER

Total irrigation in this drainage is 110 acres from ground water and 335 acres from surface sources. A total of 3.35 cubic feet per second is diverted with all of it used for irrigation. Of this amount about 2.50 second feet are from the Lummi River itself. As the Lummi River is a controlled distributary of the Nooksack River, much additional acreage could be irrigated as the need arises.

SILVER CREEK

This small stream has 19 valid filings and is one of the most heavily appropriated streams in the study area with a total of 3.026 cubic feet per second of authorized diversions.

Twelve of these filings are for irrigation purposes with 2.82 cubic feet per second and 307 acres covered under this use. This compares with 174 acres of authorized ground-water irrigation. Domestic and group domestic use amounts to 0.155 of a second foot while 0.046 of a cubic foot per second for stock water completes the consumptive use. A fish propagation use of 0.005 of a cubic foot per second is the only non-consumptive use in this basin.

Although this creek is still subject to further appropriation, there is little if any excess water during low-flow periods. No storage sites have been noted in this drainage.

LUMMI ISLAND

Only 2.5 acres of irrigation are authorized by ground-water rights here while surface-water irrigation encompasses 200 acres. This 200 acres is all irrigated from the F. Baker diversion dam project, which also produces power for emergency domestic use as well as a domestic water supply. Total surface water use on the island amounts to 3.36 cubic feet per second plus one right currently being processed. Irrigation accounts for 2.00 second feet, domestic and community domestic 1.145 cubic feet per second, and stock 0.005 of a cubic foot per second, and a non-consumptive power use of 0.21 of a cubic foot per second. The majority of the large amount for community domestic is presently undeveloped, pending subdivision development on the island.

No large storage sites are known to exist on the Island, although several smaller sites such as the F. Baker diversion site may salvage enough water for limited projects.

SUMAS RIVER

Table 47 combines all the irrigation in the Sumas Drainage Ditch and Saar, Kinney, Breckenridge, Swift, and Goodwin Creeks in the Sumas River drainage.

Ground-water irrigation amounts to 1,408 acres as compared with 913 acres from surface-water sources. Only 5.69 cubic feet per second, used to irrigate 583.5 acres, are from the Sumas River itself, however. There is no other surface water use from the Sumas River. There appears to be ample water still available from the Sumas even though there are no apparent storage sites to augment low flows here.

The Sumas River and tributary streams are not indicated as spawning streams on plate 9, as fish patterns of use are extremely sporadic and irregular due to the international complexities of fish protection for migratory fish desiring to return to this region. This is due in part to the unnatural streamflow regulation discussed in the streamflow analysis and evaluation section of this report.

SAAR CREEK

The total appropriated quantity here amounts to 1.52 cubic feet per second, none of which is from Saar Creek itself. This breaks down to 0.03 of a cubic foot per second for domestic, 0.97 of a cubic foot per second for dairy operation, plus non-consumptive uses of 0.02 of a cubic foot per second for fish propagation and 0.50 of a second foot for power. It is not known how much of this is actually being used at present although there still appears to be ample water available in these tributaries.

Saar Creek would require development of the Saar Creek minor storage site (tab. 33) for any effective water utilization program, especially during the low-flow period. This site would also provide flood protection for the lower basin.

SUMAS DRAINAGE DITCH

This ditch has but one water right listed. It amounts to 0.29 of a cubic foot per second for the irrigation of 29 acres. There is no information as to the present availability of water here.

JOHNSON CREEK

This drainage basin is the largest tributary of the Sumas River and has a total of 1,700.5 acres of authorized irrigation, 1,017.5 of which is from ground-water sources.

The surface water irrigation amounts to 683 acres using 6.65 cubic feet per second. An additional large use in this basin is 3.13 cubic feet per second for domestic and municipal supplies with 3.12 cubic feet per second of this derived from springs for use by the city of Sumas.

Although Clearbrook Creek, a small tributary of Johnson Creek, is closed to further appropriation, there still appears to be sufficient water available for future diversions in the remainder of the drainage.

KINNEY CREEK

This small tributary of the Sumas River has only one water right which amounts to 0.25 of a cubic foot per second for the irrigation of 25 acres. The amount of water still available here, if any, is not known at present.

BRECKENRIDGE CREEK

Breckenridge Creek has three authorized diversions, all of which are for irrigation. A total of 0.55 of a cubic foot per second has been appropriated for the irrigation of 95 acres. Breckenridge Creek is subject to the low-flow restrictions listed in table 49 because of its intrinsic value as a fishery resource. Elkins Creek, a small tributary of Breckenridge Creek, is completely closed to further appropriation for the same reason.

SWIFT CREEK

The one water right from this stream provides 0.40 of a cubic foot per second for the irrigation of 40 acres plus an additional domestic use of 0.01 of a cubic foot per second. Despite this limited use, there does not appear to be much water available for appropriation during the low flow period, although runoff waters are plentiful.

GOODWIN CREEK

This small drainage has five valid filings which total 1.20 cubic feet per second. They provide 1.19 cubic feet per second for the irrigation of 140.5 acres and 0.01 of a cubic foot per second for domestic use. Although this is a heavy appropriation for such a small stream, considerable water still appears to be available.

JUDSON LAKE

This drainage includes irrigation rights for 190 acres from ground-water sources and 150 acres using 1.50 cubic feet per second from the lake drainage itself. Abundant water for anticipated needs is still available here.

SUMMARY

CONCLUSIONS

It has been concluded from this study that the quantity and quality of naturally occurring waters in the Nooksack River basin are adequate to meet the needs of the area for many years to come. Actually the present low-flow demand against the Nooksack River proper, as indicated by water rights, amounts to 255.26 cubic feet per second or 26.7 percent of the mean annual low flow of the river as gaged at Lynden. This demand represents only about 10 percent of the total average annual runoff of 2,540,000 acre-feet gaged at Lynden.

In comparing the climate, geology, and hydrology of the Nooksack River basin to other regions, it is evident that here nature has provided an unusual setting suitable for the production of large quantities of water of excellent quality. These complex, integrated natural phenomena have resulted in a river basin containing two distinct climatic regions: the heavily populated lowland area of the Whatcom Basin which is adequately instrumented to define its climatology, and the less accessible mountainous region of the Eastern Upland which produces much of the area's water supply, but which is essentially devoid of hydro-climatic data. Meteorology in this mountainous region is characterized by an extreme variability with altitude and exposure.

One of the obvious shortcomings is the inability of the present network of precipitation stations to define the aerial distribution of precipitation. Over the Nooksack River basin annual precipitation ranges from 30 to over 200 inches, and to sample this distribution even in 10-inch increments would require a minimum of 17 measuring points within the basin. At the present time, sampling density is sufficient in the elevation area from sea level to 1,000 feet, while in the area above 1,000 feet, which receives the heaviest amounts of precipitation, sampling stations are entirely inadequate.

Approximately 85 percent of the precipitation and 60 percent of the total runoff from the Nooksack River basin occurs during the seven water-surplus months, October through April, which are corresponding periods of low demand. It then becomes evident that upstream storage in artificial reservoirs will be required to bring flow characteristics more in line with periods of demand.

Ground-water resources in the Whatcom Basin part of the report area and in the lower river valleys of the three major forks of the Nooksack River within the Eastern Uplands are adequate to meet those areas' requirements where water supplies are not obtained from the Nooksack River and other surface-water supplies.

Some small areas within the Whatcom Basin, principally the till-capped uplands around the periphery of the basin, are deficient in ground water. Limited areas also exist within the basin where the high iron content of the water severely limits its usability for household and some industrial supplies.

Recessional outwash sand and gravel associated with Vashon glaciation and river-laid sand and gravel contiguous to the Nooksack River are the major producers of ground water. However, in some areas wells extending beneath the Vashon till have obtained moderate amounts of water of good quality from advance outwash materials or other unconsolidated sand and gravel formations beneath the Vashon till.

The Tertiary sedimentary and pre-Tertiary metamorphic rocks restricted almost entirely to the Eastern Upland area are capable of producing only small amounts of ground water and quite often where production is obtained from those rocks, the quality is poor. Oil test wells in the Whatcom Basin which encountered Tertiary rocks of the Chuckanut formation beneath the glacial drift produced connate water or water otherwise extremely high in chloride.

Hydrographs of observation wells within the Whatcom Basin have shown no trend suggesting that annual withdrawals of ground water are exceeding natural recharge. These hydrographs together with an evaluation of pump test data studied during the investigation have led to the conclusion that much additional ground water may be developed from the major areas of production with assurance that water withdrawn will be replaced annually during the recharge period.

It can be concluded from this inventory and analysis that it is not possible to make an accurate and complete quantitative water-resource evaluation of the Nooksack basin from basic data in existence at this time. At present there appears to be no immediate need for large scale water-resource development in this area, but with an inevitable increase in future use, the time will come when it will become necessary to utilize all available water in the most efficient manner possible. In preparing for this eventuality it seems logical to start by studying the problem as soon as possible. Before such a study can be undertaken, however, accurate knowledge of the area's water budget must first be known and this information can be obtained only by an intensive and comprehensive program of basic data collection.

One means of gathering the various types of hydrologic data is to proceed as in the past by slowly augmenting the state-wide network with a few scattered instrumentation stations each year. In this procedure, however, stations are usually established where local needs demand information and less consideration is given to the station's location from the standpoint of its overall value in water-resource analysis. In the past this program has maintained a number of stations with short term or discontinuous periods of record which do not coincide in time with other data-gathering stations in the area. As a result it is difficult to draw conclusions from these data with any reasonable assurance of accuracy.

A second method would be to saturate the basin with data-collecting stations for a period of not less than 3 years. At the conclusion of the observation period, data from each of the stations would be thoroughly evaluated and those which produce the best data would be retained as permanent stations and the rest removed for installation in other basins. This latter program, though extremely costly, would furnish the data required for a thorough and accurate quantitative evaluation of the water resources of the study area.

The chemical quality of the ground waters of the Nooksack River basin ranges from excellent to very poor. In most areas of the Whatcom Basin, the ground water is good to excellent with a few isolated areas of poor quality water due to high iron content. On the basis of available analysis, shallow wells appear to produce water of better quality than deeper wells with the exception of the iron-rich areas around Everson, Deming, Lynden and in the Sumas River lowland.

The waters of the Nooksack River and adjacent streams are of excellent quality throughout the basin. They are soft, low in mineralization, relatively free of pollution, and suitable for municipal, agricultural, recreational, and most industrial uses. Analysis available at the time of the study disclosed the iron content of the Nooksack River water to increase progressively downstream. This moderate quantity of iron in the lower reaches of the river, together with suspended sediment load, are the most objectionable characteristics found in Nooksack River water.

There is considerable undeveloped hydro-electric power, flood control and water-storage capacities in the reservoir sites studied during the Nooksack River investigation. Capacities of the four major utilization areas studied are as follows:

North Fork -	24,500 KW of firm power, 200,000 acre-feet of storage.
South Fork -	24,200 KW of firm power, 450,000 acre-feet of storage.
Maple Falls -	8,900 KW of firm power, usable storage negligible.
Deming -	13,200 KW of firm power, 500,000 acre-feet of storage.

Complete development of these major sites will be dependent upon multiple-use programs since the cost of development for power purposes, water storage or flood control alone makes development economically unfeasible.

There are a number of minor dam and reservoir sites within the study area which were not studied in detail nor was their feasibility determined. Development of these minor storage sites by communities or water-use groups may provide a solution for water-short areas in some of the smaller sub-basins.

A water-use survey of the basin has shown that approximately 700 cubic feet per second of water is available for appropriation from the main stem of the Nooksack River. This figure is based upon average annual low flow records obtained at the Lynden gage site. The natural low flow ofthe Middle Fork of the Nooksack River has been appropriated by the City of Bellinghamto satisfy its municipal demand. Further appropriation from the Middle Fork during the summer months would require upstream storage.

Water is still available for appropriation from the North and South Forks of the Nooksack River as well as most of the tributaries thereto.

Some of the smaller tributaries of the main stem of the Nooksack River, as well as some of the non-tributary streams in the study area, have been heavily appropriated or closed to further appropriation. Water supplies, for further development of these areas deficient in surface water, will have to come from ground water supplies or development of artificial storage at some of the smaller reservoir sites.

A search of records at the Whatcom County Auditor's office has shown that there are a few vested claims to use of water (established prior to the State Water Code) from the Nooksack River and some of the related streams within the study area; however, a cost-benefit evaluation suggests that an adjudication of these rights is not warrented at this time.

RECOMMENDATIONS

With the publication of this report, "Water Resources of the Nooksack River Basin and Certain Adjacent Streams", the responsibility of the Division of Water Resources in matters pertaining to administration and planning for water resource development within the study area does not end. The completion of the inventory terminates one phase of a water resources program whichshould be followed by planning and culminating with actual development of projects within the basin. Conclusions drawn from this investigation have shown that, although the area is endowed with an extremely large water resource, there still remains much additional work to be done if the people residing in the area are to realize the full benefit of the maximum potential of this valuable resource. To assist those who will be charged with the responsibility of planning and developing the area's water resources, the authors offer the following recommendations:

1. It is recommended that a water resource committee be created which would be representative of all interests concerned with the proper conservation, development and ultimate uses of the available water resource in the study area.

Such a committee would serve to represent the local people and would meet with county, state and federal planning groups in the preparation of a program for orderly and complete development of the area's water resources.

One of the first programs for the water resources committee should be to review the Nooksack River inventory report and, on the basis of the data included therein, develop a water resource plan for the basin. The plan should consider such problems as: Sequence of development of water utilization and storage areas on the three major forks of the Nooksack River; ways in which present supplies could be more beneficially used; the need for a comprehensive water distribution system to serve those areas where adequate local supplies are lacking; the need for land-use zoning to assure that interim development of lands to be inundated will not make utilization of storage sites economically unfeasible.

2. It has been concluded from the study that the hydroclimatic network in the Nooksack River basin is inadequate to accurately define and evaluate all the components contributing to runoff. Also, the present demand on the water resources of the area do not require other than a casual knowledge of runoff furnished by stream-flow measurements. Therefore, piecemeal addition of hydroclimatic stations are not economically justified and therefore are not recommended for the Nooksack River basin.

At some future date when a more complete knowledge of all factors contributing to runoff becomes necessary, it is strongly recommended that consideration be given for establishing an instrumentation saturation study for the Nooksack River basin. The proposed saturation study is discussed in more detail in an addendum to the recommendations.

3. As the foregoing report discloses, the Whatcom Basin portion of the Nooksack River watershed, with only a few exceptions, possesses a ground water supply that is adequate to fulfill its needs for the present and foreseeable

future. However, certain characteristics of ground-water occurrence and movement here should be studied in greater detail so that answers may be forthcoming to questions that may arise from future problems relating to both ground and surface waters and their inter-relationship within the report area. It is thereforerecommended that the following aspects of ground water hydrology be studied further:

A. The rate and direction of ground-water movement, particularly with regard to the apparently large supply of ground-water inflow to the Nooksack River below the Deming gage, should be studied to determine how much ground water is contributed from within the report area itself, as compared to the quantity that may move southward from ground-water reservoirs located north of the Canadian border.

B. The ground-water potential of the wide lower valley bottoms of the three main Nooksack tributaries should be studied. Although much of the farming here depends, at present, on direct precipitation rather than irrigation from wells, it would be helpful to check into the characteristics of the local ground-water bodies by a program of drilling deep test wells.

C. The relationship between ground water and surface water should be studied to determine the possible contaminating effects that each source may have upon the other.

D. In order to determine more widely the annual and long-time fluctuation of the water table, it is recommended that a network of observation wells be established throughout the report area, using automatically operating and continuously-recording instruments.

4. As indicated by the streamflow analysis, basic streamflow data is lacking on many streams in the report area and before a more comprehensive water-budget evaluation can be made it would be necessary to greatly enlarge the existing stream-gage network. This is not possible under the present program of data collection, but much of the missing information could be obtained by installing a few additional stream gages at certain critical locations. It is therefor recommended that the following gaging sites be given top priority when considering expansions of the present stream-gaging network:

A. Nooksack River at Ferndale

A gage should be installed here to measure the total flow of the Nooksack River and essentially all of its tributaries. This location seems most logical for this purpose because only a negligible amount of direct runoff enters the main stem below Ferndale. A gage located farther downstream would be affected by tidal action. Records obtained at this site in conjunction with those obtained at Lynden and Deming would also provide information on ground-water inflow to the Nooksack River.

B. Nooksack River at Deming

If at all possible, this station should be reestablished as it is situated in a unique natural location to measure practically all of the runoff from the mountainous portion of the watershed. This station also provides necessary information for studying ground-water contribution in the Whatcom Basin.
From a hydrologic standpoint, streamflow data collected on the Nooksack River at Lynden is less valuable than data obtained at either Ferndale or Deming. It is therefor suggested that the Lynden gage be moved to either the Ferndale or Deming site, if sufficient funds are not available to install and maintain gages at the three sites.

C. Tenmile Creek above Barrett Lake

The Tenmile Creek system drains a major portion of the Whatcom Basin and its waters are the most heavily appropriated. Streamflow data on this stream would therefor provide much needed information for proper regulation of diversions and would provide an accurate measure of usable water produced by this part of the report area.

D. Sumas River at Sumas

The existing two years of streamflow record on the Sumas River are inadequate to accurately establish its runoff characteristics and, because this stream system occupies more than 7 per cent of the area studied and its waters are highly appropriated, additional streamflow data would be of great value.

E. Glacier Creek above Falls Creek

In the past, research projects in glaciology have been conducted on the Coleman Glacier and the installation of a stream gage at this location would help to provide much needed information in determining the role played by glaciers in the hydrologic cycle.

5. Recommended water-sampling program

A. The basin-wide observation well program should be expanded to more adequately show amounts of water in storage and/or water quality changes. Well-defined sampling programs should accompany water level measurements to ascertain those areas producing water of unsuitable quality. Iron, nitrate, sodium, and chloride are constituents which may make supplies unsuitable, and the extent of the concentration in undesirable amounts should be determined. Observation wells located close to the sea coast should be sampled periodically to detect changes which may indicate salt water intrusion before it can become a serious problem.

B. A temporary concentrated surface-water sampling program is recommended to more adequately determine the present water quality. This concentrated program would require a daily sampling station at Ferndale with numerous miscellaneous samples collected from various points throughout the basin. The program should continue for at least one complete water year.
Grab samples should be collected from Glacier Creek and from each of the three forks of the Nooksack River above their confluences. Samples should also be collected on the main stem of the Nooksack River above and below the cities of Everson and Lynden. Bertrand Creek, Anderson Creek, Fishtrap Creek, Scott Ditch, Smith Creek, Tenmile Creek and Wiser Lake Creek should also be sampled to determine their affects on the water quality of the Nooksack River proper. In addition, Dakota, California, Terrell, Silver Creeks and the Lummi River which comprise the major coastal streams should be sampled.
In the Sumas River basin, the Sumas and Saar Creeks should be sampled near the Canadian border. Johnson Creek should be sampled above the city of Sumas and the Sumas River should be sampled above the city of Nooksack.
Completed chemical tests (including iron), physical tests, sanitary tests, and limited biological tests should be conducted on all samples. Each sample should also be tested for suspended sediment load.
After completion of this concentrated program, a continuation of the existing permanent station near Lawrence, together with one or two grab samples per year at the other sampling locations should provide adequate data to detect any appreciable quality change which may occur.

6. Although studies have been conducted on the major reservoir sites in the study area, some of the minor dam and reservoir sites should be more completely investigated as to available runoff, geologic feasibility, and actual reservoir capacities. Group, community, or government-cooperative programs appear to be the best approach for development of these storage projects.

The present power potential studies appear adequate for the present time; however, possible development of this power should be reviewed from time to time as changing economic conditions suggest.

7. The primary purpose of a water-use survey is to accurately determine the present water use and thereby estimate the amount of water still available for development. Secondary purposes would be to determine waste and unauthorized diversion and to what extent authorized diversions are being utilized. The present approach for determining water-use estimates has proven inadequate since streamflow measurements and appropriation of water under authorized diversions do not necessarily coincide in time, thereby resulting in erroneous conclusions.

It is recommended that a typical stream within the Nooksack River basin be studied use-wise, to determine to what extent authorized diversions are being utilized at any given time and to learn what effect those diversions actually have upon the flow of the stream below the points of diversion. Results obtained from a typical stream study would be applicable to other similar streams within the basin.

ADDENDUM

Streamflow is the complex resultant of a number of meteorological and geographical components. Precipitation, one of the few components measured in a conventional climatological network, is unquestionably the most important contributing factor. Deposition of fog may be another significant source of supply. Evapotranspiration and interception are negative components, acting to diminish the supply. Factors such as soil moisture storage, deep percolation, accumulation and ablation of snow pack and glaciers further complicate the temporal occurrence of runoff. All these components are intricately integrated both in time and space over the remote regions of the mountain watershed and the synthesis or end product is measured as streamflow.

Precipitation accounts for at least 90 per cent of the annual variability of streamflow. Any program for collection of hydrometeorological data should place emphasis on measuring this important parameter. However, in the Nooksack basin all the convenient sites in the mountain areas where personnel are available have been instrumented. Additions to the network in uninhabited areas are less fruitful and the cost of a data-collection program that would measure all the components of runoff in the remote water-producing mountainous area would certainly not be economically justified as a solution for the Nooksack basin problem.

Unfortunately, the hydrometeorological network in the Nooksack basin is generally typical of those established in other watersheds on the west slope of the Cascades. An overall state-wide expansion will ultimately be required to meet the rising demand for water. Despite the seemingly insurmountable difficulties presented by the rugged terrain, these Cascade watersheds offer a hydrology most susceptible to precise definition by quantitative methods. Therefore, instead of dissipating hydro-climatic data-collection stations in an attempt to sample the wide variability in mountain climates and hydrology on a state-wide basis, the expansion should first be confined to a concentrated effort on one relatively small but representative basin. Since all the components of runoff are intimately related, each requires a knowledge of the other.

Because of the similarity of general climatic conditions and the relative homogeneity of the watersheds of the western slope of the Cascades, the information obtained from a saturated basin study could be applied to other similar areas in western Washington. With this basin as a control, a closer examination of the efficiency of the present state-wide hydrologic network would be possible. Also, recent developments in the use of radar to measure aerial precipitation may antiquate the conventional rain-gage network. The use of radar would be accelerated appreciably if a calibrated basin were available as a control.

Additional benefits could be expected from the use of this calibrated basin to accurately evaluate the effects of present and new weather modification techniques as they develop.

The Nooksack basin is particularly well adapted for such a research project. The gaging site at Deming offers a remarkable control for measuring the entire runoff from the mountainous watershed; also the background obtained from the Nooksack study would be readily available.

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APPENDIX A

Appendix A lists all the recorded ground-water filings in the study area as of January 1, 1960.

These filings are listed according to township and the first column lists them by sections within the township. The next three columns refer to the application, permit, and certificate numbers of a particular filing. The letter "D" in these numbers indicates the filing is a Declaration and use is claimed prior to June 6, 1945. The letter "A" indicates an application filed after that date. The term "Rejected" in the permit column or "Canc." (Cancelled) in the certificate column shows that the filing is no longer valid due to the applicant's disinterest, his failure to comply with statutory provisions, or rejection by the Division of Water Resources. The absence of a number in a column indicates that an application has not yet progressed to permit status or has not been perfected to certificate. The priority column indicates the date upon which the application was received or the date of use claimed in the case of a declaration; thus determining its priority relative to other rights which may affect or be affected by it.

The next column, "Name," refers to the name of the applicant, permittee, or original holder of the certificate, and does not necessarily refer to the present holder of the right or owner of the land. Once a certificate of water is issued, it becomes appurtenant to the land, and the Division of Water Resources does not retain records of changes of ownership.

The quantity column lists the amount of water in gallons per minute which may be withdrawn under a specific right. Quantities in parentheses are conjectural since these filings have not been perfected and are invalid.

The column, "Well Loc.," refers to the smallest recorded subdivision in which the well is located.

The column, "Use," shows the specific utilization under the right, and in the case of irrigation, lists the number of acres. The following abbreviations are used in this column.

Ac. ----------------------	Acres
Com. Dom. ---------------	Community Domestic
Dom. ---------------------	Domestic
Fire Prot. ----------------	Fire Protection
Irr. ----------------------	Irrigation

APPENDIX A

GROUND WATER RIGHTS ON RECORD WITH THE DIVISION OF WATER RESOURCES AS OF JANUARY 1, 1960

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.37N.,R.1E.			
5	A3015	2859	Canc.	2-24-53	W. T. Lockwood	(30)	Govt Lot 6	Irr. 10 Ac. & Dom.
5	A 593	589	Canc.	7-23-47	H. W. Dunn	(50)	SE SE	Irr. 38 Ac. & Dom.
					T.37N.,R.5E.			
8	A 530	511	Canc.	5-20-47	R. A. Johnson	(150)	NE SW	Irr. 28 Ac.
					T.38N.,R.1E.			
4	A2800	2563	1657A	11-3-52	Neptune Beach Water Assn.	40	Govt Lot 4	Com. Dom.
8	A4640	4365		7-5-57	James F. Bolster	100	Govt Lot 1	Com. Dom.
33	D 413		369D	1941	M. Granger	20	Govt Lot 2	Irr. 2.5 Ac. & Dom.
					T.38N.,R.2E.			
4	A3316	3302	2308A	7-29-53	H. L. Kelley	35	SE NE	Irr. 10 Ac.
6	A1054	986	1319A	1-15-49	P. Hood	130	SE SW	Irr. 40 Ac.
					T.38N.,R.4E.			
5	A4003	3727	2835A	5-12-55	Mt. Baker Water Assn. Inc.	50	Govt Lot 4	Com. Dom.
					T.38N.,R.5E.			
8	A4655	4391	3285A	8-2-57	J. Brown	150	Govt Lot 7	Irr. 60 Ac.
19	A5408	5098		9-23-59	I. Flowers	350	SE NE	Irr. 35 Ac.
29	A5030	4692	3378A	10-6-58	T. Fresla	165	NW NW	Irr. 35 Ac.
					T.39N.,R.1W.			
2	A5422	5097	3549A	10-26-59	C. W. Holeman	25	Govt Lot 4	Com. Dom.
11	A4889	4584	3474A	6-23-58	Grandview Beach Water Assn.	15	SE NW	Com. Dom.
					T.39N.,R.1E.			
1	A4940	4608	3512A	7-28-58	Custer Water Assn.	80	SW NW	Com. Dom.
1	A3222	2992	2042A	5-14-53	R. Gorze	66	SE NE	Irr. 15 Ac.
2	A3732	3487	2436A	8-10-54	Custer Water Assn.	45	SE SE	Com. Dom.
2	A4458	4205	2794A	10-10-56	Custer Water Assn.	25	SE SE	Com. Dom.
3	A3271	3252	2231A	6-15-53	Old Settlers Water Assn.	80	NE SE	Com. Dom.
3	A4550	4286	2855A	3-21-57	Old Settlers Water Assn.	16	SE SE	Com. Dom.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.39N.,R.2E. (Continued)			
11	A 513	527	Canc.	5-2-47	A. E. Vanderyacht	(200)	NW NE	Irr. 20 Ac.
11	A4143	3911	2810A	10-24-55	A. Giger	120	NE NW	Irr. 39 Ac.
11	A2813	2595	1561A	11-12-52	H. W. Rinehart	110	SW NW	Irr. 18 Ac.
11	A2368	2168	1479A	3-3-52	J. Visser	180	SE NW	Irr. 20 Ac.
11	A2465	2285	1480A	4-24-52	G. Moldenhauer	160	S½ NE	Irr. 60 Ac.
11	A4750	4505	3377A	12-26-57	L. Strube	90	W½ SW	Irr. 18 Ac.
12	D 13		7D	6-42	G. L. Murray	110	NW NE	Irr. 38.5 Ac.
12	A2155	2022	1553A	9-26-51	G. Hickey	160	NW NW	Irr. 20 Ac.
12	A5140	4794	3409A	2-24-59	W. Wiggins	20	S½ NE	Irr. 10 Ac.
12	A3702	3496	2703A	7-15-54	T. B. Koger	50	SE NE	Irr. 5 Ac. & Dom.
12	A 704	638	Canc.	1-21-48	C. D. Albright	(45)	NE NE	Irr. 11 Ac.
12	A3478	3259	1860	1-14-54	A. V. Ellingson	75	NE SE	Irr. 20 Ac.
12	A 560	523	Canc.	6-11-47	D. O. Russell	(100)	NW SE	Irr. 15 Ac.
12	A4473	4207	2898A	11-19-56	R. Dunkin	150	NW SE	Irr. 40 Ac.
13	A4275	4068	2942A	4-5-56	E. Fleming	105	NW NE	Irr. 23 Ac.
13	A4044	3777	3068A	6-28-55	E. W. Smith	200	NE NW	Irr. 20 Ac. & Dom.
13	A4232	3985		2-27-56	E. C. Tillotson	220	NW NW	Irr. 33 Ac.
13	A2041	1884	1312A	7-23-51	H. L. Holleman	200	S½ NW	Irr. 65 Ac.
14	A4722	4447	3324A	11-4-57	R. R. Murray	96	NW SW	Irr. 40 Ac.
14	A1663	1444	811A	9-15-50	G. L. Murray	160	NW SE	Irr. 37 Ac.
14	A2173	1994	1346A	10-4-51	O. L. Mills	150	S½ SW	Irr. 27 Ac.
15	A4671	4454	3583A	9-5-57	M. Small	150	NW NE	Irr. 40 Ac.
15	A 337	323	123A	8-15-46	V. J. Desmul	250	NE SW	Irr. 20 Ac.
15	A 106	212	479A	2-1-46	D. R. Nugen	260	NW SE	Irr. 40 Ac.
15	A4470	4210	2842A	11-14-56	I. Lee	100	SE SW	Irr. 10 Ac.
17	A3160	2929	Canc.	4-13-53	A. P. Anderson	(150)	SE SE	Irr. 12 Ac.
19	A4887	4701	Canc.	6-16-58	Central City Water Assn.	(200)	Govt Lot 1	Com. Dom.
19	A2179	1982	968A	10-16-51	Meridian School Dist. #505	50	NW SW	School Dom.
19	A2509	2320	1513A	5-9-52	Town of Ferndale	1000	SW SE	Municipal Supply
19	A3899	4458	3058A	2-28-55	Town of Ferndale	870	SW SE	Municipal Supply
20	A3502	3264	2150A	2-4-54	M. Vilene	60	NW NW	Irr. 10 Ac. & Dom.
20	A 907	793	175A	6-8-48	L. C. Russell	20	SE NW	Irr. 1 Ac. & Dom.
20	A3799	3587		11-5-54	Kelley, Farquhar & Co.	750	Govt Lot 4	Industrial
20	A 941	800	Canc.	7-1-48	Whatcom-Skagit Rendering Works	(110)	NE NW	Irr. 6.84 Ac. & Industrial
22	A1249	1142	2945A	10-7-49	Greenacres Memorial Park Assn.	350	SE SE	Irr. 43 Ac.
23	A2321	2146	2395A	2-6-52	L. Megard	130	SE NE	Irr. 20 Ac.
23	A 980	911	281A	8-21-48	H. F. Puariea	7	SW SW	Irr. 5 Ac. & Dom.
24	A4748	4494		1-8-58	H. W. Anderson	160	NE NW	Irr. 20 Ac.
24	A4453	4208	3086A	10-5-56	F. Ruzicka	200	S½ NW	Irr. 35 Ac.
24	A2508	2340	1403A	5-9-52	R. L. Davenport, Jr.	130	SE NW	Irr. 20 Ac. & Stock
24	A 801	718	364A	4-6-48	G. E. Claus	150	SW SW	Irr. 70 Ac.
26	A4946	4740		7-28-58	M. C. Guitteau	1000	NE	Irr. 100 Ac.
26	A2471	2333	1204A	4-25-52	C. Erdman	180	NE SW	Irr. 20 Ac.
27	A1284	1144	416A	11-17-49	J. B. O'Neall	8	NW NE	Irr. 1 Ac. & Dom.
27	A 695	632	142A	12-31-47	E. Duncan	70	NW NE	Irr. 5 Ac.
28	A2867	2623	3417A	12-12-52	E. V. Shields	140	SW SE	Irr. 14 Ac.
28	A2470	2270	1525A	4-25-52	G. H. Slater	100	SW SE	Irr. 20 Ac.
29	A 332	264	Canc.	8-9-46	Carnation Company	(1000)	Govt Lot 2	Industrial
30	A2533	2310	1205A	4-10-52	Fertile Meadows Water Assn.	17	NE NW	Com. Dom.
30	D1125	Rejected	(in favor of A2533)		Fertile Meadows Water Assn.	(166)	NE NW	Dom.
30	A1938	1817		5-7-51	J. Manner	300	NW SE	Irr. 60 Ac. & Dom.
30	D1104		1086D	4-42	F. Imhof	50	NE SW	Irr. 2 Ac. & Dom.
30	A5412	5154		10-6-59	F. Imhof	84	NE SW	Com. Dom. & Stock
33	A3082	Rejected		3-16-53	G. Kaufman	(120)	NE NE	Irr. 25 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use

T.39N., R.2E. (Continued)

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
34	A3681	3486	2130A	6-21-54	N. W. Water Assn. Inc.	30	NW NW	Com. Dom.
34	D1114		1046D	1-18-52	M. A. Gilmour	100	SW SW	Irr. & Dom.
35	A2775	2542		10-23-52	A. E. Hansen	200	NW NE	Irr. 20 Ac. & Dom.
35	A2835	2614	Canc.	11-28-52	J. C. Smith	(100)	SW NW	Irr. 10 Ac.
35	A4349	Rejected		6-12-56	A. E. Boyd	(400)	SE SW	Irr. 40 Ac.
36	A 266	261	988A	6-6-46	C. V. Wilder	450	E½	Irr. 50 Ac. & Com. Dom.
36	A5011	4811		9-18-58	C. V. Wilder	400	W½ SE	Irr. 40 Ac.

T.39N., R.3E.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
1	*A 518	491	230A	5-7-47	C. Walsh & T. J. Walsh	160	NE NE	Irr. 20.5 Ac.
1	A5169	4830		3-17-59	E. Singer	200	S½ SW	Irr. 30 Ac.
2	A3784	3641	2313A	10-18-54	Shookum Chuck Water Assn.	240	Govt Lot 2	Com. Dom.
2	A1428	1241	950A	3-23-50	T. R. Bailey	160	Govt Lot 2	Irr. 9 Ac.
2	A1041	Rejected		12-8-48	R. Schafer	(200)	NE NW	Irr. 80 Ac.
2	A 437	400		1-22-47	W. F. Hubbard	200	NE SW	Irr. 40 Ac.
2	A3671	3394	2331A	6-11-54	C. McBride	60	SW SW	Irr. 10 Ac.
2	A 256	206	176A	5-25-46	W. F. Hubbard	65	SE SW	Irr. 2.5 Ac.
3	A2549	2392	2068A	5-23-52	S. Vander Veen	160	NE SE	Irr. 30 Ac.
3	A2143	1979	1171A	9-19-51	H. J. Koppelman	85	SW SW	Irr. 20 Ac.
3	A 483	429	1040A	3-18-47	E. Knutzen	250	S½ S½	Irr. 40 Ac.
4	A3220	2909	1903A	5-14-53	A. J. Chilton	150	SW SW	Irr. 15 Ac.
4	A3167	2868	1946A	4-14-53	M. Cowen	160	E½ SW	Irr. 20 Ac.
4	A 366	311	42A	9-14-46	J. W. Bookey	150	SW SE	Irr. 20 Ac.
4	A1581	1373	943A	7-7-50	J. R. Goodman	50	SE SE	Irr. 8 Ac.
5	A 993	881	362A	9-13-48	R. E. McGhee	28	NE NW	Dom. & Irr.
5	A2539	2357	1364A	5-19-52	F. P. Maneval	150	NE SE	Irr. 15 Ac.
5	A2355	2182	1095A	2-25-52	H. B. Benedict	126	NE SW	Irr. 25 Ac.
5	A3184	2937	1907A	4-24-53	P. A. Norris	200	SW SW	Irr. 40 Ac.
5	A2356	2189	2016A	2-21-52	B. Benson	100	SW SE	Irr. 12 Ac.
5	A4057	3790	2457A	7-11-55	J. S. Sawyer	50	SE SE	Irr. 5 Ac.
5	A4059	3792	2416A	7-11-55	D. J. Arthur	42	SE SE	Irr. 4 Ac.
6	A1145	1069	448A	6-18-49	J. Jansen	50	Govt Lot 5	Irr. 5 Ac. & Dom.
6	A2448	2242	1414A	4-14-52	E. L. Stieber	140	N½ SW	Irr. 10 Ac.
6	A3663	3388	Canc.	6-4-54	W. J. Edwards	(80)	Govt Lot 7	Irr. 8 Ac.
6	A3209	2972	2029A	5-11-53	H. Tjoelker	80	SE SW	Irr. 9 Ac.
6	A3053	2907	1983A	3-9-53	W. J. Van Etten	60	SE SW	Irr. 10 Ac.
6	A2451	2248	1766A	4-17-52	C. A. Hillebrecht	150	SW SE	Irr. 20 Ac.
6	A1573	1353	534A	6-26-50	J. DeYoung	120	SE	Irr. 30 Ac.
6	A3690	3463	2385A	6-28-54	M. Burgraff	150	SE SE	Irr. 20 Ac.
7	A3715	3456	2632A	7-26-54	O. W. Blanton	50	Govt Lot 2	Irr. 8 Ac. & Dom.
7	A4601	4322	3109A	5-6-57	M. W. Door	75	SE NW	Irr. 9 Ac.
7	A3365	3174	1779A	9-3-53	S. H. Sleeth	60	SE NW	Irr. 6 Ac. & Fire Prot.
7	A1191	Rejected		8-4-49	W. & J. Kehl	(1000)	NW SE	Irr. 15 Ac.
7	A3486	3260	3284A	1-21-54	M. W. Armstrong	190	Govt Lot 3	Irr. 60 Ac.
7	A3294	3051	2363A	7-2-53	B. McPherson	210	SE SW	Irr. 40 Ac.
8	A 104	73	10A	1-28-46	J. C. Dyke	200	NE NE	Irr. 20 Ac.
8	A2878	2759	1873A	12-26-52	G. G. Sharp	100	NE NW	Irr. 18 Ac.
8	A 795	742	2918A	4-3-48	R. Haugen	150	NW NW	Irr. 20 Ac.
8	A 921	1109	1320A	5-29-48	A. Hammill	125	NW NW	Irr. 17 Ac.
9	A2859	2637	1815A	12-11-52	N. L. Honcoop, Sr.	200	W½ NE	Irr. 60 Ac.
9	A3404	3175	1951A	10-15-53	G. H. Helmsing	150	NW NW	Irr. 18 Ac.
9	A 302	257	390A	7-5-46	A. J. Chilton	200	NW NW	Irr. 17 Ac.
9	A 912	919	407A	6-9-48	C. I. Forbes	250	W½ SE	Irr. 10 Ac., Dom. & Stock
9	A 311	271	264A	7-22-46	L. Weaver	200	E½ SW	Irr. 40 Ac.
9	A 394	370	251A	11-7-46	L. Weaver	200	SE SW	Irr. 20 Ac.
9	A3617	3492	2386A	5-13-54	R. Gienger	100	SW SE	Irr. 40 Ac.

*Certificate in error--change required

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.39N.,R.3E. (Continued)			
10	A 257	Rejected		5-27-46	Lunde Brothers	(200)	NE SW	Irr. 40 Ac.
10	A 376	314	527A	9-24-46	L. Broersma	140	SW SW	Irr. 20 Ac.
11	A1432	1395	766A	3-27-50	W. Kok	110	NE NW	Irr. 19 Ac.
11	D 193		151D	5-15-45	C. Guckert	20	NW NW	Irr. 1 Ac.
11	A1494	1299	508A	4-28-50	W. Munkres	180	SW NW	Irr. 35 Ac.
11	A4380	4090	Canc.	6-11-56	P. Tjoelker	(270)	NW SW	Irr. 60 Ac.
12	A1952	1780	725A	5-14-51	A. C. Brue	300	SE SE	Irr. 19.25 Ac.
16	A 118	150	2712A	2-1-46	J. W. Boerhave	360	NE NE	Irr. 40 Ac.
16	A 125	151	106A	2-19-46	J. W. Boerhave	300	NW NE	Irr. 30 Ac.
16	A 911	801	417A	6-9-48	S. Sooter	250	NE NW	Irr. 10 Ac., Dom. & Stock
16	A 117	149	Canc.	2-1-46	J. W. Boerhave	(300)	NE NW	Irr. 10 Ac.
16	A1469	1348	506A	4-15-50	R. Georgeff	70	NW NW	Irr. 8 Ac.
16	A2505	2300	1845A	5-8-52	P. Zuidmeer	180	SW NW	Irr. 30 Ac.
16	A4184	3942	2776A	12-19-55	H. Miller	160	SW NE	Irr. 40 Ac.
16	A3436	3214	Canc.	11-20-53	G. Trapeur	(120)	NE SW	Irr. 20 Ac.
17	A5212	4885		4-15-59	H. Sterk	250	NW NW	Irr. 60 Ac.
17	A 663	600	749A	11-13-47	R. Halderman	160	NE SE	Irr. 29 Ac.
17	A2445	2257	1160A	4-11-52	M. P. Anderson	80	SE SW	Irr. 8 Ac.
18	A3788	3590	2253A	10-21-54	Guide Meridian Water Assn.	120	NW NW	Group Dom. & Farm
18	A 541	512	373A	5-26-47	W. S. DeLong	140	SE NE	Irr. 20 Ac.
18	*D 819		782D	4-1-45	H. S. Cole	60	NW SW	Irr. 30 Ac.
19	A2179	1982	968A	10-16-51	Meridian School Dist. #505	50	NW SW	School Supply
19	A1430	1271	1433A	3-23-50	C. V. Wilder	200	SE SE	Industrial
20	A2261	Rejected		12-17-51	H. Mans	(224)	SE NE	Irr. 35 Ac.
24	A4472	4211	3156A	7-17-56	G. Haggith	210	SW NW	Irr. 50 Ac.
32	D 501		438D	8-10-37	Smith Road Coop. W. Assn.	20	NW NW	Com. Dom.
33	A2007	1849	1467A	6-18-51	Victor Water Assn.	40	W½ NW	Com. Dom.
					T.39N.,R.4E.			
3	A 473	419	Canc.	3-7-47	C. Pinkey	(250)	SW SW	Irr. 40 Ac.
5	A1769	1595	1634A	12-29-50	E. Terpsma	250	Govt Lot 2	Irr. 28 Ac.
5	A2108	1934	1864A	8-29-51	H. Pulley	60	SE SW	Irr. 10 Ac.
5	A4602	4323	2905A	5-8-57	T. Dean	91	SE SW	Irr. 25 Ac.
5	A2366	2205	2148A	2-28-52	J. A. Vossbeck	120	SW SE	Irr. 30 Ac.
6	A 579	506	350A	7-7-47	J. W. Lyon	250	NW NW	Irr. 51 Ac.
8	A1868	1727	2460A	5-16-51	Flotre Brothers	320	S½ N½ & SW SE	Irr. 150 Ac.
8	A1919	1778	1170A	4-24-51	O. K. Thompson	128	NW SE	Irr. 20 Ac.
8	A3517	3274	2488A	2-19-54	H. L. Jacobson	100	NW SE	Irr. 8 Ac.
8	A2296	2101	1048A	1-14-52	T. R. Kvamme	160	E½ SE	Irr. 50 Ac.
9	A 986	865	644A	8-30-48	C. Greenfield	100	SE NW	Irr. 6 Ac.
9	A2431	2342	Canc.	4-4-52	E. O'Cain	(200)	S½ NE	Irr. 60 Ac.
9	A1985	1863	1217A	5-31-51	L. Neevel	200	SW SW	Irr. 20 Ac.
9	A4167	3956	3051A	11-29-55	T. W. Betts	120	SE SW	Irr. 16 Ac.
9	A3050	2958	2552A	3-9-53	F. J. Theel	150	SW SE	Irr. 15 Ac.
9	A4122	3873	Canc.	9-23-55	H. Helgesen	(320)	E½ SE	Irr. 60 Ac.
16	A2974	2723		2-6-53	A. Neyhart	150	NW NE	Irr. 25 Ac.
16	A5148	4795		3-2-59	R. R. Bengen	180	NW	Irr. 40 Ac.
16	A1886	1772	1142A	3-27-51	A. R. Bruland	200	NW SE	Irr. 17 Ac.
16	A1595	1381	545A	7-6-50	W. F. Richards	100	NE SE	Irr. 12 Ac.
16	A1779	1656	1147A	1-15-51	R. R. Bengen	200	NE SW	Irr. 40 Ac.
16	A4894	4671		6-20-58	L. E. Kosa	200	SW SW	Irr. 34 Ac.
16	A1295	1155	455A	12-7-49	W. F. Richards	140	SW SE	Irr. 15 Ac.

*Certificate in error--change required

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.39N.,R.4E. (Continued)			
16	A4875	4709		6-2-58	G. Aase	200	SE SE	Irr. 25 Ac.
16 & 17	A3480	3381	2342A	1-15-54	D. Hoines	200	NW NW 16 NE NE 17	Irr. 84 Ac.
19	A2494	2298	Canc.	5-5-52	R. Suchy	(100)	NE SE	Irr. 10 Ac. & Dom.
20	A3062	2941	Canc.	3-11-53	T. M. Sather	(250)	Govt Lot 4	Irr. 40 Ac.
20	A3720	3461	2692A	7-30-54	M. R. McElvain	150	NW SW	Irr. 32 Ac.
21	A4978	4755		8-27-58	L. Fullner	200	NW NE	Irr. 43 Ac.
21	A1923	1755	1037A	4-26-51	M. Harmoney	112	NE SE	Irr. 19.67 Ac.
21	A 163	108	294A	3-6-46	H. C. Blickenstaff	80	NE SE	Irr. 12 Ac.
22	A 512	456	911A	4-29-47	R. Spaulding	100	NW SW	Irr. 6 Ac.
22	A 227	222	Canc.	5-2-46	A. Reed	(80)	NW SW	Irr. 6 Ac.
26	A 148	94	225A	2-25-46	W. A. Robson	200	NE SE	Irr. 30 Ac.
26, 27 & 34	A3422	Rejected		11-5-53	L. H. & M. B. Thompson	(380)	Govt Lot 3-26 Govt Lot 7-27 Govt Lot 1-34	Irr. & Stock
27	A2138	1974	1636A	9-14-51	A. G. Larson	100	NE NW	Irr. 20 Ac.
27	A3102	2894	Canc.	3-23-53	T. Aarstol	(150)	NE NW	Irr. 15 Ac.
27	A3488	3269	2611A	1-22-54	S. A. MacDonald	200	S½ NW	Irr. 20 Ac.
27	A4068	3802	3084A	6-15-55	A. C. Monsen	100	NE SE	Irr. 34 Ac.
27	A2315	2138	1966A	2-4-52	G. A. Roemer	75	SE NE	Irr. 7.5 Ac.
31	A 864	807	873A	5-19-48	R. W. Carbee	200	SE SE	Irr. 15 Ac. & Dom.
					T.39N.,R.5E.			
21	A2953	2691	1483A	1-27-53	H. M. Ingersoll	120	SE SE	Irr. 20 Ac. & Dom.
27	A1662	1437	Canc.	9-15-50	J. Kramer	(200)	SW NE	Irr. 40 Ac.
					T.40N.,R.3W.			
11	A3693	3443	2399A	7-1-54	J. F. Waters	8	Govt Lot 2	Com. Dom.
					T.40N.,R.1E.			
1	A4131	3931	2748A	10-6-55	"H" St. Water Assn. Inc.	6	SE NE	Com. Dom.
3	A5086	4815		12-22-58	City of Blaine	750	NW SW	Municipal Supply
14	A3543	3396	2390A	2-15-54	J. Svedin	130	NW SW	Irr. 30 Ac.
17	A3538	3511		3-12-54	W. R. Loop	150	SE NE	Irr. 15 Ac. & Dom.
21	A2181	1996	1507A	10-17-51	P. E. Holtzheimer	170	NW SW	Irr. 17 Ac.
21	A4467	4385	3234A	11-5-56	P. Hansen	40	NW SW	Irr. 8 Ac. & Dom.
22	A2584	2371	1637A	6-6-52	L. K. Breidford	80	NW NW	Irr. 16 Ac.
22	A3304	3045	Canc.	7-17-53	L. F. Holtzheimer	(200)	SW NW	Irr. 20 Ac.
22	A2860	2622	1791A	12-11-52	S. A. Rosin	50	SW SE	Irr. 4 Ac.
24	A2507	2381	Canc.	5-9-52	J. J. Kliewer	(150)	SW NE	Irr. 40 Ac.
24	A3351	3178	2104A	8-28-53	A. Mohr	40	NE SE	Irr. 4 Ac.
24	A1853	1731	927A	3-3-51	S. Smith	200	N½ SE	Irr. 40 Ac.
24	A2795	2643	2232A	10-30-52	G. E. Hoagland	150	SE SW	Irr. 25 Ac.
25	A2723	2521	Canc.	9-22-52	J. T. Pemberton	(200)	NW SW	Irr. 20 Ac.
26	A 467	434	975A	3-1-47	N. P. Hardman	160	NE SW	Irr. 20 Ac.
26	A 450	408		1-29-47	W. L. Hawkins	300	SE SE	Irr. 35 Ac.
26	A 449	407		1-29-47	W. L. Hawkins	300	SE SE	Irr. 35 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.40N.,R.1E.(Continued)			
27	A5164	4884		3-16-59	W. Wilder	175	S½ NE	Irr. 73 Ac.
31	A1427	1270	666A	3-23-50	Seattle Dist. Corps of Engrs.	30	NW SE	Dom.
35	D 184		112D	7-35	G. R. Pettit	28	SW NE	Irr. 2.5 Ac.
	(Certificate of Change 619)							
35	A 178	138	477A	3-14-46	G. R. Pettit	100	SW NE	Irr. 7 Ac. & Dom.
	(Certificate of Change 619)							
35	A2809	2620	Canc.	11-7-52	E. McNallie	(400)	SE NW	Irr. 40 Ac.
35	A3505	3265	2146A	2-8-54	G. R. Pettit	7	SW NE	Irr. 8 Ac.
					T.40N.,R.2E.			
1	A4000	3764	2492A	5-10-55	F. Rehm	260	Govt Lot 2	Irr. 40 Ac.
1	A4612	4411	3309A	5-20-57	H. L. Holleman	120	SE NW	Irr. 35 Ac.
1	A4369	4097	2949A	6-29-56	H. A. Rutgers	120	NW SW	Irr. 40 Ac.
1	A3089	2964	2010A	3-18-53	R. Van Mersbergen, Sr.	150	SE SW	Irr. 40 Ac.
2	A1786	1605	830A	1-18-51	J. Axling	180	NE SE	Irr. 34 Ac.
2	A4508	4328	3229A	1-28-57	J. H. Van Dalen	200	SW SW	Irr. 20 Ac.
2	A2400	2292	1325A	3-21-52	J. H. Van Dalen	200	SW SE	Irr. 40 Ac.
8	A3609	2943	Canc.	3-12-53	L. Goodman	(180)	E½ SW	Irr. 40 Ac.
10	A3352	3227	1934A	8-28-53	J. Reimer, Jr.	180	SW SW	Irr. 30 Ac.
10	A4802	4536	3254A	3-7-58	V.M. Hoffman	160	W½ SW	Irr. 40 Ac.
10	A2745	2607	1687A	10-8-52	R. Vander Werff	150	NE SE	Irr. 20 Ac.
11	A3550	Rejected		3-22-54	J. Tolsma	(180)	NE NW	Irr. 50 Ac.
11	A3607	3355	1937A	5-10-54	G. Schoessler, Jr.	200	SW NW	Irr. 36 Ac.
11	A2393	2275	1559A	3-17-52	J. Helgath	225	SW NE	Irr. 35 Ac.
11	A2348	2172	1349A	2-20-52	I. I. Vanderyacht	225	NW SE	Irr. 35 Ac.
11	A3208	2934	1947A	5-11-53	J. Den Beston	110	NW SW	Irr. 30 Ac.
12	A2318	2131	1473A	2-5-52	L. De Jong	150	NE NE	Irr. 30 Ac.
12	A5286	5007		6-8-59	D. Bajema	180	NE NW	Irr. 30 Ac.
12	A2435	2262	1220A	4-7-52	B. Korthuis	130	SE NW	Irr. 15 Ac.
12	A2221	2047	1955A	11-16-51	B. Hendricks	180	NE SE	Irr. 60 Ac.
13	A1657	1564	1045A	9-9-50	H. Vander Griend	150	NE NE	Irr. 18 Ac.
13	A2864	2648	2910A	12-12-52	A. Schouten	240	E½ NW	Irr. 45 Ac.
13	A3134	2913	1622A	3-30-53	G. Bedlington	150	SW NW	Irr. 15 Ac.
13	A5242	4972		5-8-59	C. M. Vander Griend	160	SE NE	Irr. 40 Ac.
13	A1198	1133	757A	8-10-49	H. B. Crabtree	160	SW SE	Irr. 40 Ac.
14	A3622	3354	3262A	5-17-54	M. Cowin	72	SW SW	Irr. 60 Ac.
15	A3087	2912	1621A	3-18-53	G. Bedlington	180	NE NE	Irr. 39 Ac.
15	A 463	409	882A	2-27-47	H. O. Worthen	250	SE NE	Irr. 12.5 Ac.
15	A 161	111	1162A	3-5-46	O. L. Vineyard & Son	300	SE NE	Irr. 24 Ac.
15	A 162	112	1161A	3-5-46	O. L. Vineyard & Son	300	E½ SW	Irr. 80 Ac.
15	A3723	3506	Canc.	8-5-54	V. Menser	(100)	SW SE	Irr. 19 Ac.
15	A 668	1825	1206A	11-15-47	C. T. McClelland	70	SE SE	Irr. 20 Ac.
16	A3128	2863	1540A	3-27-53	M. Bostwick	110	NE NE	Irr. 40 Ac.
16	A4475	4263		11-21-56	H. Remington	150	W½ SW	Irr. 69.32 Ac.
17	A 533	Rejected		5-17-47	T. Skidmore	(250)	NE NE	Irr. 20 Ac.
17	A 534	Rejected		5-17-47	T. Skidmore	(250)	SE NE	Irr. 40 Ac.
17	A3687	3475	2109A	6-23-54	V. L. Brewer	160	SW SE	Irr. 40 Ac.
18	A4094	3849	2737A	8-29-55	E. A. Sawyer	120	Govt Lot 1	Irr. 22 Ac.
19	A5185	4850	3448A	3-27-59	J. Erickson	50	NE SE	Irr. 25 Ac.
19	A3747	3480	2709A	8-30-54	H. N. Hanson	144	SE SW	Irr. 29 Ac.
20	A 496	432	Canc.	4-1-47	L. E. Maberry	(160)	NE NE	Irr. 40 Ac.
20	A2921	2654	1785A	1-14-53	R. Slagle	180	NW NE	Irr. 37 Ac.
20	A2918	2685	2041A	1-13-53	E. Jansen	150	SE NE	Irr. 40 Ac.
20	A2960	2729	2127A	1-29-53	H. G. James	160	NE SE	Irr. 40 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.40N.,R.2E.(Continued)			
20	A3060	2999	Canc.	3-11-53	A. A. Bauman	(180)	SW SE	Irr. 40 Ac.
20	A3094	2881	2452A	3-19-53	A. A. Bauman	150	SW SE	Irr. 20 Ac.
22	A3189	Rejected		4-29-53	W. E. Holt	(200)	SE NE	Irr. 64.44 Ac.
22	A1973	1846	1234A	5-23-51	R. F. Rawls	75	SW SW	Irr. 7.50 Ac.
22	A2351	2162	1300A	2-21-52	L. E. Maberry	320	SW SE	Irr. 70 Ac.
23	A 929	802	866A	6-19-48	L. J. Derr	160	SW NE	Irr. 32 Ac.
23	A5151	4807		3-3-59	R. C. Bajema	175	NE SE	Irr. 70 Ac.
23	A2185	2002	1237A	10-24-51	J. S. Sawyer	70	SW SE	Irr. 10 Ac.
23	A3266	3022	2178A	6-11-53	J. P. Verduin	100	SW SE	Irr. 10 Ac.
23	A2942	2686	1438A	1-26-53	M. Clark	150	SW SE	Irr. 20 Ac.
23	A 443	406	789A	1-30-47	I. P. Fassett	160	SE SE	Irr. 36 Ac.
24	A4400	4178	2787A	8-13-56	G. Vermeulen	120	SE NW	Irr. 40 Ac.
24	*A 796	732	200A	4-5-48	E. G. Pierce	200	SW NE	Irr. 40 Ac.
24	A 393	338	501A	10-30-46	P. Geleynse	200	SW SW	Irr. 35 Ac.
24	A2419	2239	1618A	3-31-52	A. Crabtree	120	NE NW	Irr. 60 Ac.
24	A2492	2280	1512A	5-5-52	P. Geleynse	150	W½ SW	Irr. 20 Ac.
25	D 239		228D	6-1-44	C. Graves	75	NW NW	Irr. 4 Ac. & Dom.
25	A3173	2905	1930A	4-20-53	M. A. Coleman	150	NW NW	Irr. 20 Ac.
26	A3568	3364	2312A	4-5-54	J. T. Williams	130	NE NE	Irr. 15 Ac.
26	A1789	1668	1388A	1-23-51	J. Terpsma	200	W½ NE	Irr. 40 Ac.
26	A 365	315	906A	9-13-46	J. Ramerman	300	NE NW	Irr. 15 Ac.
26	A2696	2473	1853A	9-5-52	H. Smit	150	NE NW	Irr. 18 Ac.
26	A2335	2174	1410A	2-13-52	E. L. Harlow	120	NW NW	Irr. 10 Ac.
27	A3241	2977	1976A	5-27-53	M. H. Jensen	150	NW SW	Irr. 40 Ac. & Dom.
27	A3242	2978	1977A	5-27-53	M. H. Jensen	150	SW SW	Irr. 40 Ac. & Dom.
28	A4014	3841	2455A	5-25-55	C. Bedell	130	NE NE	Irr. 20 Ac.
28	A4024	3771	3075A	5-31-55	E. J. Claxton	200	NW NE	Irr. 38.74 Ac.
28	A1798	1618	2831A	1-31-51	J. L. Monohan	120	N½ SE	Irr. 30 Ac.
29	A1817	1677	1089A	2-6-51	R. W. McGowan	300	E½ NE	Irr. 40 Ac.
29	A3095	3001	2209A	3-19-53	O. E. Wilson	200	E½ SE	Irr. 80 Ac.
31	A3591	3349	1979A	4-22-54	L. Bainter	180	SE NW	Irr. 20 Ac.
31	A3043	2762	1838A	3-6-53	G. Rust	150	E½ NW	Irr. 25 Ac.
31	A2271	2084	1426A	12-24-51	E. Veldhuizen	130	NE SE	Irr. 33 Ac.
32	A1951	1857	948A	5-14-51	H. Potts	200	SW SE	Irr. 35 Ac.
33	A5161	4839	3442A	3-11-59	C. J. Wilson	150	NW	Irr. 40 Ac.
33	A2312	Rejected		1-31-52	C. Wilson	(300)	N½ NW	Irr. 100 Ac.
33	A 510	453	Canc.	4-22-47	H.L. Pettibone & U.D. Jones	(150)	SE SW	Irr. 20 Ac.
34	A4276	4053	3017A	4-5-56	H. Terpsma	90	NE NW	Irr. 20 Ac.
34	A1171	1064	Canc.	7-16-49	R. S. Ellis	(200)	NW NW	Irr. 40 Ac. & Dom.
34	A4353	4057	2670A	6-13-56	V. B. Ritter	180	Govt Lot 5	Irr. 40 Ac.
35	A 891	823	837A	6-4-48	B. O. Viddal	120	Govt Lot 2	Irr. 26 Ac.
36	A5247	4936		5-11-59	J. Larson	100	SE SW	Irr. 10 Ac.
					T.40N.,R.3E.			
1	A 474	431	244A	3-11-47	C. Kooi	250	NE NE	Irr. 40 Ac.
1	A 519	539	2078A	5-7-47	R. W. Hendrik	100	NE SW	Irr. 10 Ac.
1	A5111	4802		1-23-59	H. A. Ehlers	200	SE SE	Irr. 71 Ac.
1	A3221	3054	2115A	5-14-53	R. A. Marchant	180	SW SE	Irr. 40 Ac.
2	A1808	1659	1031A	2-5-51	F. Ondeck	160	NW NE	Irr. 60 Ac.
2	A2295	2094	Canc.	1-14-52	J. Ondeck	150	SE NE	Irr. 20 Ac.
2	A4437	4159	3139A	9-17-56	H. Nieuwsma	250	NW SW	Irr. 25 Ac. & Stock
2	A 259	256	226A	6-1-46	A. C. Bauman	120	SW SW	Irr. 30 Ac.
2	A1066	1017	972A	2-10-49	L. Kraght	160	SE SE	Irr. 40 Ac.

*Certificate in error--change required

T.40N.,R.3E.(Continued)

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
2	A4992	4736		9-8-58	Pangborn Water Assn.	30	SE SE	Com. Dom.
3	A3322	3197	2185A	8-4-53	A. E. Johnson	240	SE NW	Irr. 120 Ac.
3	A1795	1643	751A	1-25-51	A. Schoessler	175	W½ NE	Irr. 76 Ac.
3	A3229	2973	1931A	5-20-53	C. Snider	180	N½ SE	Irr. 40 Ac.
3	A 520	464	1247A	5-9-47	S. Bajema	165	N½ SE	Irr. 30 Ac.
3	A1816	1676	1069A	2-6-51	A. P. Brandt	275	SE SW	Irr. 60 Ac.
3	A3534	4342	3276A	3-11-54	A. P. Brandt	200	SE SW & SW SE	Irr. 45 Ac.
3	A1633	1590	Canc.	8-22-50	C. A. Frazier	(150)	SE SE	Irr. 10 Ac.
5	A3512	3291	2685A	2-15-54	A. De Haan	120	Govt Lot 4	Irr. 36 Ac.
5	A4104	3831	2717A	9-8-55	R. De Motts	180	NW SW	Irr. 48 Ac.
6	A3230	3011	3487A	5-21-53	C. Eshuis	250	SE NE	Irr. 35 Ac.
6	A4045	3824	2778A	6-28-55	J. Rietman	200	Govt Lot 4	Irr. 38 Ac.
6	A3904	3743	2634A	3-7-55	A. Hovander	120	NW NE	Irr. 40 Ac.
6	A5249	4891	3445A	5-11-59	B. Statema	180	E½ SW	Irr. 70 Ac.
	(Certificate of Change 614)							
6	A4496	4214	2905A	1-15-57	F. Dykman	150	Govt Lot 4	Irr. 39 Ac.
7	A5226	4907		4-24-59	J. Rupke	350	SW NE	Irr. 35 Ac.
7	D 970		735D	7-20-41	A. R. Benson	250	NE NE	Irr. 70 Ac.
8	A2476	2318	1629A	4-28-52	S. Holloman	225	W½ SW	Irr. 30 Ac.
8	A4354	4050	2671A	6-15-56	F. Otter	180	NE SE	Irr. 40 Ac.
9	A3716	3457	2062A	7-26-54	R. Nonhoff	300	NE NE	Irr. 40 Ac.
9	A3731	3469	2418A	8-10-54	Delta Water Assn.	200	SE SE	Com. Dom.
10	D 391		320D	7-44	K. F. Stallard	120	NE NW	Irr. 20 Ac.
10	A2118	1947	1314A	9-4-51	L. E. Bradley	180	NE SE	Irr. 39 Ac.
10	A2320	2132	1510A	2-6-52	O. O. Olin & Son	40	SE SE	Irr. 4 Ac.
11	A2224	2040	1396A	11-16-51	J. Lagerway	140	SW NW	Irr. 20 Ac.
11	A3554	3368	2318A	3-24-54	F. M. & G. Harvey	200	SE NW	Irr. 60 Ac.
14	A2843	2576	2114A	12-4-52	Northwood Water Assn.	70	NW NW	Com. Dom. & Stock
15	A4608	4324	2917A	5-14-57	L. H. Hersman	50	NW NE	Irr. 8 Ac.
15	A 592	579	1248A	7-23-47	J. Husfloen	100	NE NW	Irr. 10 Ac.
15	A4347	4069	2972A	6-11-56	E. Roo	150	NE NW	Irr. 20 Ac.
15	A3555	3362	2330A	3-25-54	B. E. Shea	180	SW NW	Irr. 35 Ac.
15	A3624	3399	2375A	5-17-54	C. A. Frazier	180	SW NE	Irr. 19 Ac.
15	A3592	3338	2519A	4-23-54	Meadowdale Water Assn.	150	NE SW	Com. Dom.
15	A 151	141		2-26-46	C. V. Wilder	600	NW SW	Irr. 40 Ac. & Dom.
16	A3526	3382	2013A	3-2-54	R. De Motts	130	SW NW	Irr. 28 Ac.
16	A 284	244	Canc.	6-22-46	L. F. Piercey	(150)	SW NE	Irr. 20 Ac.
16	A 543	517	641A	5-27-47	R. Stouffer & V. B. Tripp	80	NE SE	Irr. 35 Ac.
16	A3342	3206	Canc.	8-19-53	C. H. Hersman	(70)	SW SW	Irr. 7 Ac.
16	A3141	2969	2504A	4-2-53	I. Geleynse	150	SE SW	Irr. 18 Ac.
16	A1654	1435	Canc.	9-8-50	W. L. Dodson	(160)	SW SE	Irr. 40 Ac.
17	A1604	1495	933A	7-26-50	D. De Young	160	NE	Irr. 20 Ac.
17	A2139	1993	1315A	9-14-51	W. Heusinkveld	180	SW NW	Irr. 40 Ac.
17	A1620	1411	532A	8-4-50	T. J. Bay	100	SW SW	Irr. 60 Ac.
18	A4549	4297	2859A	3-13-57	N. G. Brand	150	Govt Lot 1	Irr. 35 Ac.
18	A4027	3754	2577A	6-2-55	H. Plagerman	150	Govt Lot 2	Irr. 18 Ac.
18	A5139	4792		2-20-59	T. J. Bay	165	SE SE	Irr. 40 Ac.
18	A5257	4997		5-20-59	H. Heusinkveld, Jr.	350	SE NE	Irr. 35 Ac.
18	A2562	2566	1697A	5-28-52	P. Weg, Sr.	150	NW SE	Irr. 40 Ac.
18	A2510	2366	1343A	5-9-52	G. E. Meenderinck	180	W½ SW	Irr. 40 Ac.
19	A3254	3058	1804A	6-4-53	R. Taylor	120	SW NE	Irr. 10 Ac.
20	A2382	2184	Canc.	3-10-52	J. Harkoff	(200)	NW NE	Industrial
21	A2251	2068	1261A	12-10-51	E. J. Scholten	180	S½ NE	Irr. 46 Ac.
21	A4357	Rejected		6-15-56	F. E. Landaal	(100)	SW NW	Irr. 7 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.40N., R.3E. (Continued)			
22	A3122	3155	Canc.	3-26-53	W. Lankhaar	(180)	NW SE	Irr. 20 Ac.
22 & 23	A2937	2746	2458A	1-20-53	G. Lankhaar	150	SE SE-22 SW SW-23	Irr. 38 Ac.
23	A3186	3093	2269A	4-28-53	D. Feller	150	SE NW	Irr. 20 Ac.
23	A3080	2893		3-16-53	H. Slotemaker	180	NE SW	Irr. 30 Ac.
23	A2652	2470	1653A	7-25-52	D. Slotemaker	150	SE SW	Irr. 28 Ac.
23 & 26	A3264	3116	2549A	6-9-53	S. S. Jeffcott	120	SE SE-23 NE NE-26	Irr. 28 Ac. & Stock
25	A4609	4344	2958A	5-17-57	T. Roorda	135	W½ SE	Irr. 40 Ac.
26	A2528	2397	1443A	5-15-52	J. L. Mulder	180	NE NW	Irr. 38 Ac.
26	A2149	2016	1395A	9-24-51	H. Scholten	180	NW NE	Irr. 56 Ac.
26	A3708	3453	2384A	7-21-54	N. Roosendaal	150	SW NE	Irr. 25 Ac.
26	A4649	4370	3129A	7-23-57	G. Vander Mey	140	SE NE	Irr. 35 Ac.
26	A3725	3515	2442A	7-28-54	B. Vande Kamp	250	Govt Lot 5	Irr. 32 Ac.
27	A 868	764	376A	5-15-48	T. & G. Honcoop	150	NE NE	Irr. 37 Ac.
27	A2841	2625	Canc.	12-2-52	L. M. Lankhaar	(150)	Govt Lot 1	Irr. 40 Ac.
27	A2823	2613	1417A	11-24-52	J. T. De Jong	150	SW NW	Irr. 15 Ac.
27	A3582	3370	2160A	4-15-54	O. C. Noteboom	150	NE SW	Irr. 30 Ac.
27	A2496	2354	Canc.	5-5-52	J. T. De Jong	(180)	SW SW	Irr. 40 Ac.
28	A2327	2158	2067A	2-8-52	K. Polinder	250	NW NE	Irr. 40 Ac.
28	A5168	4944		3-17-59	C. M. & M. Huisman	180	SE NE	Irr. 18 Ac.
30	A4286	4040	2711A	4-19-56	G. T. Bode	200	E½ NE	Irr. 30 Ac.
31	A 229	207	346A	5-7-46	N. J. D. McLeod	125	SE SW	Irr. 15 Ac.
32	A3012	2754	1464A	2-20-53	C. Wagner	120	NE SE	Irr. 18 Ac.
32	A1891	1753	1215A	3-31-51	H. Dykstra	180	NW SW	Irr. 40 Ac.
	(Certificate of Change 615)							
32	A 237	196	290A	5-14-46	J. Hollander	110	SE SE	Irr. 16 Ac. & Dairy
32	A5167	4945		3-17-59	C. M. & M. Huisman	100	SW NE	Irr. 10 Ac.
33	A2343	2171	1378A	2-18-52	J. F. Oltman	100	SE SW	Irr. 30 Ac.
33	A2301	2211	1626A	1-22-52	H. Boehringer	180	SW SE	Irr. 40 Ac.
33 & 34	A4237	Rejected		3-6-56	P. Van Dyk, Sr.	(250)		Irr.
34	A3088	2945	2397A	3-18-53	H. Bosman	150	SW NW	Irr. 35 Ac.
34	A4238	4165	3077A	3-6-56	P. Van Dyk, Sr.	250	SE NW	Irr. 30 Ac.
34	A 212	157	61A	4-12-46	A. J. Chilton	175	NE SE	Irr. 60 Ac.
35	A 246	198	Canc.	5-21-46	D. Bouwman	(200)	NE SW	Irr. 20 Ac.
36	A 153	148	Canc.	2-28-46	W. Pride	(70)	SE NE	Irr. 10 Ac.
36	D 492		403D	1935	Town of Everson	350	NE SE	Municipal Supply
	(Certificate of Change 587)							
36	D 493		404D	1940	Town of Everson	300	NE SE	Municipal Supply
	(Certificate of Change 588)							
36	D 10		4D	5-30	C. S. Kale Canning Co.	350	NE SE	Industrial
36	A2191	1990	1334A	10-26-51	C. S. Kale Canning Co.	300	NE SE	Industrial
36	A 331	287		8-9-46	Town of Everson	1550	NE SE	Municipal Supply
36	A4149	4104	2962A	10-27-55	G. & L. Kale	150	SW SE	Irr. 17 Ac.
36	A1980	1862	Canc.	5-28-51	J. C. Harder	(100)	SE SE	Irr. 11 Ac.
36	A2513	2382	Canc.	5-12-52	E. Kaemingk	(100)	SE SE	Irr. 10 Ac.
					T.40N., R.4E			
1	A5213	4899	3415A	4-15-59	H. Den Adel	100	NW NE	Irr. 10 Ac.
1	A5170	Rejected		3-17-59	R. Vos	(130)	Govt Lot 3	Irr. 32 Ac.
1	A2679	2472	1721A	8-14-52	E. E. Snider	180	NW SW	Irr. 30 Ac.
3	A3995	3809	Canc.	5-9-55	R. Easterbrook	(150)	NE SE	Irr. 40 Ac.
6	A1815	1738	1176A	1-24-51	E. E. Loreen	130	Govt Lot 1	Irr. 46 Ac. & Dom.
6	A3598	3386	Canc.	4-29-54	H. W. Graves	(180)	SW NE	Irr. 25 Ac.
6	A1286	1182	578A	12-1-49	C. F. Lovelace	150	SW NE	Irr. 9 Ac.
7	A4935	4659	3400A	7-25-58	R. Glass	200	Govt Lots 3 & 4	Irr. 20 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.40N.,R.4E.(Continued)			
8	A3501	3304	2324A	8-28-53	A. Swanson	120	SW SE	Irr. 20 Ac.
8	A2564	2361	1221A	5-29-52	J. J. Stadt, Jr.	180	SE SE	Irr. 39 Ac.
9	A2253	2144	2120A	12-10-51	H. Bosman	180	NE NW	Irr. 40 Ac.
9	A2886	2872	1914A	1-2-53	G. Olson	200	SW SW	Irr. 20 Ac.
9	A2350	2188	1177A	2-20-52	A. L. Olson	180	SE SW	Irr. 50 Ac.
10	A1018	923	885A	10-21-48	G. Buys	225	SE NW	Irr. 20 Ac. & Dom.
10	A3144	3047	2092A	4-6-53	J. Scheffer	175	SE NE	Irr. 38 Ac.
10	A2349	2201	1166A	2-20-52	Gargett Brothers	150	NE SE	Irr. 40 Ac.
10	A5098	4789		1-12-59	J. M. Sterk	300	SW SW	Irr. 30 Ac.
10	A2270	2089	1399A	12-24-51	E. Callenius	200	SE SE	Irr. 34 Ac.
12	A2363	2203	Canc.	2-28-52	A. Brown	(200)	SE NW	Irr. 50 Ac.
12	A2168	2063	Canc.	10-4-51	O. L. & H. Sheets	(400)	SW SW	Irr. 85 Ac. & Dom.
15	A1723	1578	Canc.	11-9-50	D. Leenders	(160)	W½ SW	Irr. 38 Ac.
16	A3620	3346	1989A	5-14-54	J. Bierlink	200	NE NE	Irr. 45 Ac.
16	A3459	3256	1859A	12-16-53	T. B. Carman	150	NW SW	Irr. 35 Ac.
17	A2424	2226	1421A	4-1-52	M. A. Reeck	100	NE NE	Irr. 7 Ac.
17	A2685	2545	1416A	8-25-52	C. E. Berendsen	180	NW NE	Irr. 38 Ac.
17	A5190	4852		3-31-59	M. B. Gillis	800	NW	Irr. 80 Ac.
17	A4861	4734	Canc.	5-14-58	F. Sterk	(200)	SW NW	Irr. 20 Ac.
17	A3139	2968	1985A	4-1-53	B. Scholten	165	SW NE	Irr. 40 Ac.
17	A2506	2446	Canc.	5-8-52	W. Westhoff	(180)	SE NE	Irr. 40 Ac.
17	A2218	2046	1282A	11-14-51	W. Vanderhage	300	N½ SW	Irr. 80 Ac.
17	A4923	4619	3312A	7-21-58	J. Scholten	160	SW SW	Irr. 67.5 Ac.
20	A 448	402	79A	2-7-47	W. Kroontje	200	NW NE	Irr. 36 Ac.
20	A2039	1870	880A	7-23-51	H. Zylstra	160	SE NE	Irr. 17 Ac.
20	A2802	2582	2038A	11-5-52	R. Koster	75	NE SE	Irr. 10 Ac.
27	A4977	4769		8-27-58	C. G. Elsner	120	SE	Irr. 12 Ac.
28	D1135		1073D	1936	J. A. Quinn	150	NW NW	Irr. 26 Ac. & Dom.
28	A2148	1987	Canc.	9-24-51	G. Leenders	(70)	SE NW	Irr. 9 Ac.
28	A5200	4898		4-7-59	T. Pearce	300	NW SE	Irr. 30 Ac.
30	A1706	1557	Canc.	10-16-50	J. L. Hill	(100)	NW NE	Irr. 8 Ac.
31	A4298	4110	2964A	4-30-56	S. H. Barnard & S. Spedding	120	N½ NE	Irr. 9 Ac.
31	A5199	4934		4-7-59	J. Hoekema	200	NE SE	Irr. 60 Ac.
31	A1679	1553	1035A	9-30-50	H. W. Cyr	180	Govt Lots 8 & 9	Irr. 40 Ac.
32	A 326	268	233A	8-1-46	I. B. Green	200	NE NW	Irr. 25 Ac.
32	A 170	142	217A	3-8-46	E. C. Lehman	400	NW SE	Irr. 10 Ac. & Dom.
33	A2061	1877	832A	8-2-51	Great Western Lumber Co.	70	NE NE	Millpond
33	A2361	2149	1159A	2-27-52	P. Berg	100	SW NW	Irr. 8 Ac.
33	A4858	4582		5-12-58	L. Jenkins	150	SE NW	Irr. 25 Ac.
					T.40N.,R.5E.			
6	A2025	2024	1083A	7-3-51	E. B. Jacobson	170	SW NE	Irr. 40 Ac.
34	A1032	914	458A	11-22-48	G. St. James	160	SE SE	Irr. 35.6 Ac.
35	A3169	3006	2443A	4-15-53	Bruns Brothers	120	NW SW	Irr. 38 Ac.
					T.41N.,R.3W.			
35	A5178	4932		3-24-59	Whalens, Inc.	1000	Govt Lot 7	Com. Dom.
					T.41N.,R.1E.			
31	A2042	1861	Canc.	7-9-51	City of Blaine	350	NW SE	Municipal Supply

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.41N.,R.2E.			
35	A3093	2860	1689A	3-19-53	J. Orange	150	E½ SE	Irr. 30 Ac.
35	A5418	5103		10-22-59	H. De Vries	250	W½ SE	Irr. 35 Ac.
36	A4352	4060		6-13-56	M. De Boer	200	W½ SW	Irr. 80 Ac.
					T.41N.,R.3E.			
31	A4611	4345	3200A	5-17-57	R. Noteboom	180	W½ SW	Irr. 63 Ac.
31	A3038	2790	1563A	3-4-53	C. A. Sorgenfrei	150	SE SE	Irr. 20 Ac.
32	A5216	4923		4-17-59	J. Honcoop	175	N½ SW	Irr. 49 Ac.
32	A5215	4922	3447A	4-16-59	W. J. Roosma	150	SW SW	Irr. 37 Ac.
32	A2407	2217	1145A	3-24-52	W. Visser	180	SE SW	Irr. 38 Ac.
33	A5238	4900	3446A	5-5-59	E. Leenders	180	NW SW	Irr. 40 Ac.
33	A2563	2525	Canc.	5-29-52	R. Kortlever	(320)	E½ SE	Irr. 120 Ac.
34	A3610	3416	2383A	5-11-54	K. W. Boeringa	200	NW SW	Irr. 60 Ac.
34	A3937	3774	2652A	3-22-55	A. Honcoop	180	S½ SW	Irr. 20 Ac.
35	A4997	4710	3599A	9-11-58	M. J. Hicks	200	SW SW	Irr. 40 Ac.
36	A2290	2099	2208A	1-11-52	W. H. Ehlers	200	S½	Irr. 50 Ac.
36	A4292	4036	2637A	4-25-56	E. Ondeck	130	SW SW	Irr. 18 Ac.
36	A2357	2167	1556A	2-26-52	W. H. Ehlers	200	SE SE	Irr. 38 Ac.
					T.41N.,R.4E.			
31	A4439	4157	2827A	9-17-56	K. S. Johnson	55	NE SE	Irr. 15 Ac.
31	A2421	2218	1283A	3-31-52	H. Johnson	300	Govt Lots 5 & 6	Irr. 50 Ac.
31	A3131	2918	1641A	3-30-53	V. L. Estergreen	150	SW SE	Irr. 40 Ac.
31	A2294	2093	1150A	1-14-52	G. W. Nestle	110	SE SE	Irr. 20 Ac.
33	A5328	4987	3485A	6-22-59	Town of Sumas	2250	Govt Lot 1	Municipal Supply
					T.41N.,R.5E.			
31	A1950	1818	863A	5-12-51	G. Groen	180	S½ SW	Irr. 53 Ac.
31	A2617	2417	2799A	6-26-52	G. Postma	200	SW SE	Irr. 40 Ac.
32	A4334	4080	2691A	6-1-56	R. Vander Meulen	200	SW SW	Irr. 90 Ac.

Sec.	Appl.	Permit	Cert.	Priority	Name	Quantity(gpm)	Well Loc.	Use
					T.39N.,R.1E. (Continued)			
6	A2537	2398	1444A	5-19-52	Bell Bay Jackson Water Assn.	60	NE NE	Dom.
6	A1762	1572	1061A	12-26-50	M. Haugen	45	SW NW	Irr. 5 Ac. & Dom.
9	A2063	1989	Canc.	8-3-51	Pleasant Valley Water Assn.	(30)	SW NW	Dom.
13	A1136	1082	393A	6-2-49	Aldergrove Water Assn.	25	NW NW	Dom. & Farm
13	A2008	1853	897A	6-18-51	Thornton Water Assn.	55	S½ SE	Com. Dom.
14	A1609	1442	983A	7-28-50	North Star Water Assn.	55	SE SW	Com. Dom., Stock & Dairy Farm
15	A2201	2053	1994A	11-9-51	L. Terrell Water Assn.	25	NW NE	Com. Dom.
18	A2888	2675	Canc.	1-2-53	G. Bruland	(200)	Govt Lot 2	Irr. 20 Ac. & Dom.
21	A2083	1903	Canc.	8-17-51	J. R. Malle	(80)	NE SW	Irr. 10 Ac.
21	A2053	1977	Canc.	7-30-51	W. E. Alley	(160)	NW SW	Irr. 20 Ac.
21	D 517		517D	12-44	J. R. Waylett	5	SW SW	Dom. & Stock
24	A 327	260	1739A	8-1-46	J. E. Sundstrom	15	SE NE	Com. Dom.
26	A1540	Rejected		6-8-50	M. M. Moles	(25)	SE SW	Irr. 20 Ac. & Dom.
28	A 485	455	194A	3-21-47	C. W. Anderson	25	SW NW	Irr. 10 Ac., Stock & Dom.
28	A3507	3290	2366A	2-9-54	W. T. Follis	20	NW SW	Dom.
35	A3981	3741	2864A	5-2-55	A. M. Illman	100	E½ SE	Irr. 50 Ac.
					T.39N.,R.2E.			
1	A4006	3748		5-19-55	J. A. Anderson	90	Govt Lot 4	Irr. 9 Ac.
1	A1898	1784	1025A	4-5-51	G. M. Hickey	120	SW SW	Irr. 20 Ac.
1	A2081	2037	1157A	8-16-51	K. Williams	150	SE SW	Irr. 15 Ac. & Dom.
1	A2490	2287	1877A	5-1-52	W. Boxx	200	SW SE	Irr. 20 Ac.
1	A2257	2073	2235A	12-12-51	R. Edwin	160	SW SE	Irr. 30 Ac.
2	A 288	240	27A	6-24-46	J. Aker	250	NW NE	Irr. 20 Ac.
2	A2824	2597	2373A	11-25-52	B. Altena	200	Govt Lot 3	Irr. 28 Ac.
2	A 289	332	Canc.	6-24-46	H. Brunhaver	(200)	SW NW	Irr. 75 Ac.
2	A 290	246	404A	6-24-46	R. A. & J. E. Kellner	(200)	SE NW	Irr. 10 Ac.
4	A2746	2616	2302A	10-9-52	R. Anderson	136	Govt Lot 4	Irr. 17 Ac.
4	A3215	2933	2666A	5-13-53	R. M. Rhea	140	SE NW	Irr. 14 Ac.
4	A3140	2015	Canc.	4-2-53	E. H. Hatter	(200)	NE SW	Irr. 35 Ac.
4	A1851	1761	747A	3-5-51	R. Dusenbery	200	NW SW	Irr. 20 Ac.
4	A2714	2495	1735A	9-17-52	C. Holmes	150	SW SW	Irr. 20 Ac.
5	A4743	4479	3354A	1-2-58	F. Eagle	130	NE SE	Irr. 13 Ac.
5	D1026		1013D	6-1-35	H. E. Taylor	60	SW NE	Irr. 25 Ac. & Dom.
5	A3423	3275	Canc.	11-6-53	J. W. Mershon	(200)	SW SE	Irr. 20 Ac.
5	A3674	3479	2803A	6-14-54	R. O'Brine	150	SE SE	Irr. 15 Ac.
6	A2715	2474	2248A	9-17-52	H. F. Rasmussen	160	SE NW	Irr. 51 Ac.
6	A3041	2866	2505A	3-5-53	W. T. Handy	200	W½ SW	Irr. 70 Ac.
6	A3193	2960	2184A	5-1-53	B. Ruffino	320	E½ SE	Irr. 32 Ac.
7	A2326	2147	1995A	2-8-52	L. Hansen	130	NW NE	Irr. 20 Ac.
7	A 56	55	714A	12-10-45	Orchard Water Assn.	50	SW SW	Irr. 2.5 Ac. & Com. Dom.
9	A5179	4866		2-24-59	E. Gorsinger	200	SW NW	Irr. 40 Ac.
10	A4859	4639	3521A	5-13-58	M. W. Witter	160	N½ NE	Irr. 55 Ac.
10	A2434	2220	1458A	4-4-52	C. Nyhus	180	SW NE	Irr. 30 Ac.
10	A 924	841	2675A	6-17-48	G. S. Bacon	160	SE NE	Irr. 50 Ac. & Dom.
10	A 482	451	502A	3-17-47	W. J. Clarkson	100	SE SW	Irr. 5 Ac.
10	A5104	4848		1-19-59	L. Doyle	160	SW SE	Irr. 80 Ac.
11	A3657	3374	2023A	6-2-54	P. O. Maneval	120	NE NE	Irr. 20 Ac.

APPENDIX B

Appendix B lists all valid surface-water filings in the study area as of January 1, 1960. Cancelled permits and rejected applications are not listed since it is assumed no diversions are taking place under them.

These rights are listed on a drainage area basis, with three major drainages, which are the Nooksack River, Coastal Area, and Sumas River drainage. Sub-basins are listed separately within each major basin. In the Nooksack and Sumas basins, the sub-basins are listed in ascending order of their junction with the main stream, while in the coastal area they are arranged geographically, north to south.

The first three columns of the tabulation refer to the application, permit, and certificate numbers of a particular right. The absence of a number in a column indicates that an application has not yet progressed to permit status or has not been perfected to certificate.

The priority column indicates the date upon which the application was received; thus determining its priority relative to other rights which may affect or be affected by it.

The source column lists the specific body of water from which the diversion is made.

The next column, "Name," refers to the name of the applicant, permittee, or original holder of the certificate, and does not necessarily refer to the present holder of the right or owner of the land. Once a certificate of water right is issued, it becomes appurtenant to the land, and the Division of Water Resources does not retain records of changes of ownership.

The quantity column lists the amount of water in cubic feet per second which may be diverted under a specific right. Storage capacity is shown in acre-feet.

The location of point of diversion column indicates the township, range, smallest recorded sub-division, and section in which the diversion point is situated.

The use column shows the specific utilization under the right, and in the case of irrigation, lists the number of acres. The following abbreviations are used in this column.

Ac. ----------------------	Acres
Com. Dom. ----------------	Community Domestic
Fire Prot. ----------------	Fire Protection
Fish ---------------------	Fish Propagation
Ind. ----------------------	Industrial
Irr. ----------------------	Irrigation
Wild ----------------------	Wildlife

APPENDIX B

SURFACE-WATER RIGHTS ON RECORD WITH THE DIVISION OF WATER RESOURCES AS OF JANUARY 1, 1960

NOOKSACK RIVER BASIN DRAINAGE

Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
7269	4958	4384	6-24-46	Nooksack River	H. Kellner	0.11	40/2E	Govt Lot 4	34	Irr. 11 Ac.
7270	4787	3875	6-24-46	Nooksack River	R. A. Kellner	0.11	40/2E	Govt Lot 6	35	Irr. 11 Ac.
7693	5099	3624	3-17-47	Nooksack River	W. J. Clarkson	0.20	39/2E	Govt Lot 8	9	Irr. 20 Ac.
10297	7564	5052	5-4-51	Nooksack River	M. G. Freeman	0.30	39/2E	Govt Lot 3	21	Irr. 30 Ac.
10651	7608	4406	8-23-51	Nooksack River	L. Frasier	0.60	40/3E	S½SE	21	Irr. 60 Ac.
11579	8556	5629	8-12-52	Nooksack River	H. Bergsma	0.60	39/2E	Govt Lot 7	29	Irr. 60 Ac.
11970	8809	6000	1-13-53	Nooksack River	General Petroleum Co.	5.00	39/2E	Govt Lot 2	29	Manufacturing
12259	9043	6613	4-14-53	Nooksack River	B. Luther	0.25	39/2E	W½NW	21	Irr. 25 Ac.
12322	9100	5442	5-5-53	Nooksack River	I. Strickland	0.80	39/2E	Govt Lot 6	3	Irr. 80 Ac.
12424	9199		6-22-53	Nooksack River	I. Anderson	0.36	39/2E	Govt Lot 4	32	Irr. 35 Ac. & Dom.
12453	9393	6003	7-15-53	Nooksack River	E. D. Alderson	0.40	40/2E	Govt Lot 8	36	Irr. 40 Ac.
12796	9590	5859	3-4-54	Nooksack River	P. H. Stuurmans	0.12	40/3E	Govt Lot 7	20	Irr. 12 Ac.
13039	9705	6343	7-23-54	Nooksack River	J. D. Parcher	0.50	40/3E	Govt Lots 8, 10 & 11	30	Irr. 50 Ac.
13788	10337	7307	4-2-56	Nooksack River	R. L. Nutter	0.60	40/2E	Govt Lot 4	34	Irr. 60 Ac.
13816	10396	7008	4-26-56	Nooksack River	G. T. Bode	0.325	40/3E	Govt Lot 5	30	Irr. 32.5 Ac.
13921	10482	6820	6-13-56	Nooksack River	V. B. Ritter	0.20	40/2E	Govt Lot 5	35	Irr. 20 Ac.
13923	10426	7009	6-15-56	Nooksack River	F. E. Landaal	0.70	39/2E	Govt Lots 9 & 10	16	Irr. 70 Ac.
14040	10579	6921	8-22-56	Nooksack River	G. J. Polinder	0.40	40/3E	Govt Lot 4	29	Irr. 40 Ac.
14152	10598	6821	12-3-56	Nooksack River	City of Lynden	5.00	40/3E	Govt Lot 4	20	Municipal Supply
14207	10649	7285	1-28-57	Nooksack River	H. De Valois	0.27	40/3E	Govt Lot 2 & S½SW	29 20	Irr. 32 Ac.
14333	10756		5-16-57	Nooksack River & Pond	W. Scholten	1.24	39/4E	NW¼ & Govt Lot 6	6	Irr. 124 Ac.
14758	11188		4-21-58	Nooksack River & Unnamed Ditch	J. A. Timmer	**0.16	40/3E	NENW & Govt Lot 8	30	Irr. 16 Ac.
14860	12017	7634	6-19-58	Nooksack River	A. & E. Elsasser	0.78	39/2E	Govt Lots 6, 7 & 11	32	Irr. 78 Ac.
15167	11236		11-14-58	Nooksack River	O. Hovander	0.30	39/2E	Govt Lot 1	32	Irr. 30 Ac.

Distributary of Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
13056	9730	7078	8-3-54	Steamboat Slough	D. L. Abshire	0.10	J. G. Hedge D.L.C., #41 (38/2E	SWSE	7)	Irr. 10 Ac.

Tenmile Creek Drainage

Tenmile Creek Tributary Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
1790	795	211	7-15-26	Tenmile Creek	B. S. Hillier	0.20	39/2E	SWSE	13	Irr. 10 Ac. & Dom.
2036	971	269	3-26-27	Tenmile Creek	C. K. McMillin	2.00	39/2E	E½SW	22	Irr. 40 Ac.
Certificate of Change		642			A. C. Pottle					
2222	1120	330	1-11-28	Tenmile Creek	J. E. McDonald	0.25	39/2E	SWNW	23	Irr. 10 Ac.
2362	1178	306	7-11-28	Tenmile Creek	W. F. Locke	0.05	39/2E	SESW	13	Dom. & Garden
4152	2276	1974	9-11-35	Barrett Lake	H. K. Russell	0.30	39/2E	SWSW	21	Irr. 30 Ac.
6669	4313	3165	9-14-45	Tenmile Creek	J. Boyd	0.13	39/3E	Govt Lot 3	18	Irr. 13 Ac.
7026	4567	2565	4-4-46	Tenmile Creek	J. Lee Bruns	0.15	39/2E	SESW	13	Irr. 15 Ac.
7253	4775	3102	6-15-46	Tenmile Creek	F. Oltman	0.20	39/3E	NWSE	18	Irr. 20 Ac.
7431	4830	2837	9-5-46	Tenmile Creek	J. E. Bruns	0.10	39/2E	SESW	13	Irr. 10 Ac.
7640	5021	6291	2-15-47	Tenmile Creek	A. M. Hougan	0.30	39/2E	NWSE	22	Irr. 40 Ac.
8438	6091	3959	5-18-48	Tenmile Creek	L. Egerdal	0.13	39/2E	SWSW	13	Irr. 13 Ac.
Certificate of Change		625			L. Egerdal					
8697	6308	5819	12-27-48	Tenmile Creek	L. Kent	0.30	39/2E	SENE	22	Irr. 30 Ac.
9498	6677	4046	3-31-50	Tenmile Creek	H. Cole	0.28	39/3E	SESW	18	Irr. 28 Ac.
9757	7051	5658	7-12-50	Barrett Lake	R. Downey	0.09	39/2E	SESW	21	Irr. 9 Ac.
10477	7511	5747	7-10-51	Tenmile Creek	H. Glass	0.19	39/3E	NESE	18	Irr. 19 Ac.
10598	7627		8-10-51	Tenmile Creek	J. Murray	0.20	39/3E	SWNE	26	Irr. 20 Ac.
10876	8086	7226	11-15-51	Barrett Lake	A. Schachtschneider	0.125	39/2E	SWSW	21	Irr. 12 Ac.

** Diversion allowed from Nooksack River and Unnamed Ditch, total quantity not to exceed 0.16 cfs.

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use

NOOKSACK RIVER BASIN DRAINAGE

Tenmile Creek Drainage (Continued)

Tenmile Creek Tributary Nooksack River

10888	11742		11-21-51	Tenmile Creek	S. A. Tarr	0.30	39/3E	NWNE	21	Irr. 30 Ac.
11210	8164	6247	3-31-52	Barrett Lake	E. Bellingar	0.02	39/2E	SWSW	21	Irr. 2 Ac.
16016			9-4-52	Tenmile Creek	D. L. Anderson	0.35	39/2E	NENW	23	Irr. 50 Ac.
11877	8806	6248	12-3-52	Barrett Creek	D. McKay	0.26	39/2E	NESE	20	Irr. 26 Ac.
12369	9180	6666	5-27-53	Barrett Lake	A. Bryant	0.07	39/2E	SWSW	21	Irr. 7 Ac.
12480	9200	6824	8-3-53	Barrett Lake	R. Stanton	0.30	39/2E	SWSE	21	Irr. 30 Ac.
13875	10415		5-28-56	Barrett Lake & Springs	J. Byers	1.00	39/2E	SESE	21	Irr. 30 Ac., Dom. & Fish
16059			9-10-56	Tenmile Creek	R. B. Hong	0.20	39/2E	SWSW	22	Irr. 20 Ac.

Deer Creek Tributary Barrett Lake

5653	3623	2404	2-26-42	Deer Creek	J. Roth	0.03	39/2E	NENW	27	Irr. 3 Ac.
7288	5455	4712	6-27-46	Deer Creek	C. A. Erdman	0.005	39/2E	NESW	26	Dom.

Ravine Creek Tributary of Tenmile Creek

4714	2687	1221	1-10-39	Ravine Creek	Woodlawn Cemetery	0.25	39/2E	SENW	22	Irr. 10 Ac.

Fourmile Creek Tributary Tenmile Creek

4898	2987	1762	7-6-39	Fourmile Creek	Fircrest Farm	0.55	39/3E	NWSE	9	Irr. 50 Ac.
6235	4013	2401	11-13-44	Fourmile Creek	E. D. Kenoyer	0.40	39/3E	SENW	18	Irr. 40 Ac.
6586	4372	2792	8-23-45	Fourmile Creek	F. Snydar	0.19	39/3E	NWNE	18	Irr. 19 Ac.
6672	4314	3166	9-18-45	Fourmile Creek	J. Boyd	0.15	39/3E	Govt Lot 3	18	Irr. 15 Ac.
7835	5627	4420	5-23-47	Green Lake	J. E. Roosma	0.15	39/3E	NENE	9	Irr. 15 Ac.
8317	5856	3851	4-5-48	Fourmile Creek	E. Brown	0.14	39/3E	SWNE	18	Irr. 14 Ac.
10556	7622	4935	8-1-51	Fourmile Creek	F. Snydar	0.60	39/3E	SWNE	18	Irr. 60 Ac.
15428	11486		5-19-52	Fourmile Creek	D. Parker	0.39	39/3E	N½NE	18	Irr. 39 Ac.
11783	8804	6443	10-22-52	Green Lake	J. Eiene	0.40	39/3E	NWNW	10	Irr. 40 Ac.
13354	10081	6702	3-28-55	Green Lake	N. Lunde	0.20	39/3E	SENE	9	Irr. 20 Ac.
13863	10347	6947	5-23-56	Unnamed Pond	J. Garrison	0.05	39/3E	W½NW	15	Irr. 5 Ac.
15429	11611		7-18-56	Fourmile Creek	B. Vander Ploeg	0.80	39/3E	SESW	8	Irr. 80 Ac.
15265	11297		12-16-58	Fourmile Creek	G. Alvord	0.40	39/3E	SWNW	18	Irr. 40 Ac.

Silver Spring Brook Tributary Tenmile Creek

4744	2725	2277	2-18-39	Silver Spring Br.	W. Holz	0.20	39/3E	NENW	19	Irr. 20 Ac. & Dom.
4858	2927	1952	5-31-39	Silver Spring Br.	W. Holz	0.25	39/3E	SENW	19	Irr. 20 Ac. & Dom.
4861	2918	2308	6-1-39	Silver Spring Br.	J. Ward	0.35	39/3E	SESW	18	Irr. 30 Ac. & Dom.

Unnamed Tributary of Tenmile Creek

12625	9521	6229	10-22-53	Unnamed Pond	E. K. Ahrens, Jr.	0.30	39/3E	S½NE	23	Irr. 30 Ac.

Unnamed Ditch Tributary Nooksack River

7718	5100	3625	3-29-47	Unnamed Ditch	W. J. Clarkson	0.67	39/2E	S½SE	9	Irr. 70 Ac.

Wiser Lake Creek Drainage

3504	1890	2460	9-8-31	Wiser Lake Creek	S. H. Johnson	0.85	39/2E	SWSE	3	Irr. 85 Ac. & Dom.
7434	4836	3950	9-6-46	Wiser Lake Creek	J. Aker	0.38	39/2E	E½SW	2	Irr. 40 Ac.
7675	5095	3097	3-11-47	Wiser Lake Creek	A. Dodd	0.20	39/2E	W½SW	2	Irr. 60 Ac.
9058	6140	3701	9-8-49	Wiser Lake	J. V. Hopfinger	0.10	39/3E	SENW	6	Irr. 10 Ac.
10069	7368	6471	1-17-51	Bellingar Ditch	O. Dykstra	0.20	39/3E	Govt Lot 4	5	Irr. 30 Ac.
10506	7775	5947	7-17-51	Wiser Lake Creek	B. A. Strickland	0.26	39/2E	NESE	3	Irr. 26 Ac.
10841	7876	5603	10-29-51	Wiser Lake Creek	S. H. VanWoudenberg	0.75	39/2E	Govt Lot 1 N½NW	9 10	Irr. 147 Ac.
10802	7750	5093	10-15-51	Wiser Lake	F. Steensma	0.30	39/3E	SWNE	6	Irr. 30 Ac.
11128	8067	5148	3-10-52	Wiser Lake	C. D. Bartlett	0.09	39/3E	SENW	6	Irr. 9 Ac.
11216	8136	6220	4-4-52	Wiser Lake	J. Jansen	0.21	39/3E	Govt Lot 5	6	Irr. 20 Ac. & Dom.
11310	8256	5470	5-1-52	Wiser Lake	W. A. Rhea	0.18	39/2E	E½NE	1	Irr. 18 Ac.
11997	9445	5875	1-22-53	Wiser Lake	I. Johnston & I. DeWaard	0.53	39/2E	Govt Lot 2	1	Irr. 53 Ac.

NOOKSACK RIVER BASIN DRAINAGE

Schneider Ditch Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.)	(Subdivision)	(Sec.)	Use
4214	2301	1552	4-6-36	Schneider Ditch	W. Menser	0.10	40/2E	NESW	29	Irr. 20 Ac.
6890	7179	5228	2-7-46	Unnamed Stream	W. E. Knutsen	0.40	39/2E	NWNE	4	Irr. 40 Ac.
11005	8107	4843	1-29-52	Schneider Ditch	G. Monson	0.76	39/2E	E½NE	4	Irr. 76 Ac.
11199	8121	4808	3-31-52	Schneider Ditch	C. Wilson	0.35	40/2E	N½NW	33	Irr. 100 Ac.
11406	8415	6142	5-29-52	Schneider Ditch	L. Bode	0.25	40/2E	SESW & NWNE	29 32	Irr. 25 Ac.
11946	8829	6507	1-7-53	Schneider Ditch	G. Barnes	0.80	39/2E	SWSE & Govt Lot 2	4 9	Irr. 85 Ac.
12411	9297	6499	6-15-53	North Branch Schneider Ditch	P. R. Jeffcott	0.10	40/2E	N½SW	28	Irr. 10 Ac.
13400	10118	7358	4-27-55	Unnamed Ditch	L. Webster	0.15	40/2E	NENW	32	Irr. 15 Ac.

Bertrand Creek Drainage

Bertrand Creek Tributary Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
1546	671	290	11-12-25	Bertrand Creek	O. L. Sheets	0.80	40/2E	SESW	14	Irr. 20 Ac. & Dom.
Certificate of Change		360			O. L. Sheets					
5117	3052	1384	3-28-40	Bertrand Creek	L. Brown	0.67	40/3E	SESE	22	Irr. 62 Ac.
6952	4495	4472	2-7-46	Bertrand Creek	P. M. Johansen	1.10	40/2E	NWNE	27	Irr. 110 Ac.
7174	4675	2630	5-25-46	Bertrand Creek	I. R. Stauffer	0.25	40/2E	SENE	2	Irr. 25 Ac.
7312	4839	2691	7-10-46	Bertrand Creek	M. Bayes	0.20	40/2E	SESE	11	Irr. 20 Ac. & Dom.
7323	4728	2646	7-15-46	Bertrand Creek	A. F. Kelly	0.25	40/2E	NENW	23	Irr. 25 Ac.
7348	4834	4554	7-30-46	Bertrand Creek	G. Bennink	0.50	40/2E	NESW	27	Irr. 50 Ac.
7520	5432	3469	11-2-46	Bertrand Creek	E. Crandall	0.25	40/2E	SENE	11	Irr. 25 Ac. & Dom.
8081	5433	3470	10-20-47	Bertrand Creek	E. Crandall	0.34	40/2E	NESE	11	Irr. 40 Ac.
9008	6104	3726	7-16-49	Bertrand Creek	E. Tremain	0.20	40/2E	SWSW	26	Irr. 20 Ac.

McClelland Creek Tributary Bertrand Creek

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
5571	3417	2109	9-2-41	McClelland Creek	O. L. Sheets	0.70	40/2E	NWNE	22	Irr. 70 Ac.
8111	7632	4627	11-15-47	McClelland Creek	C. McClelland	0.50	40/2E	S½ SE	15	Irr. 100 Ac.
12412	9184	5726	6-15-53	McClelland Creek	W. E. Holt	0.18	40/2E	SENE	22	Irr. 18 Ac.

Unnamed Tributary of Bertrand Creek

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
7407	4767	4376	8-26-46	Unnamed Slough	R. Dawson	0.10	40/2E	SENW	27	Irr. 10 Ac.
9876	7032	4435	9-10-50	Unnamed Stream	J. B. Wakefield	0.10	40/2E	SWNW	22	Irr. 10 Ac.
15156	11471		10-29-58	Unnamed Stream	A. Stauffer	0.40	40/2E	NWNW	10	Irr. 40 Ac.

Fishtrap Creek Drainage

Fishtrap Creek Tributary Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
1548	672	702	11-16-25	Fishtrap Creek	Whatcom County Dairymen's Association	1.55	40/3E	NWNE	20	Fire Prot. & Manufacturing
5557	3421	1826	8-18-41	Fishtrap Creek	W. H. Waples	0.67	40/3E	SENW & NWSW	16	Irr. 75 Ac.
7492	5242	2974	10-7-46	Fishtrap Creek	A. C. Crabtree	0.34	40/3E	E½SE	17	Irr. 34 Ac.
7737	5545	3748	4-5-47	Fishtrap Creek	W. Telgenhoff	0.05	40/3E	SESW	19	Irr. 5 Ac.
7948	5581	3575	7-26-47	Fishtrap Creek	H. Stremler	0.20	40/3E	S½N½	9	Irr. 20 Ac.
8700	6135	3576	2-18-49	Fishtrap Creek	H. Stremler	0.30	40/3E	S½N½	9	Irr. 40 Ac.
11201	8135	4881	3-31-52	Fishtrap Creek	A. Kelly	0.10	40/3E	SENE	19	Irr. 10 Ac.

Tributaries of Fishtrap Creek

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
1142	441	95	7-19-24	Double Ditch	P. M. Serrurier	1.00	40/3E	S½S½	18	Irr. 80 Ac.
4659	2713	1830	10-27-38	Double Ditch	Anderson & Cruikshank	0.20	40/3E	SENE	19	Irr. 17 Ac.
5048	3067	4097	1-4-40	W. Guide Meridian Ditch	H. Tromp	1.00	40/2E	NESW	13	Irr. 100 Ac.
5661	3594	2362	3-10-42	Double Ditch	A. Hempel	0.10	40/3E	SWSE	6	Irr. 10 Ac.
5857	3780	3434	6-25-43	E. Guide Meridian Ditch	J. Harcoff, Sr.	0.20	40/3E	NWNW	19	Irr. 20 Ac.
7244	5355	3627	6-13-46	Double Ditch	Double Ditch Water Assn.	5.0	40/3E	Govt Lots 2 & 3	31	Dom., Stock & Irr. (Gardens)
14758	11188		4-21-58	Nooksack River & Unnamed Ditch	J. A. Timmer	**0.16	40/3E	NENW & Govt Lot 8	30	Irr. 16 Ac.

** Diversion allowed from both Nooksack River and Unnamed Ditch, total quantity not to exceed 0.16 cfs.

NOOKSACK RIVER BASIN DRAINAGE

Scott Ditch (Drainage Ditch #22) Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
2028	978	1358	3-9-47	Elder Ditch	G. Knittel	1.00	40/3E	E½NE	33	Irr. 40 Ac.
2723	1395	1764	9-30-29	Scott Ditch	R. Van Dyk	0.80	40/3E	NENE &	34	Irr. 97 Ac.
								NWNW	35	
5428	3328.	4277	4-24-41	Scott Ditch	C. E. Osgood	0.66	40/3E	S½SE	29	Irr. 66 Ac.
6781	4485	2524	11-23-45	Scott Ditch	O. Graep	0.40	40/3E	SE NW	35	Irr. 40 Ac.
7073	4576	2645	4-24-46	Elder Ditch	A. Burns	0.35	39/3E	Govt Lot 1	3	Irr. 17.5 Ac.
8406	6275	7046	5-20-48	Scott Ditch	E. E. Nolte	0.75	40/3E	NWSW	36	Irr. 137 Ac.
10333	7459	4285	5-14-51	Scott Ditch	A. Brue	0.20	40/3E	SENE	35	Irr. 20 Ac.
10891	7905	5036	11-23-51	Scott Ditch	J. Andriesen	0.24	40/3E	SWSW	28	Irr. 32 Ac.
11069	8078	4867	2-18-52	Scott Ditch	C. E. Osgood	0.20	40/3E	NWNW	33	Irr. 20 Ac.
13999	10593	7135	3-6-56	Elder Ditch &	P. Van Dyk, Sr.	0.70	40/3E	E½NE &	33	Irr. 70 Ac.
				Scott Ditch				N½NW	34	
13916	10481	7116	6-11-56	Scott Ditch	J. Elenbaas	0.20	40/3E	NENW	33	Irr. 20 Ac.
14486	12055	7794	7-1-57	Scott Ditch	J. Roosma	0.18	40/3E	NWNE	33	Irr. 18 Ac.
15453	11548		5-11-59	Scott Ditch	S. Vander Veen	0.40	40/3E	SWNE	35	Irr. 40 Ac.

Stickney Slough Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
5418	3369	4213	4-18-41	Harvey Creek	J. Alexander, et al	0.04	40/3E	W½SW	11	Dom. & Stock
6503	4242	2352	6-28-45	Kamm Ditch	W. VandeKamp	0.34	40/3E	SWSE	15	Irr. 40 Ac.
10945	8074		12-31-51	Unnamed Stream	G. Bajema	0.30	40/3E	SWSW	11	Irr. 30 Ac.
11127	8132	4796	3-10-52	Mormon Ditch	P. VanDyken	0.30	40/3E	SWNW	22	Irr. 30 Ac.
11131	8212	5183	3-10-52	Stickney Slough	N. Beukelman	0.24	40/3E	E½E½	20	Irr. 24 Ac.
11241	8574	5645	4-14-52	Mormon Ditch	B. Meenderinck	0.25	40/3E	SENE	22	Irr. 25 Ac.
12277	9195	6870	4-20-53	Kamm Ditch	J. Wagter	0.20	40/3E	SESE	15	Irr. 20 Ac.
12543	9446	6623	8-31-53	Stickney Slough	G. W. Frick	0.10	40/3E	SWNW	21	Irr. 10 Ac.
13032	9742	6617	7-20-54	Kamm Ditch &	J. Weeda	0.20	40/3E	SESW &	15	Irr. 20 Ac.
				Mormon Ditch				NENW	22	
13963	10429	7010	6-15-56	Stickney Slough	F. Landaal	0.07	40/3E	SWNW	21	Irr. 7 Ac.

Anderson Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
2528	1329	872	2-16-29	Anderson Creek	Bellingham National Bank	0.05	38/4E	NWNW	17	Irr. & Dom.
4241	2321	1129	6-16-36	East Fork	Glen Echo Coal Company	1.1	38/4E	NENW	8	Mining & Power
				Anderson Creek						
5767	3636	2408	12-9-43	Anderson Creek	E. W. Gooding	0.01	38/4E	NENE	7	Dom. & Industrial
8430	5839	3480	5-28-48	Anderson Creek	L. L. Ladiser	0.01	38/4E	NWSE	6	Dom.
12320	9262	6644	5-4-53	Unnamed Brook	D. Cress	0.11	38/4E	NENW	17	Irr. 10 Ac. & Dom.
14921	12034		7-18-58	Unnamed Creek	R. Burgy	0.60	39/4E	NWNW	32	Irr. 60 Ac.
15003	11191	7506	8-19-58	Unnamed Creek	F. Lange	0.011	39/4E	NWNW	29	Irr. 1.1 Ac.
15096	11194		9-23-58	Unnamed Pond	W. Meyer	0.35	39/4E	NWSW	29	Irr. 35 Ac.

Smith Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
5384	3297	1736	3-14-41	Smith Creek	I. O. Hilliard	0.10	39/4E	NWNE	26	Irr. 8 Ac. & Dom.
7119	4613	2614	5-14-46	Smith Creek	F. I. Hatley	0.07	39/4E	SESW	22	Irr. 7 Ac.
7381	4763	3374	8-12-46	Unnamed Slough	E. Cutler	0.04	39/4E	NWSE	26	Irr. 4 Ac. & Dom.
7802	5244	3468	5-5-47	Unnamed Spring	B. Knight	0.05	39/5E	Govt Lot 5	31	Irr. 20 Ac.
10207	7347	4196	3-24-51	Smith Creek	H. Hoytema	0.24	39/4E	SWNE	21	Irr. 24 Ac.

South Fork Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
4372	4402		4-6-37	So. Fork Nooksack	City of Bellingham	50.0	37/5E	NE	35	Municipal
5657	3633	1910	3-6-42	So. Fork Nooksack	Marona Mill Company	2.50	37/5E	Govt Lot 9	6	Millpond
6477	4257	2900	6-7-45	Olsens Slough	L. Sygitowicz	0.20	38/5E	Govt Lot 11	7	Irr. 36 Ac.
11004	7957	5166	1-28-52	So. Fork Nooksack	P. Gravesgard	0.09	37/5E	Govt Lot 1	6	Irr. 9 Ac.

Various Tributaries South Fork Nooksack River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
4156	2273	936	9-18-35	McCarty Creek	Marona Mill Company	0.20	37/4E	SENE	1	Millpond
5524	3412	1719	7-24-41	Jones Creek	E. E. Boyd	0.05	37/5E	NENW	7	Millpond
7265	4765	4266	6-20-46	Unnamed Spring	W. Teeple	0.30	38/5E	SWSW	18	Irr. 30 Ac.
7820	5210	3555	5-15-47	Unnamed Creek	F. A. Kuipers	0.02	38/5E	SWSE	7	Dom.
10327	7471	4335	5-11-51	Unnamed Stream	W. W. Carr	0.05	37/5E	SWSE	21	Com. Dom.
12898	9593	6608	5-4-54	Black Slough	A. J. Johnson	0.50	38/5E	E½SW	20	Irr. 50 Ac.
14369	10751	7310	6-14-57	Unnamed Pond	C. Longstreth	0.40	38/5E	NENE	19	Irr. 40 Ac.
				Tributary Black Slough						

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
NOOKSACK RIVER BASIN DRAINAGE										
Various Tributaries South Fork Nooksack River										
15023	11362		8-27-58	Unnamed Brook	C. Keplinger	0.20	38/5E	NENE	17	Irr. 20 Ac.
15384	11441		4-8-59	Unnamed Tributary	C. Dickey	0.30	37/5E	NWSW	5	Irr. 30 Ac.
Middle Fork Nooksack River										
1517	615	98	10-15-25	Canyon Creek	Chicago, Milwaukee, St. Paul & Pacific Railroad	0.10	39/5E	SESE	27	Railway
13150	9855		10-6-56	Middle Fork Nooksack River	City of Bellingham	250.0	38/6E	NE	19	Municipal, Ind. & Dom.
North Fork Nooksack River										
13696	10406	6754	11-22-55	N. Fork Nooksack	State Fisheries	3.00	39/5E	Govt Lot 9	3	Fish
Maple Creek Drainage Tributary North Fork Nooksack River										
2711	1387	386	9-20-29	Ferry Creek	H. J. Bouma	1.00	40/6E	SWSW	8	Dom. & Lights
Certificate of Change		447			H. J. Bouma					
2838	1511	759	1-29-30	Unnamed Stream	A. L. Bennett	0.10	40/6E	Govt Lot 11	7	Power & Fire Prot.
4320	2398	1027	12-4-36	Peterson Creek	H. P. Jukes	1.0	40/6E	Govt Lot 13	6	Dom. & Power
6838	4558	2775	1-7-46	Unnamed Spring	A. Sooter	0.01	40/6E	SENW	30	Dom.
7139	4986	2751	5-17-46	Beal Creek	F. D. Fobes	0.01	40/6E	SWSW	20	Dom.
7197	4985	2752	5-31-46	Doakes Creek	A. L. & F. D. Fobes	0.03	40/5E	SESE	24	Irr. 1.5 Ac. & Dom.
7988	5575	3131	8-18-47	Unnamed Spring	Maple Falls Water Coop.	0.2	40/6E	SESE	19	Dom.
8011	5510	3033	8-30-47	Unnamed Spring	Orville Ferry	0.01	40/6E	Govt Lot 10	7	Dom. & Stock
10989	8076	5995	1-18-52	Ferry Creek	M. F. German	0.45	40/6E	NESE & NENW	18 17	Irr. 44 Ac. & Dom.
12812	9878	6772	3-15-54	Ferry Creek	H. J. Bouma	0.60	40/6E	SWSW	8	Irr. 60 Ac.
Various Tributaries North Fork Nooksack River										
4265	2305	970	8-1-36	Galena Creek	Mt. Baker Ski Club	0.80	39/9E		17	Hydro-Electric
4377	2492	1150	4-15-37	Unnamed Tributary Thompson Creek	U. S. Forest Service	0.1	39/7E	NESW	8	Dom.
4415	2493	1145	6-2-37	Unnamed Stream Trib. N. Fork Nooksack River	U. S. Forest Service	0.05	39/8E	SWNE	1	Dom.
4432	2497	1077	6-25-37	Lookout Creek	U. S. Forest Service	0.10	40/7E	SWSE	35	Dom.
5302	3224	1638	11-13-40	Trib. Bagley Lake	Mt. Baker National Forest	0.05	39/9E		19	Dom.
6014	3860	2068	4-27-44	Unnamed Stream Trib. N. Fork Nooksack River	State Highway Commission	0.10	40/8E	NESE	36	Dom.
6015	3861	2184	4-27-44	Unnamed Stream Trib. N. Fork Nooksack River	State Highway Commission	2.00	40/8E	SENE	36	Power
7670	5263	2901	3-8-47	Unnamed Spring	W. Brown	0.01	39/7E	NENW	7	Dom.
8485	5857	3719	6-18-48	Cascade Creek	L. F. Becker	0.15	39/7E	Govt Lot 5	1	Power & Dom.
8624	5951	3341	10-15-48	Maple Creek	Mt. Baker National Forest	0.06	40/7E	SWSW	33	Com. Dom.
15006	11747		8-20-57	Unnamed Stream	Baptist Gen'l Convention of Oregon Washington	1.00	40/6E	SENW	27	Com. Dom.
Separate Drainages Within Nooksack River Drainage										
Willey Lake Drainage Area										
8887	6818	4193	7-6-49	Willey Lake	R. S. Ellis	0.40	40/2E	SWSW	27	Irr. 40 Ac.
9196	6319	3751	11-7-49	Willey Lake	M. Jensen	0.50	40/2E	SWSW	27	Irr. 80 Ac. & Dom.
10053	7407	4696	1-8-51	Willey Lake	J. Monahan	0.40	40/2E	SESE	28	Irr. 40 Ac.
Unnamed Slough Drainage										
14948	12096	7757	7-30-58	Unnamed Slough	R. R. Knutzen	0.60	40/2E	Govt Lot 2	25	Irr. 60 Ac.
14997	11229		8-15-58	Unnamed Slough	G. Talmage	0.50	40/2E	SWSE	25	Irr. 50 Ac.
Lake Fazon Drainage										
11633	8580	5106	8-29-52	Fazon Lake	J. Ulrich	0.35	39/3E	W½SW	13	Irr. 35 Ac.
14010	10404	6981	8-6-56	Fazon Lake Outlet	E. K. Ahrens	0.28	39/3E	NENW	13	Irr. 30 Ac.
14035	10578	6895	8-17-56	Fazon Lake	C. Zamzow	0.10	39/3E	SW	13	Irr. 15 Ac.
14078	10559		9-14-56	Fazon Lake & Springs	R. J. Needham	0.51	39/3E	SESW & NENW	13 24	Irr. 50 Ac. & Dom.

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use

NOOKSACK RIVER BASIN DRAINAGE

Separate Drainages Within Nooksack River Drainage (Continued)

Unnamed Brook Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
13322	10215		3-2-55	Unnamed Pond	D. D. Allison	0.56	39/4E	W½NW	28	Irr. 55 Ac. & Dom.
14083	10524	7599	7-17-56	Spring-fed Pond	R. W. Carbee	0.22	39/4E	SESE	29	Irr. 20 Ac.

Germans Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
6143	4023	2433	9-9-44	Germans Creek	G. Straka	0.27	41/5E	N½SE	36	Irr. 26 Ac. & Dom.
8890	6096	4370	7-7-49	Unnamed Spring	R. N. Heller	0.015	41/6E	SWSE	31	Dom.

COASTAL AREA DRAINAGE

Dakota Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
1607	645	902	2-8-26	Spring Branch Cr.	A. Benefield	0.10	40/2E	W½SE	7	Irr. 3 Ac. & Dom.
3923	2112	889	1-17-34	Spring Branch Cr.	R. B. LeCocq	0.10	40/2E	NWSW	8	Irr. 6 Ac. & Dom.
4598	2632	1165	8-20-38	Dakota Creek	H. M. Whitford	0.10	40/1E	NWSE	15	Irr. 7 Ac.
5708	3587		6-11-42	N. Fork Dakota Cr.	J. V. Thompson	0.03	40/1E	SWSW	13	Irr. 2 Ac. & Dom.
6822	4424	3212	12-24-45	Unnamed Stream	J. A. Bingman	0.01	40/1E	NWNE	10	Dom.
7723	5474	3298	3-31-47	Dakota Creek	W. E. Pendleton	0.30	40/1E	SENE	15	Irr. 30 Ac.
8249	5702	4596	2-25-48	S. Fork Dakota Cr.	J. Leland	0.24	40/1E	NENW	24	Irr. 24 Ac.
10225	7466	5306	4-5-51	Spring Branch Cr.	R. B. LeCocq	0.50	40/2E	W½SW	8	Irr. 60 Ac.
10718	7777	4982	9-11-51	N. Fork Dakota Cr.	M. Lyle Honrud	0.18	40/1E	NENW	13	Irr. 18 Ac.
11410	8332	5462	6-2-52	N. Fork Dakota Cr.	M. O. Honrud	0.15	40/1E	NENE	13	Irr. 15 Ac.
12676	9663	6021	12-1-53	Olason Reservoir	S. Olason	0.70	40/1E	NWSE	5	Irr. 60 Ac.
15183	11460		11-24-58	Unnamed Spring	J. P. Mutch	0.20	40/1E	SWNW	10	Irr. 20 Ac.

California Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
4531	2625		5-27-38	California Creek	J. Hills	0.5	40/1E	SESE	35	Irr. 80 Ac.
6151	3993	2274	9-18-44	Unnamed Creek	S. N. Friborg	0.20	40/1E	NWNE	20	Irr. 20 Ac.
7617	4996	3436	1-29-47	Ditch District #7	C. R. Behme	0.07	40/1E	NENE	35	Irr. 7 Ac.
10441	7526	4850	6-27-51	Unnamed Stream	C. Smith	0.01	39/1E	NENW	12	Dom.
11146	8114	5311	3-14-52	Unnamed Creek	P. Holtzheimer	0.17	40/1E	NWSW	21	Irr. 17 Ac.
12955	9734	6982	6-2-54	Ditch District #7	P. L. James	0.25	40/1E	SESW	25	Irr. 25 Ac.
15125	11243		10-10-58	Unnamed Brook	H. L. Carter	0.10	39/1E	SWSE	12	Irr. 10 Ac.
15179	11244	7495	10-15-58	Pond	L. Ferrill	0.18	39/1E	NWSW	1	Irr. 18 Ac.
R15401			4-17-59	Pond	S. Timmermans	9 ac-ft	40/1E	NENE	33	Irr. 20 Ac.

Unnamed Stream Tributary of Georgia Strait

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
13623	10244	7473	10-4-55	Unnamed Spring	N. R. Townsend	0.36	39/1E	W½NW	20	Irr. 38 Ac.

Unnamed Stream Tributary Birch Bay

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
5511	3511	3177	7-15-41	Unnamed Stream	O. G. Cook	0.25	40/1E	SENW	29	Irr. 30 Ac. & Dom.
15447	11422	7774	5-7-59	Unnamed Stream	D. R. Halzer	0.02	40/1E	S½NE	30	Dom. & Stock

Unnamed Spring Tributary Drayton Harbor

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
13935	10403	6676	6-22-56	Unnamed Spring	R. M. Foster	0.01	40/1W	Govt Lot 1	13	Dom.

Unnamed Stream Tributary Drayton Harbor

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
14843	11106		6-9-58	Unnamed Spring	E. G. Westman	0.50	40/1E	SWSW	8	Irr. 20 Ac. & Fish
15036	11192		9-2-58	Unnamed Creek	H. T. Johnson	0.02	40/1E	SESE	7	Stock & Dom.

Terrell Creek Drainage Tributary Birch Bay

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
R9652	R158	4055	6-2-50	Terrell Creek	Department of Game	5600 ac-ft	39/1E		16	Fish & Wild
12547	10273	7336	9-1-53	Unnamed Stream	E. Krause	0.60	39/1E	W½SW	6	Irr. 60 Ac.
R13043	R190	6706	7-27-54	Fingalson Creek	V. F. Smrekar	24 ac-ft	39/1E	SESE	4	Irr. 15 Ac. & Wild
15068	11249		9-9-58	Med-O-Land Res.	P. J. Unruh	0.40	39/1W	SESE	1	Irr. 25 Ac.
R15069	R226		9-9-58	Unnamed Stream	P. J. Unruh	20 ac-ft	39/1W	SESE	1	Reservoir

COASTAL AREA DRAINAGE

Lummi (Red) River Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.)	(Subdivision)	(Sec.)	Use
8413	5838	3921	5-21-48	Lummi(Red)River	F. Brys	0.74	39/2E	NWSE	31	Irr. 74 Ac.
10521	7897	5165	7-23-51	Schell Ditch	G. Schaeffer, Jr.	0.35	39/1E	E½SE	25	Irr. 35 Ac.
11279	8195	5839	4-25-52	Lummi(Red)River	P. Hood	1.60	38/2E	Govt Lot 5	6	Irr. 160 Ac.
12916	9723	6066	4-21-54	Unnamed Ditch & Lummi(Red)River	F. Beck	0.16	39/1E 39/2E	SESE SWSW	36 31	Irr. 76 Ac.
15758	11746		11-6-59	Intermittent Stream	N. Nubgaard	0.50	39/1E	NESE	24	Irr. 50 Ac.

Silver Creek Drainage

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
1959	907	368	1-7-27	Silver Creek	Sunset Water Company	0.11	39/2E	SESE	34	Dom. Supplies
2004	925	918	2-17-27	Silver Creek	J. Aberg	0.016	39/2E	SWSW	34	Irr. 1 Ac. & Dom.
2027	910	199	3-7-27	Silver Creek	Andreas & Haselwood	0.02	39/2E	NWSE	34	Dom.
2395	1313	354	8-21-28	Silver Creek	S. W. Monroe	0.01	39/2E	SESE	34	Dom. & Stock
Certificate of Change		530	8-21-28	Silver Creek	A. E. Boyd	0.05	39/2E	SESW	35	Irr. 5 Ac.
3636	1903	1049	5-16-32	Silver Creek	G. Cross	0.015	39/2E	SWSE	34	Irr. 1.5 Ac. & Dom.
5755	3622	1929	7-27-42	Andreason Ditch	G. LaBounty	0.02	39/2E	NWSW	35	Dom. & Garden
6616	4363	2575	8-22-45	Silver Creek	R. Stephens	0.10	39/2E	SWSW	35	Irr. 20 Ac.
7242	4990	4123	6-13-46	Andreason Ditch	G. LaBounty	0.01	39/2E	NWSE	35	Dom.
7255	4837	2690	6-15-46	Andreason Ditch	E. Erickson	0.005	39/2E	NWSW	35	Dom.
7305	5024	4316	7-5-46	Silver Creek	F. Smith	0.1	38/2E	SENW	4	Irr. 10 Ac. & Dom.
8213	5564	3993	2-6-48	Silver Creek	E. F. Peterson	0.25	39/2E	NWSW	34	Irr. 30 Ac.
8434	5824	3332	6-1-48	Tennant Lake	E. D. Beckover	0.40	39/2E	SESE	29	Irr. 50 Ac.
12497	9618		8-10-53	Unnamed Spring	J. Sherin	0.09	38/2E	SENE	4	Irr. 9 Ac.
12726	9492	5734	1-19-54	Unn. Trib. Bear Cr.	C. A. Taylor	0.01	38/2E	NWNE	11	Stock & Fish
14087	10580	7034	9-21-56	Silver Creek	H. Gerard	0.01	39/2E	SESE	34	Irr. 0.5 Ac.
14780	11057		3-14-58	Bear Creek	E. R. Tjomsland	0.21	38/2E	S½N½	2	Irr. 20 Ac. & Stock
15101	11304		9-18-58	Unn. Reservoir	C. V. Wilder	1.60	39/2E	NWSW	36	Irr. 160 Ac.
R15102			9-18-58	Unnamed Springs	C. V. Wilder	30 ac-ft	39/2E	NWSW	36	Storage for Irrigation

Lummi Island Drainages

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
9740	7128	6143	7-3-50	Unnamed Stream & Spring	F. A. Baker	2.22	37/1E	NWNE	22	Irr. 200 Ac., Power & Dom.
11572	8647	5184	7-6-52	Unnamed Stream	Sunrise Cove Water Dev.	0.13	37/1E	NESE	15	Com. Dom.
12535	9364	5625	8-27-53	Unnamed Stream	L. H. Parberry, Sr.	0.005	37/1E	Govt Lot 3	10	Dom.
13465	10088	6729	6-9-55	Unnamed Spring	M. Granger	0.005	38/1E	NWSE	32	Stock
15673	11671		9-8-59	2 Unnamed Streams	L. D. Niedhamer	1.00	37/1E	Govt Lot 2 & SESW	24	Com. Dom.
15781			11-25-59	Unnamed Stream	A. J. & E. G. McMillan		37/1E		23	Com. Dom.
R15782			11-25-59	Unnamed Stream	A. J. & E. G. McMillan		37/1E		23	Com. Dom.

SUMAS RIVER BASIN DRAINAGE

Sumas River

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	T.R.	Subdivision	Sec.	Use
2147	1113	1302	8-23-27	Sumas River	H. E. Scheib	0.10	40/4E	SWSW	16	Irr. 4.5 Ac.
*5216	3184	2139	7-31-40	Sumas River	F. Englehart	0.25	40/4E	SWSW	11	Irr. 20 Ac.
6855	4482	2693	1-16-46	Sumas River	W. H. McRea	0.20	40/4E	NESE	15	Irr. 20 Ac.
7173	4936	3610	5-25-46	Sumas River	F. J. Wildberger	0.25	40/4E	S½S½ & NWNE	2 11	Irr. 25 Ac.
7220	4729	2907	6-7-46	Sumas River	P. Biehle	0.30	40/4E	SWSE	16	Irr. 30 Ac.
7263	4953	3113	6-19-46	Sumas River	L. E. Edwards	0.15	41/4E	Govt Lot 8	35	Irr. 15 Ac.
7355	4751	4962	7-31-46	Sumas River	P. Ostrum	0.12	40/4E	NWSW	21	Irr. 12 Ac.
7591	5000	2857	1-13-47	Sumas River	G. A. Hanowell	0.30	40/4E	W½E½	20	Irr. 30 Ac.
7716	6262	4132	3-27-47	Sumas River	L. M. Parratt	0.03	40/4E	SENE	20	Irr. 3 Ac.
7776	5573	3612	4-24-47	Sumas River	A. D. Banner	0.36	40/4E	SESE	20	Irr. 46 Ac.
8460	5842	3279	5-25-48	Sumas River	A. L. Olsen	0.20	40/4E	NENE	20	Irr. 30 Ac.
10994	8010	5014	1-24-52	Sumas River	E. Froberg	0.60	41/4E	NWSW	36	Irr. 60 Ac.
11032	8003	5039	2-7-52	Sumas River	J. Willemsen	0.20	40/4E	SWNW	15	Irr. 20 Ac.
11145	8082	4807	3-13-52	Sumas River	D. Leenders	0.38	40/4E	NWSW	15	Irr. 38 Ac.
11286	8168	4854	4-28-52	Sumas River	J. Fadden	0.20	41/4E	Govt Lot 3	36	Irr. 20 Ac.
11417	8379	6532	6-3-52	Sumas River	F. Dean	0.55	40/4E	SWNW	14	Irr. 55 Ac.
11852	8688	5885	11-24-52	Kales Slough	J. Vos	0.35	39/4E	NENE	8	Irr. 40 Ac.
14186	10608		1-9-57	Sumas River	J. Lautenbach	0.80	39/4E	NENE	5	Irr. 80 Ac.
14644	10977	7536	1-27-58	Sumas River	M. J. Honcoop	0.35	40/4E	SESE	16	Irr. 35 Ac.

* Certificate in error--change required.

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R.	Subdivision	Sec.)	Use
				SUMAS RIVER BASIN DRAINAGE						
				Saar Creek Drainage						
				Tributaries Saar Creek						
3351	1718	704	4-14-31	Anderson Lake	J. O. Anderson	1.50	40/5E	NENW	7	Power, Dom. & Dairy
8183	5561	3527	1-15-48	Unnamed Stream	C. E. Mathes	0.02	40/5E	NWSE	18	Fish Pond
				Sumas Drainage Ditch Tributary Sumas River						
7589	4952	3112	1-6-47	Sumas Drainage Ditch	L. E. Edwards	0.29	41/4E	Govt Lots 1 & 2	35	Irr. 29 Ac.
				Johnson Creek Drainage						
				Johnson Creek Tributary Sumas River						
6132	3923	2946	8-30-44	Johnson Creek	W. Swanson	0.20	40/4E	NWSW	4	Irr. 20 Ac.
9968	7093	4291	10-30-50	Johnson Creek	A. E. Swanson	0.36	40/4E	SWSE	5	Irr. 36 Ac.
10518	7882	4793	7-20-51	Johnson Creek	J. M. Hammingh	0.15	40/4E	NWNE	3	Irr. 15 Ac.
10743	7898	5087	9-29-51	Johnson Creek	J. C. Jager	0.50	40/4E	NENW	3	Irr. 50 Ac.
10825	7866	4958	10-22-51	Johnson Creek	J. E. Hagin	0.60	40/4E	NENW	8	Irr. 60 Ac.
10919	8007	5075	12-12-51	Johnson Creek	P. Dykstra	0.45	40/4E	SWNE	4	Irr. 55 Ac.
Certrificate of Change 504					P. Dykstra					
11095	8094	6299	2-25-52	Johnson Creek	E. Tyrrell	0.33	40/4E	Govt Lot 2	3	Irr. 25 Ac.
13456	10073	6984	6-3-55	Johnson Creek	F. Westhoff	0.36	40/4E	NWNE	8	Irr. 36 Ac.
15282	11322		2-11-59	Johnson Creek	P. VanWeerdhuizen	0.33	40/4E	W½	3	Irr. 33 Ac.
				Springs Tributary Johnson Creek						
6973	4592		3-14-46	Spring	Town of Sumas	1.34	41/4E	SWSW	33	Municipal Supply
6974	4593	3427	3-14-46	Spring	Town of Sumas	1.78	40/4E	Govt Lot 1	33	Municipal Supply
				Pangborn Creek Tributary Johnson Creek						
8271	5847	3936	3-11-48	Bostwick Creek	L. L. Bostwick	0.40	40/4E	SWNW	5	Irr. 65 Ac.
9516	6725	4405	4-11-50	Pangborn Creek	R. Van Dyken	0.12	40/3E	NESE	1	Irr. 12 Ac.
10774	7864	6125	10-3-51	Pangborn Ditch	J. Otter	0.29	40/3E	NWSW	1	Irr. 29 Ac.
11058	8013	5243	2-13-52	Pangborn Creek	F. Higgenson	0.40	40/4E	NWSW	6	Irr. 40 Ac.
				Clearbrook Creek Tributary Johnson Creek						
7368	4954	3897	8-6-46	Clearbrook Creek	G. Hinton	0.30	40/4E	NESE	7	Irr. 37 Ac. & Dom.
12822	9650	6805	3-22-54	Clearbrook Creek	R. Boese	0.30	40/4E	NWSE	7	Irr. 35 Ac.
15359	11438	7647	3-25-59	Unnamed Pond (no outlet)	O. L. Russell	0.15	40/4E	SENE	7	Irr. 15 Ac.
				Squaw Creek Tributary Johnson Creek						
2029	993	852	3-9-27	Squaw Creek	E. A. Knittle	0.50	40/3E	SWNW	12	Irr. 40 Ac.
4654	2638	2373	10-13-38	Squaw Creek	J. H. Bruns.	0.40	40/3E	SENW	12	Irr. 20 Ac.
7074	4545	3760	4-25-46	Unnamed Creek	S. Johnson	0.40	40/3E	NESE	12	Irr. 40 Ac.
7432	4955	3896	9-5-46	Squaw Creek	G. H. Hinton	0.20	40/4E	NESE	7	Irr. 20 Ac.
				Kinney Creek Drainage						
12297	9192		4-27-53	Kinney Creek	L. J. Ross	0.25	40/4E	N½NW	22	Irr. 25 Ac.
				Breckenridge Creek Drainage						
4218	2347	1303	4-13-36	Breckenridge Creek	T. Velthuisen	0.10	40/4E	S½NE	28	Irr. 40 Ac.
Certificate of Change 619					T. Velthuisen					
4239	2452	1576	6-12-36	Elkins Creek	C. Simpson Adams	0.05	40/4E	NESE	28	Irr. 15 Ac.
13890	10658		5-28-56	Breckenridge Creek	J. D. Bartel	0.40	40/4E	NENE	24	Irr. 40 Ac.
				Swift Creek Drainage						
13841	10342		5-11-56	Swift Creek	B. Hardin	0.41	40/4E	NESW	34	Irr. 40 Ac. & Dom.

Appl.	Permit	Cert.	Priority	Source	Name	Quantity (cfs)	Location of Point of Diversion (T.R. Subdivision Sec.)			Use
					SUMAS RIVER BASIN DRAINAGE					
					Goodwin Creek Drainage					
6335	4385	2428	3-2-45	Goodwin Creek	H. M. Ingersoll	0.02	39/4E	SWSW	3	Irr. 2.5 Ac., Dom. & Stock
12447	9229	6616	7-8-53	Goodwin Creek	G. DeKoekkoek	0.30	40/4E	NESW	33	Irr. 30 Ac.
12576	9537	7279	9-15-53	Goodwin Creek	T. E. Skinner	0.33	40/4E	N½SE	33	Irr. 38 Ac.
14935	12087		7-25-58	Goodwin Ditch	B. Holz	0.25	39/4E	Govt Lot 2	4	Irr. 40 Ac.
14947	12065		7-30-58	Unnamed Spring	C. Gorrie	0.30	40/4E	SESE	33	Irr. 30 Ac.
					Judson Lake Within Sumas River Drainage					
11287	8291	6631	4-28-52	Judson Lake	A. & H. Nordlund	0.20	41/4E	Govt Lot 7	31	Irr. 20 Ac.
15257	11350		1-23-59	Unnamed Ditch & Judson Lake	A. Holmquist	1.00	41/3E	Govt Lot 5	36	Irr. 100 Ac.
15784	11699		11-27-59	Judson Lake	H. G. Loreen	0.30	41/4E	Govt Lot 2	31	Irr. 30 Ac.

APPENDIX C

Appendix C consists of 18 maps each showing the lands covered by irrigation rights in a specific township. This appendix is based on the two preceding appendices and pictorially shows the place of irrigation use. Although an entire farm may be shown as being covered by irrigation rights, only a check of appendix A or B, as the case may be, will accurately determine the extent of a specific right.

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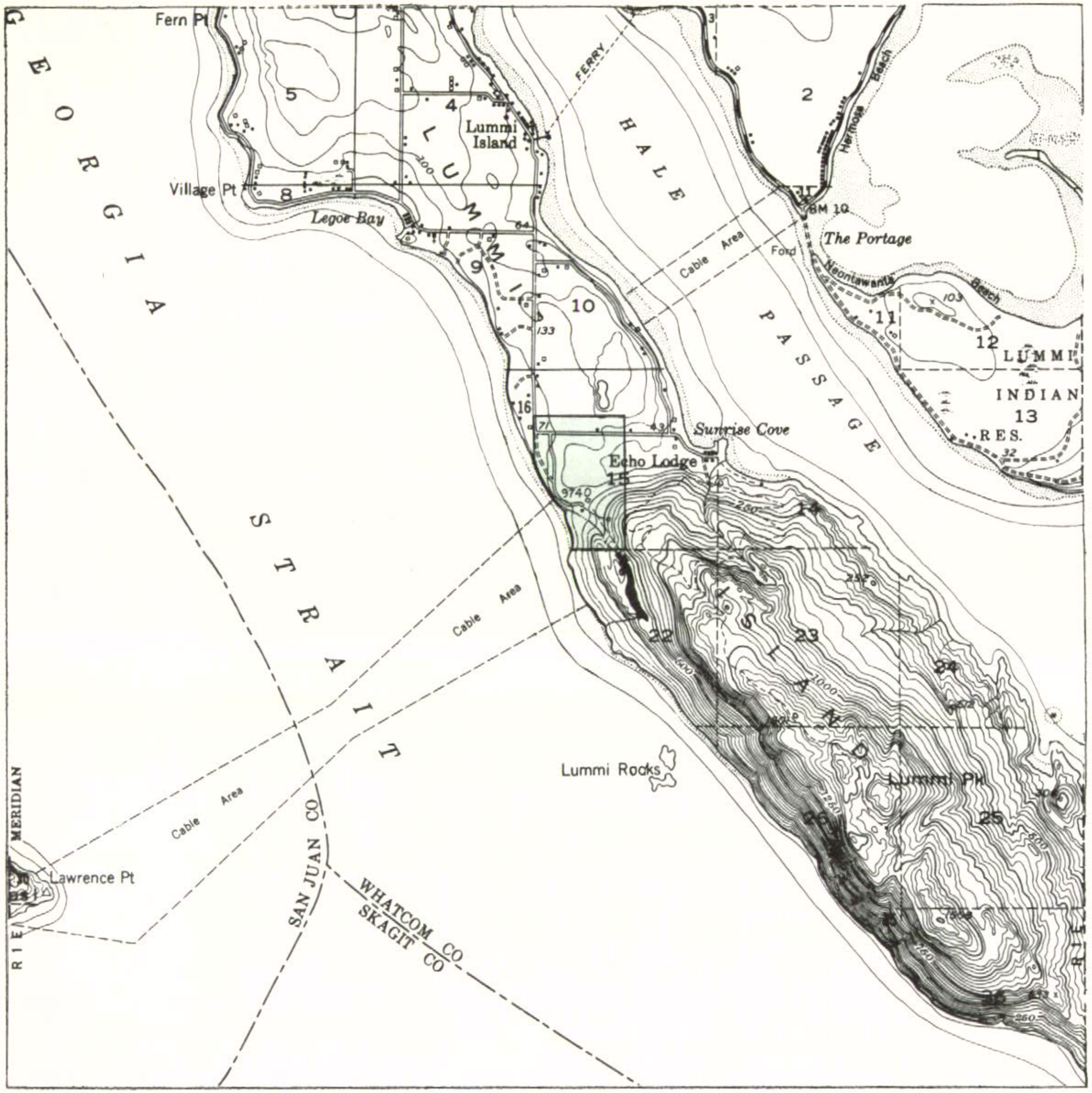


EXPLANATION

Land covered under ground water right, and associated point of withdrawal

Land covered under surface water right, and associated point of diversion

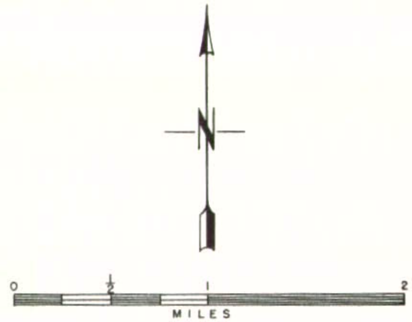
Land covered under both surface and ground water rights

Point of withdrawal with land area too small to be outlined

Point of diversion with land area too small to be outlined

Number adjacent to point of diversion or withdrawal refers to water right application number

Base maps are U. S. G. S. Topographic Quadrangles



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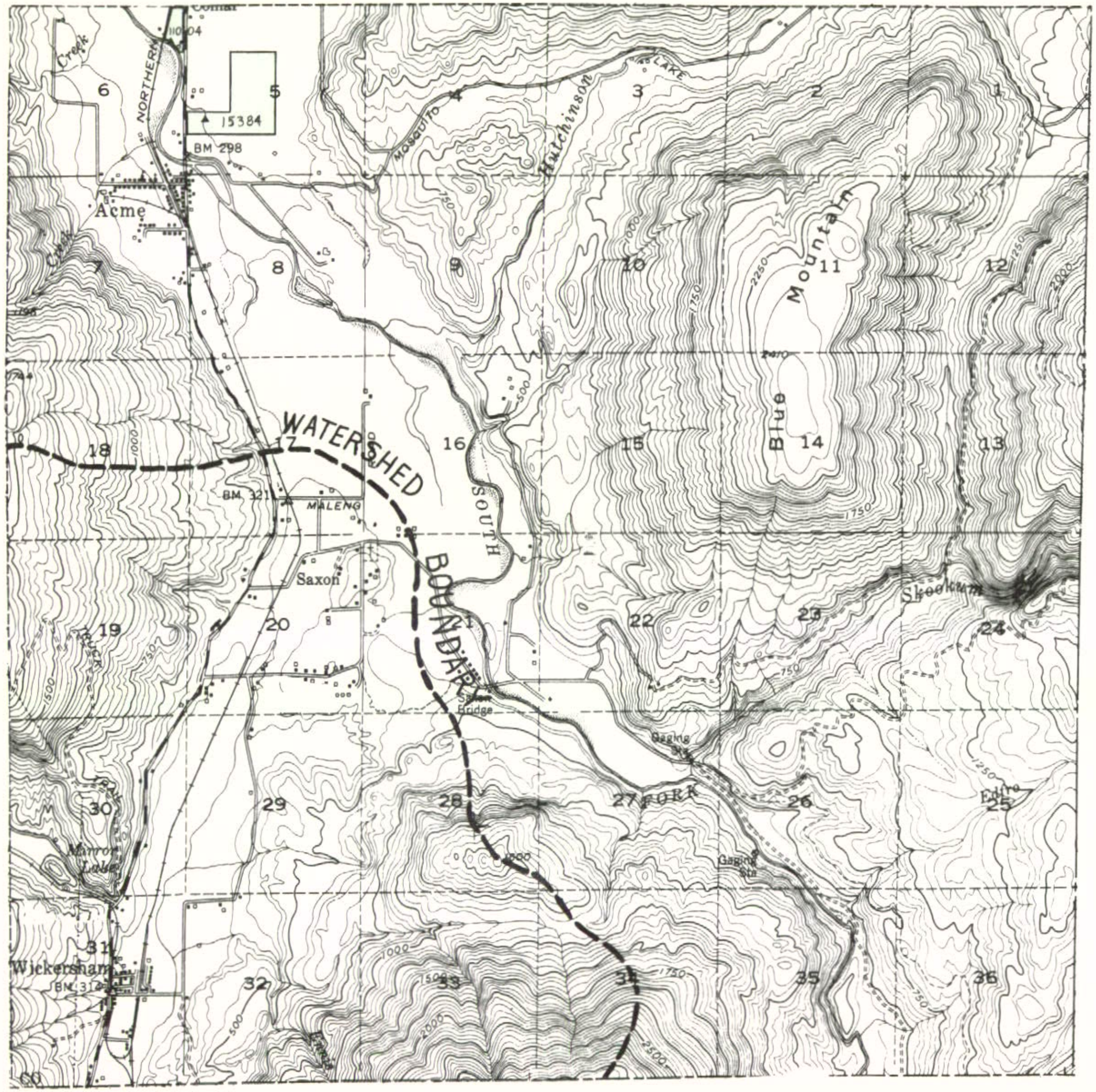

EXPLANATION

Land covered under ground water right, and associated point of withdrawal

Land covered under surface water right, and associated point of diversion

Land covered under both surface and ground water rights

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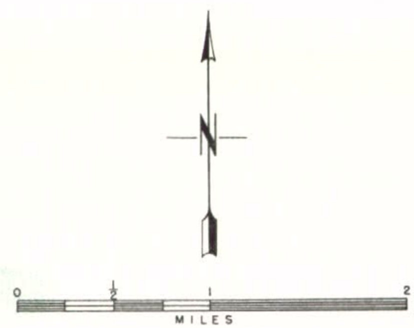

T 37 N R 5 E

EXPLANATION

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Land covered under surface water right, and associated point of diversion

Land covered under both surface and ground water rights

Point of withdrawal with land area too small to be outlined

Point of diversion with land area too small to be outlined

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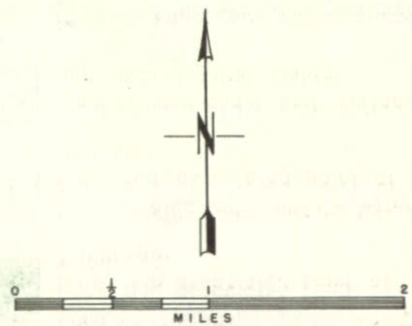


T38N R1E

EXPLANATION

Land covered under ground water right, and associated point of withdrawal

Land covered under surface water right, and associated point of diversion

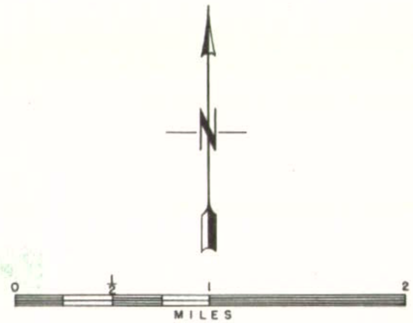
Land covered under both surface and ground water rights

Point of withdrawal with land area too small to be outlined

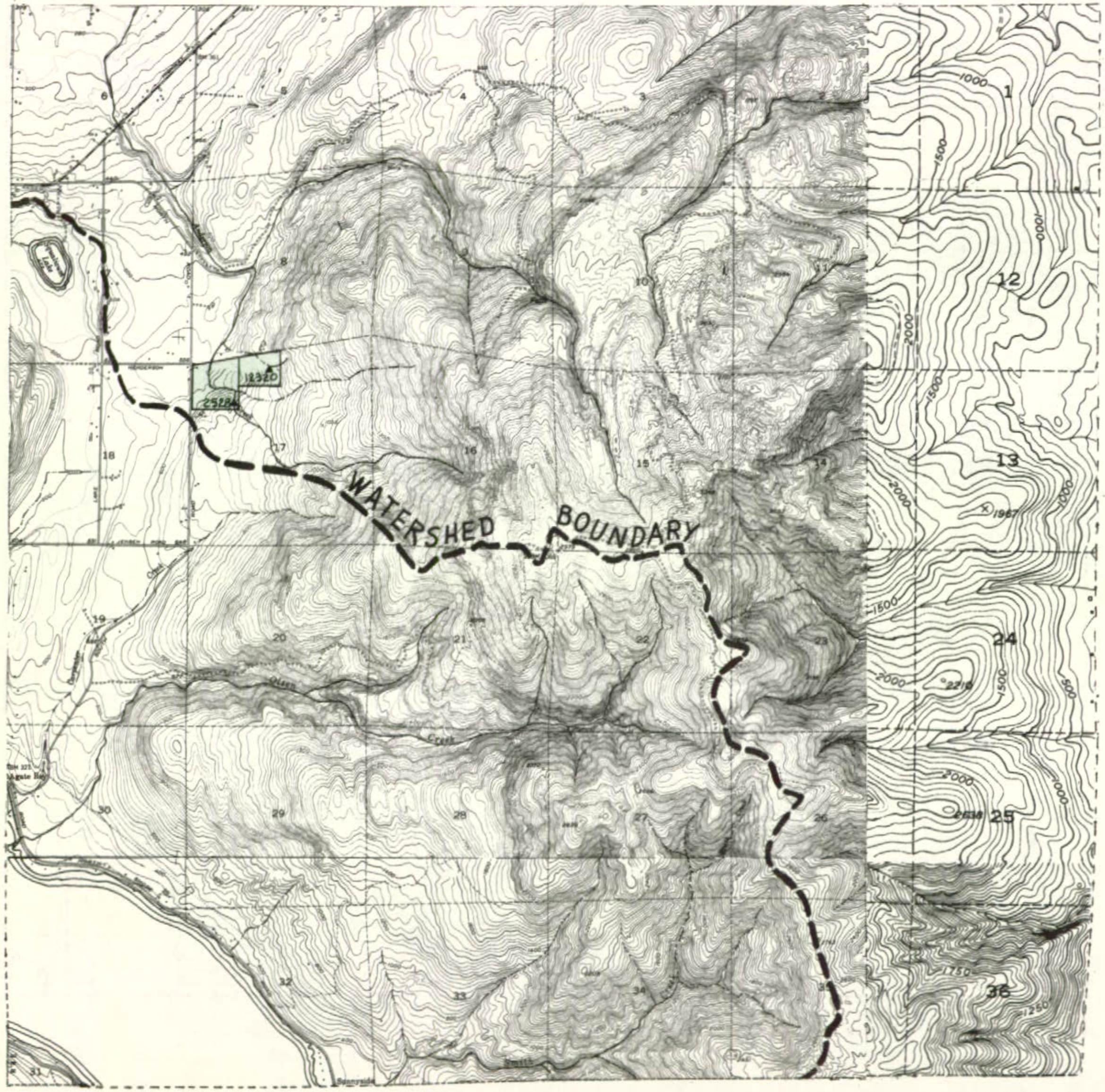
Point of diversion with land area too small to be outlined

Number adjacent to point of diversion or withdrawal refers to water right application number

Base maps are U. S. G. S. Topographic Quadrangles



T 38 N R 2 E

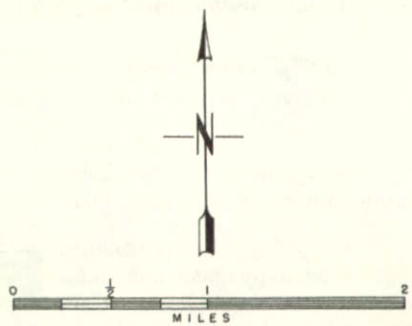


EXPLANATION

- Land covered under ground wate, right, and associated point of withdrawal
- Land covered under surface water right, and associated point of diversion
- Land covered under both surface and ground water rights
- • Point of withdrawal with land area too small to be outlined
- ▲ Point of diversion with land area too small to be outlined

Number adjacent to point of diversion or withdrawal refers to water right application number

Base maps are U. S. G. S. Topographic Quadrangles



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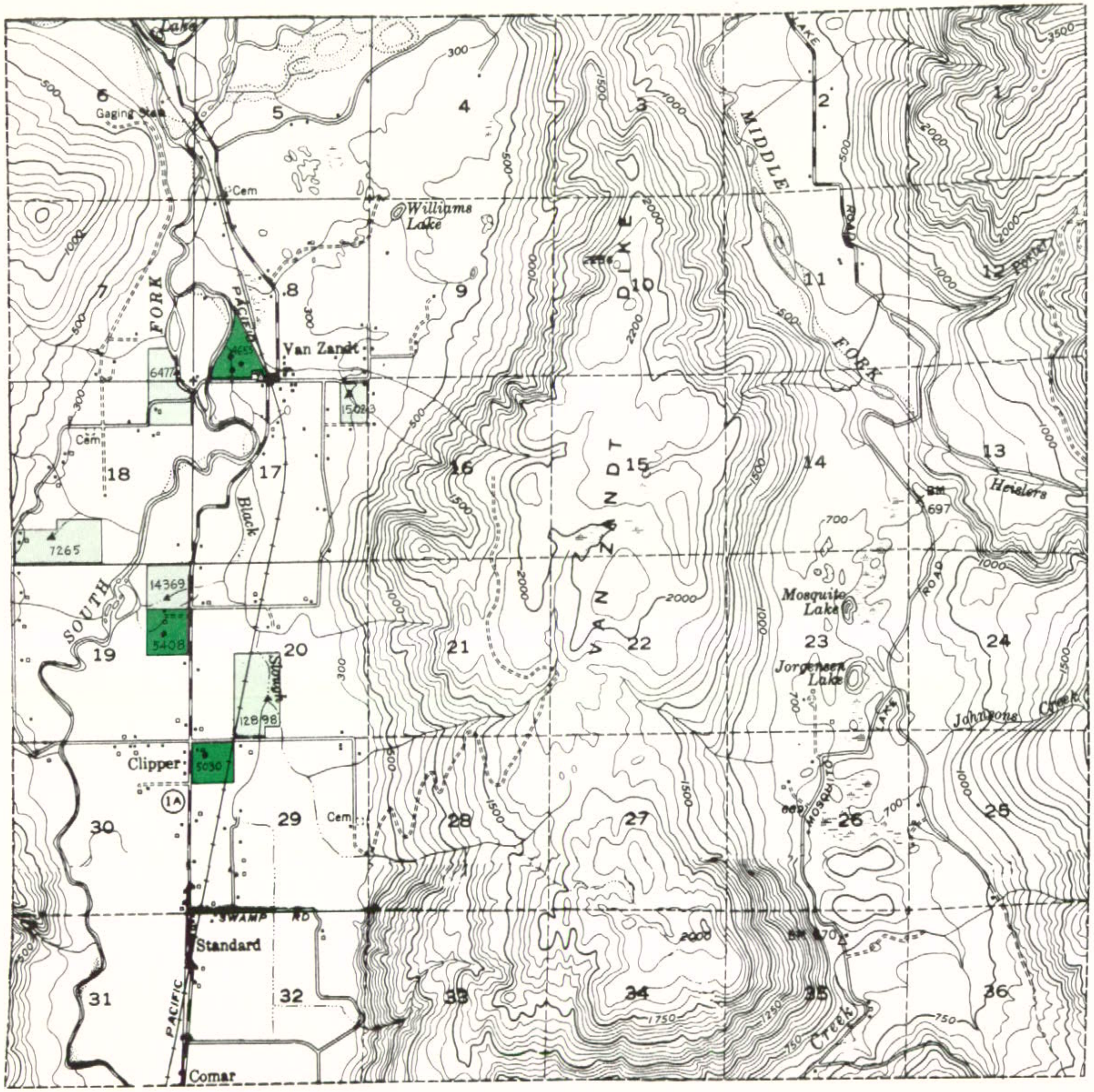

EXPLANATION

Land covered under ground water right, and associated point of withdrawal

Land covered under surface water right, and associated point of diversion

Land covered under both surface and ground water rights

Point of withdrawal with land area too small to be outlined

Point of diversion with land area too small to be outlined

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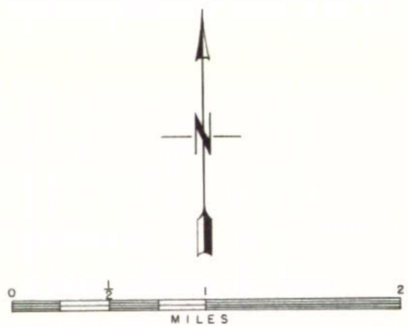

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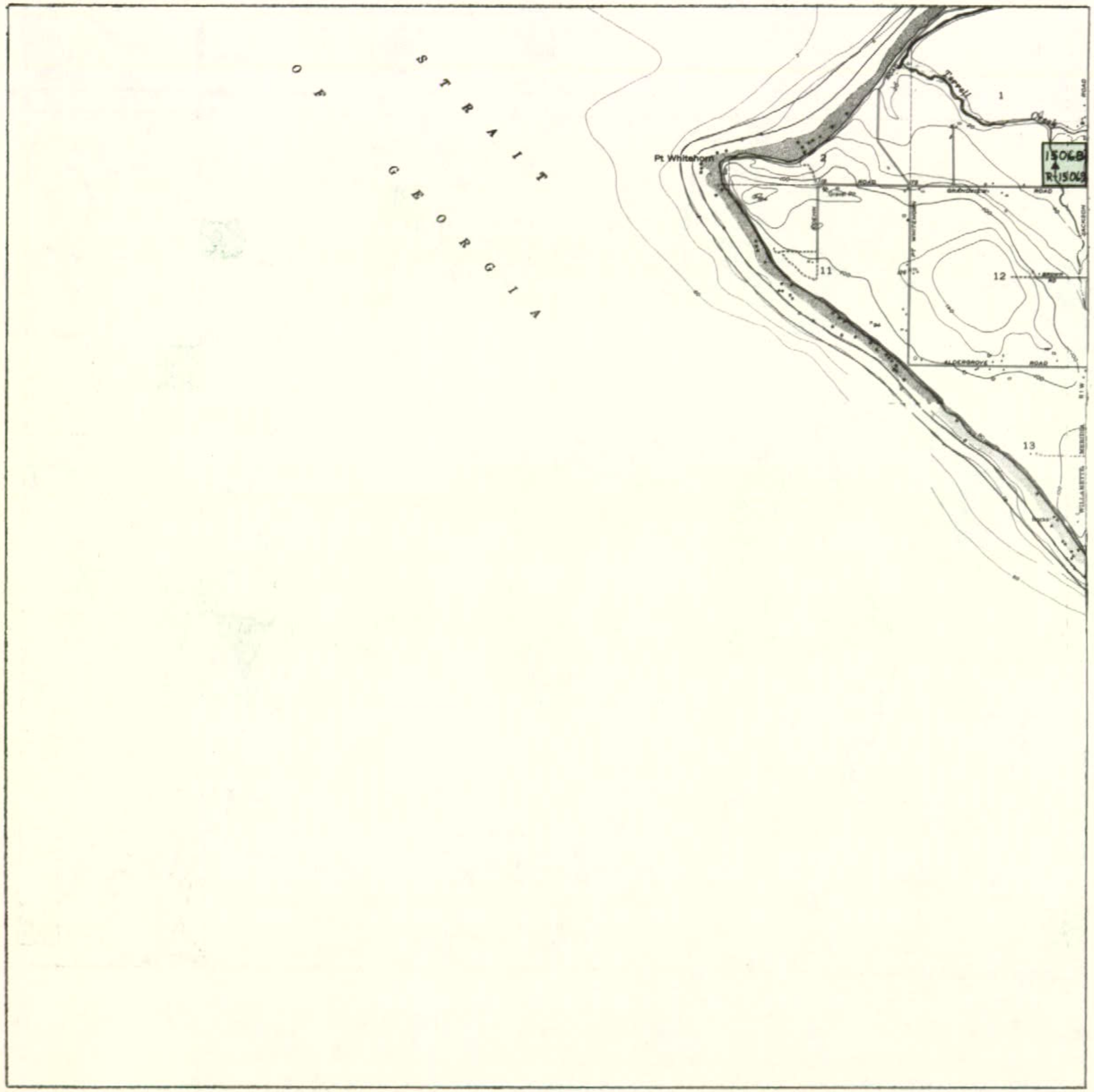

EXPLANATION

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- Land covered under surface water right, and associated point of diversion
- Land covered under both surface and ground water rights
- ● Point of withdrawal with land area too small to be outlined
- ▲ Point of diversion with land area too small to be outlined

Number adjacent to point of diversion or withdrawal refers to water right application number

Base maps are U. S. G. S. Topographic Quadrangles

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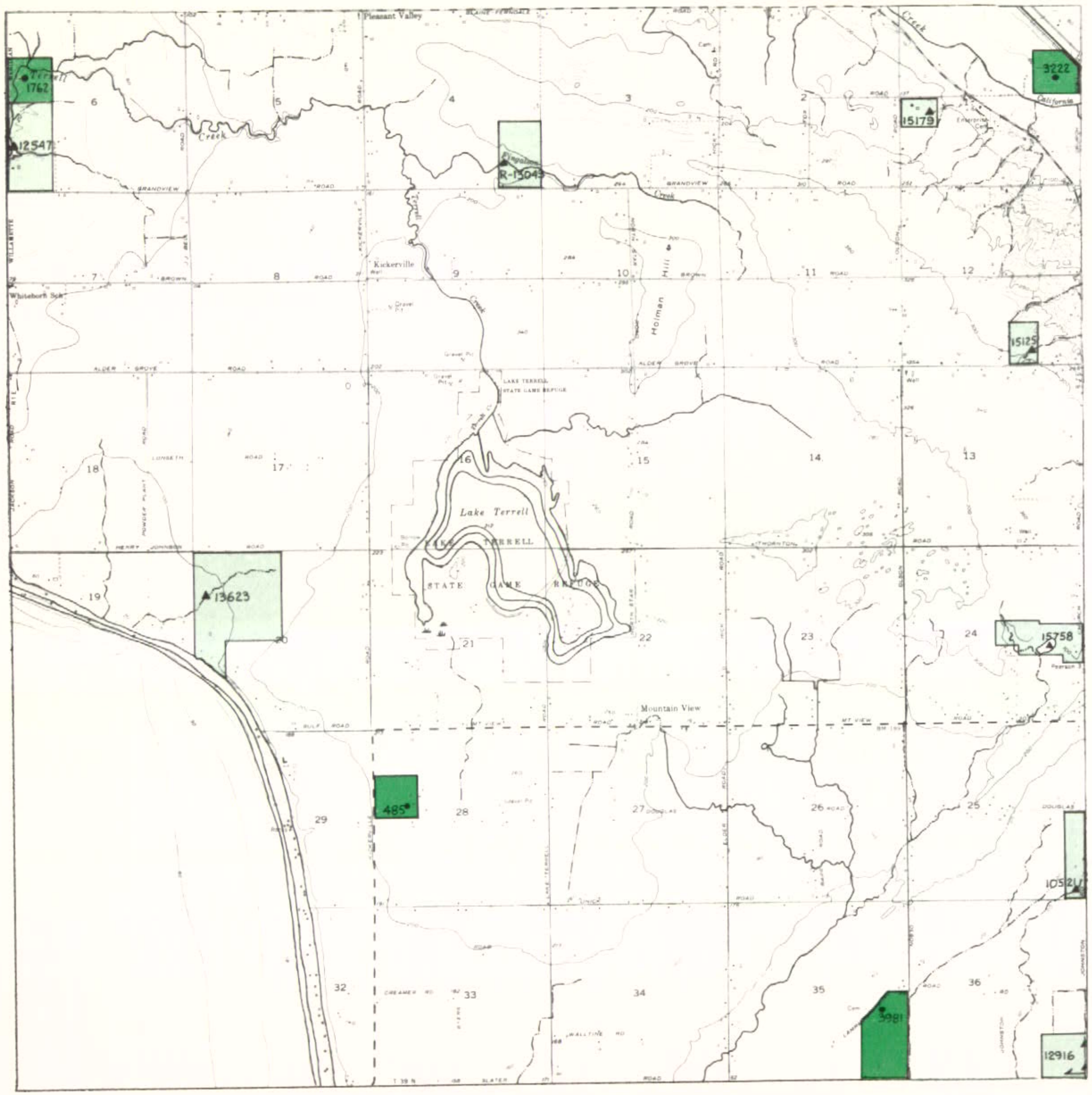
T 39 N R 1 W



EXPLANATION

Land covered under ground water right, and associated point of withdrawal

Land covered under surface water right, and associated point of diversion

Land covered under both surface and ground water rights

Point of withdrawal with land area too small to be outlined

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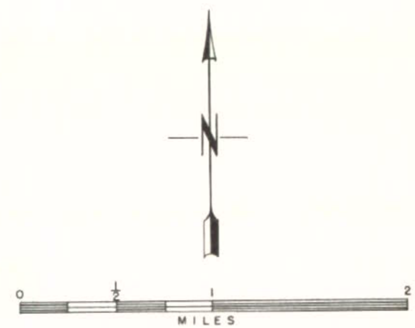
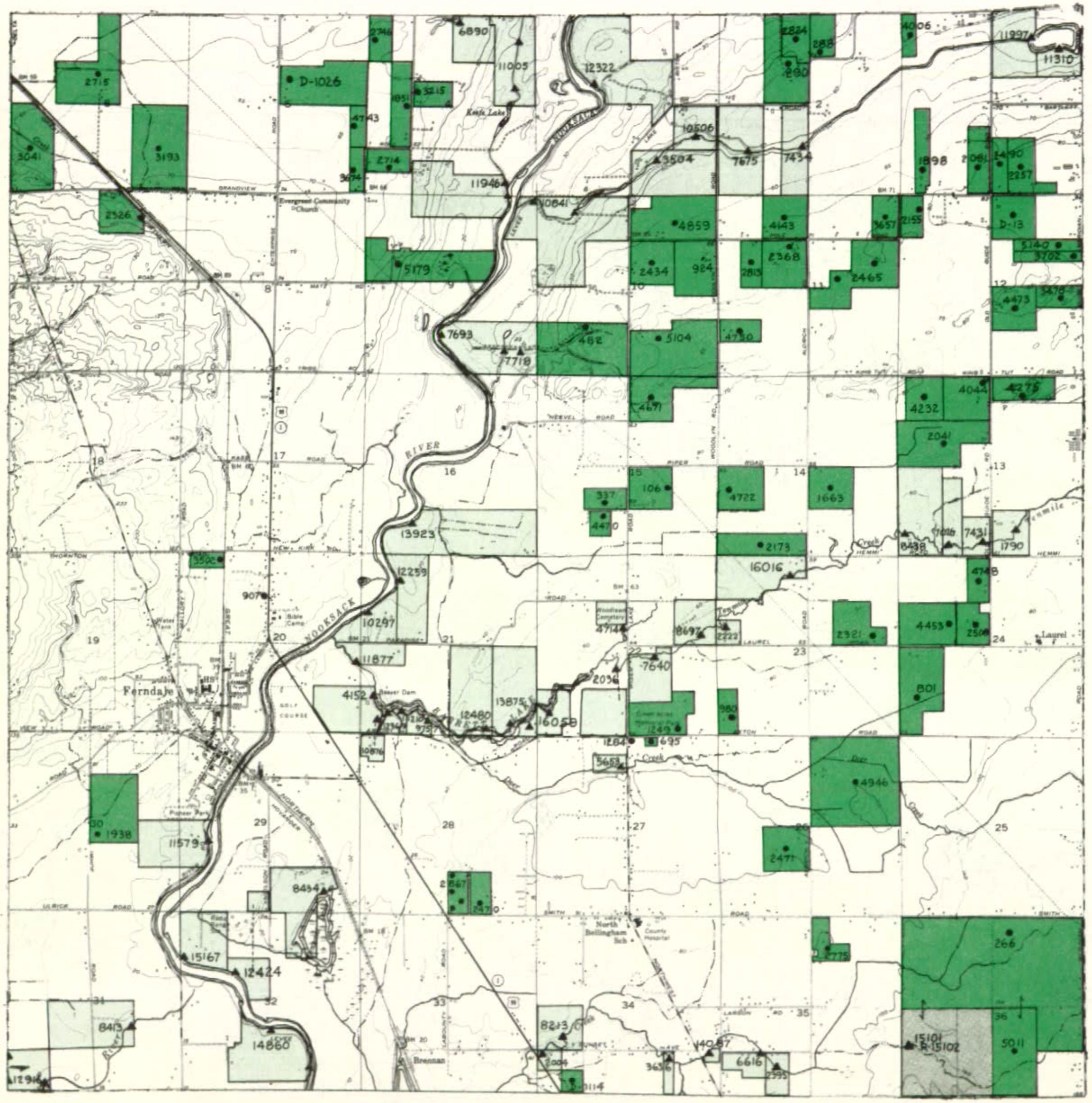


T 39 N R I E



EXPLANATION

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▲ Land covered under surface water right, and associated point of diversion

Land covered under both surface and ground water rights

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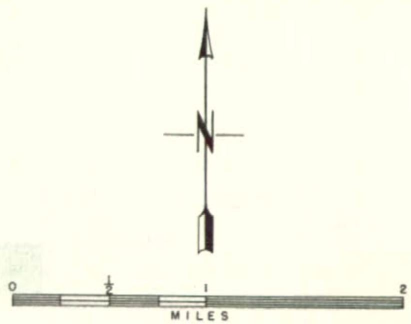

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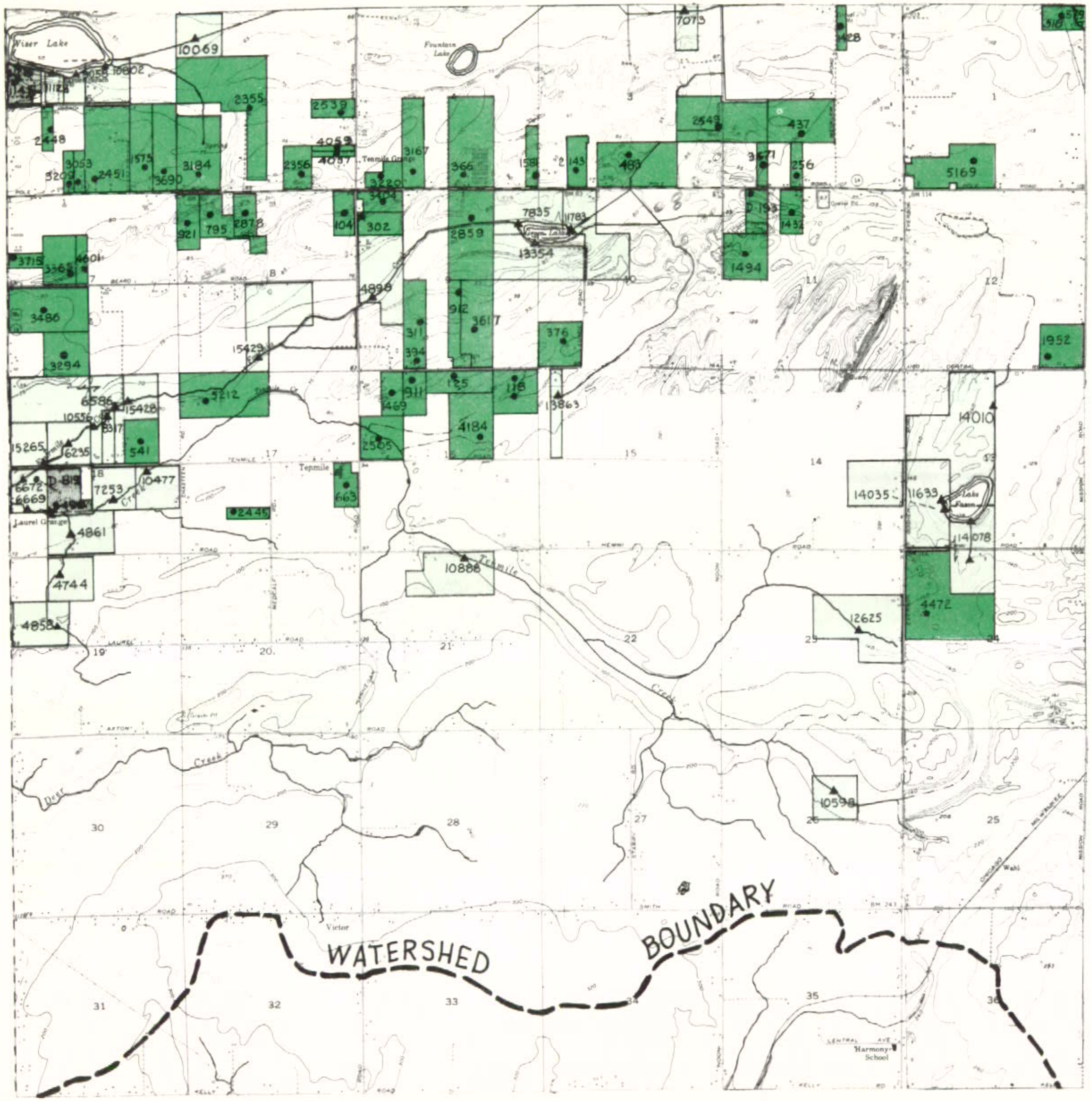

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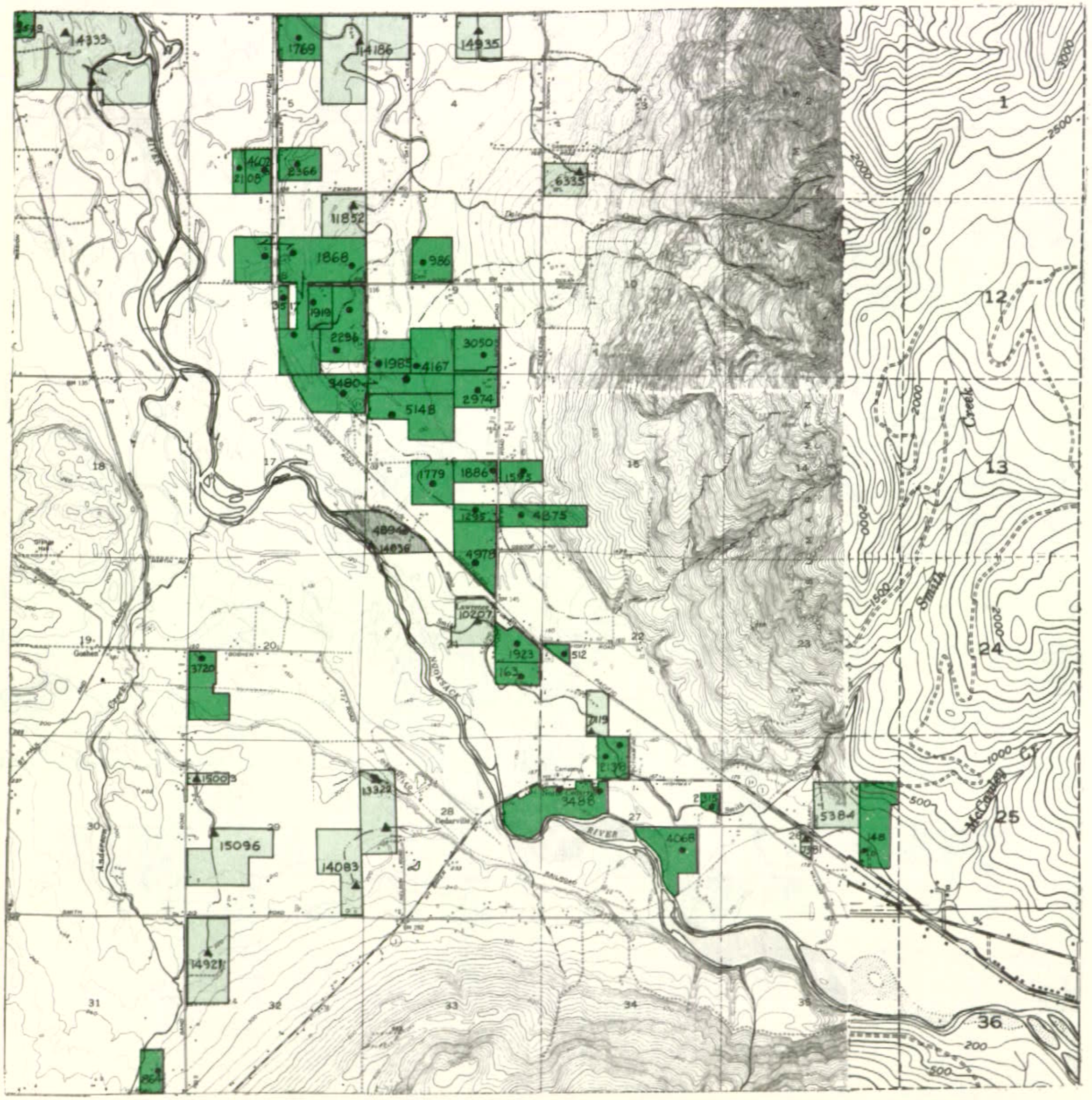

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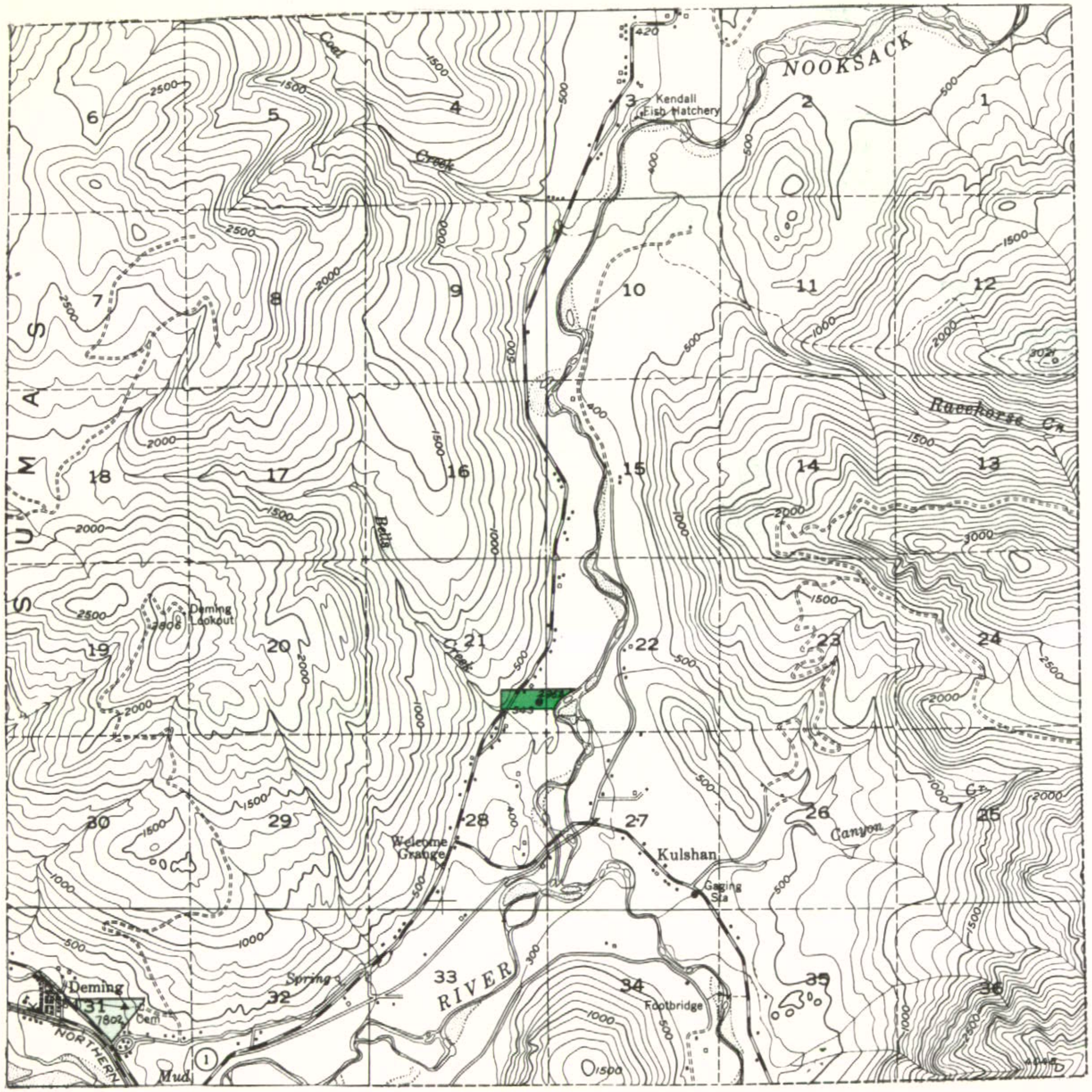
T 39 N R 4 E



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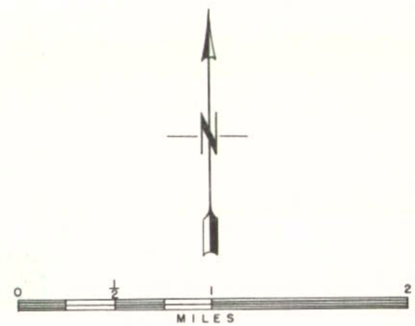

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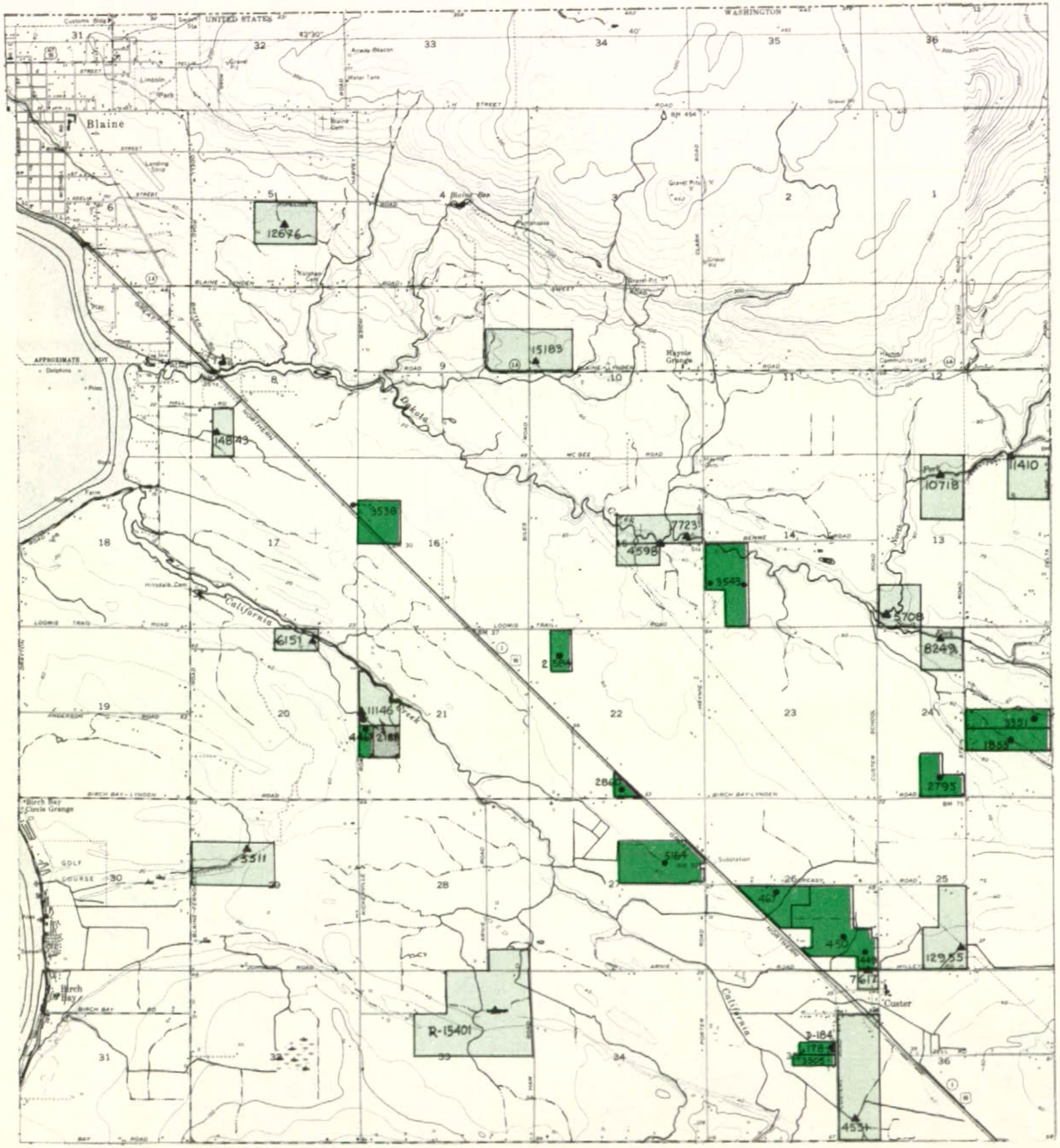

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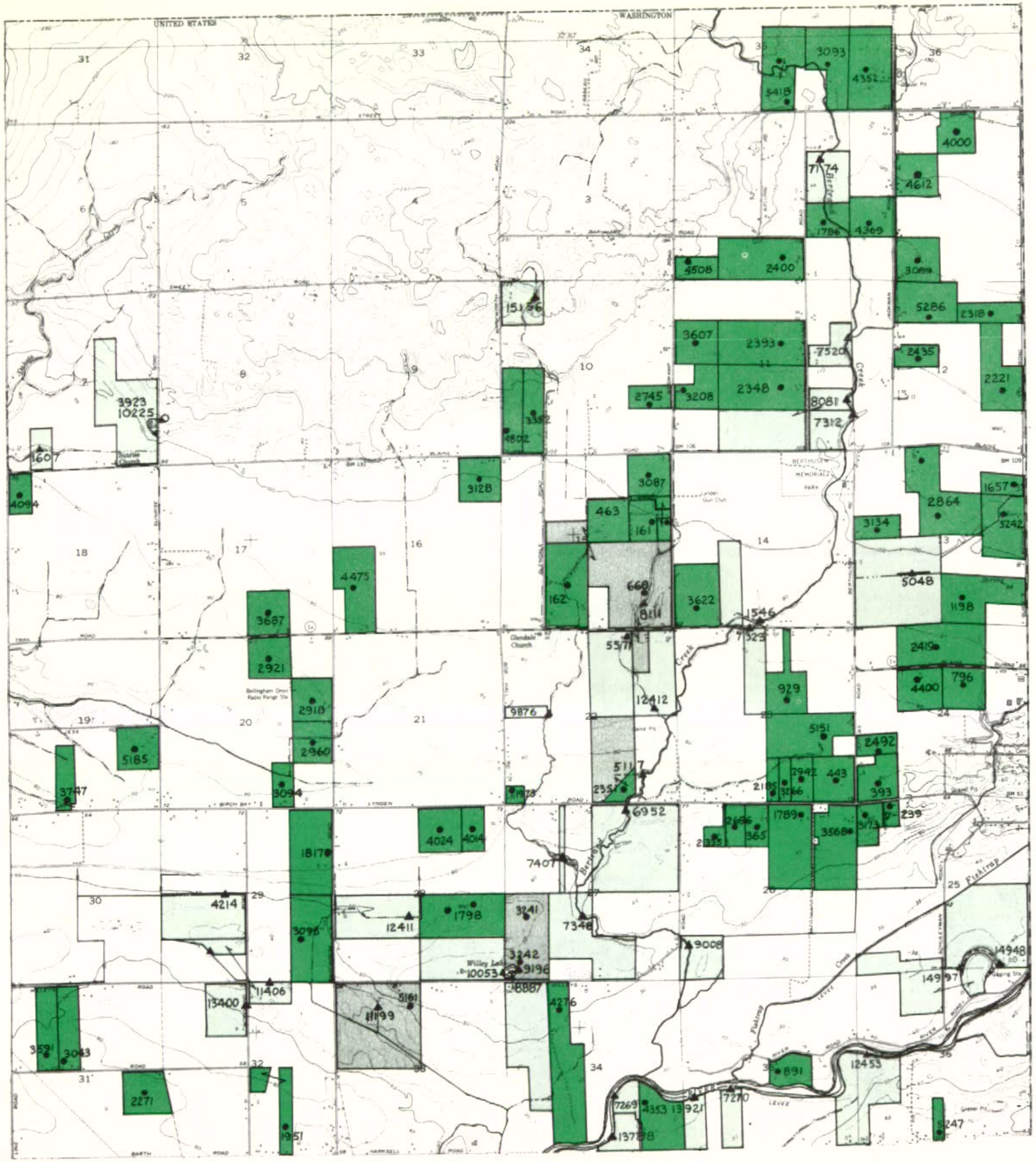

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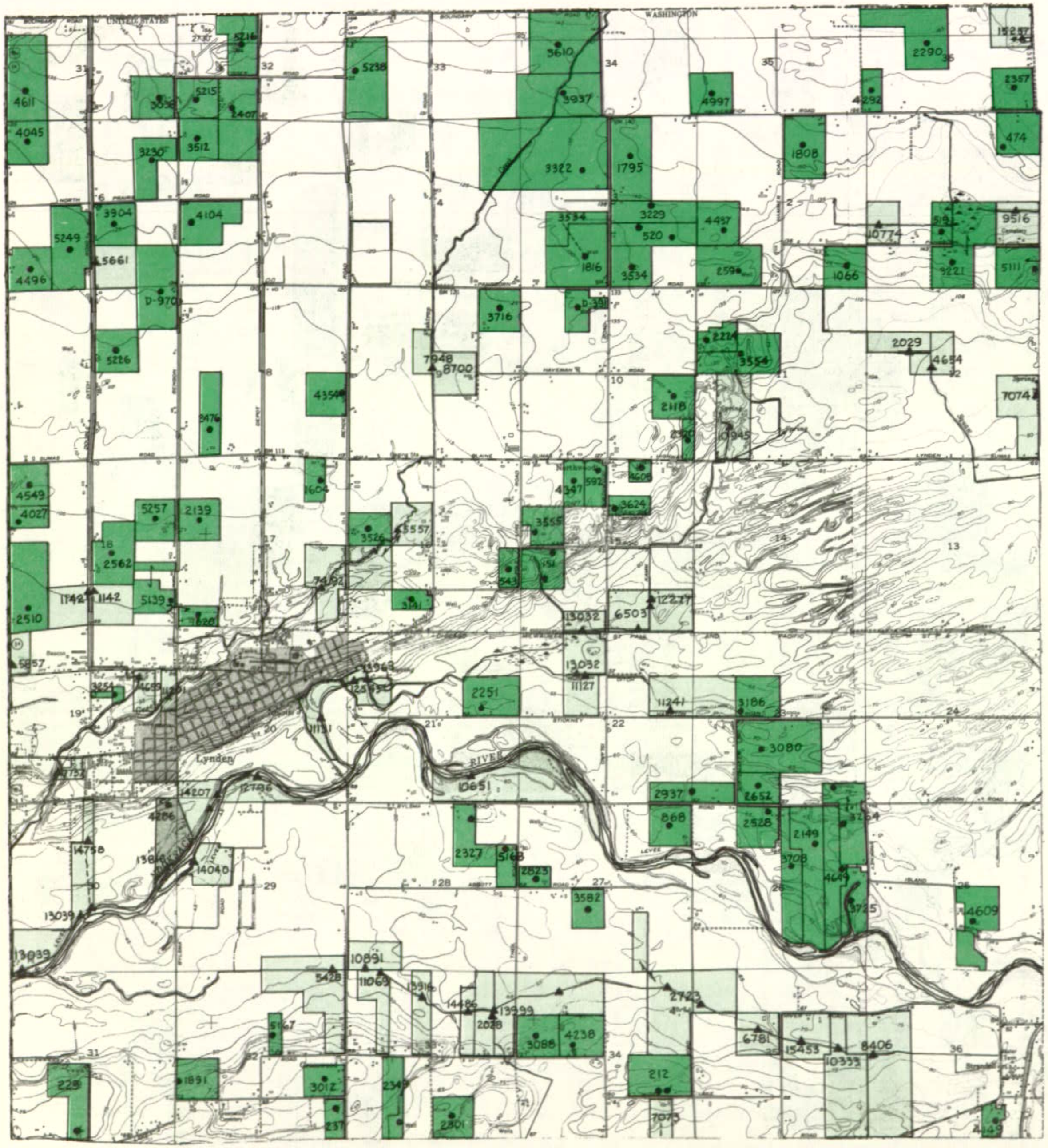
MILES

T40 & 41 N R 2 E



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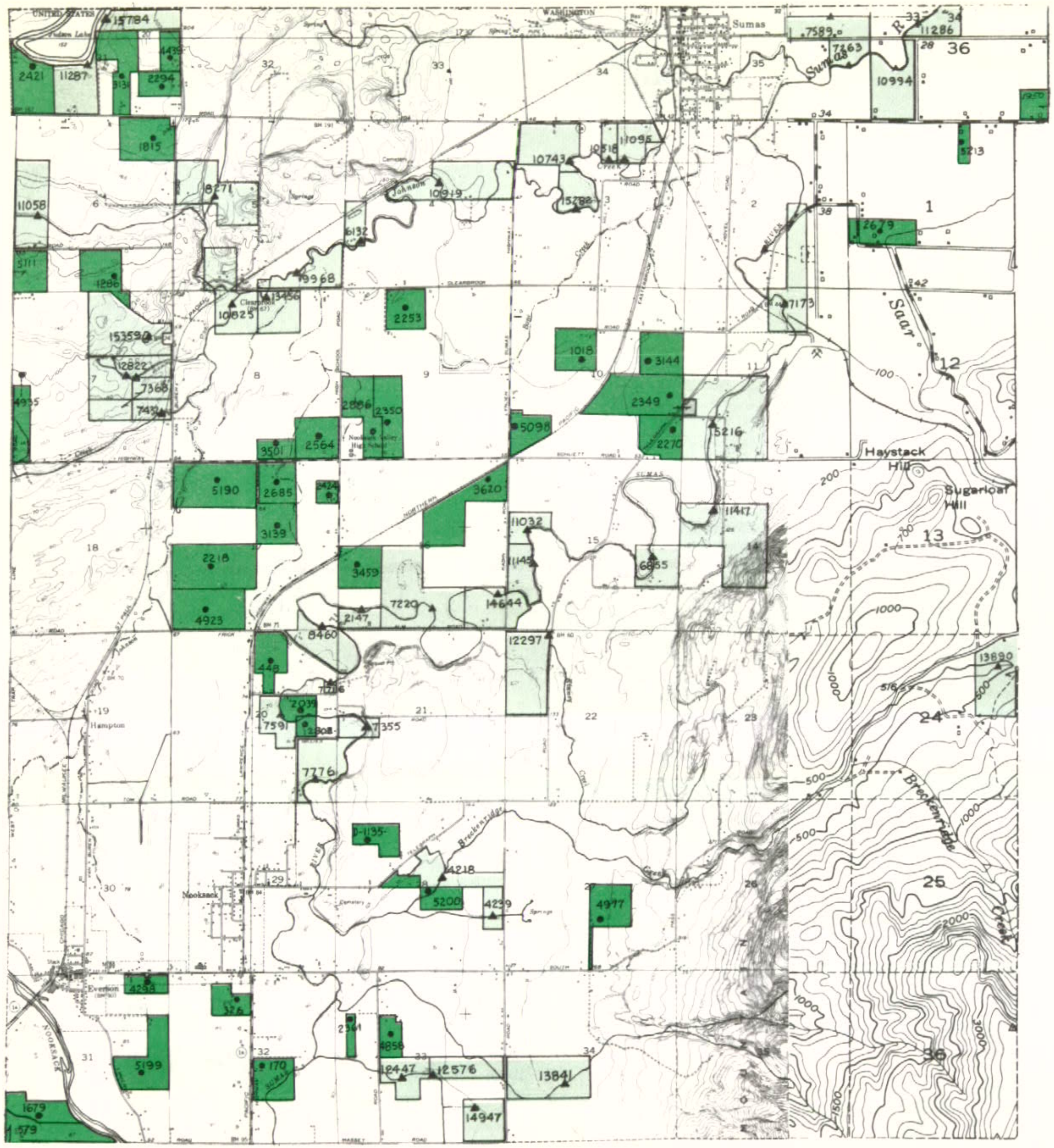
MILES

T40 & 41 N R 3 E



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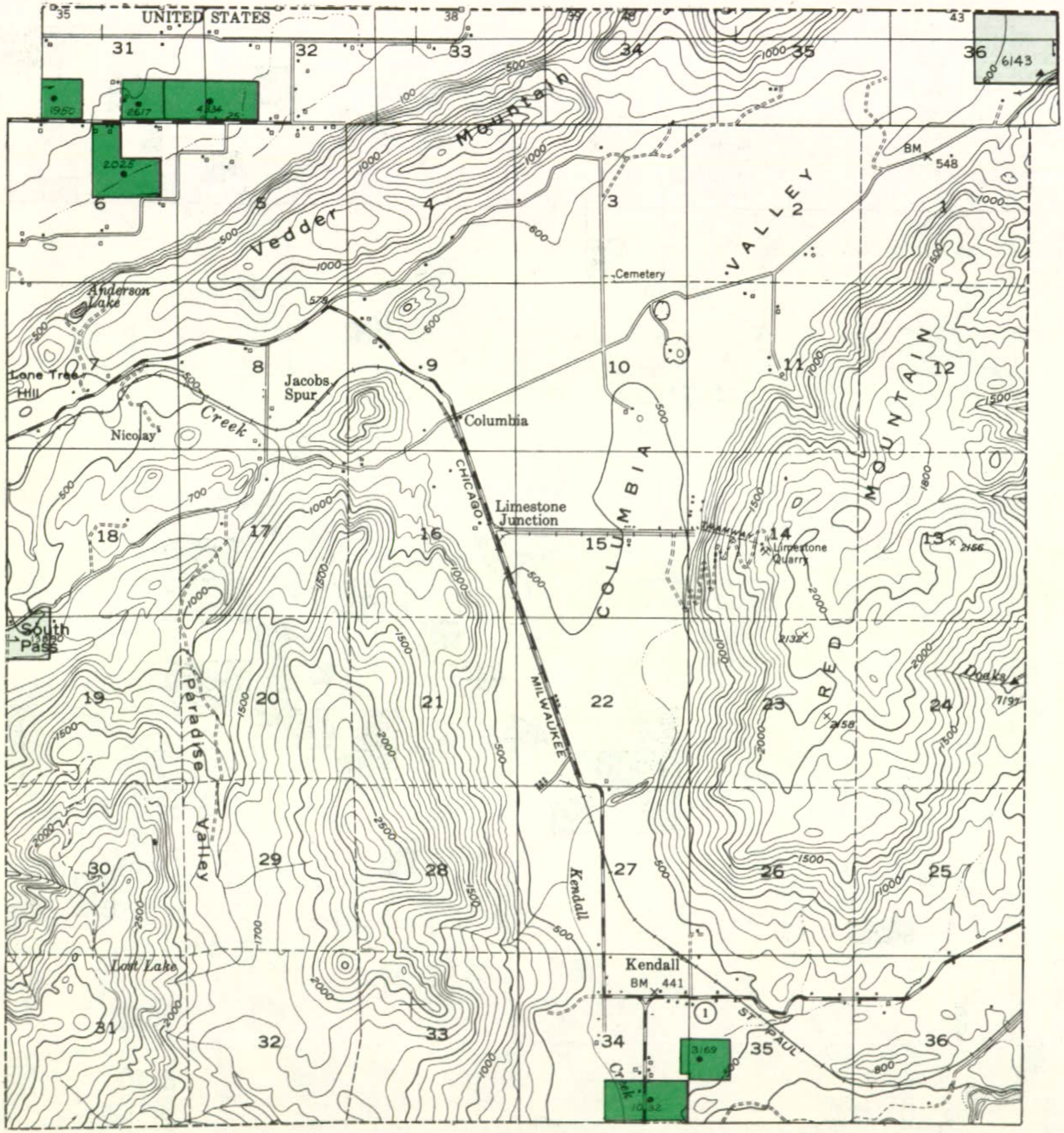

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MILES

T40 & 41N R5E

EXPLANATION

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Number adjacent to point of diversion or withdrawal refers to water right application number

Base maps are U. S. G. S. Topographic Quadrangles

0 ½ 1 2
MILES

T40 & 41N R 6 E