WATER QUALITY STUDIES IN THE WENATCHEE RIVER BASIN

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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

WATER QUALITY STUDIES IN THE WENATCHEE RIVER BASIN

by

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ABSTRACT

A study of the physical and chemical characteristics of water was made in the Wenatchee River Basin during 1954, 1955 and 1956 to provide a basis for comparison to determine the effect of impoundment on water quality in relation to the preservation of fish resources.

The waters were characterized by an extremely low content of suspended and dissolved matter, a very low hardness and alkalinity, a practically neutral pH, and a saturation with dissolved oxygen. Seasonal variations were noted in most constituents.

The Wenatchee River is capable of conserving and supplying waters of excellent physical and chemical quality.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

WATER QUALITY STUDIES IN THE WENATCHEE RIVER BASIN [1]

INTRODUCTION

One purpose of this study was to determine and evaluate the physical and chemical quality of the waters in the Wenatchee River Basin in relation to the environment. The study was made prior to the proposed development of two major hydroelectric projects, so as to provide a basis of comparison, to determine the effect they may have on the water quality. Another purpose was to make predictions, if possible, as to the changes that might take place in the water quality as a result of the impoundment due to these hydroelectric projects. The final purpose was to provide water quality data for evaluation of the Wenatchee River Basin, in relation to its value in the preservation of salmon resources of the Columbia River. A biological study of these waters was made by Sylvester and Ruggles [2] in conjunction with this investigation. It is not a part of this report.

GENERAL DISCUSSION OF FACTORS AFFECTING WATER QUALITY

Water, as it occurs in nature, is never chemically pure; it always has minute traces of impurities. Even rainwater picks up small quantities of dissolved gases and solids, during its descent. The term water quality refers to the properties and characteristics imparted by the impurities, and to the type and quantity of mineral and organic constituents present. The impurities found in water can be divided into two general classes:

1. Suspended impurities: those present as individual insoluble particles, such as clay, sand, and bits of organic matter or living organisms. These particles contribute turbidity to the water.

2. Dissolved impurities: those that intermingle with the water to form a solution, such as mineral salts and organic substances. These constituents are evidenced by the color, taste, odor, or chemical properties they impart to the water.

Carbon dioxide is soluble in water, forming carbonic acid. Since all natural waters usually contain some carbon dioxide, the resultant water is actually an acid solvent. This increased solvent power of the water does much to increase the content of dissolved minerals in surface and ground waters and hence affects its quality.

The water quality of a region always reflects the conditions and uses of land from which it drains. In attempting to establish and evaluate the water quality in the Wenatchee River Basin, a number of factors which may influence it were considered. The factors and characteristics of the drainage basin are listed below and are discussed in more detail in subsequent pages.

1. Topography
2. Flow characteristics of rivers
3. Geology
4. Soil mantle
5. Climate
6. Land use and vegetal cover
7. Population
8. Industry
9. Ground water
10. Irrigation

Topography

The Wenatchee River drainage basin is located in the southwestern extremity of Chelan County in the central portion of the State of Washington (fig. 1). It is bordered on the west by the Cascade mountains, on the north and east by the Entiat mountains, and on the south by the Wenatchee

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1/ Condensed from a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

2/ "A study of the Wenatchee and middle Columbia River prior to dam construction" by Robert O. Sylvester and Charles P. Ruggles. University of Washington (Seattle), Department of Civil Engineering and U. S. Fish and Wildlife Service. Not yet published.

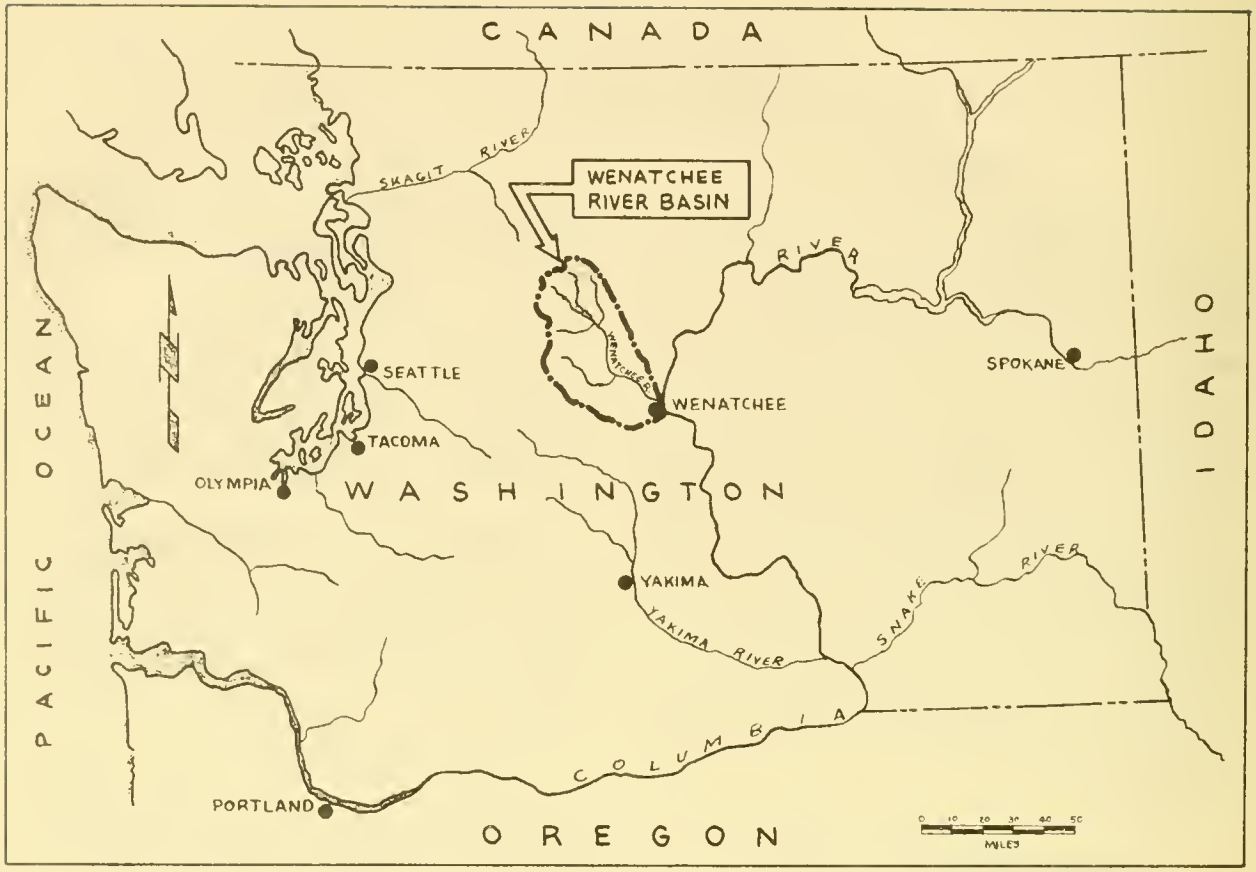


Figure 1.--Wenatchee River Basin (Location map)

mountains. It contains approximately 1,310 square miles (Washington Department of Conservation Development, Division of Water Resources, 1955). Of the three mountain masses forming the boundary of the basin, the Cascade and Wenatchee mountains are of extremely rugged topography with the mountain ridges separated in places by deeply eroded valleys. The highest peak in the area is Mt. Stuart, 9,470 feet high, with the general elevation of the two ranges being around 6,000 feet.

The Entiat mountains, which form the boundary on the north and east, are of less rugged topography. They are characterized by narrow, flat-topped ridges or plateaus and flanked by precipitous slopes descending to deep canyons. In elevation they range from 2,500 to 4,500 feet (fig. 2).

The basin can be divided into two smaller regions, the upper and lower valley. The upper valley is characterized by a more rugged, heavily forested topography, which is occasionally broken by smaller tributary valleys. It is a mountainous area, with lowlands found only along the many small streams which have eroded small valleys in their course to the Wenatchee River. Lake Wenatchee is an outstanding feature of the upper valley. The lower, broad and open valley extends from the town of Leavenworth to the confluence of the Wenatchee and Columbia Rivers at Wenatchee, a distance of around 22 miles.

The main tributaries to the Wenatchee River progressing downstream are Little Wenatchee River, White River, Nason Creek, Chiwawa River, Chiwaukum Creek, Icicle Creek, Chumstick Creek, Peshastin Creek, and Mission Creek.

Topography affects the runoff and water quality of a stream. A terrain

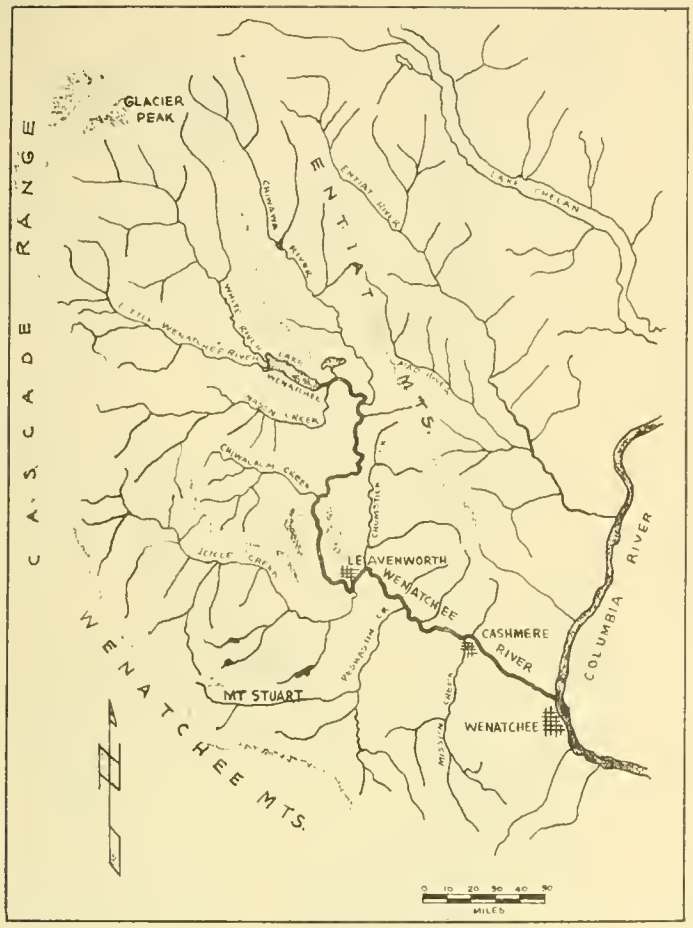


Figure 2.--Wenatchee River Basin (map)

consisting entirely of slopes with steep gradients has a rapid and high percentage of runoff with the resultant soil erosion. During this period, the solvent power of the water has little time to put into solution any of the soluble minerals. A flat terrain absorbs a large proportion of the rainfall, giving the water time to dissolve soluble mineral matter. The amount and rate of surface runoff is also lessened.

Stream Flow Characteristics

The Wenatchee River is an unregulated, rapid, snow-fed stream, with an average discharge of 2,900 cubic feet per second, having the maximum runoff usually during the month of May or June, and the minimum during the month of September (fig. 3). The river has a fall of 1,230 feet from Lake Wenatchee to its confluence with the Columbia River.

The Chiwawa River is also a snow-fed stream, with the maximum and minimum flows occurring during the same months as the Wenatchee River, with an average discharge of 443 c.f.s. (fig. 4).

A major percentage of the stream flow in the Wenatchee River

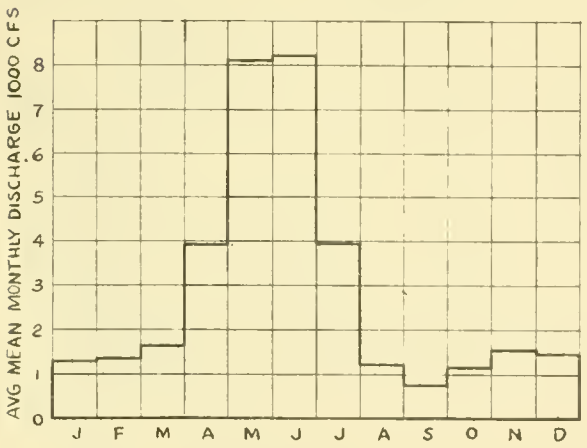


Figure 3.--Hydrograph. Wenatchee River at Peshastin, Washington. Average for period 1929-1953. Drainage area 1,000 sq. mi.

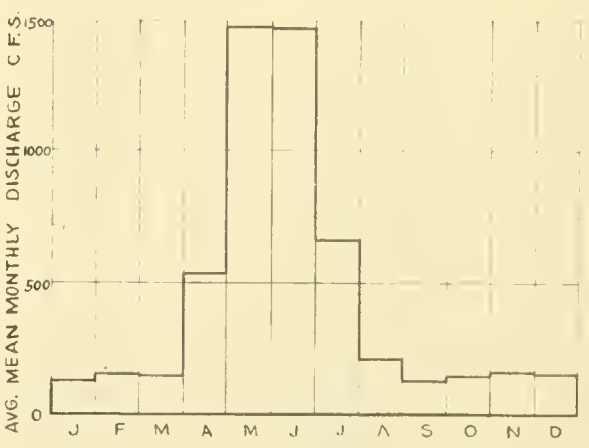
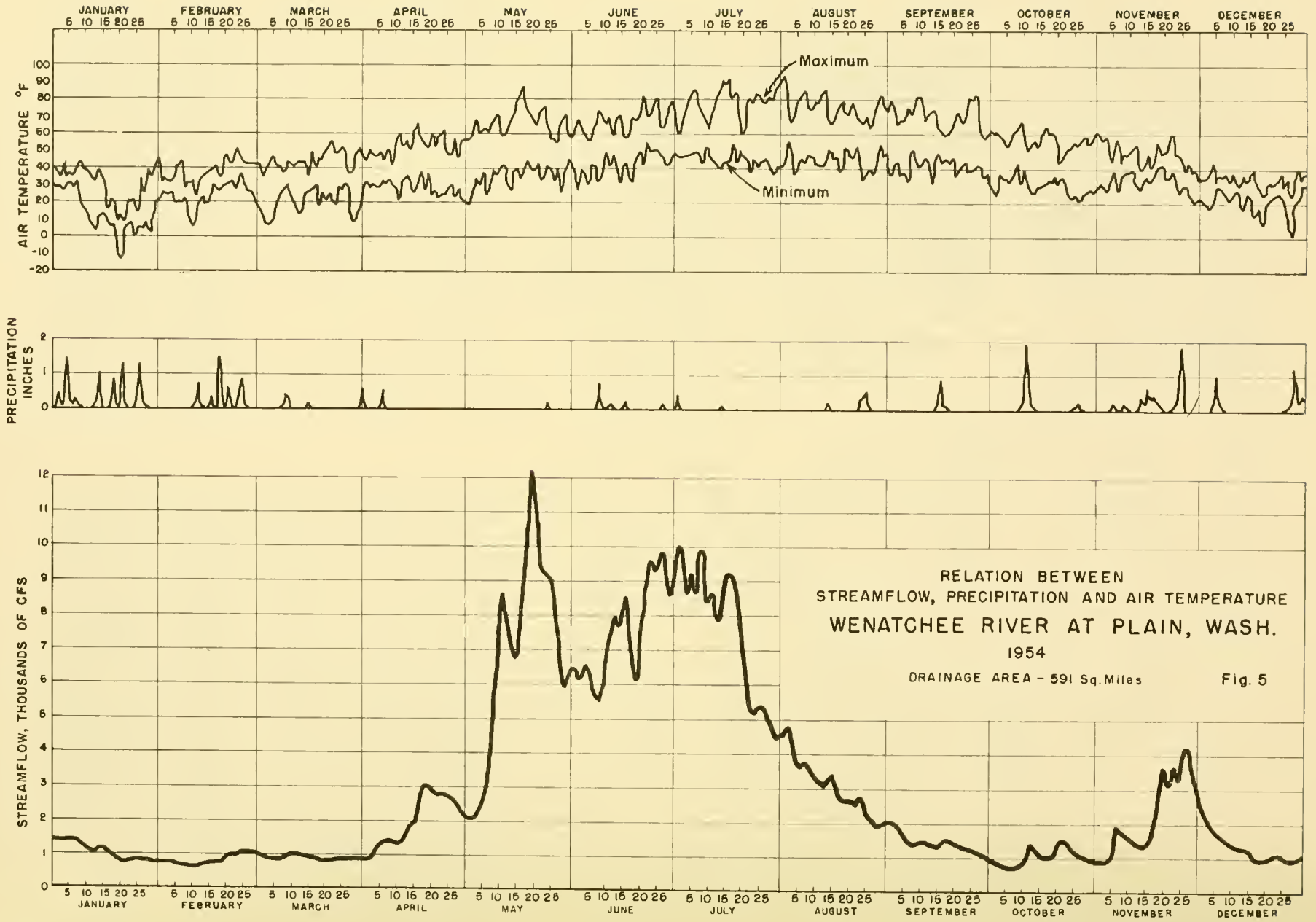


Figure 4.--Hydrograph. Chiwawa River near Plain, Washington. Average for period 1936-1950. Drainage area 170 sq. mi.


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
AIR TEMPERATURE °F
100
90
80
70
60
50
40
30
20
10
0
-10
-20
Maximum
Minimum
PRECIPITATION INCHES
2
1
0
STREAMFLOW, THOUSANDS OF CFS
12
11
10
9
8
7
6
5
4
3
2
1
0
RELATION BETWEEN
STREAMFLOW, PRECIPITATION AND AIR TEMPERATURE
WENATCHEE RIVER AT PLAIN, WASH.
1954
DRAINAGE AREA - 591 Sq. Miles
Fig. 5

Basin results from the melting of high altitude snow during the spring and early summer. The air temperature, therefore, is the controlling factor in establishing the flow in the streams of the Wenatchee River Basin. This fact is shown graphically on figure 5 where it can be seen that the run-off was dependent upon the air temperature rather than precipitation. This has an important effect on the water quality, for a stream fed mainly by freshly melting snow is low in all types of impurities.

Geology

The geology of the Wenatchee River Basin furnishes examples of metamorphic, igneous, and sedimentary rocks (Russell, 1900).

The northern portion of the Cascade mountains is composed of granites and granodiorites in large areas flanked by metamorphic rocks such as schists, gneisses, and serpentines (Van Winkle, 1914). On the north and east the Entiat mountains are largely schistose, with mica and hornblende schists predominating (Russell, 1900). On the south in the Wenatchee mountains the rocks are granitic, with large amounts of serpentine representing peridotite (Van Winkle, 1914). In the upper valley sandstone is abundant except for the portion of the valley cut through granite in Tumwater Canyon. In the lower portion, the valley of the Wenatchee is deeply gravel-filled and terraced.

The geology of a drainage basin is perhaps one of the most important factors in the establishment of the water quality. Water, in contact with the rocks either at the surface or sub-surface, slowly dissolves some of the minerals and puts them in solution. This decomposition of the soluble constituents of the rocks also loosens other particles and makes them available for transport by moving water. The greater part of the minerals in solution in a stream are contributed by ground water since it is in contact with the rocks for a much greater period of time.

It is significant that the most common rocks in the Wenatchee basin are granite. Quartz is abundant in granite and is the chief constituent of most sands and sandstone. Chemically and physically, quartz is the most resistant to decomposition of all rock-forming minerals (Hinds, 1943).

Soil Mantle

Soil is formed in many ways and is an extremely complex mixture of mineral debris from rock degradation and decomposition, organic matter, remnants of former plant and animal tissues, living organisms, soil water, gases, etc. The chief ingredients of most soils are the mineral particles originally derived from rock. Practically all the common rock-forming minerals of a region are found in the soil of the area. The large variety of rocks in the Wenatchee drainage basin causes the valley soils to be formed of a great variety of mineral fragments. These soils derived mainly from granite schist and gneiss, though usually poor in lime, are rich and fertile (Van Winkle, 1914).

Soil of a drainage basin affects the runoff rate and water quality to a large degree. If a soil is porous, the amount and rate of surface runoff is lessened. If the soil is compact, there is little absorption, and runoff and soil erosion are greater. The solubility of the constituents of the soil are also of importance from the standpoint of water quality.

Climate

The State of Washington is divided by the Cascade mountains into two very different climatic regions. On the west side the prevailing westerly winds from the Pacific Ocean are warm and humid, and supply sufficient rainfall to support a dense growth of natural vegetation. Precipitation increases as the westerly winds ascend the Cascade mountains, with some stations averaging over 100 inches of rainfall per year (U. S. Weather Bureau, 1956). The amount of precipitation is abruptly reduced once the divide is crossed. The climate east of the Cascades is characterized by slight precipitation and much greater extremes in temperature. The modifying effect of the Pacific Ocean is still effective in keeping the climate less severe than similar points inland at comparable latitudes.

The variation in precipitation, a winter maximum and summer minimum, is about

the same in the upper and lower valleys with the total for the former being much less. As shown in table 1, the amount of precipitation received is roughly proportional to the altitude.

Table 1.--Precipitation in the Wenatchee Valley.

Station	Elevation (feet)	Precipitation inches/year 1955	Average annual
Stevens Pass	4,085	88.58	1/
Chiwawa River	2,712	78.33	57.70
Lake Wenatchee	1,970	59.15	36.41
Plain	1,800	37.40	1/
Leavenworth	1,128	34.20	21.14
Wenatchee	634	9.40	8.75

1/ Not yet established.

Prom: U. S. Weather Bureau, 1956. Climatological data, Washington Section. U. S. Department of Commerce, Weather Bureau, 59 (13) (Annual Summary): 205-216.

Snowfall in the upper Wenatchee River Basin is heavy during the winter months, with the amounts varying greatly, depending upon the elevation.

The temperature in the basin is subject to extremes, with January temperatures averaging 27.5° F., and August temperatures averaging 63.1° F. at Plain, just south of Lake Wenatchee (U. S. Weather Bureau, 1956). There is also a considerable range in daily temperatures, usually producing cool nights even in the hottest summer weather.

Summer rainfall in the lower valley is not sufficient for agriculture; consequently irrigation has been necessary ever since the earliest settlement.

The climate of a drainage basin, particularly rainfall, snowfall and temperature, is an important influence on the discharge of the streams in the area. It also affects water quality of the basin, but to a somewhat lesser extent. The temperature is important during the winter months, for it may freeze the grounds, making it somewhat impervious, causing a very rapid runoff should rainfall occur. Temperature is the controlling factor in determining the spring and early summer months' runoff, in the Wenatchee River Basin. This fact is shown graphically in figure 5. Temperature, in conjunction with rainfall also to a large extent determines the character of the vegetative cover. The amount of rainfall is important from the standpoint of erosion.

Land Use and Vegetal Cover

Agriculture is the main land use in the lower Wenatchee Valley, with fruit growing the most important. In Chelan County two out of three farms receive the major part of their income from fruits (Wenatchee Chamber of Commerce 1/).

There are no large stock ranches in the basin, although the watersheds of the Icicle, Peshastin, Little Wenatchee, Chiwawa, and White Rivers provide pasture for large numbers of sheep. Most of the grazing is done within the boundaries of the Wenatchee National Forest and is sytematically controlled by trained Forest Service personnel to prevent overgrazing and the resultant erosion and flash runoffs.

Timber also contributes to the economy of the region, with the most important species being the ponderosa pine, Douglas fir, white pine, and western red cedar. The trees and other vegetation of the forest are also important from the standpoint of soil erosion and water storage, for they break the fall of rain and melting snow and act as a sponge for the moisture. The mosses, interlacing roots of the grasses, brush, etc. absorb the surface water and gradually feed the moisture down to the streams, and thereby to some extent equalize the flow. It is well known that disastrous surface water runoffs occur because fires, overlogging, and continuous overgrazing on watersheds have destroyed the ground cover and the ability of the soil to absorb moisture.

1/ "All about Wenatchee. Apple capital of the world" by Wenatchee Chamber of Commerce. Mimeographed, 2 p.

Population

The first permanent white settlement in the Wenatchee Valley was made in 1872, just north of the present City of Wenatchee. Early settlement was retarded by the lack of transportation facilities. With the coming of the Great Northern Railroad in 1893, growth was very much stimulated. Cities and towns such as Leavenworth, Cashmere, and Wenatchee have grown up where the plentiful water from snow-fed mountain streams is availabile for irrigation of the fertile lands in the sunny valley. The steady growth of the area is indicated in table 2 which shows the population growth for the City of Wenatchee.

At the present time the population is almost entirely confined to the irrigated lower valley. The estimated population in April 1955 for the entire Wenatchee River Basin was 30,000. It is evident that the population density of the watershed is very low. Excluding the population of the City of Wenatchee, it is estimated to be about 10 persons per square mile.

This has an important bearing on the quality of the water flowing from the basin. Usually man's activities, such as logging, mining, grazing, farming, and manufacturing, disturb the balance of nature in a watershed and have a detrimental effect on the water quality.

Sewage from municipalities also can alter the character of the water in a stream. The result of sewage pollution usually depends upon the quantity and strength of the waste in relation to the quantity and character of the receiving water. The sources of municipal sewage to the Wenatchee River are shown in table 3.

It is worthy of note that while the City of Wenatchee has no sewage treatment facilities, the discharge of raw sewage from the city is into the Columbia River and has no effect on the Wenatchee River.

The other sources of domestic sewage listed in table 3 have a detrimental effect on the bacteriological quality of the Wenatchee River. This investigation revealed that they do not alter the physical and chemical character appreciably.

Table 2.--Population growth of the City of Wenatchee.

Date	Population
1900	451
1910	4,050
1920	6,324
1930	11,627
1940	11,620
1950	15,600
1955	16,250

Based on U. S. Census Reports.

Table 3.--Sewage discharge to Wenatchee River.

Town	Population 1950	Type or treatment	Connected population 1953
Cashmere	1,768	Septic tank	1,700
Dryden	175	Septic tank - Contact filter	175
Leavenworth	1,503	Secondary	1,360
Peshastin 1/	250	None	No sewers
Monitor 1/	350	None	No sewers

1/ Sewage probably enters Wenatchee River.

From: Jensen and Vogel, 1954.

Industry

The leading industry in the Wenatchee River Basin is fruit production.

Mining is relatively unimportant at the present time. The major ores previously mined were gold, silver and copper, with most of the mines being located in the Blewett Pass and upper Chiwawa River areas.

The principal mills of the logging and lumbering industry are located at Peshastin, Cashmere and Wenatchee. The cut is mainly ponderosa pine, which is used principally for fruit box manufacturing 1/.

1/ "The geography of the Wenatchee River Basin" by Tim Kenneth Kelley. Master's thesis, University of Washington, Seattle. 1940. 79 pp.

Wastes from industries can be an important influence on the quality of the river water, along which the industries are located. Depending on the nature of the industrial waste, the character of the receiving water can be altered quite extensively if the waste is present in sufficient volume in relation to the quantity of water available for dilution.

In the Wenatchee River Basin, major industrial pollutants offer no serious pollution problems.

Ground Water

The rocks and soil that form the earth's crust are not solid throughout. They contain many voids which provide storage space for water. Rainwater and melted snow charged with carbon dioxide enter these pores and voids and dissolve the soluble minerals present in rocks and soils. Generally, ground water has a much higher content of dissolved minerals, a lower amount of suspended materials and less dissolved oxygen than surface water.

Ground water affects the quality of surface water if the two are allowed to mix. By either percolating directly to the stream or returning to the surface in the form of a spring, ground water usually mixes with and imparts some of its characteristics to the river.

Irrigation

Irrigation has been essential in the Wenatchee River Basin ever since the first white settlers arrived. The area of land under irrigation increased rapidly until about 1915 and has remained fairly constant since then.

According to Simons (1953), 25,470 acres were under irrigation in 1946.

The use of water to irrigate land affects both the quantity and quality of water flowing in a stream. The quantity is lowered by the amount of water lost to evaporation and transpiration. The temperature of the return flow is higher, and the water usually contains more dissolved minerals due to its prolonged contact with the soil.

SAMPLING FOR DETERMINATION OF WATER QUALITIES

Sampling Stations

Sampling stations for collection of water samples for chemical and physical analyses were established at the following locations in the Wenatchee River Basin (figs. 6 and 7).

Station 1 - Nason Creek; near mouth at State Park bridge.

Station 2 - Chiwawa River; near mouth at State Highway 15C bridge.

Station 3 - Lake Wenatchee; 3 miles above mouth, 1/4 mile from south shore.

Station 4 - Wenatchee River at Plain; 2 miles south of Plain, west side of river.

Station 5 - Wenatchee River at Tumwater Canyon; east side of river at Drury Canyon.

Station 6 - Wenatchee River at Sleepy Hollow; at bridge approximately 2 miles above Wenatchee.

These points were selected because of their present accessibility and convenience, and likelihood that they would remain so after construction of the proposed hydroelectric projects. In addition, they were free from local influences and situated so as to give a representative sample of the stream or lake.

Physical Tests

The physical characteristics of water samples collected were determined according to procedures outlined in "Standard Methods for the Examination of Water, Sewage and Industrial Wastes", tenth edition (American Public Health Association, 1955). The temperature, turbidity, color, and electrical conductance were determined.

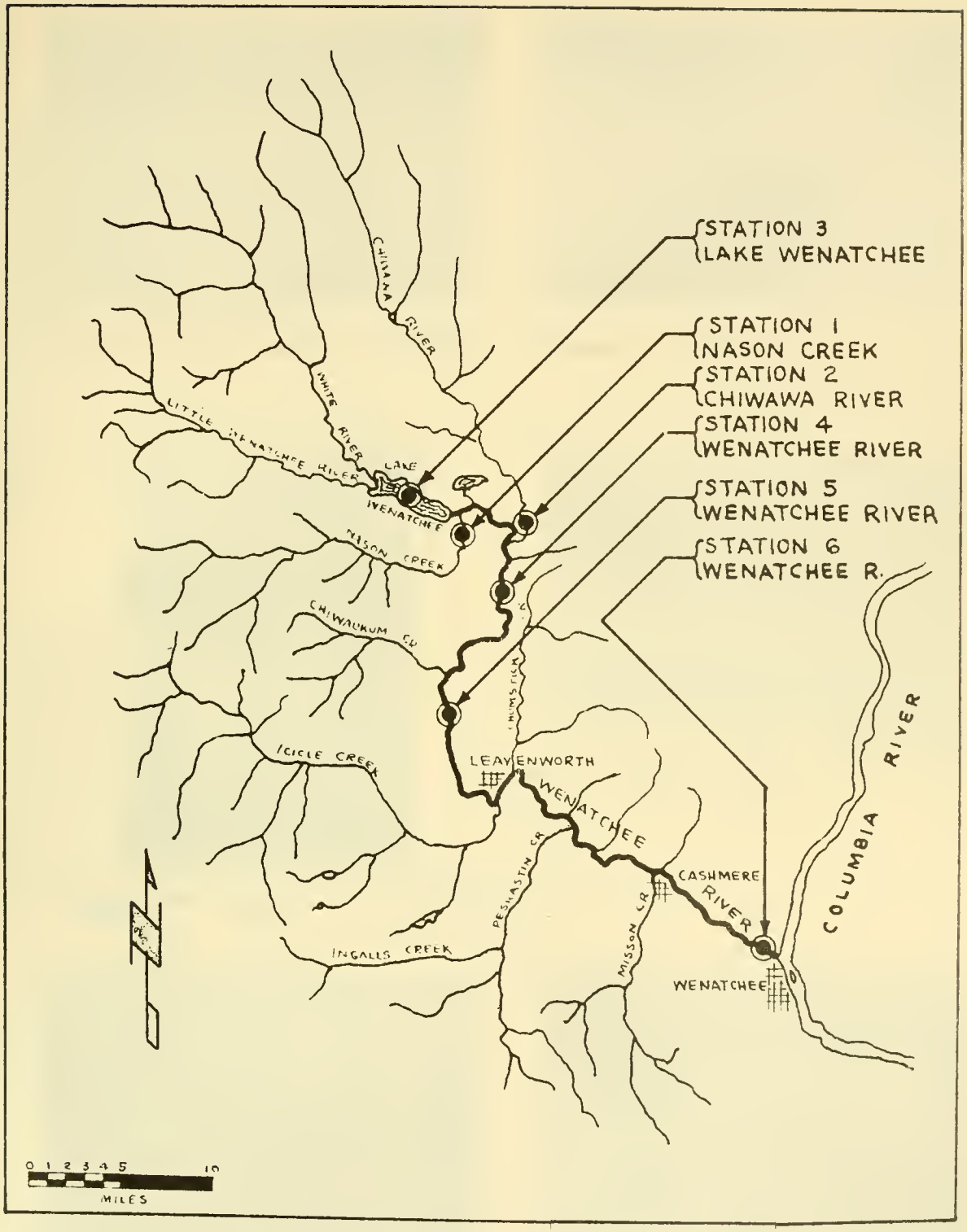
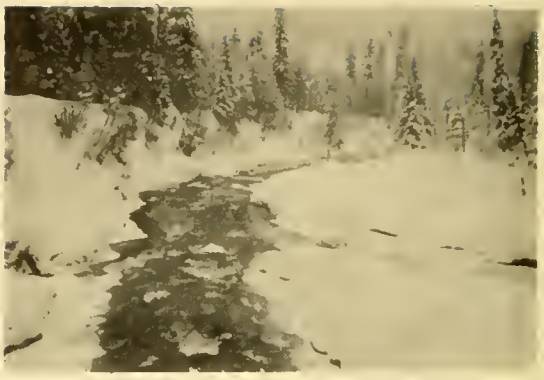


Figure 6.--Wenatchee River Basin sampling stations.
(location map)

STATION 1 NASON CREEK JAN.1956



STATION 2 CHIWAWA RIVER JAN.1956

STATION 3 LAKE WENATCHEE
APRIL 1956

STATION 4 WENATCHEE RIVER
AT PLAIN AUG.1955

STATION 5 WENATCHEE RIVER AT
TUMWATER CANYON AUG.1955

STATION 6 WENATCHEE RIVER AT
SLEEPY HOLLOW APRIL 1956

Figure 7.--Photographs of sampling stations.

Chemical Tests

Complete quantitative chemical analyses for all the constituents present in the water were not made. Determinations were made for certain chemical characteristics, dissolved gases, and metallic ions which adequately define the water quality. Specifically, tests for dissolved oxygen, carbon dioxide, pH, hardness, alkalinity, sulphates, ammonia, and total solids were carried out. They also were made in accordance with "The Standard Methods for the Examination of Water, Sewage and Industrial Wastes", tenth edition. In addition, selected seasonal samples were analyzed by a commercial testing laboratory for iron, copper, aluminum, calcium, magnesium, sodium, potassium, silver, manganese, and lead.

Sampling Procedure

At all sampling stations two separate samples were collected, and two separate determinations made for each physical and chemical test. The results reported are an average of the two determinations. Samples were usually collected at mid-depth from the left and right halves of the stream. At Lake Wenatchee, a boat was used to get to the sampling point. Samples at varying depths, usually 10 ft., 75 ft., and 175 ft., were obtained from the lake.

Frequency of Sampling

During the summer of 1954 samples were collected weekly from Station 6, Wenatchee River at Sleepy Hollow. A few random samples were also collected from this point during the winter and spring of 1954-1955. Sampling of all the stations at 1- or 2-week intervals commenced in June of 1955 and continued through September of the same year. Where possible, monthly samples were obtained from all sampling stations during the winter and spring of 1955-1956. Severe weather conditions prevented sampling some of the stations in the upper valley during this period.

WATER QUALITY IN THE WENATCHEE RIVER BASIN

Nason Creek (Station 1)

The stream is 23 miles long and enters the Wenatchee River just below Lake Wenatchee at an elevation of 1,800 feet. No up-to-date information on the quantity of stream flow was available.

Physical characteristics

The physical characteristics of the waters of Nason Creek are shown in tables 4 and 5.

These physical characteristics are plotted versus time and shown graphically in figures 8 and 9.

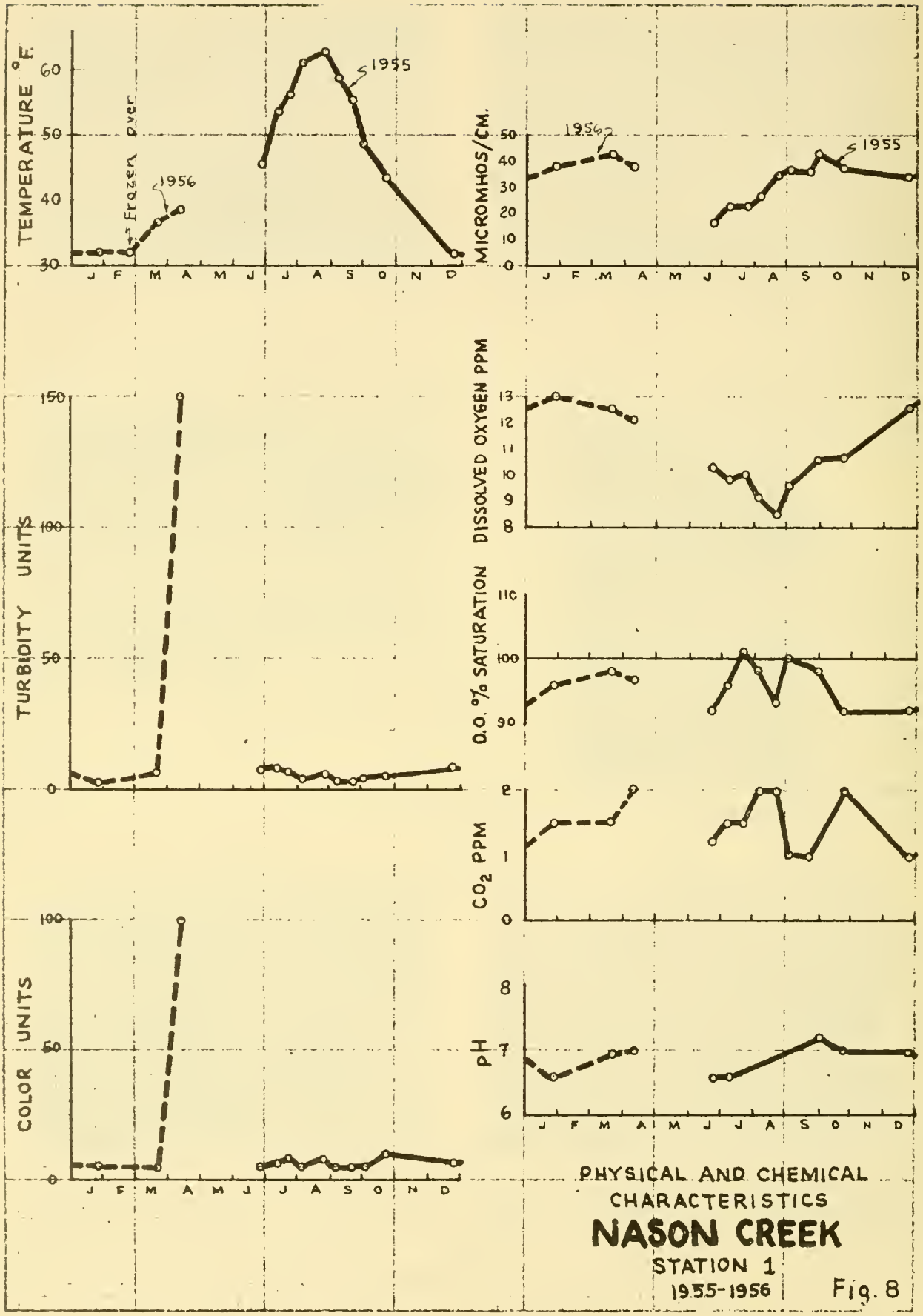
Table 4.--Nason Creek--Water quality, physical characteristics, 1955-1956.

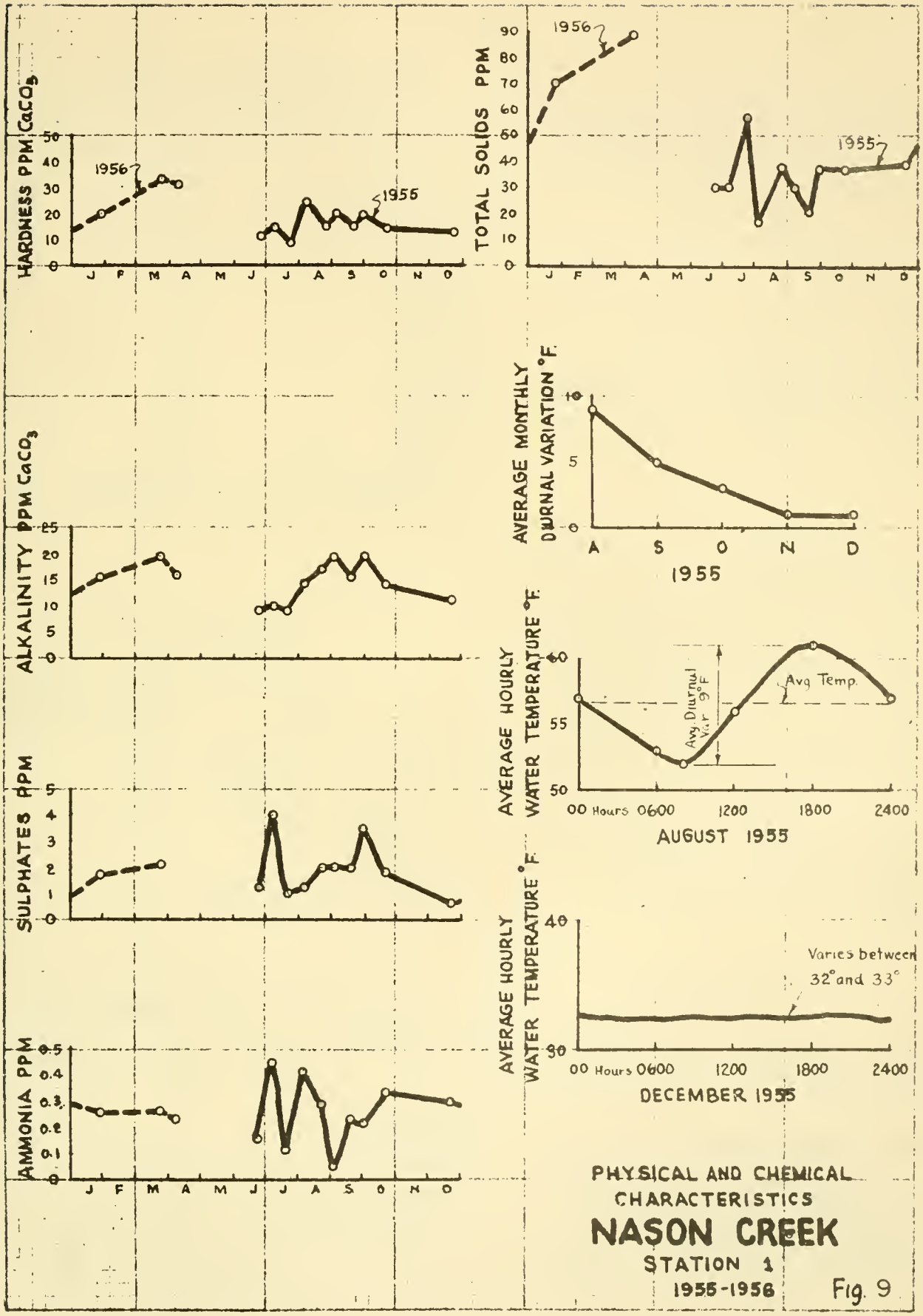
	Average	Minimum	Maximum
Temperature (° F.)	47	32	63
Turbidity (units)	5	2	150 1/
Color (units)	7	5	100 1/
Specific conductance (micromhos/cm at 25° C.)	34	17	43

1/ Abnormal due to heavy surface runoff and not considered in the average value

Table 5.--Nason Creek--Water quality, water temperature 1956

Month	Average daily Maximum temperature °F.	Average daily minimum temperature °F.	Average diurnal variation °F.
August	61	52	9
September	55	50	5
October	44	41	3
November	35	34	1
December	33	32	1


TEMPERATURE °F.
60
50
40
30
Frozen over
1956
1955
J F M A M J J A S O N D
MICROMHOS/CM.
50
40
30
20
10
0
1956
1955
J F M A M J J A S O N D
TURBIDITY UNITS
150
100
50
0
J F M A M J J A S O N D
DISSOLVED OXYGEN PPM
13
12
11
10
9
8
D.O. % SATURATION
110
100
90
CO_2 PPM
2
1
0
COLOR UNITS
100
50
0
J F M A M J J A S O N D
pH
8
7
6
J F M A M J J A S O N D
PHYSICAL AND CHEMICAL CHARACTERISTICS
NASON CREEK
STATION 1
1955-1956
Fig. 8


HARDNESS PPM $CaCO_3$
1956
1955
J F M A M J J A S O N D
TOTAL SOLIDS PPM
1956
1955
ALKALINITY PPM $CaCO_3$
SULPHATES PPM
AMMONIA PPM
AVERAGE MONTHLY DIURNAL VARIATION °F.
A S O N D
1955
AVERAGE HOURLY WATER TEMPERATURE °F.
Avg. Diurnal Var 9°F
Avg Temp.
00 Hours 0600 1200 1800 2400
AUGUST 1955
AVERAGE HOURLY WATER TEMPERATURE °F.
Varies between 32° and 33°
00 Hours 0600 1200 1800 2400
DECEMBER 1955
PHYSICAL AND CHEMICAL CHARACTERISTICS
NASON CREEK
STATION 1
1955-1956
Fig. 9

Chemical characteristics

The chemical characteristics of the waters of Nason Creek as determined during this study are listed in table 6. These chemical characteristics are plotted against time and shown graphically in figures 8 and 9.

Summary. The waters of Nason Creek contained very little suspended or dissolved matter. They were practically neutral and very soft. Color and turbidity were noticeable only on one occasion during the period of sampling. The waters were practically saturated with dissolved oxygen. Temperature of the water was subject to significant diurnal variations during the warm weather months.

Nason Creek--Comparison of 1940 and 1955-1956 Data

In 1940 a quantitative study of the food available to fish on the bottom of Nason Creek was made by the United States Fish and Wildlife Service. A limited amount of physical and chemical water quality data were also obtained during May through November of that year. The results of this investigation present a basis for comparison of the two studies, as is shown in table 7.

While these data were limited and did not cover exactly the same seasonal period, their striking similarity indicated the water of Nason Creek had not been altered during the time interval.

Chiwawa River (Station 2)

The Chiwawa River is fed by small glaciers near the Cascade summit. It flows for 27 miles before entering the Wenatchee River just above Plain.

Physical characteristics

The physical characteristics of the waters of the Chiwawa River are shown in tables 8 and 9. These physical characteristics are plotted versus time and are shown graphically in figures 10 and 11.

Table 6.--Nason Creek--Water quality, chemical characteristics, 1955-1956 1/

	Average	Minimum	Maximum
Dissolved oxygen	10.7	8.55	13.0
Percent saturation D.O.	96	92	101
Carbon dioxide	1.5	1.0	2.0
pH	6.9	6.6	7.2
Total hardness	19	9	33
Alkalinity	15	9	19
Sulfates	1.9	0.6	4.0
Ammonia	0.25	0.05	0.45
Total solids	41	17	89
Iron	0.05	-	-
Copper	0.00	-	-
Aluminum	0.20	-	-
Calcium	10.00	-	-
Magnesium	0.60	-	-
Sodium	1.50	-	-
Potassium	1.60	-	-
Chloride	0	-	-

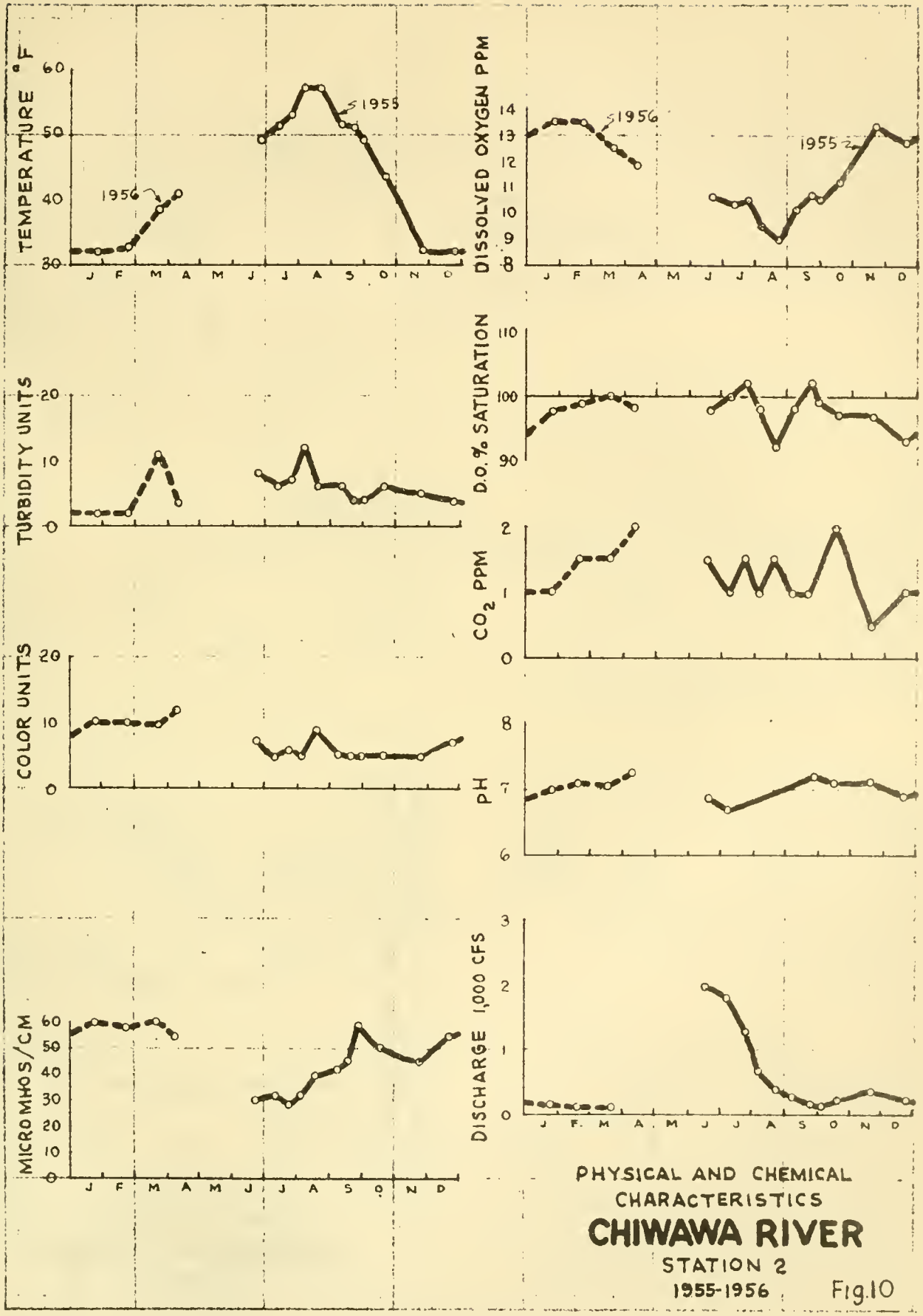
1/ All units are ppm except pH and percent saturation.

Table 7.--Nason Creek--Water quality 1940 and 1955-1956.

	1940	1955-1956
Average dissolved oxygen (ppm)	10.9	10.7
Average percent saturation D.O.	96	96
Average carbon dioxide (ppm)	1.9	1.5
Average pH	6.9	6.9
Average total alkalinity (ppm)	13	15

Table 8.--Chiwawa River--Water quality, physical characteristics, 1955-1956

	Average	Minimum	Maximum
Temperature (° F.)	45	32	58
Turbidity (units)	6	2	12
Color (units)	7	5	12
Specific conductance (micromhos/cm at 25° C.)	46	29	60

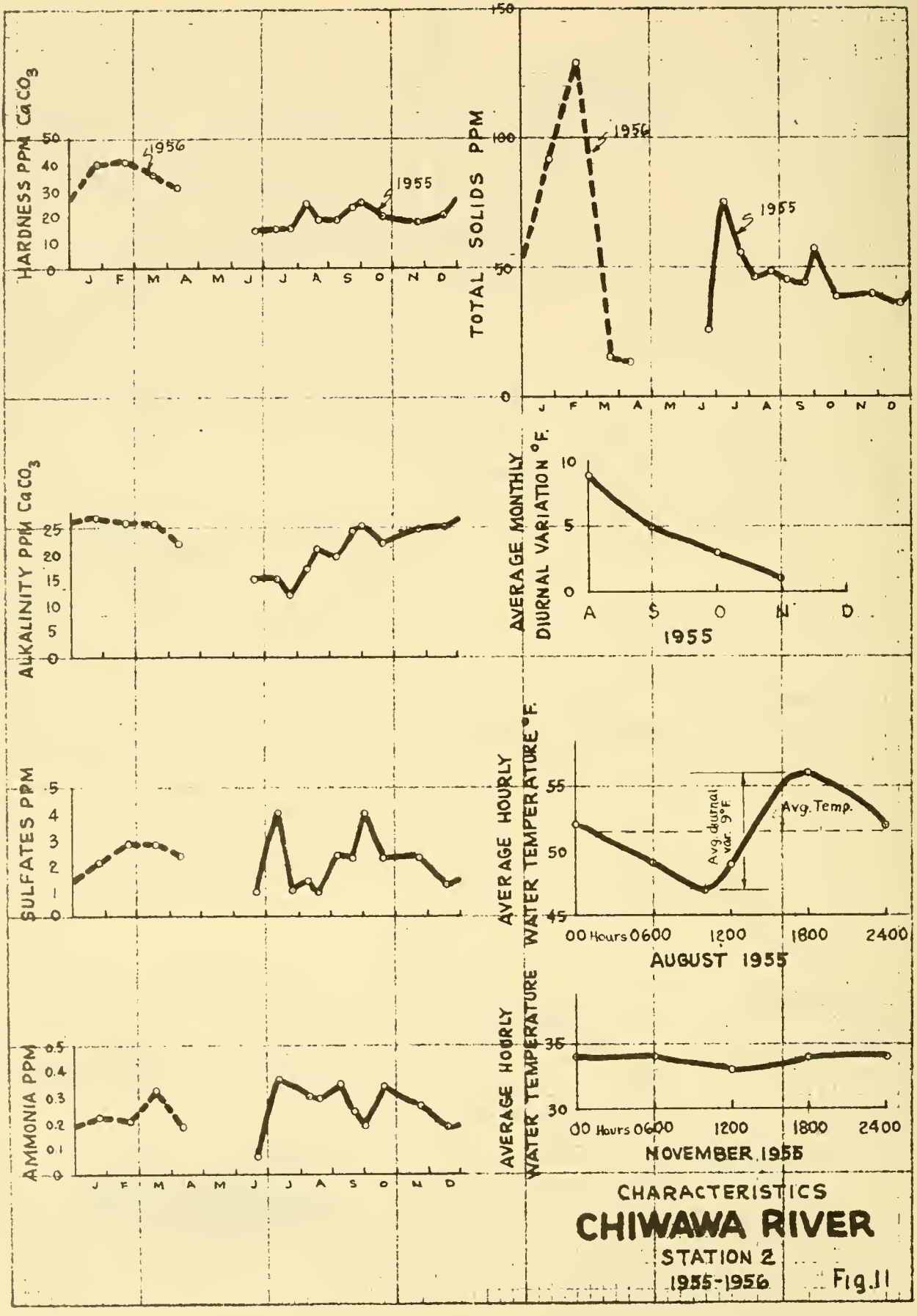


PHYSICAL AND CHEMICAL CHARACTERISTICS

CHIWAWA RIVER

STATION 2

1955-1956 Fig.10


HARDNESS PPM $CaCO_3$
1956
1955
J F M A M J J A S O N D
TOTAL SOLIDS PPM
1956
1955
J F M A M J J A S O N D
ALKALINITY PPM $CaCO_3$
SULFATES PPM
AMMONIA PPM
AVERAGE MONTHLY DIURNAL VARIATION °F.
A S O N D
1955
AVERAGE HOURLY WATER TEMPERATURE °F.
Avg. diurnal var. 9°F
Avg. Temp.
00 Hours 0600 1200 1800 2400
AUGUST 1955
AVERAGE HOURLY WATER TEMPERATURE °F.
00 Hours 0600 1200 1800 2400
NOVEMBER 1955
CHARACTERISTICS
CHIWAWA RIVER
STATION 2
1955-1956
Fig. 11

Chemical characteristics

The chemical characteristics of the waters of the Chiwawa river determined during this study are shown in table 10. These chemical characteristics are plotted against time and are shown graphically in figures 10 and 11.

Summary

A general description of the waters of the Chiwawa River would emphasize the low content of suspended and dissolved matter, the softness and neutral pH. Color and turbidity were consistently low, although the Chiwawa is known to be turbid during the late spring and early summer freshets. For practical purposes the waters were considered saturated with dissolved oxygen. A significant diurnal variation in temperature was observed during the summer months. In general, the combination of factors in the drainage basin produced a water of excellent physical and chemical characteristics.

Table 9.--Chiwawa River--Water quality, water temperature 1956

Month	Average daily maximum temperature °F.	Average daily minimum temperature °F.	Average diurnal variation °F.
August	56	47	9
September	35	48	5
October	42	39	3
November	34	33	1
December 1/	-	-	-

1/ Not available.

Table 10.--Chiwawa River--Water quality, chemical characteristics 1/, 1955-1956

	Average	minimum	maximum
Dissolved oxygen	11.3	9.0	13.5
Percent saturation D.O.	98	92	102
Carbon dioxide	1.5	0.5	2.0
pH	7.0	6.7	7.2
Total hardness	25	14	40
Total alkalinity	21	12	27
Sulfates	2.2	1.0	4.0
Ammonia	0.23	0.07	0.37
Total solids	50	13	128
Iron	0.02	0.01	0.03
Copper	0.00	0.00	0.00
Aluminum	0.015	0.01	0.02
Calcium	7.8	6.5	9.0
Magnesium	0.55	0.1	1.0
Sodium	2.0	1.0	3.0
Potassium	1.8	1.6	2.0
Chloride	0	0	0

1/ All units ppm except percent saturation and pH.

Lake Wenatchee (Station 3)

This lake located at the head of the Wenatchee River is about 5 miles long and 1 mile wide (fig. 12). It is a deep lake with the depth generally around 150 to 200 feet. The shoreline is rocky, wooded, and in places lined with summer cottages. The elevation of the water surface is 1,870 feet above mean sea level. There is a State Park at the lower end; and at the upper end, near the mouths of the Little Wenatchee and White Rivers, there is a swampy area. The lake is an important rearing area for sockeye salmon in the Columbia River System (Bryant and Parkhurst, 1950).

Water quality sampling from the lake was interrupted by severe weather during the winter of 1955-1956. The lake was completely frozen over from early February through late April 1956.

Physical characteristics

The physical characteristics of the Lake Wenatchee water at depths of 10, 75, and 175 feet are shown in table 11.

Chemical characteristics

The chemical characteristics of the lake waters are tabulated in table 12.

Summary

The waters of Lake Wenatchee were characterized by their unusually low content of suspended and dissolved matter. The most significant variable with depth was temperature.

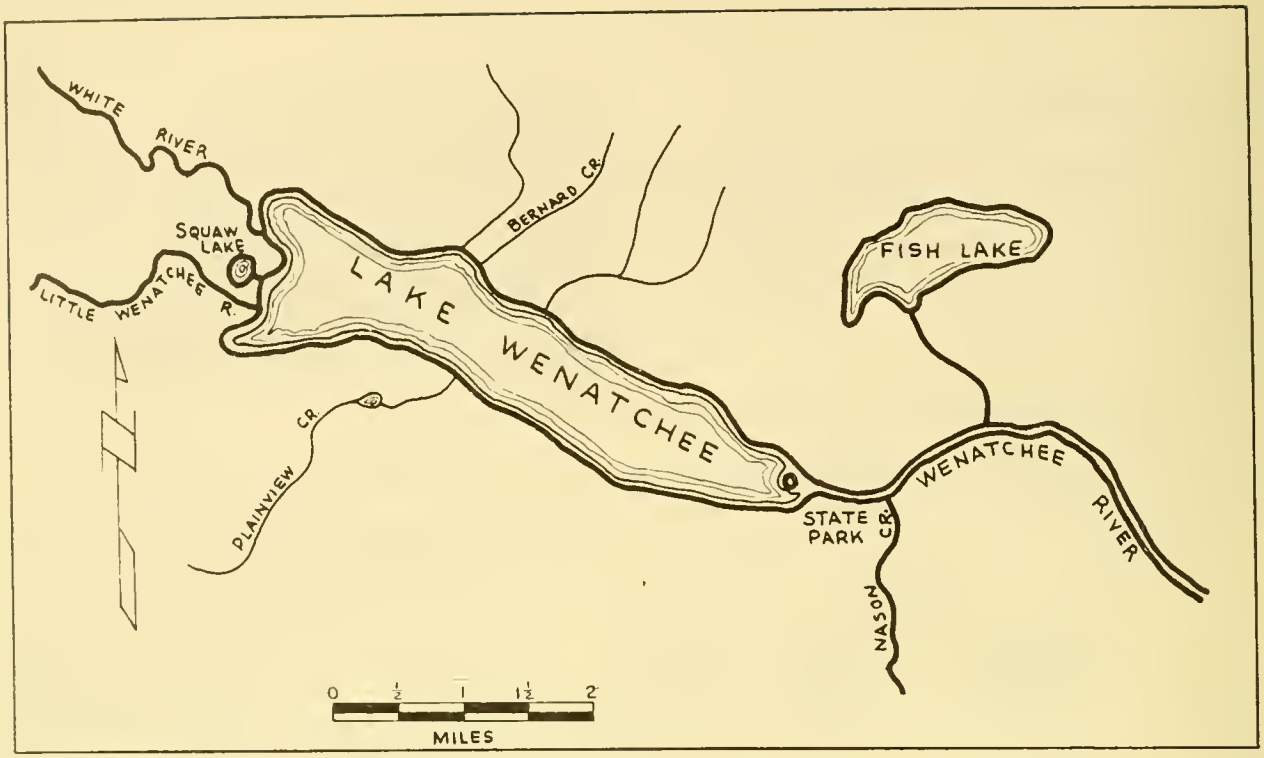


Figure 12.--Lake Wenatchee.

Table 11.--Lake Wenatchee--Water quality, physical characteristics, June-October 1955.

Average	Depth		
	10 ft.	75 ft.	175 ft.
Temperature (° F.)	53	49	46
Turbidity (units)	3	4	4
Color (units)	6	6	7
Specific conductance (micromhos/cm at 25° C.)	23	23	23

Table 12.--Lake Wenatchee--Water quality, chemical characteristics 1/, June-October 1955.

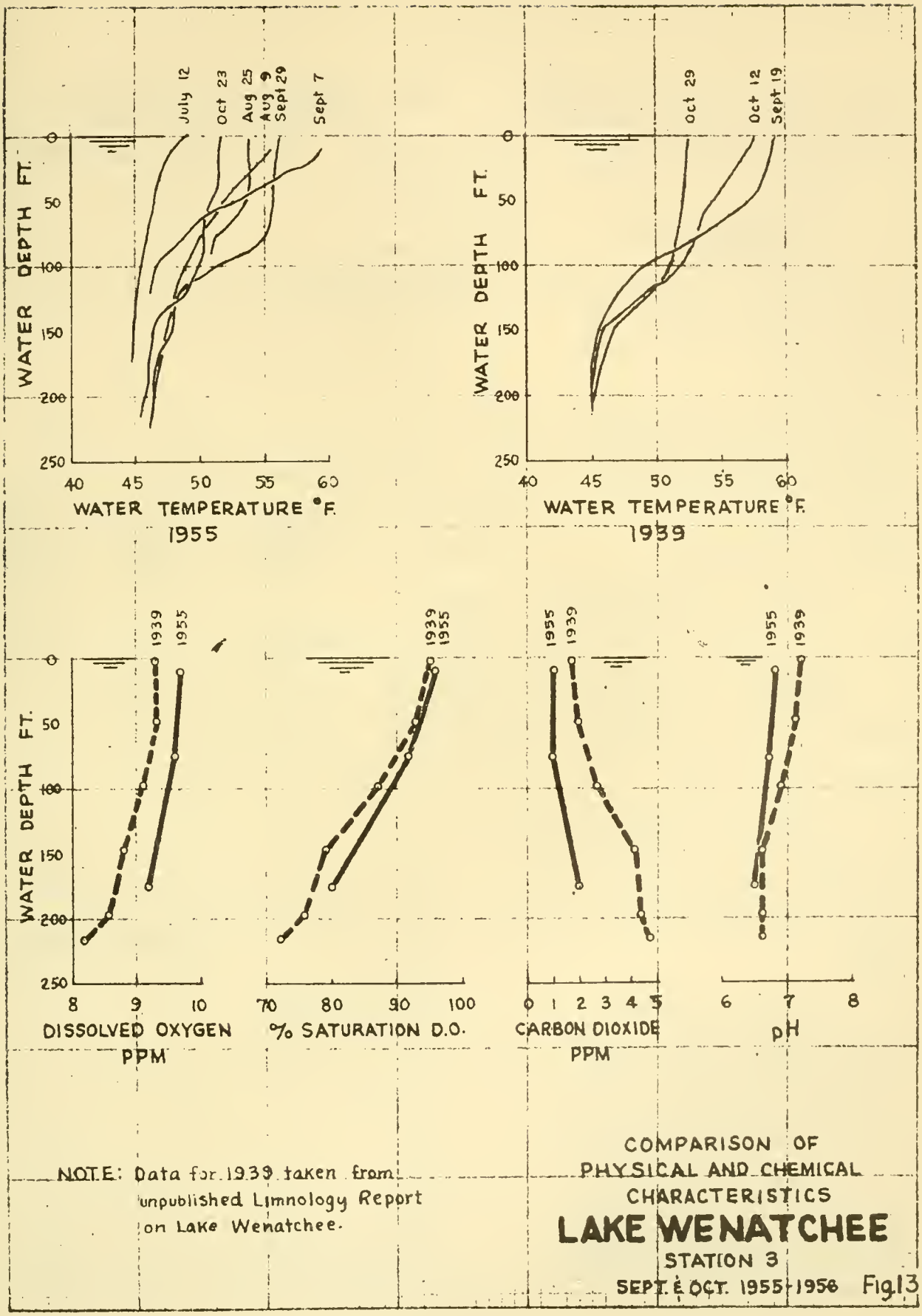
Average	Depth		
	10 ft.	75 ft.	175 ft.
Dissolved oxygen	10.0	9.9	9.6
Percent saturation D.O.	98	93	86
Carbon dioxide	1.0	1.5	2.0
pH	6.8	6.7	6.6
Total hardness	15	16	15
Total alkalinity	11	10	11
Sulfates	1.7	2.1	1.8
Ammonia	0.29	0.32	0.27
Total solids	30	29	32
Iron	0.03	-	-
Copper	0.00	-	-
Aluminum	0.02	-	-
Calcium	12.0	-	-
Magnesium	0.8	-	-
Sodium	1.0	-	-
Potassium	1.1	-	-

1/ All units are ppm except percent saturation and pH.

Other variables that decreased with depth were dissolved oxygen, percent saturation, and pH. Carbon dioxide was the only quality characteristic that showed an increase with depth. The water was very soft and slightly acidic.

Lake Wenatchee--Comparison of 1939 and 1955 Data

A limited limnological study of Lake Wenatchee was made in 1939 by the United States Fish and Wildlife Service, the results of which were not published. During that study a limited amount of water quality data were collected from the lake during September and October, 1939. The sampling station was at a point very near to Station 3 of this investigation. The data presented in the earlier report covered the same



NOTE: Data for 1939 taken from unpublished Limnology Report on Lake Wenatchee.

COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS

LAKE WENATCHEE

STATION 3

SEPT. & OCT. 1955-1956 Fig. 13

seasonal period and made an interesting basis for comparison. The data from the sources are presented graphically in figure 13.

Wenatchee River at Plain (Station 4)

The Wenatchee River near Plain has a drainage area of 591 square miles and is fed mainly by Lake Wenatchee, Nason Creek, and the Chiwawa River.

Sampling at this station was interrupted by an unusually heavy snowfall during the winter of 1955-1956. No water quality data were obtained from November through February of that period.

Physical characteristics

The physical characteristics of the waters of the Wenatchee River at Plain are shown in tables 13 and 14.

These physical characteristics are plotted versus time and shown graphically in figures 14 and 15.

Chemical characteristics

The chemical characteristics of the waters of the Wenatchee River at Plain are listed in table 15. The chemical characteristics plotted against time are shown graphically in figures 14 and 15.

Summary

The water in the Wenatchee River at Plain is largely a mixture of flow from Nason Creek, Chiwawa River, and Lake Wenatchee. Consequently, its characteristics were very similar to the aforementioned waters. As previously stated, they were in general characterized by their low suspended and dissolved matter content, their softness and neutral pH. The maximum diurnal variation in the water temperature was less in the Wenatchee River than that found in Nason Creek and the Chiwawa River.

Table 13.--Wenatchee River at Plain--Water quality, physical characteristics, 1955-1956.

	Average	Minimum	Maximum
Temperature (° F.)	53	37	63
Turbidity (units)	8	2	40
Color (units)	10	5	45
Specific conductance (micromhos/cm at 25° C.)	31	22	49

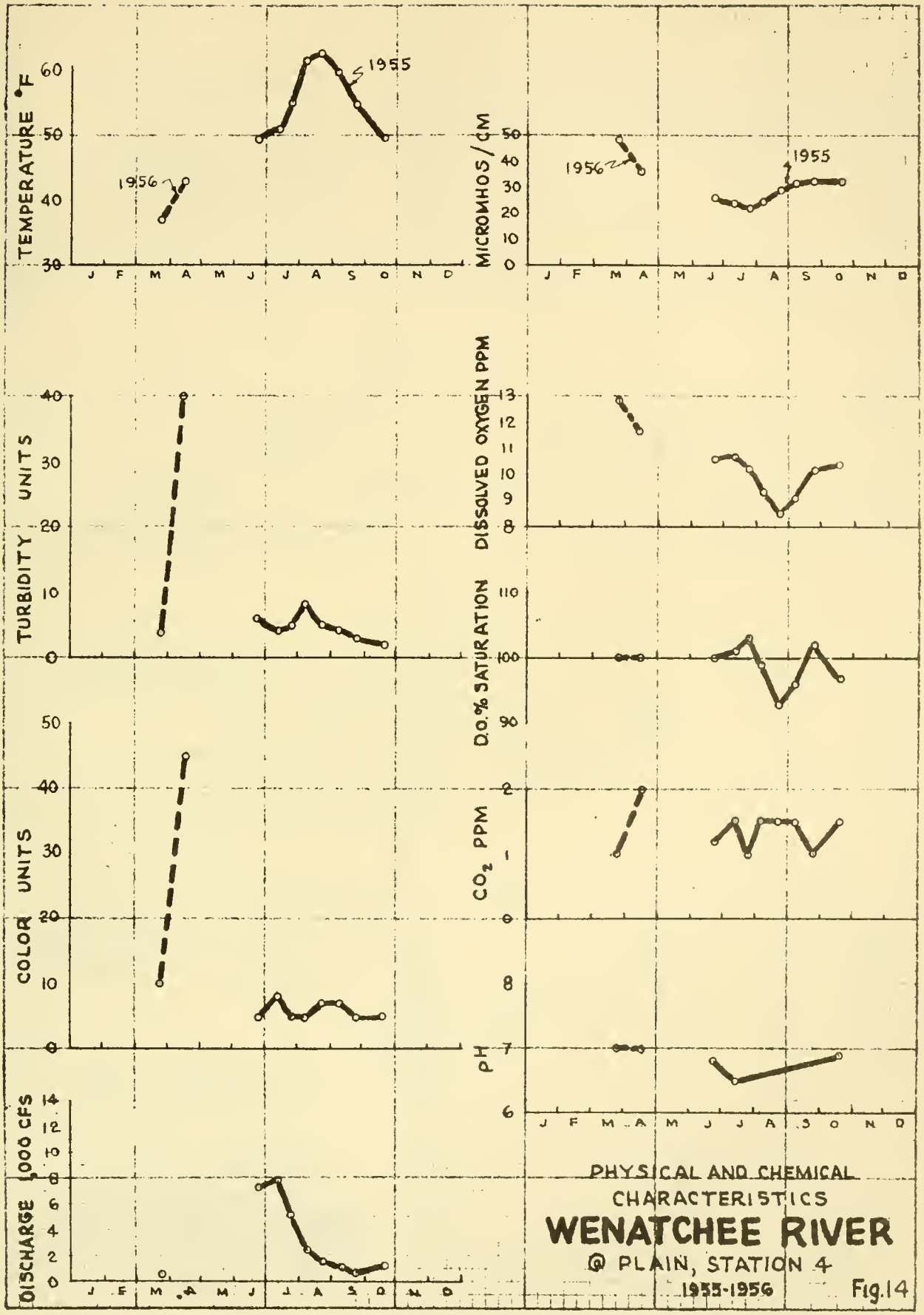
Table 14.--Wenatchee River at Plain--Water quality, water temperature, 1956.

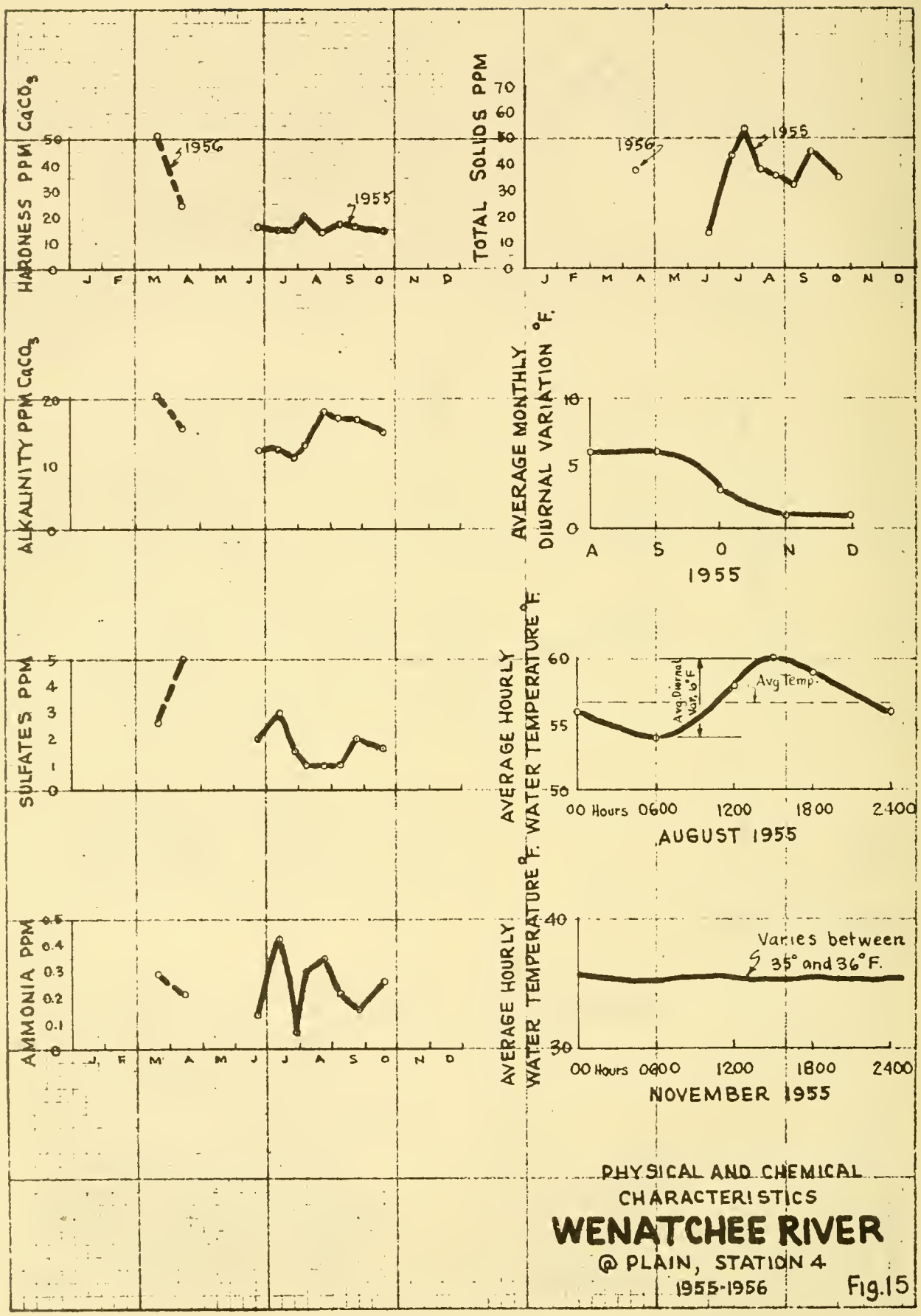
Month	Average daily maximum temperature °F.	Average daily minimum temperature °F.	Average diurnal variation °F.
August	60	54	6
September	57	51	6
October	48	45	3
November	36	35	1
December	35	34	1

Table 15.--Wenatchee River at Plain--Water quality, chemical characteristics, 1955-1956 1/

	Average	Minimum	Maximum
Dissolved	10.4	8.5	12.8
Percent saturated D.O.	99	93	103
Carbon dioxide	1.5	1.0	2.0
pH	6.8	6.5	7.0
Total hardness	20	14	51
Alkalinity	15	11	21
Sulfates	2.0	1.0	5.0
Ammonia	0.24	0.06	0.42
Total solids	37	14	54

1/ All units are ppm except pH and percent saturation.


TEMPERATURE °F
60
50
40
30
1955
1956
J F M A M J J A S O N D
MICROMHOS / CM
50
40
30
20
10
0
1956
1955
J F M A M J J A S O N D
TURBIDITY UNITS
40
30
20
10
0
DISSOLVED OXYGEN PPM
13
12
11
10
9
8
D.O. % SATURATION
110
100
90
COLOR UNITS
50
40
30
20
10
0
CO_2 PPM
2
1
0
pH
8
7
6
J F M A M J J A S O N D
DISCHARGE 1,000 CFS
14
12
10
8
6
4
2
0
J F M A M J J A S O N D
PHYSICAL AND CHEMICAL
CHARACTERISTICS
WENATCHEE RIVER
@ PLAIN, STATION 4
1955-1956
Fig. 14


HARDNESS PPM CaCO3
1956
1955
J F M A M J J A S O N D
TOTAL SOLIDS PPM
70
60
50
40
30
20
10
0
1956
1955
J F M A M J J A S O N D
ALKALINITY PPM CaCO3
20
10
0
AVERAGE MONTHLY DIURNAL VARIATION °F.
10
5
0
A S O N D
1955
SULFATES PPM
5
4
3
2
1
0
AVERAGE HOURLY WATER TEMPERATURE °F.
60
55
50
Avg. Diurnal Var. 6°F
Avg Temp.
00 Hours 0600 1200 1800 2400
AUGUST 1955
AMMONIA PPM
0.5
0.4
0.3
0.2
0.1
0
J F M A M J J A S O N D
AVERAGE HOURLY WATER TEMPERATURE °F.
40
30
Varies between 35° and 36° F.
00 Hours 0600 1200 1800 2400
NOVEMBER 1955
PHYSICAL AND CHEMICAL CHARACTERISTICS
WENATCHEE RIVER
@ PLAIN, STATION 4
1955-1956
Fig. 15

Wenatchee River at Tumwater Canyon (Station 5)

The Wenatchee River actually leaves its true valley a few miles below Plain and flows for approximately 6 miles through the steep, narrow Tumwater Canyon. This is the roughest and steepest portion of the entire river. The only additional major tributary to the river at this station is the Chiwaukum Creek.

Due to the heavy snowfall during the winter of 1955-1956, water sample collection was seriously hampered at this station. Samples obtained from January through April, 1956 were of necessity collected from the Tumwater bridge, about 2 miles upstream from Station 5. It was felt that the water quality was essentially the same at the two points.

Physical characteristics

The physical characteristics of the waters of the Wenatchee River at Tumwater Canyon are shown in tables 16 and 17.

These physical characteristics plotted against time are shown graphically in figures 16 and 17.

Chemical characteristics

The chemical characteristics of the Wenatchee River at Tumwater Canyon are shown in table 18. They are also plotted versus time and shown graphically in figures 16 and 17.

Summary

The waters of the Wenatchee River at Tumwater Canyon had practically the same characteristics as those previously noted for Station 4 upstream at Plain. A general description would emphasize their low suspended and dissolved material content, their softness and neutral pH. The diurnal variation in water temperature was for the most part the same also for the two stations.

Table 16.--Wenatchee River at Tumwater Canyon--Water quality, physical characteristics, 1955-1956.

	Average	Minimum	Maximum
Temperature (2 F.)	50	32	62
Turbidity (units)	8	2	33
Color (units)	10	4	38
Specific conductance (micromhos/cm at 25° C.)	36	25	54

Table 17.--Wenatchee River at Tumwater Canyon--Water quality, water temperature, 1956.

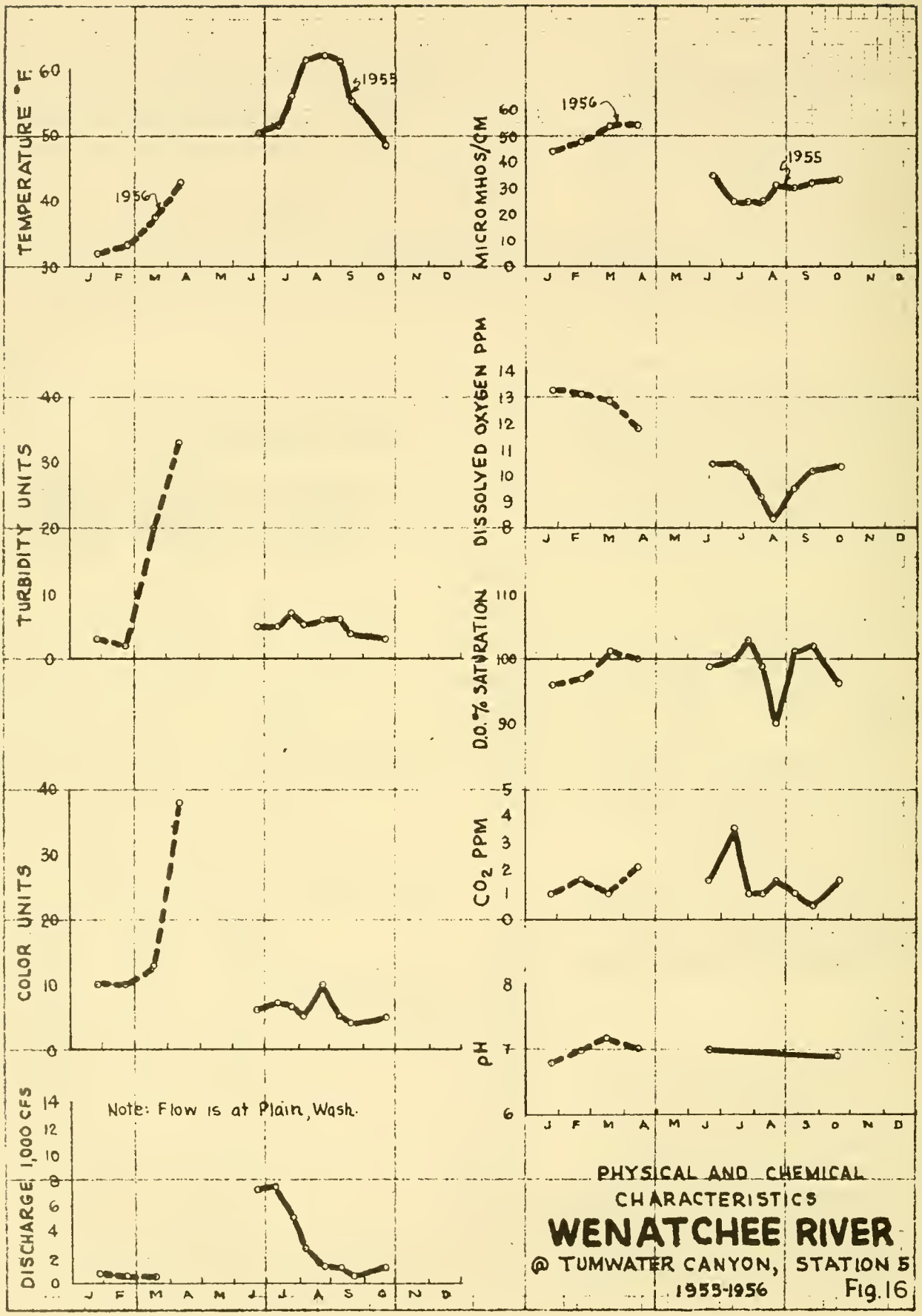
	Average daily maximum temperature °F.	Average daily minimum temperature °F.	Average diurnal variation °F.
August	61	54	7
September	56	50	6
October	49	44	5
November	36	35	1
December 1/	-	-	-

1/ Not available.

Table 18.--Wenatchee River at Tumwater Canyon--Water quality, chemical characteristics, 1955-1956 1/.

	Average	Minimum	Maximum
Dissolved oxygen	10.8	8.3	13.2
Percent saturation D.O.	99	90	103
Carbon dioxide	1.5	0.5	3.5
pH	7.0	6.8	7.1
Total hardness	22	13	37
Total alkalinity	18	12	25
Sulfates	1.9	0.9	3.0
Ammonia	0.29	0.09	0.56
Total solids	44	3	95
Iron	0.05	-	-
Copper	0.00	-	-
Aluminum	0.24	-	-
Calcium	14.0	-	-
Magnesium	1.0	-	-
Sodium	0.5	-	-
Potassium	1.2	--	-

1/ All units are ppm except pH and percent saturation.

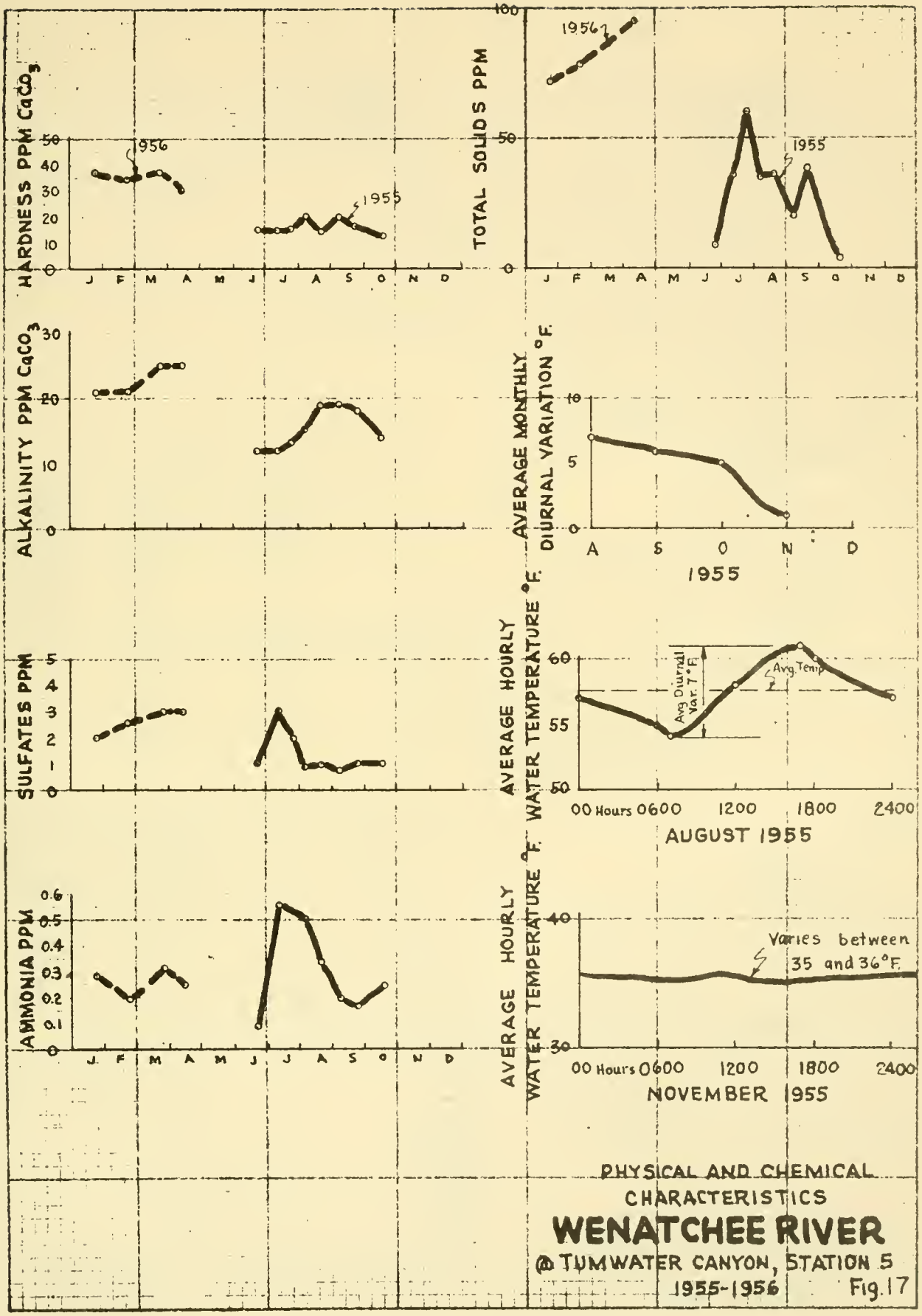


PHYSICAL AND CHEMICAL CHARACTERISTICS

WENATCHEE RIVER

@ TUMWATER CANYON, STATION 5

1955-1956 Fig. 16



PHYSICAL AND CHEMICAL CHARACTERISTICS

WENATCHEE RIVER

@ TUMWATER CANYON, STATION 5

1955-1956 Fig. 17

Wenatchee River at Sleepy Hollow (Station 6)

The sampling point at Sleepy Hollow on the Wenatchee River was located approximately 2 miles upstream from its junction with the Columbia River. Major tributaries that flow into the river between Stations 5 and 6 are Icicle Creek, Chumstick Creek, Peshastin Creek, and Mission Creek. In addition, the treated sewage from Leavenworth, plus the raw sewage from Peshastin and Cashmere, is present in the river at this station. As previously stated, the raw sewage from the City of Wenatchee is discharged into the Columbia River and does not influence the water at this station.

Physical characteristics

The physical characteristics of the waters of the Wenatchee River at Sleepy Hollow are tabulated in tables 19 and 20, and are shown graphically in figures 18 and 19.

Chemical characteristics

The chemical characteristics of the waters of the Wenatchee River at Sleepy Hollow are listed in table 21 and are also plotted versus time and shown graphically in figures 18 and 19.

Summary

The characteristics of the Wenatchee River at Station 6 were very similar to those previously noted upstream. In general there was a slight downstream increase in most physical and chemical characteristics. The amount of suspended and dissolved matter was usually very low. Turbidity and color were noticeable only during March and April, 1956. A saturation or supersaturation with dissolved oxygen was prevalent most of the time during this study. The water was very soft and slightly alkaline.

Wenatchee River Progressing Downstream from Lake Wenatchee

To show graphically the downstream changes that were noted in the

Table 19.--Wenatchee River at Sleepy Hollow--Water quality, physical characteristics, 1954, 1955 and 1956.

	Average	Minimum	Maximum
Temperatures (° F.)	51	32	66
Turbidity (units)	10	1	80
Color (units)	10	0	48
Specific conductance (micromhos/cm at 25° C.)	56	31	118

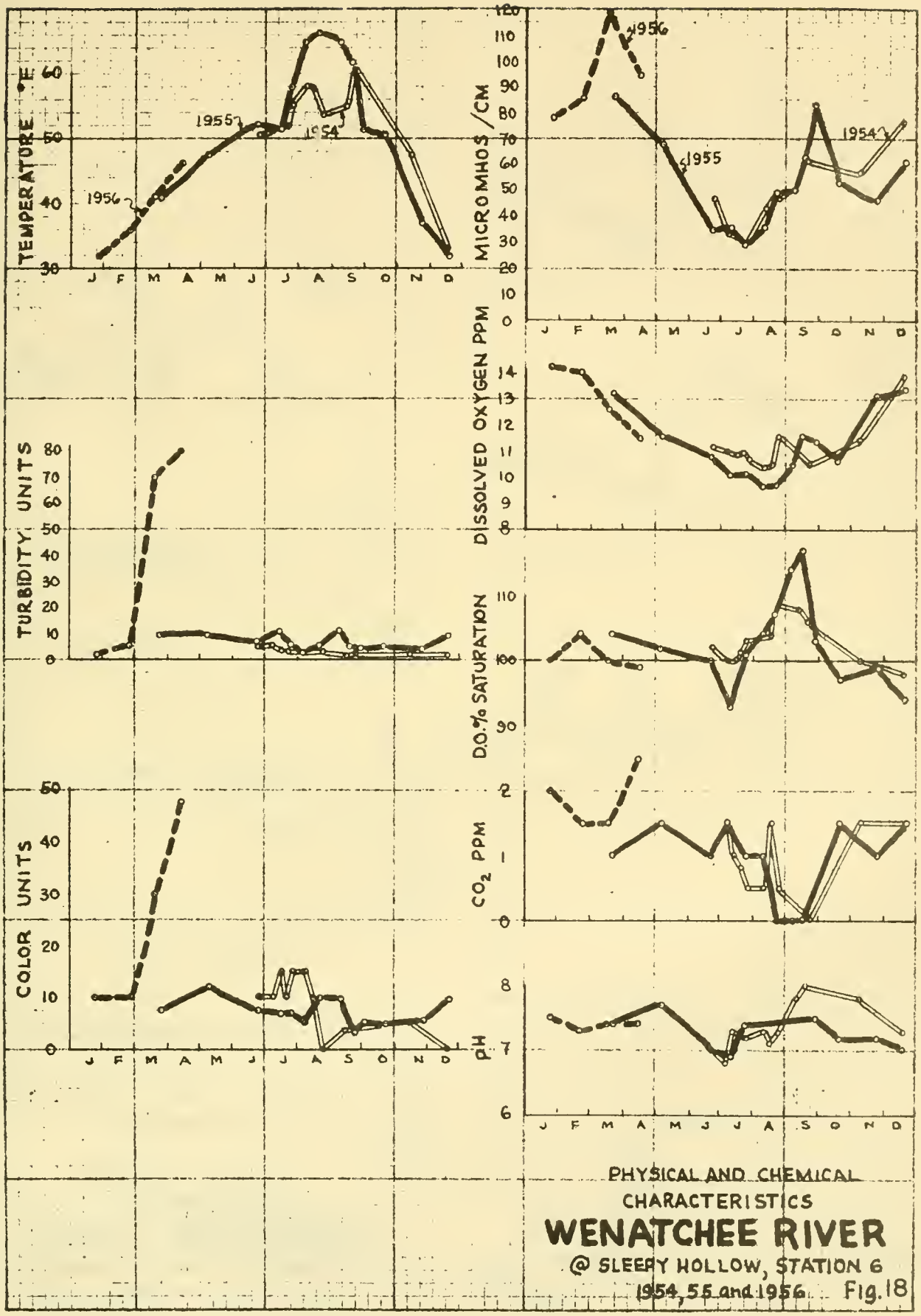
Table 20.--Wenatchee River at Sleepy Hollow-Water quality, water temperature, 1956.

Month	Average daily maximum temperature °F.	Average daily minimum temperature °F.	Average diurnal variation °F.
August	62	57	5
September	60	53	7
October	48	45	3
November	37	36	1
December	34	33	1

Table 21.--Wenatchee River at Sleepy Hollow--Water quality, chemical characteristics, 1954, 1955 and 1956 1/.

	Average	Minimum	Maximum
Dissolved oxygen	11.4	9.7	14.2
Percent saturation	103	93	117
Carbon dioxide	1.0	0	2.5
pH	7.3	6.8	8.0
Total hardness	27	7	70
Alkalinity	28	13	70
Sulfates	2.6	1.2	4.6
Ammonia	0.21	0.05	0.31
Total solids	52	0	270
Iron	0.01	0.00	0.05
Copper	0.00	0.00	0.00
Aluminum	0.01	0.00	0.02
Calcium	15.0	4.0	41.0
Magnesium	1.8	0.1	4.0
Sodium	1.7	1.0	4.0
Potassium	1.8	1.2	3.0
Zinc	0.0	-	-
Lead	0.0	-	-
Manganese	0.0	-	-
Silver	0.0	-	-
Chloride	0.0	-	-

1/ All units per ppm except pH and percent saturation.

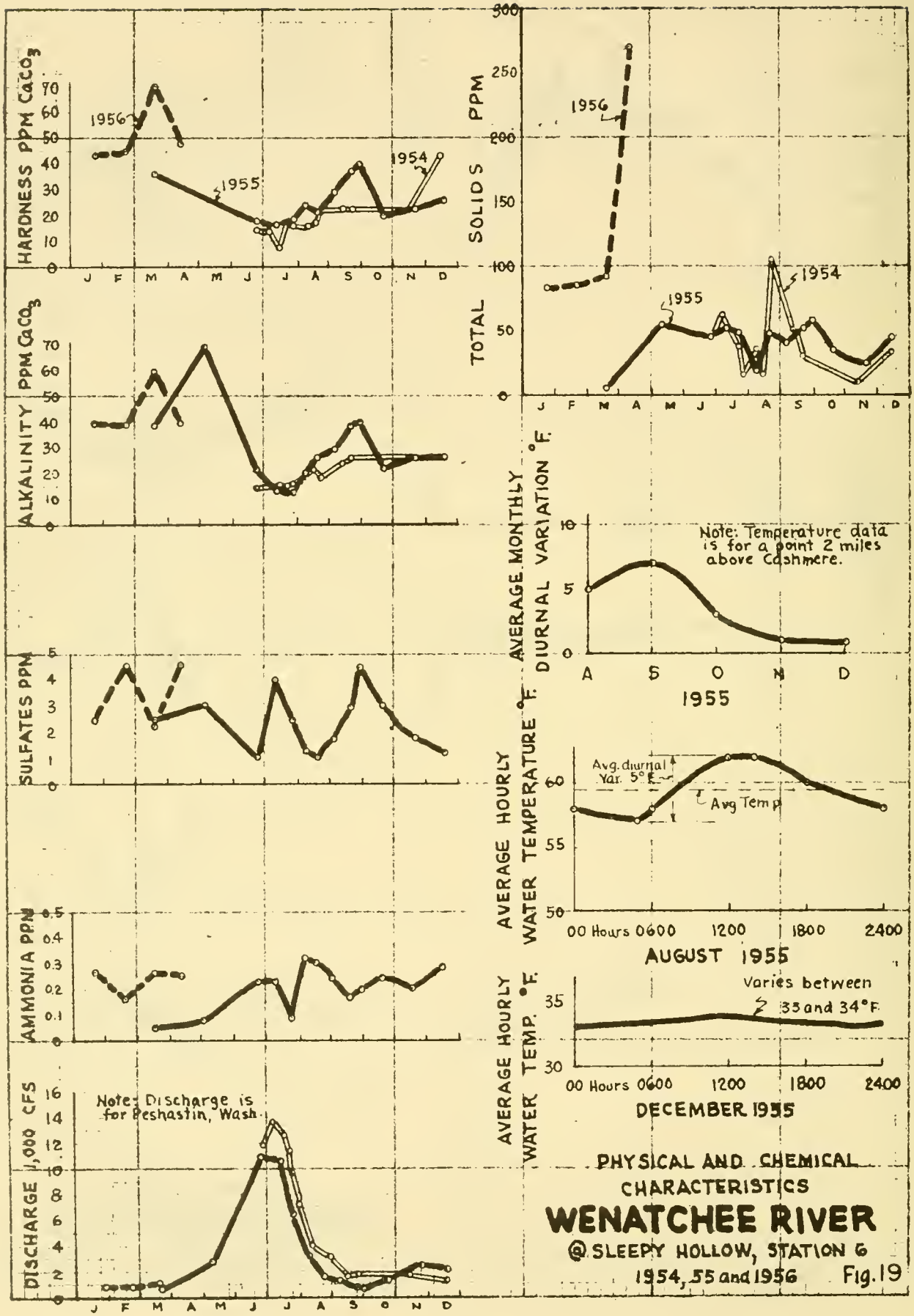


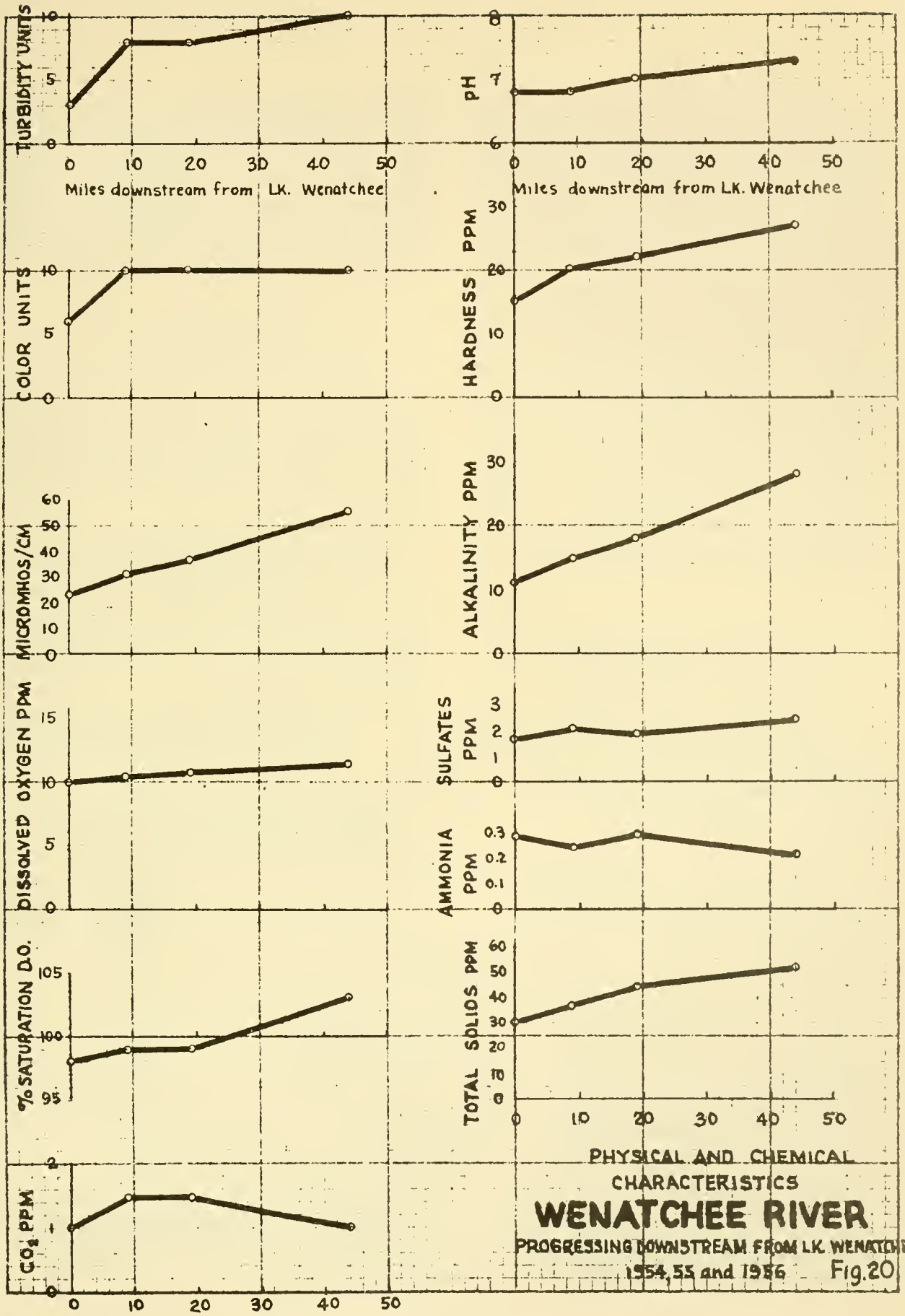
PHYSICAL AND CHEMICAL CHARACTERISTICS

WENATCHEE RIVER

@ SLEEPY HOLLOW, STATION 6

1954, 55 and 1956 Fig. 18


HARDNESS PPM CaCO3
1956
1955
1954
J F M A M J J A S O N D
ALKALINITY PPM CaCO3
SULFATES PPM
AMMONIA PPM
DISCHARGE 1,000 CFS
Note: Discharge is for Peshastin, Wash.
SOLIDS PPM
TOTAL
AVERAGE MONTHLY DIURNAL VARIATION °F.
Note: Temperature data is for a point 2 miles above Cashmere.
A S O N D
1955
AVERAGE HOURLY WATER TEMPERATURE °F.
Avg. diurnal Var. 5°F.
Avg Temp
00 Hours 0600 1200 1800 2400
AUGUST 1955
AVERAGE HOURLY WATER TEMP. °F.
Varies between 33 and 34°F.
00 Hours 0600 1200 1800 2400
DECEMBER 1955
PHYSICAL AND CHEMICAL CHARACTERISTICS
WENATCHEE RIVER
@ SLEEPY HOLLOW, STATION 6
1954, 55 and 1956 Fig. 19



PHYSICAL AND CHEMICAL CHARACTERISTICS

WENATCHEE RIVER

PROGRESSING DOWNSTREAM FROM LK. WENATCHEE

1954, 55 and 1956 Fig. 20

water quality of the Wenatchee River, the physical and chemical characteristics at the sampling stations were plotted versus miles downstream from Lake Wenatchee on figure 20. In general it can be seen that there was a downstream increase in all physical and chemical characteristics except carbon dioxide and ammonia. These slight increases were expected, for as a rule a river picks up increased amounts of suspended and dissolved constituents as it flows from its source toward the ocean. The decrease in carbon dioxide was probably due to photosynthesis. The downstream decrease in ammonia concentration was hardly significant, but nonetheless was unexpected. Ammonia is one of the results of decomposition of organic matter, and due to the upstream discharge of sewage it was anticipated that it would increase in the lower river. A possible explanation for this condition may have been that sufficient time had elapsed since the introduction of the organic matter for nitrite producing bacteria to transform the ammonia into nitrites.

COMPARISON OF WATER QUALITY, WENATCHEE RIVER AND COLUMBIA RIVER

A comparison of the physical and chemical characteristics of the Wenatchee River at Sleepy Hollow determined in this study and those found by Sylvester (1957) for the Columbia River at Rock Island is shown in table 22.

Referring to table 22, it can be seen that the waters of the two rivers were similar in some respects and different in others. The turbidity, 10 units in the Wenatchee and 6 units in the Columbia, was low in both rivers. The average color of 10 units was the same for both rivers and was considered to be low. The Columbia had almost 2-1/2 times the ionized mineral content of the Wenatchee, as indicated by the specific conductivities of 131 and 56 micromhos per cm, respectively. The dissolved oxygen content was essentially the same in both rivers, averaging 11.4 ppm in the Wenatchee and 11.8 in the Columbia. Both streams were found to be supersaturated with dissolved oxygen, with the Wenatchee averaging 103 percent and the Columbia averaging 116 percent. An average of 1.0 ppm carbon dioxide was found in both streams. These investigations revealed the two rivers to be alkaline with the Wenatchee having an average pH of 7.3 and the Columbia an average of 7.8. The hardness of the Columbia, 66 ppm, was about 2-1/2 times that of the Wenatchee, 27 ppm. The alkalinity exhibited about the same relationship, 60 ppm in the Columbia and 28 ppm in the Wenatchee.

THE EFFECT OF IMPOUNDMENT OF WATER QUALITY

Included as part of the purpose of this study was the establishment of the water quality characteristics of the Wenatchee and Chiwawa Rivers prior to impoundment due to hydroelectric projects, and to make predictions regarding the effects of the impoundments.

Effect on Physical and Chemical Water Quality

The effect impoundment has on the physical and chemical water quality is subject to a number of variables, some of which are listed below:

1. The physical and chemical quality characteristics of the water entering the impoundment.

Table 22.--Wenatchee River at Sleepy Hollow and Columbia River at Rock Island--Average water quality, 1954-1955-1956 [1/].

	Wenatchee River	Columbia River [2/]
Temperature (° F.)	51	57
Turbidity (units)	10	6
Color (units)	10	10
Specific conductance (micromhos/cm at 25° C.)	56	131
Dissolved oxygen (ppm)	11.4	11.8
Percent saturation D.O.	103	116
Carbon dioxide (ppm)	1.0	1.0
pH	7.3	7.8
Total hardness (ppm)	27	66
Alkalinity (ppm)	28	60
Sulfates (ppm)	2.6	8.3
Ammonia (ppm)	0.21	0.18
Total solides (ppm)	52	87

1/ Average values do not represent the true average since the sampling frequency was not uniform.

2/ Sylvester, 1957.

2. The stream flow characteristics of the incoming streams.

3. The general characteristics of the impoundment area, such as geology, soil mantle, vegetation, configuration, depth, etc. The amount of logging, clearing of timber and underbrush prior to the inundation is also of importance.

4. The climatic conditions of the region, such as rainfall, air temperature and amount of sunlight.

5. The depth of drawoff from the reservoir.

6. The amount of drawdown.

The more important changes that may take place in the physical and chemical characteristics of water due to impoundment are listed under two categories: adverse and beneficial, along with specific comments concerning the Wenatchee and Chiwawa Rivers.

Adverse effects:

1. Increase in surface water temperatures from the upstream to downstream portions of the reservoir and possible thermal stratification in deep reservoirs.

In addition to the natural climatic and physical features of the impounding basin which jointly control the water temperature in natural lakes, the position of the dam and the depth of drawoff have a major effect on temperature in impounded waters (Ellis, 1940). Studies on existing Columbia River impoundments have indicated little or no thermal stratification (Robeck, Henderson, and Palange, 1954). It is probable that very little area of shallow water depth will result from impoundments on the Wenatchee and Chiwawa Rivers. Therefore, if it were not due to the drawoff from the bottom of the dam, the seasonal cycle of air temperatures would produce a seasonal cycle of water temperature changes similar to that found in Lake Wenatchee.

2. Decrease in dissolved oxygen saturation with depth.

The deposition of silt and organic debris of natural origin in the impoundment creates an oxygen demand which tends to reduce the oxygen saturation. Upon inundation the organic constituents of the reservoir bottom and the non-woody vegetation thereon also contribute to the oxygen demand. In view of the high oxygen saturation and lack of significant amount of organic matter in the Wenatchee and Chiwawa Rivers, it is believed this depletion will not be of any importance. If careful and adequate clearing of timber and underbrush is not carried out prior to the damming of the streams, a temporary increased oxygen demand may result.

3. Increase in carbon dioxide concentration with depth.

The deposition of organic matter and the subsequent decomposition will contribute carbon dioxide. In the proposed reservoir the increase of carbon dioxide with depth should be very similar to that noted in Lake Wenatchee. As previously stated, if the impoundment area is not properly cleared of trees and brush, the resultant decomposition may create a temporary high concentration of carbon dioxide.

4. Decrease of pH with depth as a result of the increase of carbon dioxide.

If the carbon dioxide concentration becomes excessive, it may reduce the pH of the poorly buffered incoming waters to a relatively low value. It is doubtful whether the pH would be reduced below 6.0, the lower limit believed necessary to support good fish fauna. (Ellis, Westfall, and Ellis, 1946.)

5. Concentration of toxic elements such as copper, lead and zinc.

This is believed to be of minor significance due to the absence

of these elements in the tributary waters.

Beneficial effects:

1. Decrease in the suspended solids content.

Due to the reduction in stream velocity, the reservoir acts as a settling basin and permits the removal of settleable matter by sedimentation. Since turbidity was generally very low in the Wenatchee and Chiwawa Rivers, additional reduction would be incidental except during the spring freshets.

2. Reduction of color due to the bleaching action of sunlight.

Color was usually very low in both rivers, and any further reduction would be insignificant, except possibly during the heavy spring runoff.

3. Improvement in the sanitary quality of the impounded water, due to the unfavorable environment for intestinal bacteria.

While no bacteriological data were obtained during this investigation, the general lack of sewage discharge into these streams would indicate that they have no more than the normal surface water bacteriological contamination. Since neither stream is used for public water supply, this improvement is not of much significance. From the standpoint of recreational use of the reservoirs it might be of some importance.

4. Cooler river water below the lake in the summer and warmer water during the fall (Smith 1/).

Reservoirs that are long and deep generally discharge relatively warm water in the winter and relatively cool water in the summer (Sylvester, 1957). This may be a major improvement, from the standpoint of fish life since it has been previously shown that maximum water temperature in the Wenatchee River basin occurred in August.

Effect on the Biological Water Quality

In addition the effect impoundment has on the biological water quality is subject to a number of variables. Those noted in Roosevelt Lake on the Columbia River (Robeck et al, 1954) are listed below:

1. The annual deposition of settleable matter from the entering water creates unfavorable bottom conditions.

2. The sharp drop-off at the shore line and lack of shallow areas limits aquatic vegetation and bottom fauna.

3. The large winter and spring drawdown inhibits the natural development of shore vegetation.

The biological changes that might take place due to the impoundment, such as those noted in Roosevelt Lake (Robeck et al, 1954) are listed below:

1. A seasonal build-up of plankton populations which could have an effect on downstream water uses.

2. A change in bottom animals to less desirable types as far as fish food is concerned.

3. A change in fish population with more rough and forage species present and less food and game species.

4. A general decrease in biological productivity due, for the most part, to the large winter drawdowns.

SUMMARY

A study of the physical and chemical characteristics of water in relation to the environment was made in the Wenatchee River Basin during 1954, 1955 and 1956. Data

1/ "Report on the Lewis River salmon conservation program" by Richard T. Smith. Washington State Department of Fisheries. Unpublished manuscript. 35 pp. 1943.

from this study will provide a basis for comparison to determine the effect of impoundment on water quality, and an evaluation of the Wenatchee River Basin in relation to the preservation of fish resources.

The water quality of a region is influenced by many characteristics of the watershed, such as: (1) topography, (2) flow characteristics, (3) geology, (4) soil mantle, (5) climate, (6) land use and vegetal cover, (7) population, (8) industry, (9) ground water, and (10) irrigation.

Water samples were collected from Nason Creek, Chiwawa River, Lake Wenatchee, and Wenatchee River.

Temperature, turbidity, color, and specific conductance were determined to define the physical characteristics. Dissolved oxygen, carbon dioxide, pH, hardness, alkalinity, sulfates, ammonia, total solids, and trace metallic ions were used to interpret the chemical quality.

On the basis of the results of the physical and chemical tests made during this study, the waters of the Wenatchee River Basin may be summarized as follows:

Nason Creek. The waters of Nason Creek were characterized by an extremely low content of suspended and dissolved matter. The hardness and alkalinity was very low and the pH was practically neutral. The water was practically saturated with dissolved oxygen. A significant diurnal variation in water temperature was noted during the summer months. Seasonal variations were noted in most constituents. A comparison of a limited amount of chemical data collected during 1940 and the results of the same characteristics noted in this study revealed no changes in water quality.

Chiwawa River. The waters of the Chiwawa River were found to be extremely low in suspended and dissolved matter. They were consistently very low in color, turbidity, hardness, and alkalinity, and usually were saturated with dissolved oxygen. During the warm weather months considerable diurnal variation in water temperature was observed.

Lake Wenatchee. The waters of Lake Wenatchee were very soft, slightly acidic, and extremely low in suspended and dissolved solids. Temperature, dissolved oxygen, percent saturation of dissolved oxygen, and pH all decreased with depth. Hardness, alkalinity, sulfates, ammonia and total solids were consistent with depth. Carbon dioxide was the only constituent that increased with depth. A brief limnological study of Lake Wenatchee was made during September and October of 1939 and presented an interesting comparison for the data collected during the same two months of 1955. These data revealed similar thermal stratifications in 1939 and 1955. There was a slight increase in the dissolved oxygen content and percent saturation at all depths in 1956 as compared to 1939. This was indicative of a general decrease of the biological activity in 1955 and was corroborated by the lower carbon dioxide content noted at that time.

Wenatchee River. The waters of the Wenatchee River are largely a mixture of the flow from Nason Creek, Lake Wenatchee, Chiwawa River, and Icicle Creek and therefore possess characteristics very similar to those of the major tributaries. In general they were very low in suspended and dissolved constituents, very soft, practically neutral in pH and saturated with dissolved oxygen. A slight downstream increase in the concentrations of physical and chemical characteristics was noted. A comparison of the physical and chemical characteristics of the Wenatchee River and the Columbia River at Rock Island disclosed that they had about the same amount of turbidity, color, dissolved oxygen, carbon dioxide, and ammonia. The Columbia River, in contrast with the Wenatchee River, had about 2-1/2 times the hardness, alkalinity, and ionized mineral content along with a higher supersaturation with dissolved oxygen and pH.

The impoundment of water produces some important changes in its physical and chemical qualities. These changes may be adverse to fish life, such as an increase in surface water temperatures, decrease in dissolved oxygen saturation with depth, increase in carbon dioxide with depth, decrease of pH, and the concentration of toxic elements. Some beneficial effects might be a decrease in suspended matter, reduction of color, improvement in sanitary quality and cooler water temperatures below the dam in the warm weather months. Some biological changes are also involved, such as seasonal buildup of plankton, change in bottom animals,

change in fish population, and a general decrease in biological productivity. The data from this study will provide a basis for comparison to verify these aforementioned effects.

The combination of characteristics in the Wenatchee River Basin has formed a watershed that is capable of conserving and supplying waters of excellent physical and chemical quality. The fact that relatively insoluble granite is the major rock in the basin has an important effect on the water quality. Most of the drainage basin is part of the Wenatchee National Forest which practically precludes the detrimental effect of overgrazing and excess logging. The very sparse population and almost complete lack of industry keep the discharge of deleterious substances to the streams at a minimum. In conclusion it may be stated that the Wenatchee River System is indispensable for the continued prosperity of the irrigated agriculture in the valley and is very important as a producing area for blueback salmon in the Columbia River System.

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