DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Water-Supply Paper 486

WATER POWERS OF THE CASCADE RANGE

PART IV. WENATCHEE AND ENTIAT BASINS

BY

GLENN L. PARKER AND LASLEY LEE

Prepared in cooperation with the
WASHINGTON STATE BOARD OF GEOLOGICAL SURVEY
Ernest Lister, Chairman
Henry Landes, Geologist

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
30 CENTS PER COPY

CONTENTS.

ILLUSTRATIONS.

WATER POWERS OF THE CASCADE RANGE.

PART IV. WENATCHEE AND ENTIAT BASINS.

By Glenn L. Parker and Lasley Lee.

INTRODUCTION.

This report is the fourth of a series entitled "Water powers of the Cascade Range," prepared by the United States Geological Survey under a cooperative agreement with the Washington State Board of Geological Survey. Part I contains data on the drainage basins of Klickitat, White Salmon, Little White Salmon, Lewis, and Toutle rivers and was published in 1910 as Water-Supply Paper 253. Part II relates to the drainage basins of Cowlitz (except the Toutle), Nisqually, Puyallup, White, Green, and Cedar rivers, on the west side of the Cascade Range, and was published in 1913 as Water-Supply Paper 313. Part III refers to the Yakima basin, on the east side of the Cascade Range, and was published in 1916 as Water-Supply Paper 369. The Wenatchee and Entiat basins, described in this report, lie in the central part of the State of Washington, on the eastern slope of the Cascade Range. The location of the areas covered by Parts I, II, III, and IV is shown in figure 1, and a map of the region under consideration forms Plate I.

The data on which this report is based consist of daily stream-flow records, miscellaneous measurements, river plans and profiles (Pls. VII, *A–E*, VIII, and IX, *A* and *B*, at end of volume), reservoir surveys, topographic maps, and the results of reconnaissances made by the United States Geological Survey, supplemented by a large amount of information furnished by State officials, private individuals, and officials of private enterprises.

The potential water power in Washington, according to official estimates,[1] is greater than that of any other State in the Union, but irrigation projects susceptible of cheap development at small initial outlay are neither so numerous nor so extensive in Washington as in some other Western States. The court decisions and the trend of legislation in the State very properly recognize irrigation as a higher and more beneficial use of water than the development of power

[1] Water-power development in the United States, pp. 55-56, U. S. Dept. Commerce and Labor, Mar. 14, 1912.

and in this report allowance has therefore been made, first, for the the full use of water for irrigation, and, second, for the use of the remaining water for power. In many localities the usage does not conflict, but in some the power resources are materially reduced if ample allowance is made for irrigation. For instance, water from Wenatchee River can be used to irrigate 400,000 acres of land in the region known as Quincy Valley, but such use will reduce the power resources in the Wenatchee basin by 216,000 horsepower. Recently investigations have been started to determine the feasibility of irrigating the entire

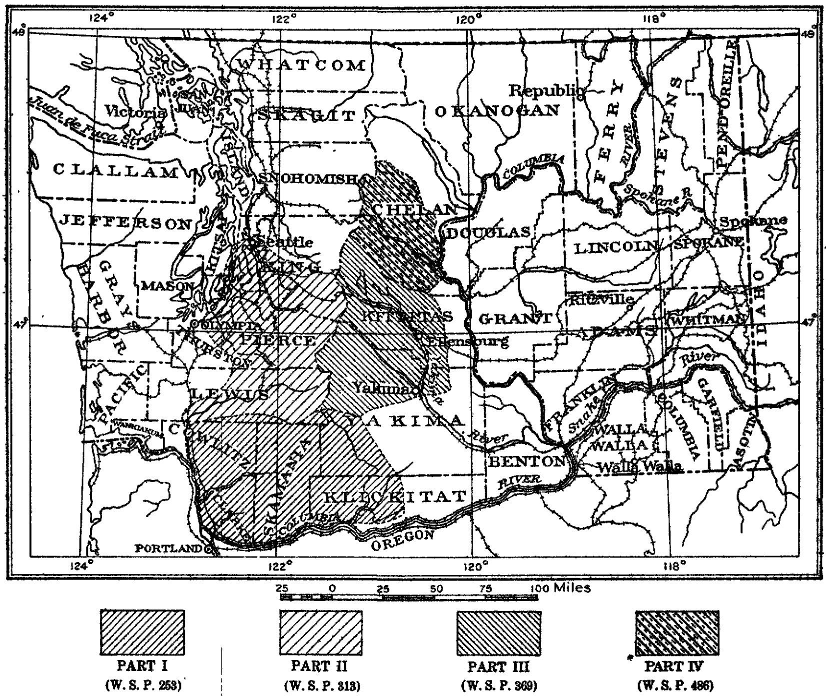


FIGURE 1.—Sketch map of Washington showing areas covered by reports on water powers of the Cascade Range.

east-central part of the State by diversion from Clark Fork. However, as Wenatchee River is a possible source of supply for irrigating a part of that area, a detailed consideration of the water supply available for the Quincy project is given herein.

No attempt has been made to present exact details of separate power projects, but the analyses and summaries indicate approximately the power resources of the area and show the relative value of chosen sections of the river systems. An effort has been made to outline a scheme of power projects that will be consistent and harmonious with the highest ultimate development in the region.

ABSTRACT.

As the use of water for irrigation has been considered higher and more beneficial than its use for power, analyses of power resources have been made with due allowance for present and future irrigation.

About 20,800 acres of land was irrigated in 1918 by water from Wenatchee River or its tributaries. The supply for 2,130 acres was pumped from gravity systems, and that for 296 acres was pumped directly from Wenatchee River. The present irrigation systems will probably be extended to serve about 8,000 acres more than was irrigated in 1918.

The Quincy project contemplates storage of water in a reservoir at Wenatchee Lake (Pl. II; Pl. VII, *C* and *D*), diversion from Wenatchee River 20 miles below the lake at an elevation of 1,600 feet, a conduit about 65 miles long crossing Columbia River, and delivery of water at an elevation of 1,340 feet near the town of Quincy. A larger area is irrigable in the Quincy Valley than can be served by Wenatchee River, and the size of the project is therefore limited by the water supply available. The area that can be watered in Quincy Valley with a diversion duty of 4.2 feet (p. 45) has been determined for two alternative plans of development, which may be called plan A and plan B.

Plan A provides for a continuous flow of 525 second-feet passing the intake of the project to satisfy a prior power right claimed by the Great Northern Railway Co. The remaining water supply, regulated by 1,190,000 acre-feet of storage from Wenatchee Lake reservoir, will irrigate 314,000 acres. A draft of 128 feet in the reservoir will be required.

Plan B provides for the use of all water available at the intake for the project. The existing power rights will not be satisfied, but plans for the project can be expanded to provide service for slightly more than 400,000 acres. A storage capacity of 1,260,000 acre-feet, representing a draft of 133 feet in Wenatchee Lake reservoir, will be required.

In 1918 about 1,190 acres was irrigated by diversion from Entiat River. The systems now in operation will probably not be greatly enlarged.

The continuous power that could be made available in the Wenatchee basin before the Quincy project is put into operation has been estimated for two conditions of flow, and the estimates represent approximately the minimum and maximum power. The minimum flow (p. 55) will yield 76,100 horsepower; and the regulated flow available through the use of an aggregate storage of 1,200,000 acre-feet in six reservoirs will yield 274,000 horsepower. The potential power with and without the Quincy project is shown in the table following.

Comparison of potential power in Wenatchee basin with and without Quincy project in operation.

Condition of flow and plan.	Continuous horsepower (70 per cent efficiency).		
	With project.	Without project.	Difference.
Minimum flow:			
Plan A	82,700	76,100	[a] +6,600
Plan B	30,300	76,100	−45,800
Regulated flow:			
Plan A	113,000	274,000	−161,000
Plan B	58,100	274,000	−216,000

[a] Greater with than without project in operation because prior power right claimed by Great Northern Railway Co. is greater than minimum flow (p. 67).

Favorable sites for storage reservoirs in the Entiat basin have not been found, so that estimates of the power resources, amounting to 4,780 horsepower, have been based on minimum flow.

COOPERATION.

The Washington State legislature passed an act during the session of 1917 authorizing the State Board of Geological Survey to continue cooperation with the United States Geological Survey and appropriating $35,000 to serve that purpose during the biennial period ending March 31, 1919. The board, which consisted of Gov. Ernest Lister, Lieut. Gov. Louis F. Hart, State Treasurer W. W. Sherman, Henry Suzzallo, president of the State university, and Ernest O. Holland, president of the State college, elected Henry Landes as State geologist and gave him authority to enter into cooperative agreements with the Director of the United States Geological Survey. The money appropriated by the State was met by equal Federal allotments for topographic mapping and water-supply investigations.

This series of reports is prepared by the water-resources branch of the United States Geological Survey as a part of its work of determining the daily stream flow of the principal rivers in the State. The river surveys for constructing a plan and profile of Wenatchee River and its tributaries were made by the topographic branch of the Geological Survey in addition to the topographic surveys. The river surveys were run by T. H. Moncure, W. O. Tufts, and Charles Hartman, jr., under the direction of T. G. Gerdine, geographer.

The gaging station on Wenatchee River near Leavenworth was maintained in cooperation with the Quincy Valley Irrigation District; the stations on Wenatchee River and Wenatchee Reclamation District canal at Dryden, Icicle Creek near Leavenworth, and Entiat River at Entiat were maintained in cooperation with the Wenatchee Valley Gas & Electric Co.

ACKNOWLEDGMENTS.

Special acknowledgment is due to Dean Henry Landes, State geologist, for the kindly relations fostered under the cooperative agreement between the Washington State Board of Geological Survey and the United States Geological Survey.

Helpful assistance in revision of early stream-flow records, analyses of available flow, preparation of mass diagrams, and compiling statistics on climate was rendered by D. J. F. Calkins, assistant engineer.

The writers are indebted to P. S. Darlington, district horticultural inspector, State of Washington, for collecting and compiling statistics concerning the area irrigated by gravity and pumping systems.

A large amount of information, without which it would have been difficult to analyze the power resources here described, has been furnished by officials of power and irrigation organizations and by private persons. Acknowledgment is due, for miscellaneous data and practical suggestions, to Arthur Gunn, O. B. McCuaig, G. D. Brown, and W. R. Thomas, Wenatchee Valley Gas & Electric Co.; Marvin Chase, State hydraulic engineer; C. J. Bartholet, assistant State hydraulic engineer; M. L. Dean, chief, division of horticulture, State department of agriculture; A. H. Sylvester, supervisor, Wenatchee National Forest; E. H. MacDaniels, supervisor, Chelan National Forest; S. P. Beecher and E. F. Stowell, Peshastin, Wash.; and L. P. Harton, Cashmere, Wash.

NATURAL FEATURES OF WENATCHEE AND ENTIAT BASINS.

TOPOGRAPHY.

WENATCHEE BASIN.

The Wenatchee basin (Pl. I) lies on the east side of the Cascade Range, between the Wenatchee and Entiat mountain ranges. It embraces a nearly oval area, about 65 miles long and 30 miles wide, whose long axis extends northwest. The southwest rim of the oval follows the crest of the Cascade Range and the Wenatchee Mountains, and the northeast rim follows the Entiat Mountains. The Wenatchee and Entiat Mountains are spurs of the Cascade Range that lie parallel to the long axis of the basin and contain peaks reaching higher elevations than the summits of the Cascades between the two spurs. The crest of Mount Stuart, in the Wenatchee Mountains, which stands at an elevation of 9,470 feet, is the highest point in the basin. A summit in the Entiat Mountains near the north edge of the basin reaches an elevation of 9,100 feet. The elevations of points along the crest of the Cascade Range vary from 8,500 feet near the junction of the

Entiat mountain spur to 4,060 feet at Stevens pass near Cascade tunnel, through which the Great Northern Railway crosses the range.

Perennial snow fields and glaciers cover small areas, which lie between elevations of 7,000 and 8,000 feet, at the northwest end of the basin and near Mount Stuart. The fields near Mount Stuart are smaller because they have a greater southern exposure. Numerous cirques and lakes at high elevations indicate severe glacial action.

Practically the whole basin is mountainous, and its topography is rough, rugged, and irregular. The river and its tributaries occupy deeply incised valleys, whose steep, uneven slopes rise to jagged peaks and ridges. The only large tract of smooth bottom land is near the mouth of the river and ranges in elevation from 600 to 900 feet.

Wenatchee River has its source in Wenatchee Lake (Pl. II; Pl. VII, *C* and *D*), at an elevation of 1,870 feet. The lake covers 4.4 square miles, is 5 miles long, and receives the drainage of Little Wenatchee and White rivers. Nason Creek and Chiwawa River join the main stream a short distance below the lake. The flow of the four tributaries just mentioned varies widely, owing to the influence of the topography. Little Wenatchee River and Nason Creek drain the lowest part of the Cascade Range within the basin, and the precipitation at their sources is therefore smaller than that farther north or south, so that the quantity of water stored in the snow that accumulates during the winter is relatively small, and as the snow melts early in the summer there is a low minimum flow during August and September. White River drains a higher part of the Cascade Range, farther north, and receives more precipitation. The snow and the glaciers there melt slowly, for they are at a higher altitude, so that the flow is well sustained throughout the summer and fall. Although the ridges in the Entiat Mountains at the head of Chiwawa River are as high as those in the Cascade Range, they receive less precipitation because the range intercepts a large proportion of the moisture carried by the prevailing winds, from the west. The flow of the Chiwawa is well sustained during the summer and fall on account of the high altitude of the snow fields, but the yield per unit of area is considerably smaller than for White River.

About 15 miles below Wenatchee Lake, Wenatchee River enters Tumwater Canyon, a narrow V-shaped trough about 10 miles long. The gradient between the lake and the canyon is about 11 feet to the mile, within the canyon it is about 56 feet to the mile, and below the canyon it is about 20 feet to the mile. An ample water supply and a steep gradient are favorable to the development of power within the canyon.

Icicle Creek, which drains a long stretch of the Cascade Range and the northern slope of the Wenatchee Mountains, enters Wenatchee River at Leavenworth, below Tumwater Canyon. The gradient of

A. WENATCHEE LAKE, LOOKING TOWARD UPPER END FROM A POINT NEAR THE OUTLET.

B. WENATCHEE LAKE, LOOKING ACROSS LAKE.

the creek for about 5 miles in its lower course averages over 170 feet to the mile.

Peshastin Creek, which joins the main stream 18 miles from its mouth, drains a part of the northern slope of the Wenatchee Mountains. The elevations in its basin range from 9,470 feet at the crest of Mount Stuart to 970 feet at the mouth of the creek.

ENTIAT BASIN.

The Entiat basin (Pl. I) is less than one-third as large as the Wenatchee basin, which it adjoins on the northeast. It is about 45 miles long, has an average width of less than 20 miles, and extends from northwest to southeast. The Entiat Mountains form its southwestern boundary and the Chelan Mountains its northeastern boundary. The ridges and peaks of the Entiat Mountains range in elevation from 9,100 feet near the source of Entiat River to 5,000 feet near its mouth. The range is narrow, its slopes are steep, and its crest is serrated. The Chelan Mountains are similar in their features but do not reach elevations so high near the source of the river. The Entiat drainage basin does not touch the Cascade Range and therefore does not receive so much precipitation as the adjoining basins, because the range intercepts a large part of the moisture carried by the prevailing westerly winds.

Entiat River has no large tributaries. Mad Creek, which enters the main stream 9 miles from its mouth, is the only considerable tributary, and its drainage area includes only 94 square miles.

The gradient of the river averages about 55 feet to the mile in its lower course and about 65 feet to the mile in its upper course. Although the gradient is uneven on account of numerous rapids and cascades, it is much more uniform than that of Wenatchee River.

DRAINAGE AREAS.

The area included in the Wenatchee and Entiat basins is covered by topographic maps prepared by the United States Geological Survey, and the drainage areas were measured on these maps and are shown in the following list. Planimeter constants for the map of each quadrangle were computed by traversing boundary lines of a 5° or 10° quadrilateral in the center of the map and comparing planimeter readings with the area of the quadrilateral. Then each topographic map was divided into a number of small sections, which were measured carefully by planimeter. The areas of these sections, when added, varied less than 0.2 per cent from the total area shown on the seven topographic maps used, and the maximum variation for a single map was 0.6 per cent. The areas of the sections were finally adjusted to give the exact area covered by each map.

Drainage areas in Wenatchee basin.[1]

	Square miles.
Little Wenatchee River below Lake Creek	52
Little Wenatchee River below Rainy Creek	81
Little Wenatchee River above Wenatchee Lake	100
Wenatchee River below Wenatchee Lake	277
Wenatchee River below Nason Creek	384
Wenatchee River below Chiwawa River	578
Wenatchee River below Beaver Creek	591
Wenatchee River below Chiwaukum Creek	662
Wenatchee River below Cabin Creek	683
Wenatchee River below Icicle Creek	908
Wenatchee River below Chumstick Creek	994
Wenatchee River below Peshastin Creek	1,154
Wenatchee River below Mission Creek	1,279
Wenatchee River at mouth	1,327
Lake Creek at mouth	17.3
Rainy Creek at mouth	16.4
White River below Indian Creek	61
White River below Cougar Creek	89
White River below North Fork	136
White River at mouth	157
Indian Creek at mouth	20.0
Cougar Creek at mouth	19.6
North Fork below Twin Lakes outlet	39.9
North Fork at mouth	41.6
Twin Lakes outlet at mouth	7.4
Nason Creek below South Fork	20.5
Nason Creek below Wildhorse Creek	60
Nason Creek at mouth	107
South Fork at mouth	7.6
Wildhorse Creek at mouth	23.5
Chiwawa River below Phelps Creek	41.6
Chiwawa River below Rock Creek	96
Chiwawa River below Big Meadow Creek	159
Chiwawa River at mouth	183
Phelps Creek at mouth	16.8
Rock Creek at mouth	22.4
Chikamin Creek at mouth	21.9
Big Meadow Creek at mouth	14.2
Beaver Creek at mouth	10.0
Chiwaukum Creek at mouth	49.6
Cabin Creek at mouth	7.9
Icicle Creek below South Fork	68
Icicle Creek below Jack Creek	112
Icicle Creek below Eightmile Creek	181
Icicle Creek below Snow Creek	205
Icicle Creek at mouth	213
South Fork at mouth	25.3
Jack Creek at mouth	29.1
Eightmile Creek at mouth	29.5
Snow Creek at mouth	11.3

[1] Relation of tributaries indicated by indention.

Wenatchee River tributaries—Continued.	Square miles.
Chumstick Creek at mouth	80
Eagle Creek at mouth	29.2
Peshastin Creek below Tronson Creek	36.1
Peshastin Creek below Ingalls Creek	101
Peshastin Creek at mouth	135
Tronsen Creek at mouth	16.5
Ingalls Creek below Cascade Creek	23.0
Ingalls Creek at mouth	41.0
Mission Creek at mouth	79

Drainage areas in Entiat basin.[a]

Entiat River below Myrtle Lake outlet	42
Entiat River below North Fork	104
Entiat River below South Fork	149
Entiat River below Potato Creek	221
Entiat River below Mad Creek	348
Entiat River below Roaring Creek	394
Entiat River at mouth	419
North Fork at mouth	26.1
South Fork at mouth	12.6
Potato Creek at mouth	10.0
Mad Creek at mouth	94
Roaring Creek at mouth	28.6

CLIMATE.

CONTROL.

The Cascade Range marks a line of separation between two areas of climatic control, the oceanic and the continental. The prevailing westerly winds cause the oceanic control to predominate for some distance eastward beyond the crest of the range, so that the temperature in the Wenatchee and Entiat basins is fairly equable and the precipitation during the winter is relatively high. On account of the effect of the continental control, however, the range in temperature is greater and the annual precipitation is less than on the west slope of the Cascades. The tendency toward relatively high precipitation during the summer, characteristic of continental control, is shown to a slight extent by records at low elevations, which indicate that the precipitation is higher in May than in the preceding and following months.

PRECIPITATION.

The prevailing winds from the Pacific Ocean bring air laden with moisture to western Washington. The air is cooled by expansion on being forced upward along the slopes of the Olympic and Cascade ranges. During the summer the cooling is offset by the heat absorbed from the land, the temperature of which is higher than that of the

[a] Relation of tributaries indicated by indention.

ocean, and therefore very little of the moisture in the air is condensed. During the winter the temperature of the land is lower than that of the ocean, so that the cooling of the air by expansion is augmented by the loss of heat absorbed from the air. As a result of the rapid condensation the moisture falls as rain or snow. The cooling by expansion increases in proportion to the slope, and the temperature decreases with increasing altitude, so that the precipitation is greatest near the crests of the ranges, and condensation continues until the air currents fall to lower elevations east of the ranges.

The Wenatchee and Entiat basins are in the so-called "rain shadow" of the Cascade Range. The precipitation is very high at or near the crest of the range but decreases rapidly from west to east. The Wenatchee basin, whose headwater streams drain a crest line of the Cascades over 50 miles long, receives a high precipitation; but the Entiat basin, which does not touch the crest of the range, receives much less.

The precipitation at different points in the basins thus differs greatly. Near the Cascade Range it may differ 10 to 20 per cent between two points that are only a few miles apart. Extreme care should therefore be exercised in using rainfall data to determine the run-off equivalent in any area. The data are serviceable chiefly as an index of yearly flow—that is, a run-off record of short duration may be referred to a comparable precipitation record of longer duration to derive a relation from which the annual run-off may be estimated. The proximity of the dividing line between oceanic and continental control renders a comparison of rainfall and run-off for periods shorter than a year unwise unless proper weight is given to all the factors involved.

As the precipitation is highest in the upper reaches of the basins, it is unfortunate that no records for them are available. The records are fragmentary and of short duration except for places at low elevations, and the stations are sparsely distributed, so that the variation in precipitation at different points can not be ascertained accurately. The monthly and the annual precipitation at certain places, compiled from publications of the United States Weather Bureau, are shown in the following tables. Records taken at some stations outside the area here considered are also given to indicate more clearly the varying characteristics:

Monthly and annual precipitation, in inches, at points in Washington for years ending Sept. 30.

Dirtyface Mountain.

[Elevation, 1,990 feet.]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1914	......	......	......	......	3.06	2.23	1.51	0.28	1.06	0.14	Tr.	2.98	......
1915	2.99	6.18	2.37	1.71	1.81	2.32	1.37	2.08	.20	1.38	0.03	.41	22.85
1916	5.04	8.75	11.23	5.32	8.95	7.14	.96	.60	1.19	.92	.17	.08	50.35
1917	1.85	5.12	3.63	5.05	2.77	7.62	4.09	.51	1.09	.36	.03	.80	32.92
1918	.85	3.39	19.37	......	......	......	......	......	......	......	......	......	......
Mean	2.68	5.86	9.15	4.03	4.15	4.83	1.98	.87	.88	.70	.06	1.07	a36.26

a Sum of monthly means.

Leavenworth.

[Elevation, a 1,158 feet.]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1915	2.16	2.79	2.24	(2.25)	3.33	0.70	0.66	2.06	0.10	1.27	(Tr.)	0.01	(17.57)
1916	1.83	5.35	8.98	3.67	4.92	5.68	.17	.64	1.73	1.02	0.06	.14	34.19
1917	.49	2.38	4.35	1.77	1.27	3.41	3.02	.52	.27	.17	.00	.50	18.15
1918	.16	2.97	12.71	2.03	2.71	.92	(Tr.)	.69	.08	.56	.25	.01	(23.09)
Mean	1.16	3.37	7.07	2.43	3.06	2.68	.96	.98	.54	.76	.08	.16	23.25

a Reported 1,100 feet prior to 1916.

NOTE.—Precipitation for January and August, 1915, estimated by comparison with precipitation during preceding, same, and subsequent months at Dirtyface Mountain, precipitation for April, 1918, estimated in same manner by comparison with records near Wenatchee.

Dryden.

[Elevation, 960 feet.]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1913	(2.25)	(1.80)	(2.75)	2.99	0.91	0.49	0.99	1.17	1.41	0.01	Tr.	0.68	(15.45)
1914	1.40	3.47	1.57	7.01	1.32	.24	.87	.14	.83	.80	0.00	1.69	19.34
1915	2.17	2.35	1.20	3.26	2.91	1.24	.81	1.89	.11	.70	.02	.03	16.69
1916	1.06	4.94	6.03	2.93	6.31	3.76	.21	.25	1.73	1.02	.15	.35	28.74
1917	.34	1.43	1.81	.92	1.78	2.42	3.44	.61	.40	Tr.	.00	.27	13.42
1918	Tr.	2.43	7.90	......	......	......	......	......	......	......	......	......	(19.60)
Mean	1.20	2.74	3.54	3.42	2.65	1.63	1.26	.81	.90	.51	.03	.60	a18.87

a Does not equal sum of monthly means because precipitation for January to September, 1918, was not considered in computing monthly means.

NOTE.—Precipitation for October to December, 1912, inclusive, estimated by comparison with record of precipitation near Wenatchee.

Near Wenatchee.

[Elevation, 2,200 feet.a]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1900	1.24	2.88	1.74	1.50	1.57	1.03	0.82	0.54	0.36	0.00	0.30	1.82	13.80
1901	2.73	1.40	1.95	3.74	2.81	.47	.40	1.32	.70	.02	.03	1.67	17.24
1902	.28	2.93	1.92	1.45	3.55	1.30	2.09	.83	.05	1.16	.08	.18	15.82
1903	.09	2.08	4.84	1.87	.72	1.23	.41	.19	.24	.38	.74	1.44	14.23
1904	.70	4.05	1.01	1.40	3.73	3.56	1.57	.01	.29	.45	.06	.15	16.98
1905	.05	1.61	2.25	2.47	.69	1.70	.34	.71	5.18	.02	.28	.22	15.52
1906	1.74	.92	1.35	1.41	.59	.86	.09	1.48	.40	.03	.67	.13	9.67
1907	.34	4.62	3.56	2.10	1.43	.37	.63	.75	1.84	.79	.36	2.26	19.05
1908	.12	1.14	3.12	1.00	1.00	1.54	.29	2.00	.03	1.33	.16	Tr.	11.73
1909	.78	.40	.85	2.65	1.43	.29	.15	.40	.44	.71	Tr.	.80	8.90
1910	.49	4.07	1.61	1.40	1.13	1.47	.17	.19	.25	.11	.41	.98	12.28
1911	.48	2.75	.96	.59	.68	.44	.06	1.42	.55	Tr.	.48	2.60	11.01
1912	(.40)	1.03	1.33	2.87	.78	.54	1.20	1.67	.83	.70	1.00	.36	(12.71)
1913	1.85	1.46	2.28	1.82	.51	.10	.46	1.71	1.77	Tr.	.14	.58	12.68
1914	1.00	2.04	1.47	3.71	1.81	.12	.44	.25	2.05	.33	Tr.	.80	14.02
1915	1.77	1.00	1.53	1.30	2.54	.97	.32	2.21	.41	1.29	Tr.	.57	13.94
1916	.56	3.73	3.87	2.10	4.75	2.94	.14	.32	1.04	1.51	.41	.20	21.57
1917	.10	1.12	1.07	.40	.69	.89	2.34	1.79	.45	.01	Tr.	.29	9.15
1918	.04	1.26	5.55	1.11	1.27	.38	.03	1.66	.13	1.41	.47	Tr.	13.31
Mean	.78	2.13	2.22	1.84	1.67	1.06	.63	1.02	.90	.54	.29	.79	13.87

a Reported 1,169 feet prior to 1916.

NOTE.—Precipitation for October, 1911, estimated by comparison with records of precipitation at Lakeside for September to November, 1911.

Monthly and annual precipitation, in inches, at points in Washington for years ending Sept. 30—Continued.

Wenatchee.

[Elevation, 743 feet.[a]]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1913	(1.30)	(1.00)	(1.60)	1.60	0.22	Tr.	0.31	1.65	1.13	0.00	0.04	0.06	(8.91)
1914	.80	1.79	1.00	2.70	.81	Tr.	.13	.14	.66	.78	.00	.98	9.79
1915	.16	.46	2.01	1.00	(2.20)	0.95	.26	1.77	.21	.28	.00	.03	(9.33)
1916	.40	2.28	2.40	.97	3.20	1.38	.07	.10	1.25	1.40	.43	.65	14.53
1917	.03	.60	.55	.49	.64	.50	1.62	1.42	.41	.14	Tr.	.17	6.57
1918	Tr.	.86	3.57	......	......	......	......	......	......	......	......	......	(9.50)
Mean	.45	1.16	1.86	1.35	1.41	.57	.48	1.02	.73	.52	.09	.38	[b]9.77

[a] Reported 639 feet prior to 1916.

[b] Does not equal sum of monthly means because precipitation for January to September, 1918, was not considered in computing monthly means.

NOTE.—Precipitation for October to December, 1912, inclusive, and for year ending Sept. 30, 1918, estimated by comparison with records of precipitation near Wenatchee; that for February, 1915, estimated by comparison with records of precipitation near Wenatchee, during preceding, same, and subsequent months.

Stehekin.

[Elevation, 1,150 feet.[a]]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1906	(6.05)	(3.05)	(4.95)	(4.90)	1.31	1.93	0.25	2.99	1.47	0.13	0.19	1.20	(28.42)
1907	3.95	10.92	6.00	3.98	2.98	1.56	2.21	.54	.66	.53	.65	1.53	35.51
1908	.45	5.47	3.66	(2.80)	(1.90)	(2.65)	1.97	1.15	Tr.	1.73	.24	Tr.	(22.02)
1916	......	......	......	......	......	......	......	.01	1.62	.73	Tr.	.45	(40.70)
1917	2.95	4.93	4.10	3.50	2.35	6.13	3.10	.51	.48	.14	.05	.78	29.02
1918	.30	2.97	16.87	4.04	4.05	3.19	.18	.39	.23	.59	.80	.18	33.79
Mean	2.74	5.47	7.12	3.84	2.52	3.09	1.54	.93	.74	.64	.32	.69	[b]31.58

[a] Reported 1,100 feet prior to 1909 and 1,350 feet for 1916.

[b] Does not equal sum of monthly means because precipitation for October, 1915, to April, 1916, was not considered in computing monthly means.

NOTE.—Precipitation for October to December, 1905, January, 1906, January to March, 1908, and year ending Sept. 30, 1916, estimated by comparison with records of precipitation at Lakeside and near Wenatchee.

Lakeside.

[Elevation, 1,116 feet.]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Annual.
1892	0.32	1.52	2.29	1.13	0.43	1.25	1.32	3.13	0.31	0.47	Tr.	0.26	12.43
1893	.59	2.40	2.39	(.75)	1.55	1.69	2.15	1.40	.21	.06	Tr.	.78	(13.97)
1894	.24	2.38	.75	1.08	.80	1.19	.34	1.37	1.20	Tr.	.06	.05	9.46
1895	1.37	.89	2.63	2.40	.30	.27	.74	.65	Tr.	Tr.	.00	.75	10.00
1896	.00	.54	2.25	2.50	.18	.70	1.33	1.80	.09	.01	.67	.64	10.71
1897	1.00	3.00	1.78	1.98	2.80	.81	.54	1.30	1.25	.88	.15	.11	15.60
1898	.74	2.93	3.37	.30	1.59	.08	Tr.	.91	1.54	Tr.	1.03	.22	12.71
1899	.03	.92	1.35	2.94	1.32	.12	.41	.54	.17	.15	1.43	.19	9.57
1900	1.50	3.50	1.56	1.15	.85	1.02	.82	.89	.65	Tr.	.14	.84	12.92
1901	2.07	1.20	2.63	2.13	2.15	.52	(.65)	1.76	1.48	.00	.02	1.21	(15.82)
1902	.08	2.42	1.84	1.01	3.30	.45	1.75	.69	Tr.	1.74	.15	.23	13.66
1903	.08	1.77	3.98	1.81	.78	.88	.61	.18	.38	.27	1.48	.43	12.65
1904	.55	3.21	.35	1.54	2.87	3.15	1.05	.05	.48	Tr.	.51	.02	13.78
1905	1.60	1.04	1.87	1.79	.27	.97	.17	.69	4.59	.20	.15	.93	14.27
1906	1.47	.70	1.38	1.24	1.95	1.02	.05	1.79	.24	.11	.10	.20	10.25
1907	.18	3.88	3.22	1.02	.81	.80	.08	.49	1.96	.96	.56	1.84	15.80
1908	.12	1.24	2.78	1.36	.71	.85	.10	1.05	.10	1.14	.04	.08	9.57
1909	.94	.77	.55	2.10	1.51	.57	.00	.43	.31	.74	Tr.	.99	8.91
1910	.90	3.64	1.61	1.14	.92	1.25	.08	.68	.16	.09	.41	.67	11.55
1911	.61	2.74	1.10	.70	.92	.48	.29	1.21	.49	Tr.	.60	.64	9.78
1912	.18	.81	1.83	3.01	.86	.37	.87	1.14	.64	.15	1.04	.24	11.14
1913	1.87	1.49	1.39	1.08	.35	.11	.67	1.87	.86	.03	.23	.17	10.12
1914	1.02	1.98	1.39	3.80	1.01	.16	.80	.13	1.49	.08	Tr.	1.39	13.25
1915	1.84	1.36	.73	1.90	2.37	1.33	.75	2.54	.31	.61	Tr.	.18	13.92
1916	.93	3.96	3.12	1.20	3.30	1.69	.12	.42	1.67	.93	.22	.98	18.54
1917	.03	.74	.77	.34	1.02	1.49	2.20	.77	.55	.09	Tr.	.15	8.15
1918	Tr.	1.24	3.84	.98	1.11	......	......	......	......	......	......	......	......
Mean	.75	1.94	1.95	1.57	1.33	.89	.69	1.07	.81	.34	.35	.55	[a]12.24

[a] Sum of monthly means.

NOTE.—Precipitation for January, 1893, and April, 1901, estimated by comparison with records of precipitation at Waterville and near Wenatchee during preceding, same, and subsequent months.

Monthly and annual precipitation, in inches, at points in Washington for years ending Sept. 30—Continued.

Snoqualmie Pass.

[Elevation, 3,000 feet.]

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Annual.
1916	(10.10)	14.00	14.30	12.18	16.90	19.69	6.98	4.35	3.76	3.40	1.14	3.35	(110.15)
1917	2.60	10.80	11.33	16.30	8.96	10.90	6.34	.65	5.80	.15	.00	.92	74.75
1918	2.45	5.13	29.72	17.30	13.90	5.80	4.10	3.27	(.20)	1.50	5.30	.10	(88.77)
Mean	5.05	9.98	18.45	15.26	13.25	12.13	5.81	2.76	3.25	1.68	2.15	1.46	91.23

NOTE.—Precipitation for October, 1915, and June, 1918, estimated by comparison with records of precipitation at Keechelus Lake. Mean annual precipitation for a period of 10 years, computed by comparison with records of precipitation at Kachess Lake, 79.60 inches.

Kachess Lake.

[Elevation, 2,235 feet.]

1909	3.83	8.11	8.19	8.70	5.52	3.59	2.76	0.83	0.92	0.53	0.16	3.77	41.91
1910	2.41	19.99	6.91	7.27	13.79	5.82	2.93	1.39	1.55	.04	.04	1.58	63.72
1911	8.05	11.76	4.13	9.45	4.10	2.13	1.20	3.65	.56	.72	.24	4.99	50.98
1912	.54	17.39	6.40	10.54	6.46	2.82	1.62	2.12	1.77	.32	3.62	.51	54.11
1913	3.21	5.60	9.92	11.16	2.22	3.71	.79	1.48	1.14	.38	.01	1.59	41.21
1914	3.65	3.66	.90	9.36	4.32	2.88	3.44	.62	2.22	.37	Tr.	2.90	34.32
1915	3.74	8.33	2.83	2.24	2.51	2.60	2.29	2.46	.30	1.78	.01	1.41	30.50
1916	7.39	10.06	10.32	5.07	8.57	9.35	1.71	1.44	1.97	2.28	.28	1.06	59.45
1917	2.11	5.77	(6.35)	9.09	4.34	9.53	3.65	.72	2.65	.32	.13	1.14	(45.80)
1918	2.06	2.66	28.12	11.18	6.21	1.94	1.71	2.72	.29	1.22	2.45	.18	60.74
Mean	3.70	8.83	8.41	8.41	5.80	4.44	2.21	1.74	1.34	.80	.69	1.91	48.28

NOTE.—Precipitation for December, 1916, estimated by comparison with record of precipitation at Keechelus Lake during preceding, same, and subsequent months.

Summary.

Station.	Years of record.	Average precipitation (inches).		Days with more than 0.01 inch precipitation.
		Total annual.	Snowfall.	
Dirtyface Mountain	3.9	36.26	260	134
Leavenworth	3.8	23.25	161	87
Dryden	5	18.87	96	98
Near Wenatchee	19	13.87	64	80
Wenatchee	5	9.77	30	52
Stehekin	4.8	31.58	142	120
Lakeside	26.2	12.24	46	66
Snoqualmie Pass	2.8	[a] 79.60	478	132
Kachess Lake	10	48.28	189	155

[a] Record short at Snoqualmie Pass; estimated by comparison with record at Kachess Lake.

The precipitation at Snoqualmie Pass, in the Cascade Range, is over eight times that at Wenatchee, near the mouth of Wenatchee River. This difference is due more to the influence of the range than to variation in elevation, a fact shown by records obtained at Lakeside and Stehekin, which are at about the same elevation, though Stehekin is much nearer the range. The precipitation at Stehekin is over two and a half times that at Lakeside.

Records of run-off also show that the precipitation is much higher in areas near the range than in areas farther east. A comparison of run-off and precipitation is shown in the following table:

Run-off and precipitation in Wenatchee and Entiat basins.

Gaging station.	Drainage area (square miles).	Mean annual run-off (depth in inches on drainage area).	Precipitation station nearest gaging station.	Mean annual precipitation (inches).
Wenatchee River below Chiwawa River	591	52.76	Dirtyface Mountain	[a] 36.80
Wenatchee River at Dryden	1,200	38.09	Dryden	18.87
White River	150	[b] 68.60	Dirtyface Mountain	[a] 36.80
Chiwawa River	181	[b] 46.40	do	[a] 36.80
Icicle Creek	211	[b] 43.10	Leavenworth	23.25
Entiat River	419	17.02	Lakeside	12.24
Stehekin River	368	[c] 53.70	Stehekin	31.58
Chelan River	950	31.61	Lakeside	12.24
Yakima River below Keechelus Lake	55	82.22	Keechelus Lake	[d] 70.10
Yakima River at Cle Elum	500	54.42	Cle Elum	24.79
Yakima River at Union Gap	3,550	18.94	Moxee	8.31
Kachess River below Kachess Lake	63	61.06	Kachess Lake	48.28

[a] Record short; precipitation computed by comparison with record of precipitation at Kachess Lake.
[b] Record short; run-off computed by comparison with record of run-off of Wenatchee River below Chiwawa River.
[c] Record short; run-off computed by comparison with record of run-off of Chelan River.
[d] Record short; precipitation computed by comparison with record of precipitation at Kachess Lake.

The run-off determined at the gaging stations represents the depth of water flowing from the drainage area above the gaging station minus losses due to evaporation, underground seepage, and plant growth. The average precipitation over a given drainage area must therefore be considerably in excess of the run-off. The results tabulated above show that the run-off at each gaging station is much larger than the precipitation. Assuming that the precipitation is greatest at or near crest of the range and decreases rapidly toward the gaging stations, it is reasonable to assume that precipitation at the highest points along the crest of the Cascades exceeds 100 inches.

TEMPERATURE.

The average latitude of the Wenatchee and Entiat basins is slightly less than 48°, or about the same as the northernmost part of the State of Maine. The climate is remarkably warm and equable for this latitude, because the prevailing westerly winds cross the Japan current before they reach the western coast of Washington. The operation of water-power plants during the winter will not be hindered greatly by ice, because the periods during which the temperature is below zero Fahrenheit are short, and the mean temperature for January, the coldest month, will average considerably less than 10° below the freezing temperature of water.

A summary of the temperature records published by the United States Weather Bureau is shown in the following table:

Summary of temperature records at stations in Washington.

Station.	Temperature in degrees Fahrenheit.							Length of record (years).	Average length of growing season (days).
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual.		
Leavenworth (elevation, 1,158 feet):[a]									
Mean	50.6	37.9	25.0	22.9	30.1	38.8	48.0	4	170
Highest	85	63	52	58	55	73	102		
Lowest	21	9	−13	−18	1	3	−18		
Near Wenatchee (elevation, 2,200 feet):[b]									
Mean	49.7	36.7	27.9	25.0	29.7	39.4	47.6	20	182
Highest	84	65	58	54	64	72	101		
Lowest	20	−3	−1	−16	−5	7	−16		
Wenatchee (elevation, 743 feet):[c]									
Mean	51.8	49.0	29.7	23.9	29.9	41.8	50.1	5	189
Highest	86	63	62	52	53	67	106		
Lowest	20	6	−7	−15	−3	4	−15		
Stehekin (elevation, 1,150 feet):									
Mean	49.2	36.3	33.4	33.1	29.4	35.1	......	([d])	152
Highest	80	79	55	48	48	65	98		
Lowest	20	22	5	5	4	4	4		
Lakeside (elevation, 1,116 feet):									
Mean	51.2	38.0	29.4	25.1	29.6	40.2	49.6	27	191
Highest	83	64	60	52	60	74	105		
Lowest	25	−3	−2	−13	−15	5	−15		
Snoqualmie Pass (elevation, 3,000 feet):									
Mean	44.3	35.3	27.5	22.9	29.7	31.4	40.0	2	74
Highest	76	64	47	48	49	43	86		
Lowest	−6	6	2	5	9	0	−6		
Lake Kachess (elevation, 2,235 feet):									
Mean	46.4	35.4	28.4	25.8	29.6	35.5	44.2	6	136
Highest	79	62	52	45	50	69	98		
Lowest	22	6	−2	−8	−2	−3	−8		

[a] Reported 1,100 feet prior to 1916.
[b] Reported 1,169 feet prior to 1916.
[c] Reported 639 feet prior to 1916.
[d] Record very fragmentary.

FORESTATION.

The equable climate and the relatively high precipitation in the Wenatchee and Entiat basins are favorable to the growth of timber, and about 90 per cent of the area is forested. The high areas are densely timbered, but the stand of timber decreases in the lower areas in proportion to the decrease in rainfall.

Forestation is an important factor in considering problems involving the water resources, because forests check erosion and regulate the stream flow. Excessive erosion fills the storage reservoirs with silt, adds to the cost of hydraulic equipment, and causes many difficulties in the operation of hydraulic works. Most of the precipitation occurs in winter and is stored as snow in the heavily timbered belt. The forest cover shades the snow, causing it to melt slowly, and increases the capacity of the soil for the storage of ground water, so that the number of floods in the spring is reduced and the flow in the summer and fall is increased.

The Forest Service recognizes the desirability of preventing erosion and retaining the forests to regulate stream flow. Federal control of the Wenatchee and Chelan forests will insure a well-sustained lumber industry, prevent excessive erosion, and preclude the possibility of marked change in the regimen of the streams. The Wenatchee National Forest, in the Wenatchee basin, covers 745 square miles and the Chelan National Forest, in the Entiat basin, covers 295 square miles. The total area thus controlled is nearly 60 per cent of the entire area in the two basins.

The estimated total stand of timber in the Wenatchee and Entiat basins was slightly more than 4,250,000,000 feet board measure. About 500,000,000 feet has been cut.

The common names of the species of trees and the estimated stand of each, in percentages, in the Wenatchee and Chelan national forests are shown below:

	Per cent.
Douglas fir	25
Amabilis fir	22
Western yellow pine	21
Mountain and western hemlock	12
Englemann spruce, lodgepole pine, black cottonwood, western larch, and alpine fir	10
Western white pine and grand fir	6
Western red cedar	4

WATER SUPPLY.

CONDITIONS AFFECTING STREAM FLOW.

The natural factors that affect the water supply in the Wenatchee and Entiat basins may be summarized in the order of importance as follows: Precipitation and temperature, topography, structure of rocks and soils, ground storage, natural lake storage, forestation and vegetation, and glaciation. A close analysis of each factor is not necessary, because estimates can be based on daily records of stream flow, miscellaneous measurements, and differences in drainage areas. The yield of the low-lying parts of the area is small, but the yield of the mountainous parts is almost as great as that for some streams west of the Cascade Mountains. The natural lake storage and the flow from the melting snow in the mountains combine to maintain a fairly high run-off for several months after water is needed for irrigation in the lower valleys.

The maximum flow occurs usually in June. Occasionally the streams reach flood stages early in the winter, owing to heavy precipitation accompanied by "chinook" or warm winds, which melt the accumulated snow quickly. The highest flood on record for Wenatchee River occurred December 30, 1917; that for Entiat River, June 17, 1916.

The minimum flow is chiefly the result of small precipitation in the summer followed by cold and dry weather in the autumn. The low temperature freezes the water in the mountainous areas, and the lack of precipitation causes a small yield in the lower areas. Although the spells of very cold weather in winter are short they may produce a low flow. An extremely low flow for Wenatchee River and its tributaries occurred in October, 1911, and again in September, 1915. The flow of Entiat River also was low during those months, but the mean flow for January, 1916, was still lower.

The total yearly flow depends more on the total precipitation than on any other feature. The climatic years of the greatest run-off since 1904 were the years ending September 30, 1910 and 1916, and the climatic year of the least run-off was the year ending September 30, 1915.

STREAM-FLOW RECORDS.

SCOPE AND CHARACTER.

Records of stream flow in this region were first obtained at a gaging station on Wenatchee River near Wenatchee in 1897 but were discontinued after a few months. A gaging station was established on Wenatchee River at Cashmere in 1904, and another near Leavenworth in 1910. Records for Entiat River and for the principal tributaries of Wenatchee River were started in 1911. The data at the gaging stations are supplemented by many miscellaneous discharge measurements of the tributaries and of the diversions.

The gage readings, usually made daily, and the measurements of flow at different stages form the basis for computing daily discharge by methods ordinarily followed by the Geological Survey.[4] Monthly summaries, derived from the daily-discharge computations, are presented in this report and give in condensed form all available discharge data in the Wenatchee and Entiat basins. Great care has been exercised to obtain reliable results, and the fact that the channels at practically all the gaging stations remain permanent except at high stages has rendered the analysis of rating curves more certain.

In addition to the monthly figures derived from observational data, some of the monthly summaries include estimates of natural discharge derived by correcting for diversion past and for depletion above gaging stations that are below the intakes of irrigation systems.

The accuracy of the computed results and the special features influencing interpretations are discussed briefly in the description of the gaging stations or in footnotes to the monthly summaries. The discussion is based on the plotting of individual measurements with reference to mean rating curves, reliability of gage readings, changes in control, drainage basin characteristics, and other factors. The letters shown in the columns headed "Accuracy" represent the judgment of the authors regarding the probable accuracy of the monthly means. They do not refer to the maximum or minimum

[4] Methods of conducting stream measurements and analyzing stream-flow records are discussed in introductions to publications entitled "Surface water supply of the United States" (U. S. Geol. Survey Water-Supply Papers 351-362, 381-392, 401-414).

discharge nor to the discharge for any one day, but indicate the probable accuracy of the computed mean monthly flow, A meaning accurate within 5 per cent, B within 10 per cent, C within 15 per cent, and D within 25 per cent.

PUBLICATIONS.

The records of stream flow in the Wenatchee and Entiat basins, from which the monthly estimates here presented have been derived, have been published annually by the United States Geological Survey as shown by the following list:

[Note.—A=Annual Report, W=Water-Supply Paper.]

1897	A. 19, Pt. IV, pp. 489–490; W. 16, p. 178
1904	W. 135, pp. 71–72; W. 272, pp. 141–145
1905	W. 178, pp. 40–42; W. 272, pp. 141–145
1906	W. 214, pp. 39–40; W. 272, pp. 141, 143–145
1907–8	W. 252, pp. 130–132; W. 272, pp. 141, 143–145
1909	W. 272, pp. 139–146
1910	W. 292, pp. 136–141; W. 312; pp. 157–158
1911	W. 312, pp. 152–165; W. 332, pp. 183–184, 188–191; W. 482, pp. 123–126
1912	W. 332–A, pp. 174–191; W. 362–A, pp. 182–183, 187; W. 462, pp. 130–133; W. 482, pp. 124–126
1913	W. 362–A, pp. 174–187; W. 462, pp. 128–131; W. 482, pp. 124–126
1914	W. 392, pp. 129–140; W. 462, pp. 129–131; W. 482, pp. 125–126
1915	W. 412, pp. 196–203
1916	W. 442, pp. 150–157
1917	W. 462, pp. 123–133
1918	W. 482, pp. 120–127

DEFINITION OF TERMS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those that represent a rate of flow, as second-feet, gallons per minute, miner's inches, and discharge in second-feet per square mile, and (2) those that represent the actual quantity of water, as run-off in inches, acre-feet, and millions of cubic feet. The principal terms used in this series of reports may be defined as follows:

"Second-feet" is an abbreviation for cubic feet per second. A second-foot is the rate of discharge of water flowing in a channel 1 foot wide and 1 foot deep at an average velocity of 1 foot per second. It is generally used as a fundamental unit from which others are computed.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off in inches" is the depth to which an area would be covered if all the water flowing from it in a given period were uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in inches.

An "acre-foot," equivalent to 43,560 cubic feet, is the quantity required to cover an acre to the depth of 1 foot. The term is commonly used in connection with storage and for expressing quantity of water used for irrigation.

The following terms not in common use are here defined:

"Stage-discharge relation" is an abbreviation for the term "relation of gage height to discharge."

"Control" is a term used to designate the section or sections of the stream below the gage which determine the stage-discharge relation at the gage. It should be noted that the control may not be the same section or sections at all stages.

The "point of zero flow" for a gaging station is that point on the gage—the gage height—to which the surface of the river would fall if there were no flow.

WENATCHEE RIVER NEAR LEAVENWORTH, WASH.

LOCATION.—In SW. ¼ sec. 12, T. 26 N., R. 17 E., 1,500 feet below highway bridge at Plain, 5 miles by river below dam site at Lake Wenatchee, and 14 miles north of Leavenworth.

DRAINAGE AREA.—591 square miles (measured on topographic maps).

RECORDS AVAILABLE.—November 27, 1910, to March 31, 1919. Monthly mean discharge October, 1909, to November, 1910, estimated by comparison with records at Cashmere and Dryden.

GAGE.—Staff gage on left bank 1,500 feet below bridge.

DISCHARGE MEASUREMENTS.—Made from cable three-eighths mile above gage or by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and small boulders. Control likely to shift during extremely high water. One channel at all stages. Banks high and not subject to overflow.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 11.1 feet at 12.30 p. m. December 30, 1917 (discharge, 18,700 second-feet); minimum stage recorded, 2.53 feet October 11 and 12, 1915 (discharge, 316 second-feet).

ICE.—Stage-discharge relation affected by ice during severe winters; flow estimated from observer's notes, discharge measurements, and weather records.

DIVERSIONS.—The Wenatchee Park Land & Irrigation Co. diverted a maximum of about 12 second-feet from Chiwawa River during irrigation seasons beginning in 1914.

REGULATION.—None.

ACCURACY.—Stage-discharge relation changed at medium high water May 1–5, 1911; affected by ice during severe winters and by logs on control March 17 to May 24, 1913, and April 2 to May 10, 1914. Rating curve used prior to May 1, 1911, fairly well defined by three discharge measurements and point of zero flow; curve used for open channel after that date well defined by many discharge measurements; curve used for periods when logs were on control fairly well defined by two discharge measurements. Gage read to hundredths once daily. Accuracy of monthly means indicated in table of monthly discharge.

COOPERATION.—Gage-height record furnished by Quincy Valley Irrigation District.

Monthly discharge of Wenatchee River near Leavenworth, Wash., 1910–1919.

[Drainage area, 591 square miles.]

Month.	Discharge in second-feet.		Run-off.		Accuracy.
	Mean.[a]	Per square mile.	Inches.	Acre-feet.	
1909–10.					
October	740	1.25	1.44	45,500	C.
November	3,800	6.43	7.17	226,000	C.
December	2,700	4.57	5.27	166,000	C.
January	1,100	1.86	2.14	67,600	C.
February	940	1.59	1.66	52,200	C.
March	2,900	4.91	5.66	178,000	C.
April	4,600	7.78	8.68	274,000	C.
May	8,500	14.4	16.60	523,000	C.
June	5,200	8.80	9.82	309,000	C.
July	3,400	5.75	6.63	209,000	C.
August	1,300	2.20	2.54	79,900	C.
September	620	1.05	1.17	36,900	C.
The year	2,990	5.06	68.78	2,170,000	

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1910–11.							
October			[a] 2,000	3.38	3.90	123,000	C.
November			[a] 3,000	5.08	5.67	179,000	C.
December [b]	2,080	970	1,240	2.10	2.42	76,200	B.
January [b]	1,140	708	876	1.48	1.71	53,900	B.
February [b]	756	468	591	1.00	1.04	32,800	B.
March [b]	2,080	468	950	1.61	1.86	58,400	B.
April [b]	4,530	1,810	2,540	4.30	4.80	151,000	B.
May [b]	7,200	3,070	4,210	7.12	8.21	259,000	A.
June [b]	10,400	3,560	6,220	10.5	11.71	370,000	A.
July [b]	3,740		2,720	4.60	5.30	167,000	A.
August [b]	1,430	714	951	1.61	1.86	58,500	A.
September [b]	1,210	476	756	1.28	1.43	45,000	A.
The year			2,170	3.67	49.91	1,570,000	
1911–12.							
October [b]	476	340	400	.677	.78	24,600	A.
November [b]	4,300	335	1,310	2.22	2.48	78,000	A.
December [b]	1,380	630	890	1.51	1.74	54,700	A.
January [b]	1,050		732	1.24	1.43	45,000	B.
February [b]	900	672	785	1.33	1.43	45,200	A.
March [b]	1,260	513	662	1.12	1.29	40,700	A.
April [b]	3,230	1,430	2,330	3.94	4.40	139,000	A.
May [b]	11,500	3,230	6,760	11.4	13.14	416,000	A.
June [b]	8,760	4,110	6,690	11.3	12.61	398,000	A.
July [b]	4,110	1,380	2,600	4.40	5.07	160,000	A.
August [b]	1,550	714	1,070	1.81	2.09	65,800	A.
September [b]	950	442	602	1.02	1.14	35,800	A.
The year	11,500	335	2,070	3.50	47.60	1,500,000	
1912–13.							
October [b]	590	402	483	.817	.94	29,700	A.
November [b]	1,050	476	733	1.24	1.38	43,600	A.
December [b]	1,000	550	698	1.18	1.36	42,900	A.
January [b]	852		621	1.05	1.21	38,200	B.
February [b]	1,320		809	1.37	1.43	44,900	B.
March [b]	900	735	815	1.38	1.59	50,100	B.
April [b]	4,160	772	2,140	3.62	4.04	127,000	B.
May [b]	10,100	2,380	5,990	10.1	11.64	368,000	B.
June [b]	14,300	6,710	9,570	16.2	18.07	569,000	A.
July [b]	7,970	2,760	5,260	8.90	10.26	323,000	A.
August [b]	3,070	1,050	1,700	2.88	3.32	105,000	A.
September [b]	2,760	714	1,130	1.91	2.13	67,200	A.
The year	14,300	402	2,500	4.23	57.37	1,810,000	

[a] Estimated by percentage comparison with record of Wenatchee River at Cashmere and Dryden. Percentage used for each month was average for that month in the period of comparison.

[b] Records for this month revised since original publication. See Water-Supply Paper 482 for revised daily discharge.

Monthly discharge of Wenatchee River near Leavenworth, Wash., 1910–1919—Continued.

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1913-14.							
October [b]	1,920	590	1,240	2.10	2.42	76,200	A.
November [b]	2,140	852	1,290	2.18	2.43	76,800	A.
December	1,290	599	830	1.40	1.61	51,000	A.
January	2,140	591	1,160	1.96	2.26	71,300	A.
February	930	575	666	1.13	1.18	37,000	A.
March	2,540	817	1,510	2.55	2.94	92,800	A.
April	5,700	1,350	3,410	5.77	6.44	203,000	B.
May	8,560	3,510	5,920	10.0	11.53	364,000	B.
June	7,760	2,970	4,560	7.72	8.61	271,000	A.
July	4,700	1,370	2,760	4.67	5.38	170,000	A.
August	1,400	700	981	1.66	1.91	60,300	A.
September	1,080	482	710	1.20	1.34	42,200	A.
The year	8,560	482	2,090	3.54	48.05	1,520,000	
1914-15.							
October	1,520	575	949	1.61	1.86	58,400	A.
November	3,610	1,520	2,230	3.77	4.21	133,000	A.
December	1,640	615	893	1.51	1.74	54,900	A.
January	658	....	491	.831	.96	30,200	C.
February	460	398	431	.729	.76	23,900	B.
March	2,010	426	1,030	1.74	2.01	63,300	A.
April	6,020	2,140	3,630	6.14	6.85	216,000	A.
May	3,960	2,140	2,610	4.42	5.10	160,000	A.
June	2,970	1,130	1,860	3.15	3.51	111,000	A.
July	1,640	745	1,060	1.79	2.06	65,200	A.
August	930	668	764	1.29	1.49	47,000	A.
September	575	316	402	.680	.76	23,900	A.
The year	6,020	316	1,360	2.30	31.31	987,000	
1915-16.							
October	1,630	316	618	1.05	1.21	38,000	A.
November	2,260	515	940	1.59	1.77	55,900	A.
December	748	515	589	.997	1.15	36,200	A.
January	....	....	547	.928	1.07	33,700	C.
February	925	....	738	1.25	1.35	42,400	C.
March	2,680	790	1,660	2.81	3.24	102,000	A.
April	4,700	1,630	3,090	5.23	5.84	184,000	A.
May	9,680	3,960	6,160	10.40	11.99	379,000	A.
June	16,400	5,540	9,370	15.90	17.74	558,000	A.
July	9,120	3,440	6,440	10.90	12.57	396,000	A.
August	3,960	1,630	2,590	4.38	5.05	159,000	A.
September	1,750	625	981	1.66	1.85	58,400	A.
The year	16,400	316	2,810	4.75	64.83	2,040,000	
1916-17.							
October	580	418	485	.821	.95	29,800	A.
November	1,030	438	557	.942	1.05	33,100	A.
December	470	....	408	.690	.80	25,100	A.
January	540	357	429	.726	.84	26,400	B.
February	700	....	604	1.02	1.06	33,500	A.
March	580	438	487	.824	.95	29,900	A.
April	1,660	438	913	1.54	1.72	54,300	A.
May	11,000	1,790	5,210	8.82	10.17	320,000	A.
June	11,000	5,550	8,030	13.6	15.17	478,000	A.
July	9,570	2,610	6,150	10.4	11.99	378,000	A.
August	2,610	1,030	1,740	2.94	3.39	107,000	A.
September	980	580	754	1.28	1.43	44,900	A.
The year	11,000	....	2,160	3.65	49.52	1,560,000	
1917-18.							
October	745	405	517	.875	1.00	31,800	A.
November	1,140	412	678	1.15	1.28	40,300	A.
December	18,700	505	3,640	6.16	7.10	224,000	A.
January	15,400	1,300	3,940	6.67	7.69	242,000	A.
February	1,660	930	1,250	2.12	2.21	69,400	A.
March	1,790	745	976	1.65	1.90	60,000	A.
April	5,110	1,660	2,880	4.87	5.43	171,000	A.
May	7,710	2,760	4,810	8.14	9.38	296,000	A.
June	11,000	3,920	6,720	11.4	12.72	400,000	A.
July	4,300	1,540	2,770	4.69	5.41	170,000	A
August	1,660	790	1,070	1.81	2.09	65,800	A.
September	835	505	647	1.09	1.22	38,500	A.
The year	18,700	405	2,500	4.23	57.43	1,810,000	

[b] Records for this month revised since original publication. See Water-Supply Paper 482 for revised daily discharge.

Monthly discharge of Wenatchee River near Leavenworth, Wash., 1910–1919—Continued.

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1918–19.							
October	2,050	540	937	1.59	1.83	57,600	A.
November	1,420	745	998	1.69	1.89	59,400	A.
December	5,110	745	1,970	3.33	3.84	121,000	A.
January	1,920	745	1,140	1.93	2.22	70,100	A.
February	1,080	700	868	1.47	1.53	48,200	A.
March	1,660	620	792	1.34	1.54	48,700	A.
The period						405,000	

WENATCHEE RIVER AT CASHMERE AND DRYDEN, WASH.

Location.—Prior to October 13, 1909, at highway bridge in Cashmere half a mile below Mission Creek, 8 miles above mouth. October 13, 1909, to September 30, 1911, in SW. ¼ sec. 32, T. 24 N., R. 19 E., at highway bridge on main road from Cashmere to Leavenworth, half a mile above Mission Creek. October 1, 1911, to September 30, 1917, in SW. ¼ sec. 26, T. 24 N., R. 18 E., at Wenatchee Valley Gas & Electric Co.'s power plant (Pl. VI, *B*) a quarter of a mile north of Dryden, a mile below intake of Wenatchee Reclamation District canal (Pl. VI, *A*), 2 miles below Peshastin Creek, and 4 miles above Cashmere.

Drainage area.—1,280 square miles (revised) above station below Mission Creek; 1,200 square miles above stations above Mission Creek (measured on topographic maps).

Records available.—July 27, 1904, to September 30, 1917.

Gage.—Staff gage on highway bridge in Cashmere, July 27, 1904, to summer of 1907, when bridge was rebuilt. Staff gage installed at original datum on new bridge at same site on September 28, 1908. Readings on temporary gages used during intervening period referred to original datum. Chain gage installed on bridge above Mission Creek October 13, 1909, and used to September 30, 1911. Vertical staff in tailrace of power plant at Dryden used from October 1, 1911, to September 16, 1915; May 4 to 7, 1916; and June 17, 1916, to September 30, 1917. Datum lowered 0.50 foot November 1, 1916. Inclined staff 80 feet below plant used October 29, 1915, to May 4, 1916, and May 8 to June 17, 1916, when it was washed out.

Discharge measurements.—Made from bridge below Mission Creek prior to 1909 and from bridge above Mission Creek beginning June, 1909. Results of measurements referred to gage at Dryden corrected for inflow between gage and measuring section at bridge.

Channel and control.—Bed at original station composed of cobblestones and small boulders; control permanent. Bed at station at bridge above Mission Creek composed of gravel and small boulders; control shifting at high water. Bed at station at Dryden composed of solid rock and boulders; high-water control permanent, low-water control shifting.

Extremes of discharge.—Maximum stage recorded, 11.1 feet, high-water mark, December 30 or 31, 1917 (discharge, 27,100 second-feet); minimum stage recorded, −0.3 foot September 14–16, 1915 (discharge, 470 second-feet); stage may have been lower during the period from September 17 to October 28, 1915, for which gage heights are not available.

ICE.—Stage discharge relation at stations at Cashmere not affected by ice; at station at Dryden, affected by ice during severe winters; flow estimated from observer's notes, discharge measurements, and weather records.

DIVERSIONS. Many diversions for irrigation above station. Wenatchee Reclamation District canal is the most important; records of flow in canal available since June, 1911. Depletion caused by irrigation above station is estimated and added to record of flow in river and canal to give probable natural run-off.

REGULATION.—Slight regulation at mill pond at Leavenworth.

ACCURACY.—Stage-discharge relation at original station permanent; rating curve fairly well defined by 12 discharge measurements. Stage-discharge relation for low water at station at bridge above Mission Creek changed April 26, 1910, and June 14, 1911; rating curves fairly well defined by four or five discharge measurements each. Stage-discharge relation for low water at station at Dryden changed June 3, 1913, November 3, 1914, September 17, 1915, November 10, 1916, and May 30, 1917; rating curves used prior to September 17, 1915, and after June 17, 1916, well defined by numerous discharge measurements; curve for inclined gage used October 29, 1915, to June 17, 1916, fairly well defined by three discharge measurements. Gage-height record reliable except for period in 1907 and 1908 when temporary gages were used. Accuracy of monthly means indicated in table of monthly discharge.

COOPERATION.—Gage-height record of Wenatchee River and Wenatchee Reclamation District canal at Dryden furnished by Wenatchee Valley Gas & Electric Co.

Estimated monthly natural discharge of Wenatchee River at Cashmere and Dryden, Wash., 1904–1917.

[Drainage area, 1,280 square miles, period to Oct. 12, 1909; 1,200 square miles after Oct. 12, 1909.]

Month.	Discharge in second-feet.						Estimated natural run-off.			Accuracy.
	Maximum.[a]	Minimum.[a]	Mean.				Per square mile.	Inches.	Acre-feet.	
			River.	Canal.[b]	Estimated depletion.	Total, estimated natural flow.				
1904.										
July 27-31	4,260	3,180	3,780	60	26	3,870	3.02	0.56	38,400	C.
August	3,180	1,280	2,080	60	24	2,160	1.69	1.95	133,000	B.
September	1,480	830	1,080	40	17	1,140	.891	.99	67,800	B.
The period									239,000	
1904-5.										
October	1,280	730	855	20	10	885	.691	.80	54,400	B.
November	1,940	690	1,100			1,100	.859	.96	65,500	B.
December	1,590	1,030	1,300			1,300	1.02	1.18	79,900	B.
January	1,110	730	900			900	.703	.81	55,300	B.
February	1,700	650	990			990	.773	.80	55,000	B.
March	6,040	1,820	4,370			4,370	3.41	3.93	269,000	B.
April	11,400	2,210	4,710	10	11	4,730	3.70	4.13	281,000	B.
May	11,600	4,740	6,550	40	24	6,610	5.16	5.95	406,000	B.
June	14,900	6,900	10,500	50	26	10,600	8.28	9.24	631,000	C.
July	7,200	2,500	4,450	70	27	4,550	3.55	4.09	280,000	B.
August	2,350	1,030	1,560	70	25	1,660	1.30	1.50	102,000	B.
September	1,820	890	1,090	40	18	1,150	.898	1.00	68,400	B.
The year	14,900	650	3,210			3,240	2.53	34.39	2,350,000	

[a] Maximum and minimum discharge prior to 1911-12 refer to flow at river gaging station. During and after that year they refer to combined flow of river and canal.

[b] Estimated monthly mean discharge of canal prior to June, 1911, used only to obtain natural run-off. Considerable error in estimate of discharge of canal makes small error in total flow.

Estimated monthly natural discharge of Wenatchee River at Cashmere and Dryden, Wash., 1904–1917—Continued.

Month.	Discharge in second-feet.						Estimated natural run-off.			Accuracy.
	Maximum.	Minimum.	Mean.							
			River.	Canal.	Estimated depletion.	Total, estimated natural flow.	Per square mile.	Inches.	Acre-feet.	
1905–6.										
October	8,760	1,190	2,950	30	11	2,990	2.34	2.70	184,000	B.
November	1,940	1,190	1,400			1,400	1.09	1.22	83,300	B.
December	1,280	780	965			965	.754	.87	59,300	B.
January	1,700	780	1,040			1,040	.812	.94	64,000	B.
February	1,940	1,190	1,520			1,520	1.19	1.24	84,400	B.
March	3,180	1,190	1,450			1,450	1.13	1.30	89,200	B.
April	9,960	3,000	5,860	10	13	5,880	4.59	5.12	350,000	B.
May	11,600	4,740	7,860	50	27	7,940	6.20	7.15	488,000	B.
June	8,760	3,800	5,390	50	29	5,470	4.27	4.76	325,000	B.
July	6,320	1,590	3,260	70	30	3,360	2.62	3.02	207,000	B.
August	1,480	890	1,160	70	28	1,260	.984	1.13	77,500	B.
September	1,700	830	1,000	50	19	1,070	.836	.93	63,700	B.
The year	11,600	780	2,830			2,870	2.24	30.38	2,080,000	
1906–7.										
October	12,400	830	2,420	30	12	2,460	1.92	2.21	151,000	B.
November			c 7,100			7,100	5.55	6.19	422,000	D.
December			c 2,200			2,200	1.72	1.98	135,000	D.
January	1,380	890	1,040			1,040	.812	.94	64,000	B.
February	4,260	960	2,420			2,420	1.89	1.97	134,000	B.
March	2,660	1,280	2,040			2,040	1.59	1.83	125,000	B.
April	7,500	1,820	4,670	10	13	4,690	3.66	4.08	279,000	B.
May	18,500	6,320	12,500	50	28	12,600	9.84	11.34	775,000	C.
June	19,000	5,500	9,500	60	30	9,590	7.49	8.36	571,000	C.
July	6,600	2,500	4,330	80	32	4,440	3.47	4.00	273,000	B.
August	2,660	1,110	1,560	80	29	1,670	1.30	1.50	103,000	B.
September	1,700	890	1,220	50	21	1,290	1.01	1.13	76,800	B.
The year		830	4,250			4,300	3.36	45.53	3,110,000	
1907–8.										
October	1,110	1,110	1,110	30	13	1,150	.898	1.04	70,700	C.
November	2,500	1,120	1,300			1,300	1.02	1.14	77,400	C.
December	2,350	1,190	1,730			1,730	1.35	1.56	106,000	C.
January	1,700	960	1,390			1,390	1.09	1.26	85,500	B.
February	1,480	890	1,210			1,210	.945	1.02	69,600	B.
March	3,580	1,380	2,380			2,380	1.86	2.14	146,000	C.
April	8,760	2,070	4,560	20	14	4,590	3.59	4.00	273,000	C.
May	9,780	5,760	8,050	50	30	8,130	6.35	7.32	500,000	C.
June		6,320	11,500	60	32	11,600	9.06	10.11	690,000	C.
July	13,200	3,800	9,590	90	33	9,710	7.59	8.75	597,000	C.
August	3,800		2,060	90	31	2,180	1.70	1.96	134,000	C.
September			d 970	60	22	1,050	.820	.91	62,500	D.
The year			3,830			3,870	3.02	41.21	2,810,000	
1908–9.										
October			d 780	40	14	834	.652	.75	51,300	D.
November			c 1,100			1,100	.859	.96	65,500	D.
December			c 920			920	.719	.83	56,600	D.
January			c 800			800	.625	.72	49,200	D.
February			c 770			770	.602	.63	42,800	D.
March			c 1,100			1,100	.859	.99	67,600	D.
April			d 3,100	20	16	3,140	2.45	2.73	187,000	D.
May	11,600	4,380	7,420	60	34	7,510	5.87	6.77	462,000	B.
June	21,400	7,800	13,600	70	36	13,700	10.7	11.94	815,000	B.
July	9,440	2,660	5,510	90	38	5,640	4.41	5.08	347,000	B.
August	1,940	1,030	1,510	100	35	1,640	1.28	1.48	101,000	B.
September	1,380	730	930	60	25	1,020	.797	.89	60,700	B.
The year	21,400		3,130			3,180	2.48	33.77	2,310,000	

c Estimated by comparison with record of Yakima River at Cle Elum and at Umtanum; should be used with caution.
d Estimated by comparison with record of Yakima River at Cle Elum; should be used with caution.

Estimated monthly natural discharge of Wenatchee River at Cashmere and Dryden, Wash., 1904–1917—Continued.

Month.	Discharge in second-feet.						Estimated natural run-off.			Accuracy.
	Maximum.	Minimum.	Mean.				Per square mile.	Inches.	Acre-feet.	
			River.	Canal.	Estimated depletion.	Total, estimated natural flow.				
1909–10.										
October	1,480	870	1,070	40	15	1,120	0.910	1.05	68,900	B.
November	20,900	1,020	5,260			5,260	4.38	4.89	313,000	A.
December	17,200	1,720	4,050			4,050	3.38	3.90	249,000	A.
January	2,680	1,220	1,630			1,630	1.36	1.57	100,000	A.
February	1,650	1,060	1,420			1,420	1.18	1.23	78,900	A.
March	10,400	1,650	4,550			4,550	3.79	4.37	280,000	A.
April	18,900	2,600	7,100	20	15	7,140	5.95	6.64	425,000	A.
May	18,500	7,920	12,600	60	31	12,700	10.6	12.22	781,000	A.
June	11,800	5,120	7,650	80	34	7,760	6.47	7.22	462,000	A.
July	6,680	2,720	4,770	100	35	4,900	4.08	4.70	301,000	A.
August	2,630	965	1,770	100	33	1,900	1.58	1.82	117,000	A.
September	1,060	670	875	70	23	968	.807	.90	57,600	A.
The year	20,900	670	4,410			4,470	3.72	50.51	3,230,000	
1910–11.										
October	4,900	710	2,980	40	14	3,030	2.52	2.90	186,000	A.
November	12,600	1,920	4,160			4,160	3.47	3.87	248,000	A.
December	3,070	1,390	1,860			1,860	1.55	1.79	114,000	A.
January	2,300	1,010	1,340			1,340	1.12	1.29	82,400	A.
February	1,100	670	900			900	.750	.78	50,000	A.
March	3,160	670	1,540			1,540	1.28	1.48	94,700	A.
April	6,100	2,140	3,470	20	17	3,510	2.92	3.26	209,000	A.
May	10,000	3,890	5,600	70	37	5,710	4.76	5.49	351,000	A.
June	15,500	5,320	9,490	95	40	9,620	8.02	8.95	572,000	A.
July	5,080	1,470	3,580	107	42	3,730	3.11	3.58	229,000	A.
August	1,870	1,020	1,340	112	38	1,490	1.24	1.43	91,600	A.
September	1,870	760	1,160	70.8	27	1,260	1.05	1.17	75,000	A.
The year	15,500	670	3,120			3,180	2.65	35.99	2,300,000	
1911–12.										
October	808	628	644	48.0	17	709	.591	.68	43,600	A.
November	5,950	580	1,740	.0		1,740	1.45	1.62	104,000	A.
December	1,610	880	1,250	.0		1,250	1.04	1.20	76,900	A.
January	1,610	710	1,000	.0		1,000	.833	.96	61,500	A.
February	1,400	880	1,080	.0		1,080	.900	.97	62,100	A.
March	2,110	760	1,010	.0		1,010	.867	1.00	64,000	A.
April	4,420	2,250	3,250	29.8	23	3,300	2.75	3.07	196,000	A.
May	18,000	4,210	9,720	68.7	49	9,840	8.20	9.45	605,000	A.
June	14,500	5,580	10,000	93.0	53	10,100	8.42	9.39	601,000	A.
July	6,540	1,720	3,370	106	56	3,530	2.94	3.39	217,000	A.
August	1,970	939	1,270	118	51	1,440	1.20	1.38	88,500	B.
September	1,230	654	784	89.9	36	910	.758	.85	54,100	A.
The year	18,000	580	2,930	46.3		2,990	2.49	33.96	2,170,000	
1912–13.										
October	954	654	687	45.3	23	755	.629	.73	46,400	A.
November	1,610	710	1,050	.0		1,050	.875	.98	62,500	A.
December	1,400	820	1,000	.0		1,000	.833	.96	61,500	A.
January	1,300	760	981	.0		981	.818	.94	60,300	B.
February	2,110	880	1,280	.0		1,280	1.07	1.11	71,100	B.
March	1,850	1,200	1,380	.0		1,380	1.15	1.33	84,800	A.
April [a]	7,080	1,290	3,950	.0	24	3,970	3.31	3.69	236,000	A.
May [a]	15,700	3,730	9,010	.0	50	9,060	7.55	8.70	557,000	A.
June [a]	20,700	9,830	13,800	108	54	14,000	11.7	13.05	833,000	A.
July [a]	10,900	3,730	7,530	116	56	7,700	6.42	7.40	473,000	A.
August [a]	5,320	1,240	2,190	118	52	2,360	1.97	2.27	145,000	A.
September [a]	3,920	808	1,430	120	37	1,590	1.32	1.47	94,600	A.
The year	20,700	654	3,700	42.5		3,760	3.13	42.63	2,730,000	

[a] Records Apr. 1, 1913, to May 31, 1914, revised. See Water-Supply Paper 462 for revised daily discharge.

Estimated monthly natural discharge of Wenatchee River at Cashmere and Dryden, Wash., 1904–1917—Continued.

Month.	Discharge in second-feet.						Estimated natural run-off.			Accuracy.
	Maximum.	Minimum.	Mean.							
			River.	Canal.	Estimated depletion.	Total estimated natural flow.	Per square mile.	Inches.	Acre-feet.	
1913–14.										
October [e]	2,960	863	1,570	68.8	23	1,660	1.38	1.59	102,000	A.
November [e]	3,070	959	1,710	11.3	....	1,720	1.43	1.60	102,000	A.
December [e]	1,850	835	1,200	.0	....	1,200	1.00	1.15	73,800	A.
January [e]	3,610	900	1,790	.0	....	1,790	1.49	1.72	110,000	A.
February [e]	1,490	900	1,040	.0	....	1,040	.867	.90	57,800	A.
March [e]	3,610	1,200	2,340	.0	....	2,340	1.95	2.25	144,000	A.
April [e]	8,670	2,120	5,510	33.5	24	5,570	4.64	5.18	331,000	A.
May [e]	13,300	5,490	9,210	86.9	51	9,350	7.79	8.98	575,000	A.
June	12,800	4,250	7,030	101	55	7,190	5.99	6.68	428,000	A.
July	7,030	1,240	3,760	104	58	3,920	3.27	3.77	241,000	A.
August	1,930	948	1,180	113	53	1,350	1.12	1.29	83,000	A.
September	1,450	776	904	90.5	37	1,030	.858	.96	61,300	A.
The year	13,300	776	3,110	51.1	....	3,190	2.66	36.07	2,310,000	
1914–15.										
October	1,980	824	1,290	36.2	23	1,350	1.12	1.29	83,000	A.
November	5,480	1,850	2,960	.0	....	2,960	2.47	2.76	176,000	A.
December	2,110	940	1,240	.0	....	1,240	1.03	1.19	76,200	A.
January	940	620	787	.0	....	787	.656	.76	48,400	A.
February	820	660	705	.0	....	705	.588	.61	39,200	A.
March	3,380	660	1,550	.0	....	1,550	1.29	1.49	95,300	A.
April	9,200	2,710	5,530	21.4	25	5,580	4.65	5.19	332,000	A.
May	6,300	3,150	3,900	113	53	4,070	3.39	3.91	250,000	A.
June	4,700	1,320	2,590	122	57	2,770	2.31	2.58	165,000	A.
July	2,250	1,010	1,360	104	60	1,520	1.27	1.46	93,500	B.
August	1,330	888	931	128	55	1,110	.925	1.07	68,200	B.
September	888	....	548	102	39	689	.574	.64	41,000	C.
The year	9,200	....	1,950	52.5	....	2,030	1.69	22.95	1,470,000	
1915–16.										
October	1,950	....	807	43.9	24	875	.729	.84	53,800	C.
November	3,300	860	1,350	.0	....	1,350	1.12	1.25	80,300	B.
December	1,240	770	975	.0	....	975	.812	.94	60,000	B.
January	950	....	803	.0	....	803	.669	.77	49,400	B.
February	1,700	690	1,110	.0	....	1,110	.925	1.00	63,800	B.
March	5,930	1,300	3,300	.0	....	3,300	2.75	3.17	203,000	B.
April	8,960	3,820	6,290	.0	25	6,320	5.27	5.88	376,000	C.
May	15,000	6,610	9,750	70.0	53	9,870	8.22	9.48	607,000	C.
June	24,500	8,850	14,000	125	57	14,200	11.8	13.17	845,000	C.
July	13,900	5,310	9,840	121	60	10,000	8.33	9.60	615,000	A.
August	6,250	2,230	3,660	125	55	3,840	3.20	3.69	236,000	A.
September	2,500	1,050	1,430	103	39	1,570	1.31	1.46	93,400	A.
The year	24,500	....	4,450	49.2	....	4,520	3.77	51.25	3,280,000	
1916–17.										
October	1,050	722	795	12.0	24	831	.692	.80	51,100	B.
November	1,370	600	798	5.8	....	804	.670	.75	47,800	C.
December	750	....	690	.0	....	690	.575	.66	42,400	C.
January	950	....	708	.0	....	708	.590	.68	43,500	D.
February	1,030	....	901	.0	....	901	.751	.78	50,000	B.
March	1,110	600	790	.0	....	790	.658	.76	48,600	B.
April	2,710	690	1,450	37.4	26	1,510	1.26	1.41	89,800	B.
May	16,100	2,560	7,730	116	54	7,900	6.58	7.59	486,000	A.
June	16,200	8,370	11,700	148	58	11,900	9.92	11.07	708,000	A.
July	14,000	3,600	8,820	163	61	9,040	7.53	8.68	556,000	A.
August	3,450	1,300	2,140	178	56	2,370	1.98	2.28	146,000	A.
September	1,460	939	989	189	40	1,220	1.02	1.14	72,600	B.
The year	16,200	....	3,140	71.1	....	3,230	2.69	36.60	2,340,000	

[e] Records Apr. 1, 1913, to May 31, 1914, revised. See Water-Supply Paper 462 for revised daily discharge.

WENATCHEE RIVER NEAR WENATCHEE, WASH.

LOCATION.—At highway bridge, 6 miles above mouth and 7 miles west of Wenatchee.

DRAINAGE AREA.—1,310 square miles (measured on topographic maps).

RECORDS AVAILABLE.—August 7 to November 20, 1897; fragmentary.

GAGE.—Vertical staff on bridge pier on left bank. Gage readings were made at bridge site of the Wenatchee Water Power Co., 5 miles below the station and referred to upper gage.

DISCHARGE MEASUREMENTS.—Made from highway bridge.

CHANNEL AND CONTROL.—Bed composed of boulders. Control permanent during period of record. Banks high. Current swift at all stages.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 5.10 feet, November 20 (discharge, 13,300 second-feet); minimum stage recorded, 0.00 October 4–12, 16–21, 29–30, November 1–7 (discharge, 700 second-feet).

DIVERSION.—Small amount of water diverted above station for irrigation.

REGULATION.—None.

ACCURACY.—Stage-discharge relation permanent. Rating curve fairly well defined by four discharge measurements. Gage-height record only fairly reliable as readings were referred to upper gage on basis of only four simultaneous readings. Records fair.

Monthly discharge of Wenatchee River near Wenatchee, Wash., 1897.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
August			2,100	129,000	C.
September			1,000	59,500	C.
October	955	700	755	46,400	C.
The period				235,000	

LITTLE WENATCHEE RIVER NEAR CHIWAUKUM, WASH.

LOCATION.—In SW. ¼ sec. 15, T. 27 N., R. 16 E., three-fourths mile above Wenatchee Lake and 11 miles northwest of Chiwaukum.

DRAINAGE AREA.—99 square miles (measured on topographic maps).

RECORDS AVAILABLE.—Fragmentary gage-height record, August 2, 1911, to April 6, 1912; and June 8–14, 1913. Discharge estimated for August, September, and October, 1911.

GAGE.—Vertical staff on left bank.

DISCHARGE MEASUREMENTS.—Made from foot log or by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and sand. Control shifted at medium high stages. One channel at all stages.

DIVERSIONS.—None.

REGULATION.—None.

ACCURACY.—Stage-discharge relation changed on September 14, 1911. Rating curves poorly defined by three discharge measurements. Gage read five times in August and seven times in September. Records poor.

COOPERATION.—Gage-height record furnished by United States Forest Service.

Monthly discharge of Little Wenatchee River near Chiwaukum, Wash., 1911.

[Drainage area, 99 square miles.]

Month.	Discharge in second-feet.		Run-off.		Accuracy.
	Mean.	Per square mile.	Inches.	Acre-feet.	
August	[a] 80	0.81	0.93	4,920	D.
September	[a] 110	1.11	1.24	6,550	D.
October	[b] 67	.68	.78	4,120	D.
The period				15,600	

[a] Computed from fragmentary gage-height record by interpolation and by comparison with results at nearby gaging stations.
[b] Estimated by comparison with results at gaging stations on Wenatchee River near Leavenworth, White River, and Chiwawa River.

WHITE RIVER NEAR CHIWAUKUM, WASH.

LOCATION.—In NE. ¼ sec. 5, T. 27 N., R. 16 E., at highway bridge 4 miles above Wenatchee Lake and 14 miles northwest of Chiwaukum.

DRAINAGE AREA.—150 square miles (measured on topographic maps).

RECORDS AVAILABLE.—May 30, 1911, to April 30, 1912; July 26 to August 31, 1913; April 19, 1914, to September 30, 1914, fragmentary. Monthly mean discharge May to September, 1912, and mean discharge October, 1913, to March, 1914, estimated from records of adjacent streams.

GAGE.—Vertical staff on left abutment of bridge.

DISCHARGE MEASUREMENTS.—Made from bridge at gage or by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and boulders. Riffle control 100 yards below gage; shifts at high water. One channel at all stages.

EXTREMES OF DISCHARGE.—Maximum stage recorded 9 feet June 13, 1911 (discharge, 3,780 second-feet); minimum stage recorded, −0.34 foot, November 1–3, 1911 (discharge, 114 second-feet).

ICE.—Stage-discharge relation not affected by ice.

DIVERSIONS.—None.

REGULATION.—None.

ACCURACY.—Stage-discharge relation changed at high water in May, 1912. Rating curve used prior to the change poorly defined below and fairly well defined above 500 second-feet by five discharge measurements; curve used after the change fairly well defined by four discharge measurements. Gage-height record excellent in 1911 and 1912, fragmentary in 1913 and 1914. Accuracy of monthly means indicated in table of monthly discharge.

COOPERATION.—Gage-height record furnished by United States Forest Service.

Monthly discharge [a] of White River near Chiwaukum, Wash., 1911–1914.

[Drainage area, 150 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1911.							
June	3,780	1,390	2,190	14.6	16.29	130,000	B.
July	2,020	730	1,290	8.60	9.92	79,300	B.
August	810	358	510	3.40	3.92	31,400	B.
September	650	167	317	2.11	2.35	18,900	C.
The period						260,000	
1911–12.							
October	194	120	150	1.00	1.15	9,220	C.
November	1,020	114	325	2.17	2.42	19,300	C.
December	327	194	239	1.59	1.83	14,700	C.
January	271	204	209	1.39	1.60	12,900	C.
February	247	204	222	1.48	1.60	12,800	C.
March	423	150	196	1.31	1.51	12,100	C.
April	892	532	701	4.67	5.21	41,700	B.
May			[b] 2,100	14.0	16.14	129,000	D.
June			[b] 2,300	15.3	17.07	137,000	D.
July			[b] 1,200	8.00	9.22	73,800	D.
August			[b] 510	3.40	3.92	31,400	D.
September			[b] 260	1.73	1.93	15,500	D.
The year			701	4.67	63.60	509,000	

[a] Records revised.

[b] Estimated by percentage comparison with results obtained by subtracting discharge of Chiwawa River from discharge of Wenatchee River near Leavenworth; should be used with caution.

Monthly discharge of White River near Chiwaukum, Wash., 1911–1914—Continued.

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1913.							
July 26–31			1,580	10.5	2.34	18,800	B.
August			771	5.14	5.93	47,400	B.
1913–14.							
October							
November							
December							
January			b 270	1.80	12.18	97,500	C.
February							
March							
April			c 1,000	6.67	7.44	59,500	C.
May			c 1,850	12.3	14.18	114,000	C.
June			c 1,600	10.7	11.94	95,200	C.
July			1,280	8.53	9.83	78,700	B.
August			c 430	2.87	3.31	26,400	C.
September			c 250	1.67	1.86	14,900	C.
The year			671	4.47	60.74	486,000	

b Estimated by percentage comparison with results obtained by substracting discharge of Chiwawa River from discharge of Wenatchee River near Leavenworth; should be used with caution.

c Based on actual record for part of month and percentage comparison with record of Wenatchee and Chiwawa rivers near Leavenworth.

NASON CREEK AT NASON, WASH.

Location.—In NE. ¼ sec. 11, T. 26 N., R. 16 E., at mouth of Roaring Creek, two-thirds mile northwest of Nason.

Drainage area.—89 square miles (measured on topographic maps).

Records available.—June 4 to September 30, 1911.

Gage.—Vertical staff fastened to railroad trestle crossing Roaring Creek.

Discharge measurements.—Made from highway bridge about half a mile below gage or by wading.

Channel and control.—Bed composed of gravel and small boulders. Riffle control about 75 feet below gage; permanent during period of record. Right bank railroad embankment; left bank low, subject to overflow.

Extremes of discharge.—Maximum stage recorded, 4.8 feet June 13 (discharge, 1,390 second-feet); minimum stage recorded, 1.15 feet, September 1–3 (discharge, 44 second-feet).

Diversions.—None.

Regulation.—None.

Accuracy.—Stage-discharge relation permanent during period. Rating curve fairly well defined by six discharge measurements. Gage read to quarter-tenths twice daily. Accuracy of monthly mean indicated in table of monthly discharge.

Monthly discharge of Nason Creek at Nason, Wash., 1911.

[Drainage area, 89 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
June 4-30	1,390	314	720	8.09	8.12	38,600	B.
July	374	105	237	2.66	3.07	14,600	B.
August	101	48	72.7	.817	.94	4,470	A.
September	152		[a] 80.9	.909	1.01	4,810	C.
The period						62,500	

[a] Discharge Sept. 4-14 revised since publication in Water-Supply Paper 312, as gage heights were apparently in error. Discharge estimated from discharge measurement and by hydrographic comparison with records of Little Wenatchee River and Chiwaukum Creek.

CHIWAWA RIVER NEAR LEAVENWORTH, WASH.

LOCATION.—In SW. ¼ sec. 30, T. 27 N., R. 18 E., at Jordan's ranch, 1 mile below Deep Creek, 3 miles above mouth, and 14 miles north of Leavenworth.

DRAINAGE AREA.—181 square miles (measured on topographic maps).

RECORDS AVAILABLE.—May 29, 1911, to October 31, 1914, fragmentary. Monthly mean discharge May, 1912, to June, 1913, estimated by comparison with record of Wenatchee River near Leavenworth.

GAGE.—Vertical staff in two sections on left bank at Jordan's ranch.

DISCHARGE MEASUREMENTS.—Made from cable 2¼ miles below gage, from bridge half a mile below gage, or by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and small boulders. Control shifts at extremely high water. One channel at all stages.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 3.3 feet May 8, 1912 (discharge, 2,410 second-feet); minimum flow estimated at 90 second-feet, February 6, 1914, during period in which stage-discharge relation was affected by ice.

ICE.—Stage-discharge relation seriously affected by ice; flow estimated from observer's notes, discharge measurements, weather records, and hydrographic comparison with record of Wenatchee River near Leavenworth.

DIVERSIONS.—The Wenatchee Park Land & Irrigation Co. diverted a maximum of about 12 second-feet from Chiwawa River during irrigation seasons beginning in 1914.

ACCURACY.—Stage-discharge relation changed at high water on May 8, 1912; affected by ice December 17, 1911, to February 12, 1912, and January 23 to February 15, 1914. Rating curve used prior to the change fairly well defined up to 500 second-feet by two discharge measurements; curve used after the change well defined below and fairly well defined above 900 second-feet by seven discharge measurements. Gage-height record fairly reliable. Accuracy of monthly means indicated in table of monthly discharge.

Monthly discharge of Chiwawa River near Leavenworth, Wash., 1911–1914.

[Drainage area, 181 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1911.							
May 29-31	1,600	1,080	1,330	7.35	0.82	7,910	B.
June	2,290	988	1,540	8.51	9.50	91,600	B.
July	1,210	470	830	4.59	5.29	51,000	B.
August	500	230	321	1.77	2.04	19,700	A.
September	335	150	231	1.28	1.43	13,700	A.
The period						184,000	
1911-12.							
October	150	123	139	.768	.89	8,550	A.
November	412	123	205	1.13	1.26	12,200	A.
December	196		159	.878	1.01	9,780	C.
January			148	.818	.94	9,100	D.
February		125	151	.834	.90	8,690	C.
March	230	114	147	.812	.94	9,040	A.
April	1,210	290	622	3.44	3.84	37,000	B.
May			[a] 1,900	10.5	12.11	117,000	D.
June			[a] 1,900	10.5	11.71	113,000	D.
July			[a] 730	4.03	4.65	44,900	D.
August			[a] 330	1.82	2.10	20,300	D.
September			[a] 190	1.05	1.17	11,300	D.
The year			552	3.05	41.52	401,000	
1912-13.							
October			[a] 140	.773	.89	8,610	D.
November			[a] 150	.829	.92	8,930	D.
December			[a] 150	.829	.96	9,220	D.
January			[a] 140	.773	.89	8,610	D.
February			[a] 180	.994	1.04	10,000	D.
March			[a] 190	1.05	1.21	11,700	D.
April			[a] 680	3.76	4.20	40,500	D.
May			[a] 1,700	9.39	10.83	105,000	D.
June			[a] 2,700	14.9	16.62	161,000	D.
July	1,670	728	1,240	6.85	7.90	76,200	A.
August	764	322	487	2.69	3.10	29,900	A.
September	1,260	240	351	1.94	2.16	20,900	A.
The year			676	3.73	50.72	491,000	
1913-14.							
October	368	221	295	1.63	1.88	18,100	A.
November	530	240	308	1.70	1.90	18,300	A.
December	300	193	222	1.23	1.42	13,600	A.
January	560		257	1.42	1.64	15,800	C.
February	206		[b] 164	.906	.94	[b] 9,110	C.
March	530	193	364	2.01	2.32	22,400	B.
April	2,020	368	1,270	7.02	7.83	75,600	A.
May	2,270	1,170	[c] 1,680	9.28	10.70	103,000	A.
June	2,270	919	[c] 1,370	7.57	8.45	81,500	A.
July	1,360	444	[c] 830	4.59	5.29	51,000	A.
August	500	210	[c] 302	1.67	1.92	18,600	A.
September	322	160	[c] 224	1.24	1.38	13,300	A.
The year	2,270		604	3.34	45.67	440,000	
1914.							
October	368	173	242	1.34	1.54	14,900	A.

[a] Estimated by percentage comparison with record of Wenatchee River near Leavenworth; should be used with caution.

[b] Corrected since publication in Water-Supply Paper 392.

[c] Includes estimate of diversion above gage for irrigation as follows: May and June, 10 second-feet; July, 12 second-feet; August, 9 second-feet; and September, 8 second-feet.

CHIWAUKUM CREEK NEAR CHIWAUKUM, WASH.

LOCATION.—At trail crossing half a mile above mouth and 1 mile southeast of Chiwaukum.

DRAINAGE AREA.—49.6 square miles (measured on topographic maps).

RECORDS AVAILABLE.—June 2 to October 5, 1911.

GAGE.—Vertical staff on left bank 10 feet above trail crossing.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and boulders. Control permanent during period of record. Banks low; subject to overflow. Two channels at high water.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 2.9 feet, June 12 (discharge, 803 second-feet); minimum stage recorded, 0.55 foot, October 4 and 5 (discharge, 24 second-feet; mean flow as estimated for October, is lower).

DIVERSIONS.—None.

REGULATION.—None.

ACCURACY.—State-discharge relation permanent. Rating curve fairly well defined by six discharge measurements. Gage read to hundredths once daily. Records good.

Monthly discharge of Chiwaukum Creek near Chiwaukum, Wash., 1911.

[Drainage area, 49.6 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
June[a]	803	255	382	7.70	8.59	22,700	B.
July	262	67	154	3.10	3.57	9,470	B.
August	72	33	45.1	.909	1.05	2,770	B.
September	47	27	34.4	.694	.77	2,050	B.
October			[b] 20	.403	.46	1,230	D.
The period						38,200	

[a] Record for month completed by estimating discharge June 1 same as June 2.
[b] Estimated by percentage comparison with record of Icicle Creek.

ICICLE CREEK NEAR LEAVENWORTH, WASH.

LOCATION.—In sec. 24, T. 24 N., R. 17 E., at Lamb's ranch, 1½ miles above mouth and 2½ miles south of Leavenworth.

DRAINAGE AREA.—211 square miles (measured on topographic maps).

RECORDS AVAILABLE.—June 9, 1911, to October 31, 1914.

GAGE.—Vertical staff on cottonwood tree on left bank.

DISCHARGE MEASUREMENTS.—Made from cable 20 feet below gage or by wading.

CHANNEL AND CONTROL.—Bed composed of coarse sand, gravel, and small boulders. Control permanent during period of record. One channel at all stages.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 8.1 feet at 8 a. m. June 3, 1913 (discharge, 4,760 second-feet); minimum stage recorded, 0.18 foot November 2-3, 1911 (discharge, 84 second-feet).

ICE.—Stage-discharge relation seriously affected by ice; flow estimated from observer's notes, weather records, and comparison with records of Wenatchee and Chiwawa rivers near Leavenworth.

DIVERSIONS.—Some water is diverted for irrigation above station. Estimated diversion above station added to give total flow.

REGULATION.—None.

ACCURACY.—Stage-discharge relation permanent; affected by ice every winter. Rating curve well defined by 16 discharge measurements. Gage read to hundredths once daily. Accuracy of monthly means indicated in table of monthly discharge.

Monthly discharge of Icicle Creek (including diversions) near Leavenworth, Wash., 1911–1914.

[Drainage area, 211 square miles.]

Month.	Discharge in second-feet.						Combined run-off.		Accuracy.
	Icicle Creek.			Estimated mean diversion.[a]	Combined.				
	Maximum.	Minimum.	Mean.		Mean.	Per square mile.	Inches.	Acre-feet.	
1911.									
June			1,870	8	1,880	8.91	9.94	112,000	A.
July	1,110	350	675	10	685	3.25	3.75	42,100	A.
August	345	139	225	10	235	1.11	1.28	14,400	A.
September	395	139	215	2	217	1.03	1.15	12,900	A.
The period		139	741		749	3.55	16.12	181,000	
1911-12.									
October	135	87	111		111	.526	.61	6,820	A.
November	1,280	84	328		328	1.55	1.73	19,500	A.
December	345	186	237		237	1.12	1.29	14,600	B.
January			220		220	1.04	1.20	13,500	B.
February		195	223		223	1.06	1.14	12,800	A.
March	345	130	186		186	.882	1.02	11,400	A.
April	725	420	552		552	2.62	2.92	32,800	A.
May	4,120	620	1,970	9	1,980	9.38	10.81	122,000	A.
June	3,010	1,000	2,030	14	2,040	9.67	10.79	121,000	A.
July	972	345	664	18	682	3.23	3.72	41,900	A.
August	370	200	273	18	291	1.38	1.59	17,900	A.
September	420	110	195	13	208	.986	1.10	12,400	A.
The year	4,120	84	582		588	2.79	37.92	427,000	
1912-13.									
October	214	106	144		144	.682	.79	8,850	A.
November	282	144	203		203	.962	1.07	12,100	A.
December	272	130	182		182	.863	.99	11,200	B.
January[b]			176		176	.834	.96	10,800	B.
February[b]	670		305		305	1.45	1.51	16,900	A.
March	272	176	227		227	1.08	1.24	14,000	A.
April	1,160	214	605		605	2.87	3.20	36,000	A.
May	4,050	620	1,740	9	1,750	8.29	9.56	108,000	A.
June	4,640	1,930	2,970	18	2,990	14.2	15.84	178,000	A.
July	2,350	725	1,460	23	1,480	7.01	8.08	91,000	A.
August	752	248	424	23	447	2.12	2.44	27,500	A.
September	890	200	300	14	314	1.49	1.66	18,700	A.
The year	4,640		728		736	3.49	47.34	533,000	
1913-14.									
October	670	153	360		360	1.71	1.97	22,100	A.
November	1,000	195	374		374	1.77	1.98	22,300	A.
December	345	176	231		231	1.09	1.26	14,200	A.
January	1,160	176	424		424	2.01	2.32	26,100	C.
February	320	140	210		210	.995	1.04	11,700	C.
March	620	224	392		392	1.86	2.14	24,100	A.
April	1,810	395	950		950	4.50	5.02	56,500	A.
May	2,890	1,110	1,820	9	1,830	8.67	10.00	113,000	A.
June	2,890	780	1,420	18	1,440	6.82	7.61	85,700	A.
July	1,330	320	706	23	729	3.46	3.99	44,800	A.
August	345	130	226	23	249	1.18	1.36	15,300	A.
September	296	110	173	15	188	.891	.99	11,200	A.
The year	2,890	110	609		616	2.92	39.68	447,000	
1914.									
October	470	130	289		289	1.37	1.58	17,800	A.

[a] Based on discharge measurements and capacity of canal. Considerable error in estimate of diversion makes small error in combined flow.

[b] Estimated discharge Jan. 6 to Feb. 5, 1913, when stage-discharge relation was effected by ice, revised since publication in Water-Supply Paper 362; mean discharge estimated at 150 second-feet.

PESHASTIN CREEK AT BLEWETT, WASH.

LOCATION.—In sec. 12, T. 22 N., R. 17 E. (unsurveyed), at Blewett, 1½ miles above Negro Creek, 1½ miles below Tronson Creek, and 13 miles above mouth.

DRAINAGE AREA.—40 square miles (measured on topographic maps).

RECORDS AVAILABLE.—June 13-22 and July 18-24, 1911; gage heights only. August 1 to December 15, 1911, and May 12 to July 7, 1912.

GAGE.—Vertical staff on left bank just below tailrace of stamp mill and above dam at placer ditch intake, installed August 1, 1911. Original gage nearer dam affected by backwater.

DISCHARGE MEASUREMENTS.—All measurements made by wading.

CHANNEL AND CONTROL.—Bed composed of gravel. Control remained permanent during period of record.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 3.05 feet May 12 and 13, 1912 (discharge, 221 second-feet); minimum stage recorded, 0.42 foot August 25-31, 1911 (discharge, 2.4 second-feet).

DIVERSIONS.—None.

REGULATIONS.—None.

ACCURACY.—Stage-discharge relation permanent. Rating curve poorly defined by six discharge measurements. Gage read to hundredths once daily. Records fair.

COOPERATION.—Gage-height record furnished voluntarily by J. W. McCarthy.

Monthly discharge of Peshastin Creek at Blewett, Wash., 1911-12.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
August	4.4	2.4	3.05	188	C.
September	4.4	2.7	3.63	216	C.
1911-12.					
October	3.8	3.2	3.34	205	C.
November	50	3.8	18.7	1,110	C.
December			a 8.68	534	C.
May			b 120	7,380	C.
June			24.4	1,450	C.
July			c 6.35	390	D.

a Based on actual record December 1-15, and comparison with record of Icicle Creek.
b Based on actual record May 12-31, and comparison with record of Peshastin Creek near Leavenworth. Gage heights May 16-31, omitted from Water-Supply Paper 332-A.
c Based on actual record July 1-7, and comparison with record of Peshastin Creek near Leavenworth.

PESHASTIN CREEK BELOW INGALLS CREEK, NEAR LEAVENWORTH, WASH.

LOCATION.—In sec. 24, T. 23 N., R. 17 E., at bridge at Allen's ranch, three-eighths mile below Ingalls Creek and 9 miles south of Leavenworth.

DRAINAGE AREA.—101 square miles (measured on topographic maps).

RECORDS AVAILABLE.—July 31, 1911, to July 27, 1912, fragmentary. Discharge during breaks in record estimated by comparison with record of Icicle Creek.

GAGE.—Vertical staff in three sections on right abutment of bridge.

DISCHARGE MEASUREMENTS.—Made from bridge at gage or by wading.

CHANNEL AND CONTROL.—Bed composed of boulders. Control permanent.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 4.5 feet at 6 p. m. May 20, 1912 (discharge, 1,560 second-feet); minimum stage recorded, 0.60 foot October 25 to November 4 and November 11, 1911 (discharge, 18 second-feet).

ICE.—Gage not read during winter.

DIVERSIONS.—None above station.

REGULATION.—None.

ACCURACY.—Stage-discharge relation permanent. Rating curve fairly well defined below 600 second-feet by six discharge measurements. Gage read once daily. Records fair.

Monthly discharge of Peshastin Creek near Leavenworth, Wash., 1911-12.

[Drainage area, 101 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Inches.	Acre-feet.	
1911.							
August	92	26	47.8	0.473	0.55	2,940	C.
September	70	26	43.7	.433	.48	2,600	C.
1911-12.							
October	31	18	24	.238	.27	1,480	C.
November			[a] 65	.644	.72	3,870	D.
December			[b] 40	.396	.46	2,460	D.
January			[b] 35	.347	.40	2,150	D.
February			[b] 35	.347	.37	2,010	D.
March			[b] 35	.347	.40	2,150	D.
April			[c] 248	2.46	2.74	14,800	C.
May	1,460	335	596	5.90	6.80	36,600	C.
June	540	180	378	3.74	4.17	22,500	C.
July	206		[d] 111	1.10	1.27	6,820	C.
August			[b] 60	.594	.68	3,690	D.
September			[b] 40	.396	.44	2,380	D.
The year			139	1.38	18.72	101,000	

[a] Based on actual record Nov. 1-11 and comparison with record of Icicle Creek.
[b] Estimated by percentage comparison with record of Icicle Creek; should be used with caution.
[c] Based on actual record Apr. 7-30 and comparison with record of Icicle Creek.
[d] Based on actual record July 1-20 and 27. Discharge July 21-26, interpolated; July 28-31, estimated at 60 second-feet.

ENTIAT RIVER AT ENTIAT, WASH.

LOCATION.—In sec. 18, T. 25 N., R. 21 E., one-eighth mile below power plant of Wenatchee Valley Gas & Electric Co. (Pl. V, *B*), three-fourths mile above Entiat and 1 mile above mouth.

DRAINAGE AREA.—419 square miles (measured on topographic maps).

RECORDS AVAILABLE.—October 5, 1910, to March 31, 1919.

GAGE.—Inclined staff on left bank one-eighth mile below power plant.

DISCHARGE MEASUREMENTS.—Made from bridge 200 feet below plant or by wading.

CHANNEL AND CONTROL.—Bed composed of gravel and boulders. Control shifts at extremely high water. One channel at all stages. Left bank high, not subject to overflow; right bank slopes gradually.

EXTREMES OF DISCHARGE.—Maximum stage recorded 5.0 feet June 17, 1916 (discharge, 5,150 second-feet); minimum stage recorded, 0.68 foot November 13, 1916 (discharge, 62 second-feet). Discharge may have been as low or lower during periods in which stage-discharge relation was affected by ice.

ICE.—Stage-discharge relation seriously affected by ice; flow estimated from observer's notes, discharge measurements, and weather records.

DIVERSIONS.—Several diversions above station for irrigation. The Entiat Irrigation Co.'s canal, capacity about 15 second-feet, carries water past station. Flow past gage in canal and depletion caused by irrigation above gage estimated and combined with observed discharge to obtain probable natural run-off.

REGULATION.—Changes in load at power plant affect flow, especially at low water.

Accuracy.—Stage-discharge relation for low stages changed on June 4, 1913, June 17, 1916, January 1 and June 13, 1918; affected by ice every winter. Rating curves used prior to June 13, 1918, fairly well defined by numerous discharge measurements; rating curve used after that date well defined. Gage read to hundredths daily. Some fluctuation at low water due to regulation at power plant. Open-water records prior to June 13, 1918, good, after that date excellent; records during periods in which stage-discharge relation was affected by ice, fair.

Cooperation.—Gage-height record furnished by Wenatchee Valley Gas & Electric Co.

Estimated natural discharge of Entiat River at Entiat, Wash., 1911–1919.

[Drainage area, 419 square miles.]

Month.	Discharge in second-feet. Observed. Maximum.	Observed. Minimum.	Observed. Mean.	Estimated diversion and depletion on account of irrigation.[a]	Estimated natural flow, mean.	Per square mile.	Run-off. Inches.	Run-off. Acre-feet.	Accuracy of observed data.
1910–11.									
October	....	....	[b] 250	6	256	0.611	0.70	15,700	
November	515	228	288	....	288	.687	.77	17,100	B.
December	285	150	213	....	213	.508	.59	13,100	C.
January	....	....	112	....	112	.267	.31	6,890	C.
February	....	....	112	....	112	.267	.28	6,220	C.
March	450	112	228	....	228	.544	.63	14,000	B.
April	950	335	533	4	537	1.28	1.43	32,000	B.
May	1,640	850	1,070	11	1,080	2.58	2.97	66,400	B.
June	3,060	950	1,860	14	1,870	4.46	4.98	111,000	B.
July	950	285	586	15	601	1.43	1.65	37,000	B.
August	285	150	207	15	222	.530	.61	13,600	B.
September	245	150	193	12	205	.489	.55	12,200	B.
The year	....	....	471	....	478	1.14	15.47	345,000	
1911–12.									
October	150	112	125	6	131	.313	.36	8,060	
November	228	90	135	....	135	.322	.36	8,030	B.
December	150	80	118	....	118	.282	.33	7,260	B.
January	150	....	118	....	118	.282	.33	7,260	B.
February	150	70	116	....	116	.277	.30	6,670	C.
March	245	92	137	....	137	.327	.38	8,420	B.
April	590	265	391	4	395	.943	1.05	23,500	B.
May	3,060	515	1,710	11	1,720	4.11	4.74	106,000	B.
June	2,380	950	1,760	14	1,770	4.22	4.71	105,000	B.
July	850	265	501	15	516	1.23	1.42	31,700	B.
August	335	165	227	15	242	.578	.67	14,900	B.
September	195	105	146	12	158	.377	.42	9,400	B.
The year	3,060	70	457	....	463	1.11	15.07	336,000	
1912–13.									
October	138	100	119	6	125	.298	.34	7,690	B.
November	138	112	128	....	128	.305	.34	7,620	B.
December	165	102	125	....	125	.298	.34	7,690	B.
January	....	....	108	....	108	.258	.30	6,640	C.
February	....	....	136	....	136	.325	.34	7,550	C.
March	180	112	149	....	149	.356	.41	9,160	B.
April	715	150	409	4	413	.986	1.10	24,600	B.
May	3,060	450	1,450	11	1,460	3.48	4.01	89,800	B.
June	3,800	1,720	2,680	14	2,690	6.42	7.16	160,000	B.
July	1,860	491	1,040	15	1,060	2.53	2.92	65,200	B.
August	491	186	301	15	316	.754	.87	19,400	B.
September	256	143	186	12	198	.473	.53	11,800	B.
The year	3,800	....	569	....	576	1.37	18.66	417,000	

[a] Flow past gage in canal estimated from two discharge measurements and high-water mark in canal. Distribution by months made on basis of six-year record of Wenatchee Reclamation District canal at Dryden. Depletion above gage based on careful studies of irrigation in Yakima basin. (See Water-Supply Paper 369, pp. 50–55). Total depletion assumed to be 2.8 feet per acre. Basin is small and return flow probably reaches river in short time. Depletion is therefore distributed by months in same proportion as estimated diversions.

[b] Based on actual record Oct. 5–9 and hydrographic comparison with Wenatchee and Methow rivers.

Estimated natural discharge of Entiat River at Entiat, Wash., 1911–1919—Continued.

Month.	Discharge in second-feet.						Run-off.		Accuracy of observed data.
	Observed.			Estimated diversion and depletion on account of irrigation.	Estimated natural flow, mean.	Per square mile.	Inches.	Acre-feet.	
	Maximum.	Minimum.	Mean.						
1913–14.									
October	171	134	155	6	161	0.384	0.44	9,900	B.
November	185	134	161	....	161	.384	.43	9,580	B.
December	158	119	140	....	140	.334	.39	8,610	B.
January	231	119	171	....	171	.408	.47	10,500	B.
February	171	65	136	....	136	.325	.34	7,550	B.
March	360	156	233	....	233	.556	.64	14,300	B.
April	1,060	250	725	4	729	1.74	1.94	43,400	B.
May	2,700	870	1,770	11	1,780	4.25	4.90	109,000	B.
June	2,870	1,010	1,580	14	1,590	3.79	4.23	94,600	B.
July	1,390	311	736	15	751	1.79	2.06	46,200	B.
August	311	134	196	15	211	.504	.58	13,000	B.
September	199	123	146	12	158	.377	.42	9,400	B.
The year	2,870	65	514	....	520	1.24	16.84	376,000	
1914–15.									
October	199	146	167	6	173	.413	.48	10,600	B.
November	268	205	239	....	239	.570	.64	14,200	B.
December	250	....	161	....	161	.384	.44	9,900	D.
January	151	....	127	....	127	.303	.35	7,810	D.
February	124	104	111	....	111	.265	.28	6,160	B.
March	311	112	179	....	179	.427	.49	11,000	B.
April	1,510	250	840	4	844	2.01	2.24	50,200	B.
May	1,510	780	980	11	991	2.37	2.73	60,900	B.
June	1,110	360	704	14	718	1.71	1.91	42,700	B.
July	545	179	275	15	290	.692	.80	17,800	B.
August	246	124	168	15	183	.437	.50	11,300	B.
September	142	83	98.0	12	110	.263	.29	6,550	B.
The year	1,510	83	338	....	344	.821	11.15	249,000	
1915–16.									
October	171	83	98.4	6	104	.248	.29	6,400	B.
November	199	73	114	....	114	.272	.30	6,780	B.
December	124	....	98.7	....	98.7	.236	.27	6,070	C.
January	....	....	91.8	....	91.8	.219	.25	5,640	C.
February	164	....	116	....	116	.277	.30	6,670	C.
March	620	137	367	....	367	.876	1.01	22,600	B.
April	1,330	415	853	4	857	2.05	2.29	51,000	B.
May	2,700	1,110	1,830	11	1,840	4.39	5.06	113,000	B.
June	5,150	2,060	3,160	14	3,170	7.57	8.45	189,000	B.
July	3,240	1,000	2,090	15	2,100	5.01	5.78	129,000	B.
August	1,000	388	609	15	624	1.49	1.72	38,400	B.
September	388	169	226	12	238	.568	.63	14,200	B.
The year	5,150	73	804	....	811	1.94	26.35	589,000	
1916–17.									
October	190	142	163	6	169	.403	.46	10,400	B.
November	159	62	124	....	124	.296	.33	7,200	B.
December	....	....	107	....	107	.255	.29	6,580	C.
January	....	....	107	....	107	.255	.29	6,580	C.
February	....	....	112	....	112	.267	.28	6,220	B.
March	123	90	105	....	105	.251	.29	6,460	B.
April	299	92	195	4	199	.475	.53	11,800	B.
May	3,120	222	1,190	11	1,200	2.86	3.30	73,800	B.
June	2,950	1,680	2,220	14	2,230	5.32	5.94	133,000	B.
July	2,290	473	1,230	15	1,240	2.96	3.41	76,200	B.
August	446	222	323	15	338	.807	.93	20,800	B.
September	228	142	182	12	194	.463	.52	11,500	B.
The year	3,120	62	506	....	511	1.22	16.57	371,000	

Estimated natural discharge of Entiat River at Entiat, Wash., 1911–1919—Continued.

Month.	Discharge in second-feet.						Run-off.		Accuracy of observed data.
	Observed.			Estimated diversion and depletion on account of irrigation.	Estimated natural flow, mean.	Per square mile.	Inches.	Acre-feet.	
	Maximum.	Minimum.	Mean.						
1917–18.									
October	155	100	127	6	133	0.317	0.37	8,180	B.
November	148	95	121	....	121	.289	.32	7,200	B.
December	....	....	230	....	230	.549	.63	14,100	C.
January	1,290	....	497	....	497	1.19	1.37	30,600	B.
February	267	....	193	....	193	.461	.48	10,700	C.
March	224	126	145	....	145	.346	.40	8,920	B.
April	990	276	524	4	528	1.26	1.41	31,400	B.
May	2,130	990	1,380	11	1,390	3.32	3.83	85,500	B.
June	3,120	938	1,780	14	1,790	4.27	4.76	107,000	B.
July	893	289	527	15	542	1.29	1.49	33,300	A.
August	289	141	203	15	218	.520	.60	13,400	A.
September	146	109	122	12	134	.320	.36	7,970	A.
The year	3,120	....	488	....	494	1.18	16.02	358,000	
1918–19.									
October	583	114	170	6	176	.420	.48	10,800	A.
November	138	64	119	....	119	.284	.32	7,080	A.
December	355	....	150	....	150	.358	.41	9,220	A.
January	229	....	147	....	147	.351	.40	9,040	C.
February	149	....	121	....	121	.289	.30	6,720	A.
March	355	104	152	....	152	.363	.42	9,350	A.
The period	....	....	....	....	....	....	....	52,200	

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous measurements have been made in the Wenatchee and Entiat basins.

Miscellaneous measurements in Wenatchee and Entiat basins.

Wenatchee basin.

Date.	Stream.	Tributary to or diverting from—	Locality.	Discharge.
June 14, 1904	Wenatchee River	Columbia River	Peshastin	10,800
June 16, 1904	.....do	.....do	Wenatchee	13,100
Oct. 3, 1911	Little Wenatchee River.	Wenatchee River	Above Lake Creek	34
Oct. 4, 1911	.....do	.....do	Above Rainy Creek	54
Aug. 2, 1911	.....do	.....do	Three-fourths mile above Wenatchee Lake.	130
Sept. 16, 1911	.....do	.....do	.....do	275
Oct. 3, 1911	.....do	.....do	.....do	88
Oct. 2, 1912	.....do	.....do	.....do	95
Sept. 11, 1913	.....do	.....do	.....do	226
Oct. 3, 1911	Lake Creek	Little Wenatchee River.	Mouth	12.4
Oct. 4, 1911	Rainy Creek	.....do	.....do	16.2
Sept. 13, 1911	White River	Wenatchee River	Above Indian Creek	132
Sept. 11, 1913	.....do	.....do	Gaging station 4 miles above Wenatchee Lake.	391
Sept. 13, 1911	Indian Creek	White River	Mouth	53
Do	Cougar Creek	.....do	.....do	37.8
Sept. 12, 1911	North Fork of White River.	.....do	.....do	200

Miscellaneous measurements in Wenatchee and Entiat basins—Continued.

Wenatchee basin—Continued.

Date.	Stream.	Tributary to or diverting from—	Locality.	Discharge.
Sept. 14, 1911	North Fork of White River.	White River	Mouth	125
Do	Twin Lakes outlet	North Fork of White River.	do	2.3
Sept. 11, 1911	Nason Creek	Wenatchee River	Above Wildhorse Creek	18.2
Feb. 19, 1912	do	do	Gaging station near Nason	164
June 11, 1912	do	do	do	1,080
Sept. 13, 1913	do	do	do	98
Sept. 11, 1911	Wildhorse Creek	Nason Creek	Mouth	22.2
Aug. 15, 1914	Wenatchee Park canal.	Chiwawa River	Half a mile below intake	9.2
Oct. 4, 1915	do	do	do	2.2
Sept. 12, 1913	Chiwaukum Creek	Wenatchee River	Gaging station near Chiwaukum	45.5
Nov. 28, 1910	Beaver Creek	do	Mouth	3.6
Mar. 11, 1911	do	do	do	3.6
Sept. 24, 1911	Icicle Creek	do	Above Jack Creek	103
Do	do	do	Above Eightmile Creek	148
Aug. 24, 1909	do	do	10 miles above mouth	262
Sept. 24, 1911	Jack Creek	Icicle Creek	Mouth	25.6
Do	Trout Creek	do	do	7.9
Do	Eightmile Creek	do	do	27.7
Sept. 18, 1911	Icicle canal	do	Near intake	1.6
Sept. 7, 1912	do	do	do	5.9
Sept. 8, 1913	do	do	do	7.7
Sept. 23, 1914	do	do	Opposite gage on Icicle Creek	7.6
Sept. 25, 1914	South branch of Icicle canal.	do	Above Peshastin siphon	3.8
June 9, 1911	Snow Creek	do	Mouth	58
July 29, 1911	do	do	do	30
Sept. 23, 1911	do	do	do	21
July 27, 1911	Cascade Orchards canal.	do	Opposite gage on Icicle Creek	9.4
Sept. 18, 1911	do	do	do	2.0
Sept. 7, 1912	do	do	do	6.8
Sept. 8, 1913	do	do	do	2.0
Sept. 23, 1914	do	do	At intake	7.3
June 14, 1904	Peshastin Creek	Wenatchee River	Mouth	521
Sept. 25, 1914	do	do	Above diversions	29.7
Sept. 21, 1911	Negro Creek	Peshastin Creek	Mouth	4.1
Sept. 22, 1911	Ingalls Creek	do	Below Cascade Creek	21.1
July 31, 1911	do	do	Mouth	42.9
Sept. 22, 1911	do	do	do	30.9
Sept. 21, 1911	Beecher ditch	do		6.1
Sept. 25, 1914	do	do	Near Icicle canal siphon, a mile above mouth of Peshastin Creek.	.4
Do	Union ditch	do	do	.2
Do	Peshastin ditch	do	do	8.1
Do	Otis ditch	do	do	2.3
Do	Gibbs ditch	do	do	1.8
June 15, 1904	Wenatchee Irrigation District canal.	Wenatchee River	Above power plant	60
June 12, 1909	do	do	do	92
July 26, 1904	do	do	Below power plant	42
June 12, 1909	do	do	do	26.7
Sept. 25, 1911	Jones & Shotwell ditch.	do	Cashmere	6.2
Sept. 10, 1913	do	do	do	11.0
Apr. 13, 1907	Mission Creek	do	Mouth	194
Apr. 6, 1910	do	do	do	113
May 20, 1910	do	do	do	[a] 75
Nov. 26, 1910	do	do	do	[a] 15

Entiat basin.

Sept. 26, 1912	Entiat River	Columbia River	3 miles above Stormy Creek	86
Do	Mad River	Entiat River	Mouth	21.0
Sept. 26, 1911	Entiat Irrigation canal.	do	Opposite power plant	5.3
Sept. 23, 1913	do	do	do	6.4

[a] Estimated.

Summary of estimated natural discharge, by climatic years, for Wenatchee and Entiat rivers and tributaries.

Stream and location.	Year ending Sept. 30.	Minimum calendar month.		Mean discharge for year.	Discharge per square mile.		Run-off.	
		Discharge.	Month.		Minimum calendar month.	Mean for year.	Acre-feet.	Inches.
		Sec.-ft.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		
Wenatchee River near Leavenworth.	1910	620	September.	2,990	1.05	5.06	2,170,000	68.78
Do.	1911	591	February.	2,170	1.00	3.67	1,570,000	49.91
Do.	1912	400	October.	2,070	.677	3.50	1,500,000	47.60
Do.	1913	483	....do.	2,500	.817	4.23	1,810,000	57.37
Do.	1914	666	February.	2,090	1.13	3.54	1,520,000	48.05
Do.	1915	402	September.	1,360	.680	2.30	987,000	31.31
Do.	1916	547	January.	2,810	.928	4.75	2,040,000	64.83
Do.	1917	408	December.	2,160	.690	3.65	1,560,000	49.52
Do.	1918	517	October.	2,500	.875	4.23	1,810,000	57.43
Mean.		519		2,290	.872	3.88	1,660,000	52.76
Wenatchee River at Cashmere and Dryden.	1905	885	October.	3,240	.691	2.53	2,350,000	34.39
Do.	1906	965	December.	2,870	.754	2.24	2,080,000	30.38
Do.	1907	1,040	January.	4,300	.812	3.36	3,110,000	45.58
Do.	1908	1,050	September.	3,870	.820	3.02	2,810,000	41.21
Do.	1909	770	February.	3,180	.602	2.48	2,310,000	33.77
Do.	1910	968	September.	4,470	.807	3.72	3,230,000	50.51
Do.	1911	900	February.	3,180	.750	2.65	2,300,000	35.99
Do.	1912	709	October.	2,990	.591	2.49	2,170,000	33.96
Do.	1913	755	....do.	3,760	.629	3.13	2,730,000	42.68
Do.	1914	1,030	September.	3,190	.858	2.66	2,310,000	36.07
Do.	1915	689	....do.	2,030	.574	1.69	1,470,000	22.95
Do.	1916	803	January.	4,520	.669	3.77	3,280,000	51.25
Do.	1917	690	December.	3,230	.575	2.69	2,340,000	36.60
Mean.		857		3,440	.696	2.79	2,490,000	38.99
White River near Chiwaukum.	1911	317	September.		2.11			
Do.	1912	150	October.	701	1.00	4.67	509,000	63.60
Do.	1914			671		4.47	486,000	60.74
Nason Creek near Nason.	1911	72.7	August.		.817			
Chiwawa River near Leavenworth.	1911	231	September.		1.28			
Do.	1912	139	October.	552	.768	3.05	401,000	41.52
Do.	1913	140	{....do. / January.}	676	.773	3.73	490,000	50.72
Do.	1914	164	February.	604	.906	3.34	440,000	45.67
Mean.		168		611	.932	3.37	444,000	45.97
Chiwaukum Creek near Chiwaukum.	1911	34.4	September.		.694			
Icicle Creek near Leavenworth.	1911	217	....do.		1.03			
Do.	1912	111	October.	588	.526	2.79	427,000	37.92
Do.	1913	144	....do.	736	.682	3.49	533,000	47.34
Do.	1914	188	September.	616	.891	2.92	447,000	39.68
Mean.		165		647	.782	3.07	469,000	41.65
Peshastin Creek near Leavenworth.	1912	24.0	October.	139	.238	1.38	101,000	18.72
Entiat River at Entiat	1911	112	{January. / February.}	478	.267	1.14	345,000	15.47
Do.	1912	116	February.	463	.277	1.11	336,000	15.07
Do.	1913	108	January.	576	.258	1.37	417,000	18.66
Do.	1914	136	February.	520	.325	1.24	376,000	16.84
Do.	1915	110	September.	344	.263	.821	249,000	11.15
Do.	1916	91.8	January.	811	.219	1.94	589,000	26.35
Do.	1917	105	March.	511	.251	1.22	371,000	16.57
Do.	1918	121	November.	494	.289	1.18	358,000	16.02
Mean.		112		525	.269	1.25	380,000	17.02

IRRIGATION.

PRESENT DEVELOPMENT.

GRAVITY SYSTEMS.

During the irrigation season of 1918 water distributed through the gravity systems diverting it from Wenatchee River or tributaries served about 20,500 acres of land. Nearly 4,000 acres of the area irrigated lies on the east side of Columbia River. Some features of the systems as reported by P. S. Darlington, district horticultural inspector, Wenatchee, Wash., are shown in the following table:

Gravity irrigation systems in the Wenatchee basin.

System.	Diverting from—	Elevation at intake.	Length of main canal.	Area served in 1918.
		Feet.	*Miles.*	*Acres.*
Wenatchee Reclamation District	Wenatchee River	967	40	11,200
Jones & Shotwell ditch	do	805	7	690
Pioneer Water Users' Association	do	680	8	1,000
Wenatchee Park Land & Irrigation Co.	Chiwawa River	a 2,000	15	150
Icicle Canal Co.	Icicle Creek	1,396	42	2,380
Cascade Orchards Canal Co.	do	1,171		197
Snow Creek ditch	Snow Creek			50
Small ditches	Chumstick and Eagle creeks			690
Tandy or Beecher ditch	Peshastin Creek	a 1,225	6	602
Union ditch	do	a 1,195	2	104
Peshastin ditch	do	a 1,155	12	1,890
Pioneer ditch	do	a 1,155	4	328
Gibbs ditch	do	a 1,125	4	532
Otis, Stewart, Boston, and Gray ditches	do			116
Small ditches	Mission Creek			565
				b 20,494

a Estimated; accuracy uncertain.
b This total includes 2,130 acres served by water pumped from gravity systems

The largest gravity system in the Wenatchee basin is operated by the Wenatchee Reclamation District. The original conduit, formerly called the Wenatchee high line, was constructed in 1902; and water was first delivered in 1903. This conduit, which was extended in 1907 to serve land on the east side of Columbia River, was afterwards enlarged and improved. Water is diverted (Pl. VI, *A*) by low timber-crib dams built across two channels of Wenatchee River and is carried by a canal on the left side of the valley for 1.1 miles to the Dryden power plant (p. 71), where a part of the water is used and the remainder is delivered for irrigation. Below the power plant the water is carried by flume, tunnel, canal, and pipe lines to a point on the left side of the valley near the mouth of Wenatchee River, where the conduit branches. The smaller branch delivers water to land on the left side of the river; and the larger branch crosses the river, serves land near Wenatchee, and extends across Columbia River to irrigate land in Douglas County. The main conduits consist of 1.6 miles of tunnel, 2.6 miles of flume, 5.3 miles of pipe line, 7.7 miles of concrete lined canal, and the remainder unlined canal.

One of the oldest gravity systems in the valley is operated by the Pioneer Water Users' Association. The main conduit, commonly known as the Gunn ditch, was constructed in 1896 by the Wenatchee Water Power Co. It diverts water from the left side of Wenatchee River nearly opposite the town of Monitor and serves land on the north side of the river between the intake and Columbia River. A branch that crosses Wenatchee River near its mouth furnishes water to land near Wenatchee. The main conduit is a canal which is unlined except for 2,000 feet of pipe line and 205 feet of flume.

The Icicle Canal Co. began construction in 1910 and delivered water on the north side of Wenatchee River in July, 1911, and on the south side in July, 1912. The water is diverted from Icicle Creek and is carried about 7 miles by flume along the right side of the valley to a point opposite Leavenworth, where the conduit branches. One branch crosses Wenatchee River on a bridge about a mile below Leavenworth, and the other branch extends down the right side of the Wenatchee Valley. The main conduit consists of about 4 miles of pipe line, 11 miles of flume, and 27 miles of canal.

The Peshastin ditch is the largest diversion from Peshastin Creek. It was constructed in 1898, or possibly earlier, to irrigate land near the mouth of Peshastin Creek and along the south side of Wenatchee River between Dryden and Cashmere. Except for about 1,000 feet of flume the main conduit consists of unlined canal.

PUMPING SYSTEMS.

Pumping systems in the Wenatchee Valley and along Columbia River from Chelan to Wenatchee have been operated successfully for several years. Nearly 4,700 acres was irrigated in 1918 by about 60 pumping plants. The areas served by different types of pumping plants, as reported by P. S. Darlington, district horticultural inspector, Wenatchee, Wash., are as follows:

Areas in Wenatchee Valley and in a part of the adjoining Columbia Valley irrigated by pumping.

Type of plant.	Area irrigated in 1918 (acres).
Electric	3,762
Internal combustion	814
Steam	85
Hydraulic ram and water wheel	30
	4,691

The water for 2,265 acres of the total area irrigated was furnished from Columbia River, that for 2,130 acres was pumped from gravity systems, and that for the remaining 296 acres was pumped directly from Wenatchee River.

PROSPECTIVE DEVELOPMENT.

IRRIGABLE AREA.

The present irrigation systems that divert water from Wenatchee River and its tributaries will probably be extended to serve about 8,000 acres more than was irrigated in 1918. In order that proper allowance for irrigating this additional area may be made in the power analyses, it has been estimated that Chiwawa River will supply water for irrigating an additional area of 2,900 acres, Icicle Creek for 2,200 acres, Chumstick Creek for 400 acres, and Wenatchee River proper for 2,500 acres. Part of this additional area will be irrigated by pumping from the present gravity systems.

The systems in Entiat Valley will probably not be enlarged greatly.

QUINCY PROJECT.

GENERAL FEATURES.[5]

The irrigable area in the proposed Quincy project embraces a plateau lying slightly southeast of the geographic center of the State. This area is roughly rectangular and is about 36 miles long and 30 miles wide; its longer axis extends east and west. The Great Northern Railway parallels the west half of its northern boundary, and the Chicago, Milwaukee & St. Paul Railway, which extends along Crab Creek, forms the southern boundary. Columbia River limits it on the west, and the township line between Rs. 28 and 29 forms its approximate eastern boundary. This project covers about 1,080 square miles, of which at least 450,000 acres is readily irrigable if a suitable water supply is provided.

The tract to be irrigated is divided into two parts by the Frenchman Hills, a narrow ridge that ranges in elevation from 1,500 to 1,700 feet and that extends east and west. About two-thirds of this tract lies north of the Frenchman Hills and consists of a rolling plateau free from marked surface irregularities. It slopes gradually to the east and south and includes elevations ranging from 1,000 to 1,400 feet. The remaining third slopes rather steeply but regularly southward from the Frenchman Hills to the low basaltic bluffs directly north of the Crab Creek valley.

The soil[6] is the basaltic loam that is characteristic of central Washington. Much of it is similar to the soil in the Sunnyside project, in the Yakima Valley, and if it is properly irrigated it will be well suited to diversified farming.

The climate is favorable for irrigation. The mean annual temperature is higher, the period between killing frosts longer, and the

[5] Abstracted in part from Landes, Henry, and Jacobs, Joseph, Preliminary report on the Quincy Valley irrigation project: Washington Geol. Survey Bull. 14, 1912.

[6] Mangum, A. W., Van Duyne, Cornelius, and Westover, H. L., Soil survey of the Quincy area, Wash.: U. S. Dept. Agr. Bur. Soils Field Operations, 1911, 64 pp., 1913.

precipitation in July, August, and September slightly greater than on the Sunnyside project, in the Yakima Valley, where irrigation has proved very successful.

The sources of water supply considered for irrigating the Quincy project are Clark Fork, Spokane River, Columbia River, Moses Lake, Crab Creek, ground and artesian water supplies, and Wenatchee River. Considerable evidence has recently been obtained to indicate the feasibility of irrigating, by diversion from Clark Fork, 2,000,000 acres of land in the arid region of east-central Washington, which would include the area here described. The immensity of this undertaking and its great initial cost have heretofore discouraged those who have made investigation having this end in view, but it now seems that an enormous area can be reclaimed at a reasonable cost if the proper Federal and State agencies will finance and execute the plan. Until recently, however, it has seemed that the Quincy Valley tract could be most economically irrigated by diversion from Wenatchee River.

Preliminary plans call for a diversion on the left side of Wenatchee River at an elevation of about 1,600 feet at a point 1½ miles above Fall Creek, the water to be carried through a tunnel about 3 miles long into Freund Creek canyon, thence along the Chumstick Valley to the north side of the Wenatchee, and thence parallel to it for about 31 miles to Columbia River. The proposed conduit will cross the Columbia Valley about 3 miles north of Wenatchee and extend southeastward along the Columbia for 21 miles to Moses Coulee and thence eastward for 12 miles to the end of the main canal at an elevation of 1,340 feet, about a mile north of the town of Quincy. The main canal will be about 65 miles long, will have a capacity of about 5,000 second-feet, and will require lining throughout, except for a stretch of 5 or 6 miles, and as it will traverse a mountainous and hilly country it will involve considerable rock work and heavy construction and will require siphons across seven wide valleys. The Columbia River crossing, nearly 2 miles long, will be the most difficult piece of work. A bridge for supporting the conduit across the Columbia may not be practical, because clearance is necessary for navigation and because the weight of conduit and water would represent a load at least five times that imposed upon the heaviest modern single-track railway bridge. The preliminary plan proposes the use of a pressure tunnel similar to the aqueduct under Hudson River, N. Y. The tunnel will be about 22 feet in diameter and will operate under a maximum head of about 1,000 feet.

ADVERSE WATER RIGHTS.

Rights to use water from Wenatchee River for operating power plants (pp. 70–72) have been acquired by the Great Northern Railway Co., Tumwater Light & Power Co., and Wenatchee Valley Gas &

Electric Co. The Great Northern Railway Co. claims a right to 525 second-feet[7] of water and has sufficient machinery capacity to use that amount continuously. If a flow of 525 second-feet is maintained at the diversion works of the Great Northern plant the other two plants can operate continuously at full capacity and yet all the demands of irrigation will be met.

About 20,800 acres of land was irrigated from Wenatchee River and its tributaries during the season of 1918. It is estimated that during the season of 1915, when the flow of the river was very low, enough water entered the river system below the proposed diversion dam of the Quincy project to irrigate 24,000 acres.

The entire water supply above the point of the proposed diversion may therefore be used for the Quincy project without affecting present irrigation rights. However, diversion of the total flow for the Quincy project would render the Great Northern plant useless and would damage to some extent the rights of the Wenatchee Valley Gas & Electric Co. at the Dryden power plant.

WATER REQUIREMENTS.

The amount of water required for successful irrigation varies considerably with climate, texture, and composition of soil, subsurface drainage, and kind of crops raised. The climate and the characteristics of soil of the irrigable areas in the proposed Quincy project are similar to those in the Sunnyside project in the Yakima Valley. Statistics[8] compiled by the United States Reclamation Service have been considered in choosing the probable water requirements for the Quincy project shown in the following table:

Water requirements for the Sunnyside and Quincy projects.

	Sunnyside, 1912–1918.		Quincy, as chosen.	
	Depth in feet on area irrigated.	Per cent.	Depth in feet on area irrigated.	Per cent.
Total, diversion for direct use	4.71		4.20	
Delivery to farms:				
April	.27	8.7	0.24	8
May	.54	17.5	.51	17
June	.54	17.5	.55	18
July	.59	19.1	.58	19
August	.55	17.8	.55	18
September	.36	11.6	.36	12
October	.24	7.8	.24	8
	3.09	100.0	3.03	100

NOTE.—The area irrigated in the Sunnyside project ranged from 62,800 acres in 1912 to 84,650 acres in 1918.

[7] The minimum flow (see p. 54) at the intake of the Great Northern plant has been estimated at 451 second-feet.

[8] Moritz, E. A., Tables showing quantities of water used on projects of the United States Reclamation Service: Reclamation Rec., vol. 9, p. 538, 1918.

The Sunnyside canal is unlined and is longer than the proposed main canal of the Quincy project, which will require lining for about 90 per cent of its length. The losses in delivery to the proposed Quincy project are estimated as follows: Waste in regulation and seepage in the main canal, 13 per cent; seepage in the distribution system, 17 per cent. A total diversion of 4.2 feet reduced by these losses would yield 3.03 feet for use on the farms. Greater economy in the delivery, distribution, and application of water will be effected in all the projects as the value of water increases. The data here chosen to determine the limits of the project in acres seem to give reasonable results. If experience proves that greater economy is possible, a larger tract may be watered.

WENATCHEE LAKE RESERVOIR.

PROPOSED DAM.

Wenatchee Lake (Pl. II; Pl. VII, *D*, *E*), which has an area of 2,830 acres, lies at an elevation of 1,870 feet and receives the drainage of 277 square miles of mountainous country. Chiwawa River and Nason Creek, which have an aggregate drainage area of 290 square miles, enter Wenatchee River a short distance below the lake and can be diverted to a large reservoir.

Several sites are available for a dam to create a reservoir embracing Wenatchee Lake. The site chosen by preliminary investigation for the Quincy project is 3.1 miles below the lake, in secs. 26 and 35, T. 27 N., R. 17 E., where the elevation of the stream bed is 1,854 feet. An earth-fill dam, 20 feet wide at the crest, with upstream slope of 3 to 1 and downstream slope of 2 to 1, is contemplated. Parallel concrete cut-off walls supported by bedrock will extend 5 feet into the body of the dam. The slopes will be protected by riprap 18 inches thick. The length of the dam on the crest will be 4,446 feet, and the volume will be 4,600,000 cubic yards. The proposed spillway will extend around the south end of the dam, will be lined with concrete, and will have a capacity of 25,000 second-feet.

As the dam site is above Chiwawa River, it is proposed to divert the flow of that stream into the reservoir by a canal less than 2 miles long, having a capacity of 2,000 second-feet.

CAPACITY.

The capacity of the proposed Wenatchee Lake reservoir was determined by measuring areas within 10-foot contours on Plate VII, *D*, *E*, and computing the volume between contours by the method of average end areas. One engineer measured each area three times with a planimeter, using the scale indicated on Plate VII, *D*, *E*, for deriving coefficients applicable to planimeter readings. Another engineer remeasured the areas within the contours of 1,980 and 1,990 feet with a different setting on planimeter arm. Then both engineers, working independently, computed and checked all computations of area and found that the respective areas inclosed in the contours of 1,980 and 1,990 feet agreed within less than three-fourths of 1 per cent. By using different settings on the planimeter arm both engineers determined and checked the area within the 1,985-foot contour as traversed for the Quincy Valley Irrigation District. The area measured on traverse checked the average area between the contours of 1,980 and 1,990 feet within one-half of 1 per cent. The areas and capacities determined are shown in the following table:

Areas and capacities of Wenatchee Lake reservoir.

Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
1,870	2,830	0	1,960	12,040	695,000
1,880	3,980	34,000	1,970	12,580	818,000
1,890	5,330	80,600	1,980	13,210	947,000
1,900	6,380	139,000	1,985	[a] 13,490	1,014,000
1,910	7,100	207,000	1,990	13,680	1,082,000
1,920	7,950	282,000	1,995	13,910	1,151,000
1,930	9,080	367,000	2,000	14,140	1,221,000
1,940	10,700	466,000	2,005	14,370	1,292,000
1,950	11,530	577,000	2,010	14,600	1,364,000

[a] Measured from traverse surveyed by engineers of the Quincy Valley Irrigation District.

RUN-OFF AVAILABLE FOR STORAGE.

The gaging station on Wenatchee River near Leavenworth (p. 19) was established in November, 1910, and has been maintained since that date in cooperation with the Quincy Valley Irrigation District. Records of daily discharge have been obtained for more than eight years to determine the run-off available for the proposed Quincy project.

The run-off available for storage is less than that recorded at the gaging station on account of difference in drainage area, evaporation, loss by Chiwawa diversion, and loss by seepage through the reservoir dam.

Difference in drainage area.—The area supplying water to the proposed reservoir, including the area of the Chiwawa basin above the point of diversion into the reservoir, is 29.9 square miles less than at the gaging station. A comparison of the run-off at the gaging station on Wenachee River near Leavenworth increased by the run-off from Chiwaukum, Icicle, and Peshastin creeks with the recorded discharge of Wenatchee River at Dryden indicates the yield of the intervening low-lying area that has characteristics similar to the area of 29.9 square miles just mentioned. It is reasonable to assume, however, that the yield of the 29.9 square miles will be slightly larger, because it lies at a higher elevation and doubtless receives greater precipitation.

Evaporation.—The loss by evaporation from Wenatchee Lake at its present area of 2,830 acres need not be considered because the records made at the gaging station on Wenatchee River near Leavenworth indicate the run-off after that loss has been deducted. The reservoir will have sufficient capacity to regulate the run-off for a period of years, considering the excess water contributed during the years of high yield for use during the years of low yield. Consequently, the area of the reservoir will seldom be as small as the present area of the lake, so that evaporation from the increased area should be deducted from the run-off recorded at the gaging station.

As records of evaporation for Wenatchee Lake are lacking, evaporation has been estimated from records obtained on Kachess Lake by the United States Reclamation Service. Wenatchee and Kachess lakes, which are on the eastern slope of the Cascade Range at about the same elevation, are only 45 miles apart and have similar climatic charateristics.

The records of evaporation on Kachess Lake are fragmentary but extend over part of each year for 1906–1908 and 1910–11. The evaporation pan was 3 feet square and 1½ feet deep. It was partly submerged in the lake some distance from the shore and was protected from wave action by two concentric log booms chained together. Average evaporation, by months, as computed from the observations made, is shown in the following table:

Average evaporation, in feet, observed at Kachess Lake.

Month.	Observed evaporation.	Month.	Observed evaporation.	Month.	Observed evaporation.
October	0.15	February	[a] 0.03	June	0.20
November	.07	March	.04	July	.37
December	.05	April	.07	August	.36
January	[a] .03	May	.09	September	.21
Total for average year					1.67

[a] No evaporation observations during January and February; values assumed arbitrarily.

NOTE.—Average for March, November, and December computed from records for those months during only two years of period.

It seems to be well established that the evaporation determined by observations taken as just described is larger than the actual evaporation from large bodies of water, because evaporation from those bodies is diminished by a "vapor blanket."[9] As Wenatchee Lake lies 350 feet lower than Kachess Lake the average temperature must be slightly higher and the loss by evaporation slightly greater. Negative corrections on account of "vapor blanket" are doubtless greater

[9] Duryea, Edwin, and Haehl, H. L., A study of the depth of annual evaporation from Lake Conchos, Mexico: Am. Soc. Civ. Eng. Trans., vol. 80, p. 1831, 1916. Sleight, R. B., Evaporation from the surfaces of water and river-bed materials: Jour. Agr. Research, vol. 10, p. 237, 1917.

than positive corrections on account of difference in elevation and temperature, and the figures showing the observed evaporation at Kachess Lake have therefore been used for computing loss by evaporation from the increased area in the proposed reservoir, because it is advisable to make allowance for a slightly greater loss than will be sustained.

The increased area in the proposed reservoir was determined from a preliminary mass diagram similar to that shown on Plate III and from the table showing the area and capacity of Wenatchee Lake reservoir on page 47.

Loss by Chiwawa diversion.—During normal years very little water will pass the diversion dam if the diversion conduit is constructed with a capacity of 2,000 second-feet. During years of high water considerable water will pass the diversion dam in May and June, but the quantity will be small as compared with the total flow of Chiwawa River, and it will be available at the headworks of the project for supplying the demand for irrigation. The delivery from the reservoir could be so regulated that there would be no loss of water.

Loss by seepage at reservoir dam.—Some loss by seepage through the proposed earth-fill dam must be expected, but it may be assumed that the loss will not be more than 1 per cent of the flow into the reservoir, because an earth-fill dam would not be safe if more than 20 second-feet passed through it. During the irrigation season, which includes seven months of each year, the loss through the dam will be available for use at the project headworks. The loss during the remainder of the year will be too small to be considered, when other larger unknown or incomputable losses influence determinations.

The run-off available for storage, computed from the discharge at the gaging station on Wenatchee River near Leavenworth after taking into account the negative corrections for difference in drainage area and evaporation is shown in the following table:

Estimated run-off, in units of 1,000 acre-feet, available for storage in Wenatchee Lake reservoir, November, 1909, to October, 1918.

Year.	January.			February.			March.			April.		
	1-10	11-20	21-31	1-10	11-20	21-28 *a*	1-10	11-20	21-31	1-10	11-20	21-30
1910	19.4	18.2	29.3	19.6	18.2	13.5	30.9	53.8	91.3	50.2	55.7	161.0
1911	19.5	16.5	17.0	13.1	11.2	7.7	9.0	11.8	35.1	41.0	35.4	69.5
1912	10.7	15.7	17.8	15.2	16.0	13.1	11.1	10.2	17.0	36.2	47.1	49.8
1913	13.6	11.6	12.3	11.4	17.3	15.4	15.0	16.6	16.1	14.2	45.1	62.5
1914	24.3	26.4	19.4	13.9	11.7	10.6	16.2	27.2	46.7	39.5	85.4	72.7
1915	11.5	9.5	8.4	8.7	8.0	6.5	8.2	15.8	36.7	79.9	71.1	59.6
1916	9.9	9.9	13.3	11.7	15.0	15.1	18.0	42.7	38.8	45.2	65.2	68.4
1917	8.6	7.8	9.3	11.1	12.3	9.3	9.3	8.0	10.1	9.7	15.0	24.3
1918	158.0	47.5	36.3	27.6	25.7	15.2	16.0	14.6	26.9	34.2	46.9	84.8

a Feb. 21 to 29 in leap years, 1912 and 1916.

Estimated run-off, in units of 1,000 acre-feet, available for storage in Wenatchee Lake reservoir, November, 1909, to October, 1918—Continued.

Year.	May.			June.			July.			August.		
	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31
1910	154.0	169.0	194.0	117.0	113.0	72.7	83.5	71.6	49.2	32.4	25.4	17.3
1911	86.5	70.5	96.2	125.0	155.0	83.6	63.1	58.8	39.6	23.8	15.7	14.3
1912	88.2	161.0	161.0	134.0	128.0	130.0	63.6	54.0	37.1	23.4	20.0	17.7
1913	72.6	105.0	185.0	236.0	173.0	154.0	126.0	91.6	100.0	49.4	27.2	23.1
1914	100.0	131.0	127.0	94.9	101.0	69.1	76.5	54.3	33.5	22.3	17.9	15.4
1915	55.9	48.5	50.4	44.8	34.1	25.3	27.6	14.8	17.8	15.3	13.9	14.7
1916	145.0	97.1	131.0	137.0	235.0	179.0	154.0	143.0	93.2	66.4	49.3	39.2
1917	46.1	109 0	160.0	150.0	166.0	156.0	160.0	136.0	76.4	43.9	33.4	25.4
1918	115.0	96.6	77.5	120.0	160.0	114.0	68.7	59.9	36.1	24.2	18.4	17.4

Year.	September.			October.			November.			December.		
	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31
1909	......	......	......	......	......	......	39.4	33.1	153.0	94.5	42.9	27.7
1910	12.6	9.6	11.7	42.6	38.7	39.6	42.2	47.2	87.7	32.7	21.0	21.7
1911	15.1	16.4	10.8	7.9	7.6	7.2	8.5	25.5	42.7	21.4	17.2	15.2
1912	13.7	10.7	8.7	8.3	9.1	10.5	10.4	13.8	18.2	16.6	12.9	12.4
1913	29.7	19.4	15.3	12.2	31.8	30.6	19.5	26.6	29.3	21.2	15.4	13.6
1914	11.0	12.0	16.5	12.8	19.1	24.6	56.1	39.4	36.2	25.7	14.1	14.2
1915	9.3	6.5	6.5	8.3	9.2	19.7	28.0	15.0	12.3	11.4	10.6	13.6
1916	26.4	16.1	13.2	9.6	8.9	9.6	12.4	11.0	8.8	8.4	7.9	7.9
1917	15.4	14.5	12.2	12.6	9.0	8.5	12.1	10.5	16.9	11.3	64.3	147.0
1918	13.3	12.2	10.0	12.1	20.4	23.2	......	......	......	......	......	......

NOTE.—Flow Nov. 1, 1909, to Nov. 26, 1910, at gaging station on Wenatchee River near Leavenworth, Wash., estimated by comparison with records at gaging station on Wenatchee River at Cashmere, Wash. Total run-off Nov. 1, 1909, to Oct. 31, 1915, equals 9,319,400 acre-feet, which is equivalent to a continuous flow of 2,145 second-feet.

ANALYSIS OF THE MASS DIAGRAM.

A preliminary consideration of the run-off available for storage in Wenatchee Lake reservoir indicated that the average flow from November 1, 1909, to October 31, 1915 (2,145 second-feet), might be chosen as an indication of the irrigation demand for the nine-year period ending October 31, 1918. A smaller average demand would result in excessive accumulation of stored water after the extremely low year of 1915. A larger average demand would necessitate the assumption that the reservoir contained some hold-over stored water November 1, 1909, when the average flow for the year preceding that date was about 2,100 second-feet. A summation of the run-off presented in the foregoing table, reduced by the cumulative run-off equivalent to a continuous flow of 2,145 second-feet, is shown by a mass diagram in Plate III. Two alternative plans of diversion to the Quincy project (plan A and plan B) are also shown on the mass diagram.

Plan A represents the quantity of water required for use for both power and irrigation. It provides for a continuous flow of 525 second-feet past the project diversion works to satisfy the prior power right claimed by the Great Northern Railway Co. and for

MASS DIAGRAM SHOWING WATER SUPPLY AVAILABLE AND STORAGE REQUIREMENTS FOR WENATCHEE LAKE RESERVOIR AND ALTERNATIVE PLANS FOR QUINCY PROJECT the diversion of the remainder for the Quincy project. The annual run-off available from the reservoir (equivalent to a continuous flow of 2,145 second-feet) increased by the run-off during a normal year from 75.8 square miles of drainage area between the reservoir and the project diversion works gives the total quantity of water annually available for the combined use. This total decreased by a run-off equivalent to a continuous flow of 525 second-feet represents the remaining flow that may be annually used for the Quincy project. This remainder, if segregated into monthly diversion requirements in accordance with the percentages given in the table on page 45, forms the basis for computing the demand made on the reservoir, as shown in the following table:

Computation of requirement for plan A.

[Acre-feet.]

Month.	1 Water available for Quincy project.	2 Run-off equivalent to continuous flow of 525 second-feet.	3 Total water supply (1+2 or 4+5).	4 Estimated inflow between reservoir and project diversion works.	5 Requirement from reservoir by plan A (3−4).
November	(a)	31,200	31,200	3,900	27,300
December	(a)	32,300	32,300	3,000	29,300
January	(a)	32,300	32,300	3,300	29,000
February	(a)	29,200	29,200	2,700	26,500
March	(a)	32,300	32,300	6,600	25,700
April	105,600	31,200	136,800	26,600	110,200
May	224,400	32,300	256,700	42,300	214,400
June	237,700	31,200	268,900	32,700	236,200
July	250,900	32,300	283,200	14,400	268,800
August	237,700	32,300	270,000	5,100	264,900
September	158,400	31,200	189,600	3,500	186,100
October	105,600	32,300	137,900	3,100	134,800
	1,320,300	380,100	1,700,400	147,200	[b] 1,553,200

[a] No requirement. [b] Equivalent to a continuous flow of 2,145 second-feet for one year.

Plan A as plotted on the mass diagram represents a summation of the figures in column 5 of the above table decreased by a cumulative run-off equivalent to a continuous flow of 2,145 second-feet.

Plan B represents the requirement from the reservoir when all water available is diverted for the Quincy project. The annual run-off available from the reservoir (equivalent to a continuous flow of 2,145 second-feet) increased by run-off during the irrigation season in a normal year from 75.8 square miles of drainage area between reservoir and project diversion works gives the total water that may be utilized by the project. The total water thus available, segregated into monthly diversion requirements in accordance with percentages given in the table on page 45, forms the basis for computing the demand made on the reservoir, as shown in the following table:

Computation of requirement for plan B.

[Acre-feet.]

Month.	1 Water available for Quincy project.	2 Estimated inflow between reservoir and project works.	3 Require-ment from reservoir by Plan B (1–2).	Month.	1 Water available for Quincy project.	2 Estimated inflow between reservoir and project works.	3 Require-ment from reservoir by Plan B (1–2).
November	(a)	(b)	0	June	302,500	32,700	269,800
December	(a)	(b)	0	July	319,400	14,400	305,000
January	(a)	(b)	0	August	302,500	5,100	297,400
February	(a)	(b)	0	September	201,700	3,500	198,200
March	(a)	(b)	0	October	134,500	3,100	131,400
April	134,500	26,600	107,900				
May	285,800	42,300	243,500		1,680,900	127,700	[c] 1,553,200

[a] No requirement.
[b] Not required for Quincy project.
[c] Equivalent to a continuous flow of 2,145 second-feet for one year.

Plan B, as shown on the mass diagram, represents a summation of the figures in column 3 of the above table decreased by cumulative run-off equivalent to a continuous flow of 2,145 second-feet.

During the critical period, November 1, 1909, to October 31, 1915, chosen for utilization of the entire run-off available at the reservoir, the date of maximum storage requirement was about June 20, 1914. The maximum requirements of 1,165,000 acre-feet for plan A and 1,254,000 acre-feet for plan B are equivalent to the capacity of the reservoir when the water is at a height of 1,996 and 2,002 feet, respectively, or 142 and 148 feet, respectively, above the bed of the river channel at the proposed dam site.

After October 31, 1915, the storage requirements increased until about June 30, 1918, when they exceeded those just described by an amount equivalent to a reservoir draft of about 2 feet. The requirement on June 30, 1918, was 1,190,000 acre-feet for plan A and 1,260,000 acre-feet for plan B. It would seem wise to provide sufficient storage capacity to meet these requirements rather than to waste water that might be needed during years of extremely low water. The hold-over storage at the end of the irrigation season of 1918, amounting to 644,000 acre-feet, is only 23,000 acre-feet more than that at the beginning of the year ending October 31, 1915, the lowest on record. It was exceeded by 72,000 acre-feet at the end of the irrigation season of 1913.

LIMITS OF AREA.

There is more good irrigable land in the Quincy project than can be irrigated by water from Wenatchee River, so that the size of the project is limited by the water supply available. Analyses of run-off for the two plans of diversion just described permit the determination of the number of acres that can be served.

If the prior power right of the Great Northern Railway Co. remains effective a continuous flow of 525 second-feet must pass the project diversion works. The remaining water annually available for diversion will be 1,320,300 acre-feet, as shown for plan A in the table on page 51. This volume of water will irrigate 314,400 acres with a diversion duty of 4.2 feet (p. 45).

The utilization of all the water available from Wenatchee River will permit an annual diversion of 1,680,900 acre-feet, as shown for plan B in the table on page 52, or sufficient water to irrigate 400,200 acres with a diversion duty of 4.2 feet.

It has been shown (p. 45) that the use of all the water available at the project diversion works would not affect present irrigation rights adversely. The difference in the size of the project with and without prior power rights effective is 85,800 acres. The feasibility of the larger project will depend upon the cost of acquiring adverse power rights and the additional expenditure necessary to serve this area.

The foregoing analyses make no allowance for irrigation in the upper Wenatchee and Chumstick valleys. Only about 150 acres was irrigated by diversion from Chiwawa River in 1918, but about 2,900 acres may be irrigated by an extension of the Wenatchee Park Land & Irrigation Co.'s system. Effective irrigation rights on Chiwawa River will reduce the size of the Quincy project by an area equivalent to that for which such rights are held.

WATER POWER.

POWER SITES.

SCOPE OF DISCUSSION.

Irrigation is a more important use of water than power, especially in a State so richly endowed with power resources as Washington. Therefore, the power available as shown in this report has been computed after ample allowance has been made for the present and future demands of irrigation. If the Quincy project is placed in operation, it will require most of the water available in the Wenatchee basin, so that the power resources of Wenatchee River have been considered with and without the project in operation.

METHOD OF ANALYSIS.

Units of development.—Before an analysis of the power available is undertaken each river system must be divided into parts, and certain stretches of the rivers and their tributaries have therefore been assumed to form logical units of development. In some places the limits of a unit are defined unmistakably by outstanding natural features; in others they can be determined only by systematic study and even then engineers working independently may differ as to details. The units selected for this report are based on general considerations of water supply, stream gradient, topography, and other physical features. Although other units may be as good or better, the units selected are well adapted to show the relative limits of good, bad, and indifferent power sites.

All the potential power in a given basin can not be made available, because the cost of developing some small isolated power sites is prohibitive, yet as sites that are not now available may become available within 50 or 100 years, it is extremely difficult, in a report of this kind, to discriminate between merely potential and economically practicable sources of power. The development units chosen in this report do not include the upper reaches of the river systems and some large tributaries, such as Nason and Mad creeks, because the power they might furnish is too remote in time of utilization to be considered.

Stream flow fluctuates so greatly that it is necessary to select a certain rate or rates of flow in order to compute the power that can be made available on any stream. The rate chosen for an individual project can be adjusted to the exact use to which the power will be put and can be determined within definite economic limits after detailed data showing the cost have been assembled. Rates of flow that will exactly fulfill the economic requirements for a number of diverse projects can not be selected by the same rule, but computation of power in accordance with the two rates to be described gives results indicating approximately the minimum and maximum power that can be made available for each unit of development.

Minimum flow.—As used in this report the term "minimum flow" means the average of the figures representing the flow for the calendar month of minimum mean flow during each five-year period or major fraction thereof. In order that the minimum flow of streams at different points in a given basin may be comparable the gaging station in that basin at which reliable records have been kept for the longest period has been selected as a base from which the minimum flow at other points has been determined. Thus the minimum flow of all streams in a given basin has been determined by data obtained during a long period at a base gaging station.

Regulated flow.—Regulated flow means the flow made available by the storage of part of the natural flow at certain specified reservoir sites. The storage capacity is assumed to be sufficient to insure a uniform and constant flow during the critical period. Such regulation is rare, but information showing the probable seasonal fluctuation in the demand for power is lacking. An analysis of the regulated flow has been made by means of diagrams indicating the cumulative natural run-off decreased by a cumulative run-off equivalent to the average flow during the critical period. These diagrams are referred to in this report as mass diagrams, although they really represent the difference in run-off between a mass diagram of natural run-off and another mass diagram representing a continuous and uniform run-off during the critical period. The flow with storage represents the maximum flow considered available for the development of power.

The fall or gross head in each development unit has been ascertained from river plans and profiles (Pls. VII, *A–E;* VIII; IX, *A*, *B*, at end of volume) or from topographic maps.

The continuous horsepower available in each unit has been estimated as 70 per cent of the theoretical power because of losses due to friction in diversion conduits, penstocks, and water wheels. These losses for a number of diverse projects can not be represented accurately in terms of an average coefficient, but the lack of sufficient information for fixing conduit losses precludes the use of other methods of computing the power obtainable on turbine shafts.

SITES IN WENATCHEE BASIN.

MINIMUM FLOW.

The gaging station on Wenatchee River at Cashmere and Dryden (p. 22), whose records extend over 13 years, has been considered the base gaging station for computing the minimum flow of streams in the Wenatchee basin. The minimum flow thus determined for each gaging station is shown in the following table:

Minimum flow, in second-feet, of streams in Wenatchee basin.

Stream and gaging station.	Minimum flow for one calendar month during years ending Sept. 30—			Minimum flow.
	1905 to 1909 (February, 1909).	1910 to 1914 (October, 1911).	1915 to 1918 (September, 1915).	
Wenatchee River at Cashmere and Dryden (base gaging station)	[a] 750	709	689	716
Wenatchee River near Leavenworth		400	402	411
Little Wenatchee River		67		[b] 68
White River		150		[b] 152
Chiwawa River		139		[b] 140
Chiwaukum Creek		20		[b] 20
Icicle Creek		111		[b] 112
Peshastin Creek		24		[b] 24

[a] This figure was determined by deducting from the flow below Mission Creek (770 sec.-ft.) the probable flow at Mission Creek (20 sec.-ft.) for February, 1909. Gaging station located below Mission Creek from 1905 to 1909 and above Mission Creek thereafter.

[b] Computed by comparing flow for October, 1911, with both flow for the same month and minimum flow at the base gaging station.

Minima for other points in the basin were computed by comparing miscellaneous measurements, differences in drainage areas, and known characteristics of basins with the minimum flow at the nearest gaging station.

In this report the use of water for irrigation has been considered more urgent than its use for power, and the minimum flow available for power has therefore been reduced by the amount required for irrigation. The preceding table indicates that two of the three minima at the base gaging station occurred during September or October. Thus the minimum flow is controlled largely by minima that occur in the irrigation season. The minimum flow for the development units, in which the uses for power and for irrigation conflict, has been reduced by two-thirds of the average demand for present and probable future irrigation during September and October.

RESERVOIRS AND STORAGE REGULATION.

Feasible sites.—The minimum flow of Wenatchee River and its tributaries is so low, as compared with the mean annual flow, that storage is essential in power development. Although exact information is lacking, a consideration of the river surveys (Pls. VII, *A–E;* VIII; IX, *A*, *B*, at end of volume), topographic maps, and data gathered by field reconnaissance indicates that storage, primarily for power development, is feasible at the six reservoir sites shown in the following table:

Reservoirs in Wenatchee basin.

Name.	Stream.	Height of water stored.	Capacity.	Flow realized in excess of minimum.
		Feet.	*Acre-feet.*	*Sec.-ft.*
Rainy Creek	Little Wenatchee River	60	11,900	81
Twin Lakes	North Fork of White River	95	37,000	110
Wenatchee Lake [a]	Wenatchee River	101	835,000	1,250
Chiwawa	Chiwawa River	115	318,000	404
Trout Creek	Icicle Creek	55	1,900	30
Eightmile	do	40	1,080	18
			1,204,880	1,893

[a] The use of Wenatchee Lake reservoir as a part of the proposed Quincy project is discussed on pages 46–52.

Wenatchee Lake, Chiwawa, and Twin Lakes reservoirs are large enough to regulate the entire flow of the tributary drainage area. The remainder of the reservoirs, though small, will be useful in supplementing the natural flow during critical periods of low water. Another small reservoir can be formed near the source of Snow Creek, a tributary of Icicle Creek, by constructing a dam across the outlet of Twin Lakes.[10] This project has been investigated by both power and irrigation interests, but in this report it has been considered more useful for irrigation than for power. A brief discussion of the possibilities at each reservoir site follows.

Rainy Creek reservoir.—A dam across Little Wenatchee River, about 0.6 mile below the mouth of Rainy Creek, would form a small reservoir having the areas and capacities shown in the following table:

[10] Should not be confused with Twin Lakes reservoir site, in the southeastern part of the White River basin mentioned in the preceding table.

Areas and capacities of Rainy Creek reservoir.

Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
2,090	10	0	2,130	260	6,110
2,100	85	480	2,140	290	8,860
2,110	170	1,760	2,150	310	11,900
2,120	220	3,710			

A rough estimate of the flow at the dam site, based on miscellaneous measurements, differences in drainage areas, and a comparison of records at the near-by gaging stations, indicates that the critical period extended from September, 1916, to March, 1917. The use of 11,900 acre-feet of stored water during that period would have produced a continuous flow of about 135 second-feet.

Twin Lakes reservoir.—There is a good reservoir site at Twin Lakes, in the southeastern part of the White River basin. The outlet of the lakes occupies a narrow rock canyon, which should afford a favorable dam site. The bottom of the canyon at the dam site is filled with a mass of broken rock into which the flow disappears at low water. Although the flow reappears a few feet below the dam site, bedrock may lie some distance beneath the stream bed.

The areas as measured on a topographic map and the capacities computed from them are shown in the following table:

Areas and capacities of Twin Lakes reservoir.

Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
2,808	300	0	2,900	470	35,500
2,850	380	14,300	2,950	560	61,300

The drainage area tributary to Twin Lakes reservoir (7.1 square miles) is so small that little storage would be needed to regulate the entire inflow. As a diversion from North Fork of White River into the reservoir by a conduit having a capacity of 300 second-feet is assumed to be feasible, the run-off available for storage has been estimated from miscellaneous measurements and from records at gaging stations near by.

Run-off, in units of 1,000 acre-feet, available for storage in Twin Lakes reservoir, 1911–1913.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1911	......	3.4	6.8	19.0	33.0	53.0	32.0	13.0	7.8	3.8	7.9	6.0
1912	5.3	5.2	5.0	17.0	53.0	56.0	30.0	13.0	6.4	4.0	4.4	4.8
1913	4.5	5.0	5.6	16.0	......	......	......	......	......	......	......	......

NOTE.—These figures should be used with caution, as they are estimated from meager information.

A mass diagram (fig. 2), derived from the run-off shown in the preceding table, indicates that a reservoir having a storage capacity of 37,000 acre-feet could have provided a continuous flow of 170 second-feet during the critical period between April, 1911, and March, 1913. The water in the reservoir would have reached an elevation of about 2,903 feet in August, 1912.

Although no satisfactory method of estimating the run-off after April, 1913, has been found, slightly more storage might have been

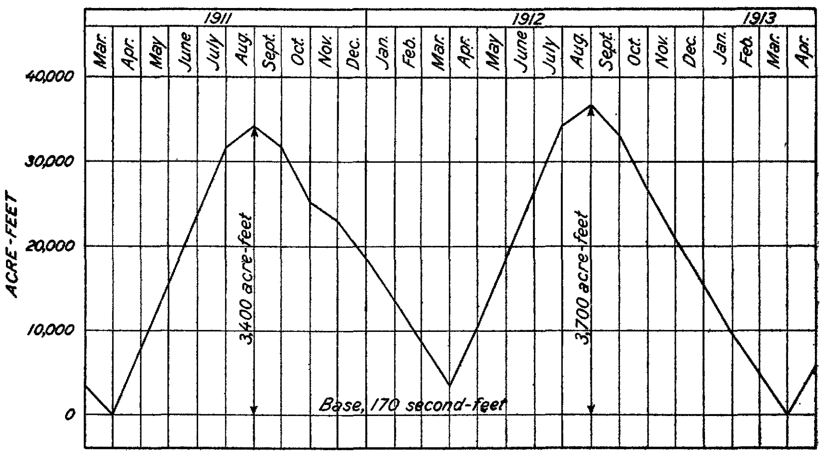


FIGURE 2.—Mass diagram showing water supply available and storage requirements for Twin Lakes reservoir.

required to insure a continuous flow of 170 second-feet during the period from April, 1914, to February, 1916.

Chiwawa reservoir.—Chiwawa River, between Rock and Grouse creeks, has a very flat gradient and occupies a wide U-shaped valley. Below Grouse Creek the river flows through a deeply incised canyon and passes several dam sites, which appear to be suitable for forming a reservoir about 10 miles long and nearly three-fourths of a mile wide. The areas and capacities measured on Plate VIII (at end of volume) are shown in the following table:

Areas and capacities of Chiwawa reservoir.

Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
2,400	685	0	2,470	3,140	146,700
2,410	1,160	9,240	2,480	3,440	179,600
2,420	1,640	23,300	2,490	3,760	215,600
2,430	2,000	41,500	2,500	4,000	254,400
2,440	2,390	63,400	2,510	4,300	295,900
2,450	2,660	88,700	2,520	4,600	340,400
2,460	2,900	116,500			

The run-off available for use for power and for storage in Chiwawa reservoir has been estimated by decreasing the run-off at the gaging station on Chiwawa River by (1) run-off between possible dam sites and measuring section at gaging station, (2) loss by evaporation from reservoir, and (3) future requirement in excess of natural run-off below possible dam sites for irrigating 2,900 acres of land (p. 53).

The run-off below possible dam sites and the loss by evaporation have been estimated by methods similar to those described on pages 47–49. The future requirement for irrigation in excess of inflow has been computed by assuming an annual diversion duty of 4.2 feet, distributed in accordance with percentages shown in the table on page 45 and by reducing the demand, thus derived, by the probable inflow between the possible dam sites and Wenatchee Park Land & Irrigation Co.'s intake. If 2,900 acres of land is irrigated some water must be released from the reservoir between July and October every year.

Estimated run-off, in units of 1,000 acre-feet, available for storage in Chiwawa reservoir.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909									11.0	11.7	44.4	35.7
1910	13.5	10.9	38.0	81.5	140.0	79.7	46.3	19.5	9.1	32.8	34.9	16.0
1911	10.5	6.5	10.4	42.0	65.9	84.8	47.1	16.0	11.4	7.0	11.3	9.0
1912	8.4	8.0	6.1	30.8	110.0	106.0	41.0	16.7	9.0	7.1	8.1	8.4
1913	7.9	9.3	8.7	34.3	98.5	154.0	72.2	26.2	18.5	16.5	17.4	12.8
1914	15.0	8.5	19.4	69.3	96.4	74.6	47.0	14.8	10.9	13.3	25.7	11.2
1915	5.6	4.6	11.6	62.8	38.2	24.3	11.8	10.1	5.2	9.1	10.4	7.2
1916	6.4	8.7	20.6	52.8	99.5	149.0						

A mass diagram (Pl. IV), prepared for the run-off data shown in the preceding table, indicates that a storage capacity of 318,000 acre-feet would have maintained a continuous flow of 521 second-feet during the critical period between March 1, 1910, and March 31, 1916. The maximum storage requirement, equivalent to a stage in the reservoir at an elevation of 2,515 feet, would have occurred about July 20, 1914.

Probably a storage capacity of 318,000 acre-feet would have insured a continuous flow of 521 second-feet from March 1, 1909, to March 31, 1919, and considerable hold-over water would have been available on March 31, 1919.

Wenatchee Lake reservoir.—The discussion of the Quincy project (pp. 43–53) includes a description of the Wenatchee Lake reservoir and a table showing areas and capacities. The dam site chosen for the analysis of the Quincy project is 3.1 miles below the lake, and it may not be the one best suited to the development of power; but it has been chosen for the analysis of power because there is no satisfactory evidence regarding the feasibility of other sites between Chiwawa River and Chiwaukum Creek.

The run-off available for storage in the reservoir for use for power has been derived by decreasing the run-off at the gaging station on Wenatchee River near Leavenworth by (1) the run-off at the gaging station on Chiwawa River, (2) the run-off from the drainage area between the dam site and the measuring sections at the gaging stations on Chiwawa and Wenatchee rivers, and (3) the loss by evaporation from the area in the reservoir which exceeds the present area of Wenatchee Lake. These decreases have been estimated by methods similar to those described on pages 47–49.

Estimated run-off, in units of 1,000 acre-feet, available for storage in Wenatchee Lake reservoir.

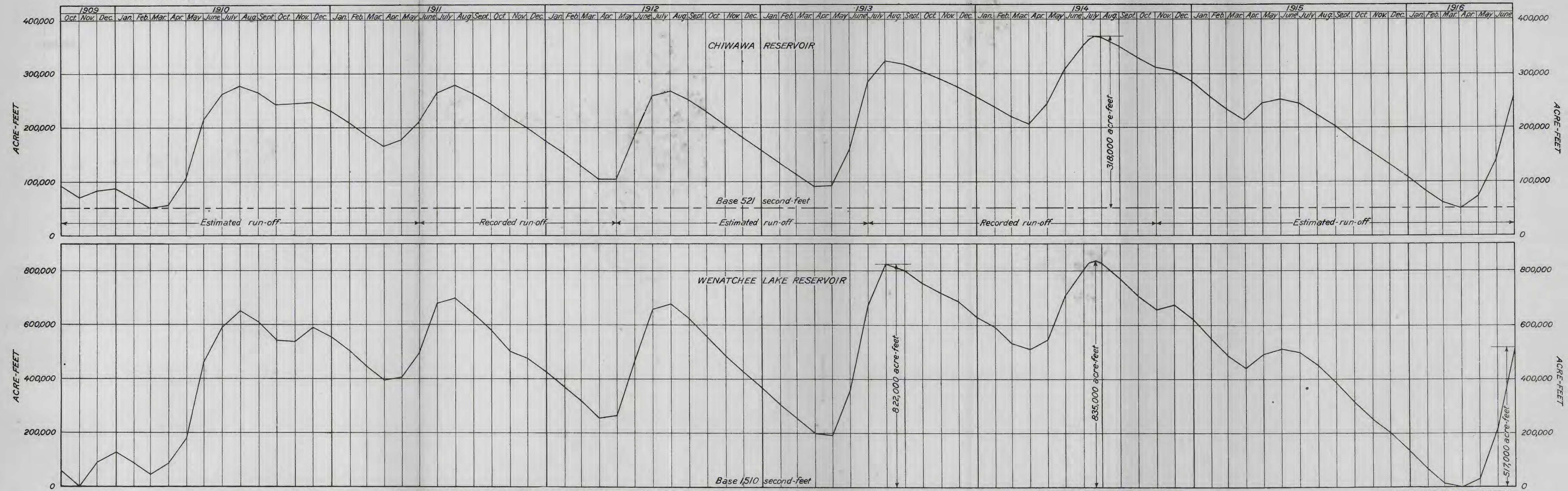
Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	......	......	......	......	......	......	......	......	......	32.4	180.0	129.0
1910	53.0	40.4	136.0	183.0	373.0	218.0	155.0	53.0	23.3	87.1	142.0	58.7
1911	42.1	25.1	43.4	99.5	183.0	274.0	112.0	35.1	29.0	14.5	65.0	44.3
1912	35.4	36.1	30.2	98.9	296.0	281.0	111.0	41.8	22.2	19.6	33.9	33.1
1913	29.8	34.5	36.9	83.5	260.0	404.0	242.0	71.2	43.9	56.4	57.6	36.7
1914	54.9	27.3	68.8	124.0	257.0	185.0	114.0	37.8	26.5	41.8	106.0	42.1
1915	23.3	18.1	47.1	144.0	112.0	75.5	45.9	30.4	14.8	26.4	44.1	27.8
1916	26.2	32.8	77.2	122.0	270.0	388.0	......	......	......	......	......	......

A mass diagram (Pl. IV), derived from the run-off available for storage in the reservoir for use for power indicates that the period from November 1, 1909, to March 31, 1916, was critical and that the mean flow during this period, 1,510 second-feet, could have been maintained continuously with a storage capacity of 835,000 acre-feet. The maximum storage requirement, equivalent to a stage in the reservoir at an elevation of 1,971 feet, would have occurred about July 20, 1914.

A storage capacity of 835,000 acre-feet would have insured a continuous flow of 1,510 second-feet from November 1, 1909, to March 31, 1919, and considerable hold-over water would have been available on March 31, 1919.

The run-off available and the storage capacity required for the operation of the proposed Quincy project are given on page 47–52.

Trout Creek and Eightmile Flat reservoirs.—The Trout Creek and Eightmile Flat reservoirs will furnish only enough storage to increase the flow of Icicle Creek during one or two low-water months each year. The Trout Creek reservoir can be formed by a dam built several hundred yards below Trout Creek, and the Eightmile Flat reservoir by a dam built three-fourths of a mile above Eightmile Creek. The areas as measured from Plate IX, *A*, *B*, and the capacities of the reservoirs are shown in the following table:



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MASS DIAGRAMS SHOWING WATER SUPPLY AVAILABLE AND STORAGE REQUIREMENTS FOR WENATCHEE LAKE AND CHIWAWA RESERVOIRS

Areas and capacities of Trout Creek and Eightmile Flat reservoirs.

Trout Creek.			Eightmile Flat.		
Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
2,620	2	0	2,060	8	0
2,630	8	50	2,070	17	125
2,640	19	185	2,080	26	340
2,650	30	430	2,090	37	655
2,660	55	845	2,100	48	1,080
2,670	76	1,490			
2,675	87	1,900			

A comparison of the records at the gaging station on Icicle Creek with the records at the gaging stations on Wenatchee River indicate that the flow for October, 1911, was lower than for any other calendar month from 1905 to 1918 and that all the water stored in the reservoirs would have been needed during that month. In determining regulated flow October, 1911, has therefore been considered critical. An estimated natural flow during October, 1911, of 76 second-feet at Trout Creek reservoir and 100 second-feet at Eightmile Flat reservoir has been derived by comparing records at the gaging station on Icicle Creek with miscellaneous measurements. The natural flow, thus derived, supplemented by water stored in Trout Creek reservoir, would yield a flow of 106 second-feet and, supplemented by water from both reservoirs, would yield a flow of 148 second-feet at Eightmile Flat reservoir.

REGULATED FLOW IN DEVELOPMENT UNITS.

The regulated flow available in the development units below the reservoir sites has been estimated by increasing the regulated flow at reservoir sites (determined as described in the preceding pages) by differences in minimum flow at the reservoir sites and at the respective development units. In other words, the natural flow from the drainage areas below the reservoir sites has been assumed to augment the regulated flow by amounts equal to the minimum flow from those drainage areas.

The regulated flow for the units in which the uses for power and for irrigation conflict has been decreased by two-thirds of the average demand for present and future irrigation during September and October (p. 56).

POWER RESOURCES WITHOUT QUINCY PROJECT IN OPERATION.

The essential features and the power resources of each development unit, derived as already explained, are summarized in the following table. Allowance has been made for present and probable future irrigation of areas aggregating about 28,800 acres in Wenatchee Valley and of areas in a part of the adjoining Columbia Valley, but no allowance has been made for the requirements of the proposed Quincy project (p. 45). Regulated flow has been determined by assuming the use of all water stored primarily for the development of power.

Power resources in Wenatchee basin without Quincy project in operation.

Unit No.	Stream and location.	Distance above mouth (miles).		Elevation above mean sea level (feet).		Total fall in unit (feet).	Flow at diversion point (second-feet).		Continuous horsepower (70 per cent efficiency).	
		Upper end of unit.	Lower end of unit.	Upper end of unit.	Lower end of unit.		Minimum.	Regulated.	Minimum flow.	Regulated flow.
1	Little Wenatchee River between Rainy Creek and Wenatchee Lake reservoirs	70.7	67.4	2,090	1,960	130	54	135	558	1,400
2	White River between elevation 2,355 feet and Wenatchee Lake reservoir	18.5	14.5	2,355	1,960	395	[a] 81	....	2,540	2,540
3	White River between North Fork, Twin Lakes, and Wenatchee Lake reservoir	....	....	2,808	1,960	848	60	170	4,040	11,500
4	Chiwawa River between elevations 2,400 and 1,870 feet	....	....	2,400	1,870	530	117	521	4,930	22,000
5	Wenatchee River between Wenatchee Lake reservoir and Chiwaukum Creek	48.5	36.6	1,870	1,665	205	405	[b] 2,060	6,600	33,600
6	Wenatchee River between Chiwaukum Creek and intake of Great Northern power plant	36.6	32.2	1,665	1,486	179	444	2,100	6,320	29,900
7	Wenatchee River between intake and tailrace of Great Northern power plant	32.2	29.3	1,486	1,285	201	451	2,110	7,200	33,700
8	Wenatchee River between tailrace of Great Northern power plant and elevation 1,110 feet	29.3	27.2	1,285	1,110	175	461	2,120	6,420	29,500
9	Icicle Creek between South Fork and Trout Creek reservoir	21.0	18.0	2,900	2,665	235	54	....	1,010	1,010
10	Icicle Creek between Trout Creek and Eightmile Flat reservoirs	18.0	10.8	2,620	2,090	530	76	106	3,200	4,470
11	Icicle Creek between Eightmile Flat reservoir and intake of Icicle canal	10.8	6.2	2,060	1,396	664	100	148	5,280	7,820

[a] Includes minimum flow of Cougar Creek.
[b] Based on regulation of entire flow of Wenatchee River below Chiwawa River.

Power resources in Wenatchee basin without Quincy project in operation—Continued.

Unit No.	Stream and location.	Distance above mouth (miles).		Elevation above mean sea level (feet).		Total fall in unit (feet).	Flow at diversion point (second-feet).		Continuous horsepower (70 per cent efficiency).	
		Upper end of unit.	Lower end of unit.	Upper end of unit.	Lower end of unit.		Minimum.	Regulated.	Minimum flow.	Regulated flow.
12	Icicle Creek between intake of Icicle canal and elevation 1,110 feet	6.2	....	1,396	1,110	286	[c] 94	[c] 142	2,140	3,200
13	Wenatchee River between elevation 1,110 feet and intake of Dryden power plant	27.2	18.2	1,110	967	143	[d] 619	[d] 2,330	7,040	26,500
14	Peshastin Creek between Ingalls Creek and intake of Beecher ditch	....	....	1,800	1,225	575	24	....	1,100	1,100
15	Wenatchee River between intake and tailrace of Dryden power plant	18.2	16.5	967	905	62	[d] 609	[d] 2,320	3,000	11,400
16	Wenatchee River between tailrace of Dryden power plant and elevation 695 feet	16.5	6.8	905	695	210	[d] 607	[d] 2,320	10,100	38,800
17	Wenatchee River between elevations 695 and 612 feet	6.8	1.5	695	612	83	[d] 694	[d] 2,400	4,580	15,800
									76,100	274,000

[c] Reduced only by the part of the demand for irrigation that can not be satisfied by diverting entire low-water flow of Snow Creek.

[d] Reduced to satisfy the demand for present and future irrigation (p. 56).

The general topographic features of the development units may be ascertained from topographic maps published by the United States Geological Survey. More detailed topography is shown on the plates indicating river plans and profiles (at end of volume), as follows: Units 1–2, Plate VII, *E;* unit 3, Plate VII, *D;* unit 4, Plates VII, *C,* and VIII; unit 5, Plate VII, *B* and *C;* units 6–8, Plate VII, *B;* units 9 and 10, Plate IX, *B;* units 11 and 12, Plate IX, *A;* unit 13, Plate VII, *A* and *B;* unit 14, no plan and profile (see topographic maps); units 15–17, plate VII, *A.* Other features of the units are briefly described in the following paragraphs.

Unit 1. Little Wenatchee River between Rainy Creek and Wenatchee Lake reservoirs.—Rainy Creek and Wenatchee Lake reservoirs control elevations at the upper and lower ends of unit 1. The elevation at the lower end of the unit has been assumed 11 feet lower than the maximum stage in Wenatchee Lake reservoir because a study of the mass diagram (Pl. IV) for Wenatchee Lake reservoir indicates that during the 81 months shown in the diagram the stage would have been above 1,960 feet for only 9 months, above 1,965 feet for only 5 months, and above 1,970 feet for only 1½ months.

Unit 2. White River between elevation of 2,355 feet and Wenatchee Lake reservoir.—A point 1¾ miles below Indian Creek has been chosen for the upper end of unit 2, because heavy rock construction would be encountered farther upstream. An elevation of 1,960 feet has been chosen for the lower end of the unit, for the reason described in connection with unit 1. It has been assumed that the flow of Cougar Creek will be intercepted by a conduit on the right side of the valley, where the supporting ground, which consists of earth and broken rock, offers a favorable location for a conduit.

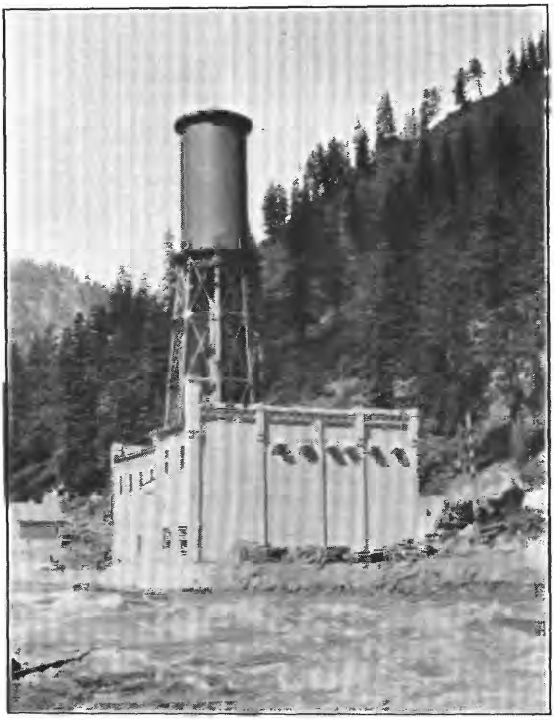
Unit 3. North Fork of White River to Twin Lakes and Wenatchee Lake reservoir.—The feasibility of a plant for unit 3 will depend largely on the cost of diversion from North Fork into Twin Lakes reservoir. A conduit about 4½ miles long, constructed along steep rocky slopes, will be required. The power plant may be built on North Fork about 1½ miles above its mouth and about the same distance from a forebay in Twin Lakes reservoir. An elevation of 1,960 feet has been chosen for the lower end of the unit, for the reason described in connection with unit 1.

Unit 4. Chiwawa River between elevations of 2,400 and 1,870 feet.—The upper end of unit 4 is controlled by Chiwawa reservoir, and the lower end by an elevation at which water will be drawn from Wenatchee Lake reservoir. The most economical location for the conduit is on the right side of Chiwawa River from the reservoir to Fish Lake and on the left side of Wenatchee River from Fish Lake to a power plant just below the dam site chosen for the Wenatchee Lake reservoir. This location would require pressure pipes across Big Meadows Creek and across a depression east of Fish Lake.

Unit 5. Wenatchee River between Wenatchee Lake reservoir and Chiwaukum Creek.—Analyses for unit 5 have been based on the assumption that a diversion dam, with its crest at an elevation of 1,870 feet, will be built three-fourths of a mile below Chiwawa River. Additional power may be developed in summer at the dam forming Wenatchee Lake reservoir by utilizing the mean draft of 1,510 second-feet. The additional power, computed from average stages in the reservoir for a period of six years (Pl. IV), amounts to 9,000 horsepower for May and 11,500 horsepower from June to September.

Unit 6. Wenatchee River between Chiwaukum Creek and intake of Great Northern power plant.—The lower end of unit 6 is controlled by the crest elevation of the Great Northern Railway Co.'s diversion dam. Over half of the head available in the unit is concentrated between the power-house site, one-fourth of a mile above Fall Creek, and a point 1 mile upstream. The head that can be realized by a diversion dam in the upper part of the unit is limited by the grade line of the Great Northern Railway.

Unit 7. Wenatchee River between intake and tailrace of Great Northern power plant.—The upper and lower ends of unit 7 are fixed by a power plant (Pl. V, *A*, and p. 70) operated by the Great Northern Railway Co.



A. GREAT NORTHERN POWER PLANT.

B. ENTIAT POWER PLANT.

Unit 8. Wenatchee River between tailrace of Great Northern power plant and elevation of 1,110 feet.—The Great Northern grade line would interfere with an economical location of the conduit on the left side of Wenatchee River in unit 8, although the topography and supporting ground are more favorable there than on the right side. If the conduit is carried along on the right side a tunnel through the ridge between mile 27.2 and 28.3 (Pl. VII, *B*, at end of volume) might prove feasible. The Tumwater Light & Power Co. (p. 71), utilizes a part of the fall in this section.

Unit 9. Icicle Creek between South Fork and Trout Creek reservoir.—The elevation of the lower end of unit 9 has been fixed at 10 feet below the spillway elevation of the Trout Creek reservoir site because the water stored in the reservoir will be used for only one or two months each year. The cost of the conduit would be high on account of heavy construction and the isolation of the locality.

Unit 10. Icicle Creek between Trout Creek and Eightmile Flat reservoirs.—The elevation at the lower end of unit 10 has been fixed at 10 feet below the spillway elevation of the Eightmile Flat reservoir site because the water stored in the reservoir will be utilized for only one or two months each year. The best location for the conduit is on the right side, where the supporting ground is favorable for 4 miles below Trout Creek, although the remaining 3 miles is steep and rough. The power plant may be built 1½ miles above Eightmile Creek.

Unit 11. Icicle Creek between Eightmile Flat reservoir and intake of Icicle canal.—The lower end of unit 11 is controlled by the intake of Icicle canal (p. 42). It has been assumed that the flow of Eightmile Creek would be diverted into a conduit on the right side.

Unit 12. Icicle Creek between intake of Icicle canal and elevation of 1,110 feet.—Icicle canal, which is on the right side of Icicle Creek, might be enlarged to serve a combined use for power and irrigation; but for power alone the left side appears to offer a shorter and more favorable location for a conduit.

Unit 13. Wenatchee River between elevation of 1,110 feet and intake of Dryden power plant.—It has been assumed that the elevation of the mill pond opposite Leavenworth could be raised about 6 feet without serious damage to property. As the gradient in the upper half of unit 13 is rather flat, a diversion dam high enough to utilize some of the fall might prove practicable. The selection of the best site for a diversion dam will be influenced largely by the present grade line of the Great Northern Railway. Although considerable water could be stored by providing a diversion dam with a removable crest, such storage has not been considered available in computing the power resources for this unit.

Unit 14. Peshastin Creek between Ingalls Creek and intake of Beecher ditch.—The entire low-water flow of Peshastin Creek is diverted for irrigation, so that the lower end of unit 14 has been fixed at the elevation of the highest irrigation diversion.

Unit 15. Wenatchee River between intake and tailrace of Dryden power plant.—The upper and lower ends of unit 15 are fixed by a power plant operated by the Wenatchee Valley Gas & Electric Co. (Pl. VI and p. 71).

Unit 16. Wenatchee River between tailrace of Dryden power plant and elevation of 695 feet.—As the gradient throughout unit 16 is rather flat, development in two or three small projects by low dams and short conduits might prove more practicable than to utilize most of the fall in the unit by a single conduit. The location of the Great Northern Railway, roads, and fruit farms will limit the height to which diversion dams can be built at a reasonable cost.

Unit 17. Wenatchee River between elevations of 695 and 612 feet.—In unit 17 the river flows through a highly improved agricultural district, and the feasibility of development would depend on the cost of property rights.

The elevation at the lower end of the unit is controlled by the stage of Columbia River during floods. The maximum stage on record for Columbia River occurred in June, 1894, when the elevation at the mouth of Wenatchee River was about 643 feet. The stage at the mouth of Wenatchee River equivalent to United States Weather Bureau "flood stage" at Wenatchee is at an elevation of about 628 feet. Weather Bureau records at Wenatchee from 1904 to 1918 indicate that "flood stage" was exceeded 5 days in 1908, 28 days in 1913, and 29 days in 1916. The highest stage recorded from 1904 to 1918 occurred in June, 1913, when the elevation at the mouth of Wenatchee River was about 634 feet. The elevation of extremely low water at the mouth of Wenatchee River is about 590 feet. If the tailrace of the power plant is placed at an elevation of 612 feet, as chosen for this unit, provision should be made to protect the machinery during an extreme flood similar to that of June, 1894.

COMPARISON OF POWER RESOURCES WITH AND WITHOUT QUINCY PROJECT IN OPERATION.

Alternative plans.—The analyses in the preceding discussion are based on the use of the available water primarily for power, whereas the successful development of the Quincy project (p. 43) requires its use primarily for irrigation. A comparison of the power resources with and without the project in operation has been made for two plans of developing the project. Plan A contemplates the use of the water for both irrigation and power. It provides for a continuous flow of

A. CANAL DELIVERING WATER TO DRYDEN POWER PLANT AND TO WENATCHEE RECLAMATION DISTRICT.

B. DRYDEN POWER PLANT.

525 second-feet past the project diversion works to satisfy the prior power right claimed by the Great Northern Railway Co. Plan B contemplates the use of the entire water supply available at the project diversion works for irrigation.

Minimum flow.—Computations of power with the Quincy project in operation, based on minimum flow, have been made comparable to those in the preceding discussion by the following assumptions: (1) Regulation of storage in Wenatchee Lake reservoir to accommodate plan A and plan B but with no other storage in use; (2) allowance for present and probable future irrigation in Wenatchee Valley and a part of Columbia Valley.

Power resources from minimum flow.

	Continuous horsepower (70 per cent efficiency).	
	Plan A.	Plan B.
With Quincy project in operation	82,700	30,300
Without Quincy project in operation	76,100	76,100
Difference	+6,600	−45,800

NOTE.—The difference shown for plan A is greater with than without the Quincy project in operation, because the prior power right claimed by the Great Northern Railway Co. (525 second-feet) is greater than the estimated minimum flow (451 second-feet) at the intake of the Great Northern power plant.

Regulated flow.—Wenatchee Lake reservoir is the largest and most useful storage site considered in this report. Its use as a part of the Quincy project will decrease considerably the power resources with regulated flow. The power resources with the Quincy project in operation, shown in the following comparison, have been computed in accordance with the following assumptions: (1) Use of water stored in the Wenatchee Lake reservoir to accommodate plan A and plan B; (2) use of remaining stored water, aggregating about 370,000 acre-feet in five reservoirs, for power; and (3) allowance for present and probable future irrigation in Wenatchee Valley and in a part of Columbia Valley.

Power resources with flow regulated.

Unit No.	Stream and location.	Total fall in unit (feet).	With project. Regulated flow (sec.-ft.) as controlled by— Plan A.	Plan B.	Continuous horsepower (70 per cent efficiency). Plan A.	Plan B.
1	Little Wenatchee River between Rainy Creek and Wenatchee Lake reservoirs	100	135	135	1,070	1,070
2	White River between elevation 2,355 and Wenatchee Lake reservoirs	365	81	81	2,350	2,350
3	White River between North Fork, Twin Lakes, and Wenatchee Lake reservoir	818	170	170	11,100	11,100
4	Chiwawa River between elevations 2,400 and 1,990 feet	410	521	521	17,000	17,000
[a]4a	Chiwawa River between elevations 1,990 and 1,870 feet	120	[b]418	0	3,990	0
5	Wenatchee River between Wenatchee Lake reservoir and Chiwaukum Creek	205	[c]442	5	7,210	([d])
6	Wenatchee River between Chiwaukum Creek and intake of Great Northern power plant	179	525	0	7,480	0
7	Wenatchee River between intake and tailrace of Great Northern power plant	201	525	5	8,390	([d])
8	Wenatchee River between tailrace of Great Northern power plant and elevation 1,110 feet	175	539	14	7,500	([d])
9	Icicle Creek between South Fork and Trout Creek reservoir	235	54	54	1,010	1,010
10	Icicle Creek between Trout Creek and Eightmile Flat reservoirs	530	106	106	4,470	4,470
11	Icicle Creek between Eightmile Flat reservoir and intake of Icicle canal	664	148	148	7,820	7,820
12	Icicle Creek between intake of Icicle canal and elevation 1,110 feet	286	142	142	3,223	3,230
13	Wenatchee River between elevation 1,110 feet and intake of Dryden power plant	143	745	220	8,480	2,500
14	Peshastin Creek between Ingalls Creek and intake of Beecher ditch	575	24	24	1,100	1,100
15	Wenatchee River between intake and tailrace of Dryden power plant	62	735	210	3,620	1,040
16	Wenatchee River between tailrace of Dryden power plant and elevation 695 feet	210	733	208	12,200	3,470
17	Wenatchee River between elevations 695 and 612 feet	83	820	295	5,410	1,950
	Total with Quincy project in operation				113,000	58,100
	Total without Quincy project in operation				274,000	274,000
	Difference				−161,000	−216,000

[a] Subunit can be developed only in accordance with plan A.
[b] Release required from Wenatchee Lake reservoir during March to maintain flow of 525 second-feet at intake of Quincy project.
[c] Estimated flow during March and minimum for year.
[d] Power development not feasible.

The power available with storage will be decreased by 161,000 horsepower if the Quincy project is operated in accordance with plan A and by 216,000 horsepower if operated in accordance with plan B. Plan B will therefore develop 55,000 horsepower less than plan A but will irrigate 85,800 acres more (p. 53). If no other means of bringing this area under cultivation appears feasible, this sacrifice of power would be warranted.

SITES IN ENTIAT BASIN.

MINIMUM FLOW.

The gaging station on Entiat River at Entiat, whose records extend over a period of eight and one-half years, has been considered the base gaging station for computing the minimum flow of the streams in Entiat basin. The lowest flow for any one calendar month in the first group of climatic years (1911–1915) was 108 second-feet and occurred in January, 1913. The lowest flow for any one calendar month in the second group of climatic years (1916–1919) was 91.8 second-feet and occurred in January, 1916. Therefore, the mean of these two months of lowest flow, 100 second-feet, has been chosen as the minimum flow at the gaging station. The minimum flow at other points in the basin has been estimated by comparing records at the gaging station with miscellaneous measurements and differences in drainage areas.

As the lowest monthly flow in each group of years occurred in January and was considerably lower than the flow during any irrigation season the minima used in estimating the power resources have not been reduced to satisfy the demands for irrigation.

REGULATED FLOW.

The minimum flow of Entiat River is so much lower than the mean annual flow that storage would be desirable in the development of power, but a consideration of the topographic maps and the data gathered by field reconnaissance indicates that storage in the Entiat basin is not feasible.

POWER RESOURCES.

The following table summarizes the essential features of each development unit and indicates the power that may be developed.

Power resources in Entiat basin.

Unit No.	Location on Entiat River.	Distance above mouth (miles).		Elevation above mean sea level (feet).		Total fall in unit (feet).	Minimum flow at diversion point (second-feet).	Continuous horsepower (70 per cent efficiency).
		Upper end of unit.	Lower end of unit.	Upper end of unit.	Lower end of unit.			
1	Between Potato Creek and Mad River	14	9	1,450	1,180	270	71	1,520
2	Between Mad River and intake of Entiat power plant	9	2.6	1,180	822	358	91	2,590
3	Between intake and tailrace of Entiat power plant	2.6	1.1	822	738	84	100	668
								4,780

POWER PLANTS.

GREAT NORTHERN POWER PLANT.[11]

A hydroelectric power plant on Wenatchee River (Pl. V, *A*) was constructed by the Great Northern Railway Co. in 1908–9, and the electric traction service through the Cascade tunnel started July 10, 1909. The power house is on the left side of the river, in Tumwater Canyon, 2½ miles above Leavenworth, Wash.

A concrete diversion dam 23 feet high, with a crest 400 feet long, forms a narrow pond three-fourths of a mile long. The dam has three headgates, a log sluiceway, and a fishway. Water is diverted from the right end of the dam through a wood-stave pipe, 8.5 feet in inside diameter, for 10,908 feet; thence through a steel pipe for 962 feet, crossing the river on a steel bridge and connecting at the power house with a steel surge tank 30 feet in diameter, having a capacity of about 38,000 cubic feet, The pipe line has a gradient about the same as the railway but follows the opposite side of the river for almost its entire length. The static head at normal stage is 201 feet.

The hydraulic machinery consists of three 4,000-horsepower turbines and two small turbines, used as exciter units, constructed by the Platt Iron Works for operation at an effective head of 180 feet. The large turbines are hung on horizontal shafts, discharge inward, and are equipped with single sets of vanes. Each large turbine is directly connected to alternating-current 6,600-volt 3-phase 25-cycle generators operating at 375 revolutions a minute, constructed by the General Electric Co. to generate 2,500 kilowatts while working at an overload of 25 per cent. Excitation is furnished by two 125-kilowatt direct-current motors. Only one exciter is needed for operation; the other is held in reserve. Voltage is increased from 6,600 to 33,000 by three transformers in use and one in reserve. Each transformer has a capacity of 833 kilowatts but is guaranteed to operate at 100 per cent overload for one hour with a low rise in temperature.

Energy is transmitted 30 miles from the power house to a substation near the east portal of Cascade tunnel. Duplicate circuits of No. 2 Brown & Sharpe stranded hard-drawn copper wire are carried on a single set of substantial poles 40 feet long. The circuits are supported by pin insulators so arranged on cross arms that the wires of each circuit are held in vertical planes on either side of poles.

The substation contains four single-phase 33,000 to 6,600 volt transformers identical with those in the power house; three are connected in a bank, and the fourth is held in reserve. The 3-phase current is distributed by two overhead trolleys and the railway

[11] Description abstracted in part from Hutchinson, C. T., The electric system of the Great Northern Railway Co. at Cascade tunnel: Am. Inst. Elec. Eng. Proc., November, 1909.

track. The electric locomotives used, constructed by the General Electric Co., are equipped each with four 475-horsepower 3-phase 25-cycle 500-volt motors and suitable transformers. Trains are operated through the tunnel, which projects through Cascade Range in a tangent 13,873 feet long with a uniform grade of 1.7 per cent.

The system was designed for the extension of electric service over the mountainous part of the main line from Skykomish to Leavenworth, a distance of 57 miles, in which the ruling grade is 2.2 per cent. Additional power in two plants utilizing gross heads of 200 feet was considered available in Tumwater Canyon. Utilization of regeneration produced by trains running down grade was proposed. Thus far the electric service is limited to operation through the tunnel.

TUMWATER POWER PLANT.

A small hydroelectric plant operated by the Tumwater Light & Water Co. is built at the lower end of Tumwater Canyon, about a mile below the Great Northern power house. Water is diverted from the right side of Wenatchee River through a concrete intake carried by a flume and a wood-stave pressure pipe for a distance of about 1,000 feet, and delivered through a 250-horsepower turbine constructed by the Dayton Manufacturing Co. The gross head is 59 feet, and the effective operating head at full load about 47 feet. A Westinghouse alternating-current single-phase 60-cycle generator, operating at 600 revolutions a minute, is direct-connected to the turbine and delivers, under maximum load, about 155 kilowatts at 2,200 volts.

DRYDEN POWER PLANT.

A water-power plant (Pl. VI, *B*) on Wenatchee River at Dryden, below Peshastin Creek and 16 miles above the mouth of the river, was constructed by the Valley Power Co. in 1909 and enlarged in 1910. It is now operated by the Wenatchee Valley Gas & Electric Co. and is the largest plant of that company's system.

Water is diverted by low timber-crib dams across two channels of the river at an elevation of 967 feet and is carried 1.1 miles along the left side of the valley by a canal (Pl. VI, *A*) 40 feet wide and averaging about 9 feet in depth. This canal delivers water to the Wenatchee Reclamation District and to the Dryden power plant at a gross head of 55 feet. The hydraulic machinery, manufactured by the S. Morgan Smith Co., consists of twin turbines each with a rated capacity of 1,040 horsepower, operating at 514 revolutions a minute and controlled by Lombard oil-pressure governors. A smaller turbine, controlled by a Woodward mechanical governor and having a capacity of 300 horsepower, was also installed but is seldom used. The large turbines are direct-connected to Westinghouse 600-kilowatt and the small turbine to Allis-Chalmers 200-kilowatt alternating-current generators supplying 3-phase 60-cycle 2,200-volt current. Excitation is effected by three direct-current generators belted to the respective generators. The generated voltage is stepped up to 16,500 volts for transmission by six 200-kilowatt oil-insulated water-cooled transformers.

ENTIAT POWER PLANT.

The only power plant (Pl. V, *B*) on Entiat River is near its mouth. It was constructed in 1909 by the Entiat Light & Power Co. and is now operated by the Wenatchee Valley Gas & Electric Co.

Water is diverted from the river through headgates on the left end of a low concrete diversion dam 400 feet long, is delivered to a forebay or settling basin, five-eighths of an acre in area, by a canal 6,200 feet long, and passes on to a power house through a wood-stave pressure pipe 8 feet in diameter and 1,715 feet long. At the entrance to the power house the wooden pipe is joined to a steel pipe of the same diameter. This pipe branches into two sections of equal size leading to separate 1,000-horsepower turbines manufactured by the S. Morgan Smith Co. to operate at 450 revolutions a minute under a gross head of 78 feet between forebay and tailrace. The turbines are regulated by Lombard oil-pressure governors. Each turbine is direct-connected to 550-kilowatt 3-phase 60-cycle 2,200-volt alternating-current generators supplied by the Westinghouse Electric & Manufacturing Co. The exciter equipment consists of two 25-kilowatt 125-volt direct-current generators designed to operate at 1,100 revolutions a minute. One exciter is direct-connected to a 60-horsepower turbine, and the other is so placed that it can be driven by belt from either main generator unit. The voltage is increased for transmission from 2,200 to 16,500 volts by three oil-insulated water-cooled transformers, each having a capacity of 400 kilowatts.

LOAD CHARACTERISTICS OF WENATCHEE VALLEY GAS & ELECTRIC CO.

The Wenatchee Valley Gas & Electric Co. supplies energy for lighting, for minor industrial activity, and for pumping the municipal water supply for Wenatchee, Waterville, Cashmere, and Monitor. It also serves a large agricultural district with energy for pumping water for irrigation. The irrigation pumping load, developed since about 1910, is so large compared with other loads that the maximum output each year occurs in August, when the most water is needed for crops. The practice of pumping water for irrigation will undoubtedly increase rapidly and will furnish revenue for water-power enterprises in the region. The accompanying diagrams (fig. 3) showing load characteristics, constructed from data furnished by the company, are therefore useful in planning future projects. The high demand from May to September, shown in figure 3, is similar to that of the Pacific Power & Light Co. in the Yakima basin.[12]

[12] Parker, G. L., and Storey, F. B., Water powers of the Cascade Range, Part III: U. S. Geol. Survey Water-Supply Paper 369, p. 153, 1916.

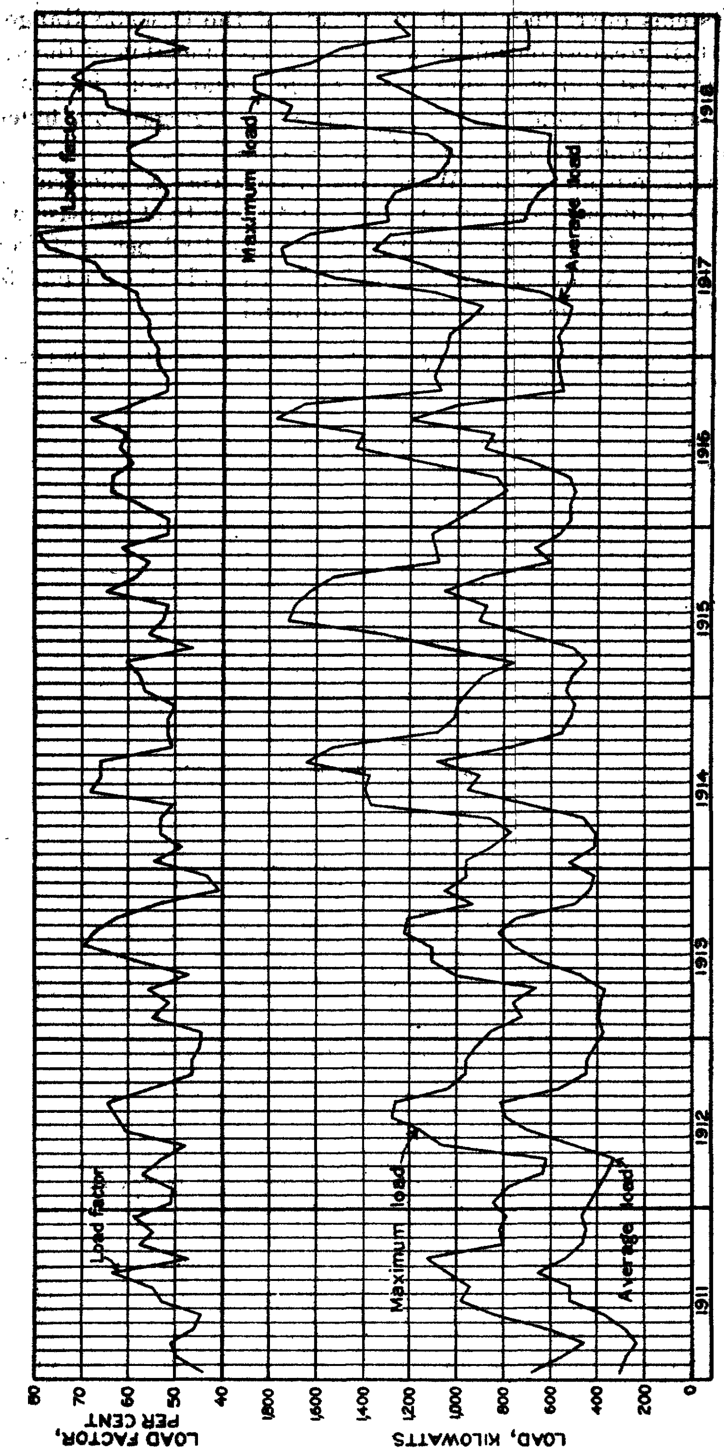


FIGURE 3.—Load characteristics of the Wenatchee Valley Gas & Electric Co.

The systems operating on the west side of the Cascade Range[13] produce their greatest output in winter. Interconnection of the systems on the east and west side of the range would result in a more nearly balanced demand and would require less aggregate machinery than the independent operation of the systems.

The yearly output of the Wenatchee Valley Gas & Electric Co. increased 94 per cent from 1911 to 1917, and the rate of increase was fairly uniform. The output for August increased 66 per cent from 1911 to 1917. A breakdown of one unit caused the output for August, 1918, to be less than the true demand.

---

[13] Henshaw, F. F., and Parker, G. L., Water powers of the Cascade Range, Part II: U. S. Geol. Survey Water-Supply paper 313, pp. 147-151, 1913.

INDEX.