GEOLOGICAL SURVEY CIRCULAR 109

WATER POWER RESOURCES OF HAMMA HAMMA, DUCKABUSH AND DOSEWALLIPS RIVERS WASHINGTON

By Fred F. Lawrence

PREPARED IN COOPERATION WITH THE
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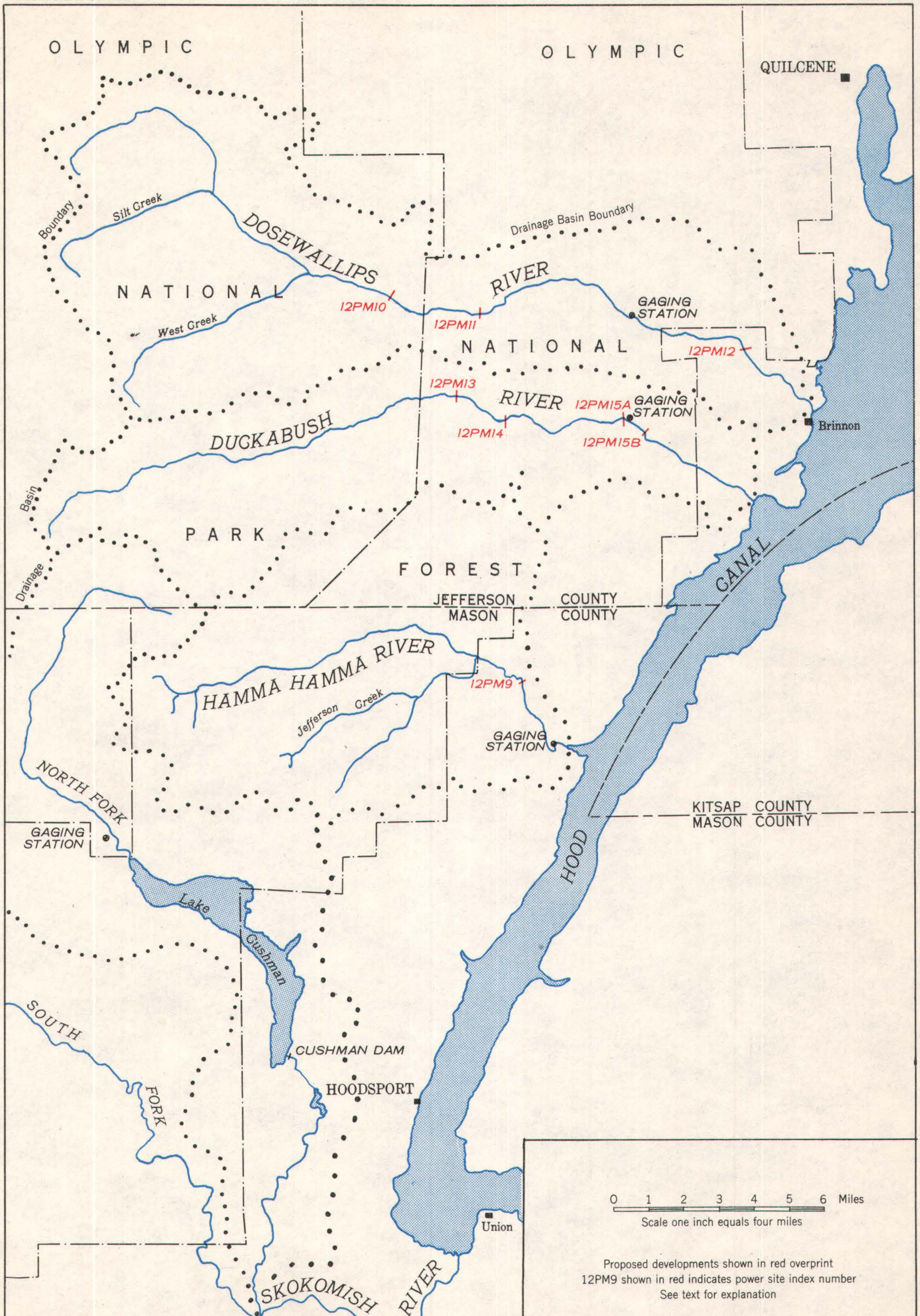

LOCATION MAP OF HAMMA HAMMA, DUCKABUSH, AND DOSEWALLIPS RIVERS

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ABSTRACT

The Hamma Hamma, Duckabush, and Dosewallips Rivers drain part of the east slope of the Olympic Mountains in northwestern Washington. The area is sparsely settled and for the most part is public domain lying in either the Olympic National Park or the Olympic National Forest.

There are 500 feet of fall on the Hamma Hamma River, 1,100 feet on the Duckabush River, and 1,500 feet on the Dosewallips River available for power development. There are no reservoir sites in the upper portions of the basins so the proportion of firm power to total power is quite small. Each basin has one reservoir site near the mouth of the stream which can provide adequate regulation. It will not be possible to divert the entire streamflow for power because each of these streams is used as spawning ground for salmon. The amount of water necessary to maintain this spawning cycle will be a large proportion of the low flow of each stream, thus greatly reducing the power available 95 and 90 percent of the time in a run-of-river plant.

INTRODUCTION

This report is one of a series prepared to assist in the classification of land within the public domain, with regard to its value in the production of hydro-electric power.

The field work incidental to the preparation of the report included plane-table surveys of each of the three streams studied. These surveys were all made by Mr. W. C. Senkpiel in 1932 except Jefferson and Lena Creeks in the Hamma Hamma River basin, which were mapped by Mr. G. W. Crippen in 1936, and the Hamma Hamma River dam site mapped by Mr. Arthur Johnson in 1937. The 1936 and 1937 surveys were made in cooperation with the Department of Conservation and Development of the State of Washington. The author made two short reconnaissance trips into the three basins by automobile in 1949.

Previous Investigations and Reports

Mr. E. E. Jones made reconnaissance surveys of the three streams in 1927 and prepared reports on the potential power available. These reports and maps were not released to the public.

Maps

Geological Survey-- River survey maps, all on a scale of 1:31,680 (½ mile to 1 inch) with contour intervals of 20 feet on land and either 5 or 10 feet on the water surface, have been published for all three streams. These maps are: Plan and profile of Hamma Hamma River and tributaries, Washington, with dam site (1 plan sheet, 1 profile sheet); Plan and profile of Duckabush River, Washington, from mouth to mile 18 (1 sheet showing plan and profile); and Plan and profile of Dosewallips River, Washington, from mouth to Deception Creek, and dam site (1 plan sheet, 1 profile sheet).

The dam sites on the Hamma Hamma and Dosewallips Rivers are on a scale of 1:4,800 (400 feet to 1 inch) with contour intervals of 10 feet on land and 5 feet on the river surface. Mt. Constance quadrangle, scale 1:125,000, contour interval 100 feet, covers all of the Hamma Hamma River and those parts of the Duckabush and Dosewallips Rivers upstream from their respective gaging stations. The Brothers and Mt. Steele quadrangles, scale 1:62,500, contour interval 100 feet, cover the south half of Mt. Constance quadrangle and include the same parts of all three basins.

Corps of Engineers, U. S. Army-- Pt. Misery quadrangle, scale 1:62,500, contour interval 20 feet, covers the area to the east of The Brothers quadrangle and includes the area downstream from the gaging stations on the Duckabush and Dosewallips Rivers except for a small part of the Dosewallips River basin which appears on the Quilcene quadrangle, scale 1:62,500, contour interval 50 feet.

U. S. Forest Service-- Two maps of the Olympic Peninsula; one on a scale of 2 miles to 1 inch shows contours where available. The other, on a scale of 4 miles to 1 inch, shows no contours but covers a slightly larger area on the north and south.

The above Geological Survey and Corps of Engineers maps may be obtained from the Map Distribution Section, U. S. Geological Survey, Denver Federal Center, Denver, Colo. The price for quadrangle maps is 20 cents per sheet, and for river surveys 10 cents per sheet. The Forest Service maps are obtainable from offices of the Forest Service in Olympia, Wash., or Portland, Oreg.

In connection with the preparation of the maps of The Brothers and Mt. Steele quadrangles, a line of levels was run up each of the three river valleys and a series of bench marks set. Copies of the bench mark descriptions and elevations may be obtained from the Regional Engineer, U. S. Geological Survey, Sacramento, Calif.

Future work

Detailed topographic surveys are required at those dam sites not already mapped on a large scale, and the geology of all the dam sites should be investigated before any detailed planning is undertaken.

GEOLOGY

Very little geologic investigation has been made in the basins of the Hamma Hamma, Duckabush, and Dosewallips Rivers. So far as is known no reports have been published.

The Geology Department of the College of Puget Sound in Tacoma, headed by Professor F. A. McMillin, has maintained a summer camp in the area for some years, studying the geology. No results have been published.

GEOGRAPHY AND HISTORY

The basins of the Hamma Hamma, Duckabush, and Dosewallips Rivers are on the eastern side of the Olympic Peninsula in the northwestern part of the State of Washington, about 30 airline miles west of Seattle. All three streams drain into Hood Canal which is an arm of Puget Sound. The adjacent drainage systems are as follows: on the south, the North Fork of the Skokomish River; on the west, the Quinault and Elwah Rivers; on the north, the Dungeness and Quilcene Rivers; and on the east, Hood Canal. Part of the Hamma Hamma River basin is in Mason County and the rest of it and all of the Duckabush and Dosewallips River basins are in Jefferson County.

The central portions of the Duckabush and Dosewallips River basins and the remainder of the Hamma Hamma River basin are in the Olympic National Forest, and the upper parts of the Duckabush and Dosewallips River basins are in the Olympic National Park. Most of the land along the lower reaches of the three rivers is privately owned. The land which is under private ownership has, for the most part, been logged off and in many places a good stand of second-growth timber has come up. In spite of some rather heavy logging between 1920 and 1930, the National Forest land has hardly been touched. No logging operations were under way at the time of this writing and the Forest Service has not planned any large timber sales for the next 5 years. Except for a fine stand along Washington and Jefferson Creeks in the Hamma Hamma River basin the timber in the three basins is difficult to reach, and probably will not be sold until the more accessible Forest Service stands have been cut. The timber is predominantly an excellent grade of Douglas fir with small amounts of silver fir, cedar, and hemlock.

The topography of all three basins is very rough except for the first few miles adjacent to Hood Canal. Altitudes vary from sea level at the mouth of each stream to

7,772 feet on Mt. Deception at the headwaters of the Dosewallips River. The Brothers Mountain, which has an altitude of 6,866 feet and which lies between the Hamma Hamma and Duckabush Rivers, is the highest point in either basin.

The table below summarizes some of the geographic data available for the basins. The median altitudes were determined from the topographic maps of Mt. Constance, Mt. Misery, and Quilcene quadrangles.

Basin	Drainage area (square miles)		Median altitude (feet)		Zero of gage altitude (feet)
	Above mouth	Above gaging station	Above mouth	Above gaging station	
Hamma Hamma	84.4	83.6	2910	2910	1/5 ±
Duckabush	76.3	66.2	3360	3670	241.5
Dosewallips	116.8	93.6	4060	4300	2/300 ±

1/ Estimated from river survey map. Tide effect noticeable at certain times.
2/ Estimated from river survey map.

There are no railroads or airports within the three basins. U. S. Highway 101, a paved road, follows the shore of Hood Canal and crosses the three rivers near their mouths. Gravelled roads go up the valley of each stream. The Hamma Hamma River road extends 14 miles up the valley to a point about 1 mile above Whitehorse Creek. The Duckabush River road extends 6 miles up the valley to a point locally known as Big Hump. The Dosewallips River road extends 15 miles up the valley ending just inside the Olympic National Park. These roads are not passable at times during the winter months.

The first settlements in this part of the State were at Shelton and Quilcene, on opposite sides of the three basins, in the 1850's. By 1900 Hoodsport, Eldon, Duckabush, and Brinnon were thriving lumber towns, but as the timber was cut off the more accessible hillsides, the population decreased considerably. Hoodsport, with a population in 1940 of 565, is the largest town in the general area although it is not within any of the three basins. The other three towns mentioned above each have a few inhabitants catering mainly to tourists, and marketing a limited amount of shell fish from Hood Canal.

In each of the three valleys there are a few "stump ranches" on the privately owned land between the National Forest boundary and Hood Canal. The U. S. Fish and Wildlife Service once operated a fish hatchery near the mouth of the Duckabush River but discontinued its operations some years ago. Game fish for the Olympic National Park were raised at the site but this work has now been transferred to the hatchery near Quilcene.

The basins are now used primarily for growing timber, for recreation, and for fishing and salmon spawning.

POWER SITE INDEX NUMBERS

For convenience in identifying power sites in the United States the country has been divided into 12 major drainage basins. Each of these basins has been subdivided, and each subdivision has been divided. The major drainage basins are designated by numbers from 1 to 12, and the subdivisions and minor subdivisions are both designated by a system of lettering. Thus the area under discussion here is in major drainage 12, which includes the Columbia River basin and Pacific Ocean drainage north of the Klamath River. The first subdivision is lettered "P" and includes Puget Sound drainage from Boundary Bay to Cape Flattery. The second subdivision is lettered "M" and includes Hood Canal and Puget Sound drainage from and including the Skokomish River to and including the Dungeness River. Thus the basins of the Hamma Hamma, Duckabush, and Dosewallips Rivers are all within the area known as 12PM. Within the sub-subarea, which in most cases is a subdivision of a river basin, the power sites are numbered consecutively beginning at the headwaters and numbering downstream. Where several small independent basins fall within the smallest subdivision, as is the case here, numbering is begun with the first stream investigated and continued to the next without regard to the geographical position of the stream in the sub-subdivision. Thus power site 12PM9 is on the Hamma Hamma River, 12PM10, 12PM11, and 12PM12, are on the Dosewallips River, and 12PM13, 12PM14, and 12PM15 are on the Duckabush River.

WATER SUPPLY

Precipitation

Precipitation over the three basins is heavy and the major part falls in the seven months from October through April. (See fig. 2.) At Cushman Dam, altitude 790 feet, just outside the area on the south, 87 percent of the annual precipitation falls in these seven months. At Brinnon, at the mouth of the Dosewallips River on Hood Canal, 86 percent falls in the same period, and at Quilcene, just north of the area and also at tidewater, 83 percent of the precipitation occurs in these same seven months. Thus the percentage falling in the summer months is almost one-third greater at Quilcene than at Cushman Dam.

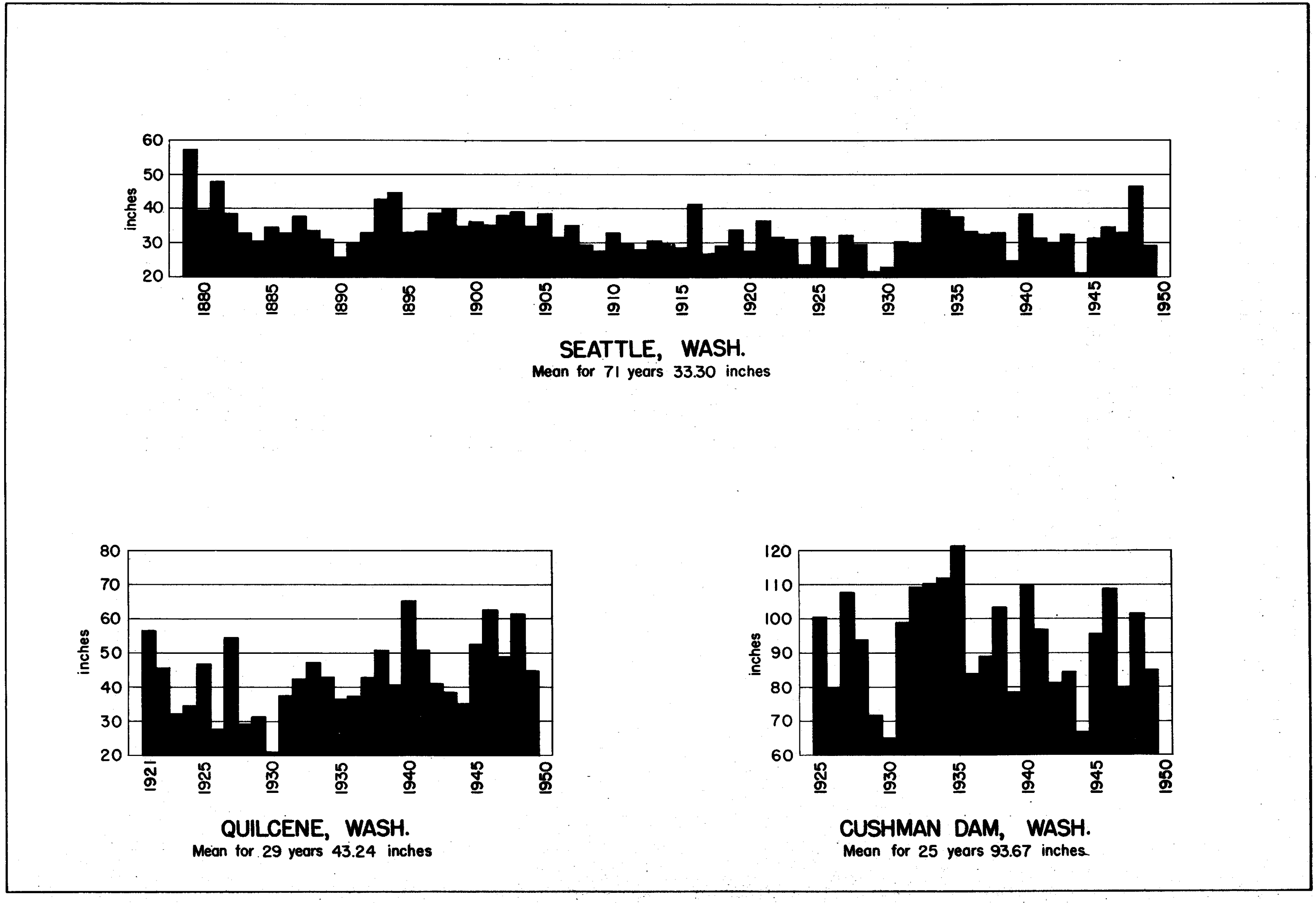


Figure 1. - Annual precipitation, Seattle, Quilcene, and Cushman Dam.

The total annual precipitation shows a marked decrease from south to north. (See fig. 1.) Cushman Dam has a mean precipitation of 93.7 inches, Brinnon 75.4 inches, and Quilcene 43.2 inches. Although the record at Brinnon covers only the period 1899-1906 when, according to the 1879-1949 record at Seattle, precipitation was somewhat higher than during the periods 1921-49 when records were obtained at Quilcene or 1925-49 when records were obtained at Cushman Dam, the difference is not so great that it changes the over-all picture. The mean annual precipitation at Brinnon during the period 1921-49 was probably between 65 and 70 inches.

The variation in precipitation is due to the topography of the Olympic Mountains and to the direction of approach of the prevailing winds. These winds blow from the southwest and the air, while rising to clear the Olympic Mountains, loses a large part of its moisture. The mountains form a rectangle with its narrow side east and west, and its southern extremity bounded by the Chehalis River. The ridge slope is fairly regular from near sea level on the Chehalis River to Mt. Olympus, altitude 7,923 feet, which lies due west of the Dosewallips River. Thus the air passing over the Dosewallips River and Quilcene has traversed considerably higher ground than that which passes over the Hamma Hamma River and Cushman Dam, and consequently has lost a larger proportion of its moisture. This subject will be discussed further in the section on Runoff.

A comparison of the long-time record at Seattle, 71 years, with the shorter records at Cushman Dam, 25 years, and at Quilcene, 29 years, indicates that the latter two records cover periods of slightly below normal precipitation (the period 1879-1949 is considered normal) but that the true mean will not differ greatly from the mean for these periods. (See fig. 1.) The record at Seattle shows that the 13-year period 1893-1905 was wetter than normal with no year falling below the 71-year median of 32.80 inches. The period 1908-32 (25 years) was drier than normal with only 3 years above the median. The first 15 years of the period of record 1879-93 had 6 years below median, 1 at median and 8 years above, and the last 15 years, 1935-49, show 7 years above and 8 below median. Thus, although there have been rather extended dry periods and wet periods, no definite trend is apparent.

Runoff

Streamflow records for the three streams which have been used in this report cover the following periods:

Hamma Hamma River......Oct. 1, 1926 through Sept. 30, 1930.
Duckabush River........Oct. 1, 1938 through Sept. 30, 1948.
Dosewallips River......Oct. 1, 1930 through Sept. 30, 1948.

Hydrographs of mean monthly flows for the three streams are shown on figure 3.

Since these records are of varying length and cover different periods an attempt was made to determine the relationship of the runoff throughout the period from the earliest to the latest record to a common base. To do this, the record for the North Fork of the Skokomish River below Staircase Rapids near Hoodsport, Wash., was used. This stream drains the area south and west of the Hamma Hamma River, an area of 60 square miles, and records are available for the period October 1, 1924 through September 30, 1947. For purposes of comparison this 23-year period will be considered normal.

This comparison shows that during the period 1927-30, when records were obtained on the Hamma Hamma River, the flow in the North Fork of the Skokomish River was 87 percent of normal. The mean flow in the Hamma Hamma River, which was 5.50 second-feet per square mile for these 4 years, is probably close to 6.3 second-feet per square mile. The mean flow in the North Fork of the Skokomish River during the driest 2 months, August and September, for these 4 years, was 86 percent of normal, but the flow during the driest 2 months in the period, 1927-30, August-September 1930, was 50 percent higher than the lowest 2 months (October and November, 1936) in the 23-year period, 1925-47. Extreme low flows of about 0.4 second-feet per square mile can be expected for 2-month periods on the Hamma Hamma River. This 4-year period included the driest year of the 23-year "normal" period, 1930, and one rather wet year 1927, which was fifth wettest in the period.

The mean flow for the Duckabush River for the 10-year period of record was 96 percent of normal; the mean flow for August and September was 93 percent normal. The driest year for the 10-year period was 1944, which was the second driest in the "normal" 23-year period. Mean flow for 1930 was 20 percent less than for 1944. The driest 2-month period in the 10 years of record occurred in September and October 1942 with mean monthly flows of 0.87 and 1.09 second-feet per square mile. The flow in the North Fork of the Skokomish River was about 180 percent of the extreme low during these 2 months. It is estimated that monthly mean flows of 0.7 and 0.6 second-feet per square mile occurred in October and November 1937, on the Duckabush River.

Streamflow records for the Dosewallips River are available for 17 years and the mean flow for this period is 107 percent of the flow for the 23-year period. For the low-water months of August and September the flow was 106 and 109 percent of normal. The driest 2-month period occurred in October and November 1937 for both the Dosewallips and North Fork of the Skokomish River. The flow of the Dosewallips River during these 2 months was 1.14 and 0.84 second-feet per square mile.

The hydrology of the area covered by these three basins is considerably more complex than would be expected of an area of only 244 square miles. The following table brings out some of the apparent inconsistencies. In this table the streams are listed from south to north.

River	Drainage area 1/ (sq. mi.)	Median altitude 1/ (feet)	Mean annual runoff (sec.-ft. per sq. mi.)	Mean monthly runoff, Sept. 2/ (sec.-ft. per sq. mi.)
Hamma Hamma River	84	2,900	3/ 6.3	3/ 1.1
Duckabush River	66	3,700	5.5	1.5
Dosewallips River	94	4,300	4.7	1.9

1/ For portion of basin upstream from gaging station.
2/ Month of minimum flow.
3/ Estimated by comparison with the 23-year record on the North Fork of the Skokomish River.

It will be noted that the runoff per square mile varies considerably, varying inversely with altitude for the annual figure but directly with altitude for the month of September, which is the month of lowest streamflow, and that the unit runoff decreases as latitude increases. This seeming inconsistency is due primarily to the effect of the Olympic rain shadow in which some of the most remarkable variations of precipitation in the United States occur. For example, the runoff of streams on the west slope of Mt. Olympus indicates that the precipitation at high elevations exceeds 200 inches per year yet the mean annual precipitation at Sequim, only 35 miles northeast of Mt. Olympus, is 15 inches. The prevailing winds during the precipitation period, November through March, are from the southwest and drop most of their moisture on the west and south sides of the Olympic Mountains. The Hamma Hamma River, draining the southern part of these mountains, is only partially in the rain shadow while the Dosewallips River to the north is much more affected. The effect is even more pronounced further north where the Dungeness River, which flows north and drains the area north of the Dosewallips River, has a mean flow of only 1.6 second-feet per square mile for 16 years of record. It should be noted that during the low-water season the precipitation is ordinarily so low that it affects the streamflow only slightly and streamflow is primarily from ground-water return. Basins with the higher median altitudes produce the greater flow. For Dosewallips River the summer flow is also increased by small glacial areas at its headwaters. Although obscured by the rain shadow for annual figures, the effect of altitude on runoff because of snow storage and melt is quite apparent when the annual distribution of runoff is examined. (See fig. 2.) The Hamma Hamma River with the lowest median altitude has its high-water season from November through January with a somewhat lower peak in the spring. The Dosewallips River with the highest median altitude has its highest peak in the spring with a smaller one in December and January. The Duckabush River with a median altitude lower than the Dosewallips River but higher than the Hamma Hamma River has two peaks very nearly the same height, December showing the greatest runoff with May a close second. For all three streams flow falls off rapidly from May to October with September showing the lowest flow. The set of flow duration curves shown in figure 4 also shows that the unit runoff is considerably higher in the low-water period on the streams with the higher median altitude. The low flows for the year are of particular interest on these streams because of the bearing they will have on the amount of water to be left in the stream to protect fish life. This water will not, of course, be available for generating power.

Because of the many variables and the lack of records of streamflow in the higher portions of the three basins, estimates of streamflow at points remote from the gaging stations involve considerable error. Since data prerequisite to a more precise analysis are not available, for the purpose of these preliminary estimates the streamflow at each site upstream from the gaging stations has been computed on the basis of a direct relation between drainage-area and discharge. The flows at all sites except 12PM12 on the Dosewallips River have been computed in this manner. For site 12PM12 the streamflow has been assumed to be 110 percent of the flow at the gage. More detailed analyses, if made, should be based on actual gaging of streamflow at the prospective sites.

Since a power plant constructed on any of these three streams will, in all probability, be interconnected with the Northwest Power Pool, and since the heaviest load for the pool comes in December and January when the power from Columbia River is at its lowest point, some thought should be given to developing power on these streams utilizing the heavy winter runoff. Although the power available during the low-water period of August through October may be negligible, it seems possible that an economical project could be built to produce power primarily during the winter months. In the following discussion of each of the three streams, special emphasis has been placed on the streamflow during these months.

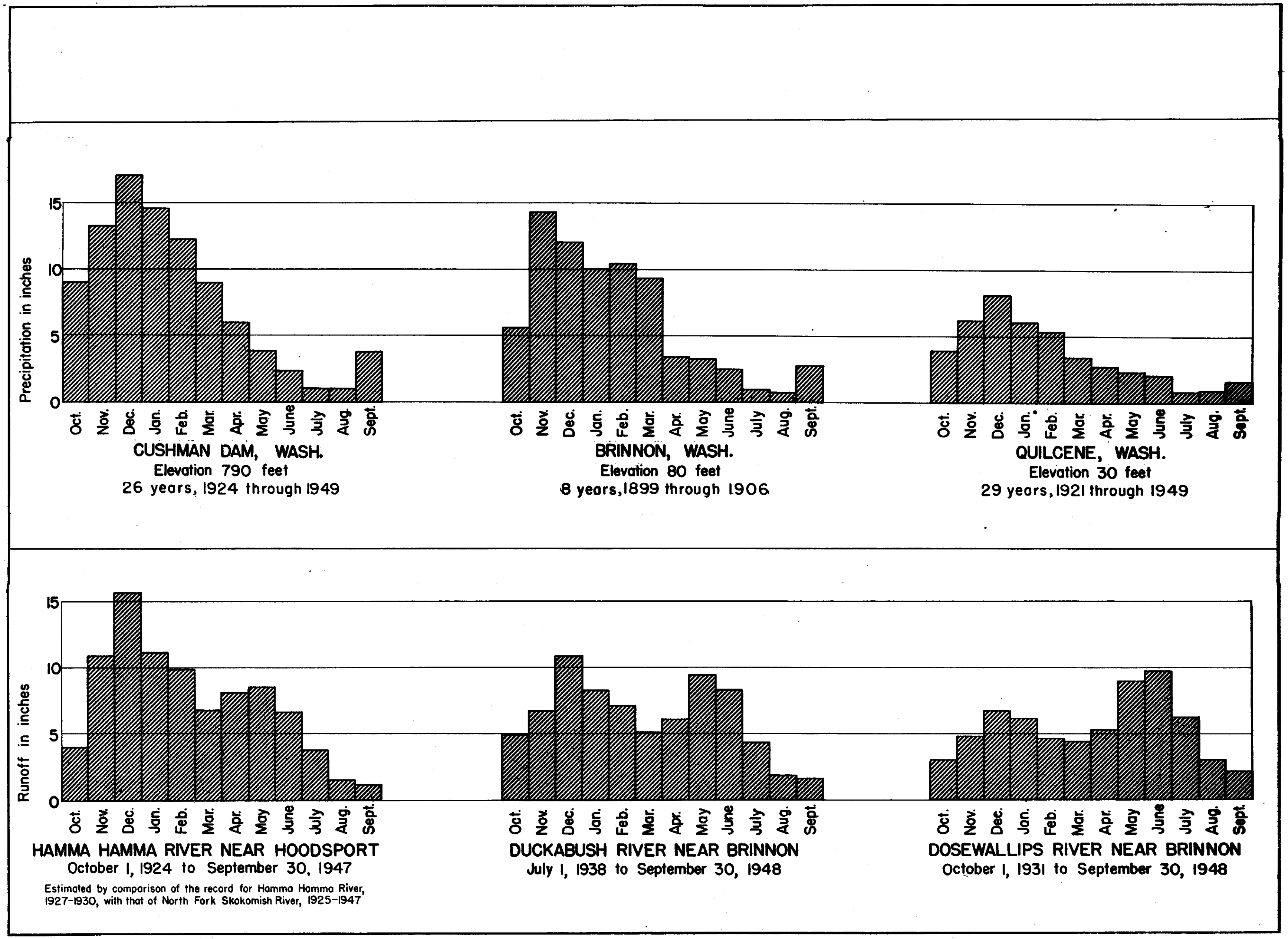


Figure 2. — Annual distribution of precipitation at Cushman Dam, Brinnon, and Quilcene, and Runoff of the Hamma Hamma, Duckabush, and Dosewallips Rivers.

A detailed discussion of the water supply in each of the three basins follows.

Hamma Hamma River

The Hamma Hamma River is the southernmost river, has the lowest median altitude (2,900 feet), is least affected by the Olympic rain shadow, has the highest mean unit flow, and has the lowest unit flow during low-water of the three streams under discussion. An examination of figure 2 will show that although there are two peaks in the monthly hydrograph the peak in December is considerably higher. The streamflow record covers only 4 years, 1927-30, a period which was considerably drier than normal and very much drier for the month of December. The mean monthly runoff at the gage for this month for the 4 years was 8.65 second-feet per square mile. Using the North Fork of the Skokomish River as a base and comparing the December flow for the period 1927-30 with the same flow for the period 1924-47, it is apparent that the 1927-30 flow in December was only about 64 percent of normal and that the mean flow on the Hamma Hamma River in December is very likely near 13.5 second-feet per square mile.

The period of record covers one of the two periods of lowest flow in the last 25 years. The two years 1929 and 1930 were both very dry. The lowest flow recorded in 23 years of record for the North Fork of the Skokomish River below Staircase Rapids occurred in September 1930, when the flow at the gage dropped to 16 second-feet, or 0.27 second-feet per square mile. During the same month the low flow on the Hamma Hamma River was 37 second-feet, or 0.44 second-feet per square mile. However, in September 1929 the reverse relationship prevailed when the North Fork of the Skokomish River had a low of 47 second-feet or 0.78 second-feet per square mile and the Hamma Hamma River had 23 second-feet or 0.27 second-feet per square mile. The mean of the five annual minimum flows recorded for the Hamma Hamma River is 42 second-feet, or exactly one-half second-foot per square mile. Based on the 23-year record of the North Fork of the Skokomish River, the mean low annual flow of the Hamma Hamma River is probably about 54 second-feet, or 0.64 second-feet per square mile while the median for 23 years is 50 second-feet, or 0.60 second-feet per square mile. This latter amount is probably close to the flow which will be required for fish life.

Daily flow duration curves for the 4 years of record are shown on figure 4. The following data on streamflow were taken from these curves.

Flow duration on the Hamma Hamma River
(Flow in sec.-ft. per sq. mi.)

Year	Q 95	Q 90	Q 50	Q mean
1927	1.37	1.90	5.41	7.98
1928	.56	.75	4.08	5.58
1929	.47	.75	3.16	4.48
1930	.32	.36	1.88	3.95
Mean flow Oct. 1, 1926 - Sept. 30, 1930 ----------- 5.50				

Of the above 4 years, 1927 was a wet year and 1930 was a very dry year but none of the four could be classed as an average year which would fall somewhere between 1927 and 1928.

The table below shows the estimated flows at power site 12PM9, where the drainage area is 76 square miles, for dry, average, and wet years. Since the period of record did not include what could be called an average year a synthetic average year has been assumed when the streamflow was less than in 1927 but more than in 1928.

Hamma Hamma River streamflow
(in sec.-ft.) at power site 12PM9

Year		Q 95	Q 90	Q 50	Q mean
Dry	1930	24	27	143	300
Average		54	70	350	479
Wet	1927	104	144	411	606

The Hamma Hamma River has its high-water period during the winter season and December is the month of greatest runoff. Since this is the time of year when the demand for power is greatest and when the flow of the Columbia River is low, some consideration should be given to the possibility of developing power in the winter even though the power available in August and September is negligible.

The following table shows the mean monthly flows for the winter periods from 1927 to 1930 and the corresponding winter flows from 1925 to 1947 estimated on the basis of the record for the North Fork of the Skokomish River.

Flow on the Hamma Hamma River
during the winter months 1927-30
(In sec.-ft. per sq. mi.)

Mean monthly 1927-30		Probable long time	Minimum monthly mean		Minimum daily flow	
Month	Flow	mean 1/	Month	Flow	Date	Flow
Nov.	9.01	9.7	Nov. 1929	0.35	Nov. 19-23, 1929	0.31
Dec.	8.65	13.5	Dec. 1927	5.47	Dec. 1-3, 1929	.32
Jan.	7.69	9.7	Jan. 1930	2.13	Jan. 25, 1930	.65
Feb.	7.90	9.4	Feb. 1929	1.04	Feb. 20, 1929	.88
Mar.	5.38	5.9	Mar. 1930	4.14	Mar. 1-4, 1929	1.29

1/ Based on comparison with flow of the North Fork of the Skokomish River below Staircase Rapids.

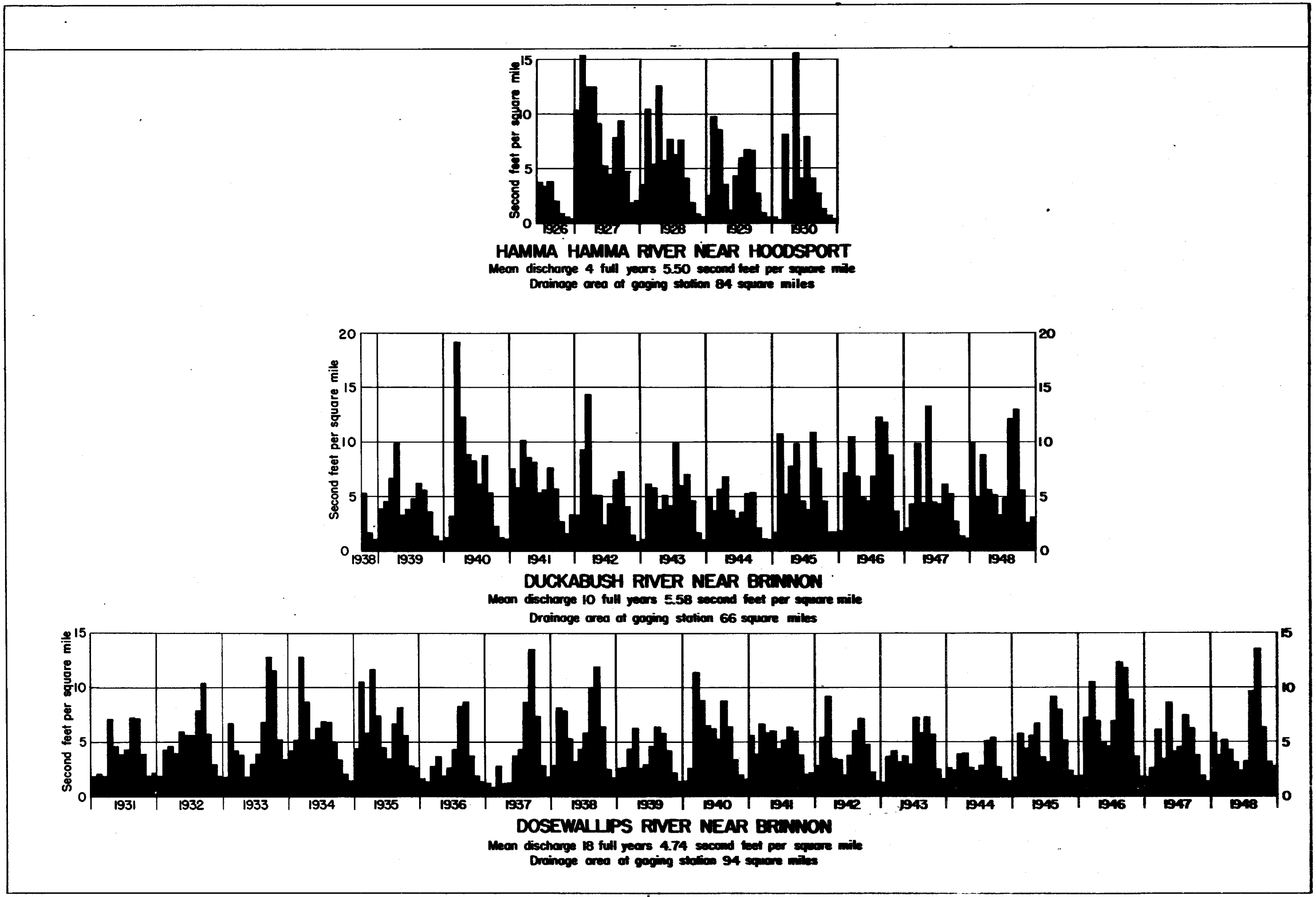


Figure 3.— Monthly hydrographs for the Hamma Hamma, Duckabush, and Dosewallips Rivers.

Since this 4-year period included a period of very low streamflow (1929-30), a record for the period of comparison (1925-47) would show extreme low flows very nearly the same as for the shorter period. Slightly lower flows might have existed in 1936-37.

Duckabush River

The hydrograph of mean monthly runoff shows that, similar to the Hamma Hamma River, the Duckabush River has two periods of high runoff and one of very low runoff, (See fig. 2.) However, because of the higher median altitude of the drainage basin, the winter peak is lower and the spring peak higher than for the Hamma Hamma River. The two peaks for the Duckabush River are of nearly equal height. It should also be noted that although the mean annual unit runoff is lower on the Duckabush River than on the Hamma Hamma River, 5.5 against 6.3 second-feet per square mile, the unit runoff in September, which is the lowest month, is higher on the Duckabush River, 1.5 against 1.1 second-feet per square mile. These figures for the Hamma Hamma River are somewhat higher than the mean for the 4 years of record, but are based on the comparison of these 4 years with the 23-year record on the North Fork of the Skokomish River.

Flow duration curves for a dry, average, and wet year are shown on figure 4. The following data on streamflow were taken from that figure.

Flow duration on the Duckabush River
(Flow in sec.-ft. per sq. mi.)

Year	Q 95	Q 90	Q 50	Q mean
1944	0.85	1.01	2.91	3.89
1945	.94	1.33	4.31	5.82
1946	1.03	1.67	5.29	6.78
Mean flow Oct. 1, 1938 to Sept. 30, 1948 --------------				5.58

The above figures are fairly representative of the flows to be expected on the stream except that it is probable that for a dry year Q 95 and Q 90 are somewhat high. Comparison of the record with that of the North Fork of the Skokomish River indicates that Q 95 and Q 90 were 0.6 and 0.7 second-feet per square mile respectively in 1936-37. For the period of record, the mean of the seasonal low flows is 0.89 and the median 0.77 second-feet per square mile.

The table below has been developed from the flow duration table by applying the appropriate drainage-basin area.

Streamflow on the Duckabush River
(In sec.-ft.)

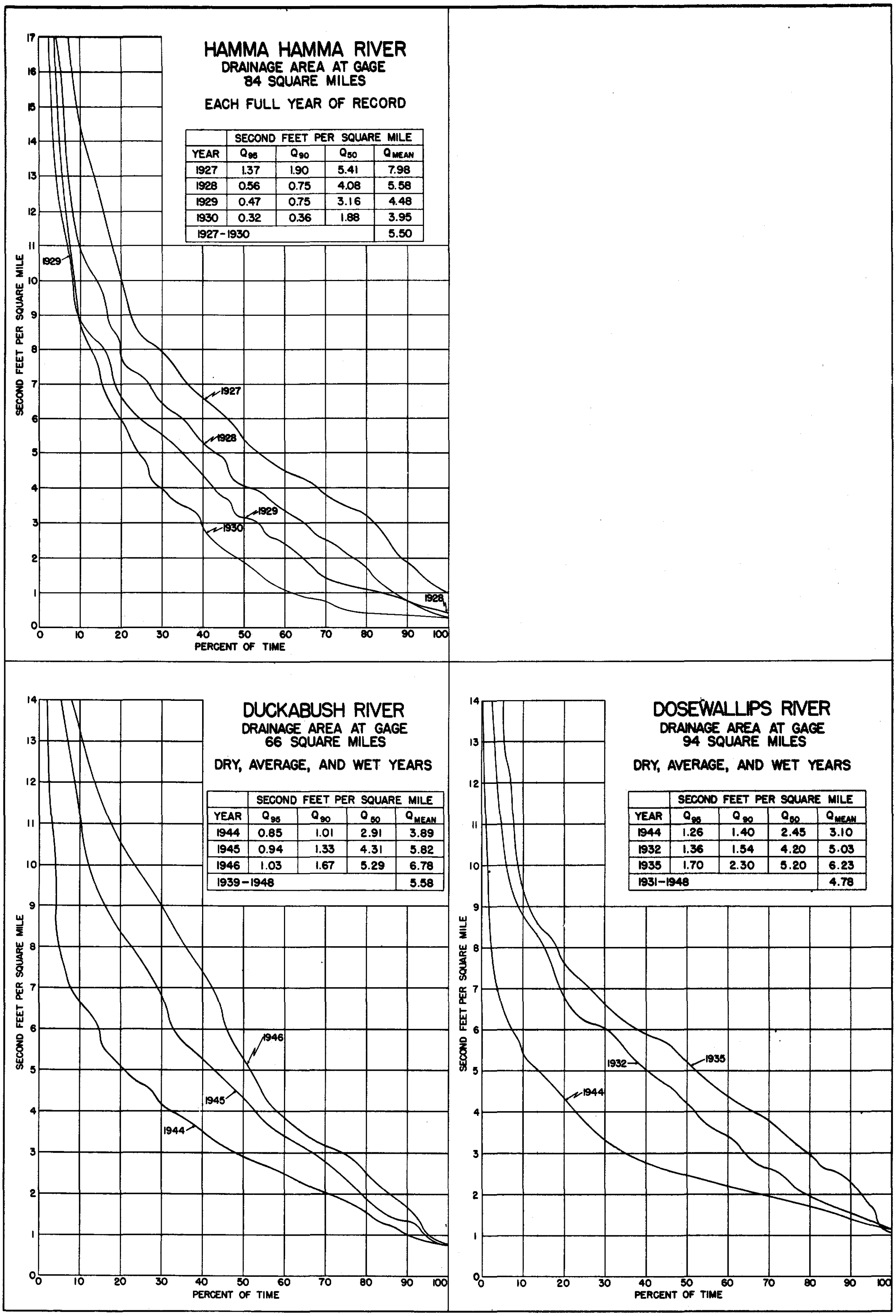
Power site No. (See plate 1)	Year	Q 95	Q 90	Q 50	Q mean	Mean flow 10 years	Reserve for fish
12PM13 Drainage area, 47 sq. mi.	1944	40	47	137	183	260	36
	1945	44	63	203	274		
	1946	48	78	249	319		
12PM14 Drainage area, 54 sq. mi.	1944	46	55	157	210	299	42
	1945	51	72	233	314		
	1946	56	90	286	366		
12PM15 Drainage area, 66 sq. mi.	1944	56	67	192	257	365	51
	1945	62	88	284	384		
	1946	68	110	349	447		

Mean monthly flow and minimum monthly and minimum daily flow for the winter period are shown in the table below.

Flow on the Duckabush River
during winter months 1939-48
(In sec.-ft. per sq. mi.)

Mean Monthly: Month	Mean Monthly: Flow	Probable long time mean 1/	Minimum monthly mean: Month	Minimum monthly mean: Flow	Minimum daily flow: Date	Minimum daily flow: Flow
Nov.	6.00	6.9	Nov. 1939	3.29	Nov. 5, 1939	1.08
Dec.	9.43	8.3	Dec. 1944	5.18	Dec. 12, 1947	2.03
Jan.	7.15	7.1	Jan. 1943	3.88	Jan. 15, 1947	1.97
Feb.	6.74	5.9	Feb. 1938	3.33	Feb. 13, 1948	1.5 (est.)
Mar.	4.42	4.8	Mar. 1942	2.45	Mar. 9-10, 1939	1.45

1/ Based on comparison with flow of the North Fork of the Skokomish River below Staircase Rapids.



Hamma Hamma River — second feet per square mile

YEAR	Q_{95}	Q_{90}	Q_{50}	Q_{MEAN}
1927	1.37	1.90	5.41	7.98
1928	0.56	0.75	4.08	5.58
1929	0.47	0.75	3.16	4.48
1930	0.32	0.36	1.88	3.95
1927-1930				5.50

Duckabush River — second feet per square mile

YEAR	Q_{95}	Q_{90}	Q_{50}	Q_{MEAN}
1944	0.85	1.01	2.91	3.89
1945	0.94	1.33	4.31	5.82
1946	1.03	1.67	5.29	6.78
1939-1948				5.58

Dosewallips River — second feet per square mile

YEAR	Q_{95}	Q_{90}	Q_{50}	Q_{MEAN}
1944	1.26	1.40	2.45	3.10
1932	1.36	1.54	4.20	5.03
1935	1.70	2.30	5.20	6.23
1931-1948				4.78

Figure 4. — Daily flow duration curves for the Hamma Hamma, Duckabush, and Dosewallips Rivers.

Daily flow duration curves were drawn for the 90-day period from December 1 through February 28 for dry, average, and wet years and the following table was prepared showing the mean flow and the flow available 95, 90, and 50 percent of the time.

Winter daily flow duration on the Duckabush River
December 1 through February 28 (90 days)
(In sec.-ft.)

Power site No.	Year	Q 95	Q 90	Q 50	Q mean
12PM13 Drainage area 47 sq. mi.	1944	90	105	169	255
	1946	112	121	226	350
	1945	127	134	239	358
12PM14 Drainage area 54 sq. mi.	1944	104	121	194	293
	1946	129	139	259	402
	1945	146	154	275	411
12PM15 Drainage area 66 sq. mi. (At gaging station)	1944	127	148	237	358
	1946	157	170	317	492
	1945	178	188	336	503

Dosewallips River

Examination of the hydrograph of mean monthly runoff for the Dosewallips River shows that, as for the other two streams, there are two periods of high runoff, but on this stream the spring peak is the highest. Because of the higher median altitude for the basin more winter precipitation falls as snow. This higher altitude together with some small areas of glaciers, probably accounts for the somewhat higher unit flows in the low-water season. This basin is affected more than either the Hamma Hamma or Duckabush Rivers by the Olympic rain shadow and its annual unit runoff is consequently the least of the three.

Flow duration curves for a dry, a wet, and an average year are shown on figure 4 from which the following data on streamflow were taken.

Flow duration on the Dosewallips River
(Flow in sec.-ft. per sq. mi.)

Year	Q 95	Q 90	Q 50	Q mean
1944 dry	1.26	1.40	2.45	3.10
1932 average	1.36	1.54	4.20	5.03
1935 wet	1.70	2.30	5.20	6.23
Mean flow Oct. 1, 1930 to Sept. 30, 1948----------------				4.78

The mean low annual flow at the gage for the 18-year period is 97 second-feet and the median 98 second-feet or 1.04 and 1.05 second-feet per square mile respectively. These annual low flows varied from 65 second-feet (or 0.70 second-feet per square mile) in 1937 to 121 second-feet (or 1.30 second-feet per square mile) in 1938. It has been assumed for this report that 100 second-feet will be released at all times at storage site 12PM12 and that 75 and 80 second-feet respectively will be released over the dam or through the fishways at sites 12PM10 and 12PM11 when available.

The following table for streamflow at the three power sites has been developed from the flow-duration table by applying the drainage-basin area for sites 12PM10 and 12PM11. Since site 12PM12 is downstream from the gaging station the unit runoff is estimated to be less than at the gage, and streamflow has been estimated to be 110 percent of the flow there although the drainage area is 119 percent of the area above the gaging station or 111 square miles.

Streamflow on the Dosewallips River
(In sec.-ft.)

Power site No. (See plate 1)	Year	Q 95	Q 90	Q 50	Q mean	Mean flow 18 years	Reserve for fish
12PM10 Drainage area, 70 sq. mi.	1944	88	98	172	217		
	1932	95	108	294	352	335	75
	1935	119	161	364	436		
12PM11 Drainage area, 76.5 sq. mi.	1944	96	107	187	237		
	1932	104	118	321	385	366	80
	1935	130	176	398	477		
12PM12 Drainage area, 111 sq. mi.	1944	130	144	252	318		
	1932	140	158	431	516	491	100
	1935	175	236	534	639		
Gaging Sta. Drainage area, 93.3 sq. mi.	1944	118	131	229	289		
	1932	127	144	392	469	446	---
	1935	159	215	485	581		

Winter flows are not proportionately as high on the Dosewallips River as on Hamma Hamma and Duckabush Rivers, but the spring peak is somewhat higher. Nevertheless the amount of power available at this time of combined high demand and low Columbia River flow is worth considering. The mean monthly, minimum monthly, and minimum daily flows for the five winter months are tabulated below.

Flow on the Dosewallips River
during winter months 1931-48
(In sec.-ft. per sq. mi.)

Mean monthly		Minimum monthly mean		Minimum daily	
Month	Flow	Month	Flow	Date	Flow
November	4.27	Nov. 1936	0.84	Nov. 30, 1936	0.74
December	5.78	Dec. 1930	1.81	Dec. 3-4, 1936	1/.70
January	5.28	Jan. 1937	1.13	Jan. 20, 30-31, 1937---	.89
February	4.30	Feb. 1937	1.18	Feb. 8-9, 1937	.86
March	3.78	Mar. 1942	1.97	Mar. 14, 1939	1.51
				Mar. 1, 1944	1.51

1/ Lowest daily flow recorded for period of record 1931-48.

The 1945-46 water year had an average winter flow. The mean monthly and minimum daily flows at the gaging station and at the three power sites are shown in the following table.

Flow on the Dosewallips River
during winter months 1945-46
(In second-feet)

Month	Flow at gaging station		Flow at power sites					
			Mean			Minimum daily		
	Mean	Minimum daily	1/ 12PM10	1/ 12PM11	2/ 12PM12	1/ 12PM10	1/ 12PM11	2/ 12PM12
November 1945	381	157	286	312	419	118	129	173
December 1945	562	227	421	461	618	170	186	250
January 1946	434	281	326	356	477	211	230	309
February 1946	291	188	218	239	320	141	155	207

1/ Computed on straight line drainage-area ratio.
2/ Computed as 110 percent of flow at gage.

Flow duration during the 3-month period from December 1 to February 28 is shown on the table below for a dry year (1944), an average year (1946), and a wet year (1945). The flows at the three sites have been computed from the flow at the gage on a straight line drainage-basin-area ratio for sites 12PM10 and 12PM11. For site 12PM12 the flow has been computed as 110 percent of the flow at the gage.

Winter daily flow duration on the Dosewallips River
December 1 through February 28 (90 days)
(In second-feet)

Power site No. (See Plate 1)	Year	Q 95	Q 90	Q 50	Q mean
12PM10	(1944	120	126	182	248
Drainage area,	(1946	140	149	259	325
70 sq. mi.	(1945	164	179	270	377
12PM11	(1944	131	138	199	271
Drainage area,	(1946	153	162	283	355
76.5 sq. mi.	(1945	179	196	295	412
12PM12	(1944	176	185	267	363
Drainage area	(1946	206	218	380	476
111 sq. mi.	(1945	240	263	396	552

WATER UTILIZATION PLAN

Except for a few small farms near Hood Canal, all three basins are now used only for recreational purposes. No water resources development has taken place on any of the three streams except for a fish hatchery, now abandoned, which was once operated on the Duckabush River by the U. S. Fish and Wildlife Service.

Salmon spawn in all three streams and game fish are comparatively plentiful in the three main streams and their tributaries.

There is little land to be reclaimed or benefited by irrigation or flood control projects, and any future development of the water resources of any of the three streams will probably involve hydro-electric power generation.

Any development which would obstruct the channel of any of the streams will have to include adequate facilities for passing fish life over or around the obstruction. It is probable that permission to develop power on any of these streams will include a stipulation that a minimum amount of water must be permitted to flow in the natural channel at all times. In the power estimates included in this report this minimum amount has been assumed to be the median of the seasonal low flows for the period of streamflow record. Since all the power sites discussed involve diversion through artificial conduits, this amount of water must be deducted from the total flow to give the flow available for power. The proposed developments on each stream are discussed in detail as follows.

Hamma Hamma River

Power site 12PM9

Location.--At mile 3.5, in sec. 16, T. 24 N., R. 3 W.

Drainage area.--76 square miles.

Type.--Storage dam with tunnel to power house at tidewater.

Altitude and head.--The altitude of the water surface at the dam site is approximately 400 feet. A dam 140 feet high will give a maximum flow line at altitude 540 feet, and when regulated a mean water-surface altitude of 515 feet. Loss of head in the tunnel is estimated at 10 feet leaving a mean gross head from top of penstock to tailrace of plant of 505 feet when regulated, and 530 feet with the reservoir full.

Storage or pondage.--18,000 acre-feet of usable storage with a dam 140 feet high. (See figure 5 and capacity table in section entitled Stream regulation.)

Duckabush River

Power site 12PM13

Location.--Point of diversion at mile 10.5, 1½ miles upstream from Cliff Creek and one-half mile downstream from the east boundary of the Olympic National Park. The site is in the Olympic National Forest.

Drainage area.--47 square miles.

Type.--Diversion and conduit (probably tunnel). A low dam for diversion purposes only, combined with a tunnel 1.5 miles long to a power house located at the forebay of power site 12PM14 (see below).

Altitude and head.--The forebay at the point of diversion would be at approximate altitude 1,125 feet and the tailrace (forebay of site 12PM14) would be at approximate altitude 720, giving an over-all difference in altitude of 405 feet. Loss of head in the tunnel is estimated at 5 feet leaving a gross head of 400 feet.

Storage or pondage.--None.

Power site 12PM14

Location.--Point of diversion at mile 8.9, just downstream from Cliff Creek. The site is in the Olympic National Forest.

Drainage area.--54 square miles.

Type.--Diversion and conduit (probably tunnel). A low diversion dam combined with a tunnel discharging into a power house at the upper end of the reservoir created by a dam at site 12PM15. This latter site offers two alternative dam sites and, of course, many possible heights of dam. Two possible schemes of development will be discussed here with maximum pool altitudes of 340 and 500 feet. The former would require a 2.4-mile tunnel at site 12PM14, and the latter would require one only 1.5 miles long.

Altitude and head.--The forebay of this site would be at approximate altitude 720 feet (the tailrace altitude of site 12PM13), and the tailrace of the power plant would be either at altitude 500 feet or 340 feet, giving differences in altitude of 220 or 380 feet. Loss of head in the tunnel is estimated at 5 feet for the 1.5-mile tunnel and 10 feet for the 2.4-mile tunnel leaving a gross head of 215 or 370 feet.

Storage or pondage.--None.

Remarks.--If site 12PM15 should be built to a reservoir elevation of 500 feet, it is possible that the most economical plan would combine sites 12PM13 and 12PM14 into one unit with a tunnel 3.0 miles long and a gross head of 615 feet. Such a plan would lose the power from the water entering the stream between mile 8.9 and 10.5 but would require only one power house.

Power site 12PM15

Location.--Two alternative dam sites. If a low dam is built to provide usable storage of 14,000 acre-feet or less, the site at mile 4.3 (12PM15B) in sec. 12, T. 25 N., R. 3 W. would probably be more desirable. If a higher dam is required providing usable storage up to 60,000 acre-feet, then the dam site at mile 4.8 (12PM15A) in sec. 1, T. 25 N., R. 3 W., would probably be more satisfactory. A tunnel 4.2 miles long for 12PM15A and 3.7 miles long for 12PM15B would connect the dam with the power house located at sea level in sec. 16 or 21, T. 25 N., R. 2 W.

Drainage area.--66 square miles.

Type.--Storage dam with tunnel and power house at tidewater.

Altitude and head.--The river surface at the dam site of 12PM15A is at altitude 253 feet and at 12PM15B, 207 feet. With a dam 247 feet high and usable storage of 60,000 acre-feet, the mean water-surface altitude in the reservoir for site 12PM15A would be 440 feet. With a dam 133 feet high and usable storage of 14,000 acre-feet, the mean water-surface altitude of the reservoir for site 12PM15B would be 320 feet. The loss of head in either tunnel is estimated to be 20 feet leaving a mean gross head of 420 feet for 12PM15A and 300 feet for 12PM15B.

Storage or pondage.--12PM15A: 60,000 acre-feet of usable storage with a dam 247 feet high. 12PM15B: 14,000 acre-feet of usable storage with a dam 133 feet high. (See figure 5, and capacity table in section entitled Stream regulation.)

Dosewallips River

Power site 12PM10

Location.--Point of diversion at mile 15 at upstream side of Upper Jumpoff and 1 mile inside the Olympic National Park.

Drainage area.--70 square miles.

Type.--Diversion dam and tunnel 2.4 miles long to power house at forebay of site 12PM11.

Altitude and head.--Forebay elevation 1,520, tailrace elevation, 780. Over-all head, forebay at dam to tailrace, 740 feet. The loss of head in the tunnel is estimated to be 15 feet leaving a gross head estimated to be 725 feet.

Storage or pondage.--None.

Remarks.--Since this site is within the Olympic National Park and would divert water around a scenic falls, its development will be opposed. Approval might be obtained with the stipulation that water would be diverted only in the winter time.

Power site 12PM11

Location.--Point of diversion at mile 12.6, 1½ miles east of the Olympic National Park boundary and in the Olympic National Forest.

Drainage area.--76 square miles.

Type.--Diversion dam and tunnel 4.1 miles long to a power house at mile 8.5, at upper end of reservoir site 12PM12.

Altitude and head.--Forebay elevation 780 feet, tailrace elevation 400 feet. Over-all head, forebay of dam to tailrace, 380 feet. The loss of head in the tunnel is estimated at 20 feet leaving a gross head of 360 feet.

Storage or pondage.--None.

Remarks.--If site 12PM10 is not developed, the point of diversion for this site could very well be moved upstream to the east boundary of the Olympic National Park where the water-surface altitude is 1,040 feet.

Power site 12PM12

Location.--Dam site at mile 3.1, in sec. 28, T. 26 N., R. 2 W. Power house in sec. 35, T. 26 N., R. 2 W., on the shore of Hood Canal.

Drainage area.--111 square miles.

Type.--Storage dam at Rocky Brook dam site and pressure tunnel 2.1 miles long to power house at sea level.

Altitude and head.--The altitude of the river surface at the dam site is 98 feet. A dam 300 feet high will provide 100,000 acre-feet of usable storage with a mean altitude of the pool surface of 340 feet. The estimated loss in the 2.1-mile tunnel is 10 feet, leaving an average gross head of 330 feet.

Storage.--100,000 acre-feet of usable storage with 300-foot dam. (See figure 5 and capacity table in section entitled Stream regulation).

The foregoing scheme of development is by no means the only way to develop the water-power resources of the three streams but it is illustrative of the magnitude of these resources.

It will be noted on the location map (pl. 1) that the Dosewallips and Duckabush Rivers come quite close to each other near the west boundary of the Olympic National Park. The water-surface altitude of the Duckabush River at the park boundary is 1,140 feet, while on the Dosewallips River at the park boundary, it is 1,050 feet. A tunnel 2.5 miles long could divert the Duckabush River at power site 12PM13, where the drainage area is 47 square miles, into the Dosewallips River. The Dosewallips River could be diverted into the Duckabush River in the same general area by a slightly longer tunnel or tunnel and conduit. The power of both streams could therefore be developed through one set of power houses.

Diversion could also be made at power site 12PM15A (mile 4.8) on the Duckabush River through a tunnel 2.7 miles long to a point in the reservoir site for power site 12PM12 on the Dosewallips River. Stream altitude at power site 12PM15A on the Duckabush River is 253 feet. The reservoir on the Dosewallips River can be raised to 400 feet. If this reservoir is developed to its full height, diversion on the Duckabush River would have to be made near mile 7. Such a development would involve only one reservoir on the two streams thus reducing the area of salmon spawning grounds which would be flooded. Diversion between the Hamma Hamma and Duckabush Rivers, although possible, does not appear particularly attractive.

STREAM REGULATION

The flow of all three streams drops to a very low stage during August and September, as indicated by figure 2. If any appreciable amount of firm power is to be developed, it will be necessary to provide reservoirs to impound the high-water flow and release it during the low-water period. There is such a reservoir site on each stream but in each case it is near the mouth. On the Hamma Hamma River the only power site is near the mouth of the stream. All the available power can be firmed to some extent on each, but on the other two streams there are power sites upstream from the reservoir sites which must be operated as run-of-river plants with little or no power available during the low-water period. A detailed discussion of regulation in each of the three basins follows.

Hamma Hamma River

The flow of the Hamma Hamma River can be partially regulated by a dam at power site 12PM9, the capacity table for which is shown below.

Capacity table at power site 12PM9
on the Hamma Hamma River
(Dam site at mile 3.5 in sec. 16,
T. 24 N., R. 3 W.)

Altitude (feet)	Area (acres)	Capacity (acre-feet)
400	0	0
420	6.4	64
440	25.7	385
460	69.0	1,330
480	119	3,210
500	184	6,240
520	324	11,320
540	439	18,950

By regulating between altitudes 455 and 540, 18,000 acre-feet of usable storage can be made available. This storage could have been used to increase low-water flows so that for the period of record, 1927-30, the minimum flow would have been 120 second-feet in the fall of 1929. In an average year the minimum flow would have been 120 second-feet in the fall of 1929. In an average year the minimum flow would be about 200 to 250 second-feet. The availability of 18,000 acre-feet of storage during the 4-year period of record, 1927-30, would have resulted in the following flows:

Q 95-----140 sec.-ft.	Q 50-----400 sec.-ft.
Q 90-----167 sec.-ft.	Q mean---420 sec.-ft.

Because of the importance of winter power, a daily differential mass curve was plotted for the period November 1, 1926, through February 28, 1927. This period approximates a normal winter. By utilizing 18,000 acre-feet of storage, a flow of 614 second-feet would have been available during the period under consideration with some additional water being lost over spillway on December 3, 4, and January 12-16. Under this assumed operation the reservoir was empty November 11 and full on December 3 and 4 and from January 12 through January 16. On February 28, 4,500 acre-feet of water remained in the reservoir.

Duckabush River

There are two possible storage sites on the Duckabush River. These are alternate sites and development at one would preclude development of the other. The first designated as power site 12PM15A, is at mile 4.8 in sec. 1, T. 25 N., R. 3 W. The capacity table for the reservoir created by a dam at this point is shown below.

Capacity table at power site 12PM15A
on the Duckabush River

(Dam site at mile 4.8 in sec. 1,
T. 25 N., R. 3 W.)

Altitude (feet)	Area (acres)	Capacity (acre-feet)
253	0	0
260	4	14
280	35	414
300	109	1,850
320	168	4,610
340	237	8,650
360	285	13,870
380	336	20,070
400	379	27,230
420	416	35,190
440	437	43,730
460	462	52,730
480	499	62,330
500	539	72,710

By regulating between elevations 360 and 500, approximately 60,000 acre-feet of storage is available, enough to give almost complete regulation on a yearly basis. A differential mass curve of monthly flows was prepared for the period October 1938 through September 1948 when the mean flow for the 10-year period was 365 second-feet. The period of lowest flow occurred in the 28 months from July 1942 through October 1944. A regulated flow of 305 second-feet could have been maintained for the first 13 months and 290 second-feet for the last 15 months. In an average year a regulated flow of 365 second-feet could be maintained 100 percent of the time, and in a wet year 420 second-feet would be obtainable.

The other site, designated as power site 12PM15B, is known as the Interrorem dam site and is located at mile 4.3, in sec. 12, T. 25 N., R. 3 W. The capacity table for the reservoir created by a dam at this site is shown below.

Capacity table at power site 12PM15B,
Interrorem dam site,
on the Duckabush River

(Dam site at mile 4.3, in sec. 12,
T. 25 N., R. 3 W.)

Altitude (feet)	Area (acres)	Capacity (acre-ft.)
210	0	0
220	2	10
240	6	90
260	26	410
280	74	1,410
300	181	3,960
320	262	8,390
340	339	14,400

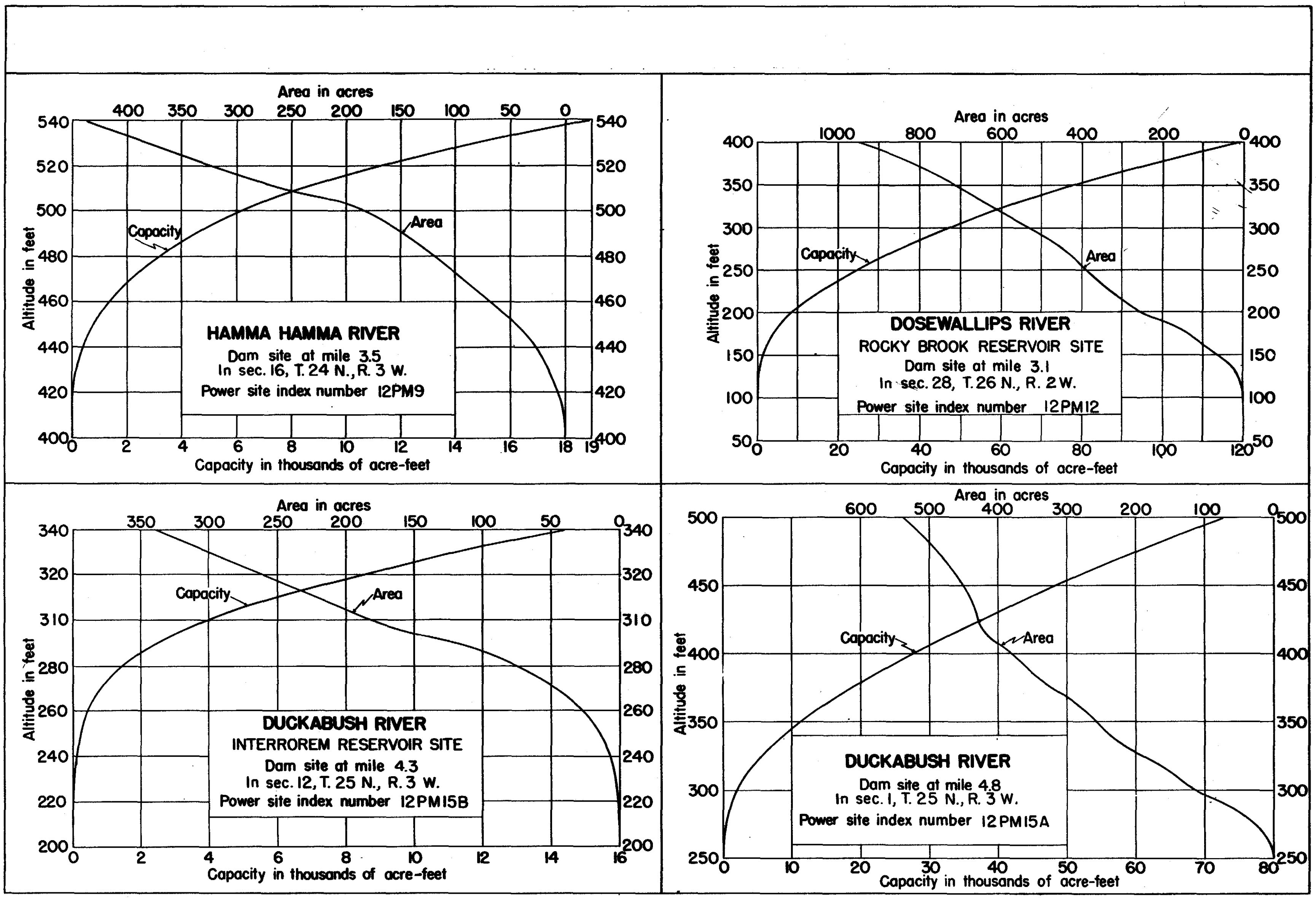


Figure 5.— Reservoir area and capacity curves for sites on the Hamma Hamma, Duckabush, and Dosewallips Rivers.

By regulating between elevations 260 and 340, 14,000 acre-feet of storage is available. This is not sufficient to control the stream but does increase the low-water flows. Computations on the differential mass curve indicate that this storage would have been drawn upon for 15 periods between October 1, 1938 and September 30, 1948. These periods varied from 2 to 5 months and totaled 56 months or 47 percent of the time. Low flow for the period was during a 3-month period in the summer and fall of 1942 when only 153 second-feet could have been maintained. The flow would have been less than 200 second-feet for 17 months, and the mean flow during the 56 months of regulation would have been 252 second-feet. A very considerable part of the flow of the stream would have been lost over the spillway with only 14,000 acre-feet of storage. The flow duration for regulated flow would have been as follows.

	Q 95	Q 90	Q 50	Q mean
12PM15A	290	290	365	372
12PM15B	158	195	339	365

Because of the special importance of winter flows, a differential mass curve of daily flows was prepared for the period November 1, 1945, through February 28, 1946. This period is fairly representative of an average winter, and 14,000 acre-feet of storage was found to be sufficient to regulate the flow during this period. The reservoir did not start to fill until November 13, but from then until January 5 a flow of 586 second-feet could have been maintained with the reservoir full on the latter date. From January 6 through February 22, a flow of 431 second-feet was available with the reservoir empty on the latter date. For the rest of February, flows in excess of 500 second-feet could have been maintained with the reservoir filling.

Dosewallips River

As with both the Hamma Hamma and the Duckabush Rivers no storage sites exist in the headwaters of the Dosewallips River and no regulation is possible at power sites 12PM10 and 12PM11. Plants at these sites will operate as run-of-river plants and will develop little if any power during the low-water season in August and September. The small glacial areas at the headwaters act as natural storage reservoirs but do not release enough water in the low-water periods to be of any practical value since all this flow will probably be required for fish preservation.

Site 12PM12 includes a reservoir site which will regulate the flow through the lowest 400 feet of head on the stream. A capacity table for this site follows.

Capacity table at power site 12PM12, Rocky Brook reservoir site, on the Dosewallips River (Dam site at mile 3.1 in sec. 28, T. 26 N., R. 2 W.)

Altitude (feet)	Area (acres)	Capacity (acre-feet)
98	0	0
120	8	88
140	34	508
160	93	1,780
180	150	4,210
200	250	8,210
220	314	13,850
240	368	20,670
260	406	28,410
280	458	37,050
300	525	46,880
320	603	58,160
340	675	70,940
360	752	85,210
380	838	101,110
400	950	118,990

By regulating the top 160 feet of the reservoir 100,000 acre-feet of usable storage is available with a mean water-surface elevation of 340 feet.

The differential mass curve for the period October 1930 to September 1948 shows that with 100,000 acre-feet of usable storage, a regulated flow of 400 second-feet could have been maintained 100 percent of the time. The minimum flow would have occurred from August 1936 through April 1944. The flows available under these conditions would have varied from 400 second-feet to 645 second-feet, with a flow in an average year about the same as the mean flow for the period, 491 second-feet. In a wet year such as 1935, the average flow would have been 590 second-feet. The available flow for power generation would be reduced 100 second-feet for fish preservation, leaving 300 second-feet in a minimum year, 391 second-feet in an average year, and 490 second-feet in a wet year.

A dam 142 feet high with a flow line at altitude 240 feet would provide 15,000 acre-feet of storage between altitudes 188 feet and 240 feet. The mean water-surface altitude, while regulated through this range, would be 218 feet. This amount of storage will not completely regulate the flow of the stream and considerable water will be lost over the spillway during high water. It will increase the low flow considerably, however, and is sufficient to completely regulate the flow during the winter months of an average year such as 1946.

Storage of 15,000 acre-feet at Rocky Brook dam site would increase the low-water flow to about 200 second-feet in a dry year and to 320 second-feet in an average year.

A differential mass curve of daily flows was plotted for the period November 1, 1945 through February 28, 1946, which period approximates a normal winter. By utilizing 15,000 acre-feet of storage the following flows could have been maintained during this period. The reservoir would have started to fill on November 13 and from then until the end of February a flow of 485 second-feet could have been maintained. With 100 second-feet reserved for fish preservation, 385 second-feet would have been available continuously for power development.

The flow duration for regulated flow would have been as follows.

Power site 12PM12	Q 95	Q 90	Q 50	Q mean
Dam to alt. 240 ft.	250	280	435	491
Dam to alt. 400 ft.	400	400	489	491

WATER POWER

Any power plants constructed on these streams will very likely be interconnected with the Northwest Power Pool. The largest source of power in this pool is the Columbia River where the available storage is only a small fraction of that needed to completely regulate the flow and where both minimum flow and minimum power production come in January or February. Since peak demand in the Pacific Northwest comes in December or January, any generating capacity on the smaller western Washington streams which is firm for the 90-day period from December 1 through February 28, can be used to firm up the Columbia River capacity. For this reason power estimates in the following pages have been shown in two ways.

The first is the conventional basis which gives power estimates based on the mean flow and the flow available 95, 90, and 50 percent of the time. The second shows the power available during the 90-day period December-February based on the above-mentioned flow conditions.

In the following pages all water-power estimates have been computed from the formula: $P = 0.068\ Q\ H$

where P = power in kilowatts at low side of power house transformer.
Q = flow of water through the turbine in second-feet.
H = gross head, the difference in altitude between the top of the penstock and the tailrace of the plant, in feet.

This formula assumes an over-all efficiency of 80 percent.

Hamma Hamma River

At power site 12PM9 (mile 3.5) a dam 140 feet high would have a maximum flow line at altitude 540 feet and while regulated the mean altitude would be 515 feet. A tunnel 2.0 miles long would connect the dam with a penstock to the power house at sea level on Hood Canal. The mean gross head on such a plant is estimated at 505 feet. If a plant were operated on a run-of-river basis with the reservoir elevation always at 540 feet the gross head would be 530 feet.

In the following estimates of power it has been assumed that 50 second-feet have been spilled at the dam continuously to provide for fish life. This amount of water has been subtracted from the available flows.

The following table shows the power available on an all-year basis for the period 1927-30. This period was one of subnormal flow and these estimates are believed to be conservative.

The power available during an average winter period has also been shown in this table.

Power estimates in kilowatts at power site 12PM9,
mile 3.5 on the Hamma Hamma River

Year or Period	Gross head, feet	Flow in second-feet percent of time				Power in kilowatts percent of time			
		95	90	50	mean	95	90	50	mean
With natural flow1/									
Dry year 1930	530	0	0	93	250	0	0	3,350	9,000
Average year	530	4	20	300	429	144	720	10,800	15,460
Wet year 1927	530	54	94	361	556	1,950	3,390	13,000	20,040
With regulated flow2/									
1927-30	505	90	117	350	370	3,090	4,020	12,020	12,700
Winter power3/									
Nov. 11, 1926 to Feb. 28, 1927 (Average winter).	505	-	-	-	564	-	-	-	19,370

1/ Flow available after bypassing 50 second-feet for fish preservation.
2/ Flow available with 18,000 acre-feet of storage and bypassing 50 second-feet for fish preservation.
3/ Flow available continuously with 18,000 acre-feet of storage and bypassing 50 second-feet for fish preservation.

Duckabush River

Estimates of flow available 95, 90, and 50 percent of the time and mean annual flow for dry, average, and wet years at the three power sites have been listed in the table entitled Streamflow on Duckabush River. Since some water will have to be left in the stream for the protection of fish life, the water available for power generation will be the amount shown in this table less the amount required for fish. This amount has been assumed to be the median low annual flow or 51 second-feet at the gaging station. On a straight drainage-basin-area ratio the flow would be 36, 42, and 51 second-feet at power sites 12PM13, 12PM14, and 12PM15 respectively.

Power from regulated flow.--A dam built at site 12PM15A to provide 60,000 acre-feet of usable storage will regulate the flow at this site. Estimates of the power available with the stream so regulated, allowing 51 second-feet for fish preservation, for the 10-year period from October 1938 through September 1948 are as follow. The minimum-flow period came from July 1942 through October 1944. For the first 13 months of this period, 7,250 kilowatts and for the second part of the period, 15 months, 6,830 kilowatts could have been generated continuously. In an average year, such as 1945, 8,970 kilowatts, and in a wet year, such as 1946, 10,540 kilowatts could have been generated 100 percent of the time.

If a low dam were constructed at site 12PM15B, 14,000 acre-feet of usable storage, would be provided. This amount of storage, while insufficient to permit utilization of all the runoff from the basin, will materially increase the low-water flow. The lowest flow came in a 3-month period in the summer and fall of 1942 when 2,080 kilowatts of power could have been generated. Storage would have been drawn upon for 56 months or 47 percent of the 10-year period of record. The regulated flows provided during these low-water periods would have generated power varying from 2,080 to 7,900 kilowatts with a mean of 4,100 kilowatts. During the remaining 53 percent of the time more than 7,900 kilowatts could have been generated.

Because of the importance of winter power when the Columbia River flow is low and power demand is at its maximum, the power available during an average winter period such as November 1, 1945 to February 28, 1946 was determined. For such a period the 14,000 acre-feet of storage provided adequate control. In the above period the reservoir would have started to fill on November 13. From that date until January 5, 10,900 kilowatts and from January 5 until February 28, 7,750 kilowatts could have been generated.

Power for various years and periods is shown in the following table. The years 1944, 1945, and 1946 shown for natural flow are considered representative of dry, average, and wet years. For winter power with natural flow the representative dry, average, and wet years were 1944, 1946, and 1945 respectively.

Power estimates, in kilowatts,
on the Duckabush River

Power site number	Gross Head feet	Year or period	Flow in second-feet percent of time				Power in kilowatts percent of time			
			95	90	50	mean	95	90	50	mean
With natural flow 1/										
12PM13	400	1944	4	11	101	147	109	299	2,750	4,000
		1945	8	27	167	238	218	734	4,540	6,470
		1946	12	42	213	283	326	1,140	5,790	7,700
12PM14A	215	1944	4	13	115	168	58	190	1,680	2,460
		1945	9	30	191	272	132	439	2,790	3,980
		1946	14	48	244	324	205	702	3,570	4,740
12PM14B	370	1944	4	13	115	168	100	327	2,890	4,230
		1945	9	30	191	272	226	755	4,800	6,840
		1946	14	48	244	324	352	1,210	6,140	8,150
12PM15A 2/	480	1944	5	16	141	206	163	522	4,600	6,720
		1945	11	37	233	333	359	1,210	7,600	10,870
		1946	17	59	298	396	555	1,930	9,730	12,920
12PM15B 2/	320	1944	5	16	141	206	109	348	3,070	4,480
		1945	11	37	233	333	239	805	5,070	7,250
		1946	17	59	298	396	370	1,280	6,480	8,620
With regulated flow										
12PM15A 3/	420	1938 to 1948	239	239	314	321	6,830	6,830	8,970	9,170
12PM15B 4/	300	1938 to 1948	107	144	288	314	2,180	2,940	5,880	6,410
Winter power with natural flow 5/ 6/										
12PM13	400	1944	54	69	133	219	1,470	1,880	3,620	5,960
		1946	76	85	190	314	2,070	2,310	5,170	8,540
		1945	91	98	203	322	2,480	2,670	5,520	8,760
12PM14A	215	1944	62	79	152	251	906	1,150	2,220	3,670
		1946	87	97	217	360	1,270	1,420	3,170	5,260
		1945	104	112	233	369	1,520	1,640	3,410	5,390
12PM14B	370	1944	62	79	152	251	1,560	1,990	3,820	6,320
		1946	87	97	217	360	2,190	2,440	5,460	9,060
		1945	104	112	233	369	2,620	2,820	5,860	9,280
Winter power with regulated flow 5/										
12PM15A	420	1946	380	380	441	535	10,850	10,850	12,590	15,280
12PM15B	300	1946	380	380	441	535	7,750	7,750	9,000	10,900

1/ Flow available after appropriate deduction for fish purposes from values shown in table on page 10.

2/ With reservoir full and operating as a run-of-river plant.

3/ Flow available utilizing 60,000 acre-feet of storage and bypassing 51 sec.-ft. for fish preservation.

4/ Flow available utilizing 14,000 acre-feet of storage and bypassing 51 sec.-ft. for fish preservation.

5/ Three-month period ending February 28 of year indicated.

6/ Flow available after appropriate deduction for fish purposes from values shown in table on page 12.

Dosewallips River

Estimates of flow available 95, 90, and 50 percent of the time and mean annual flow for dry, average, and wet years have been listed in the table entitled Streamflow on the Dosewallips River. These estimates are for the entire flow past the three power sites. Since some water will have to be left in the stream for the protection of fish life, the water available for power generation will be the amount shown in this table less the amount required for fish. The amount has been assumed to be the median of the lowest flows recorded each year for the period of record, or 98 sec.-ft. at the gaging station. The comparable flows, computed on a straight drainage-basin-area ratio, would be 75 second-feet for site 12PM10, and 80 second-feet for site 12PM11. A value of 100 second-feet has been assumed for site 12PM12 as the tributary area between it and the gaging station contributes very little runoff during the low-water period.

Power sites 12PM10 and 12PM11 have no storage possibilities and will be operated as run-of-river plants. Power site 12PM12 is located at the Rocky Brook dam site where regulation is possible. Regulated streamflow from behind dams 142 and 302 feet high have been discussed under Stream regulation, and flows available 95, 90, and 50 percent of the time and mean flow have been listed on page 19. The flow available for power generation will be reduced 100 second-feet because of the requirements for fish preservation.

Available winter power is not as great, proportionately, on the Dosewallips River as on the Hamma Hamma or Duckabush Rivers. It is however, considerably greater than that available in July and August. Complete regulation of the winter flow at site 12PM12 is possible with only 15,000 acre-feet of storage in an average winter such as 1946. The power available on the Dosewallips River under the conditions outlined above is shown in the table on the next page.

Power estimates, in kilowatts, on the Dosewallips River

Power site number	Gross Head feet	Year or period	Flow in second-feet percent of time 95	90	50	mean	Power in kilowatts percent of time 95	90	50	mean
With natural flow 1/										
12PM10	725	1944	13	23	97	142	641	1,130	4,780	7,000
		1932	20	33	219	277	986	1,630	10,800	13,660
		1935	44	86	289	361	2,170	4,240	14,250	17,800
12PM11	360	1944	16	27	107	157	392	661	2,620	3,840
		1932	24	38	241	305	588	930	5,900	7,470
		1935	50	96	318	397	1,220	2,350	7,780	9,720
12PM12 2/	390	1944	30	44	152	218	796	1,170	4,030	5,780
		1932	40	58	331	416	1,060	1,540	8,780	11,030
		1935	75	136	434	539	1,990	3,610	11,510	14,290
With regulated flow										
12PM12 3/	330	1930	300	300	389	391	6,730	6,730	8,730	8,770
12PM12 4/	208	1948	150	180	335	391	2,120	2,540	4,740	5,530
Winter power with natural flow 5/ 6/										
12PM10	725	1944	45	51	107	173	2,220	2,510	5,280	8,530
		1946	65	74	184	250	3,200	3,650	9,070	12,320
		1945	89	104	195	302	4,390	5,130	9,610	14,890
12PM11	360	1944	51	58	119	191	1,250	1,420	2,910	4,680
		1946	73	82	203	275	1,790	2,010	4,970	6,730
		1945	99	116	215	332	2,420	2,840	5,260	8,130
12PM12 2/	390	1944	76	85	167	263	2,020	2,250	4,430	6,970
		1946	106	118	280	376	2,810	3,130	7,430	9,970
		1945	140	163	296	452	3,710	4,320	7,850	11,990
Winter power with regulated flow 6/										
12PM12	330	1946	7/ 385				7/ 8,640			
	208	1946	8/ 385				8/ 5,450			

1/ Flow available after appropriate deduction for fish purposes from values shown in table on page 12.
2/ With reservoir full and operating as run-of-river plant.
3/ Flow available utilizing 100,000 acre-feet of storage and bypassing 100 second-feet for fish preservation.
4/ Flow available utilizing 15,000 acre-feet of storage and bypassing 100 second-feet for fish preservation.
5/ Flow available after appropriate deduction for fish purposes from values shown in table on page 13.
6/ Three-month period ending February 28 of year indicated.
7/ Flow and power available 100 percent of time for 90 days utilizing 15,000 acre-feet of storage, dam built to an altitude of 400 feet, 100 second-feet bypassed for fish preservation.
8/ Flow and power available 100 percent of time for 90 days utilizing 15,000 acre-feet of storage, dam built to an altitude of 240 feet, 100 second-feet bypassed for fish preservation.

The power on the three streams under consideration has been summarized in the following table. This table has two sections, one showing power with natural flow at all sites and one showing power with the regulated flow at the one storage site on each stream combined with the run-of-river sites. In the former case the dams at the potential storage sites have been considered as developing head only and no use made of the storage, operating always at a full reservoir. Details relating to the sites are shown in the footnotes to the table. Power values at the sites using natural flow are based on streamflow values for what was considered an average year whereas power values at the sites with regulated flow are based on a mean value for the period of available streamflow record.

The values in the following table clearly indicate the advantage to be gained by using regulated flow at the sites where it can be developed.

Summary of estimated power, in kilowatts

Location	Type of flow	Percent of time 95	90	50	mean
Hamma Hamma River Site 12PM9	natural 1/	144	720	10,800	15,460
	regulated	3,090	4,020	12,020	12,700
Duckabush River Sites 12PM13, 12PM14A, and 12PM15A	natural 1/	710	2,380	14,930	21,320
	regulated 2/	7,180	8,000	16,300	19,600
Dosewallips River Sites 12PM10, 12PM11, and 12PM12	natural 1/	2,630	4,100	25,480	32,160
	regulated 3/	8,300	9,290	25,430	29,900
Total	natural	3,480	7,200	51,210	68,940
	regulated	18,570	21,310	53,750	62,200

1/ All sites operated as run-of-river plants.
2/ Natural flow at sites 12PM13 and 12PM14A; regulated flow at site 12PM15A.
3/ Natural flow at sites 12PM10 and 12PM11; regulated flow at site 12PM12.

An analysis of the effect on the power picture of operating several of the run-of-river plants jointly with one or more of the storage plants has not been attempted. Such an analysis would undoubtedly show a greater amount of firm power than the sum generated by the individual plants, but since the plants will be operated in connection with the Northwest Power Pool the value of the data so obtained would be small. Such interconnection will be a very simple and inexpensive operation because Bonneville Power Admininistration has recently constructed a transmission line along the west side of Hood Canal a few miles back from tidewater which cuts across all three basins. In addition, the city of Tacoma operates a transmission line from Hoodsport to Tacoma, where ties exist with the Bonneville Power Administration, the city of Seattle, and the Puget Sound Power and Light Company systems.

The illustrative plans of development suggested in this report may not be the ones followed in actual development. However, these schemes along with the basic data do indicate the magnitude of the potential power available and the methods by which it can be most logically developed.

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