7. Interested parties were advised of the nature of the report of the division engineer and invited to present additional information to the Board. Careful consideration was given to the communications received.

VIEWS AND RECOMMENDATIONS OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

8. The Board concurs generally in the views of the reporting officers. The proposed Foster Creek project is essentially a power development, well situated and capable of producing at low cost a large amount of electrical energy for the needs of the northwest area. Its value for irrigation is small and it is of no value for navigation or flood control. Authorization of the Foster Creek project at this time is considered advisable in order that plans can be made in advance and construction undertaken at the proper time to meet the regional needs for hydroelectric power. In no event should construction of the Foster Creek project take precedence over that of the more important multiple-purpose projects on the Columbia and Snake Rivers already authorized by Congress.

9. The Board recommends authorization, as a part of the comprehensive plan for improvement of the Columbia River, of construction of Foster Creek Dam and powerhouse in accordance with the plans in the report of the district engineer and with modification thereof as in the discretion of the Secretary of War and the Chief of Engineers may be advisable at an estimated cost of $71,000,000 for the construction of the first three units, and $33,000,000 additional for a total of 15 units, and with annual maintenance and operation ranging from $650,000 for the first three units to $1,200,000 for the 15 units.

For the Board:

THOMAS M. ROBINS,
Major General, Senior Member.

REVIEW REPORT ON COLUMBIA RIVER AT FOSTER CREEK, WASH.

SYLLABUS

The district engineer finds that construction of a dam for the improvement of Columbia River at Foster Creek is practicable and that it is favorable in cost and in the power rate required to carry the investment.

He submits a plan for a straight gravity overflow dam with normal pool at elevation 937.5, a powerhouse of 960,000-kilowatt capacity, and an intake with provision for increased capacity as required to utilize future upstream storage.

He believes the growth of power load in the region will absorb the output of the Foster Creek project, in addition to that of all other generating capacity definitely planned for other locations within a few years.

He recommends adoption of the project as the next step in the comprehensive development of the Columbia River Basin.

TABLE 1.—*Pertinent data*

1. Location of dam site, Okanogan and Douglas Counties, Wash., sec. 21, T. 29 N., R. 25 E., Willamette meridian:

Above mouth of Columbia River	river-miles	545
Above mouth of Snake River	do	221
Above mouth of Okanogan River	do	12
Below origin of Columbia River	do	660
Below international boundary	do	200
Below Grand Coulee Dam	do	51

TABLE 1.—*Pertinent data*—Continued

1. Location of dam site—Continued		
From Seattle, Wash. (principal city west, population, 368,000)	road-miles	[illegible]
From Spokane, Wash. (principal city east, population, 122,000)	do	[illegible]
From Brewster, Wash. (nearest railroad, population, 447)	do	[illegible]
From Bridgeport, Wash. (post office, population 320)	do	[illegible]
2. Stream flow:		
Drainage area above dam site	square miles	7[illegible]
Run-off, mean annual, 1913–42	acre-feet	77,[illegible]
Run-off, mean annual, 1913–42	inches	1[illegible]
Discharge (Grand Coulee gage):		
Minimum daily, unregulated January–February 1937	cubic feet per second	13,[illegible]
Mean, usual minimum month (February), 1913–42	do	3[illegible]
Mean, usual maximum month (June), 1913–42	do	2[illegible]
Mean, annual, 1913–42	do	10[illegible]
Maximum flood, June 1894, USGS estimate	do	7[illegible]
Spillway design flood	do	1,250,[illegible]
Slope, average low-water, international boundary-Snake River	feet/mile	[illegible]
Slope, average low-water, Grand Coulee-Foster Creek	do	[illegible]
Slope, maximum low-water, Grand Coulee-Foster Creek	do	1[illegible]
3. Hydraulics:		
Pool elevation, normal	feet mean sea level	937[illegible]
Pool elevation, minimum probable	do	93[illegible]
Pool elevation, maximum known flood (1894)	do	943[illegible]
Pool elevation, spillway design flood	do	957.[illegible]
Draw-down, usual maximum below tops of gates	feet	[illegible]
Tail-water elevation, normal low (45,000 cubic feet per second)	feet mean sea level	765[illegible]
Tail-water elevation, at spillway design flood	do	84[illegible]
Tail-water elevation, maximum known flood (1894)	do	81[illegible]
Reservoir contents, normal pool	acre-feet	480,000
Reservoir pondage, maximum (5 feet) drawn-down	do	36,000
4. Dam, straight concrete gravity over-flow type.		
Spillway section:		
Height, foundation to roadway	feet	229
Length, net opening	do	1,000
Crest elevation	feet mean sea level	908
Tops of gates, elevation	do	940
Top of roadway, elevation	do	960
Tainter gates (25), length	feet	40
Sluices (12), dimensions	do	5.67 x 10
Sluices, capacity at design flood, total	cubic feet per second	55,000
Spillway capacity at design flood	do	1,250,000
Nonoverflow sections:		
Length, right (north) side	feet	390
Length, left (south) side	do	94
Top elevation	feet mean sea level	960
Freeboard	feet	2.6
5. Intake:		
Wall, concrete gravity, length	feet	1,642
Wall height	do	130
Canal, floor elevation	feet mean sea level	850
Penstocks, (15), steel plate, diameter	feet	23
6. Powerhouse:		
Building dimensions, over-all	do	166 x 1,162
Installation:		
Main generators	units	15
Main generators rated capacity each	kilowatts	64,000
Main generators spacing	feet	67
House generators	units	3
Main turbines, Francis, rating each	horsepower	87,000
Plant, installed capacity	kilowatts	960,000
Transformers, 8 banks of 3, rating per bank	kilovolt-amperes	150,000
Power characteristics, critical period:		
Study 6. Uniform flows from Flathead and Kootenay Lakes; Grand Coulee operation coordinated with Foster Creek:		
Prime power	megawatts	526
Firm capability, 67 percent load factor	do	785
Annual firm energy, 67 percent load factor	million kilowatt-hours	4,607
Hydraulic characteristics:		
Plant discharge, full gate, rated head	cubic feet per second	83,800
Head, maximum gross at 15,000 cubic feet per second	feet	183.1
Head, minimum gross at 500,000 cubic feet per second	do	148.6
Head, rated net	do	162.0
7. Land and relocations:		
Reservoir:		
Area within meanders	acres	6,687
Area above meanders, Government-owned	do	2,115
Area above meanders, to be acquired	do	13,043
Area over-all	do	21,845
Relocations, roads	miles	4.6
Access and construction:		
Areas, construction zone	acres	5,946
Areas, construction right-of-way (including transmission line)	do	547
Railroad construction (including sidings)	miles	12.5
Highway construction	do	13.0
Highway relocations	do	2.2
Bridges, major construction	units	3
Transmission-line construction	miles	30

TABLE 1.—*Pertinent data*—Continued

8. Cost estimates, 15-unit installation:	
Construction (1940 prices)	$104,050,000
Interest during construction (3 percent on average time)	6,380,000
Investment, total	110,430,000
Investment, per kilowatt installed capacity	115
Annual, uniform after completion of 15-unit installation:	
Interest on investment, 3 percent	3,313,000
Amortization and replacements, 50-year items	624,000
Amortization and replacements, 35-year items	699,000
Payments in lieu of taxes	2,000
Contingency reserve, 0.10 percent	110,000
Operation and maintenance	1,202,000
Total annual charges	5,950,000

WAR DEPARTMENT,
OFFICE OF THE DISTRICT ENGINEER,
Seattle, Wash., August 15, 1945.

Subject: Review of report on Columbia River in the vicinity of Foster Creek.
To: The Division Engineer, Pacific Division, San Francisco, Calif.

CHAPTER I—INTRODUCTION

1. *Authority.*—This report is submitted pursuant to the following resolution adopted March 24, 1942:

Resolved by the Committee on Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors created under section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby, requested to review the reports on the Columbia River and tributaries, Oregon and Washington, submitted in House Document Numbered 103, Seventy-third Congress, first session, and previous reports, with a view to determining if improvements at and in the vicinity of Foster Creek are advisable at the present time.

2. *Report under review.*—The report contained in House Document No. 103 referred to in the committee resolution and reviewed herein, was made under the provisions of House Document No. 308, Sixty-ninth Congress, first session, which was enacted into law with modifications, in section 1 of the River and Harbor Act approved January 21, 1927. As defined in House Document No. 308 and in the River and Harbor Act of March 3, 1925, the primary purpose of House Document No. 103 was—

the formulation of general plans for the most effective improvement of the river for the purpose of navigation, and the prosecution of such improvement in combination with the most efficient development of the potential water power, the control of floods, and the needs of irrigation.

3. The report outlined a general plan for 10 dams on the main stream at the following sites between the international boundary and tidewater: Grand Coulee, Foster Creek, Chelan, Rocky Reach, Rock Island Rapids, and Priest Rapids in Washington; Umatilla Rapids, John Day Rapids, The Dalles, and Warrendale (now Bonneville) in both Oregon and Washington. In his report on the general plan, the Chief of Engineers concluded that coordinated power development on Columbia River was feasible and economical; that power for future irrigation should be supplied at the cost of production; that flood control was a minor interest, susceptible of easy solution by local

interests. As to navigation, the Chief of Engineers found it to difficult and costly in the upper Columbia above Wenatchee without prospect of water-borne commerce under those condition.

4. The dams at Grand Coulee and Bonneville have been built Federal agencies. The Rock Island Rapids site has been develo for power by private interests. Umatilla Dam was authorized the River and Harbor Act of March 2, 1945. The Foster Creek D as contemplated in House Document No. 103, was a straight, co crete, gravity type structure 225 feet high and 2,000 feet long. was proposed primarily for hydroelectric power production, wi installed capacity of 691,200 kilowatts, a hydraulic capacity of 77,0 cubic feet per second, and average head of 154.9 feet. It would bac the river up to the foot of Grand Coulee Dam, a distance of 51 rive miles.

5. *Scope.*—This report is limited by the authorizing resolution to a consideration of improvements at and in the vicinity of Foster Creek. In accordance with the comprehensive plan, it considers development of the site primarily for the production of power, presents plans and cost estimates therefor, and discusses the benefits that would result.

6. *Geographical names.*—Certain terms and place names used in this report are defined or clarified as follows:

(*a*) *Coulee Dam.*—The town situated on both banks of Columbia River, including the former Mason City, just below Grand Coulee Dam.

(*b*) *Grand Coulee Dam.*—The dam structure across Columbia River near the Grand Coulee, a prehistoric, dry channel from which the dam takes its name.

(*c*) *Grand Coulee.*—Used briefly for the Grand Coulee project, which includes the dam, reservoir, and power development. In connection with hydrology, it refers to the gage just below the dam.

(*d*) *Columbia River Reservoir.*—The reservoir formed by Grand Coulee Dam, extending to the international boundary.

(*e*) *Clark Fork.*—Clark Fork, as used in this report, includes Pend Oreille River, the portion of the river system below Pend Oreille Lake.

7. *Available data.*—In addition to the data in the report under review, the principal data available at the inception of this study were:

(*a*) Okanogan quadrangle, Washington, (1905) United States Geological Survey, topographic sheet. Scale 1:125,000; contour interval, 100 feet.

(*b*) Jameson quadrangle, Washington, (1918) Corps of Engineers, U. S. Army, progressive military map. Scale 1:125,000.

(*c*) Original Township Survey and Resurvey Plats, General Land Office, photographs.

(*d*) Township maps, Metsker. Scale 2 inches equals 1 mile.

(*e*) Plan of Columbia River, International boundary to Rock Island Rapids (below Wenatchee), Wash. (1930), Corps of Engineers and the U. S. Geological Survey, 10 sheets. Scale 1:31,680 (1 mile equals 2 inches); contour interval 20 feet; land topography from aerial photographs (item (*f*) below) by stereophotogrammetry; river topography from a profile taken at low water.

(*f*) Aerial survey photographs (1930), Corps of Engineers and the U. S. Geological Survey, 4¾ inches by 4¾ inches; scale 1:22,500.

(*g*) Aerial survey photographs (1939), Agricultural Adjustment Agency, 9¾ inches by 12¼ inches; scale approximately 1 inch equals 1,320 feet.

(*h*) General highway and transportation maps. (1936) Department of Highways, State of Washington.

(*i*) State highway plans and profiles in the vicinity of Foster Creek, Department of Highways, State of Washington. Scale 1 inch equals 200 feet Horizontal, and 1 inch equals 40 feet vertical.

(*j*) Plan and profile of location from Brewster to Peach, Wash., Great Northern Railway Co., survey of December 1909 and January 1910.

8. *Prior reports.*—The only prior report on the Foster Creek site by this Department is the report under review. Earlier reports by the War Department on examinations and surveys of the upper Columbia River were primarily in the interest of navigation. These reports, all of which are listed in the report under review, were submitted at various times from 1884 to 1917, inclusive.

Chapter II—General Data

9. *Description.*—Columbia River and its tributaries drain an area of 259,000 square miles in southwestern Canada and northwestern United States, between latitudes 41° and 53° north and longitudes 110° and 124° west. Of the total area, about 39,700 square miles lie in British Columbia, Canada, and the remainder in the United States. Included are western Montana, most of Idaho, eastern and southern Washington, and eastern and northern Oregon, together with adjacent small parts of Wyoming, Utah, and Nevada.

10. Columbia River proper is about 1,210 miles in length, of which about 460 miles lie in Canada. It rises in Columbia Lake, British Columbia, at elevation 2,650, flows northwesterly for nearly 200 miles through the Rocky Mountain trench, then turns abruptly around the north end of the Selkirk Range and flows southerly through Upper and Lower Arrow Lakes to enter the United States near the northeastern corner of Washington. At the international boundary, the Columbia enters Columbia River Reservoir and continues south for 112 miles to a point below the mouth of Spokane River. It then turns and flows west for 100 miles to the mouth of Okanogan River, passing Grand Coulee Dam and Foster Creek Dam site en route. Swinging south, the river follows the eastern foothills of the Cascades for 209 miles to its confluence with Snake River. A few miles below the Snake, it turns sharply westward and flows for 324 miles, forming the Washington-Oregon boundary, to the Pacific Ocean.

11. Principal tributaries of Columbia River above the Foster Creek Dam site are the Kootenai (spelled Kootenay in Canada), Clark Fork, Kettle, and Spokane Rivers. The Kootenai rises in British Columbia north of Columbia Lake, flows southeasterly through the Rocky Mountain trench, loops through western Montana and northern Idaho, then returns to Canada to pass through Kootenay Lake and join the Columbia 30 miles north of the international boundary. It drains an area of 19,450 square miles, including 14,530 square miles in Canada, and contributes annually an average of some 34,000 cubic feet per second to the Columbia.

12. Clark Fork rises near Butte, Mont., flows northwest between the Continental Divide and the Bitterroot Mountains, passes through Pend Oreille Lake in northern Idaho, traverses the northeastern corner of Washington, and joins the Columbia in Canada about one-half mile north of the boundary. The stretch from Pend Oreille Lake to the junction with the Columbia is known as Pend Oreille River. Clark Fork and its tributaries drain an area of 25,820 square miles of which 1,180 square miles are in Canada. It delivers an average annual flow of 25,000 cubic feet per second to the Columbia.

13. Kettle River rises in Canada between the Columbia and Okanogan Rivers, flows in a southerly direction, and discharges a mean

annual flow of 3,000 cubic feet per second into Columbia River R ervoir about 40 miles south of the boundary. It drains 4,260 squ miles, of which 3,150 square miles are in Canada.

14. Spokane River enters Columbia River Reservoir about miles south of the international boundary, contributing a mean ann flow of 8,000 cubic feet per second from a drainage area of 6,600 squ miles. The river forms the outlet of Coeur d'Alene Lake which turn drains the westerly slopes of the Bitterroot Range through t St. Joe and Coeur d'Alene Rivers.

15. The natural profile of Columbia River between the internation boundary and the mouth of Snake River is a series of steep slope intervening sections of comparatively low grade, and occasional pro nounced drops such as Long Rapids, Rock Island Rapids, and Pries Rapids. Prior to the construction of Grand Coulee Dam, the medium low-water slope from the boundary to the dam averaged more than 2 feet per mile with extremes ranging from 0.7 foot to 37 feet per mile. From Grand Coulee to Bridgeport, the slope averages 3.3 feet per mile, as shown on plate 5.[1] Within this reach, however, the drop at Long Rapids is 14 feet per mile and from the head of Long Rapids to the foot of Foster Creek Rapids, 6 feet per mile. The average slope for the entire 421 miles from the boundary to Snake River is 2.3 feet per mile.

16. Data for a complete high-water profile of the river are not available. From records of isolated high-water elevations during the highest known flood, in 1894, extreme stage differences have been estimated to be 52 feet at Foster Creek, 68.5 at Grand Coulee, and from 35 to 77 feet elsewhere between the international boundary and the mouth of the Snake.

17. The upper Columbia River Basin, lying between the Rocky Mountains (Continental Divide) on the north and east and the Cascade Mountains on the west, is characterized by mountain ranges and broad, rugged plateaus with intervening deep, narrow valleys. The summits of the Rockies rise from 7,000 to 12,000 feet above sea level, and those of the Cascades from 6,000 to 8,000 feet, above which tower Mount Rainier (elevation 14,408 feet) and other volcanic peaks. Within the basin itself are various mountain ranges that attain altitudes of 5,000 to more than 10,000 feet above sea level. Of the benches and plateaus in the basin, the largest is the Columbia Plateau. It is bounded on the west and north by the Columbia and Spokane Rivers, on the east by the Bitterroot Mountains, and on the south by the northerly Snake River Divide. It ranges in elevation from 1,000 to 5,000 feet and is characterized by rolling prairies, exposed lava sheets, parallel ridges, and dry stream gorges. Between the mountain ranges and plateaus, great depressions provide the drainage outlets for the river system, often occuring as deep, narrow canyons, or again as extensive storage basins where glacial action has broadened the valleys into lake basins.

18. The mountainous areas of the basin receive the bulk of precipitation in the form of winter snows that compact to great depths among the high peaks. The slow thawing of this accumulation produces the single extended high water that begins in April or May, reaches a peak usually in June, and recedes during the summer and fall. Summer precipitation in most of the basin is deficient for diversified

[1] Not printed.

farming, and irrigation is a large factor in the agricultural scheme. Cultivation is limited to scattered areas, usually in valleys where suitable topography, soils, and growing conditions exist. Coniferous forests of the mountain slopes support an extensive lumber industry. Mineralization of the mountains in numerous localities provides another important resource.

19. Although navigation is hazardous and difficult on most of the upper Columbia and its tributaries, early settlement and subsequent development of transportation routes naturally followed the water grades through the mountains. The geographic pattern influenced the locating of communities along the rivers. Economically, however, these communities must rely largely upon railways and highways for transportation, and upon the upland wilderness for the raw materials of mining and lumbering, as well as for the water of irrigation. Water power is one of the great, undeveloped resources of the basin. The great discharge and fall of the streams create a tremendous power potentiality. Dam and reservoir possibilities are numerous throughout the river system. Among these, the proposed development at Foster Creek is one of the most favorable.

20. *Regional geology.*—The Columbia Plateau, at the northern border of which Foster Creek Dam site is located, is an interior, arid to semiarid region covering approximately 200,000 square miles in eastern Washington and Oregon and southern Idaho. The entire area is underlaid with basalt flows that are known to be several thousand feet thick in places. As the valley of the Columbia evidently antedates the adjacent topography, it is probable that the lava flows diverted the Columbia from its original more direct course between the mouths of Spokane and Snake Rivers, resulting in the great bend to the westward, where it has since carved out a canyon along most of its way.

21. To the north of this westward course of the Columbia, the Okanogan Highlands extend northward into Canada and eastward to join the Rocky Mountains. Underlying the greater part of this section of Washington is a series of granite batholiths with scattered exposures where erosion has removed the country rock cover.

22. The westward course of the river defines approximately the southern limit of direct glacial action. The country to the north was glaciated, and drainages of the minor streams were modified considerably. Both the Columbia and Okanogan Rivers, however, probably are flowing in their preglacial valleys with but slight modifications. Glacial drift mantles the granite bedrock as a veneer of stratified silt, sand, and gravel, intercalated with glacial sheets of varying composition. Glacial and preglacial gravels, lying directly on bedrock and overlaid by a massive till sheet, form the right bank of the river in the vicinity of Foster Creek and extend several thousand feet upstream and downstream.

23. *Soils.*—A variety of soils exist in the region, but few are residual in character. The oldest soils are those found on the uplands that were not influenced by the ice invasion. These were borne by the prevailing westerly winds and contain a considerable admixture of volcanic ash from the Cascades. In the river valleys, the glacial or alluvial debris is covered with fine-grained topsoil of Eolian origin. Areas affected by glaciation are covered in places with a veneer of glacial till, coarse sand, and gravel; in other cases they are stripped of their

original soil covers. Among the latter are the prominent scablands of east-central Washington, exposed by the erosion of torrents from the ice fronts. In general, soils along the Columbia in the Plateau Province are lighter in color and contain much less humus than those to the east and to the west where vegetation is more abundant.

24. *Climate.*—The climate of the Columbia River Basin above Foster Creek Dam site is characterized by warm, dry summers and cool winters with considerable snow at higher elevations. Because of its geographical location, the basin is subject to modified meteorological influences, both oceanic and continental. Oceanic influences are strongest during the winter and result in comparatively heavy snowfall as the warm, moisture-laden air masses from the Pacific Ocean are cooled in passing over the mountain ranges of the upper basin. Continental influences are strongest during the summer and result in semiarid conditions over the plains and showers in the mountainous regions. Meteorological data for stations near the dam site are shown in table 2.

25. *Precipitation.*—Physical factors in the seasonal variation of rainfall over the basin are wind direction and land temperature. Prevailing winds are westerly, bringing air masses over the basin from the Pacific Ocean, which has quite uniform temperature throughout the year and contributes moisture continuously to the atmosphere. As land surfaces change temperature with the seasons more quickly than water, moisture borne by the Pacific air masses in winter is cooled and condenses when crossing the land. During the summer months, the air masses are warmed when crossing the land and therefore absorb rather than lose moisture. As the ocean is comparatively warm in winter and the land is comparatively cold, a condition occurs favorable to creation of low-pressure areas. The storms that result move inland and are the primary cause of winter precipitation. The effect of these storms coincides with that resulting from the cooling influence of the land on the moisture-holding capacity of the westerly winds. During the summer months, the low-pressure zone moves northward, and only occasional showers result.

26. In addition to the winter cooling effect of the land, the Coast, Cascade, and Rocky Mountain Ranges concentrate the precipitation because the air is further cooled by expansion as it ascends their western slopes. As the air masses move down the eastern slopes they are warmed dynamically under the greater atmospheric pressure at lower elevation and the plains lying east of the mountains receive low precipitation. This orographic influence produces abrupt changes in precipitation. The most pronounced is that between the western Cascade summits and the central Washington plain, where the respective precipitations change from over 100 inches to less than 10 inches a year within about 50 miles.

TABLE 2.—*Meteorological data*

NESPELEM, WASH.

[Elevation, 1,800 feet. Period of record, 1915–43]

Item	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Precipitation (inches):													
Mean	1.22	1.09	0.85	0.90	0.85	1.25	0.37	0.45	0.81	0.99	1.58	1.37	11.73
Maximum	2.23	4.53	2.86	2.80	3.81	3.31	2.13	2.15	2.98	2.60	3.17	3.39	19.99
Minimum	.19	.06	.05	.05	T	T	.00	T	T	.00	T	.31	6.24
Mean snowfall													27.1
Maximum snowfall													63.9
Minimum snowfall													12.8
Temperature (degrees Fahrenheit):													
Mean	22.8	28.0	39.2	47.8	54.0	62.0	68.5	67.1	58.2	48.4	34.8	27.2	46.5
Maximum	53	59	79	87	96	101	106	99	96	85	68	58	106
Minimum	−25	−28	−8	9	24	28	31	32	17	11	1	−22	−28

OKANOGAN, WASH.

[Elevation, 910 feet. Period of record, 1926–43]

Item	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Precipitation (inches):													
Mean	1.22	1.10	0.82	0.90	0.71	1.29	0.34	0.38	0.68	0.76	1.28	1.71	11.19
Maximum	2.83	3.13	1.99	3.11	3.67	4.10	1.42	2.07	2.71	2.43	3.15	4.33	20.52
Minimum	.27	T	.04	.07	.01	.04	0	0	0	.05	T	.17	4.67
Mean snowfall													29.9
Maximum snowfall													60.8
Minimum snowfall													10.8
Temperature (degrees Fahrenheit):													
Mean	24.6	29.1	43.2	53.0	60.0	67.6	75.2	73.4	64.0	52.0	36.9	29.1	50.7
Maximum	55	58	79	95	100	104	111	105	103	87	69	65	111
Minimum	−18	−23	14	18	29	35	46	40	23	11	5	−9	−23

TABLE 2.—*Meteorological data*—Continued

SPOKANE, WASH.

[Elevation, 1,929 feet. Period of record, 1881–1940]

Item	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Precipitation (inches):													
Mean	2.05	1.66	1.26	1.07	1.22	1.25	0.57	0.55	0.88	1.19	1.99	2.19	15.88
Maximum	4.54	5.62	2.91	3.97	3.42	5.12	2.37	2.12	5.58	4.81	5.85	4.35	25.99
Minimum	.51	.09	.12	.11	.06	.01	.00	T	.03	T	T	.21	7.54
Mean snowfall													36.7
Temperature (degrees Fahrenheit):													
Mean	27.5	31.3	39.7	48.4	55.5	62.8	69.0	68.1	59.2	48.3	38.5	30.5	48.2
Maximum	62	60	74	90	97	100	108	104	98	87	70	59	108
Minimum	−30	−23	−10	12	29	34	41	37	22	7	−13	−18	−30

BREWSTER, WASH.

[Elevation, 878 feet. Period of record, 1910–30]

Item	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Precipitation (inches):													
Mean	1.35	0.96	0.51	0.60	0.88	0.93	0.39	0.42	0.67	0.75	1.64	1.38	10.48
Maximum	4.72	2.82	1.85	2.00	2.71	2.53	1.57	1.99	1.77	1.91	3.25	3.23	16.63
Minimum	.09	.03	.01	.00	.05	.04	.00	.00	.00	.00	.36	.29	7.38
Mean snowfall													31.9
Maximum snowfall													71.4
Temperature (degrees Fahrenheit):													
Mean	22.2	28.3	41.3	51.8	59.5	66.3	73.8	72.5	62.4	50.1	36.2	26.6	49.3
Maximum	62	62	80	94	100	102	110	107	101	88	65	65	110
Minimum	−17	−11	−4	21	31	35	41	39	24	19	−5	−23	−23

GRAND COULEE DAM, WASH.

[Elevation, 1,100 feet. Period of record, 1934–43]

Precipitation (inches):													
Mean	0.93	1.17	0.74	0.92	0.90	1.65	0.43	0.38	0.49	0.79	0.97	1.19	10.56
Maximum	1.65	3.58	1.70	1.75	2.70	4.29	1.17	1.75	1.42	1.56	2.58	1.89	15.87
Minimum	.35	.29	.14	.30	.04	.13	T	T	T	.05	.14	.54	6.39
Mean snowfall													19.5
Maximum snowfall													36.4
Temperature (degrees Fahrenheit):													
Mean	27.2	31.6	43.4	53.8	61.0	66.7	75.2	73.3	66.6	54.4	38.0	32.8	52.0
Maximum	52	58	74	92	99	105	113	106	104	90	63	58	113
Minimum	−13	−11	18	20	36	44	48	46	35	12	10	12	−13

MANSFIELD, WASH.

[Elevation, 2,267 feet. Period of record, 1922–43]

Precipitation (inches):													
Mean	1.22	1.04	0.65	0.66	0.61	1.17	0.30	0.39	0.61	0.70	1.21	1.48	10.04
Maximum	2.58	3.60	1.91	2.26	3.52	4.64	.99	2.13	2.51	2.41	3.11	3.20	15.92
Minimum	.36	.06	.07	.02	.03	.15	.00	.00	.00	T	.00	.38	5.60
Mean snowfall													38.0
Maximum snowfall													80.4
Minimum snowfall													19.1

27. *Temperature.*—The range in altitude and latitude, the topography, and the general north-south trend of the various mountain ranges are the influences that create local variations of temperature. In general, temperatures are such that winter precipitation over most of the basin falls in the form of snow. Although some melt occurs during the winter at lower elevations, the snow blanket over most of the basin generally continues to build up throughout the winter months until it reaches its maximum, usually in March.

28. *Stream flow.*—Columbia River above Foster Creek Dam site drains a region of diverse topographic and meteorological features. The numerous mountain ranges form an extremely rugged and precipitous terrain in most of the basin. The mountain axes trend in a north and south direction roughly parallel to the Cascade Mountains and perpendicular to prevailing winds from the west and southwest. Several times in the past, the northern part of the drainage basin has been covered to a large extent by glaciers. Movement of the glaciers gouged great troughs, also trending north and south, that are now partially occupied by a multitude of lakes. The lakes have a combined area of at least 1,100 square miles, and their capacity is about 9,000,000 acre-feet between low stage and average annual crest. The annual filling and draining of these natural reservoirs has a marked equalizing effect on run-off. The lakes capture a considerable portion of the flood flow and release it gradually during the summer and fall, thereby producing a well-sustained flow in the main river and on some of the tributaries.

29. As pointed out previously, precipitation is heavy on the western slopes of the mountains and relatively light on the eastern slopes. This unequal distribution causes marked differences in run-off per unit of area. The yields of tributaries vary widely, depending upon where their origins lie with reference to the mountains and to what extent they drain arid and semiarid intermountain basins. Therefore, estimates of stream flow based upon drainage areas or on precipitation data at sparsely located observation stations are subject to considerable uncertainty.

30. Variations in altitude and a spread in latitude of about 7½° are responsible for marked differences in the accumulation of snow and ice in the winter and in the rate of melting in the spring and summer. In the southern part of the basin, melting snow begins to augment stream flow much earlier in the season than in the northern part. The later yield of the northern part, however, is decidedly advantageous, because it produces an increased run-off during the hot, dry summer months and, in conjunction with lake storage, even into the fall months. In general, the flow at Foster Creek Dam site begins to rise in March or April and continues to increase with the intensity of snow melt until June. It does not recede to winter stage until late in October or in November, thus maintaining relatively high flows throughout the summer season. The mean annual flow for water years ending September 30 varies from year to year depending upon the amount of winter precipitation stored in the form of lake pondage and snow cover, and ranges from 51 to 103 million acre-feet at Grand Coulee. Table 3 gives pertinent stream-flow data, and plate 6 [1] shows river hydrographs for the years 1913 to 1944, inclusive.

[1] Not printed.

TABLE 3.—*Stream-flow data*

Item	Columbia River at Grand Coulee (74,100 square miles drainage), corrected for storage in Columbia River Reservoir [1]	Pend Oreille River below Z Canyon (25,200 square miles drainage)		Kootenay River at Nelson, British Columbia (17,700 square miles drainage), observed and estimated [3]	Flathead River near Polson, Mont. (7,010 square miles drainage)	
		Observed [2]	Corrected for storage in Pend Oreille Lake [2]		Observed [4]	Corrected for storage in Flathead Lake [5]
Mean monthly flow, cubic feet per second, for—						
January	38,900	12,600	12,300	8,700	4,230	3,220
February	36,300	11,800	11,700	8,070	3,510	2,900
March	42,400	13,100	14,200	8,580	3,440	4,020
April	81,300	24,200	30,400	17,400	8,110	14,720
May	197,400	55,200	64,700	52,100	27,850	37,290
June	295,200	76,300	74,500	83,100	39,230	37,380
July	230,500	47,300	35,600	61,900	21,460	14,020
August	130,400	19,200	15,100	29,900	8,360	4,870
September	81,600	11,500	10,500	18,300	5,140	3,560
October	55,800	10,300	10,300	13,700	4,280	4,000
November	48,800	11,600	11,900	12,000	4,490	4,280
December	42,500	12,200	12,500	10,100	4,360	3,840
Mean flow, cubic feet per second	107,100	25,500	25,300	27,100	11,240	11,200
Mean annual run-off: Acre-feet	77,540,000	18,450,000	18,340,000	19,620,000	8,134,000	8,108,000
Inches	19.62	13.73	13.65	20.78	21.75	21.68
Maximum flow, exclusive of 1894, cubic feet per second	492,000	139,000	-----------	146,000	82,100	-----------
Minimum flow, cubic feet per second	15,300	2,500	-----------	4,100	[7] 5	-----------
1894 maximum discharge (estimated), cubic feet per second	725,000	[6] 217,000	-----------	225,000	115,000	-----------

[1] Observed record, June to December 1923, June 1928 to September 1942; estimated record, April 1913 to June 1923, and January 1924 to May 1928.
[2] Observed record, October 1912 to September 1943.
[3] Observed record, January 1913 to September 1937; estimated record, October 1937 to September 1942.
[4] Observed record, July 1907 to September 1943.
[5] Observed record, February 1910 to September 1943.
[6] 1894 discharge of Pend Oreille River at Priest River.
[7] Caused by power regulation.

31. *The critical period.*—The most critical period of record from the standpoint of low stream flow and existing storage occurred at Grand Coulee Dam and Foster Creek Dam sites from October 1936 through March 1937. An important factor contributing to the low flow during that period was the unusually low temperature in January and February.

32. The 900 square miles of drainage area between the two sites represents a 1.2 percent increment to the area tributary above Grand Coulee gage. As this intervening area is extremely arid and contains but one small tributary, it is assumed that no appreciable increase in volume occurred between Grand Coulee and Foster Creek during the critical period. Stream-flow data therefore are used interchangeably as between the Grand Coulee gage and Foster Creek.

33. *Spillway design flood.*—The spillway design flood adopted for the Foster Creek project is 1,250,000 cubic feet per second. This figure is based on a study of maximum possible temperature conditions in the basin prior to the peak-flow date, and their effect on the accumulated snow pack that would be produced by maximum possible precipitation during the winter season. It includes a 15-percent factor

of safety and agrees closely with the spillway design flood used at Grand Coulee Dam.

34. *Existing storage.*—At the present time there are three large, controlled reservoirs upstream from Foster Creek Dam site. These are Columbia River Reservoir with 5,200,000 acre-feet of usable storage, controlled at Grand Coulee Dam; Flathead Lake with 1,200,000 acre-feet of usable storage, controlled at Kerr Dam; and Kootenay Lake in British Columbia with about 800,000 acre-feet of usable storage, controlled at Corra Linn Dam. There are a number of smaller reservoirs, the largest of which is Coeur d'Alene Lake with 178,000 acre-feet of usable storage, controlled at Post Falls Dam. The effect of upstream storage upon stream flow at Grand Coulee for the critical period is shown in table 4, by assuming regulation of existing reservoirs as indicated therein. In addition, the effect of a possible future reservoir having 3,200,000 acre-feet of usable storage on Clark Fork is shown under two plans of operation.

TABLE 4.—*Mean monthly flow in cubic feet per second, June 1936 through May 1937*

Month	Observed for Columbia River at Grand Coulee, Wash.	Existing storage in Columbia River Reservoir					
		Regulated outflow with existing storage in Columbia River Reservoir only	Existing storage in Columbia River Reservoir, Kootenay and Flathead Lakes, each operated for maximum uniform flow at site		Additional 3,200,000 acre-feet of future upstream storage operated to obtain maximum uniform flow at Grand Coulee		
			Modified inflow	Regulated outflow	Modified inflow: To maintain full pool as long as possible	Modified inflow: To maintain maximum possible uniform inflow during the critical period	Regulated outflow (either method of operation)
June	301,300	301,300	290,500	290,500	281,400	281,400	281,400
July	170,800	170,800	164,100	164,100	156,500	156,500	156,500
August	106,700	106,700	102,300	102,300	99,700	99,700	99,700
September	65,950	65,950	62,400	62,400	61,600	61,600	61,600
October	41,970	41,970	43,200	44,100	52,200	51,400	52,200
November	28,480	39,800	31,900	44,100	52,200	40,400	52,200
December	23,200	39,800	27,700	44,100	50,700	36,100	52,200
January	18,220	39,800	23,600	44,100	23,200	33,600	52,200
February	18,200	39,800	23,300	44,100	23,500	32,700	52,200
March	23,840	39,800	27,700	44,100	28,000	35,300	52,200
April	44,060	39,800	45,000	44,100	48,100	48,800	52,200
May	135,500	55,000	131,800	48,100	136,800	119,900	52,200

35. *Economic development.*—Columbia River power is distributed by a network serving the States of Idaho, Montana, Oregon, Utah, and Washington. Since the early fur-trading days, the economic life of these States has been based primarily on the production and export of raw material: Lumber, agricultural products, and minerals. Extensive waterways and many natural harbors have been important factors in the economic development of coastal areas, such as Puget Sound and lower Columbia River. In these coastal areas, fishing is a large industry.

36. *Population.*—The growth of population in the five-State region is reflected in table 5, showing by States the census of urban and rural

populations for 1920, 1930, and 1940. The air-line distances and 1940 population of major cities, within 250 miles radius of the dam site, are given in the following table:

State and city	1940 population	Air-miles	State and city	1940 population	Air-miles
Oregon: Portland	305, 394	222	Washington—Continued.		
Washington:			Spokane	122, 001	106
Bellingham	29, 314	142	Tacoma	109, 408	143
Everett	30, 224	121	Yakima	27, 221	104
Seattle	368, 302	130			

TABLE 5.—*Population distribution, urban and rural*

State and year	United States		Urban places		Rural population	Percent of total		Density per square mile
	Land area, square miles	Population	Number	Population		Urban	Rural	
Idaho:								
1940	82, 808	524, 873	26	176, 708	348, 165	33. 7	66. 3	6. 3
1930		445, 032	21	129, 507	315, 525	29. 1	70. 9	
1920		431, 866	20	119, 037	312, 829	27. 6	72. 4	
Montana:								
1940	146, 316	559, 456	23	211, 535	347, 921	37. 8	62. 2	3. 8
1930		537, 606	18	181, 036	356, 570	33. 7	66. 3	
1920		548, 889	17	172, 011	376, 878	31. 3	68. 7	
Oregon:								
1940	96, 350	1, 089, 684	34	531, 675	558, 009	48. 8	51. 2	11. 3
1930		953, 786	28	489, 746	464, 040	51. 3	48. 7	
1920		783, 389	23	390, 346	393, 043	49. 8	50. 2	
Utah:								
1940	82, 346	550, 310	25	305, 493	244, 817	55. 5	44. 5	6. 7
1930		507, 847	21	266, 264	241, 583	52. 4	47. 6	
1920		449, 396	17	215, 584	233, 812	48. 0	52. 0	
Washington:								
1940	66, 977	1, 736, 191	40	921, 969	814, 222	53. 1	46. 9	26. 0
1930		1, 563, 396	38	884, 539	678, 857	56. 6	43. 4	
1920		1, 356, 621	33	742, 801	613, 820	54. 8	45. 2	
Region total:								
1940	474, 797	4, 460, 514	148	2, 147, 380	2, 313, 134	48. 3	51. 8	9. 4
1930		4, 007, 667	126	1, 951, 092	2, 056, 575	48. 7	51. 3	
1920		3, 570, 161	110	1, 639, 779	1, 930, 382	45. 9	54. 1	

37. The distribution of population varies widely as a result of adjustment to topography, climate, water supply, soils, mineral deposits, and forest cover. The greater part of the region's population is found west of the Cascade Mountains where rich agricultural and timber resources, great natural harbors, and an equable climate exist. The densely populated metropolitan districts of Seattle, Tacoma, and Portland are within this area. East of the Cascades the population is generally scattered except for a few widely separated communities, such as Spokane, Yakima, and Butte, that have developed as a result of nearby resources, irrigation, or concentration of transportation facilities. Over much of this intermountain area rugged terrain or insufficient rainfall have tended to limit settlement. War conditions have induced some changes in the distribution pattern. Large urban centers, such as Seattle, Portland, and Spokane, have gained population rapidly through war industry. East of the Cascades some communities have lost population as a result of migration to communities with more war industries. Readjustment will take place after the war and the future trends, both of population growth and distribution,