

TABLE No. 165.—*Estimated monthly power duration, Spokane River sites for the period Apr. 1, 1913 to Mar. 31, 1931, at 80 percent efficiency (kilowatt)*

Site	Natural—corrected for storage			Recorded			Plan no. 2-A			Plan no. 4		
	Percent of time			Percent of time			Percent of time			Percent of time		
	50	90	100	50	90	100	50	90	100	50	90	100
Post Falls ¹	9,020	2,700	1,580	9,310	4,110	3,410	14,500	4,640	3,520	11,600	7,030	4,940
Crossing ²	8,100	3,000	1,640	7,320	3,890	3,260	7,780	4,710	4,050	8,850	5,850	5,470
Waterworks ² & Spokane, Upper Falls ¹	4,470	1,650	900	4,010	2,130	1,790	4,280	2,680	2,220	4,850	3,220	3,000
Spokane, Monroe Street ¹	13,000	5,230	3,170	12,000	6,640	5,560	12,700	7,880	6,760	14,300	9,630	8,920
Bowl and Pitch- er ²	15,600	6,250	3,780	14,300	7,930	6,640	15,200	9,420	8,080	17,100	11,500	10,600
Nine Mile ¹	17,800	7,620	4,920	16,700	9,360	7,900	17,600	11,100	9,580	19,700	13,500	12,500
Long Lake ¹	13,700	5,940	3,870	12,900	7,280	6,060	13,600	8,640	7,380	15,200	10,500	9,710
Little Falls ¹	44,200	22,800	16,800	42,300	26,300	21,800	44,200	29,800	25,200	48,700	34,600	31,100
Fish Hawk ²	18,800	9,700	7,150	18,000	11,200	9,320	18,900	12,700	10,700	20,800	14,700	13,300
Narrows ²	22,200	11,500	8,450	21,200	13,200	11,000	22,200	15,000	12,600	24,500	17,400	15,700
	26,400	13,600	10,300	25,400	15,800	13,200	26,500	17,900	15,200	29,200	20,700	18,700
Total.....	193,290	89,990	62,560	183,440	107,820	89,940	197,450	124,370	105,290	214,800	148,630	133,940
Developed sites ¹	114,320	52,620	36,350	108,810	63,440	52,790	119,100	73,080	61,640	127,700	87,960	78,570
Undeveloped sites ²	78,970	37,370	26,210	74,630	44,380	37,150	78,360	51,290	43,650	87,100	60,670	55,370

¹ Developed sites.² Undeveloped sites.³ The waterworks site is now partially developed.

27. Regulation of Coeur d'Alene Lake below elevation 2,129.1 would increase the flow of Spokane River during the months of low flow and hence would increase the available potential low-water power on that stream. The power output of the various sites has been given in table no. 165 for recorded flow and for two plans of regulation. It must be understood that the method of regulation under plan no. 2-A involves the diversion of about 45,000 acre-feet of water during each year from the Clark Fork to the Spokane through the gravity supply canal of the Columbia Basin irrigation project. This diversion would be effected during September, October, November, and December of each year. Under this plan of regulation the power output of the existing Post Falls plant would be decreased during the post-irrigation season. Any loss of power at Post Falls, following the end of the irrigation diversion period (i.e., Aug. 31) would be offset by increased flow at the downstream plants effected by diverting water from the Clark Fork to the Spokane through the Columbia Basin irrigation project canal.

28. Referring again to table no. 165 and using the data for 90-percent time, it will be noted that the power available at the undeveloped sites would be increased from 37,370 kilowatts under natural conditions (corrected for storage) to 51,290 kilowatts under plan no. 2-A, and to 60,670 kilowatts under plan no. 4. The corresponding figures for the developed plants are 52,620 kilowatts for natural conditions (corrected for storage), 73,080 kilowatts for plan no. 2-A, and 87,960 kilowatts for plan no. 4. The increase in power from that obtaining for natural (recorded) conditions to that obtaining for plan no. 2-A is accounted for by the difference between ideal and actual regulation of Coeur d'Alene Lake, and by the assumptions set up in the water-supply studies. Any increased output from the developed

plants under either plan of regulation could be attained without any large capital outlay in the plants themselves, and could be readily absorbed in a normally expanding market and would not materially affect the market for power to be developed on the Columbia proper.

2. AUGMENTING FLOW OF SPOKANE RIVER BY DIVERSION FROM CLARK FORK

829. The Columbia Basin Survey Commission of the State of Washington provided in its report for a spillway to discharge water into the Spokane River from the proposed gravity supply canal for the Columbia Basin irrigation project near the point where the canal crosses the river. Appendix C of the Gault report calls attention to the possibility of utilizing spare capacity in the proposed conduit for delivery of Clark Fork water to Spokane River for the purpose of increasing power capacities of present and future power plants on Spokane River. The proposed conduit for the gravity irrigation project must cross Spokane River about 8 miles above Spokane Falls at a sufficiently high elevation to clear flood stages in the river, and therefore arrangements to deliver water from the conduit to Spokane River can be made with ease. The conduit must be constructed large enough to carry the maximum irrigation requirement, which maximum is needed only during July of each year. If the conduit is used solely for irrigation purposes, it will have some excess capacity for the remainder of the irrigation season and will serve no useful purpose during the late fall and winter months when the normal flow of Spokane River is low. Hence, water may be diverted through the conduit for use at power plants on Spokane River during all months of the year except July.

830. The diversion of Clark Fork water through the irrigating canal and into Spokane River would not change the total theoretical power within that part of the Columbia River system subjected to its influence, but would change the relative amounts obtainable at the several power sites. The head susceptible of economic development via Clark Fork and Columbia River is about the same as that via the Spokane. However, the increased flow in Spokane River resulting from such a diversion could be used in the existing plants on that river to generate an increased output without further capital outlay; whereas, to gain a corresponding power output on Clark Fork and Columbia would require a considerable capital outlay.

831. To evaluate this diversion feature it was assumed that all present and possible future plants on Spokane River would be operated in a system having power plants on Columbia River at Kettle Falls and on Chelan River. It was further assumed that the aggregate output of all these plants would be adjusted to monthly system loads varying with probable seasonal demand. The results of these studies indicate an average system increase of about 135,000 kilowatts in potential power for the low-water year 1919-20. This amount of power is equivalent to 1,183,000,000 kilowatt-hours annually. Assuming a rate of 2 mills per kilowatt-hour, the annual income from the sale of this energy would be \$2,366,000. Capitalizing this income at 6 percent represents a value of \$39,433,000 or about \$26 per acre for the area included in plan no. 2-A of irrigating the Columbia Basin irrigation project. The data just given are necessarily very approximate, depending as they do on assumed control of output in a more or

less fictitious power system and on assumed rates for energy and interest. It will have been noted from paragraph 827 that plan no. 2-A, herein discussed, assumes diversion of only so much water from Clark Fork to Spokane River as would be necessary to obtain the same power output along the river as now available.

832. The legal right to divert water from one watershed to another, from one State to another, and from an international stream may well be questioned, and these points must be carefully considered in the formation of any opinion regarding that legal right.

(F) WENATCHEE RIVER

833. The water-supply studies and storage analyses for Wenatchee River, described in the section "Stream Flow and Storage", were made prior to the survey of the Chiwawa Dam site on Chiwawa River, one of the tributaries of the Wenatchee, and assumed a usable storage of 482,000 acre-feet in Chiwawa Reservoir, between elevations 2,550 and 2,409 feet (see plates nos. 23² and 24² and United States Geological Survey map of the Chiwaukum quadrangle and Water-Supply Paper 368). Estimates of cost of a dam at the Chiwawa site about three quarters of a mile above Twin Creek in section 34, township 28 north, range 17 east, Willamette meridian, at natural low-water elevation 2,325 feet, based on the survey shown on plate no. 23,² showed such a high cost (approximately \$5,000,000) that it did not appear feasible to construct a dam to the height assumed in the water-supply analyses. However, future conditions may justify such an expenditure or, possibly, a site capable of being more cheaply developed may be discovered. The 482,000 acre-feet of storage capacity assumed for the Chiwawa Reservoir would have completely regulated Chiwawa River downstream from the dam to a uniform flow of 548 second-feet for the 17-year period ended March 1930 and 324 second-feet for the single year ended March 31, 1931. It was suggested that water could be conveyed about 3½ miles from the Chiwawa Dam to a power house on Fish Lake which would be merged into Wenatchee Lake by the construction of a dam on Wenatchee River. A head of about 500 feet would be available.

834. Storage was to be provided in Wenatchee Lake by the construction of a dam on Wenatchee River about 9 miles below the outlet of the lake in section 13, township 26 north, range 17 east, Willamette meridian, at natural low-water elevation 1,798 feet. About 1,656,000 acre-feet of usable storage could be provided in Wenatchee Lake between elevations 2,009 and 1,875 feet, and about 1,000,000 acre-feet between elevations 1,980 and 1,901. (See area-capacity curve, plate no. 21,² topography, plate no. 22.²)

835. The 6,000-kilowatt power plant of the Great Northern Railway (now leased to the Washington Electric Co., a subsidiary of Puget Sound Power & Light Co.) is located near Leavenworth in Tumwater Canyon, in section 10, township 24 north, range 17 east, Willamette meridian, and, according to the 1920 Columbia Basin project report of the Columbia Basin Survey Commission of the State of Washington, has a penstock capacity and water right of 525 second-feet under a head of about 187 feet. This appropriation or right was made prior to the effective date (June 15, 1917) of the State Water Code. The

¹ Not printed.

amount of water claimed by the owners in their payment of the State annual license fee is 1,413 second-feet.

836. The possibilities of storage and power development on the Wenatchee and Chiwawa were investigated to a greater extent than power on other small tributaries of the Columbia, as it was believed that the irrigation of a large area in the vicinity of Quincy by water from the Wenatchee might permit of a favorable stage development of the Columbia Basin irrigation project.

837. In the plan for irrigation of the Quincy and Wenatchee areas, water would be diverted from Wenatchee Lake and conveyed by canal, tunnel, and flume sections to the land. It was suggested that the entire flow from the reservoir be diverted into this canal system. Some power could be developed at the Wenatchee Lake Dam, but, due to the changing head resulting from the operation of storage in the lake, the output would be quite variable. A portion of this water would be returned to the river through a suggested power house near Dryden, the remainder of the water passing on through the proposed canal to supply the irrigation needs. The head, under this arrangement, at this new Dryden plant would be about 575 feet. Such an arrangement would require scrapping the present Tumwater plant, but the new plant at Dryden could supply the 6,000 kilowatts now generated at the Tumwater plant and leave a surplus for commercial sale amounting to about 18,000 kilowatts.

838. The excess cost (as occasioned by the greater size of canal for the combined uses) of the canal from the lake to the Dryden diversion would amount to about \$850,000.

839. By eliminating the Chiwawa Dam, reservoir, and power plant and the new Dryden plant, but retaining the present Tumwater plant and the suggested plant at Wenatchee Lake Dam, the storage requirements in Wenatchee Lake reservoir for supply of irrigation and power needs would be reduced to about 1,000,000 acre-feet. The head under such an arrangement would vary from about 175 feet to about 100 feet, with an average head of about 150 feet. The water required for the Tumwater plant would be returned to the river at the dam, the remainder passing through the canal to supply irrigation needs.

840. The flow durations obtaining under various schemes of regulation are indicated in table no. 166 and in plates nos. 112² and 113.²

TABLE NO. 166.—*Monthly flow duration in second-feet for sites on Wenatchee and Chiwawa Rivers for the 18-year period ended Mar. 31, 1931*

Site	Natural flow			Regulated flow			
	Percent time			Plan no. ^a	Percent time		
	50	90	100		50	90	100
Chiwawa Dam ^b	257	103	45	2-A, 4, 6-A	548	548	^c 324
Wenatchee Lake High Dam ^d	1,250	492	240	6-A	2,510	^e 636	^f 636
Wenatchee Lake Low Dam ^f	1,250	492	240	2-A, 4	2,220	2,120	1,300

^a Refers to the plan of irrigation for the Columbia Basin irrigation project.

^b Regulated flows resulting from control of 482,000 acre-feet in Chiwawa Reservoir.

^c 548 second-feet for 17-year period ended Mar. 31, 1930.

^d Regulated flows resulting from control of 482,000 acre-feet in Chiwawa Reservoir and 1,656,000 acre-feet in Wenatchee Lake Reservoir. Regulated primarily in interest of irrigation.

^e 730 second-feet for 17-year period ended Mar. 31, 1930.

^f Regulated flows resulting from control of 482,000 acre-feet in Chiwawa Reservoir and 1,000,000 acre-feet in Wenatchee Lake Reservoir. Regulated primarily in interest of power.

² Not printed.

841. Using the flows given in table no. 166, and assuming two power developments, one with a head of 500 feet in connection with the Chiwawa dam and reservoir and the other at the Wenatchee Lake dam with an average head of 150 feet, the power duration will be as shown in table no. 167. The total power given in table no. 167 by no means represents the total power available on the Wenatchee and its tributaries, as a thorough study of the power possibilities thereon has not been attempted in these present investigations.

TABLE No. 167.—*Approximate power duration of Wenatchee River sites for the period Apr. 1, 1913, to Mar. 31, 1931, in kilowatts at 80 percent efficiency*

Site	Natural flow			Regulated flow ¹		
	Percent time			Percent time		
	50	90	100	50	90	100
Chiwawa.....	8,700	3,500	1,500	18,600	18,600	11,000
Wenatchee Lake Dam.....	12,700	5,000	2,400	22,600	21,600	13,300
Total.....	21,400	8,500	3,900	41,200	40,200	24,300

¹ Regulation of 482,000 acre-feet in Chiwawa Reservoir and 1,000,000 acre-feet in Wenatchee Lake Reservoir for either plan no. 2-A or plan no. 4 of irrigating the Columbia Basin irrigation project.

842. A recent dispatch from Wenatchee states that the State supervisor of hydraulics has granted a permit to the Wenatchee reclamation district for the construction of a low dam across Wenatchee River to permit storing 30,000 acre-feet of water in Wenatchee Lake. It is claimed that this would assure sufficient water for the irrigation of about 20,000 acres of orchard land in the lower Wenatchee valley. Under the agreement with the State, work on the dam must be started within 3 years and must be completed within 6 years. It is claimed that under this plan the water of Wenatchee Lake would not be raised above the normal high-water level.

(G) MINOR TRIBUTARIES

843. Excepting Chelan River, the Columbia above the Snake has a number of minor tributaries no one of which is an important power stream. The annual inflow to Lake Chelan averages 1,950 second-foot with a variation in monthly flows from a minimum of 140 second-foot to a maximum of 9,010 second-feet. Outflow from Lake Chelan is now affected by regulation of about 665,000 acre-feet of storage in the lake. The lake is regulated by the Washington Water Power Co. in the interest of power at its Chelan plant, which utilizes a head of about 400 feet between the lake and Columbia River. Kettle, Colville, San Poil, Okanogan, Methow, and Entiat Rivers are not at all important as power streams, and any power that will be developed on them would be insignificant when compared with that available on the main river. Some power, about 18,675 horsepower, is now developed in 11 plants on the Yakima, its tributaries, or along the irrigation canals taking water therefrom. No material increase in the developed power on the Yakima is expected, as the greater part of the water in the stream is, or will be, required by the various irrigation projects in that valley.

(II) SUMMARY

844. Complete estimates of the potential power available on the tributaries of the Columbia above the Snake and in the United States have never been made. Estimates made by the United States Geological Survey in 1908 gave values for the four major tributaries as shown in table no. 168. This same estimate lumped the "minor tributaries" of the Columbia in Oregon and Washington as having 535,000 minimum kilowatts and 918,000 maximum. Just how these amounts were divided between the two States cannot be determined from the record.

TABLE No. 168.—*Potential water power on four tributaries of the Columbia (kilowatts)*

Tributary	Percent of time	
	90	50
Spokane.....	177,000	455,000
Clark Fork.....	1,140,000	1,950,000
Yakima.....	145,000	467,000
Kootenai.....	154,000	266,000
Total.....	1,616,000	3,138,000

845. Table no. 169 gives a summary of the power possibilities at certain specific sites as discussed in the preceding text. It will be noted that the table does not take into account potential sites in Canada. The Clark Fork, with its total fall in Canada of 400 feet in less than 16 miles, would have a potential power (at 80 percent efficiency) of about 149,000 kilowatts for 100 percent of the time with natural flow, and about 397,000 kilowatts with the flow regulated for plan no. 4, or an increase in 100 percent power under plan no. 4 of 246,000 kilowatts. The developed sites on the Clark Fork and Spokane are included in that table, as the various plans of regulation and of irrigation withdrawals quite materially affect their output. Of the 43 sites or alternative sites given in table no. 169, but one, that at Z Canyon on Clark Fork, has a capacity in excess of 100,000 kilowatts for 90 percent of the time, with either natural or regulated flow. The second largest project is that on the Flathead near Polson. As previously stated in the text, this site is now being developed by a subsidiary of the Montana Power Co. The remaining undeveloped sites have an average capacity of about 24,000 kilowatts for 90 percent of the time, for regulated flow. Development of plants of this size could not materially affect the market for power to be generated at any of the large sites on the Columbia, but may fill a real need in the near future by providing sites capable of early development. The site at Z Canyon is comparable in possible power output with several of the smaller sites on the Columbia above the Snake. Because of its size, the problem of marketing its output is one of considerable magnitude.

TABLE NO. 169.—Summary of power possibilities on tributaries of Columbia River (above the Snake and within the United States) period Apr. 1, 1913, to Mar. 31, 1931

Item No.	Stream and site	Regulation	Power in kilowatts at 80 percent efficiency								
			Percent time, natural flow			Percent time, regulated flow					
			50	90	100	50	90	100			
1	Kootenai River:										
2	Koofanal Falls	None	33,300	18,200	13,100	33,300	18,200	13,100			
	Leonla	do	18,700	10,200	7,400	18,700	10,200	7,400			
3	Flathead River and tributaries:										
4	Diverstons of Middle Fork to South Fork	No estimate									
5	Flathead River below Middle Fork	1,100,000 acre-feet in Hungry Horse Reservoir	28,600	10,800	7,400	63,300	51,700	14,600			
6	South Fork at Hungry Horse Creek	No estimate									
7	Flathead River near Coram	1,100,000 acre-feet in Flathead Lake	64,000	32,800	19,000	82,300	64,200	51,000			
8	Flathead River near Polson	1,100,000 acre-feet in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake	64,000	32,800	19,000	113,500	96,000	88,100			
9	Flathead River, 4 sites below tailrace of site near Polson	do	60,600	31,100	18,000	107,200	90,800	83,500			
10	Clark Fork:										
11	Fish Creek	None	45,500	25,000	8,800	45,500	25,000	8,800			
	Thompson Falls (35,000 kilowatts now developed)	1,110,000 acre-feet in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake	36,800	20,000	13,200	47,300	36,400	30,200			
12	Donlan	do	29,400	16,000	10,600	37,800	29,200	24,200			
13	Rock Island Gorge	do	42,200	26,000	15,300	52,900	39,400	32,500			
14	Cabinet Gorge	do	63,300	34,500	23,000	79,100	59,200	48,700			
15	Albany Falls	1,100,000 acre-feet in Hungry Horse; 1,540,000 in Flathead Lake; 599,000 in Priest Lake with Pend Oreille regulated below elevation 2066.8 (U. S. Coast and Geodetic Survey datum); Columbia Basin irrigation project irrigated by gravity (plan 2-A).	22,000	12,000	8,000	23,000	15,000	10,000			
16	Do	do									
17	Z Canyon	Same as item 15	22,000	12,000	8,000	30,000	20,000	16,000			
18	Do	Same as item 16	243,000	137,000	91,100	238,000	188,000	146,000			
19	Priest River and Lake	Same as item 16	243,000	137,000	91,100	337,000	268,000	213,000			
20	Spokane River:										
	Post Falls (11,250 kilowatts now developed)	599,000 acre-feet in Priest Lake	5,280	2,190	1,460	10,600	8,910	5,920			
		293,100 acre-feet in Coeur d'Alene Lake, not including the amount now used by the Washington Water Power Co.; Columbia Basin irrigation project irrigated by gravity (plan 2-A).	9,310	4,110	3,410	14,500	4,640	3,520			
21	Do	do	9,310	4,110	3,410	11,600	7,030	4,940			

1 Except plan 4 for irrigation.

TABLE NO. 169.—Summary of power possibilities of Columbia River (above the Snake and within the United States) prior Apr. 1, 1913, to Mar. 31, 1931—Continued

Item No.	Stream and site	Regulation	Power in kilowatts at 80 percent efficiency					
			Percent time, natural flow			Percent time, regulated flow		
			50	90	100	50	90	100
22	Crossing.....		7,320	3,860	3,260	7,780	4,710	4,050
23	Do.....	Same as item 20	7,320	3,860	3,260	8,850	5,850	5,470
24	Water Works (Spokane pumping plant)	Same as item 21	4,010	2,130	1,790	4,280	2,580	2,220
25	Do.....	Same as item 21	4,010	2,130	1,790	4,850	3,230	3,000
26	Upper Falls, Spokane (10,000 kilowatts now developed).	Same as item 20	12,000	6,640	5,560	12,700	7,380	6,760
27	Do.....	Same as item 21	12,000	6,640	5,560	14,360	9,630	8,920
28	Monroe Street, Spokane (8,800 kilowatts now developed).	Same as item 20	14,300	7,930	6,640	15,200	9,430	8,080
29	Do.....	Same as item 21	14,300	7,930	6,640	17,100	11,500	10,600
30	Bowl and Fitcher.....	Same as item 20	16,700	9,360	7,900	17,600	11,100	9,580
31	Do.....	Same as item 21	16,700	9,360	7,900	19,700	13,500	12,500
32	Nine Mile (12,000 kilowatts now developed)	Same as item 20	12,900	7,260	6,060	13,600	8,640	7,380
33	Do.....	Same as item 21	12,900	7,260	6,060	15,200	10,500	9,710
34	Long Lake (70,000 kilowatts now developed)	Same as item 20	42,300	26,300	21,800	44,200	29,800	25,200
35	Do.....	Same as item 21	42,300	26,300	21,800	48,700	34,000	31,100
36	Little Falls (26,500 kilowatts now developed)	Same as item 20	18,000	11,200	9,320	18,900	12,700	10,700
37	Do.....	Same as item 21	18,000	11,200	9,320	20,800	14,000	13,300
38	Fish Hawk.....	Same as item 20	21,200	13,200	11,000	22,200	15,000	12,600
39	Do.....	Same as item 21	21,200	13,200	11,000	24,500	17,400	15,700
40	Narrows.....	Same as item 20	25,400	15,800	13,200	26,500	17,000	15,200
41	Do.....	Same as item 21	25,400	15,800	13,200	29,200	20,700	18,700
42	Wenatchee River and tributaries:							
43	Chiwawa.....	482,000 acre-feet in Chiwawa Reservoir	8,700	3,500	1,500	18,600	18,000	11,000
	Wenatchee Lake.....	482,000 acre-feet in Chiwawa Reservoir and 1,000,000 acre-feet in Wenatchee Lake Reservoir, as regulated for plan 2-A or plan 4.	12,700	5,000	2,400	22,600	21,000	13,300
44	Total under plan 2-A of irrigating Columbia Basin	irrigation project, items 1, 2, 5, 8, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 43.	897,500	489,110	350,200	1,128,760	832,580	642,610
45	Total under plan 4 of irrigating Columbia Basin	irrigation project, items 1, 2, 5, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 42, 43.	897,500	489,110	350,200	1,232,100	941,840	774,260
46	Total under plan 2-A for low Grand Coulee Dam	in Columbia River, item 44 minus 40.	872,100	473,310	317,000	1,102,260	814,680	637,410
47	Total under plan 2-A for high Grand Coulee Dam	in Columbia River, item 44 minus (38+40)	850,900	460,100	306,000	1,080,060	793,680	614,810
48	Total under plan 4 for low Grand Coulee Dam	in Columbia River, item 45 minus 41.	872,100	473,310	317,000	1,202,900	921,140	755,560
49	Total under plan 4 for high Grand Coulee Dam	in Columbia River, item 45 minus (39+41)	850,900	460,110	306,000	1,178,400	963,740	739,860

(3) DEVELOPED POWER

I. POWER PLANTS

846. There is but one developed hydroelectric power plant on the Columbia between the international boundary and Snake River, see map, plate no. 114.² This is a small plant rated at 1,800 kilovolt-amperes, located in section 2, township 13 north, range 23 east, Willamette meridian, at Priest Rapids. It is owned by the Black Rock Power & Irrigation Co., a company which is affiliated with the Electric Bond & Share Co. Water is diverted by a wing dam and conveyed through a canal to the power house on the right bank. The operating head is 26 feet. Power generated at this plant is transmitted to Coyote Rapids, about 15 miles downstream from the plant, where it is used to pump water from the river for the Hanford irrigation tract. Some surplus energy is sold to the Pacific Power & Light Co., an associated company. A full development of the power possibilities at Priest Rapids, as outlined in paragraphs 712 to 757, would require scrapping this plant.

847. A hydroelectric power project is being developed by the Puget Sound Power & Light Co., at Rock Island, about 11 miles below Wenatchee. This project has been described in paragraphs 670 to 688. It is expected that the first two units of this development will be in operation by January 1, 1932, and two more units by January 1, 1933. The initial development will have an installed capacity of 60,000 kilowatts, and the ultimate development a total capacity of between 150,000 and 200,000 kilowatts, the whole of which is expected to be installed by 1937.

848. On the tributaries of the Columbia above the Snake and within the United States are a number of important hydro-power plants. In the drainage basin of the Columbia in Montana there is but one developed plant of any considerable importance and one additional plant under construction. Both of these are owned by the Montana Power Co. or its subsidiaries. A description of the one now under construction on Flathead River below Flathead Lake has already been given earlier in this report under the caption "Tributary effects." (See pars. 776 to 780.)

849. The other plant of the Montana Power Co. is the one at Thompson Falls (see par. 784) on the Clark Fork, near the extreme western boundary of Montana. The development consists of a main concrete dam, 1,000 feet long and 35 feet high, located above the falls, and a smaller concrete dam across a side or high-water channel. Water is conveyed 600 feet through the side channel, and an open rock-cut canal to the power house on the main river. A natural fall of 15 feet was utilized in connection with the dam to make a total head of 50 feet. The concrete power house has six vertical-type water-wheel units with a total capacity of 35,000 kilowatts. The minimum monthly natural flow is about 5,000 second-feet and the mean flow is about 22,900 second-feet. This development is not connected with the main system of the Montana Power Co. except by way of the Chicago, Milwaukee, St. Paul & Pacific Railroad Co.'s line serving the electrified portion of that company's road in Montana. A small-capacity line from the Thompson Falls distribution system

² Not printed.

serves the needs of the construction work now in progress at the previously-mentioned Flathead power site. The Thompson Falls plant furnishes power to the Coeur d'Alene mining district in Idaho, and to the Chicago, Milwaukee, St. Paul & Pacific Railroad Co.'s electrification. The Montana Power Co. has an additional 253,500 kilowatts of installed capacity in nine plants located east of the Continental Divide. Because of their distance from the Columbia, these plants are not listed herein.

850. In the drainage basin of the Columbia above the Snake in Idaho, there are two developed power plants—one a small stand-by steam plant at Sandpoint, and the other the Post Falls hydro plant of the Washington Water Power Co. on the Spokane River, 25 miles east of Spokane. This station was built in 1906, and houses five generators of 11,250 kilowatts total capacity. The dam at Post Falls now controls storage amounting to 155,000 acre-feet in Coeur d'Alene Lake.

851. On the tributaries of the Columbia above the Snake, and in Washington are about a dozen developed hydro plants of importance to the operating public utilities. There are also a few isolated industrial hydro plants in this area, but these have not been listed, as they do not materially affect the power situation. In this area, the Washington Water Power Co. owns five plants on the Spokane, namely, Upper Falls, 10,000 kilowatts; Lower Falls, 8,800 kilowatts; Nine Mile Falls, 12,000 kilowatts; Long Lake, 70,000 kilowatts, with 80,000 acre-feet usable storage at the site; and Little Falls, 29,500 kilowatts. In addition, this company owns the Chelan plant, 48,000 kilowatts, on Chelan River, with 672,000 acre-feet usable storage, and some smaller plants on other tributaries. This same company also owns a 10,000-kilowatt plant on the Clearwater, a tributary of the Snake at Lewiston, Idaho, and also some smaller plants on other tributaries of that stream. These latter plants are mentioned here although they are located outside of the area considered in the Seattle district report.

852. The Puget Sound Power & Light Co. operates five plants in the area under consideration, all in the vicinity of Wenatchee—namely, Dryden, 2,450 kilowatts; Entiat, 1,100 kilowatts; Leavenworth, 135 kilowatts; Tumwater, 6,000 kilowatts, leased from the Great Northern Railway; and the Wenatchee steam plant of 1,500 kilowatts capacity. Other plants of this company located in the Puget Sound area will be listed later herein.

853. The Pacific Power & Light Co. operates 2 hydro plants and 1 steam plant in that portion of its Yakima system in the drainage basin of the Columbia above the Snake, as follows: Naches Drop, 1,450 kilowatts; Naches, 7,500 kilowatts; and the Naches steam plant of 2,000 kilowatts capacity. This company operates several other small plants, some of which are a part of their Yakima system, but which are located in the drainage area below the Snake.

854. A summary of the principal public utility companies operating within or adjacent to the drainage basin of the Columbia above the Snake, together with the ratings of the individual plants, developed and under construction, is given in table no. 170. Subsidiary or associated companies are not, in general, mentioned by name, although the plants of such subsidiaries are, in general, included in the table.

TABLE NO. 170.—Principal public utility companies and developed power

Ref. no. on plate no. 114 ¹	Company and plant	Head of hydro plants	Installed capacity	
			Hydro	Fuel
	The Montana Power Co. (west of Continental Divide):	<i>Feet</i>	<i>Kw.</i>	<i>Kw.</i>
	Thompson Falls ²	50	35,000	
	Flathead (under construction) ²	185	(³)	
	System total (developed).....		35,000	
3	Mountain States Power Co.:			
	Sandpoint, Idaho ²			500
6	Pacific Power & Light Co.:			
	Naches Drop, Wash. ²	53	1,450	2,000
	Naches, Wash. ²	151	7,500	1,000
	Walla Walla, Wash.			1,000
	Walla Walla River.....	362	2,750	
	Wallowa Falls, Wash.	1,175	800	
	Joseph, Wash.	155	1,000	
	System total.....		13,500	3,000
7	Washington Gas & Electric Co.:			
	Longview, Wash.			24,000
8	The Washington Water Power Co.:			
	Post Falls, Idaho ²	50	11,250	
	Long Lake, Wash. ²	172	70,000	
	Little Falls, Wash. ²	73	23,500	
	Upper Falls, Wash. ²	64	10,000	
	Monroe Street, Wash. (Spokane) ²	70	8,800	
	Nine Mile Falls, Wash. ²	60	12,000	
	Oroville, Wash. ²	80	3,200	
	Cheban, Wash. ²	400	48,000	
	Dalkena, Wash. ²	309	560	
	Lewiston, Idaho.....	36	10,000	
	Asotin, Wash.	503	1,500	
	Orofino, Idaho.....			150
	Grangeville, Idaho.....	60	624	
	System total.....		205,434	150
9	Puget Sound Power & Light Co.:			
	Rock Island (under construction):			
	(Initial development).....	32	60,000	
	White River.....	475	60,000	
	Snoqualmie Falls.....	290	20,000	
	Electron.....	865	22,500	
	Baker River.....	216	40,000	
	Granite Falls.....	8	60	
	Nooksack Falls.....	228	1,750	
	Jim Creek.....	70	200	
	Sulltan.....	212	90	
	Dryden ²	55	2,450	
	Entiat ²	78	1,100	
	Leavenworth ²	56	135	
	Tumwater (leased from G. N. Ry.) ²	200	6,000	
	Lake Sylvia.....	60	200	
	Olympia.....	84	1,650	
	Kalama.....	40	600	
	Post Street.....			3,500
	Georgetown.....			23,000
	Everett.....			500
	Bellingham.....			2,000
	Wenatchee ²			1,500
	Chehalis.....			4,500
	Shuffleton.....			80,000
	System total (developed and leased).....		156,735	112,000
10	City of Seattle:			
	Diablo (under construction).....	310	120,000	
	Lake Union.....	410	1,500	30,000
	Cedar Falls.....	618	38,800	
	Gorge Plant.....	271	56,000	
	Newhalem Creek.....	535	2,000	
	System total (developed).....		98,300	30,000
11	City of Tacoma:			
	La Grande.....	425	24,000	
	Tacoma Steam No. 1.....			9,000
	Tacoma Steam No. 2.....			25,000
	Cushman No. 1.....	215	32,000	
	Cushman No. 2.....	480	54,000	
	System total.....		110,000	34,000

¹ Not printed.² Located in drainage basin of Columbia above the Snake and in the United States.³ 56,000 kw. initial.

TABLE NO. 170.—Principal public utility companies and developed power—Con.

Ref. no. on plate no. 114	Company and plant	Head of hydro plants	Installed capacity	
			Hydro	Fuel
12	Subsidiaries of Crown-Zellerbach Corporation:	110	13,000	
	Elwha.....			4,000
	Port Angeles.....		4,000	
	Port Angeles No. 2.....	180	12,000	4,000
	Glines Canyon.....			9,500
	Port Angeles.....			7,250
	Port Townsend.....			1,000
	Hoquiam.....			
Shelton.....				
	System total.....		25,000	30,150
13	Grays Harbor Railway & Light Co., and associated companies:			
	Electric Park.....			12,900
	Anderson Middleton Lumber Co.....			1,000
	Grays Harbor Lumber Co.....			3,000
	Willapa Lumber Co.....			1,000
	System total.....			17,900
18 20	City of Centralia, Wash.....	208	4,000	
	Weyerhaeuser Timber Co., and subsidiaries:			
	Longview.....			15,000
	Everett.....			7,000
	Snoqualmie Falls.....			7,000
	System total.....			29,000
<i>Summary</i>				
Total developed power in drainage basin of Columbia above the Snake and in the United States.....			246,945	4,000
Total developed outside drainage basin of Columbia above the Snake.....			401,024	276,700
Total developed.....			647,969	280,700
Total under construction in drainage basin of Columbia above the Snake and in the United States.....			118,000	
Total under construction outside drainage basin of Columbia above the Snake.....			120,000	
Total developed and under construction.....			883,969	280,700

855. Hydroelectric plants in the Canadian portion of the drainage basin are important as concerns local industries in that country, but are not now and are not likely to be very important as regards American industries. It is true that transmission distances to the market centers in the United States from the developed sites, and from those potential sites scheduled for early development, are not unreasonable in length. But the international boundary is more than an imaginary line separating the two countries, since certain legal restrictions have been set up for regulation of energy exchanges. M. J. Patton⁵¹ says that "no power may be exported from Canada except under a revocable Federal permit and that in 1925 an export duty of three one-hundredths of a cent per kilowatt-hour was imposed on such exports. Canadian public sentiment is strongly in favor of retaining Canadian power at home to build up Canadian industry. It is felt that if industries in a foreign country are built up with Canadian power, it will be impossible, without serious international complications, to withdraw that power when it is required in Canada". However, to complete the power story, data on the developed plants in Canada, both for the region within the basin of the Columbia and for that portion outside the basin but within reasonable transmission distance of the Puget Sound market centers, are given in table no. 171.

⁵¹ M. J. Patton, Economist, National Resources Intelligence Service, Canada. From vol. II, no. 2, April 1926.

TABLE NO. 171.—Principal developed powers in British Columbia (kilowatts)

Company and plant	Site	Installed capacity	
		Hydro	Fuel
Columbia River Drainage Basin:			
East Kootenay Power Co.:			
Aberfeldie	Bull River	4,000	-----
Elko	Elk River	9,600	-----
Hedley Gold Mining Co., Hedley	Similkameen River	1,000	-----
City of Nelson; upper Bonnington Falls	Kootenay	1,750	-----
Municipality of Revelstoke	Illecillawaet River	9,600	-----
Do.	Revelstoke River	-----	400
West Kootenay Power & Light Co.:			
Lower Bonnington Falls	Kootenay River	42,000	-----
Upper Bonnington Falls	do	24,000	-----
South Stocan	do	42,000	-----
West Canadian Hydroelectric Corporation:			
Vernon	-----	-----	580
Miscellaneous plants	-----	305	1,765
Subtotal	-----	134,255	2,745
Outside Columbia River Drainage Basin:			
Victoria Lumber & Manufacturing Co.: Chemainus	Chemainus River	-----	3,300
Municipality of Kamloops:	-----	-----	-----
Barriere	Barriere River	1,200	1,200
Kamloops	-----	-----	-----
Pacific Mills: Ocean Falls	Link River	12,000	-----
British Columbia Pulp & Paper Co.: Port Alice	Victoria Lake	250	5,000
Powell River Co.: Powell	Powell River	17,080	-----
Municipality of Prince Rupert:	-----	-----	-----
Woodworth	Shawatlans River	900	-----
Prince Rupert	-----	-----	2,000
British Columbia Electric Ry. Co. and affiliated companies:			
Goldstream	Goldstream River	1,200	-----
Bridge River (under construction)	Bridge River (initial)	40,000	-----
Stave Falls	Stave River	54,000	-----
Jordan	Jordan River	25,400	-----
Brentwood Bay	-----	-----	3,200
Coquitlam-Buntzen:			
No. 1	North Avon River	18,900	-----
No. 2	do	24,030	-----
Vancouver	-----	-----	12,500
Stave Lake (Alouette)	Stave Lake	9,000	-----
Ruskin	Stave River (initial)	35,000	-----
West Canadian Hydroelectric Corporation: Shuswap Falls	Shuswap River	2,400	-----
Miscellaneous plants	-----	56,475	1,351
Subtotal outside Columbia River drainage	-----	257,835	28,551
Subtotal Columbia River drainage	-----	134,255	2,745
Total British Columbia (developed)	-----	392,090	31,296

856. The water-power resources of the Province of British Columbia have been estimated⁵² by the Dominion Water Power and Reclamation Service at 1,931,000 horsepower minimum and 5,103,000 for six months, of which 473,000 horsepower has already been developed. The full opportunities are, however, not reflected in these figures, as, in most cases, they are based upon the actual unregulated flow and take no account of possible storage and diversions which would make possible a total development of power considerably in excess of the above figures. Of the total resources, 336,000 horsepower minimum, and 1,092,000 horsepower for six months, are located on the Columbia or its tributaries.

II. TRANSMISSION LINES

857. The territory under consideration in this report is well served by transmission lines, as may be seen from an inspection of plate no. 114.² New main lines and feeders have been constructed from time to time as required by the development of the various power projects and by the increase in number and distribution of customers. Data on the principal transmission lines in the basin of the

² Not printed.

⁵² Water Resources Paper No. 55, Dominion Water Power and Reclamation Service (May 1, 1928).

Columbia above the Snake and in the adjacent territory to the north and west are included in this section of this report. Additional details covering the operating companies and their transmission systems may be found later in this report under the head of "Markets for power".

858. The Washington Water Power Co. is the only major public utility operating wholly within the territory included within the scope of this report. This company's system is served by a network of 110- and 60-kilovolt main transmission lines with extensions and feeders as required operating at 33, 22, 13, and 11 kilovolts. The company's principal interconnections are with the Montana Power Co. on the east, with the Pacific Power & Light Co. on the south, and with the Puget Sound & Light Co. on the west.

859. The Montana Power Co. and subsidiary companies serve the territory included within the basin of the Clark Fork, and also considerable territory in the drainage basin of the Mississippi. The Pacific Power & Light Co. serves several scattered sections extending from Astoria, Oreg., at the mouth of the Columbia to eastern Washington and Oregon.

860. The Puget Sound Power & Light Co. and subsidiary companies serve most of the Puget Sound region, the Wenatchee Valley, and a narrow strip along the Columbia near Wenatchee. The Chicago, Milwaukee, St. Paul & Pacific Railroad owns and operates the lines indicated in table no. 173. These lines, as well as those of the Great Northern Railway, parallel and serve the electrified section of those roads. The city of Seattle and the city of Tacoma each has a municipal system supplying some of the needs of their respective communities. The Puget Sound Power & Light Co. is an active competitor in these same communities, although the Tacoma system enjoys practically noncompetitive control of their urban load. The Grays Harbor Railway & Light Co., with its associated companies, supplies the territory immediately adjacent to Grays Harbor and Willapa Bay.

861. As evidence of the thoroughness with which these companies have covered their respective territories, data on the number of miles of circuits at various voltages are presented in table no. 172.

TABLE NO. 172.—Mileage of overhead electric transmission and distribution lines

Voltage (kilovolts)	Montana Power Co.	Washington Water Power Co.	Pacific Power & Light Co.	Puget Sound Power & Light Co.	City of Seattle	City of Tacoma	Grays Harbor Railway & Light Co.
165.....					100		
110.....	806	632	15	351		88	
66.....		27	571	97			31
60.....	317	539			85		
35.....				787			
50.....	1,381					90	
45.....	50			77			
33.....		52		129			
26.....					152		
22.....	8	220	9	29			
16.....	62						
13.....	83	572		534		15	35
11.....	56	13	29	247			
Total of 11 kilovolts or more.....	2,760	2,055	624	2,251	337	193	66
Total of 6.6 kilovolts and less.....	1,323	1,281	1,323	7,180	1,015	1,950	142
Total circuit miles.....	4,083	3,336	1,947	9,431	1,352	1,143	208

¹ Estimated.

862. An inspection of the map (pl. no. 114²) indicates the extent of the transmission line net in British Columbia. Only one Canadian-owned line enters the United States—the line from Rossland, British Columbia, to Northport, Wash., but this is not interconnected with any system on this side of the boundary. An actual interconnection between a Canadian company and the Puget Sound Power & Light Co. exists at Sumas, Wash., and at times a considerable amount of energy has been exchanged.

863. The region considered in this report, and that within reasonable transmission distance therefrom, excluding British Columbia and that part of the Montana Power Co.'s territory east of the continental divide, is served by the principal transmission lines indicated in table no. 173. All of these are 3-phase, 60-cycle lines except those of the Great Northern Railway, which are single-phase, 25-cycle lines. In addition to the lines shown in table no. 173, there are two major transmission lines scheduled for early completion—one, the Puget Sound Power & Light Co.'s 110-kilovolt line now under construction from Everett (Beverly substation) to Rock Island; the other being the 165-kilovolt line of the city of Seattle from their Diablo plant to Seattle. A third major line will be constructed from the Polson, Mont., plant of the Montana Power Co. (now under construction) to Anaconda, Mont.

TABLE NO. 173.—Principal transmission lines

From—	To—	Number of circuits	Voltage	Nominal total capacity
Montana Power Co.: Thompson Falls.....	Burke, Idaho, with tie to Chicago, Milwaukee, St. Paul & Pacific R.R. at Avery, Idaho.	2	Kilovolts 110	Kilovolt amperes 70,000
Do.....	Polson, Mont.....	1	50	5,000
Washington Water Power Co.:				
Long Lake.....	Spokane.....	2	110	70,000
Little Falls.....	do.....	2	60	40,000
Do.....	Lind (with tie to Coulee city).....	1	60	10,000
Long Lake.....	Taunton.....	2	110	50,000
Nine Mile.....	Spokane.....	2	60	20,000
Post Falls.....	do.....	2	60	16,000
Spokane.....	Burke, Idaho, via Latah Junction.....	1	110	20,000
Do.....	Kellogg, Idaho.....	1	110	50,000
Chelan.....	Okanogan.....	1	110	20,000
Do.....	6 miles southwest of Chelan ^a	1	110	40,000
Do.....	Stratford.....	2	110	80,000
Latah Junction.....	Pomeroy, via Lewiston.....	1	60 22 66	^b 8,500
Puget Sound Power & Light Co.:				
Electron.....	White River.....	2	55	40,000
Do.....	Tenino.....	1	55	15,000
White River.....	Tacoma.....	3	55	30,000
Do.....	Seattle.....	4	55	60,000
Do.....	Wenatchee.....	1	110	20,000
Snoqualmie Falls.....	Renton.....	2	55	30,000
Do.....	Cedar Falls.....	1	110	12,000
Everett.....	Seattle.....	2	55	45,000
Do.....	Skykomish.....	1	110	35,000
Baker River.....	Everett.....	2	110	50,000
Sedro Woolley.....	Bellingham.....	1	55	15,000
Port Angeles.....	Bremerton.....	1	66	5,000
Wenatchee.....	Washington Water Power Co. line near Chelan.....	1	110	40,000
Renton.....	Everett.....	1	55	20,000

^a Connects with Puget Sound Power & Light Co. line from Wenatchee.

^b Capacity between Moscow and Lewiston limited to 1,500 kilovolt-amperes.

² Not printed.

TABLE No. 173.—Principal transmission lines—Continued

From—	To—	Number of circuits	Voltage	Nominal total capacity
Pacific Power & Light Co.:			<i>Kilovolts</i>	<i>Kilovolt amperes</i>
Naches.....	Yakima.....	2	66	20,000
Yakima.....	Pasco.....	2	66	16,650
Hanford.....	Taunton.....	1	110	19,000
Pasco.....	Lind.....	1	66	10,000
Do.....	Pendleton.....	2	66	24,000
Walla Walla.....	Pomeroy.....	1	66	8,500
Condit.....	Yakima.....	1	110	25,000
City of Seattle:				
Cedar Falls.....	Seattle.....	2	60	50,000
Gorge.....	do.....	1	165	80,000
Seattle.....	Tacoma.....	1	60	15,000
City of Tacoma:				
La Grande.....	do.....	2	55	40,000
Cushman Plant.....	do.....	2	110	150,000
Great Northern Ry. Co., Skykomish.....	Wenatchee.....	2	44	15,000
Grays Harbor Railway & Light Co., Aberdeen.....	Raymond.....	1	66	25,000
Chicago, Milwaukee, St. Paul & Pacific R. R. Co.:				
Taunton.....	Cedar Falls.....	1	110	12,000
Snoqualmie Falls.....	Tacoma.....	1	110	20,000
Avery, Idaho.....	Harlowtown, Mont.....	1	110	12,000

* Owned jointly by cities of Seattle and Tacoma.

(4) MARKET—PRESENT AND PROSPECTIVE—I. PAST AND PRESENT USES

(A) CHARACTER—WITH RELATION TO GENERAL USE MADE OF POWER, IMPORTANT INDUSTRIES, ETC.

864. The power market in this district is divided geographically into two parts by the Cascade Mountains. West of the mountains and surrounding Puget Sound is a metropolitan area including Seattle, Tacoma, and a number of smaller cities in which is concentrated the greater part of the population of the State of Washington. Adjacent are the large lumber, pulp, and paper mills which at this time represent the basic industries of the region. Immediately east of the Cascades, in the drainage basin of the Columbia, is an agricultural section which is largely dependent on irrigation. Farther east are mountain ranges in which both lumbering and mining are important. Spokane is the largest city of the upper Columbia Basin.

865. Domestic load, both urban and rural, has expanded rapidly during recent years. The same can be said of commercial uses of electricity.

866. The metropolitan areas contain many factories which serve the basic timber and mining industries and the population of the region. While individually they are relatively small, in the aggregate they are an important factor in balancing the electrical industry and contributing to its diversification and stability.

867. The lumber and paper mills at this time generate a large part of the power they use and frequently have a surplus which is sold to the utilities. Their fuel is the refuse of the industry.

868. Mining companies are large users of purchased power. Electrification of the Chicago, Milwaukee, St. Paul & Pacific Railroad and of the Great Northern is an important contribution to the market.

(B) GROWTH OF TERRITORY SINCE ABOUT 1900

1. BEARING OF POPULATION GROWTH ON POWER USES

869. Both population and use of electricity have increased greatly in Washington and the Pacific Northwest during the past three decades. If relative increases are compared for the Northwestern States or for other sections of the United States, there appears to be no direct correlation between changes of population and production of kilowatt-hours. This is due to the rapid increase of applications of electric power to all manner of industrial uses, which, in the aggregate, are so large that they overshadow the applications which are more directly affected by population.

870. Nevertheless, it is obvious that size and character of population are important elements in the marketing of electric power. This is shown where statistics are available which permit of the separation of the energy sold for residential purposes. Growth occurs in two ways; by the increase in the number of residential consumers and by the increase in the average consumption per consumer.

871. The number of residential consumers of several public utilities operating in Washington are shown in table no. 174 for the years indicated.

TABLE No. 174.—*Number of residential consumers of electric power*

[Compiled from supplements to Electrical World]

Utility	1925	1926	1927	1928	1929
Puget Sound Power & Light Co.....			105,335	108,354	120,919
The Washington Water Power Co.....					43,399
Pacific Power & Light Co.....	32,206	35,190	37,350	48,645	49,063
City of Seattle.....			75,083	80,540	82,824
City of Tacoma.....			31,122		32,002

872. The increasing consumption per residential consumer is well illustrated by the figures for recent years which are given in table no. 175, insofar as they are available for public utilities operating in the State of Washington.

TABLE No. 175.—*Average sales to residential consumers in kilowatt-hours per year per consumer*

[Computed from data published by Electrical World]

Utility	1925	1926	1927	1928	1929
Puget Sound Power & Light Co.....			726	520	1,011
The Washington Water Power Co.....					1,799
Pacific Power & Light Co.....	454	533	620	778	890
City of Seattle.....			853	925	1,018
City of Tacoma.....			1,050		1,161

873. These figures compare well with those for the various sections of the United States. See table no. 176. Results for 1930 have not yet been published, but it is certain that the trend continues rapidly upwards. It is the general consensus of opinion among the utilities that the residential market is far from saturated. A statistical study by the Electrical World concludes that there is possible an annual "economic domestic use of 40,000 kilowatt-hours per home for a large percentage of the customers."

TABLE No. 176.—*Kilowatt-hours per domestic consumer*

[From Electrical World, Jan. 3, 1931, p. 71. These averages are computed from figures obtained from 41 major utility systems which are regarded as typical of the entire industry]

Section	1925	1926	1927	1928	1929
New England.....	330	335	371	422	468
Middle Atlantic.....	394	440	471	485	492
East North Central.....	470	487	512	548	595
West North Central.....	377	388	415	460	494
South Atlantic.....	393	423	472	506	550
East South Central.....	317	342	397	427	513
West South Central.....	340	344	366	391	418
Mountain.....	517	512	500	470	551
Pacific.....	508	592	603	714	728
Total, United States.....	447	452	473	507	547

874. According to statistics published in *Electrical World*⁵³ the residential use of electricity in the United States increased 295 percent from 1920 to 1930. In 1920 it was 9.1 percent of the total energy delivered to the ultimate consumers. By 1930 it had grown to 15.3 percent of the greater total.

875. During the same interval the revenue from residential consumers increased 316 percent. In 1920 it was 25.4 percent of the total revenue for electric service. By 1930 it had become 32.7 percent of the total.

876. Although comparable figures are not given for the Pacific Northwest, other data indicate that the trends have been quite similar to those for the United States. Data for 1929 in table no. 177 show the importance of residential service in the business of the principal Washington utilities, these sales being 20.9 percent of the total deliveries to consumers.

TABLE No. 177.—*Sales to residential customers, 1929*

Utility	Kilowatt-hours (millions)	Percent of total sales to consumers
Puget Sound Power & Light Co.....	122.4	18.2
The Washington Water Power Co.....	77.9	17.6
Pacific Power & Light Co.....	43.6	27.0
City of Seattle.....	84.2	31.1
City of Tacoma.....	37.3	18.7
Total.....	365.4	20.9

877. Parallel stories are told by statistics of the power sales in classes designated as "retail light and power" (which includes small commercial consumers) and as "municipal" (which includes street lighting, water pumping, and power for other municipal functions). It is probable that the growth of sales of electricity in both these classes will be influenced by the growth of population in much the same manner as in the "residential" class. During 1929 the five utilities listed in table no. 177 reported their sales of "retail light and power" to be 15.1 percent of their total deliveries, and sales for municipal uses (excluding municipal railways) to be 3.3 percent of the total.

⁵³ Issue of Jan. 3, 1931, p. 28.

2. INDUSTRIAL DEVELOPMENT

878. The settlement of the Pacific Northwest followed the explorations of hunters and trappers. Trading centers and agricultural communities were gradually established, and towns with numerous small repair and manufacturing shops grew up to serve the growing population, which was so far removed from centers of industry.

879. With the improvement of transportation have come the lumber, paper, mineral, fishing, fruit, and other basic industries which convert the raw material of the region into exportable products. In the same manner that small industries were established in the early days, many secondary industries are now undertaking to furnish the various specialized materials and supplies needed by the larger establishments and by the population. The tendency has been and continues to be toward an integrated community along the Pacific seaboard.

880. The relative importance of manufacturing industries in the State of Washington as shown on the reports of the Bureau of the Census, is given in table no. 178. In this table, the figures represent the "value added in manufacture" by each industry which are obtained by subtracting the cost of the raw materials from the selling value of the products. This avoids the duplications which enter when the "selling value of the product" is used for comparison; duplications that are due to the use of one process as the raw material for another.

TABLE No. 178.—*Value added in manufacture by Washington industries by census years expressed in \$1,000 units. Arranged in order of size in 1927*

[Source: Reports of Bureau of the Census]

Industry	1909	1914	1919	1921	1923	1925	1927
Lumber.....	52, 276	45, 062	141, 753	75, 890	168, 075	140, 214	120, 066
Printing and publishing.....	7, 062	7, 389	12, 796	13, 114	14, 931	17, 392	19, 620
Foundry and machine shop.....	4, 274	3, 837	19, 507	5, 998	10, 063	10, 208	9, 517
Paper and pulp.....	(1)	(1)	5, 590	4, 595	5, 223	6, 884	9, 433
Steam railroad car shops.....	2, 182	3, 947	9, 211	9, 309	11, 907	9, 312	8, 415
Bread and bakery.....	2, 004	3, 024	5, 808	5, 930	6, 816	7, 564	9, 074
Canning.....	4, 549	4, 171	9, 903	5, 226	6, 970	9, 978	7, 798
Flour.....	2, 379	3, 393	7, 936	7, 950	5, 027	5, 981	5, 117
Butter and cheese.....	1, 595	2, 296	6, 280	1, 821	3, 914	4, 061	5, 080
Slaughtering.....	1, 894	2, 543	5, 265	3, 927	5, 539	4, 806	4, 695
Shipbuilding.....	998	2, 114	92, 204	6, 947	5, 064	2, 625	3, 572
Furniture.....	787	646	1, 724	1, 132	2, 180	2, 787	3, 020
Clothing.....	87	206	1, 327	1, 214	1, 909	2, 041	2, 893
Gas, manufactured.....	1, 023	1, 610	2, 074	2, 183	2, 492	2, 812	2, 858
Confectionery.....	(1)	1, 115	4, 618	2, 940	2, 537	3, 931	2, 522
Clay products.....	2, 319	1, 498	1, 228	899	1, 391	1, 914	2, 382
Wood preserving.....	(1)	(1)	(1)	365	705	635	2, 160
Coffees and spices.....	(1) 575	(3) 735	1, 191	746	1, 265	(1)	1, 756
Ice cream.....	(1)	(3)	(3)	(3)	1, 124	1, 427	1, 685
Sheet metal.....	1, 043	791	2, 587	1, 663	1, 335	107	1, 667
Ice, manufactured.....	417	407	640	(3) 747	886	1, 251	1, 305
Stock feeds.....	(3)	(3)	(3)	(3)	(3)	(5)	1, 230
Other industries not shown.....	17, 369	23, 933	34, 755	35, 883	46, 096	51, 651	62, 166
Total—all industries.....	102, 858	108, 717	366, 445	188, 479	306, 499	286, 581	288, 021

¹ Not reported separately.

² Included in confectionery above.

³ Included in flour above.

881. Reports of public utilities listed in table no. 179 give an indication of the importance of sales of power to large commercial and industrial consumers in 1929. There is some difference in the classification as used by the several organizations and therefore, the figures are not strictly comparable.

TABLE NO. 179.—Sales to large power consumers, 1929

Utility	Kilowatt-hours (millions)	Percent of total sales
Puget Sound Power & Light Co.	325.6	48.5
The Washington Water Power Co.	304.0	68.6
Pacific Power & Light Co.	92.7	57.3
City of Seattle.	130.7	48.5
City of Tacoma.	114.6	57.7
Total.	967.6	55.5

882. In the United States the corresponding wholesale use of power and light increased 196 percent during the decade from 1920 to 1930.⁵⁴ In 1920 it represented 61.3 percent of the total power delivered to the ultimate consumer. By 1930 it had become 51.6 percent of the larger total.

883. Revenue from these wholesale deliveries is estimated to have increased 152 percent during the decade. In 1920 it was 38.3 percent of the total revenue. In 1930 it had decreased to 23.7 percent. Corresponding figures are not available for the utilities of the Northwest, but it is probable the trend has been somewhat similar.

(C) PRESENT GROWTH

I. COMPANIES AND MUNICIPALITIES SUPPLYING MARKET

884. A considerable number of companies and municipalities are engaged in generating electric power to meet the requirements of the region covered by this report. Of these, the principal are as follows:

*Utility companies**Municipalities*

Puget Sound Power & Light Co.
The Washington Water Power Co.
Pacific Power & Light Co.
Mountain States Power Co.
Grays Harbor Railway & Light Co.,
and associated companies.
Washington Gas & Electric Co.
The Montana Power Co.

Seattle.
Tacoma.
Centralia.

Manufacturing companies

Crown-Zellerbach Corporation.
Weyerhaeuser Timber Co.

885. *a. Puget Sound Power & Light Co.*—This company was incorporated in 1912 as a consolidation of the properties of the Seattle Electric Co., Pacific Coast Power Co., Puget Sound Power Co., Seattle-Tacoma Power Co., and Whatcom County Railway & Light Co.

886. During the years 1923 and 1924 the company purchased the Washington Coast Utilities, which served the Wenatchee Valley and scattered communities west of the Cascades, the North Coast Power Co., which furnished wholesale and retail electrical energy to certain towns in southwestern Washington, and the Olympia Light and Power Co., which supplied the city of Olympia and a small water power plant on the Des Chutes River near Olympia. It also acquired the Washington Power, Light & Water Co., serving the city of Anacortes, and several small properties serving various districts, such as the Granite Falls Electric Co. and the Mutual Electric Light & Power Co.

⁵⁴ This and the following figures are computed from statistics contained in *Electrical World*, Jan. 3, 1931, p. 28.

887. In 1925 the company acquired a part of the electrical distribution system of the Washington-Idaho Water, Light & Power Co., serving scattered communities in southwestern Washington.

888. In 1926 it acquired several properties on the Olympic Peninsula of Washington, including the transmission line of the Northwestern Power & Light Co., and the distribution systems of the Hub Electric Co. and the Sequim Light & Power Co., together with the property of the North Pacific Public Service Co., serving Bremerton and vicinity. During the same year the company also acquired the Sultan Electric Co., the Avery Public Utilities, the Thurston County Utilities Co., and property of J. L. Mills, each of which served one or more small communities in western Washington.

889. In 1927 the company acquired the distribution systems serving the cities of Monroe and Snohomish from the Mountain States Power Co., together with the smaller systems belonging to the town of Skykomish, the Farmers Cooperative Light & Power Co. and the Coupeville Lighting Co.

890. In 1929 it acquired the property of the Darrington Electric Co., and the distribution system serving the town of Clear Lake.

891. In 1930 the company acquired the Island Light & Power Co. and the Langley Light & Power Co., both located on Whidbey Island, together with the Acme Distribution System.

892. The acquisitions have in general been small properties. Only four of these properties included generating plants now in operating condition; the majority had previously purchased their power from the Puget Sound Power & Light Co. Therefore, the consolidations do not materially affect the trend of production as shown by the company's records.

893. The development and operation of this system has been under the supervision of Stone & Webster and their successors, Stone & Webster, Inc., during the past 31 years. In December 1928 Engineers Public Service Co. purchased a majority of the stock of Puget Sound Power & Light Co. and in April 1930 a plan of affiliation of Engineers Public Service Co. and Stone & Webster, Inc., was consummated, as a result of which over 90 percent of the total outstanding common stock of Engineers Public Service Co. is now controlled by Stone & Webster, Inc. On May 1, 1931, the contracts for supervision of these properties by Stone & Webster Service Corporation were canceled and executive supervision is now provided by Engineers Public Service Co., Inc., all of the stock of which is owned by the constituent companies of Engineers Public Service Co.

894. The company operates mostly in western Washington, supplying electricity in the cities of Seattle, Tacoma, Bellingham, Everett, Olympia, Chchalis, Bremerton, and Wenatchee, serving an area containing a population of over 918,000. The number of consumers was about 150,000 at the close of 1930. In Seattle the company is in competition with the municipal system. In Tacoma the company has been serving about 30 consumers under a franchise which expired in 1930.

895. The company owns, controls, and operates under lease, 15 hydroelectric plants with a combined capacity of 156,735 kilowatts and 7 steam plants with combined capacity of 112,000 kilowatts or a total generating capacity of 268,735 kilowatts.

896. The main transmission system of the company is operated at 110,000 and 55,000 volts. In and close to Seattle it has a network of 13,000-volt tie lines and feeders between the various substations.

897. The company is interconnected with the Washington Water Power Co. at Chelan, Wash., and indirectly at Snoqualmie Falls through Chicago, Milwaukee, St. Paul & Pacific Railroad circuits. Large amounts of power pass through these connections, sometimes in one direction and sometimes in the other, depending upon conditions obtaining on the two systems. Interconnections are also available between the company and the city of Tacoma at Tacoma, Wash., Washington Pulp & Paper Corporation at Port Angeles, Wash.; Northwestern Electric Co. at Kalama, Wash.; Western Canada Power Co. at Sumas, Wash.; Great Northern Railway at Tumwater, Skykomish, and Wenatchee, Wash.; Weyerhaeuser Timber Co. at Longview, Everett, and Snoqualmie, Wash.; navy yard at Bremerton, Wash.; and with some 10 other plants variously located.

898. Construction has begun on a dam and power plant at the Rock Island site on Columbia River, where two 15,000-kilowatt units are expected to be ready for service by January 1, 1932, and two more units by January 1, 1933. Additional units will be brought in from time to time. The entire installation of 10 units with a total capacity of between 150,000 and 200,000 kilowatts is expected to be installed by 1937.

899. The accompanying diagrams, plates nos. 115² and 116,² show the gradual development of the business of the company. Part of this information has been furnished by the company, and the remainder has been collected from other sources.

900. *b. The Washington Water Power Co.*—This company was incorporated in 1889 to serve the city of Spokane and surrounding territory. Since February 1928 it has been controlled by the American Power & Light Co., and under supervision of the Electric Bond & Share Co. In its growth, it has absorbed a number of companies. In recent years these have included:

Intermountain Power Co.....	July 1, 1922
Okanogan Valley Power Co.....	Jan. 1, 1923
Chelan Electric Co.....	May 3, 1926
Potlatch Consolidated Electric Co.....	Sept. 13, 1927
La Crosse Electric Co.....	Nov. 21, 1927
Greenacres Light & Power Co.....	Dec. 16, 1927
Kootenai Power Co.....	Feb. 1, 1930
Grangeville and Lewiston properties of Inland Power & Light Co.	Feb. 13, 1930

The generating equipment of these companies was unimportant in all cases except the Lewiston plant, which added 10,000 kilowatts installed capacity.

901. In 1925 the company purchased the hydroelectric station of the Spokane Eastern Railway, known as "Nine-mile", which has a capacity of 12,000 kilowatts.

902. The company now serves Spokane and 65 other communities in eastern Washington and 35 communities in northern Idaho. The population served at the close of 1930 is estimated by the company to be 232,000.

903. At the present time the Washington Water Power Co. has in operation 13 generating stations all of which are hydroelectric

² Not printed.

except one of 150 kilowatts capacity. Combined they have an installed capacity of 205,584 kilowatts.

904. Coeur d'Alene Lake, 30 miles east of Spokane, is regulated and used as a primary storage reservoir for the series of generating stations on the Spokane River. Lake Chelan near Wenatchee is used as a reservoir serving the station at Chelan Falls.

905. The company has high-tension interconnections with other companies operating in adjoining territory as follows:

Interconnecting company	Exchange point	Voltage
Mountain States Power Co.	Newport, Wash.	60,000
Pacific Power & Light Co.	Lind, Wash.	110,000 to 66,000
Do.	Pomeroy, Wash.	66,000
Do.	Taunton, Wash.	110,000
Thompson Falls Power Co. (subsidiary of Montana Power Co.)	Burke, Idaho.	110,000
Stevens County Power & Light Co.	Chewelah, Wash.	60,000 to 33,000
Do.	Marcus, Wash.	11,000
Chicago, Milwaukee, St. Paul, & Pacific R.R. Co.	Taunton, Wash.	110,000
Puget Sound Power & Light Co.	Chelan, Wash.	110,000
Do.	Through Chicago, Milwaukee, St. Paul & Pacific R.R. at Taunton, Wash.	

906. The interconnections with the Pacific Power & Light Co. at Lind, Pomeroy, and Taunton, Wash., with the Thompson Falls Power Co. (or The Montana Power Co.) at Burke, Idaho; and with the Puget Sound Power & Light Co. at Chelan, Wash., and through the Chicago, Milwaukee, St. Paul & Pacific Railroad, are particularly important for exchange of energy between the companies. They make it possible and are regularly used to take advantage of differences in the seasonal run-off from the several watersheds and to make the installed capacity and the available storage of the different companies of greater service than if they were used independently.

907. While the company's principal generating stations are located near the load centers, it has an extensive system of transmission lines, totaling approximately 1,900 miles, operated at 110,000 volts, 60,000 volts, and lower voltages. In Spokane and vicinity the company has a network of feeders and tie lines operated at 13,000 volts.

908. At the close of 1930 the number of customers served was given as 61,393.

909. On April 4, 1925, the Washington Water Power Co. applied to the Federal Power Commission for a license to develop Kettle Falls on the Columbia River. The application is being held pending further study of the possibilities of the river.

910. An ultimate development of 120,000 kilowatts is planned at Chelan Falls. This is more than double the present installation.

911. Plates nos. 117² and 118² show the gradual development that has occurred in the growth of the company since 1905. Attention is called to the fact that only two times in the history has energy been purchased in appreciable amounts, from August to December 1925 and in August and September 1926 and in the first-mentioned period this energy was resold to other generating utilities. The installation of new generating capacity is noted and compared with peak loads on the company's system.

² Not printed.

941. Power is also obtained from the following lumber mills, which have their own power plants and use the mill refuse for fuel.

	Installed capacity in kilowatts	
	Plant	Total
St. Paul & Tacoma Lumber Co.	6,500
Wheeler-Osgood Lumber Co.	4,000
Buffelen Mill Co.	2,500
Estonville Mill Co.	1,500	14,500

942. In addition, power is interchanged with the city of Seattle, and with Puget Sound Power & Light Co. Power from Nisqually is transmitted to Tacoma over 55,000-volt transmission lines. From Cushman the transmission is at 110,000 volts. The tie lines between substations in the city are operated at 55,000 volts and 13,200 volts. The accompanying plates nos. 116² and 119² show the gradual development of the electrical load of the city of Tacoma from 1905 to 1930, inclusive.

943. From 1917 until its manufacturing plant at La Grande burned in 1923, the American Nitrogen Products Co. purchased surplus power from the city of Tacoma for use in the manufacture of sodium nitrate. beginning with about 1,000 kilowatts maximum in 1917, the load grew to 7,000 or 8,000 kilowatts maximum in 1922 and 1923. This accounts for some of the irregularity of the load curves during these years.

944. *k. City of Centralia.*—For several years Centralia has operated a distribution system and purchased power from the Western Crossarm & Manufacturing Co. During 1930 the city completed a hydroelectric plant with an ultimate capacity of 11,000 kilowatts. The dams, intake, canal, flumes, etc. were built for the full 11,000-kilowatt installation. Two units developing a total of 4,000 kilowatts are complete at this time, the additional units to be added as the growing demands of the utility justify. Upon completion of this plant, the city discontinued its interconnection with the Western Crossarm & Manufacturing Co., except for stand-by service. Energy is delivered to the municipal distribution system over a 66,000-volt transmission line from the power plant at Yelm, Wash. From October to the end of December 1930, the energy generated by the city amounted to 1,760,000 kilowatt-hours. During 1930, before the hydro plant began operation, the city purchased 3,848,000 kilowatt-hours from the Western Crossarm & Manufacturing Co.

945. The industry of Centralia is principally lumbering. There is also dairying and poultry raising. The population in 1930 was 8,051, having increased from 7,549 in 1920.

946. *m. Crown-Zellerbach Corporation.*—The lumber and paper industries are basic in Washington. Lumbering has been long established. Paper manufacturing is more recent, but from a power standpoint it is becoming even more important than lumber. The Crown-Zellerbach Corporation is the largest in the paper industry. Five of its subsidiary companies own and operate large generating stations. Two hydro plants have a combined capacity of 25,000 kilowatts. Six steam plants have a capacity of 30,150 kilowatts. The total installed capacity is 55,150 kilowatts.

² Not printed.

947. The hydro plants and the Port Angeles steam plants are connected to each other through a 66,000-volt transmission system owned by the company. They are also connected to the Puget Sound Power & Light Co. system to which they sell more or less power. Power is also exchanged with Fiberboard Products, Inc. The Shelton plant exchanges power with the Simpson Logging Co. The exchange of energy with these companies is shown below as it occurred in 1930.

Energy from other sources delivered and received by properties of Crown-Zellerbach Corporation during 1930

Interconnecting Company	Kilowatt hours delivered to interconnecting company	Kilowatt hours received from interconnecting company
Puget Sound Power & Light Co	65, 150
Fiberboard Products, Inc.....	4, 933, 200	171, 600
Simpson Logging Co.....	11, 902, 529
Total.....	4, 998, 350	12, 074, 129

948. The steam plants of the Crown-Zellerbach Corporation all use wood waste as fuel. Steam power is generated in connection with the use of process steam. However, the requirement for process steam is usually insufficient to meet the full demand for power. As wood wastes become more valuable for the manufacture of byproducts it is to be expected that there will be a gradual change in the practice of the companies, first, to the substitution of hydro or purchased power for needs in excess of the steam requirements, and later, to the substitution of other fuels or methods for securing process heat. Plates nos. 119² and 120² show the growth of the Washington Pulp & Paper Corporation, the largest of the Crown-Zellerbach group in Washington.

949. *n. Weyerhaeuser Timber Co.*—Sawmills of the Weyerhaeuser Timber Co. or its subsidiary companies are located at many points in the Pacific Northwest. Those located within the area covered by this report have three important electric generating stations with installed capacity totaling 29,000 kilowatts.

950. All the properties use wood waste as fuel for the generation of steam. Power is developed by turbo-generator units.

951. Since September 1, 1930, the Longview plant has been connected with the system of the Puget Sound Power & Light Co. at West Kelso, Wash. During the 4-month period from September 1 to December 31 the timber company sold 3,366,000 kilowatt-hours of surplus power over this connection.

952. Besides the waste wood burned in the steam plants of the company, there is produced a large additional quantity of waste, much of which is now reduced to the form of hogged fuel and sold by contract or in the open market.

953. As in the paper industry, the gradually increasing diversion of wood waste to the manufacturer of various byproducts is likely in the future to reduce the supply of wood available for fuel. The demand for process steam in the lumber mills is small. The mills are well adapted to the use of hydro or purchased power when the

² Not printed.

byproduct value of their waste material makes it uneconomical to operate the present steam plants.

2. CHARACTERISTICS OF SUPPLY OF POWER

954. *a. Steam—fuel, etc.*—Washington and the entire area included within the Seattle district are mainly dependent upon hydropower. The portion developed with fuel varies from year to year depending upon water supply conditions and other variables. Figures for 12 years are shown in the following table.

Fuel power for public use produced in Washington

[From reports of the U.S. Geological Survey]

Year	Kilowatt-hours produced by fuel (in millions)	Fuel power in percent of total production	Year	Kilowatt-hours produced by fuel (in millions)	Fuel power in percent of total production
1920	42.6	3.6	1926	63.4	3.6
1921	36.8	3.1	1927	68.5	3.2
1922	76.3	5.9	1928	126.2	5.1
1923	88.2	6.5	1929	369.9	14.5
1924	89.1	5.9	1930	265.3	10.4
1925	88.2	5.4			

955. The drought of 1929 and 1930 accounts for the sudden increase in the use of steam power in those years. The beginning of the drought was also a factor in the fall and winter of 1928. Practically no fuel power is produced in this district outside the State of Washington.

956. Industrial plants and particularly the lumber and paper mills use wood waste which has been reduced to the form of "hogged fuel."⁵⁵ Storage is effected in large piles convenient to the points of use. Some of the utility plants use hogged fuel purchased from the lumber mills. The United States Geological Survey states that in 1930 in the State of Washington 47,000,000 kilowatt-hours were produced for public use with wood as fuel. This is only 1.8 percent of the total kilowatt-hour production in the State and 17.7 percent of the electric energy produced with fuel. Higher lumber prices might temporarily increase the supply by making profitable the closer utilization of material now left in the woods. The waste in these poorer grades of timber and logs will be a higher percentage of the total. However, it is probable that any trend in that direction will be more than offset by the development of byproducts of the timber industry, which will make use of increasing quantities of the waste that is now burned. Domestic and commercial heating plants absorb important quantities of wood waste. It is apparent that expansion in steam power production will be dependent on fuels other than wood.

957. During 1930, oil was burned in public utility generating stations in Washington to the amount of 758,000 barrels while coal consumption amounted to only 8,500 tons. The ratio between these two fuels varies with the fluctuations of prices. Both are readily obtainable.

⁵⁵ Slabs and other large pieces included in the waste wood are run through a "hog" which chips and shreds them into flakes of a size suitable for conveyers and automatic feed to boiler furnaces. The resulting material mixed with sawdust and planer shavings is known as "hogged fuel."

958. Fuel oil is shipped from California and delivered by tankers. In recent years it has outranked all other commodities in the quantity received at Puget Sound ports. The freight rate is approximately 25 cents per barrel and at present (1931) low prices in California, it can be delivered for \$1 or less per barrel. This is less than the cost of mining the equivalent coal.

959. At the present time the Puget Sound Power & Light Co. is using oil in its Shuffleton steam plant on the shores of Lake Washington in spite of the fact that it owns coal properties adjacent to the plant. There are also commercially-operated coal mines in the immediate vicinity.

960. Washington is well favored with deposits of coal of fair quality. The locations of the several fields are shown on the map (pl. no. 122)² accompanied by average analyses of the coal. To obtain these figures all analyses published by the United States Bureau of Mines⁵⁶ have been averaged for each field.

961. The Roslyn field, near Cle Elum in Kittitas County (see appendix no. 1, pl. no. 148)² is the principal producing area of the State. The annual output usually exceeds 1,000,000 tons, about three fourths of which is used by the Northern Pacific Railway in its locomotives and its shops. The remainder enters the commercial field and is sold in practically all of the markets in the State.⁵⁷

962. With the extensive coal reserves which are conveniently available, the public-utility systems are well protected against any shortage of fuel for the operation of steam generating stations, and from danger of excessive prices.

963. In 1912 natural gas was discovered in Benton County, Wash., about 12 miles north of Benton City. The gas was encountered at a depth of about 700 feet beneath a stratum of clay 90 feet in thickness. Other wells have since been drilled and 10 are now producing. The individual wells vary in their daily capacity from 100,000 to 1,000,000 cubic feet. A diamond drill hole about 2,200 feet deep has been sunk to explore the formation but failed to find other important reservoirs below the one at the base of the 90-foot clay bed. Analyses showed the gas to be dry and not connected with petroleum. The pressures are low. The only operator in the field at the present time is the Northwestern Natural Gas Corporation of Delaware, which has its headquarters at Wichita, Kans. The local office is at Grandview, Wash. Pipe lines have been laid to Prosser, Grandview, Sunnyside, and Mabton—a main line total of about 40 miles. Extensions are contemplated. The daily sales at the present time amount to 500,000 cubic feet.⁵⁸

964. It appears probable that the limited gas supply, thus far discovered, will find a market in domestic and small commercial uses. Apparently the yield of the field will not be sufficient to make the gas an active competitor of fuel for the generation of power in utility stations.

965. *b. Hydro, seasonal variations, etc.*—The power companies of the Pacific Northwest have always depended principally upon water power as a source of energy. A great number of power sites exist.

² Not printed.

⁵⁶ Department of Interior, Bureau of Mines, Bulletins No. 22, 85, and 193.

⁵⁷ See appendix no. 1, Mineral Resources of Columbia River Basin in Eastern Washington, by Henry Landes, Geologist, par. 135.

⁵⁸ See appendix no. 1, Mineral Resources of Columbia River Basin in Eastern Washington, by Henry Landes, Geologist, par. 187-189.

The first developments were of sites having low construction cost and small capacity commensurate with the market for electricity in the early days of the industry. As the requirements for power have grown from year to year it has become economical to develop sites of larger capacity and greater first cost to secure the advantage of lower cost per kilowatt of capacity and lower cost of operation. This trend is illustrated in the foregoing diagrams showing the growth of the loads of the various companies.

966. The heavy winter precipitation occurring on the western slopes of the Cascades and Coast ranges of mountains is closely followed by the run-off in the streams. Winter maximums and summer minimums are the rule. Natural storage is effected in the snowfields and the glaciers of the higher elevations. These furnish an important part of the summer flow.

967. Load curves of the utilities using these streams have a similar but less extreme variation. Until the occurrence of the drought of 1929 and 1930, there was little call for storage reservoirs and standby steam plants. The drought has made it incumbent upon the utilities to protect themselves against irregularities in the natural water supply.

968. East of the Cascades the conditions are modified. Having their main drainage basins in the higher altitudes, the principal tributaries of the Columbia River are fed by snows which accumulate during the winter and gradually melt as the summer advances. In consequence these rivers have a more regular regime than those nearer the coast and a smaller percentage difference between maximums and minimums. The maximum flow occurs in the summer and the minimum in the winter. The power companies which supply the communities in the interior basin have developed irrigation pumping load to an extent that gives them a summer peak. (See pl. no. 117.)² Thus their seasonal requirements follow in general the water supply available at their hydroplants and the agreement has thus far been close enough to make it unnecessary to maintain large auxiliary steam plants. By the use of natural lakes the Washington Water Power Co. has developed considerable storage which gives it facilities for seasonal regulation.

969. Interconnection of the power systems lying east of the Cascades with systems to the west of those mountains such as is now in effect between the Washington Water Power Co. and the Puget Sound Power & Light Co. make possible a seasonal interchange of power developed by water to correspond with the available production of hydroplants and with load requirements. With the expansion of the electrical business such interconnection will become increasingly desirable and important.

970. *c. Oil engines.*—The place which internal combustion engines have found for themselves among the public utilities in this area has thus far been unimportant and is not likely to expand. These engines are in use in a few places supplying small loads or serving as standby capacity. As interconnection of systems progresses the occasion for their use will decrease.

3. COST AND SALE PRICE OF POWER AS AFFECTING MARKETS

971. Two primary sources are available to supply the future power requirements of the Pacific Northwest: Water and steam. Each has its place. Each is, within limits, adaptable to meet conditions which

² Not printed.

may exist. In some cases water power may prove to have an advantage; in other cases steam may be better adapted. In general, it is cost which determines whether steam or water should be used for generation. The determining cost is not only the initial investment but includes all elements that enter into the annual cost of delivering electric service to the consumer.

972. In considering the place that water power will occupy in the future, it is well to observe that the cost of steam power fixes a definite limit to the economic availability of the water-power resources which are under consideration.

973. A steam plant has some important advantages. Its location can be chosen to fit the load it is to serve, giving due consideration to the supply of fuel and condensing water. Its size can also be chosen to fit the actual and prospective load. The cost of constructing a steam plant may be materially less than the combined costs of the dam, water channels, and power house for a hydroelectric installation. A steam plant can be built quickly with standardized equipment to meet well defined requirements, and extensions can then follow on a scale and at the time acutally needed without tying up large sums of money in idleness over long periods of time. Fuel can be stored and held in reserve to be promptly available for emergencies and for stand-by purposes. With these advantages go, of course, definite disadvantages such as a relatively short useful life with correspondingly high rates for depreciation and amortization, expensive fuel, and high maintenance cost.

974. Cost of steam power under modern conditions has recently been studied by the United States Bureau of Reclamation to determine the price at which Boulder Canyon hydroelectric power from the Colorado River could be sold in competition with power generated by steam.⁵⁹

975. Figures were based upon the experience of the new power plant known as "Long Beach No. 3" of the Southern California Edison Co., containing generating units with individual capacities of 100,000 kilowatts. Such a plant constructed at tidewater where there are ample supplies of condensing water and using either oil or natural gas for fuel was found to require an investment of \$77.50 per installed kilowatt. This same figure can be safely used as adapted to conditions which exist on Puget Sound.

976. Annual costs consist of fixed charges and operating expenses. Some modifications of the fixed charges have been made to adapt them to the present study. The experience of the Southern California Edison Co. has been utilized to arrive at probable fuel consumption and operating costs.

977. Interest on the investment is the largest item among the fixed charges. In this report interest on money invested by the United States or a State has been calculated at 4 percent. A municipality can secure money for such construction at approximately 4.75 percent. A utility company will probably find money costing it 6 percent. Regulatory commissions are allowing such utilities to earn 7 or 7.5 percent on the investment; this affects the selling price to the

⁵⁹ Department of the Interior, Bureau of Reclamation, Boulder Canyon Project, "Rate which public and private corporations can afford to pay for power at Boulder Canyon and rate which will produce sufficient revenue to repay cost of Boulder Canyon Dam and power plant in 50 years with interest," Sept. 10, 1929.

public although not the cost to the utility. It is here assumed that a competitive steam plant would be constructed by private capital and not by the United States or a State. Therefore, in the example that has been computed and which is shown graphically in plate no. 123² (cost of generating steam power at varying load factors), 6 percent has been used as the rate of interest.

978. For a steam plant a reasonable depreciation rate is considered to be one that allows approximately a 16-year life. On a sinking fund basis, for the case of a utility company, interest on the sinking fund being computed at 6 percent per annum, the depreciation rate selected for the present study is 4 percent.⁶⁰ An allowance of 1.5 percent of the investment is made for taxes.

979. General expenses while not strictly proportional to investment may be so considered with a reasonable degree of accuracy. An allowance of 0.5 percent is made for them.

980. Experience on the part of the Southern California Edison Co. with the Long Beach No. 3 plant has given a figure of \$2.25 per year per kilowatt of capacity as a fair allowance for the cost of supervision, labor, and supplies necessary for operation and maintenance.

981. The annual charges per kilowatt are summarized in the following table:

Interest, \$77.50 at 6 percent.....	\$4. 65
Depreciation, \$77.50 at 4 percent.....	3. 10
Taxes, \$77.50 at 1.5 percent.....	1. 1625
General expense, \$77.50 at 0.5 percent.....	. 3875
<hr/>	
Total, 12 percent.....	9. 30
Supervision, labor, and supplies.....	2. 25
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Total.....	11. 55

982. All of the items of total annual cost except fuel are determined almost solely by the size of the installation. They are not changed by the output of the power plant. These costs per kilowatt-hour are therefore inversely proportional to the load factor, assuming the installation to be properly proportioned to the peak load.

983. Fuel consumption has been assumed at 0.55 barrel of oil per kilowatt of capacity per year plus 0.002 barrel of oil per kilowatt-hour. If gas or coal is used for fuel, substitution may be made by comparing them with oil on a heat-unit basis. A barrel of fuel oil contains approximately 6,250,000 British thermal units. No difficulty is encountered in using natural gas and fuel oil interchangeably. Pulverized coal can be used with the same furnace settings, but requires additional investment and labor for storing, pulverizing, and conveying equipment.

984. The above conditions of cost can be expressed in formulæ as follows:

Annual cost in dollars per kilowatt of steam plant capacity: $C=11.55+0.55 P+0.002 PK$.

Cost per kilowatt-hour in dollars: $c=\frac{11.55}{K}+\frac{0.55P}{K}+0.002P$

In which—

P =Cost of fuel oil in dollars per barrel.

K =Kilowatt-hours produced annually per kilowatt of plant capacity.

² Not printed.

⁶⁰ The Bureau of Reclamation allowed only 1.9 percent for depreciation in the case of private development. This arose from certain special considerations and is believed to be lower than is warranted by the probable useful life of a steam power plant.