feet. The surface elevation is 426 feet for the ordinary high water, approximating a discharge of 400,000 second-feet. The general plan of the structures is shown on plate no. 91.[2]

716. The country rock in the vicinity is basalt. Logs of test borings made by a private company are available to this office. On the right bank, these test holes were located near the site herein considered, but on the left bank are about a mile upstream from this site.

717. *c'. Power possibilities.*—The mean monthly discharges for the natural and regulated flows for the 18-year period, April 1913 to March 1931, inclusive, are shown on tables nos. 26 and 51.

718. The proposed elevation of the forebay is 488 feet, which is the same as the low tail-water elevation at the Vantage project. The backwater effect at the Vantage plant would probably not be serious. A drawdown of 5 feet with a resulting pondage of 38,000 acre-feet is considered ample to provide for the daily variation of load. The maximum head at the site would be 82 feet and the average static head 75.3 feet for natural flow. The head available for the maximum month of record, 480,000 second-feet, would be 58.6 feet, and for a maximum discharge of 1,000,000 second-feet the head would be 43 feet; therefore, the turbines could continue operation at all stages.

719. Plate no. 92[2] contains 27 power graphs showing the available power for the high, mean and low years of the 17-year period ended March 31, 1930, for three hydraulic capacities and three conditions of flow. The latter consists of natural flow, case 1 of table no. 135, and flows regulated by means of upstream storage for cases 2 and 6 of table no. 135. No drawdown was considered in the Priest Rapids reservoir in the preparation of these graphs. The three hydraulic plant capacities considered on plate no. 92[2] are equal to the natural flow for 35 percent, 50 and 90 percent of the time respectively. These three capacities were selected arbitrarily to study the power possibilities of the site and are not to be confused with the proposed hydraulic capacity as set up in the résumé and hereafter in this report. In cases 2, 3, and 4 of table no. 135, the Columbia Basin Irrigation project would be irrigated with water from Clark Fork and Spokane River. In case 5, it would be irrigated with water from Clark Fork, Spokane, and Wenatchee Rivers.

720. The tables at the bottom of the graphs also show the utilization and plant-capacity factors for 100 percent operation. The annual factors are shown graphically on plate no. 93.[2] By comparison of graphs 2, 11, and 20 on plate no. 92,[2] it is noted that regulation would increase the annual utilization factor from 60 percent for natural conditions to 72 and 69 percent, respectively, for the pumping and gravity plans for the low year, with a hydraulic capacity of 73,200 second-feet, which discharge would be equalled or exceeded 50 percent of the time during that year. See case 1 of table no. 135. Likewise, the total energy available for the low year with the above plant capacity would be respectively, 257,000, 295,000, and 282,000 kilowatt-years for natural flow and for regulated flow for the pumping and gravity plans.

721. Table no. 135 shows the flow and power duration for 35, 50, 65, 80, 90, and 100 percent of the time for the 17-year period ended March 1930 for natural flow and for seven assumed conditions of regulation and irrigation. In obtaining the regulated flows shown in that table, control of the following reservoirs was assumed after allowing for withdrawal of irrigation water as stated in paragraph 178.

[2] Not printed.

	Approximate capacity (acre-feet)
Reservoir:	
Hungary Horse	1, 100, 000
Flathead Lake	1, 540, 000
Priest Lake	569, 000
Pend Oreille Lake	1, 610, 000
Kootenai Lake	715, 000
Coeur d'Alene Lake	[43] 430, 000
Lake Chelan	665, 000
Grand Coulee (low dam)	776, 000
Grand Coulee (high dam)	5, 028, 000
Wenatchee Lake (Plans Nos. 2-A & 4)	1, 000, 000
Wenatchee Lake (Plan No. 6-A=1,650,000 acre-feet).	
Chiwawa	482, 000
Total, Grand Coulee (low dam)	8, 887, 000
Total, Grand Coulee (high dam)	13, 139, 000

TABLE No. 135.—*Principal data, Priest Rapids site, low dam, for the 17-year period ended Mar. 31, 1930. For power-duration curves, see plate no. 94* [2]

Plan	Regulation	Case no.	Grand Coulee Dam	Time	Flow	Static head forebay elevation 488	Potential power—80 percent efficiency	Potential energy available annually
				Percent	*1,000 second-feet*	*Feet*	*1,000 kilowatts*	*1,000 kilowatt-years*
Natural	No regulation	1	None	35	119. 0	75. 5	611	412
				50	73. 2	77. 3	385	317
				65	54. 1	78. 2	288	262
				80	43. 6	79. 0	234	223
				90	32. 2	80. 0	175	174
				100	23. 3	81. 5	129	129
Gravity	Upstream regulation without Columbia River storage—plan no. 2-A.	2	Low or high	35	114. 8	75. 7	590	425
				50	80. 9	77. 0	424	358
				65	62. 4	77. 8	330	306
				80	49. 8	78. 5	266	259
				90	44. 2	78. 9	237	235
				100	34. 3	79. 8	186	186
	Upstream regulation including Columbia River storage—plan no. 2-A.	3	Low dam	35	114. 8	75. 7	590	429
				50	80. 0	77. 0	419	360
				65	62. 7	77. 8	332	311
				80	51. 2	78. 4	273	268
				90	46. 9	78. 8	251	249
				100	39. 0	79. 3	210	210
		4	High dam	35	109. 0	75. 9	563	447
				50	83. 7	76. 9	438	395
				65	73. 2	77. 3	385	365
				80	62. 8	77. 8	332	327
				90	57. 8	78. 0	307	305
				100	51. 3	78. 4	273	273
	Upstream regulation including Columbia River storage, Quincy Flats irrigated from Wenatchee Lake—plan no. 6-A.	5	Low dam	35	115. 6	75. 6	595	427
				50	76. 1	77. 2	399	347
				65	62. 4	77. 8	330	308
				80	50. 6	78. 5	270	264
				90	45. 9	78. 8	246	244
				100	38. 6	79. 3	208	208
Pumping	Upstream regulation without Columbia River storage—plan no. 4.	6	Low or high	35	114. 0	75. 7	585	427
				50	79. 8	77. 0	418	361
				65	64. 6	77. 7	341	319
				80	53. 5	78. 3	285	278
				90	47. 2	78. 7	253	251
				100	39. 9	79. 3	215	215
	Upstream regulation including Columbia River storage—plan no. 4.	7	Low dam	35	109. 8	75. 9	566	422
				50	76. 9	77. 1	403	356
				65	64. 6	77. 7	341	322
				80	54. 1	78. 2	288	283
				90	50. 3	78. 5	269	267
				100	43. 8	79. 0	235	235
		8	High dam	35	99. 1	76. 3	514	429
				50	81. 8	76. 9	428	394
				65	73. 8	77. 3	388	372
				80	64. 8	77. 7	342	338
				90	61. 0	77. 8	323	322
				100	56. 2	78. 1	298	298

[2] Not printed.

[43] Includes 155,000 acre-feet now used by the Washington Water Power Co.

722. The last column of table no. 135 shows the potential energy available annually in thousands of kilowatt-years for certain percentages of time for each case. Note that both the potential power and the annual energy, as shown in the table, were not limited by assumed plant capacities.

723. As a basis of comparison, the potential power available 90 percent of the time as shown on table no. 135 is, respectively, 175,000; 237,000; 251,000; 307,000; 246,000; 253,000; 269,000; and 323,000 kilowatts for cases 1 to 8, inclusive; or, considering case 1 as 100 percent, cases 2 to 8 are 135, 143, 175, 141, 144, 154, and 185 percent, respectively. For similar conditions of regulation, the increase in potential power under the pumping plan for 80, 90, and 100 percent of the time over that obtained under the gravity plan is worthy of note, as is also the marked effect of regulation of storage at the high Grand Coulee Dam as compared with the low Grand Coulee Dam. The duration of potential power for cases 1, 6, and 8 is shown graphically on plate no. 94.[2]

724. *d' Proposed development.*—The project works, as planned, would involve the construction of a power house 900 feet long, located parallel to the stream on the right bank opposite the lower end of Panhandle Island, and a concrete spillway of gravity section, 3,270 feet long, located partly parallel to the stream and partly across it. The spillway would contain 82 Stoney gates, each 22 feet high by 30 feet long, with a total capacity of 1,000,000 second-feet. The crest elevation would be 466 feet. Piers 10 feet thick would support the gates and an operating deck, the latter having a top elevation of 498 feet. At the east end of the spillway there is a concrete gravity section, nonoverflow dam about 350 feet long. At the west end and forming an angle with the power house, is a nonoverflow section about 380 feet long. The remainder of the dam at both ends would be composed of earth dikes running perpendicularly to the stream and protected against seepage by concrete core walls extending to bedrock or impervious material. The total length of the dam would be approximately 10,500 feet. Locks and other navigation features would be provided on the right bank. The project works, as planned, are shown on plates nos. 91 and 95.[2]

725. The kinetic energy of the flood flows would amount to 6,080 horsepower per lineal foot of clear crest for normal forebay, or approximately 4,660 horsepower per lineal foot of apron. Dissipation of this energy is discussed in paragraph 549. The portion of the spillway located at right angles to the stream would be used for average floods, and the remainder would be used for the excess.

726. The installed generating capacity selected for discussion is 390,000 kilowatts, which is based on the available potential power in case 6 for 90 percent of the time, 253,000 kilowatts, with a 65 percent plant-capacity factor. The power house, as shown on plate no. 95,[2] and the estimates of cost given hereafter were based on this installed capacity.

727. The power house, as planned, would provide space for 12 units, each consisting of a vertical Francis turbine, direct connected to a 32,500-kilowatt generator, 13,800 volts, 3-phase, 60 cycles. The hydraulic capacity of each turbine would be 7,750 second-feet at a head of 62.0 feet. Transformers located in the upstream portion of

[2] Not printed.

the building would step the voltage up to 220 kilovolts for delivery to an outdoor switching station on the roof.

728. The estimate of capital cost contains an allowance of $1,629,000 to cover the cost of a certain amount of tailrace excavation. The benefits in lowered tail water to accrue from this improvement are difficult to evaluate and, to be conservative, the estimate of power output and the plans themselves use the elevation fixed by the rating curve as established for the power house under natural conditions.

729. For construction purposes, it was planned to extend the railroad spur line of the Chicago, Milwaukee, St. Paul & Pacific Railroad (Hanford branch), now existing on the right bank. It connects the main line at Beverly with Vernita and other points south. This location of the spur line would not be affected by the construction of the low dam at Priest Rapids.

730. The reservoir site lies in a region of very sparse population. Practically no tillable land would be flooded at normal forebay level. Neither the town of Beverly nor the bridge of the Chicago, Milwaukee, St. Paul & Pacific Railroad Co. at Beverly would be affected by the construction of the Priest Rapids low dam described herein. About 12 miles of inexpensive secondary earth and gravel roads would have to be relocated. The reservoir flood rights should not be difficult or expensive to acquire.

731. *e'. Economic features.*—The principal items of construction and the estimated capital cost of the project are shown in table no. 136. The cost of locks and other navigation features in connection with the power project are not shown herein but will be given later in paragraphs 1648–1649. It will be noted that the total capital cost per kilowatt of installed capacity would be $96 for public development and $101 for private development.

TABLE No. 136.—*Estimate of capital cost of development at Priest Rapids site low dam for an installed capacity of 390,000 kilowatts*

Preliminary expenses	$1, 237, 500
Construction railway	300, 000
Reservoir	100, 000
River diversion	1, 000, 000
Spillway dam and earth dikes	9, 721, 140
Intake and bulkhead section	2, 865, 700
Power-house substructure	2, 002, 125
Power-house superstructure	1, 389, 500
Hydraulic equipment	3, 132, 000
Electrical equipment (390,000 kilowatts)	3, 978, 000
Cranes, stop-logs and steel for switch yard	276, 000
Tailrace excavation	1, 629, 000
Contingencies, 10 per cent	2, 763, 097
Total field cost	30, 394, 062
Overhead, 12½ percent	3, 799, 258
Total construction cost	34, 193, 320
For public development:	
Total construction cost	34, 193, 320
Interest charged during construction, 10 percent	3, 419, 332
Total capital cost	37, 612, 652
Capital cost per kilowatt	96
For private development:	
Total construction cost	34, 193, 320
Interest charged during construction, 15 percent	5, 128, 998
Total capital cost	39, 322, 318
Capital cost per kilowatt	101

732. The financial set-up and annual operating cost for both public and private development are shown in table no. 137. They are based on delivering power to the low-tension side of step-up transformers, including high-tension switch structure, but omitting step-up transformers, high-tension insulators, switches, arresters, and oil circuit breakers, which are included in the terminal stations for transmission lines.

733. Plate no. 96 [2] shows graphically the cost per kilowatt-hour of energy generated for plant-capacity factors varying from 10 to 100 percent. It will be noted that the cost per kilowatt-hour for a 50 percent plant-capacity factor is 1.34 mills for public development, 1.9 mills for private development for an annual operating cost of 8.34 percent of the capital cost, and 2.86 mills for private development for an annual operating cost of 12.5 percent of the capital cost. The cost of steam-generated power for the same range of plant-capacity factor is also shown, computed for fuel oil at $1 per barrel.

TABLE NO. 137.—*Estimate of annual cost of power production at Priest Rapids low dam, with an installed capacity of 390,000 kilowatts*

	Public development	Private development
1. Investment cost:		
Lands and water rights and nondepreciated items	$136,125	$142,313
Dams and substructures	24,037,587	25,130,204
Subtotal "A"	24,173,712	25,272,517
Power plant, machinery, and superstructures	13,438,940	14,049,801
Total development, capital cost	37,612,652	39,322,318
2. Basis of annual cost:		
(a) Return or interest in percent of capital cost	4	6
(b) Amortization of bonds, 40-year sinking-fund basis, in percent of capital cost	1.05	0
(c) Depreciation:		
(1) Lands and water rights, in percent of capital cost	0	0
(2) Dams and substructures, 100-year sinking-fund basis, in percent of capital cost	.08	.018
(3) Power plant, machinery, and superstructures, 30-year sinking-fund basis, in percent of capital cost	1.78	1.26
(d) Taxes, in percent of capital cost	0	1.5
(e) Maintenance and operation expense, including 10 percent of cost of labor and material for general expense	$148,616	$148,616
3. Total annual cost:		
Items included in subtotal "A":		
Interest or return	966,948	1,516,351
Amortization	253,824	
Depreciation	19,230	4,523
Taxes		379,088
Maintenance and operation (included under Power plant)		
Subtotal	1,240,002	1,899,962
Power plant:		
Interest or return	537,557	842,988
Amortization	141,109	
Depreciation	239,213	177,027
Taxes		210,747
Maintenance and operation	148,616	148,616
Subtotal	1,066,495	1,379,378
Total project:		
Interest or return	1,504,505	2,359,339
Amortization	394,933	
Depreciation	258,443	181,550
Taxes		589,835
Maintenance and operation	148,616	148,616
Total annual cost	2,306,497	3,279,340
Total annual cost in percent of capital cost	6.14	8.34

[2] Not printed.

734. *b. High dam.*—This plan of development would involve the construction of a dam to a height which would back the water to the Rock Island plant now under construction.

a'. Résumé.—

Drainage area	square miles	95, 400
Length of pool	miles	56
Length of dam, including earth embankments	feet	11, 700
Height of dam (maximum section, foundation to walkway, excluding cut-off)	feet	202
Normal forebay elevation	do	540
Drawdown (elevation, 540 to 535 feet)	do	5
Useful storage	acre-feet	160, 000
Natural low-water elevation	feet	406
Maximum known discharge (June, 1894)	second-feet	740, 000
Spillway capacity	do	1, 000, 000
Natural river flow (April 1913 to March 1931, inclusive):		
Maximum discharge, 24 hours	do	528, 000
Mean discharge	do	121, 000
Minimum discharge, 24 hours	do	21, 000
Average static head	feet	127. 3
Power capacity (Federal Power Commission definition)	horsepower	328, 000
Proposed hydraulic capacity	second-feet	83, 000
Proposed generating capacity	kilowatts	648, 000

735. *b'. Topography and geology.*—The site selected by this office for the high dam is the same as the one selected for the low dam and described under that heading. The general plan of the structure is shown on plate no. 97.[2]

736. The mean monthly discharges of the natural and regulated flows for the 18-year period, April 1913 to March 1931, inclusive, are shown on tables nos. 26 and 51.

737. *c'. Power possibilities.*—The proposed elevation of the forebay is 540 feet, which is 8 feet below the natural low-water elevation of the Rock Island site. A drawdown of 5 feet with a resulting pondage of 160,000 acre-feet is considered ample to provide for the daily variation of load. The maximum head at the site would be 135 feet and the mean static head 127.3 feet for natural flow. The head available for an average high-water discharge of 350,000 second-feet would be 116.4 feet, and for a maximum discharge of 1,000,000 second-feet the head would be 92 feet; therefore, the turbines could continue operation at all stages.

738. Plate no. 98[2] contains 27 power graphs showing the available power for the high, mean, and low years of the 17-year period ended March 31, 1930, for 3 hydraulic capacities and 3 conditions of flow. The latter consists of natural flow, case 1 of table no. 138, and flows regulated by means of upstream storage for cases 2 and 6 of table no. 138. No drawdown was considered in the Priest Rapids Reservoir in the preparation of these graphs. The three hydraulic plant capacities considered on plate no. 98[2] are equal to the natural flow for 35 percent, 50 percent, and 90 percent of the time, respectively. These 3 hydraulic plant capacities were selected arbitrarily to study the power possibilities of the site and are not to be confused with the proposed hydraulic capacity as set up in the résumé and hereafter in this report.

739. The tables below the graphs also show the utilization and plant-capacity factors for 100 percent operation. These annual factors are

[2] Not printed.

shown graphically on plate no. 99.[2] By comparison of graphs 2, 11, and 20 on plate no. 98,[2] it is noted that regulation would increase the annual utilization factor from 60 percent to 71 percent and 69 percent, respectively, for the pumping and gravity plans for the low year, with a hydraulic plant capacity of 73,200 second-feet, which discharge is equaled or exceeded 50 percent of the time during that year. See case 1 of table no. 138. Likewise, the total energy available for the low year with the above plant capacity would be, respectively, 434,000, 495,000, and 474,000 kilowatt-years for natural flow and for regulated flow for the pumping and gravity plans.

740. Table no. 138 shows the power duration for 35, 50, 65, 80, 90, and 100 percent of the time for the 17-year period ended March 1930 for natural flow and for seven assumed conditions of regulation and irrigation. Regulation would be effected by control of the same reservoirs as mentioned in paragraph 721 for the low dam at Priest Rapids.

TABLE NO. 138.—*Principal data, Priest Rapids, site, High Dam, for 17-year period ended Mar. 31, 1930. For power-duration curves, see plate no. 100* [2]

Plan	Regulation	Case No.	Grand Coulee Dam	Time	Flow	Static head forebay El. 540	Potential power 80 percent efficiency	Potential available annually
				Percent	*1,000 sec.-ft.*	*Feet*	*1,000 kw.*	*1,000 kw.-yrs.*
Natural	No regulation	1	None	35	119.0	127.5	1,032	699
				50	73.2	129.3	644	520
				65	54.1	130.2	479	435
				80	43.6	131.0	388	370
				90	32.2	132.0	289	286
				100	23.3	133.5	212	212
Gravity	Upstream regulation without Columbia River storage—plan no. 2-A.	2	Low or high	35	115.0	127.7	996	713
				50	80.0	129.0	710	598
				65	62.4	129.8	551	510
				80	49.8	130.5	442	431
				90	44.2	130.9	394	391
				100	34.3	131.8	307	307
	Upstream regulation including Columbia River storage, plan no. 2-A.	3	Low Dam	35	114.8	127.7	996	721
				50	80.0	129.0	702	602
				65	62.7	129.8	554	518
				80	51.2	130.4	454	445
				90	46.9	130.8	417	414
				100	39.0	131.3	348	348
	Do	4	High Dam	35	109.0	127.9	948	750
				50	83.7	128.9	734	660
				65	73.2	129.3	644	610
				80	62.8	129.8	553	544
				90	57.8	130.0	511	509
				100	51.3	130.4	455	455
	Upstream regulation including Columbia River storage. Quincy Flats irrigated from Wenatchee Lake. plan no. 6-A.	5	Low Dam	35	115.6	127.6	1,003	717
				50	76.1	129.2	669	580
				65	62.4	129.8	551	513
				80	50.6	130.5	449	439
				90	45.9	130.8	408	405
				100	38.6	131.3	345	345
Pumping	Upstream regulation without Columbia River storage. plan no. 4.	6	Low or high	35	114.0	127.7	986	717
				50	79.8	129.0	700	603
				65	64.6	129.7	570	531
				80	53.5	130.3	474	463
				90	47.2	130.7	420	417
				100	39.9	131.3	356	356
	Upstream regulation including Columbia River storage. plan no. 4.	7	Low Dam	35	109.8	127.9	954	709
				50	76.9	129.1	675	596
				65	64.6	129.7	570	537
				80	54.1	130.2	479	471
				90	50.3	130.5	446	443
				100	43.8	131.0	390	390
	Do	8	High dam	35	99.1	128.3	865	720
				50	81.8	128.9	717	659
				65	73.8	129.3	649	621
				80	64.8	129.7	572	565
				90	61.0	129.8	539	537
				100	56.2	130.1	497	497

[2] Not printed

741. As a basis of comparison, the potential power available 90 percent of the time as shown on table no. 138 is, respectively, 289,000, 394,000, 417,000, 511,000, 408,000, 420,000, 446,000, and 539,000 kilowatts for cases 1 to 8, inclusive; or, considering case 1 as 100 percent, cases 2 to 8 are 136, 144, 177, 141, 145, 154, and 186 percent, respectively. For similar conditions of regulation, the increase in potential power under the pumping plan for 80, 90, and 100 percent of the time over that obtained under the gravity plan is worthy of note, as is also the marked effect of regulation of storage at the high Grand Coulee Dam as compared with the low Grand Coulee Dam. The duration of potential power for cases 1, 6, and 8 is shown graphically on plate no. 100.[2]

742. *d'. Proposed development.*—The project works, as planned, would involve the construction of a power house 900 feet long, located parallel to the stream, on the right bank opposite the lower end of Panhandle Island, and a concrete spillway of gravity section, 3,270 feet long, located partly parallel to the stream and partly across it. The spillway would contain 82 Stoney gates, each 22 feet high by 30 feet long, with a total capacity of 1,000,000 second-feet. The crest elevation would be 518 feet. Piers 10 feet thick would support the gates and an operating deck, the latter having a top elevation of 550 feet. At the east end of spillway, there is a concrete, gravity section nonoverflow dam about 350 feet long. At the west end there is a nonoverflow section about 380 feet long. The remainder of the dam at both ends would be composed of earth dikes running perpendicularly to the stream and protected against seepage by concrete core walls extending to bedrock, or impervious material. Where ends of core wall are not anchored to bedrock, spur walls must be provided. The total length of the dam would be approximately 11,700 feet. Locks and other navigation features would be provided for on the right bank. The project works, as planned, are shown on plates nos. 97 and 101.[2]

743. The kinetic energy of the flood flows would amount to 9,150 horsepower per lineal foot of clear crest at normal forebay, or approximately 6,900 horsepower per lineal foot of apron. See discussion in paragraph 549 of methods for dissipation of this energy. The portion of the spillway located at right angles to the stream would be used for average floods, and the remainder would be used for the excess.

744. The installed generating capacity selected for discussion is 648,000 kilowatts, which is based on the available potential power. 420,000 kilowatts, in case 6 for 90 percent of the time, with 65 percent plant-capacity factor. The power house as shown on plate no. 101 [2] and the estimates of cost given hereafter were based on this installed capacity.

745. The power house, as planned, would provide space for 12 units, each consisting of a vertical Francis turbine direct-connected to a 54,000 kilowatt generator, 13,800 volts, 3-phase, 60 cycles. Each turbine would have a hydraulic capacity of 6,670 second-feet at a head of 115 feet. Transformers in the upstream portion of the building would step the voltage up to 220 kilovolts for delivery to an outdoor switching station on the roof.

746. The estimate of capital cost contains an allowance of $1,629,000 to cover the cost of a certain amount of tailrace excavation. The

[2] Not printed.

benefits in lowered tailwater to accrue from this improvement are difficult to evaluate and, to be conservative, the estimate of power output and the plans themselves use the elevation fixed by the rating curve as established for the power house under natural conditions.

747. For construction purposes, it was planned to extend the railroad spur line of the Chicago, Milwaukee, St. Paul & Pacific Railroad (Hanford Branch), now existing on the right bank. It connects the main line at Beverly with Vernita and other points south.

748. The reservoir site lies in a region of very sparse population. Practically no cultivated land would be flooded at normal forebay level. The town of Beverly, with a population of about 50 people, as well as about 15 miles of main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad including the bridge at Beverly and about 15 miles of the above-mentioned branch line, would be flooded out. The new highway now under construction in the river channel at Vantage as well as about 25 miles of secondary earth and gravel roads, would have to be relocated. An amount of $2,000,000 has been inserted in the estimate of capital cost to cover the relocation of the above-mentioned items.

749. *e' Economic features.*—The principal items of construction and the estimated capital cost of the project are shown in table no. 139. The cost of locks and other navigation features in connection with the power project are not shown herein but will be given later in chapter II, under "Combined Uses." It will be noted that the total capital cost per kilowatt of installed capacity would be $89 for public development and $93 for private development.

TABLE NO. 139.—*Estimate of capital cost of development at Priest Rapids site, high dam, for an installed capacity of 648,000 kilowatts*

Preliminary expenses	$1, 237, 500
Construction railway	300, 000
Relocation of existing items	2, 000, 000
Reservoir	250, 000
River diversion	1, 000, 000
Spillway dam and earth dikes	17, 551, 985
Intake and bulkhead section	4, 275, 550
Power-house substructure	3, 093, 175
Power-house superstructure	1, 942, 000
Hydraulic equipment	4, 200, 000
Electrical equipment	4, 773, 600
Cranes, stop logs, and steel for switch yard	276, 000
Tailrace excavation	1, 629, 000
Contingencies, 10 percent	4, 252, 881
Total field cost	46, 781, 691
Overhead, 12½ percent	5, 847, 711
Total construction cost	52, 629, 402
For public development:	
Total construction cost	52, 629, 402
Total interest charged during construction, 10 percent	5, 262, 940
Total capital cost	57, 892, 342
Capital cost per kilowatt	89
For private development:	
Total construction cost	52, 629, 402
Total interest charged during construction, 15 percent	7, 894, 409
Total capital cost	60, 523, 811
Capital cost per kilowatt	93

750. The financial set-up and annual operating cost for both public and private development are shown in table no. 140. They are based on delivering power to the low-tension side of step-up transformers, including high-tension switch structure but omitting step-up transformers, high-tension insulators, switches, arresters, and oil circuit breakers, which are included in the terminal stations for transmission lines.

751. Plate no. 102[2] shows graphically the cost per kilowatt-hour of energy generated for plant-capacity factors varying from 10 percent to 100 percent. It will be noted that the cost per kilowatt-hour for a 50 percent plant-capacity factor would be 1.22 mills for public development, 1.79 mills for private development for an annual operating cost of 8.10 percent of the capital cost, and 2.76 mills for private development for annual operating cost of 12.5 percent of the capital cost. The cost of steam-generated power for the same range of plant-capacity factor is also shown, computed for fuel oil at $1 per barrel.

TABLE No. 140.—*Estimate of annual cost of power production at Priest Rapids High Dam, with an installed capacity of 648,000 kilowatts*

	Public development	Private development
1. Investment cost:		
Lands and water rights and nondepreciated items	$3,062,813	$3,202,031
Dams and substructures	38,238,819	39,976,947
Subtotal "A"	41,301,632	43,178,978
Power plant, machinery, and superstructures	16,590,710	17,344,833
Total development, capital cost	57,892,342	60,523,811
2. Basis of annual cost:		
(a) Return or interest in percent of capital cost	4	6
(b) Amortization of bonds, 40-year sinking-fund basis, in percent of capital cost	1.05	0
(c) Depreciation:		
(1) Lands and water rights, in percent of capital cost	0	0
(2) Dams and substructures, 100-year sinking-fund basis, in percent of capital cost	0.08	0.018
(3) Power plant, machinery, and superstructures, 30-year sinking-fund basis, in percent of capital cost	1.78	1.26
(d) Taxes, in percent of capital cost	0	1.5
(e) Maintenance and operation expense, including 10 percent of cost of labor and material for general expense	148,616	148,616
3. Total annual cost:		
Items included in subtotal "A":		
Interest or return	1,652,065	2,590,000
Amortization	433,667	----------
Depreciation	30,591	7,196
Taxes	----------	647,685
Maintenance and operation (included under power plant)	----------	----------
Subtotal	2,116,323	3,244,881
Power plant:		
Interest or return	663,628	1,040,690
Amortization	174,202	----------
Depreciation	295,314	218,544
Taxes	----------	260,172
Maintenance and operation	148,616	148,616
Subtotal	1,281,760	1,668,022
Total project:		
Interest or return	2,315,693	3,630,690
Amortization	607,869	393,404
Depreciation	325,905	225,740
Taxes	----------	907,857
Maintenance and operation	148,616	148,616
Total annual cost	3,398,083	4,912,903
Total annual cost in percent of capital cost	5.87	8.10

[2] Not printed.

2. EARLIER PLANS OF DEVELOPMENT

752. A license for a power project at Priest Rapids was issued on March 5, 1925, by the Federal Power Commission to the Washington Irrigation & Development Co. This license was extended to March 1, 1929, and was terminated on June 14, 1929. A new application of the Washington Irrigation & Development Co. for a license was rejected on July 2, 1930, by the Federal Power Commission, for failure to make a satisfactory showing of ability to finance the project and market the power. The license provided for a dam and power house comparable to that herein set up for the low dam.

753. No comprehensive plans of development have previously been made for a high dam at the Priest Rapids site, which would back the water to the Rock Island plant now under construction.

754. *a. Principal works proposed.*—Plans, as submitted by this company, called for an earth-fill dam with a crest elevation of 500 feet, extending from the west side of the valley to the Hanford forebay channel. A concrete section connected this earth section with the power house located on the right bank of the west channel and running upstream parallel to the channel. The spillway section of the dam extended from the upper end of the power house to a point about half a mile upstream, where it turned east across the west channel and Whale Island to the right bank of the east channel. The plans called for another earth-fill dam to extend across the east channel and on to the east side of the valley. It was planned to construct locks in the existing Hanford forebay channel if and when required.

755. The contemplated normal water level of the forebay was 488.0 feet, and the crest elevation of the spillway was 470 feet. The tail-water elevations were given as follows: Low water, 405.0 feet; ordinary floods, 431.0 feet; extreme floods, 445.0 feet. A spillway capacity of 1,200,000 second-feet was to be provided. Regulation was to be made by the mechanical operation of 127 Stoney gates 18 feet high by 30 feet long.

756. *b. Power.*—The initial development provided sufficient space in the power house for eight units. A temporary multiple-arch dam about 660 feet long, adjoining this power house, was to provide space for a future extension of sufficient length to accommodate 10 additional units. Each unit was to consist of a vertical-shaft turbine of 42,500 horsepower, direct-connected to a 34,000-kilowatt generator. The transformers and switching station were to be placed on the east bank across the river from the power house.

757. *c. Estimated cost.*—The cost of the initial development was estimated as $28,267,000 for a capacity of 272,000 kilowatts, corresponding to $104 per kilowatt. The estimated cost of the ultimate development was $41,242,000 for 612,000 kilowatts, corresponding to $67 per kilowatt.

II. TRIBUTARY EFFECTS

758. A brief general description of each of the most important tributaries of the Columbia above the Snake has already been given in this report under the general descriptive data (pars. 43 to 64). Further details will be given in this section where necessary for a clear understanding of a particular situation.

759. Power development on the tributaries will affect power development on the main stream in two ways: First, storage on the tributaries for power development will affect stream discharge and therefore power development on the main river. Second, power developed on the tributaries will enter the power market as a competitor to power developed on the main stream and will thus influence, both in amount and time, development on the main river. Potential power on the tributaries is here described only sufficiently to indicate its effect on the power market and on stream flow on the Columbia itself. No detailed surveys of potential power sites on the tributaries have been made by this office; however, detailed information is available for some sites, particularly for the development, now under construction, at outlet of Flathead Lake by the Rocky Mountain Power Co., through their application to the Federal Power Commission. Detailed studies (given in appendix no. 2) have been made of the effect on stream flow of regulation at the proposed Hungry Horse site on South Fork of Flathead River; of Flathead, Priest, and Pend Oreille Lakes on the Clark Fork; of Coeur d'Alene Lake on the Spokane; of Kootenai Lake on Kootenai River in Canada; of Lake Chelan on the Chelan; and of the Chiwawa and Wenatchee reservoir sites on the Wenatchee. The data available are believed to be sufficiently accurate to indicate in general what might be expected through development of power on the tributary streams.

760. The purpose, then, of this section is not to set up a plan of development for each of the may power sites on the tributaries within the United States, but rather to point out the locations of the larger power and reservoir sites; to estimate the power duration of the individual plants, and to compare the totals thus obtained with the possible output at sites on the main stream. The effect of storage in these reservoirs on the flow of the main stream will be discussed in detail elsewhere in this report and in appendix no. 2.

(A) KOOTENAI RIVER

1. IN THE UNITED STATES

761. There are but two important power sites on that portion of the Kootenai within the United States, the upper one at Kootenai Falls between Libby and Troy, Montana, and the lower one near Leonia, Idaho, at the Montana-Idaho line. E. W. Kramer[44] estimated the primary power available at these sites to be 20,000 horsepower at Kootenai Falls and 11,000 horsepower at Leonia. The Kootenai Power Construction Co., under date of June 4, 1921, applied to the Federal Power Commission for a preliminary permit for power development at the Kootenai Falls site, but the application was rejected by the Commission on March 2, 1923. Mr. Kramer reported heads of 89 and 50 feet at these two sites, respectively. The mean monthly flow for the past 17 years at Libby, Mont., upstream from these sites, was 11,700 second-feet, the Q 50 flow was approximately 5,500 second-feet, the Q 90 flow was approximately 3,000 second-feet, and Q 100 was 2,170 second-feet. To be conservative, no allowance is here made

[44] E. W. Kramer, "Water Power in Montana", Jan. 28, 1921. Unpublished report to the United States Forest Service.

for inflow below the gaging station. From these data the power duration with natural flow at 80 percent efficiency in kilowatts at these two sites is estimated to be as shown herewith:

Site	Percent of time		
	50	90	100
	Kilowatts	*Kilowatts*	*Kilowatts*
Kootenai Falls	33, 300	18, 200	13, 100
Leonia	18, 700	10, 200	7, 400

2. IN CANADA

762. As noted later in this report, the effect of power produced at plants in Canada on the market for power generated in that portion of the basin of the Columbia within the United States will not be considered herein. However, the water-supply studies carried out in appendix no. 2 consider the effect on stream flow in the main river of using 715,000 acre-feet of storage in Kootenai Lake in Canada.

763. Kootenai River is the principal tributary and the only distributary of Kootenai Lake. As shown in table no. 171, page 833, the West Kootenay Power and Light Co. has three power plants with an aggregate capacity of 108,000 kilowatts on Kootenai River below Kootenai Lake, all of which would benefit by regulation of storage in the lake. This company has, accordingly, applied to the Canadian authorities and to the International Joint Commission for permission to construct regulatory works below the lake and to control the lake below an elevation corresponding to a reading of 6 feet on the Nelson gage. At this 6-foot mark, the natural capacity of the outlet channel is 33,000 second-feet. After improvement as contemplated by the company this same discharge will pass at a lake elevation of 1,746 (U.S.C. & G.S. datum), and this elevation has been taken for the purposes of the present study as the upper limit of regulation on the lake. It was found necessary in these studies to draw the lake down to elevation 1,740.2 feet to maintain a minimum flow of 7,600 second-feet. The storage between these two limits is 715,000 acre-feet. The area-capacity curve for the lake is shown on plate no. 17 [2] and flow-duration curves and data are shown in plate no. 103.[2]

764. The natural and regulated discharges for the Kootenai at Nelson, British Columbia, have been given in tables no. 27 and no. 53. A summary of the mean monthly flows for both conditions is given in table no. 141.

TABLE NO. 141.—*Mean monthly discharge in second-feet, Kootenai River at Nelson, British Columbia, for the 18-year period ended March 31, 1931. The mean annual discharge for the same period is 28,000 second-feet*

Condition	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Natural	16, 700	49, 200	86, 400	68, 200	33, 700	20, 900	14, 900	12, 500	9, 530	8, 250	7, 610	7, 850
Regulated [a]	17, 400	49, 200	86, 400	67, 900	31, 300	17, 400	13, 400	11, 700	10, 400	10, 200	10, 200	10, 200
Effect	+700	0	0	−300	−2, 400	−3, 500	−1, 500	−800	+870	+1, 950	+2, 590	+2, 350

[a] Using 715,000 acre-feet of storage in Kootenai Lake.

[2] Not printed.

(B) FLATHEAD RIVER

1. DIVERSION OF MIDDLE FORK TO SOUTH FORK

765. From a study of the Nyack quadrangle map of the United States Geological Survey, there appears to be a possible dam site on the Middle Fork of Flathead River just above Bear Creek. The entire flow of the stream above this point could be diverted from the forebay so created, elevation 4,000 feet, to the South Fork of Flathead through an 8-mile tunnel and conduit. A power house to use this water could be located at the upper regulated limit of the Hungry Horse Reservoir (about elevation 3,435 feet), thus providing an operating head of about 500 feet.

766. There are no stream-flow records applicable to the diversion site; however, of the 900 square miles of drainage area tributary to the Middle Fork above the gaging station at Belton, Mont., 420 square miles are above the point of diversion. Using the measured run-off at Belton and proportional areas, it appears conservative to assume an available regulated discharge of 2,000 second-feet for the flow available 50 percent of the time. The possibilities are merely pointed out as a suggestion for future investigations. Should such future investigations prove that there is merit in the tentative scheme just suggested, the increased water supply thus made available to the Hungry Horse project would enhance the value of that project and, through regulation in that reservoir, the value of all downstream projects.

2. FLATHEAD RIVER ABOVE MIDDLE FORK

767. But few engineering data are available for this, the main branch of Flathead River. Mr. Kramer reported a dam site at a point one half mile above the mouth of Canyon Creek and 6 miles above the confluence with the Middle Fork, where solid rock foundations and abutments are in sight. The dam would be 145 feet high above low-water level, and 525 feet long on top. Very little storage would be developed by the dam.

768. There is a site for a storage reservoir about 8 miles farther upstream, but the site for a storage dam is somewhat questionable. It is believed that sufficient storage for complete regulation of the river can be obtained with a dam about 275 feet high above low water, backing water to elevation 3,600. The total storage capacity between these levels is about 2,000,000 acre-feet with a useful storage of about 1,000,000 acre-feet. Mr. Kramer reports the valley at this dam site to be 1,250 feet wide at a level 140 feet above low water. From the meager data available it appears that the 275-foot dam would require about one and one-half million cubic yards of concrete for a gravity section. Even assuming good foundation and abutments, such a dam would not be feasible unless it can be established by further investigation that full regulation for the joint uses of power, flood control, and irrigation would justify such a large expenditure.

769. Pertinent data from the existing records indicate maximum, mean, and minimum flows of 29,500 second-feet, 3,040 second-feet, and 350 second-feet, respectively, for natural conditions. Due to lack of data, studies of these two sites have not been possible and they are mentioned here merely for purposes of record and as a guidepost for possible future investigations.

3. SOUTH FORK FLATHEAD RIVER AT HUNGRY HORSE CREEK

770. This project has been investigated by the United States Geological Survey [45] and is believed to merit serious consideration in any scheme of developing Flathead River. The dam site is located in township 30 north range 19 west, Montana meridian, at water-surface elevation 3,080 feet where a good foundation is available for an arch dam and flanking abutments. The site is about 700 feet above "The Devils Elbow", and about 4 miles above the mouth of South Fork. A dam at this location with a crest elevation of 3,530 feet (450 feet above low-water stage) would be about 1,900 feet long on top, would back water up South Fork for a distance of about 39 miles, and would provide a storage capacity of about 3,060,000 acre-feet by regulation below elevation 3,520 feet. If so constructed, the usable storage would insure complete regulation of the estimated flow of South Fork. Careful investigation, borings, water-supply analyses and cost estimates might demonstrate the practicability of a dam this high, for the combined benefit of power, irrigation development, and flood control. Lacking complete information, the water-supply studies given in appendix no. 2 of this report assumed regulation between elevations 3,435 feet and 3,312 feet with a usable storage of 1,100,000 acre-feet between those limits. A dam with a maximum height of 360 feet above low-water stage would have a crest length of 1,250 feet, would accommodate the proposed regulation, and would provide a freeboard of 5 feet. In appendix no. 2 consideration was also given to the possibility of using additional storage between elevations 3,435 feet and 3,455 feet, amounting to about 279,000 acre-feet, for the control of flood stages. Area-capacity curves for the reservoir are shown on plate no. 12.[2]

771. Stream-flow records applicable to the site are fragmentary and of but short duration, but the data shown in tables no. 28 and no. 54 and on plate no. 104 [2] indicate the natural and regulated monthly discharges to be expected and their duration. The head would vary from 355 feet to 232 feet, with an average head of about 303 feet. The regulating effect of the 1,100,000 acre-feet of storage would be carried down Flathead River to Clark Fork and on to the Columbia proper. Table no. 142, abstracted from tables nos. 28 and 54, gives the mean monthly discharge for the 18-year period ended March 31, 1931, for both natural and regulated flow.

TABLE NO. 142.—*Mean monthly discharge in second-feet, Hungry Horse Project, for the 18-year period ended March 31, 1931. The mean annual flow for the same period is 3,290 second-feet*

Condition	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Natural	4,100	2,100	11,900	3,950	1,360	977	1,030	1,020	799	813	627	793
Regulated [a]	3,240	3,600	3,600	4,020	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120
Effect	−860	−8,500	−8,300	+70	+1,760	+2,143	+2,090	+2,100	+2,321	+2,307	+2,493	+2,327

[a] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir.

[2] Not printed.

[45] Reconnaissance Report of South Fork Flathead River by E. E. Jones, January 1924. Unpublished. Extracts from this report were published in Engineering News-Record, vol. 93, p. 96.
Storage Regulation in Flathead Basin for Power and Its Effect on the Columbia Basin Project, by G. L. Parker, May 1926. Unpublished.
Geology of Dam Sites on South Fork of Flathead River below Hungry Horse Creek, Flathead County, Mont., by J. T. Pardee, January 1928. Unpublished.

772. The estimated flow and power output is given in table no. 143, assuming an average head of 350 feet for natural flow and 303 feet for regulated flow and an efficiency of 80 percent.

TABLE NO. 143.—*Hungry Horse Site. Estimated flow and power duration for the 18-year period ended Mar. 31, 1931*

Time (percent)	Discharge		Power output at 80 percent efficiency	
	Natural	Regulated [1]	Natural	Regulated
	Sec.-ft.	*Sec.-ft.*	*Kilowatts*	*Kilowatts*
50	1,200	3,070	28,600	63,300
90	453	2,510	10,800	51,700
100	309	708	7,400	14,600

[1] Using 1,100,000 acre-feet storage.

773. Tentative studies for the control of floods were made to ascertain the effect at Flathead and Pend Oreille Lakes of using various amounts of storage reserved solely for control of floods. The utilization of Hungry Horse Reservoir for both power and flood-control purposes would involve reserving storage in the upper part of the reservoir solely for flood control and placing some limitations on the rate at which the reservoir may be filled during certain years when snow surveys, made prior to the filling period, would indicate clearly that a flood might occur. Preliminary analyses were made for floods of the magnitude of those occurring during 1894 and 1928, with results as indicated in table no. 144.

TABLE NO. 144.—*Flood control analysis, Hungry Horse Reservoir*

Flood	Reserve storage in Hungry Horse Reservoir (U.S. Geological Survey datum)		Flathead Lake (U.S. Geological Survey datum)			Pend Oreille Lake (U.S. Coast and Geodetic Survey datum)		
			Crest elevation		Reduction	Crest elevation		Reduction
	Between elevations	Amount	Natural	Controlled		Natural	Controlled	
	Feet	*Acre-feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1894	3,435–3,455	279,000	2,900.00	2,896.72	3.28	2,076.09	2,073.77	2.32
1928	3,435–3,445	135,000	[1] 2,895.85	2,893.00	2.85	2,068.67	2,065.76	2.91

[1] Based on original Geological Survey records which were subsequently revised to elevation 2,896.00 feet.

774. Sufficient data are not now available to fix the proper amount of flood reserve storage or its economic feasibility; but any plan for power development at this site should include definite and thorough consideration of flood-control possibilities.

4. FLATHEAD RIVER NEAR CORAM, MONT.

775. No data regarding this site are known other than those given by Mr. Kramer, which data are, in part, as follows:

The site is "about a quarter of a mile below the mouth of the South Fork. The Great Northern Railway runs along the north bank of the Flathead River at the site. It is 20 miles from Kalispell by railway. There is a rock cliff abutment at the north end of the dam site and a gravel ridge at the south end. It is not known at what depth bedrock could be found at the south abutment or in the stream bed. If satisfactory foundations were found, it would be feasible to construct a dam 90 feet high above low-water level, which would be 700 feet long on top." Mr. Kramer adds that an installation of 20,000 horsepower would probably be justified. This capacity could be materially increased if the upstream reservoirs previously described prove feasible.

5. FLATHEAD RIVER BELOW FLATHEAD LAKE, NEAR POLSON, MONT.

776. This site, located on Flathead River about 5 miles downstream from Polson at the outlet of Flathead Lake, has been under investigation for a number of years by various private and governmental agencies. On June 18, 1920, the Rocky Mountain Power Co. applied to the Federal Power Commission for a preliminary permit to develop this site. On March 26, 1928, the same company applied to the Commission for a license which was finally granted on May 23, 1930. Construction work was started July 2, 1930, and it is expected that the first unit will be in operation by 1933 or 1934. A collection of data regarding this site, including a copy of the license granted the Rocky Mountain Power Co., is given in Senate Document No. 153, Seventy-first Congress, second session, entitled "Flathead Power Development."

777. The plan of development involves the construction of an arch dam and the conveyance of water from the dam through tunnels 770 feet long to the power house, where an average head of 185 feet will be available. Under the terms of the license the company was to begin construction within 1 year from May 23, 1930, "and shall within 3 years thereafter complete the installation of three units of not less than 150,000 horsepower aggregate capacity." The project works will be so constructed that a fourth unit can be installed later if required. However, the company has applied to the Commission for authority to install ultimately three 56,000-kilowatt units, and to install initially one of these units and the foundations and penstock for the second unit, deferring the installation of the third unit until conditions warrant.

778. This site is particularly valuable because of the upstream storage available in Flathead Lake. Initially, the company will be permitted under the license to regulate Flathead Lake between elevations 2,883 and 2,893 feet; but these limits may be changed to such limits between elevations 2,880 and 2,893 feet as will make available not less than 1,100,000 acre-feet of storage capacity, corresponding to about 16,000,000 kilowatt-hours of energy. The area-capacity curves for Flathead Lake are given on plate no. 13.[2] If and when the Hungry Horse Reservoir site, discussed in paragraphs 770 and 774, is developed, the Rocky Mountain Power Co. will be materially benefited because of the equalization of stream flow effected thereby.

779. Tables of natural and regulated flow of Flathead River at Polson have been given in tables nos. 29 and 55. Data relative to the monthly duration of stream flow for both natural and regulated conditions for the 18-year period ended March 31, 1931, are given in

[2] Not printed.

table no. 145 and on plate no. 105.[2] The capacity between elevations 2,880 and 2,893 feet is 1,540,000 acre-feet (see area-capacity curves, plate no. 13)[2] and this figure has been used in computing the regulated flows given in the last column of table no. 145. The data in column 3 of table no. 145 are presented for ready comparison with those in column 4, the differences serving as an indication of the value to this project of upstream storage at the Hungry Horse site and of additional storage (amounting to 440,000 acre-feet) in Flathead Lake. Initially, the storage in Flathead Lake will undoubtedly be limited to 1,100,000 acre-feet, but, for the purposes of these studies, it was considered that the ultimate development should provide for the use of all the storage, amounting to 1,540,000 acre-feet, available between the limits of regulation fixed by the Federal Power Commission.

TABLE No. 145.—*Monthly flow duration in second-feet of Flathead River, near Polson, Mont., for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural flow	Regulated flow	
		Using Flathead Lake alone [1]	Using Hungry Horse and Flathead Lake [2]
(1)	(2)	(3)	(4)
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*
50	5,090	6,540	9,020
90	2,610	5,100	7,630
100	1,510	4,050	7,010

[1] Based on the use of 1,100,000 acre-feet.
[2] Includes the effect of 1,100,000 acre-feet storage in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

Table no. 146, abstracted from tables nos. 29 and 55, gives the mean monthly discharges applicable to the site.

TABLE No. 146.—*Mean monthly discharge in second-feet, Flathead River at Polson, for the 18-year period ended Mar. 31, 1931. The mean annual discharge for the same period is 11,700 second-feet.*

	April	May	June	July	August	September	October	November	December	January	February	March
Condition:												
Natural	7,530	28,200	42,600	24,800	9,380	5,350	4,510	4,300	3,830	3,560	3,020	3,340
Regulated:												
Flathead Lake alone [1]	10,500	25,900	37,100	15,900	6,430	6,240	6,020	6,010	6,010	6,010	6,010	6,130
Hungry Horse and Flathead Lake [2]	9,190	14,500	27,600	15,600	9,040	9,000	8,920	8,920	8,920	8,920	8,920	8,920
Effect:												
Flathead Lake alone	+2,970	−2,300	−5,500	−8,900	−2,950	+890	+1,510	+1,710	+2,180	+2,450	+2,990	+2,790
Hungry Horse and Flathead Lake	+1,660	−13,700	−15,000	−9,200	−340	+3,650	+4,410	+4,620	+5,090	+5,360	+5,900	+5,580

[1] Using 1,100,000 acre-feet in Flathead Lake.
[2] Using 1,100,000 acre-feet in Hungary Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

780. Taking the flows and conditions set up in table no. 145, and assuming an average head of 185 feet, the power duration will be as given in table no. 147.

[2] Not printed.

TABLE No. 147.—*Mean monthly power duration at 80 percent efficiency, Flathead River at Polson, for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural flow	Regulated flow: Using 1,100,000 acre-feet storage in Flathead Lake alone	Regulated flow: Using 1,100,000 acre-feet in Hungry Horse and 1,540,000 acre-feet in Flathead Lake
	Kilowatt	*Kilowatt*	*Kilowatt*
50	64,000	82,300	113,500
90	32,800	64,200	96,000
100	19,000	51,000	88,100

6. FLATHEAD RIVER, FROM THE TAILRACE OF THE SITE NEAR POLSON TO ITS CONFLUENCE WITH THE CLARK FORK

781. Mr. Kramer's report indicated that it would probably be feasible to develop a fall of 175 feet in four projects in this stretch. The Rocky Mountain Power Co. in its application of December 31, 1920 (which expired before application for license was filed) to the Federal Power Commission for a preliminary permit to develop power on Flathead River, asked for rights at five sites, the most important of which is the one described in paragraphs 776 to 780 of this report. The other four sites are presumably the same as those mentioned by Mr. Kramer. The operating heads for the four sites as given in the application of the Rocky Mountain Power Co. are as follows:

Site no:	*Feet*
1	51
2	26
3	88
4	17
Total	182

782. There is relatively little inflow in the stretch of the river under consideration, and more and more of this natural inflow is being used for irrigation purposes. Therefore, to be conservative, the flow at the site near Polson will be assumed as available at these four downstream sites. Taking, then, flows as shown in table no. 148, and assuming a total average head of 175 feet for the four sites under discussion, the power duration at 80 percent efficiency for this entire stretch of river will be as shown in table no. 148.

TABLE No. 148.—*Mean monthly power duration at 80 percent efficiency, for 4 Flathead River sites for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural flow	Regulated flow: Using Flathead Lake alone [1]	Regulated flow: Using Hungry Horse and Flathead Lake [2]
	Kilowatts	*Kilowatts*	*Kilowatts*
50	60,600	77,800	107,200
90	31,100	60,700	90,800
100	18,000	48,200	83,500

[1] Based on the use of 1,100,000 acre-feet.
[2] Includes the effect of 1,100,000 acre-feet storage in Hungry Horse and of 1,540,000 acre-feet in Flathead Lake.

(C) CLARK FORK

1. FISH CREEK SITE

783. This project is located on Clark Fork about 45 miles below Missoula, Mont., and about 50 miles upstream from the confluence with Flathead River. A head of 108 feet can be developed by a dam, backing water to about elevation 2,903 feet. Approximate flow-duration and power-duration data are shown in table no. 149.

TABLE NO. 149.—*Estimated monthly flow and power duration, Fish Creek site*

Time (percent)	Flow duration	Power duration at 80 percent efficiency
	Second-feet	*Kilowatts*
50	6,200	45,500
90	3,400	25,000
100	1,200	8,800

2. THOMPSON FALLS

784. This site is now developed and will be described in paragraph 849. The present installed capacity is 35,000 kilowatts with a head of 50 feet; but, if and when controlled upstream storage is developed in Hungry Horse Reservoir and in Flathead Lake, a materially increased annual energy output could be obtained. Assuming development of these reservoirs as outlined in the preceding text, the estimated natural and regulated stream flow and power durations would be as indicated in table no. 150.

TABLE NO. 150.—*Mean monthly flow-duration and power-duration at 80 percent efficiency for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural		Regulated [1]	
	Discharge	Power	Discharge	Power
	Second-feet	*Kilowatts*	*Second-feet*	*Kilowatts*
50	10,800	36,800	13,900	47,300
90	5,900	20,000	10,700	36,400
100	3,900	13,200	8,900	30,200

[1] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

3. DONLAN SITE

785. This site is about 6 miles below Thompson Falls. A head of 40 feet can be developed by means of a dam. Such a dam would raise the natural low-water level from about elevation 2,325 feet to about elevation 2,365 feet, which is the elevation of the tail water at Thompson Falls, and would provide pondage only. Using the flows given in table no. 151 (since there is very little inflow between the Thompson Falls plant and the Donlan site), the estimated power output with upstream regulation in Hungry Horse Reservoir and in Flathead Lake is as shown in table no. 151.

TABLE NO. 151.—*Donlan Site, mean monthly flow-duration and power-duration at 80 percent efficiency for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural		Regulated [1]	
	Discharge	Power	Discharge	Power
	Second-feet	*Kilowatts*	*Second-feet*	*Kilowatts*
50	10,800	29,400	13,900	37,800
90	5,900	16,000	10,700	29,200
100	3,900	10,600	8,900	24,200

[1] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

4. ROCK ISLAND GORGE

786. This site is located about 35 miles below Thompson Falls near Noxon, Mont. Mr. Kramer reports that "The stream at this point runs over a rock ledge, dividing into two channels around a rock island. The abutments are of ledge rock. The channels are 550 and 400 feet wide at an elevation 50 feet above the low-water level. The widths of the channels at low-water level are 250 and 150 feet. The dam would develop enough pondage for daily regulation, but no storage." A head of 50 feet can be developed by the dam, raising the water to elevation 2,215 feet.

787. The site is about 18 miles upstream from the Montana-Idaho boundary. There is a relatively small inflow between this site and the boundary and therefore the flows given in tables nos. 30 and 56 can be applied here without appreciable error. From these data the estimated power output and duration is as shown in table no. 152.

TABLE NO. 152.—*Rock Island Gorge, mean monthly flow-duration and power-duration at 80 percent efficiency for the 18-year period ended Mar. 31, 1931*

Time (percent)	Natural		Regulated [1]	
	Discharge	Power	Discharge	Power
	Second-feet	*Kilowatts*	*Second-feet*	*Kilowatts*
50	12,400	42,200	15,500	52,800
90	6,770	23,000	11,600	39,400
100	4,500	15,300	9,550	32,500

[1] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

5. CABINET GORGE

788. Cabinet Gorge is in Idaho near the Montana-Idaho line. Mr. Kramer reports that the rock walls of the gorge are 115 feet high above low-water mark. The width of the canyon at the low-water elevation is 175 feet, and the width at the top is 185 feet. The height of the dam would be limited by the Northern Pacific Railway Co.'s tracks, and by tail water at the Rock Island Gorge site, to about 77 feet above low water.

789. Complete tables of natural and regulated monthly flows for the period April 1, 1913, to March 31, 1931, for the Clark Fork at the Montana-Idaho line are given in tables nos. 30 and 56. Flow-duration data for both these conditions are shown on plate no. 106.[2] A summary of the mean monthly flows for both conditions is given in table no. 153. The estimated power output and duration is shown in table no. 154.

TABLE NO. 153.—*Mean monthly discharge in second-feet, Clark Fork at Montana-Idaho line, for the 18-year period ended Mar. 31, 1931. The mean annual discharge for the same period is 23,000 second-feet*

Condition	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Natural	22,600	57,600	71,000	38,200	15,300	10,100	9,770	10,400	10,100	9,370	9,400	11,000
Regulated [a]	24,100	43,000	53,800	27,300	14,100	13,500	14,100	14,900	15,100	14,700	15,200	16,400
Effect	+1,500	−14,600	−17,200	−10,900	−1,200	+3,400	+4,330	+4,500	+5,000	+5,330	+5,800	+5,400

[a] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir, and 1,540,000 acre-feet in Flathead Lake.

[2] Not printed.

TABLE No. 154.—*Cabinet Gorge, mean monthly flow-duration and power-duration at 80 percent efficiency for the 18-year period ended Mar. 31, 1931 (assumed average head, 75 feet)*

Time (percent)	Natural		Regulated [1]	
	Discharge	Power	Discharge	Power
	Second-feet	*Kilowatts*	*Second-feet*	*Kilowatts*
50	12, 400	63, 300	15, 500	79, 100
90	6, 770	34, 500	11, 600	59, 200
100	4, 500	23, 000	9, 550	48, 700

[1] Using 1,100,000 acre-feet storage in Hungry Horse Reservoir and 1,540,000 acre-feet in Flathead Lake.

6. ALBANY FALLS

790. Soon after entering the State of Idaho, the channel of Clark Fork expands into Pend Oreille Lake, which has a low-water area of about 80,000 acres. For area-capacity curves, see Plate No. 15.[2] Most of the shore line of the lake is steep, rocky, and rugged. At the upper and lower ends, however, considerable areas are farmed, although the natural range in stage, during years of high water, is quite unfavorable to agriculture, as high water occurs during the growing season.

791. Below Pend Oreille Lake the river continues its course in a westerly direction to Albany Falls, located in Idaho near the Idaho-Washington boundary. At Albany Falls the river has three channels through a granite dike and, at low stages, drops about 7 feet within a distance of 125 feet. A dam here may be made to serve as a control dam for the storage in Pend Oreille Lake, to provide head for a possible power development at the falls, and to serve as a diversion dam for the intake of a gravity supply canal for the irrigation of the Columbia Basin irrigation project. Control of storage in Pend Oreille Lake requires the construction of a dam either at Albany Falls, or at some other point downstream.

792. The head available at Albany Falls is small, even at low stages, and decreases rapidly as the stage increases. The power plant could not be operated effectively at heads below 15 feet, due to resulting low efficiency and reduced water capacity. A head of 15 feet would be available when the lake elevation is 2,066.8 feet (U. S. C. & G. S. datum) and the discharge at Albany Falls is about 90,000 second-feet with no diversions for the Columbia Basin irrigation project. The available head would be limited to the natural drop at the falls when the discharge is approximately 120,000 second-feet or greater. A discharge of 100,000 second-feet or greater has occurred at the falls about 2.5 percent of the time. The frictional losses in the channel between the lake and Albany Falls represent a large percentage of the total head available unless the water behind an Albany Falls Dam is held high enough to partly drown out the channel. Under these circumstances the highest level practicable in Pend Oreille Lake is desirable for power development at Albany Falls.[46] If Pend Oreille Lake were regulated for the direct benefit of a power plant at Albany Falls, the lake would be maintained at a relatively high level even during the low-water season, because at low-lake levels, head is more

[2] Not printed.
[46] Abstracted from an unpublished report, made in November 1926, by Eugene Logan and Glenn L. Parker, entitled "Preliminary Report, Columbia Basin Project, Water Power Analyses, Albany Falls Power Project."

valuable for power than the increase in water supply resulting from lowering the lake level.

793. A careful study of the effect of a dam at Albany Falls is contained in an unpublished report by Eugene Logan in 1930, to the supervisor of hydraulics, State of Washington. Mr. Logan's report bears the title, "Backwater Effect of Proposed Albany Falls Diversion Dam on Clark Fork", and ends with the conclusion that channel improvement to reduce the frictional losses, referred to in paragraph 792, between the lake and Albany Falls, "is feasible and economical and greatly to be desired."

794. If the Columbia Basin irrigation project is to be irrigated by gravity diversion from Clark Fork above Albany Falls, it will be necessary to control Pend Oreille Lake primarily in the interest of irrigation and not for power at Albany Falls and downstream sites. The level below which Pend Oreille Lake should be controlled must be determined by a proper study of flood damages and of benefits to power and irrigation. The Legislature of the State of Idaho by the act (H.B. No. 43, Idaho Session Laws, 1927, pp. 6–7) approved January 24, 1927, authorized the Governor of Idaho to appropriate and hold in trust for the people of the State all the unappropriated water of Priest, Pend Oreille, and Coeur d'Alene Lakes and declared the preservation of the waters of those lakes to be a beneficial use; also declared the land belonging to the State of Idaho adjacent to said lakes to be now devoted to a public use more necessary than the use thereof for storage-reservoir purposes. However, for the purposes of this report it has been assumed that Pend Oreille Lake would be regulated below elevation 2,066.8 feet, United States Coast and Geodetic Survey datum, elevation 2,070.0 feet United States Geological Survey datum, and the water-supply analyses given in appendix no. 2, page 1112, have been made on that basis.

795. The natural monthly discharge at Newport, Wash., immediately below the falls, has been given in table no. 31 for the 18-year period ended March 31, 1931. Table no. 57 gives corresponding data as determined for the pumping scheme of irrigating the Columbia Basin irrigation project (plan no. 4). Table no. 155, abstracted in part from tables nos. 31 and 57, gives the mean monthly discharge at Newport for the 18-year period ended March 31, 1931, for both natural and regulated flows.

TABLE NO. 155.—*Mean monthly discharge in second-feet, Clark Fork at Newport, Wash. (Albany Falls), for the 18-year period ended March 31, 1931. The mean annual discharge for the same period is 26,100 second-feet*

Condition	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Natural	22,900	54,100	79,900	52,200	21,600	12,500	10,800	11,500	11,300	11,400	11,200	12,600
Regulated [1]												
Plan 2-A [2]	18,400	30,600	39,200	20,500	13,900	13,900	14,200	15,000	15,500	16,400	16,600	17,500
Plan 4 [3]	22,600	39,400	52,500	29,400	20,000	19,600	19,600	19,600	19,600	19,600	19,600	19,800
Effect plan 2-A [2]	−4,500	−23,500	−40,700	−31,700	−7,700	+1,400	+3,400	+3,500	+4,200	+5,000	+5,400	+4,900
Plan 4	−300	−14,700	−27,400	−22,800	−1,600	+7,100	+8,800	+8,100	+8,300	+8,200	+8,400	+7,200

[1] Includes effect of storage amounting to 1,100,000 acre-feet in Hungry Horse Reservoir; 1,540,000 acre-feet in Flathead Lake; 569,000 acre-feet in Priest Lake; and of regulating Pend Oreille Lake below elevation 2,066.8, United States Coast and Geodetic Survey datum.

[2] Provides for irrigation of 1,520,000 acres in Columbia Basin irrigation project by gravity diversion from Clark Fork and Spokane River, and supplemental pumping.

[3] Provides for irrigation of 1,200,000 acres in Columbia Basin irrigation project by pumping diversion from Columbia River, and supplemental pumping.

796. The water-supply analyses contained in appendix no. 2 give the computed elevation of Pend Oreille Lake at the end of each month during the 18-year period ended March 31, 1931, after taking into account the effect of upstream storage, amounting to 1,100,000 acre-feet in the Hungry Horse Reservoir site, 1,540,000 acre-feet in Flathead Lake, and 570,000 acre-feet in Priest Lake; of regulating storage in Pend Oreille below elevation 2,066.8, United States Coast and Geodetic Survey datum, and the effect of withdrawals from the lake for varying downstream power and irrigation uses. The work involved in computing the corresponding elevations of the forebay at an Albany Falls dam was too great to be justified for the present purpose (as this would involve a determination of the backwater curves for the 24-mile stretch of river between the lake and Albany Falls for varying discharges and lake elevations), and, therefore, the corresponding heads are not available. The flow-duration data for these various studies are shown on plate no. 107 [2] but, since the corresponding data for head are not available, it is difficult to evaluate the power output of an Albany Falls power plant. However, table no. 156, which presents the results of some very rough approximations, indicates the general order of the power durations at an Albany Falls plant. Due to lack of time, estimates of power output at this and other sites are not given for plan no. 6-A (gravity diversion from Clark Fork and Spokane River with Quincy area covered by water from Wenatchee River).

TABLE NO. 156.—*Estimated power duration at Albany Falls at 80 percent efficiency*

Scheme of development	Percent of time		
	50	90	100
	Kilowatts	*Kilowatts*	*Kilowatts*
Natural	22,000	12,000	8,000
Regulated:[1]			
Plan no. 2-A	23,000	15,000	10,000
Plan no. 4	30,000	20,000	16,000

[1] For details see footnotes under table no. 155.

7. Z CANYON

797. This project contemplates the construction of a dam and power station at Z Canyon on Clark Fork about 2 miles upstream from the international boundary, and about 70 miles downstream from Albany Falls, which is at the Washington-Idaho boundary. Under date of August 24, 1927, Hugh L. Cooper applied to the Federal Power Commission for a preliminary permit covering this site, and after investigation, a preliminary permit covering a 2-year period was granted on June 14, 1928. Subsequently, the Commission issued an amendment to the preliminary permit extending the period of priority of application for license to June 14, 1931. A license was applied for by Colonel Cooper on June 10, 1931. The supervisor of hydraulics of the State of Washington issued a permit to Hugh L. Cooper on February 14, 1928, authorizing the appropriation for beneficial use of 7,000 cubic feet per second of Clark Fork water perpetually, and 1,500 cubic feet per second additional for a period of 50 years, conditional

[2] Not printed.

on actual construction work being started on or before March 1, 1930, and completed on or before March 1, 1935. Later the time for beginning construction was extended by the State to June 14, 1931.

798. As indicated by the name of the project, the dam site is located in a canyon at a point where the river makes a sharp "Z" curve. Exploration work carried on by Colonel Cooper indicates that the site affords excellent foundations and abutments for a dam. As planned by Colonel Cooper, the upper forebay level would be at elevation 2,025 feet with a draw-down of about 5 feet to take care of daily load fluctuations only. According to data furnished with the application for preliminary permit this forebay elevation would produce backwater to the foot of Albany Falls. The elevation of the tail-water varies from about 1,745 feet at low water to a maximum of 1,790 feet at high water with a mean at about 1,752.3 feet, making a range in head of from about 280 feet to about 235 feet. The mean head, as given by the application for preliminary permit is 245 feet. It appears that there is some doubt as to the datum of these elevations as given by the application for preliminary permit. Colonel Cooper proposed to develop 300,000 horsepower initially, and to install an additional 300,000 horsepower as and when permitting arrangements can be effected for the use of stored water in Pend Oreille Lake.

799. Complete tables of natural and regulated monthly flows for the period April 1, 1913, to March 31, 1931, for the Clark Fork at Metaline Falls, 9 miles upstream, are given in tables nos. 32 and 58. The inflow between Metaline Falls and Z Canyon is negligible. Flow-duration data for these conditions are shown on plate no. 108.[2] A summary of the mean monthly flows for these conditions is given in table no. 157.

TABLE NO. 157.—*Mean monthly discharge in second-feet, Clark Fork at Metaline Falls for the 18-year period ended March 31, 1931. The mean annual discharge for the same period is 26,600 second-feet*

	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Condition:												
Natural	23,400	55,400	81,700	53,100	22,100	12,800	11,100	11,800	11,600	11,600	11,500	12,900
Regulated:[1]												
Plan no. 2-A	18,900	32,000	41,000	21,300	14,300	14,200	14,500	15,300	15,800	16,600	16,900	17,800
Plan no. 4	23,000	40,800	54,300	30,200	20,400	19,900	19,900	19,900	19,900	19,900	19,900	20,100
Effect:												
Plan no. 2-A	−4,500	−23,400	−40,700	−31,800	−7,800	+1,400	+3,400	+3,500	+4,200	+5,000	+5,400	+4,900
Plan no. 4	−400	−14,600	−27,400	−22,900	−1,700	+7,100	+8,800	+8,100	+8,300	+8,300	+8,400	+7,200

[1] For explanation, see footnotes under table no. 155.

800. As mentioned in paragraph 794, the gravity plan of irrigating the Columbia Basin irrigation project would require the construction of a dam across the Clark Fork either at Albany Falls or at some other site. Although no study of an alternative site has been made either by this office or, so far as can be determined by this office, by any other agency, it appears possible to construct a dam at Z Canyon that will back water over Albany Falls and control Pend Oreille Lake levels. Such a dam would cause inundation of a greater area between Z Canyon and Albany Falls than would the dam contemplated by

[2] Not printed.

Colonel Cooper, but would flood the same area above Albany Falls as would an Albany Falls dam.

801. Considered from the power standpoint alone, the Albany Falls project is not especially attractive, due to the low head and the "drowning out" at high flows. The higher Z Canyon dam would permit full development of all the head in the stretch from Pend Oreille Lake to Z Canyon with no more sacrifice of head at the higher flows than would obtain for the lower dam. Such a higher dam would provide navigable depths from Z Canyon to Pend Oreille Lake and, if found feasible, might be better "adapted to a comprehensive scheme of improvement and utilization for the purposes of navigation, of water-power development, and of other beneficial public uses" than would the lower dam. Investigation of this possibility was not undertaken, as the site is on a tributary and not on the main stream and detailed investigations under this report have been limited to the main stream.

802. From the data given in the preceding text the power output of a plant with the dam constructed to the height contemplated in the preliminary permit, average head, 245 feet, is estimated to be as shown in table no. 158.

TABLE NO. 158.—*Estimated power duration at Z Canyon at 80 percent efficiency.*

Scheme of development	Percentage of time		
	50	90	100
	Kilowatts	*Kilowatts*	*Kilowatts*
Natural	243,000	137,000	91,100
Regulated:[1]			
Plan no. 2-A	258,000	188,000	146,000
Plan no. 4	337,000	268,000	243,000

[1] For details see footnotes under table no. 155.

(D) PRIEST RIVER AND LAKE

803. Priest Lake is located in northern Idaho, approximately 14 miles south of the boundary between the United States and Canada. At low stage the elevation of the lake is 2,436 feet and the surface area is about 37 square miles. Priest River heads in Canada and flows south into Priest Lake, and thence southward again in a tortuous course for about 40 miles, emptying into Clark Fork about 7 miles above Albany Falls, the proposed diversion point for the gravity water supply of the Columbia Basin irrigation project. The river has a drainage area of 572 square miles, at the outlet of the lake with a mean annual discharge at that point of 1,080 second-feet for the 18-year period ended March 31, 1931.

804. The shores of the lake are generally quite steep, rugged, and unfitted for cultivation. They are heavily covered with second-growth timber, the original stand having been either logged off or destroyed by fire. There are a number of camping sites and small summer cottages scattered around the lake. Small steamers ply from Coolin at the lower end of the lake to the various camps and mining properties near the head of the lake, and logs are rafted down the lake to its outlet. The logs are "driven" down the river to the mills at

the mouth during high-water periods, as the flow is insufficient to float logs at other times of the year.

805. A license for a power development on Priest River, about 2 miles below the lake, was granted to the city of Sandpoint, Idaho, by the Federal Power Commission on August 26, 1930. Under the license the project works will consist "of a buttress and rock-fill dam in and across Priest River about 2 miles below the outlet of Priest Lake, in sec. 7, T. 59 N., R. 44 W., Boise meridian, a reservoir in said Priest River and Lake, a power-house integral with the dam, a transmission line to the border of the Kaniksu National Forest, and appurtenant equipment." The licensee will be permitted to regulate Priest Lake between elevations 2,436.1 and 2,440.2 feet, United States Coast and Geodetic Survey datum, between which limits there will be 97,600 acre-feet of usable storage. However, the Commission reserved the right to authorize the construction of a higher dam at the outlet of Priest Lake and the proper utilization of the additional storage thereby created.

806. The minimum flow of record at Coolin, Idaho, occurred with the lake level at elevation 2,435.6 feet when the outlet was obstructed with logs and when the flow was only 120 second-feet. The elevation of average low water is about 2,435.6 feet (when outlet is unobstructed), at which lake elevation the river discharge is about 235 second-feet. The elevation of the maximum high water, during period of record since 1911, is about 2,442.4 feet, with a corresponding discharge of 7,290 second-feet.

807. Area-capacity curves for Priest Lake are shown on plate no. 14.[2] From these data the capacity between the natural range, elevations 2,435.6 and 2,442.4 feet, is about 163,000 acre-feet. For the purpose of this report the water-supply analyses given in appendix no. 2 assumed that the lake would be regulated below elevation 2,459.0 feet, United States Coast and Geodetic Survey datum, giving 569,000 acre-feet usable storage, although the State of Idaho has placed a legal restriction on the use of the lake for a storage basin, see paragraph 794. This allowance for a larger usable storage than that contemplated by the city of Sandpoint appeared desirable in the interest of a greater utilization of the water resources of the stream and would be permissible under the reservation, mentioned in paragraph 805, made by the Commission in granting the license.

808. Complete tables of natural and regulated monthly flows for the period April 1, 1913, to March 31, 1931, for Priest River near Coolin, Idaho, are given in tables nos. 33 and 59. Flow-duration curves and data for both these conditions are shown on plate no. 109.[2] A summary of the mean monthly flows for both conditions is given in table no. 159.

TABLE No. 159.—*Mean monthly discharge in second-feet of Priest River near Coolin, Idaho for the 18-year period ended Mar. 31, 1931. The mean annaul natural discharge for the same period is 1,080 second-feet*

Condition	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Natural	1,310	3,340	3,280	1,420	552	367	385	425	464	461	447	502
Regulated [a]	1,050	1,050	1,060	1,040	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Effect	−260	−2,290	−2,220	−380	+498	+683	+665	+625	+586	+589	+603	+548

[a] Using 569,000 acre-feet storage in Priest Lake and allowing for future irrigation requirements.

[2] Not printed.

809. The United States Forest Service estimated [47] the entire stream between the lake and Clark Fork to have a "power capacity" of 16,500 horsepower, based on a total fall of 368 [48] feet and a regulated flow of 560 second-feet as made possible by 115,500 acre-feet or controlled storage in the lake. In the application of the city of Sandpoint to the Federal Power Commission it was proposed to develop about 138 feet of this total head in four plants with heads of 22, 29, 21, and 66 feet, respectively, proceeding downstream. The license as granted covers the first (upper) of these plants only, and the city's plans provide for two units of 750 kilovolt-ampere each, only one of which will be installed initially.

810. A study of the Sandpoint topographic maps of the United States Geological Survey seems to indicate that a reservoir could be formed by constructing a dam across the lower West Fork of Priest River at Terrell Falls to backwater up to elevation 2,400 feet or slightly higher. As the water-surface elevation at Terrell Falls is about 2,290 feet, the dam would be about 125 feet high. The reservoir would probably be large enough to regulate most of the flow of Lower West Fork. If a detailed investigation and surveys should indicate that such a reservoir were feasible, regulated flow from Priest Lake could be diverted into it. This flow as augmented by the regulated yield of lower West Fork could be carried by closed conduit from the Terrell Falls dam site to a point near the mouth of West Fork and a gross head of about 320 feet realized. Several conduit locations would be possible. The topographic map seems to indicate that the most direct route would be about 5½ miles long. It would involve two tunnels, each slightly over a mile long, a pipe-line around and across the headwaters of Pine Creek, and another pipe-line at the lower end. The intake would be in the southeast quarter of sec. 20, T. 57 N., R. 5 W., Boise meridian. The uncertainties regarding the suggested Terrell Falls development are so great that no estimate of the power possibilities is made herein.

811. From the foregoing it can be seen that Priest River is, relatively speaking, not an important power stream; however, full development of the storage possibilities in Priest Lake would produce beneficial results at all downstream power sites. Assuming that storage in the lake will be developed as outlined in paragraph 807 and appendix no. 2, and that 138 feet of head will be utilized, the estimated power-duration of Priest River is as shown in table no. 160.

TABLE NO. 160.—*Estimated power-duration of Priest River at 80 percent efficiency (kilowatt)*

Condition	Percent of time		
	50	90	100
Natural	5, 260	2, 190	1, 460
Regulated [a]	10, 600	8, 910	5, 920

[a] Assuming use of 569,000 acre-feet in Priest Lake.

[47] Report to Federal Power Commission on application of city of Sandpoint, Idaho, for power project on Priest Lake and Priest River, by Harold Townsend, 1928. Unpublished.

[48] Topographic and river survey maps of the United States Geological Survey indicate a total fall at low stage of 389 feet.

(E) COEUR D'ALENE LAKE AND SPOKANE RIVER

1. GENERAL [49]

812. Spokane River rises in Coeur d'Alene Lake in the "panhandle" of northern Idaho. The lake is 24 miles long, and in most places from 1 to 2 miles wide. The chief tributaries of the lake are Coeur d'Alene and St. Joe Rivers. The low-water elevation of the lake is 2,117.1 feet, at which elevation the area of the lake is about 27,000 acres. The highest level that the lake has been known to reach was 2,134.7 feet, during the spring flood of 1894. Between these two levels lie about 30,000 acres, including the alluvial bottom lands and the lakes and swamps that, at low-water elevation, are not a part of the lake proper. Considerably more than two thirds of this area is below an elevation of 2,127 feet, and is subject to overflow by high water in more than half the years. Area capacity curves for the lake are given on plate no. 16,[2] which also gives a statement of the datum (U.S. Coast and Geodetic Survey), to which all elevations here given are referred.

813. The Spokane flows westward from Coeur d'Alene Lake about 100 miles and discharges into Columbia River at mile 105 downstream from the international boundary, and about 46 miles above the site of the Grand Coulee Dam. The river has a fall of about 1,050 feet. For 9 miles below the outlet of the lake the river has a very flat slope. It then drops 40 feet at Post Falls, and downstream at Spokane has a concentrated fall of over 140 feet.

814. The Washington Water Power Co. completed a dam and power plant at Post Falls in July 1906. By operation of the gates in this dam, the level of Coeur d'Alene Lake is controlled between certain limits, and water is released as required to suit the load demands on the six hydropower plants of the company located on Spokane River. The company claims that it has a legal right to regulate the lake below elevation 2,125.1 feet but actual operation is confined below elevation 2,123.6 feet, the latter giving a usable storage of about 155,000 acre-feet.

815. As mentioned in paragraphs 794 and 807, the State of Idaho has placed certain legal restrictions which may prevent a more complete use of storage in Coeur d'Alene Lake than that obtained at present by the power company. However, for the purposes of this present study, it has been assumed in the water-supply analyses given in appendix no. 2, that the lake would ultimately be regulated below elevation 2,129.1, which would provide about 268,100 acre-feet of usable storage in addition to that now used by the Washington Water Power Co.

816. The six hydropower plants of the Washington Water Power Co., as mentioned in paragraphs 850–851, with their respective operating heads, are:

Plant	Capacity	Head available	Assumed average head
	Kilowatts	*Feet*	*Feet*
Post Falls	11,250	47– 58	55
Spokane:			
Upper Falls	10,000	54– 64	61
Monroe Street	8,800	71– 74	73
Nine Mile	12,000	56– 65	61
Long Lake	70,000	154–172	169
Little Falls	29,500	66– 74	72
Total	141,550	448–507	491

[2] Not printed.
[49] Many of the data in this section have been taken from U.S. Geological Survey Water-Supply Papers 377 and 500-A.

Thus, of the 1,050 feet of total fall in the river, about 47 percent is now developed.

817. Relatively long-time stream-flow records are available for the gaging station at Spokane, extending, as they do, back to April 1891. Since July 1906 the records at this station reflect the effect of operation of the Post Falls Dam. The recorded and regulated monthly discharge at Spokane for the 18-year period ended March 31, 1931, have been given in tables nos. 35 and 61. A summary of these and other tables is here given in table no. 161. Monthly flow-duration data for the same period and station are given on plate no. 110.[2]

TABLE NO. 161.—*Mean monthly discharge in second-feet, Spokane River at Spokane, Wash., for the 18-year period ended Mar. 31, 1931*

[The mean annual discharge is 6,410 second-feet]

Condition	April	May	June	July	August	September	October	November	December	January	February	Mar.
Recorded	14.4	18.1	10.6	3.15	1.86	1.77	2.07	3.01	4.26	4.99	5.44	7.33
Regulated:[1]												
Plan no. 2-A	12.9	14.5	7.73	2.45	2.28	2.37	2.41	3.00	3.85	4.76	5.68	7.67
Plan no. 4	12.8	16.2	9.13	3.39	2.93	2.93	2.96	3.49	4.11	5.03	5.71	7.81
Effect:												
Plan no. 2-A	−1.5	−3.6	−2.87	−.70	+.42	+.60	+.34	−.01	−.41	−.23	+.24	+.34
Plan no. 4	−1.6	−1.9	−1.47	+.24	+1.07	+1.16	+.89	+.48	−.15	+.04	+.27	+.48

[1] Assumes regulation of Coeur d'Alene Lake below elevation 2,129.1 (U.S. Coast and Geodetic Survey datum), involving the use of about 268,100 acre-feet, not including the amount now used by the Washington Water Power Co. See footnotes under table no. 155 for explanation of "Plans" of regulation.

818. The recorded monthly discharges for the 18-year period ended March 31, 1931, for the station at Little Falls have been given in table no. 36. Monthly flow durations for the recorded flows only at this same station are given on plate no. 111.[2] Accurate flow durations for the regulated flows have not been worked out for the Little Falls station. However, by adding the differences between the recorded flows at Spokane and those at Little Falls (which difference is assumed to be the inflow between these two points) to the regulated flows at Spokane, an approximation of the regulated flows at Little Falls can be obtained. This process is summarized in table no. 162.

TABLE NO. 162.—*Monthly flow duration in second-feet at Little Falls for the period from Apr. 1, 1913, to Mar. 31, 1931*

Station	Line	Percent of time		
		50	90	100
Recorded flow at Spokane	1	2,890	1,600	1,340
Recorded flow at Little Falls	2	3,680	2,290	1,900
Difference	3	790	690	560
Regulated flow at Spokane:				
Plan no. 2-A [a]	4	3,060	1,900	1,630
Plan no. 4 [a]	5	3,450	2,320	2,150
Regulated flow at Little Falls:				
Plan no. 2-A (3 + 4)	6	3,850	2,590	2,190
Plan no. 4 (3 + 5)	7	4,240	3,010	2,710

[a] For explanation, see footnotes under table no. 155.
[2] Not printed.

819. From table no. 162 and a consideration of drainage areas at the various sites the estimated flow-durations for all sites, developed and undeveloped, are as shown in table no. 163.

TABLE NO. 163.—*Estimated monthly flow duration in second-feet, Spokane River sites, for the period from Apr. 1, 1913 to Mar. 31, 1931*

	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	2, 410	722	423	2, 490	1, 100	913	3, 870	1, 240	940	3, 110	1, 880	1, 320
Crossing	2, 980	1, 00	604	2, 690	1, 430	1, 200	2, 860	1, 730	1, 490	3, 250	2, 150	2, 010
Water works	2, 980	1, 100	604	2, 690	1, 430	1, 200	2, 860	1, 730	1, 490	3, 250	2, 150	2, 010
Spokane, Upper Falls	3, 140	1, 260	764	2, 890	1, 600	1, 340	3, 060	1, 900	1, 630	3, 450	2, 320	2, 150
Spokane, Monroe Street	3, 140	1, 260	764	2, 890	1, 600	1, 340	3, 060	1, 900	1, 630	3, 450	2, 320	2, 150
Bowl and Pitcher	3, 280	1, 400	904	3, 070	1, 720	1, 450	3, 240	2, 050	1, 760	3, 630	2, 480	2, 300
Nine Mile	3, 310	1, 430	934	3, 110	1, 750	1, 460	3, 280	2, 080	1, 780	3, 670	2, 520	2, 340
Long Lake	3, 840	1, 980	1, 460	3, 680	2, 290	1, 900	3, 850	2, 590	2, 190	4, 240	3, 010	2, 710
Little Falls	3, 840	1, 980	1, 460	3, 680	2, 290	1, 900	3, 850	2, 590	2, 190	4, 240	3, 010	2, 710
Fish Hawk	3, 840	1, 980	1, 460	3, 680	2, 290	1, 900	3, 850	2, 590	2, 190	4, 240	3, 010	2, 710
Narrows	3, 890	2, 010	1, 510	3, 730	2, 330	1, 940	3, 900	2, 630	2, 230	4, 290	3, 050	2, 750

820. The undeveloped sites on Spokane River, as listed in table no. 164, are considered economically feasible, and will complete the development of the total head available on that stream. Thus, of the 1,050 feet total fall in the Spokane, about 47 percent is now developed and an additional 30 percent is considered feasible of development.

TABLE NO. 164.—*Undeveloped power sites on Spokane River*

Site	Location	Head available	Assumed average head
		Feet	*Feet*
Crossing	Gravity canal (Columbia Basin irrigation project) crossing over Spokane River, 8 miles east of Spokane.	35- 45	40
Waterworks	City of Spokane, 5 miles east of Spokane	20- 25	22
Bowl and Pitcher	3 miles west of Spokane	75- 85	80
Fish Hawk	45 miles west of Spokane	85-90	85
Narrows	60 miles west of Spokane, near mouth of Spokane River.	95-110	100
Total		310-355	327

821. *a. Crossing site.*—The Columbia Basin Board of Engineers in their report to the Department of the Interior in 1925 recommended that a dam be placed across the Spokane river where the main gravity supply canal for the Columbia Basin irrigation project would cross Spokane River.[50] That board found that "the dam appears to be somewhat cheaper than either a siphon or flume, but its chief advantage is that it simplifies the waterway provision required at this crossing, facilitiates the diversion of Spokane River water into the irrigation system, and it makes possible the development of 9,600 continuous horsepower at this point." The district engineer's plan

[50] P. 26, Senate committee print, 69th Cong., 2d sess., Columbia Basin Project.

no. 2-A for irrigating the Columbia Basin irrigation project provides for carrying the water from Clark Fork across Spokane River in a flume, but such a plan would not interfere with the construction of a dam for power development at that point.

822. *b. Waterworks site.*—The city of Spokane operates a small pumping plant downstream from the conduit crossing. The energy developed in this plant is used for pumping a part of Spokane's domestic water supply from wells located near the station. The energy developed by the city is insufficient for their purposes and additional power as required is secured from the Washington Water Power Co. The present dam could be replaced with one slightly higher which would permit regulating the forebay so that backwater would extend to the tailrace of conduit crossing station.

823. *c. Bowl and Pitcher site.*—This development is located about 3 miles downstream from the city limits of Spokane. Backwater from this dam will extend to Natatorium Park in Spokane. The formation at the dam site is basalt, which is exposed on one side of the river above the level of the forebay and extends across the river to a point about half-way up to the proposed level. The lava flow on this side is covered by a sand and gravel plateau extending back about a mile from the river. However, it is believed that a suitable cut-off wall could be constructed to prevent any great amount of seepage through this formation.

824. *d. Fish Hawk site.*—The proposed Fish Hawk Rapids development is located 15 miles downstream from the Little Falls power plant of the Washington Water Power Co., and 17 miles above the mouth of Spokane River. The forebay elevation will approximate the low-water tailrace elevation of the Little Falls plant, and the tailrace level is approximately the forebay elevation of the Narrows site (see next paragraph) near the mouth of the river. The formation at this site is similar in character to that of the Bowl and Pitcher site near Spokane, a basalt dike extending across the valley and forming rapids in the river. However, rock is exposed to a higher level at this site. This site would be drowned out by a high dam (forebay elevation 1290) across Columbia River at the Grand Coulee.

825. *e. Narrows site.*—The Narrows site is located about 1½ miles above the mouth of Spokane River, which at this point runs through a narrow canyon with very precipitous walls of basalt rock. The forebay will be at approximately the tailrace level of the Fish Hawk site described in the preceding paragraph. The low-water tailrace level will coincide quite closely with the high-water level of the Columbia, which backs up to the power-house site below the mouth of the gorge. This site would be practically drowned out by either a low dam, forebay elevation 1,160 feet, or by a high dam, forebay elevation 1,290 feet, across the Columbia at the Grand Coulee. So far as the foundations at the Narrows are concerned there is a possibility that a higher dam than the one herein suggested could be constructed. That is, the total head of the Narrows and Fish Hawk sites might be developed by one dam at the Narrows. However, because of the possibility of being drowned out by a Grand Coulee Dam in the Columbia, it is not probable that any dam will be constructed at the Narrows.

826. *f. General.*—From the data given in paragraph 816 and in tables nos. 163 and 164 the power durations for the sites on Spokane River are estimated to be as shown in table no. 165.