APPENDIX II

to

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UNITED STATES and CANADA

WATER RESOURCES

of the

Columbia River Basin

KOOTENAY BASIN

Prepared by

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APPENDIX II

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APPENDIX II

KOOTENAY BASIN

I. DESCRIPTION

GEOGRAPHY

1. The Kootenay Basin covers parts of southeastern British Columbia, northwestern Montana, and northern Idaho. A map of the basin is shown on Plate 1 and a profile on Plate 2. Of the total basin area of 19,300 square miles, 14,500 square miles are in Canada and the remaining 4,800 square miles are in the United States. By drainage area the Kootenay is the third largest tributary of the Columbia River, being exceeded by the Clark Fork-Pend Oreille and Snake Rivers. The Kootenay River is about 472 miles long with 165 miles or a little more than one-third of its length in the United States. It rises in the Rocky Mountains about 40 miles west of Banff, Alberta, and flows in a southerly direction for some 250 miles. In the next 220 miles it swings first to the west, then northwest, through Kootenay Lake, and finally southwest from the lake to enter the Columbia River. The Kootenay Basin is bounded on the west and north by the Columbia River basin, on the east by the Continental Divide and the Flathead River basin, and on the south by Clark Fork-Pend Oreille basin.

TOPOGRAPHY

2. The Kootenay Basin is very mountainous and is dominated by three major mountain systems. On the east are the Rocky Mountains; in the centre, the Purcell Mountains; and on the west, the Selkirk and Cabinet Mountains. Separating these three mountain systems are the Rocky Mountain Trench and the Purcell Trench, both of which run in a northwesterly-southeasterly direction. Generally the elevation of the mountains is higher in the northern part of the basin than in the southern part, ranging between 7,000 and 12,000 feet. The elevation of the floor of the Rocky Mountain Trench decreases from 2,700 feet in the northern part of the basin to about 2,500 feet in the southern part, whereas the elevations of the Purcell Trench vary from 1,740 feet in the central part of the basin to 4,700 feet at the headwaters of the Duncan River. Those stretches of the Kootenay River and tributaries which are located in the two major trenches and in valleys parallel to the trenches flow in broad, flat valleys, generally with fairly moderate slopes, whereas in those stretches where the Kootenay River and tributaries cut across the general trend of the mountain ranges the rivers flow in narrow, steep-sided valleys generally with decided slopes and rapids or waterfalls. The main tributaries, except the Vermilion, Tobacco, and Duncan Rivers, join the Kootenay River through deep, narrow valleys. Much of the watershed is heavily forested, with the type of cover varying with climatic conditions.

STREAMS

3. The headwaters of the Kootenay River are in a low, flat, marshy divide adjacent to the headwaters of the northerly flowing Beaverfoot River. The two rivers flow in opposite directions in an intermontane valley in the Rocky Mountains, about seven miles east of Harrogate. The elevation of this divide is about 4,100 feet. The Kootenay River flows southeasterly in this broad intermontane valley to its confluence with the White River, about 20 miles upstream from Canal Flats. In this stretch of the Kootenay River, all the large tributaries join it from the east, draining from the summits of the Rocky Mountains, which are about 25 miles away. The tributaries on the west are small and short, draining the eastern slopes of the mountain range which separates the headwaters of the Kootenay and Columbia Rivers. Stream data are listed in Table 1.

4. The Vermilion River, the most northerly of these larger tributaries, is about 40 miles long and flows in a broad valley parallel to and about ten miles east of the Kootenay River for about 20 miles where it turns

TABLE 1

Elevations and Mileages

River Miles above Mouth	Location	Elevation above Mean Sea Level for Mean Flow
472.1	Source	about 4,150
453.8	Kootenay Crossing	3,840
377.7	Canal Flats	2,678
365.7	COPPER CREEK SITE	-
357.0	Skookumchuck	2,570
311.0	BULL RIVER SITE	-
306.0	Wardner	2,440
279.2	DORR SITE	-
268.7	International Boundary, Newgate	2,314
217.5	LIBBY SITE	2,115
189.5	KOOTENAI FALLS SITE	1,900
174.6	Yaak River	1,832
158.5	Moyie River	-
103.3	International Boundary, Porthill	1,743
(84.0 North)	Duncan River	1,743
75.0	Kootenay Landing	1,743
47.1	Proctor	1,743
15.7	Plant #4, Corra Linn	-
14.2	Plant #2, Upper Bonnington	-
13.7	Plant #1, Lower Bonnington	-
13.0	Plant #3, South Slocan	-
10.2	Slocan River	1,470
1.8	Plant #5, Brilliant	-
0	Columbia River	1,380

westerly to cut through the mountain ranges in a narrow valley to join the Kootenay River about six miles downstream from Kootenay Crossing. At their confluence the flow of the Vermilion River is larger than that of the Kootenay River. Simpson River is the major tributary of the Vermilion River.

5. The Cross River joins the Kootenay River near the south boundary of Kootenay National Park. This river and its major tributary, the Mitchell River, drain the area around 11,870-foot Mount Assiniboine. For the last three-quarters of a mile above its confluence with the Kootenay River, the Cross River flows in a canyon about 160 feet deep with almost perpendicular sides. There are three falls in this stretch, and in places the canyon is barely ten feet wide at the top.

6. The Palliser River has a drainage basin of about 270 square miles. After flowing southerly in a wide valley for about ten miles, it swings westerly across the ranges in a more restricted valley, being joined in its course by several tributaries, the largest of which is Albert River. About 19 miles upstream from its junction with the Kootenay, the Palliser River falls about 104 feet in 2,000 feet, with one waterfall of 52 feet. Below the fall, for about 1,500 feet, there is a narrow canyon with sheer walls only 20 feet apart. Eight miles from its mouth there is another fall of about 30 feet, and a half mile from the confluence there is another descent of 175 feet in about 4,500 feet, with a deep canyon below the main fall.

7. The White River, about 55 miles long, is the most southerly of the rivers tributary to the Kootenay River in the intermontane valley east of the Rocky Mountain Trench. It is bordered on the east by the Elk River, on the south by the Bull River, and on the west by the Lussier River. From its headwaters, the White River flows south for a few miles, then cuts through the ranges to the west. Before entering the Kootenay River it follows a valley parallel to the Kootenay and flows northerly for about 20 miles.

8. At its junction with the White River, the Kootenay River turns to the southwest and cuts through the most westerly range of the Rocky Mountains in a narrow, steep-sided valley to enter the Rocky Mountain Trench at Canal Flats.

9. In the Rocky Mountain Trench, the Kootenay River passes within one and one-half miles of Columbia Lake and turns south to flow down the broad, flat valley bottom in the Trench. The three major tributaries of the Kootenay River between Canal Flats and the international boundary at Newgate, British Columbia, are the St. Mary from the west, and the Bull and Elk Rivers from the east.

10. The St. Mary River, which is about 57 miles long, joins the Kootenay River at Fort Steele. The tributaries of the St. Mary River flow in broad, U-shaped valleys in their upper courses, but near their confluence with the main stream their valleys become narrow canyons through which the tributaries flow with a series of rapids or falls, then with lower gradients they enter the St. Mary valley through gravel banks about 50 feet high. The St. Mary River meanders widely over a broad valley floor with abrupt walls rising to 4,000 or 5,000 feet, then gently sloping back to the upland surface. As the Kootenay valley is approached, terraces are noticeable and the river flows over a floor cut in stratified drift and gravel.

11. Bull River is a stream about 50 miles long. It rises in the Rocky Mountains, amongst peaks from 8,000 to 10,000 feet above sea level, and flows generally in a southwesterly direction through various canyons and over shifting gravel beds into the Kootenay River, near the settlement of Bull River, six miles from Wardner, British Columbia. The stream generally is from 30 to 150 feet wide, but about six miles from the mouth it is confined in a deep rock canyon, in places not over 15 feet in width at the top. This canyon extends for about 400 feet, and in this distance the river drops 175 feet, about half of this being a perpendicular fall 100 feet from the head of the canyon.

12. The Elk River drains the western slopes of the Rocky Mountains from the headwaters of the Palliser River as far south as the Flathead River, which drains into the Clark Fork-Pend Oreille. The headwaters of this stream which is 115 miles long are in two mountain valleys close to the Continental Divide. In its upper reaches it is joined by Fording River. Near its mouth it is joined by its largest tributary, the Wigwam River, whose source is in Montana about five miles south of the boundary.

13. A few miles south of Newgate, the Kootenay River leaves the Rocky Mountain Trench in which it has been flowing south-southeast from Canal Flats, and flows almost due south to Jennings, Montana. Here it turns west to flow around the south end of the Purcell Mountains and at Troy turns to flow northwest to Bonners Ferry, where it enters the Purcell Trench. Between these trenches, the Kootenay River is swift flowing, confined between steep rock banks which rise to broad terraces, generally several hundred feet above the river. Between Libby and Troy there is a deep canyon with a cataract midway along its course. Where the tributary valleys join this part of the Kootenay River, there are wide flats which provide excellent places for townsites, especially at Libby and Troy. The two main tributaries of the Kootenay River in this stretch flow in from the north.

14. The Yaak River (spelled Yahk in Canada) rises in southern British Columbia between the McGillivray and Yahk Ranges, flows generally south between ranges, but breaks west through the Yahk Range before continuing south to join the Kootenay River. The stream is 61 miles long, with 16 miles of its headwaters and 21.5 percent of its total drainage area of 790 square miles in Canada. The Yaak drains an area of relatively low rainfall in a well-timbered, rough, mountainous region. The river falls about 770 feet in the lowermost ten miles of its course. About one-third of this fall occurs at Yaak Falls.

15. The Moyie River rises in the Purcell Mountains southwest of Cranbrook. In its upper reaches it flows easterly in a broad, mature trough, then plunges over a fall of about 75 feet into a narrow gorge cut through gravels and bedrock, for about 200 feet below the general level of the floor of the valley. Then turning sharply, it flows through a narrow valley for three miles to again enter the wide, mature valley in which Moyie Lake lies. The river, on leaving the lake, flows southwesterly between the Yahk and Moyie Mountains and joins the Kootenay River about eight miles east of Bonners Ferry.

16. At Bonners Ferry, where the Kootenay River swings north to flow in the Purcell Trench, the valley bottom widens and the river meanders back and forth across the bottom land. Forty-seven river miles downstream from Bonners Ferry, the Kootenay River crosses the international boundary at Porthill, Idaho, and 28 miles further downstream it enters Kootenay Lake.

17. The Duncan River with its major tributary, the Lardeau River, drains more than 1,400 square miles of rugged, mountainous country north of Kootenay Lake. This is the area of highest unit run-off in the basin. The Duncan River flows southward in the Purcell Trench in a U-shaped valley. Most of the tributaries entering from the west are short and steep, while those from the east are longer, draining the summit of the Purcell Mountains which range up to 11,000 feet in elevation, and contain numerous glaciers. North of the headwaters of the Duncan River, the Beaver River flows northwards to join the Columbia River at Beavermouth.

18. The Lardeau River joins the Duncan River eight miles upstream from Kootenay Lake. From its headwaters, which are west of the midpoint of the Duncan River, Lardeau Creek flows north, then west for about 20 miles to enter Trout Lake. The northwest-southeast valley, in which Trout Lake lies, extends to the northwest to Beaton Creek and the head of Upper Arrow Lake, and southeast to the Duncan River. The Lardeau River flows southeast in this valley from the outlet of Trout Lake. Most of the tributaries are steep and flow in narrow, steep-walled valleys.

19. About the mid-point of the west side of Kootenay Lake, the West Arm runs about 24 miles to the west. From here, the Kootenay River flows another 23 miles, dropping about 400 feet to join the Columbia River near Castlegar. In these lower 47 miles the valley in which the river flows is quite narrow with steep mountain sides rising from close to the river's edge.

20. The Slocan River, which joins the Kootenay River ten miles upstream from Castlegar, is the only important tributary of the Kootenay downstream from Kootenay Lake. It drains an area of 1,320 square miles north of the Kootenay River between Kootenay Lake and the Arrow Lakes. This drainage area is about 65 miles long. It drops rapidly from ridges and mountains averaging more than 8,000 feet in height into narrow valleys, which in turn fall rapidly into the main valley. Slocan Lake occupies the main valley for 25 miles and has a normal elevation of 1,762 feet. The river falls about 270 feet in a distance of 27 miles from the lake to its mouth.

LAKES

21. Kootenay Lake, the largest in the basin, is 65 miles long and from two to three miles wide, and covers170 square miles. Down the middle of the lake and to within a short distance of the shore, the bottom is almost flat and is from 300 to 500 feet below the surface of the lake. On either side of this floor the sides rise steeply. The lake is hemmed in by mountains which reach altitudes of 9,000 to 10,000 feet. On the east and west sides of the lake the tributary streams are short with steep gradients. There is little bench land, as the mountains generally rise directly from the lake shore. The lake has a mean annual variation in water level of about 19 feet, with a maximum knownseasonal variation of 32 feet. There is six feet of controlled storage in Kootenay Lake at present.

22. Slocan Lake is 24 miles long, about a mile wide, and covers 24 square miles. The lake is very deep, having a depth of 830 feet opposite New Denver and about 930 feet near Slocan.

23. Two other large lakes in the basin are Duncan and Trout Lakes, each about ten square miles in area. There are many other small lakes scattered throughout the basin, including Whiteswan, Premier, St. Mary, Hansen, Grave, Moyie, Duck, Little Slocan, and Summit Lakes in Canada, and Bull and Loon Lakes in the United States.

GEOLOGY

24. The Kootenay Basin contains mainly crystalline sedimentary and metamorphic rocks, which are largely Palaeozoic or older, intruded by Mesozoic batholiths and stocks of granitic composition. The crystalline rocks are locally covered by unconsolidated deposits accumulated during and since the glacial epoch. The evolution of the drainage system has been governed by folding and faulting whereby the Rocky Mountain Trench and Purcell Trench were formed. The interconnecting east-west canyon through which Kootenay River flows in Montana and Idaho was apparently formed largely by faulting. Subsequent glaciation has further modified patterns of drainage.

25. West of Kootenay Lake and the Lardeau Valley granitic rocks of the Nelson and Kuskanax batholiths predominate. They intrude complexly folded early Mesozoic sedimentary and volcanic rocks and are flanked on the east by a curving belt of sedimentary and metamorphic rocks. Rocks in this belt are isoclinally folded, strongly sheared, and become successively older toward the east.

26. The southern part of the Purcell Mountains east of Kootenay Lake is composed mainly of clastic, non-calcareous, sedimentary rock of the late Precambrian Purcell (or Belt) series. Remnants of Cambrian sedimentary rocks and small masses of intrusive rocks are found locally. Folds are characteristically open and regionally form a broad geanticline plunging gently to the north. Rocks and structures in the Purcell Mountains continue

southward and dominate the bedrock geology in the Kootenay drainage south of the international boundary.

27. Rocks of the Purcell Mountains are separated from those of the Rockies to the east by a zone of complex faulting in the Rocky Mountain Trench. In the Rocky Mountains is a thick sequence of Palaeozoic sedimentary rocks containing many carbonate formations. In general, the rocks are strongly folded on axes trending northwest, and are broken by major thrust faults related to the folds.

28. Rocks in the Kootenay Basin contain several of the major mineralized areas of British Columbia. Included are the Slocan, Ainsworth, and Lardeau mining camps in the west and the Sullivan mine at Kimberley.

SOILS AND COVER

29. About 88 percent of that part of the Kootenay Basin in the United States is forest-covered, and 68 percent supports forest stands of commercial character. The Canadian portion of the basin is forest-covered with the exception of a few small areas. Of this forest cover, approximately 45 percent is of commercial value. The large area of forest land is one of the greatest economic resources of the basin. The chief uses of non-commercial forest land (that which bears scrubby or inaccessible stands) are for recreation and grazing.

30. The only extensive areas adapted to agriculture, without preliminary clearing, are in an area along the Kootenay River between Skookumchuck and Fort Steele, in an area along the Tobacco River, and in the broad flood plain of the Kootenay River extending north from Bonners Ferry to Kootenay Lake. This flood plain is the most important agricultural area in the basin. It consists of 72,600 acres of deep, fertile, alluvial soil, of which 34,440 acres in the United States and 20,860 acres in Canada are protected from normal high water by dykes. Other areas topographically suited to agriculture consist chiefly of benchland areas in British Columbia along St. Mary River and Kootenay River between Canal Flats and the international boundary; and in Montana along Fisher River, the Kootenay River in the vicinity of Libby, and the upper reaches of Pleasant Valley.

31. The soils of the Kootenay Basin may be divided into three broad classes:

a. Light-colored upland soils, representing the large areas of well-drained forested upland.

b. Dark-colored bottom-land soils.

c. Miscellaneous land types.

32. The light-colored upland soils are by far the most extensive soils in the basin. Their chief value lies mainly in their ability to produce profitable crops of timber. They include, however, a few areas of comparatively level and fertile benchlands that are now, or could be, cultivated with good results.

33. The most important of these upland benches is an area north of Bonners Ferry, extending into Canada, parallel to and east of the Kootenay River valley. The area is about 30 miles long and of variable width. It is adapted to agricultural use mainly because of soils and topographic conditions. The topography varies from level to rolling, with small areas of rough, broken lands included along the drainage ways. The soils retain moisture because they consist of deep, fine, sandy loams, silt loams, clay loams, or clay, with silt or clay subsoils.

34. Other level benchland areas of light-coloured upland soils are found scattered throughout the basin along the banks of the main water courses,

but none are so extensive as the area north of Bonners Ferry.

35. The dark-colored bottom-land soils are the most important agricultural lands in the basin. The most extensive area occurs along both sides of the Kootenay River between Bonners Ferry and Kootenay Lake. The area is about 42 miles long, from 2 to 3 miles wide, and totals about 73,000 acres. The soils include muck and peat, loams and clay loams. They contain large amounts of organic matter and are very fertile. Of the total area, 34,440 acres in the United States and 20,860 acres in Canada are protected by levees and are cultivated.

36. The miscellaneous land types include rough mountainous, rough stony and steep broken lands. Dense growths of valuable conifers are produced on the rough mountainous and rough stony areas.

CLIMATE

37. General. - The climate of the Kootenay Basin varies greatly with elevation and with location relative to mountain masses. The basin is subject to modified meteorological influences, both oceanic and continental. Oceanic influences are strongest during the winter, particularly over the western portion of the basin, and result in comparatively heavy snowfall as warm, moisture-laden air masses from the Pacific Ocean are cooled on passing over mountain ranges of the basin. The prevailing wind over the basin is westerly. The eastern portion of the basin is subject to maximum rainfall during the summer as a result of storms characterized by heavy showers and occasional cloudbursts caused by the northward extension of low-pressure areas from the hot southerly interior. Mean annual temperatures in the basin vary from a minimum of 40°F. at Fernie, British Columbia, to a maximum of 46°F. at Nelson, British Columbia. Fortine, Montana, has recorded a minimum temperature of -49°F. Libby, Montana, has a maximum recorded temperature of 109°F.

38. Annual precipitation for any given elevation is greatest in the western portion of the basin, and decreases toward the east until the minimum precipitation is reached in the easternmost valley of the Kootenay. The average annual precipitation based on available records varies from 14.3 inches at Newgate, British Columbia, elevation 2,375, to 39.9 inches at Fernie, British Columbia, elevation 3,305; for the entire basin it is about 35 inches. Most of the stations in the western part of the basin record the greatest monthly precipitation during the winter months, whereas many of the stations in the eastern part record greatest monthly precipitation during the summer months. Annual snowfall varies from 43 inches at Newgate to 162 inches at Gerrard.

39. The growing season varies with elevation and local conditions. It is probable that freezing temperatures are experienced every month at areas of high elevation. At Bonners Ferry Meteorological station, elevation 1,975, the average growing season is 146 days, the maximum frost-free period recorded being 169 days and the minimum 111 days. At Fortine, Montana, elevation 3,000, the average growing season is 98 days.

40. Relative humidity data recorded at Nelson show the mean to be 74 percent. The maximum, 88 percent, was recorded in January and December, and the minimum, 58 percent, was recorded in July.

41. Records. - Climatological records have been kept at 41 stations, 30 of which were in British Columbia. Of the 41 stations, 13 existed for periods of a few months or years and have only fragmentary records. Twenty-one stations in British Columbia and seven in Montana and Idaho have reported precipitation data for a period of five or more consecutive years. Climatological data are tabulated in Tables 2, 3, and 4.

42. Storms. - The Kootenay Basin is so far inland that it receives relatively little of the precipitable moisture in the air masses moving inland from the Pacific Ocean because most of the moisture is deposited on the

TABLE 2

Summary of Climatological Data (to 1957 except Inactive Stations)

		Precipitation in Inches				Snowfall-Inches		Temperature °F.				
Station	Elev. Feet	Years of Record	Mean Annual	Annual Maximum	Annual Minimum	Years of Record	Mean Annual	Years of Record	Mean Annual	Extreme Max.	Extreme Min.	Growing Season Days
★ Canal Flats	2,653	37	16.35	28.52	9.76	37	47.7	-	-	-	-	-
Wasa	3,050	37	14.49	25.29	8.73	37	54.0	-	-	-	-	-
Kimberley	3,016	13	15.47	21.99	9.78	13	60.3	13	40	108	-40	108
Cranbrook	2,997	49	14.88	26.45	3.07	49	55.6	49	41	102	-42	77
Aberfeldie	2,640	7	21.04	27.97	14.67	7	60.3	7	43	98	-33	-
Fernie	3,305	42	39.90	56.04	26.00	42	132.8	42	40	97	-40	98
Elko	3,080	36	19.32	37.41	5.49	36	51.9	5	43	98	-26	-
★ Baynes Lake	2,800	7	16.23	-	-	7	50.9	7	41	96	-35	92
Newgate	2,375	41	14.27	24.57	8.24	41	42.9	41	43	103	-40	93
Rexford Ranger Sta.	2,350	5	16.33	20.67	11.74	3	99.3	5	43.9	109	-39	102
Fortine 1NNE	3,000	51	17.53	26.27	10.70	44	53.6	51	41.8	107	-49	102
Pleasant Valley	3,600	42	18.81	25.92	10.39	35	66.6	37	40.0	99	-51	-
Libby 32SSE	3,600	7	26.94	33.43	9.22	8	139.0	8	40.3	100	-32	41
Libby 1NE Ranger Sta.	2,080	61	18.33	32.03	9.18	52	57.2	51	44.8	109	-46	100
Bonners Ferry 1SW	1,812	29	20.84	34.01	10.93	25	67.4	24	45.4	104	-29	143
Porthill	1,800	62	19.29	38.63	9.26	58	67.4	61	44.8	102	-31	141
Kingsgate	2,680	41	21.89	44.74	8.18	41	76.4	-	-	-	-	-
West Creston Ferry	1,800	8	25.10	29.86	22.14	8	74.2	6	44	95	-31	-
Creston	2,085	43	18.58	26.22	8.78	43	53.0	43	45	103	-27	120
★ Nelson	1,760	55	28.01	38.93	15.35	55	83.7	53	46	103	-17	144
South Slocan	1,540	15	31.29	35.70	22.89	15	90.5	15	46	104	-25	157
★ Howser	1,874	13	21.15	24.42	17.81	13	64.5	13	44	99	-44	145
★ Gerrard	2,350	21	30.51	47.24	12.92	21	161.6	20	42	99	-36	126
Kaslo	1,930	44	27.19	37.14	16.16	44	81.2	44	44	100	-17	157
Sandon	3,550	14	38.07	51.59	28.86	14	160.7	-	-	-	-	-
New Denver	1,850	40	29.38	37.41	21.29	40	76.3	-	-	-	-	-
★ Perry Siding	1,700	26	23.81	28.85	16.89	26	77.0	26	44	107	-22	117
Crescent Valley	2,000	17	30.75	36.98	21.74	17	107.7	15	44	100	-28	97
★ Castlegar	1,480	12	24.26	28.21	20.77	12	63.8	12	46	106	-14	116

★ Inactive Stations

TABLE 3

Average Precipitation in Inches for the Period of Record

(To December 1957 except for Inactive Stations)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
* Canal Flats	1.54	1.28	1.03	0.83	1.51	2.10	1.22	1.36	1.23	1.18	1.46	1.61	16.35
Wasa	1.41	1.07	0.79	0.73	1.39	1.91	0.88	1.14	1.09	1.29	1.15	1.64	14.49
Kimberley	1.86	1.12	0.98	0.82	1.30	2.10	0.80	1.34	0.82	1.34	1.20	1.79	15.47
Cranbrook	1.63	1.19	0.85	0.73	1.23	1.90	1.09	1.12	1.10	1.05	1.29	1.70	14.88
Aberfeldie	3.57	1.24	0.89	1.02	1.38	3.23	1.16	1.73	1.32	1.54	1.29	2.67	21.04
Fernie	5.30	3.92	3.30	2.36	2.52	2.89	1.58	1.66	2.54	4.08	4.13	5.62	39.90
Elko	2.13	1.22	1.15	1.21	1.62	2.72	1.32	1.33	1.45	1.68	1.54	1.95	19.32
* Baynes Lake	1.54	1.36	0.89	1.32	1.36	1.94	1.04	0.94	1.75	0.64	1.16	2.29	16.23
Newgate	1.68	1.08	0.98	0.80	1.17	1.72	0.90	0.98	0.88	1.07	1.30	1.71	14.27
Rexford Ranger Sta.	2.97	1.73	0.94	0.97	0.81	1.18	0.94	1.05	0.68	1.36	1.42	2.28	16.33
Fortine 1NNE	1.48	1.02	1.13	1.23	1.66	2.51	1.20	1.34	1.29	1.54	1.48	1.65	17.53
Pleasant Valley	1.97	1.51	1.33	1.17	1.40	2.14	1.01	0.91	1.15	1.84	2.13	2.25	18.81
Libby 32SSE	4.35	2.81	2.35	1.83	1.29	2.42	1.14	0.98	1.11	2.57	2.47	3.62	26.94
Libby 1NE Ranger Sta.	2.22	1.45	1.41	0.99	1.19	1.74	0.64	0.84	1.16	2.02	2.16	2.51	18.33
Bonners Ferry 1SW	2.69	1.65	1.68	1.06	1.57	1.60	0.86	0.88	1.39	1.84	2.62	3.00	20.84
Porthill	2.35	1.58	1.41	0.94	1.65	1.59	0.89	0.82	1.52	1.68	2.56	2.30	19.29
Kingsgate	2.90	1.91	1.59	1.31	1.93	2.07	0.85	1.02	1.40	1.78	2.28	2.85	21.89
West Creston Ferry	4.48	2.49	1.59	1.10	1.18	2.36	0.86	1.55	1.25	2.44	1.82	3.98	25.10
Creston	2.33	1.54	1.34	0.98	1.32	1.82	0.96	0.95	1.17	1.65	2.01	2.51	18.58
* Nelson	3.52	2.43	1.95	1.58	2.16	2.65	1.46	1.43	1.73	2.55	2.90	3.65	28.01
South Slocan	4.26	3.07	2.08	1.68	2.11	2.69	1.60	1.53	1.81	2.97	3.37	4.12	31.29
* Howser	3.44	1.65	1.31	1.09	1.48	1.84	0.74	1.50	1.77	1.67	1.99	2.67	21.15
* Gerrard	5.03	3.19	2.09	1.40	1.44	1.98	1.46	0.93	1.48	2.74	3.91	4.86	30.51
Kaslo	3.69	2.60	1.87	1.47	1.58	2.12	1.15	1.56	1.71	2.48	3.01	3.95	27.19
Sandon	3.75	3.14	2.65	2.41	2.84	3.48	2.39	2.82	2.41	4.02	3.92	4.24	38.07
New Denver	3.59	2.63	2.27	1.62	2.17	2.48	1.42	1.61	1.82	2.98	2.85	3.94	29.38
* Perry Siding	3.09	1.80	1.76	1.62	1.69	2.21	1.12	1.17	1.67	2.13	2.44	3.11	23.81
Crescent Valley	4.08	3.22	2.14	1.67	1.98	2.58	1.46	1.39	1.84	2.98	3.14	4.27	30.75
* Castlegar	3.05	2.15	2.00	1.32	1.62	1.76	0.73	1.26	2.06	2.02	2.90	3.39	24.26

* Inactive Stations

TABLE 4

Average Temperatures in °F. for the Period of Record

(To December 1957 except for Inactive Stations)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Kimberley	15	23	26	42	51	57	64	62	54	43	29	20	40
Cranbrook	16	22	32	43	51	58	64	62	53	42	29	20	41
Aberfeldie	20	26	32	43	53	57	64	63	56	44	31	25	43
Fernie	17	21	29	41	50	56	62	60	51	42	29	20	40
Elko	20	25	31	41	53	58	65	64	56	44	31	27	43
★ Baynes Lake	18	22	31	42	49	57	65	64	54	41	30	19	41
Newgate	19	25	35	45	53	59	66	63	54	44	32	23	43
Rexford Ranger Sta.	20.9	26.3	33.1	43.4	54.1	59.7	66.6	64.2	56.3	42.9	31.7	27.0	43.9
Fortine 1NNE	19.9	24.6	32.8	42.9	50.7	56.5	62.8	60.1	52.7	43.1	31.1	24.4	41.8
Pleasant Valley	19.4	23.4	30.0	40.1	48.2	54.0	60.0	58.0	50.8	42.3	30.3	23.8	40.0
Libby 32SSE	19.2	26.1	29.1	38.3	47.9	53.8	60.5	59.5	52.7	41.7	29.4	25.0	40.3
Libby 1NE Ranger Sta.	22.6	27.5	36.8	46.3	53.6	60.0	66.3	64.2	55.8	45.8	33.5	25.4	44.8
Bonners Ferry 1SW	23.4	28.4	37.4	46.7	53.5	59.6	66.4	64.3	56.8	46.1	34.4	27.7	45.4
Porthill	23.7	27.4	35.8	45.8	53.6	59.5	66.2	63.9	54.5	45.2	34.0	27.6	44.8
West Creston Ferry	25	27	33	44	54	57	64	62	56	45	33	29	44
Creston	23	27	35	45	53	59	66	64	55	44	34	27	45
★ Nelson	25	29	36	46	54	60	67	65	57	47	36	29	46
South Slocan	23	29	36	48	56	61	68	67	58	47	35	28	46
★ Howser	24	27	34	43	52	60	65	62	53	44	35	27	42
★ Gerrard	22	23	29	40	51	57	63	60	53	44	35	26	42
Kaslo	25	28	35	44	52	58	64	63	55	45	35	28	44
★ Perry Siding	22	24	35	46	53	61	67	65	55	45	33	25	44
Crescent Valley	22	29	35	44	53	58	64	63	54	44	31	27	44
★ Castlegar	26	29	37	46	54	57	68	66	56	46	35	26	46

★ Inactive Stations

intervening mountain ranges. Therefore, storms with rainfall of high intensity and short duration occur only over small, scattered areas rather than over major areas of the basin. The principal storm centre is on the westerly slopes of the mountain range east of Kootenay Lake. The general elevation of these mountains exceeds 6,000 feet; however, extensive areas are over 8,000 feet and several peaks exceed elevation 10,000 feet. As the air masses continue eastward, each succeeding range extracts some moisture, but the amounts naturally decrease, although the elevations of these various ranges are approximately the same. The Rocky Mountains, which form the eastern boundary of the basin, receive a relatively low amount of precipitation compared with the other ranges to the west having the same or even lower elevations.

HYDROLOGY

43. General. - The run-off from 19,100 square miles, or 98 percent, of the Kootenay River basin has been recorded at a station near Glade, British Columbia, from May 1913 to June 1944. The normal annual run-off at Glade is equivalent to 20.0 inches over the basin. This represents 20,400,000 acre-feet of run-off per year, or an average flow of 28,000 cubic feet per second. The variation in annual run-off during 31 years of record has been from 12,200,000 to 28,400,000 acre-feet. Hydrographs shown in Figure 1 illustrate years of maximum, minimum, and mean run-off for the Kootenay River at Glade.

44. In terms of drainage area, the Kootenay River is the third largest tributary of the Columbia, being exceeded only by the Snake and the Clark Fork-Pend Oreille. In terms of volume of run-off, it is the second largest, being exceeded only by the Snake. Many tributaries of the Kootenay River rise on the slopes of mountain peaks 7,000 to 12,000 feet in elevation. In many instances their sources are the permanent snow fields and glaciers on these peaks. These snow fields and the winter accumulation of snow in all the mountain systems are the sources of the water that cause the pronounced annual rise of the river. Winter flows are ordinarily low, but as spring progresses into summer, with its warmer temperatures, these accumulated snows of the preceding winter melt and cause the spring flood. Ordinarily the rise is gradual, beginning in April and continuing until late in May or June, when the maximum stage occurs. Occasionally, however, a period of high temperatures or excessive rains will increase the rate of rise and cause the peak stage to be higher than would occur under normal melting conditions.

45. Rainstorms alone rarely cause high run-off in the basin except in small drainage areas over which local storms of high intensity may centre. These storms have little effect on the flow of the Kootenay, but are mentioned because they do cause flooding on the smaller tributaries. The principal tributary in the United States having damaging floods of this character is Libby Creek. Late fall floods on this stream are sometimes caused by the run-off from warm rains augmented by the melting of some snow at lower elevations.

46. Surface Water. - Records of stages only of the Kootenay River at Nelson, British Columbia, were obtained during the summer and fall for the period 1891 to 1913. Continuous records of stage and discharge are available from 1913 to 1937. Since 1937, records of stages only have been obtained. The record at Nelson is the earliest in the basin. Since 1891, 165 stations have been in existence for varying lengths of time in the United States and Canada. During 1957 there were 55 gauging stations in operation in the basin. Thirty-nine of these are rated for discharge and the remaining 16 for stage only. Data for representative stations are given in Tables 5 and 6.

47. The headwaters of Kootenay River lie along the western slopes of the Rocky Mountain Range. The headwaters of the streams directly tributary to Kootenay Lake rise in the mountain ranges east and west of Kootenay Lake which are parallel to and comparable in height to the Rocky Mountains. The average contribution to the flow of Kootenay River upstream from the lake, as determined from the records of the gauging station at Porthill, is 15,700

KOOTENAY RIVER AT GLADE

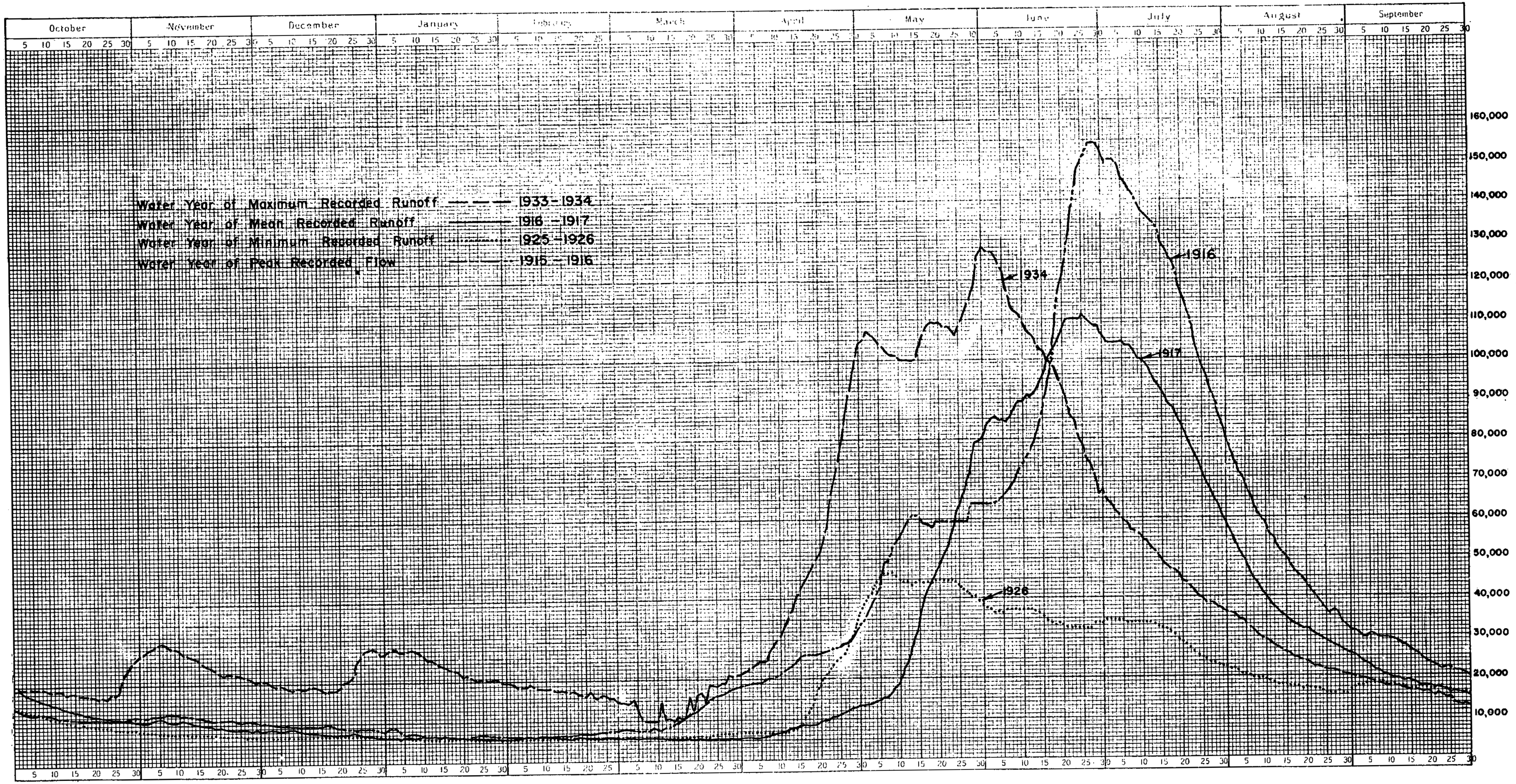


FIGURE I

TABLE 5

Summary of Stream-flow Data (Through Water Year 1956)

Station	Drainage Area (Sq.Mi.)	Period of Record	Discharge (c.f.s. per Sq. Mi.)	Annual Discharge in c.f.s. Average Annual	Max. Annual	Min. Annual	Extreme Discharge in c.f.s. Instantaneous Maximum	Daily Maximum	Daily Minimum
Kootenay at Kootenay Crossing	160	1939-1941 1944-	1.15	184	279	89	1,610	1,600	nil
Vermilion River near Radium Hot Springs	360	1946-1956	2.19	789	1,020	497	6,740	5,870	60
White River	360	1940-1948	1.66	597	717	426	-	6,020	150
Kootenay at Canal Flats	2,040	1939-1950	1.36	2,770	3,840	2,070	-	29,700	178
Findlay Creek	277	1924-1927 1947-1955	1.70	470	580	323	-	3,950	46
Skookumchuck Creek	260	1949-1955	1.58	411	494	332	-	4,020	35
Kootenay at Skookumchuck	2,470	1950-	1.79	4,420	5,200	3,800	30,500	29,900	485
Lussier River	95	1940-1949	2.43	231	267	154	-	1,430	51
St. Mary River	940	1914-1917 1946-	2.01	1,890	2,400	1,330	-	37,900	143
Bull River	610	1914-1922 1927-	1.89	1,150	1,600	679	-	12,200	60
Kootenay at Wardner	5,200	1914-	1.36	7,050	9,800	4,180	-	67,500	600
Elk River	1,720	1924-	1.57	2,700	3,820	1,400	-	33,500	200
Gold Creek	353	1914-1916 1949-1955	0.67	238	290	188	2,170	1,870	32

TABLE 5 (continued)

Summary of Stream-Flow Data (Through Water Year 1956)

Station	Drainage Area (Sq.Mi.)	Period of Record	Discharge (c.f.s. per Sq. Mi.)	Annual Discharge in c.f.s.			Extreme Discharge in c.f.s.		
				Average Annual	Max. Annual	Min. Annual	Instantaneous Maximum	Daily Maximum	Daily Minimum
Kootenay at Newgate	7,660	1930-	1.38	10,600	14,300	6,110	98,200	97,900	944
Kootenay at Libby	10,240	1910-	1.16	11,870	16,700	6,510	120,000	119,000	1,000
Moyie River at Eileen	755	1925-	1.14	863	1,323	323	11,000	9,800	50
Kootenay River at Porthill	13,700	1928-	1.15	15,700	22,350	8,200	-	125,000	1,380
Goat River	430	1914-1922 1925-1952 1955-	2.12	910	1,480	342	-	15,900	40
Summit Creek	116	1946-1955	2.55	296	325	230	5,000	2,710	19
Duncan River	770	1915-1919 1934-	4.06	3,130	3,930	2,400	-	21,400	268
Lardeau River at Marblehead	610	1917-1919 1945-	3.44	2,100	2,850	1,610	-	12,600	320
Kootenay at Nelson	17,700	1913-1937	1.48	26,200	35,300	15,300	-	142,000	3,270
Slocan River	1,270	1913-1915 1925-	2.32	2,950	3,890	1,860	-	24,100	280
Kootenay at Glade	19,100	1913-1944	1.47	28,000	39,200	16,800	-	154,000	3,900

TABLE 6

Average Discharge in c.f.s. (Through Water Year 1956)

Station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Kootenay at Kootenay Crossing	68	35	19	12	7	6	38	435	641	430	166	102	184
Vermilion River	426	289	186	132	113	108	187	1,340	2,570	2,160	1,160	668	789
White River	349	251	214	234	228	184	249	1,030	1,870	1,500	616	433	597
Kootenay at Canal Flats	1,610	1,290	812	709	664	662	1,070	5,730	8,840	6,370	3,280	2,220	2,770
Findlay Creek	251	198	154	105	93	85	207	929	1,610	1,300	568	318	470
Skookumchuck Creek	166	141	93	75	67	67	166	868	1,620	1,140	300	192	411
Kootenay at Skookumchuck	2,200	1,520	1,060	924	856	801	1,440	7,600	15,200	12,100	5,050	3,070	4,420
Lussier River	112	119	120	110	101	122	137	423	654	478	194	132	231
St. Mary River	839	655	463	341	295	293	1,250	5,400	7,820	4,150	1,270	779	1,890
Bull River	539	439	342	268	262	309	1,130	3,450	3,670	1,850	739	546	1,150
Kootenay at Wardner	3,750	2,730	2,000	1,730	1,580	1,590	4,180	16,400	24,400	15,100	6,820	4,580	7,050
Elk River	1,370	1,100	868	732	688	793	2,580	8,230	8,750	3,950	1,700	1,380	2,700
Gold River	72	70	63	61	55	60	312	829	543	202	80	63	238
Kootenay at Newgate	5,220	4,140	3,100	2,570	2,480	2,690	7,650	26,500	34,300	19,600	8,460	5,880	10,600
Kootenay at Libby	6,157	5,078	3,980	3,355	3,296	3,812	10,520	29,460	38,270	21,640	9,736	6,918	11,870
Moyie at Eileen	274	323	347	256	263	377	1,801	3,593	2,167	589	183	165	863
Kootenay at Porthill	6,983	6,457	5,689	4,654	4,782	5,683	18,320	45,220	48,060	24,890	10,290	7,023	15,700
Goat River	378	352	311	222	220	319	1,540	3,600	2,840	745	249	247	910
Summit Creek	144	128	105	71	44	59	234	1,090	1,170	359	87	60	296
Duncan River	1,700	1,080	747	583	508	514	1,290	5,260	8,870	8,640	5,290	2,970	3,130
Lardeau River	1,010	861	679	523	459	437	948	4,330	6,840	5,380	2,300	1,250	2,090
Kootenay at Nelson	13,400	11,700	9,480	8,480	7,710	8,050	14,700	49,400	81,500	61,400	30,400	18,400	26,200
Slocan River	1,470	1,350	1,050	839	717	800	2,400	7,580	10,300	5,720	2,210	1,480	2,950
Kootenay at Glade	13,700	12,300	10,400	8,980	8,280	8,850	19,100	55,300	87,000	63,700	29,800	18,000	28,000

cubic feet per second, or 16.4 inches from the watershed. The average annual discharge for the Kootenay River at Glade is 28,000 cubic feet per second, or the equivalent of 20.0 inches from the entire tributary area. The Kootenay contributes about 40 percent of the total flow of the Columbia at Birchbank, British Columbia.

48. Floods. - Floods in the Kootenay Basin occur during the snowmelt season and over the period of record have reached damaging stages one year out of five at Bonners Ferry. Intense rains occasionally augment the flood peaks.

49. Floods on Kootenay River are of long duration and are notable for great volume rather than extreme crest discharge. Because of the backwater effect of Kootenay Lake, maximum discharge of the river at Bonners Ferry usually occurs prior to the maximum river elevation. As Kootenay Lake rises, the gradient of the river becomes less, the velocity decreases, and a higher stage for a given discharge occurs. This effect is illustrated by the following data for the 1956 flood.

Date	Bonners Ferry Stage (feet)	Bonners Ferry Discharge c.f.s.	Kootenay Lake Stage (feet)
May 22 (Maximum discharge at Bonners Ferry)	1775.8	127,000	1753.7
May 24 (Maximum stage at Bonners Ferry)	1780.1	125,000	1755.8
June 5 (Maximum stage at Kootenay Lake)	1777.9	95,000	1761.6

Figure 2 shows hydrographs for various gauging stations on the Kootenay River for the high-water period of 1956.

50. In 1894 the peak discharges produced the maximum floods known in the Columbia River basin as a whole. It also appears that the greatest volume of run-off occurred on the Kootenay River. The stage at Bonners Ferry for this flood was exceeded not only by the 1948 flood but also by those of 1954 and 1956 because of confinement of the river in dyked areas (See Table 7). Although the backwater effect of Kootenay Lake has been reduced since 1938 due to enlarged outlet conditions, records show that peak flood stages at Bonners Ferry have increased with the strengthening and raising of the Kootenay Flats levee systems. For the 1894 flood the peak river stage at Bonners Ferry was at elevation 1777.2 feet. The 1956 flood with a maximum discharge of about 77 per cent of the 1894 flood reached a peak river stage at Bonners Ferry of 1780.09 feet, an increase of 2.9 feet over that for the 1894 flood. The following tabulation shows that peak river stages for floods at Bonners Ferry have increased as the levees have been raised and strengthened.

Year	Actual river elevation at Bonners Ferry (feet)	Maximum river discharge at Bonners Ferry (c.f.s.)
1894	1777.2	160,000 (est.)
1948	1778.32	139,000
1954	1778.55	132,000
1956	1780.09	125,000

51. Additional data on flood crests for floods occurring since 1894 are given in Table 7. As shown therein, the time of peak stage and maximum discharge at Bonners Ferry do not always coincide.

HYDROGRAPH FOR 1956 PEAK FLOWS FOR KOOTENAY RIVER STATIONS

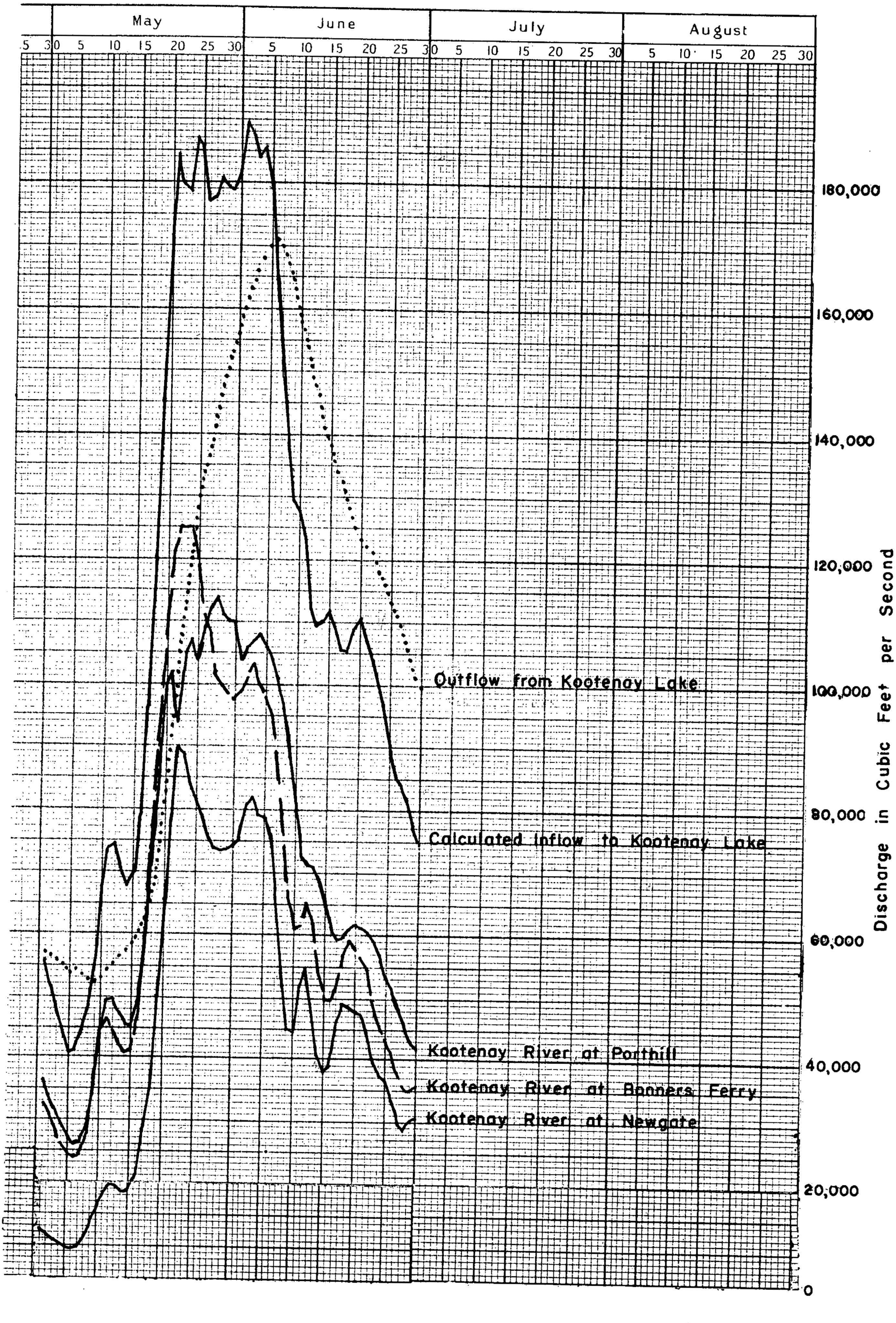


FIGURE 2

TABLE 7

Maximum Flood Stages and Discharges

	Kootenay River at Bonners Ferry				Kootenay Lake 2/	
Year	Date	Elevation	Date	Discharge c.f.s.	Date	Elevation
1894	June	1777.2	3/	160,000 1/	3/	1772
1903	3/	1773.7	3/	3/	June 19	1763.77
1908	June 10-11	1770.8	3/	3/	June 17	1758.6
1909	June 6	1770.9	3/	3/	June 23	1758.6
1913	June 4, 5	1772.6	June 4	95,000	June 13	3/
1916	June 22	1775.8	June 22	125,000	June 28-30	1763.24
1919	May 30	1771.6	May 29	98,000	June 3	3/
1921	June 10	1770.8	June 9	90,000	June 14	1760.39
1923	June 14	1770.2	June 14	88,000	June 17	1758.39
1925	May 24	1772.2	May 23	98,600	May 29	1758.79
1927	June 14	1772.85	June 10	82,600	June 20	1759.59
1928	May 28	1772.78	May 25, 27	82,800	May 31	1760.99
1932	June 17	1770.5	May 23	74,700	June 30	1757.96
1933	June 19	1774.98	June 18	99,800	June 23	1761.32
1934	April 29	1773.04	April 29	89,400	June 2	1758.87
1938	May 30	1774.44	May 27	89,800	June 7	1758.90
1942	May 23	1772.0	May 27	81,100	June 11	1753.20 4/
1946	May 31	1773.41	May 30	80,500	June 7	1755.68 4/
1948	May 29	1778.3	May 29	139,000	June 11	1760.78 4/
1950	June 24	1776.98	June 22-23	90,100	June 25	1758.28 4/
1954	May 21	1778.55	May 21	132,000	May 28	1756.93 4/
1956	May 24	1780.09	May 24	125,000	June 5	1761.58 4/

1/ Estimate
2/ At Kootenay Landing
3/ Data not available
4/ At Queens Bay

NOTE: The stage-discharge relationship at Bonners Ferry is complex and has been altered radically in intervening years by the enlargement of Kootenay Lake outlet, the regulation at Corra Linn Dam, the choking effects of levees constructed between Bonners Ferry and the lake, and the occurrence of levee failures during the larger floods.

52. A stage-frequency study has been made for the gauging station at Bonners Ferry based on observed and estimated annual crest stages at this point for the period since 1894, but giving due weight to conditions introduced after 1894 that affect the stage-discharge relationship. To illustrate the effect of the changed conditions, the 1894 flood occurring under present conditions would reach an estimated elevation of 1781.5 feet at Bonners Ferry, 4.3 feet higher than the actual elevation (1,777.2) which the flood reached that year under natural conditions. Results of the stage-frequency study are shown in the following tabulation referring to elevations under present conditions:

Average recurrence interval (years)	Maximum elevation (feet)
2	1772.0
10	1778.8
20	1780.0
50	1781.0

53. Water Rights. - Major water development in the Kootenay Basin in Canada consists of hydro-electric power projects of which the five plants on the Kootenay River between Nelson and Castlegar are the most important. Development of water for irrigation and other uses has been carried out to suit the needs of local areas or for individual requirements. Water licences issued in British Columbia under authority of the Provincial Water Act are summarized in Table 8.

54. No major water developments have taken place in the United States portion of the basin. Development of water for irrigation and other uses has been on a small scale to satisfy the needs of local areas or individuals. Data on licenced uses of water are not available.

TABLE 8

Summary of Water Licences in Kootenay Basin in Canada

	Amount in			Equivalent Total Diversion in c.f.s. at Point of Use
	Acre-Feet	Imperial Gallons Per Day	Cubic Feet Per Second	
Irrigation	39,729			167.1
Storage	1,050,825			-
Domestic		1,292,830		2.4
Waterworks		21,020,635		39.0
Industrial		11,281,148		20.9
Mining		10,525,617		19.6
Power			63,094	63,094.0
Logging		10,834,060		20.1
Municipal			16.2	16.2
Miscellaneous	501	1,350,760	2	6.6
			TOTAL	- 63,385.9

NOTE: Irrigation period assumed in compiling this table is 120 days.

II. ECONOMIC DEVELOPMENT

POPULATION

55. Population characteristics of the basin are typical of mountainous, forested areas. Concentrations are small, and occur at places along the valleys of the main streams favourable for development of the natural resources of the immediate area and for transportation of the products to centres of consumption. Population is almost entirely rural; the only towns containing more than 3,000 persons are Nelson, Kimberley, and Cranbrook, British Columbia. Important centres of population are shown in Table 9.

56. In Canada, the population of the basin has increased from 38,300 in 1941 to 53,000 in 1956, and now constitutes four percent of the population of British Columbia. In the United States, the population of the basin has increased from 13,900 in 1940 to 14,600 in 1950.

57. In Canada, the labour force for this area is employed primarily in the mining, forestry, and agricultural industries. The labour force amounted to 13,116 in 1941 and 18,500 in 1956. In the United States, 4,731 people were employed in the basin in 1950. The percentage distribution of the labour force is shown in the following tabulation:

	Canada	United States
Forestry	7	3
Mining	33	4
Manufacturing	13	23
Agriculture	5	20
Services	28	4
Trade & Commerce	9	15
Other	5	31
Total	100	100

RESOURCES AND INDUSTRIES

58. Development of Kootenay Basin is based on its natural resources of agricultural lands, forests, minerals, fish and wildlife, and water power.

AGRICULTURE

59. The only extensive areas developed for agriculture are along the Tobacco River in Montana and in the broad flood plain from Bonners Ferry, Idaho, to Kootenay Lake near Creston, British Columbia. This latter area is the important agricultural area in the basin. It consists of 72,600 acres of fertile, deep alluvial soil, 55,300 acres of which are protected in varying degrees by dykes. Wheat, oats, and alfalfa are the principal crops. Livestock and livestock products are another important source of income.

60. In the remainder of the basin, farming is carried out mainly utilizing benchlands in three general areas. Between Canal Flats and the international boundary the principal farm income is derived from livestock and livestock products. Dry-land grains, mainly wheat, are grown on the St. Mary's Prairie. Between Bonners Ferry and Creston the farm production is more diversified. Tree fruits, principally apples and cherries, are grown

TABLE 9

Important Centres of the Kootenay Basin

Centre	Population 1956	Population 1941	Principal Economic Activities
BRITISH COLUMBIA			
Nelson	7226	5912	Trading and distribution centre, railway division point, lumber manufacturing, mining and tourism
Kimberley	5774	4281	Mining.
Cranbrook	4562	2568	Trading and distribution centre, railway division point, lumber manufacturing and tourism.
Fernie	2808	2545	Coal mining, lumbering and agriculture.
Creston	1844	1153	Distribution centre and agriculture.
New Denver	736	310	Mining and lumbering.

Centre	Population 1950	Population 1940	Principal Economic Activities
MONTANA			
Libby	2401	1837	Lumber manufacturing and tourism.
Eureka	929	912	Lumbering and agriculture.
Troy	770	796	Lumber manufacturing.
IDAHO			
Bonners Ferry	1776	1345	Agriculture, lumber manufacturing and tourism.

on irrigated land near Creston. Livestock and livestock products with hay production are the other main source of farm income. Along Kootenay Lake and between Nelson and Castlegar, including the Slocan area, small-scale mixed farming is carried out producing mainly small fruits and vegetables and poultry and livestock products. Many of the benchland farms are part-time enterprises.

FORESTRY

61. Extensive logging and sawmill activities are well distributed throughout the Canadian portion of the Kootenay Basin and are of major importance in the area. The saw-log cut increased substantially over the last five years. Miscellaneous products include Christmas trees, mine timbers and props, cordwood, and railway ties. A large pulp mill, now under construction near Castlegar, will increase forest utilization. The 130 active sawmills and 50 planer mills processed approximately 30,000,000 cubic feet of saw-timber in 1955.

62. The species and quantities of mature merchantable timber in the Canadian portion of the basin are as follows:

Species	*) Volume in Thousand Cubic Feet
Spruce	1,227,020
Hemlock	451,071
Cedar	409,458
Balsam	389,183
Fir	361,915
Larch	232,774
Lodgepole Pine	251,615
White Pine	61,454
Yellow Pine	24,807
Other	51,887
Total -	3,461,184

*) Average conversion factor: one cubic foot = 5.75 board feet, British Columbia log scale.

63. The main species utilized by the industry are Douglas fir, larch and spruce. Cedar, hemlock, lodgepole pine, white pine, and other species are also cut. There are approximately 7,800 square miles of productive forest area within the basin made up of 2,300 square miles of mature timber, 4,750 square miles of immature timber, and 750 square miles requiring re-stocking.

64. In the United States portion of the basin, forest land comprises 4,200 square miles or 88 percent of the basin area. Of this amount 3,300 square miles are commercial forest land containing about 12 billion board feet of merchantable timber. Ponderosa and western white pine, western larch, and Douglas fir are the principal species. A recent breakdown by species is not available. Most of the remaining forest land in the United States portion of the basin is above the altitude range of timber

merchantability and contains subalpine species valueless from the saw-timber standpoint. There are, however, some 100 square miles of deforested land which could be converted to commercial forest land with artificial reforestation.

65. The manufacture of lumber is a major industry. The annual Christmas-tree cut is valued at about $130,000. The supply of trees, which is found chiefly around Eureka, Montana, is being maintained on a sustained-yield basis.

66. In addition to the timber removed from the woods for the manufacture of lumber and for poles, considerable quantities are cut for other uses. Among these are fuel wood, fence posts, pulpwood, ties, mine timber, and piling, which require only limited, if any, processing by lumber mills. It is estimated that approximately 25 million board feet of timber are removed from the forest annually to provide these products.

67. The largest mill is situated at Libby. Other mills are located at Troy and Bonners Ferry. A shingle mill also operates at Troy. Small mills cutting small quantities of lumber and railroad ties are scattered throughout the basin.

MINERALS AND MINING

68. In Canada a well-defined, mineralized and productive belt, named the Kootenay Arc, extends through Trout Lake and down Kootenay Lake. The Yale Lead and Zinc Mines Limited at Ainsworth has been a substantial producer of crude lead ore, zinc concentrates, and lead concentrates. At present, the mine operation is closed down but the mill continues with small-scale, sporadic processing of minerals from surrounding areas. The Bluebell mine at Riondel has also contributed to the increased production of zinc and lead. The gross quantities of metals mined and their values for selected years are shown in Table 10. Similar data are not available for the mineral products in the United States.

69. One of the largest silver-lead-zinc mines in the world is the Sullivan Mine at Kimberley. This mine has been in production since 1899. In 1955 it produced 2,836,577 tons of ore and employed 1500 men in its mine and mill operation.

70. Coal has been mined near Fernie and Michel since 1898, and in 1955 this area produced 1,050,149 tons or 73 percent of the value of all coal produced in British Columbia. In 1958 the coal-mining operations at Fernie were closed down indefinitely because of adverse market and economic conditions.

71. Up to the present time the principal mining activity in the United States portion of the basin was concentrated in two districts, the Porthill District in Idaho, and the Libby District in Montana. The principal metals produced in the past in these districts were gold, silver, lead, copper, and zinc. However, recent production of these metals has been minor.

72. Vermiculite, a micaceous mineral found in extensive deposits about 7 miles east of Libby, has been the most valuable mineral produced in recent years in the United States portion of the Kootenay Basin. The value of this mineral for commercial insulation has recently been widely recognized and its use for this purpose is increasing rapidly. Other minerals known to occur in the basin in appreciable quantities are cobalt, molybdenum, tungsten, asbestos, barite, feldspar, fluorspar, limestone, pyrite and pyrrhotite.

MANUFACTURING

73. Sawmills and planing mills account for a large percentage of manufacturing employment in the Canadian portion of the basin. A new dry-kiln

TABLE 10

Production of Metal in the Kootenay Basin in British Columbia

Item	Unit	1945	1950	1955
Gold	-Fine Ounces	42	319	623
	-Dollars	1,538	11,989	21,292
Silver	-Fine Ounces	5,591,581	5,028,958	3,696,452
	-Dollars	2,628,043	4,055,101	3,247,370
Lead	-Pounds	348,592,633	285,779,588	250,418,564
	-Dollars	17,429,631	41,306,581	37,377,475
Zinc	-Pounds	291,923,694	262,819,825	254,809,965
	-Dollars	18,799,186	39,620,089	30,900,804
Cadmium	-Pounds	-	-	111,335
	-Dollars	-	1,535,274	187,043
Tin	-Dollars	-	828,259	-
Total Value - Dollars		38,858,398	87,357,293	71,733,984
Total Producing Mines		7	50	22
Total Ore Production - Tons		2,556,164	2,913,300	3,162,335

at Cranbrook with a capacity of 140,000 feet board measure per charge was begun in 1955. An ammonium phosphate fertilizer plant at Kimberley began operations in 1953. The first plant in British Columbia for the commercial briquetting of coal began operations at Michel in 1954. This plant has a capacity of 25 tons of briquettes per hour. The by-product ovens at Michel produced 177,030 tons of coke and 1,100,000 gallons of coal-tar in 1955. A steel plant, which will use electro-metallurgical processes, is under construction at Kimberley. The first phase will be in operation in 1961 with an annual production capacity of 36,500 tons of pig iron per year. The second phase, for making steel, will be completed in 1962. Table 11 gives the manufacturing statistics for 1956 for the Canadian portion of the Kootenay Basin.

74. In the United States, comparable statistics are not available; however, aside from the large lumber mill at Libby, the manufacturing plants in the basin are small and exist primarily for the local market. Approximately 50 percent of the plants are engaged in processing foods, chiefly dairy products. The 21 manufacturing establishments in the basin are reported to have employed an average of 615 people in 1939, or 4.3 percent of the population. Of these, 554 were employed in sawmills and planing mills.

RECREATION

75. The Kootenay Basin has all the natural attributes required for outdoor recreation. Forests, streams, lakes, and mountains present numerous scenic attractions, and fish and wildlife abound. In its present state of development, the basin offers many inducements to the individual who desires to "camp out" and who carries his own equipment for this purpose. The lands set aside for recreational use in the Canadian portion of the basin consist of almost all of Kootenay National Park, 17 Provincial parks of which Kokanee Glacier and Mount Assiniboine are the largest, and 131 small land reserves to ensure public access at key points or to cover local phenomena.

76. The United States portion of the basin affords similar recreational attractions. The Kootenai National Forest contains camp grounds, picnic areas and a winter sports area.

POWER

77. The most important developments in the East Kootenay area are those operated by the East Kootenay Power Company Limited on the Bull and Elk Rivers, which are tributaries of the Kootenay River. The main consumers are coal mines located in and around the Crowsnest Pass, the Consolidated Mining and Smelting Company's Sullivan mine at Kimberley, and the cities of Cranbrook, Fernie, and Kimberley, which take electricity in bulk for distribution in their respective municipal areas. The system is interconnected on the west to the West Kootenay Power and Light Company and on the east to the Calgary Power Company. The Bull River plant, which began operation in 1922, is situated at Aberfeldie on the Bull River, approximately five miles upstream from the Bull River's confluence with the Kootenay. This plant has an installed capacity of 4,000 kilowatts. The Elk River plant, situated about one mile south of the town of Elko, was brought into operation in 1924 and has an installed capacity of 9,600 kilowatts. The electrical needs of Creston and its surrounding district led to the construction of a plant in 1932 on Goat River about three miles from Creston. This plant has an installed capacity of 1,280 kilowatts.

78. The only hydro-electric developments on the main stem of the Kootenay River are in Canada near Nelson, British Columbia. The development of a smelter at Trail in 1895 provided a market for electrical power. In 1897 the West Kootenay Power and Light Company, Limited, was formed and immediately started construction of a dam and powerhouse at Lower Bonnington Falls, 11 miles downstream from Nelson. This plant was completed in 1898 with a capacity of 4,000 horsepower under a 34-foot head. The Lower Bonnington plant was rebuilt in 1923 to increase the output to 60,000 horsepower under a

TABLE 11

Manufacturing Statistics, Kootenay Basin, British Columbia, 1956.

Industry	Number of Establish-ments	Employees	Value of Factory Shipments
Sawmills and Planing Mills	124	1,600	$19,700,000
Bread and Other Bakery	8	53	400,000
Printing and Publishing	6	90	580,000
Breweries	4	99	900,000
Carbonated Beverages	3	25	204,000
Sash and Door Factories	9	566	3,331,000
Machine Shops	4	31	216,000
Fruit and Vegetable Preparations	5	134	228,000
Metalworking	3	12	64,000
Woodworking	9	200	3,210,000
Food	12	52	465,000
Chemical	4	307	8,216,000
Miscellaneous	8	16	87,000
Total	199	3,185	$37,601,000

70-foot head. In 1905, the City of Nelson and the West Kootenay Power and Light Company each started construction of a powerhouse and dam at Upper Bonnington Falls. In 1940, the Upper Bonnington plant was enlarged to increase the capacity from 34,000 horsepower to 84,000 horsepower under a 70-foot head. In 1947, the City of Nelson plant was enlarged to increase the capacity from 6,570 horsepower to 13,250 horsepower. The South Slocan plant was completed in 1926 with a total capacity of 75,000 horsepower under a 70-foot head. Construction of the Corra Linn dam and power plant, located nine miles downstream from Nelson, was completed in 1932. The power plant has an installed capacity of 57,000 horsepower, developing 53 feet of head, and the dam provides control of storage in Kootenay Lake. When the Brilliant plant, developing 74,000 horsepower at a 90-foot head, was completed in 1944, the total head of the Kootenay River between the West Arm and the Columbia River was developed. In 1950, a third 37,000-horsepower unit at Brilliant was brought into operation, to bring the plant to its present capacity of 111,000 horsepower. The total operating head on the Kootenay River between the forebay of Corra Linn dam and the tailwater of Brilliant dam varies from 365 feet during periods of low river flow to 300 feet during flood flows. Data on the plants in the Basin are given in Table 12.

79. The International Joint Commission Order of 1938 authorized six feet of controlled storage in Kootenay Lake between elevations 1739.32 and 1745.32. This provides a storage volume of 673,000 acre-feet. By additional drawdown, the storage can be increased to about 817,000 acre-feet. The level of Kootenay Lake can be controlled at Corra Linn except during periods of high flow when restrictions along the West Arm influence the outflow from the lake. The Order of 1938 states that after the summer high water when "the lake level at Nelson on its falling stages recedes to elevation 1743.32, Geodetic Survey of Canada datum, 1928 adjustment", the lake level may be held at that elevation until 31 August when the level of Kootenay Lake may be raised to 1745.32, which is six feet above the gauge zero. This maximum storage level may be maintained until 7 January when the lake "shall be lowered so that it shall not exceed elevation 1744 on 1 February, elevation 1742.4 on 1 March, and elevation 1739.32 on or about 1 April, except under extraordinary natural high-inflow conditions, when sufficient gates shall be opened and remain open throughout such period of excess so as to lower the level of the main body of Kootenay Lake to the storage level at that time obtaining as above defined". The International Joint Commission has further ordered that certain minimum flows must be passed at Corra Linn dam during the annual high-water periods, to provide specified lowerings of the main body of Kootenay Lake, and that the West Kootenay Power and Light Company, Limited, shall pay costs up to $3,000.00 annually "incurred in the State of Idaho by reason of the construction and/or operation of said works". The Commission shall retain jurisdiction over these matters through the International Kootenay Lake Board of Control. The West Kootenay Power and Light Company, Limited, shall operate certain automatic water level recorders on Kootenay Lake and Kootenay River and shall provide for discharge measurements of the river. Figure 3 shows maximum allowable Kootenay Lake stages under the Order.

80. Development in the United States portion of the basin is confined to a few small plants, mostly on tributary streams, generating power for purely local domestic and industrial uses. Pertinent data regarding the existing hydro-electric power plants in the Kootenay Basin are shown in Table 12 and the locations of these plants are shown on Plate 1.

TRANSPORTATION AND COMMERCE

81. Navigation extends from Bonners Ferry north to Kootenay Lake, where the river is from 500 to 800 feet wide and from 12 to 50 feet deep at low water, except at a few gravel bars where the controlling depth is about 6 feet. The current is sluggish at low water and not excessive at normal high water. Log towing is carried out on the Canadian portion of this reach and improvements for navigation are carried out annually by the removal of snags. There is no commercial shipping at present on the United States portion.

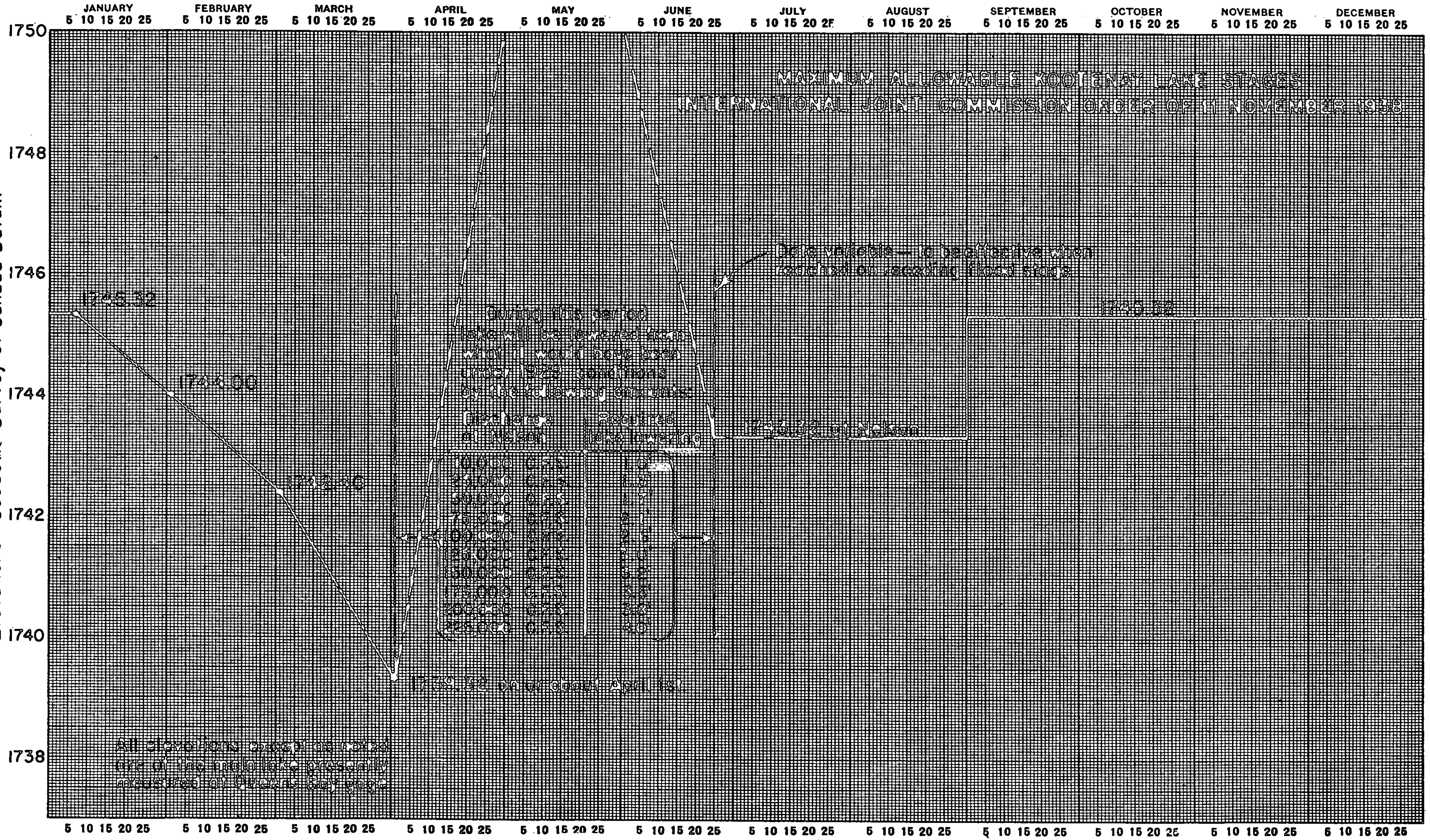

MAXIMUM ALLOWABLE KOOTENAY LAKE STAGES
INTERNATIONAL JOINT COMMISSION ORDER OF 11 NOVEMBER 1938
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
1750
1748
1746
1744
1742
1740
1738
Elevations—Geodetic Survey of Canada Datum
1745.32
1744.00
1742.40
1739.32 on or about April 1st.
During this period lake will be lowered from what it would have been under 1928 conditions by the following amounts:
Discharge at Nelson
Required lake lowering
10,000 C.F.S. 1.0'
25,000 C.F.S. 1.3'
50,000 C.F.S. 1.7'
75,000 C.F.S. 2.1'
100,000 C.F.S. 2.5'
125,000 C.F.S. 3.0'
150,000 C.F.S. 3.2'
175,000 C.F.S. 3.5'
200,000 C.F.S. 3.8'
225,000 C.F.S. 4.0'
Date variable — to be effective when reached on receding flood stage
1743.32 at Nelson
1745.32
All elevations except as noted are of the main lake presently measured at Queens Bay gage

FIGURE 3

TABLE 12

Hydro-Electric Power Installions

Name of Project	Location	Head Feet	Total Installed Capacity	Operator
Aberfeldie	Bull River, B.C.	275	4,000 kw	East Kootenay Power & Light Co.
Elko	Elk River, B.C.	190	9,600 kw	"
Lake Creek 1	Lake Creek, Montana	150	3,500 kw	Montana Light & Power
Lake Creek 2	" "	150	1,000 kw	"
Moyie	Moyie River, Idaho	210	2,380 kw	Town of Bonners Ferry
Goat River	Goat River, B.C.	70	1,280 kw	West Kootenay Power & Light Co. Ltd.
Corra Linn	Kootenay River, B.C.	53	40,500 kw	C.M. & S. Co. Ltd.
Upper Bonnington	"	70	54,700 kw	"
City of Nelson	"	70	9,200 kw	City of Nelson, B.C.
Lower Bonnington	"	70	47,250 kw	West Kootenay Power & Light Co. Ltd.
South Slocan	"	70	47,250 kw	C.M. & S. Co. Ltd.
Brilliant	"	93	81,600 kw	"

82. In Canada, Kootenay Lake is used for transportation of ore and logs. Logs are towed from both ends of the lake down the West Arm to the mills at Nelson. Ore is shipped by car barge from the Bluebird mine at Riondel to Proctor on the West Arm. Approximately 400,000 tons of ore are shipped annually in this manner. The Provincial Department of Highways maintains a ferry service between Balfour and Kootenay Bay. The Federal Government maintains 13 public wharves on the lake.

83. The Kootenay Basin in the United States is largely served by the Great Northern Railway. Its east-west trans-continental line enters the basin from the east by way of the pass between the headwaters of the Stillwater (Flathead tributary) and Tobacco Rivers. It follows the Tobacco River valley to Rexford, Montana, and the Kootenay valley from there downstream to Bonners Ferry, Idaho. Here it turns south and crosses the divide between the Kootenay and Clark Fork watersheds at Elmira, Idaho, on the way to Sandpoint, Idaho, and thence to Spokane, Washington. The Kootenay Valley branch of the same railway extends from the main line at Bonners Ferry northward along the east side of the valley to its terminus at Porthill, Idaho, on the international boundary.

84. The westerly portion of the basin is served by the Spokane International Railroad, a Union Pacific Railroad subsidiary. It enters the United States from Canada at Eastport, Idaho, and follows the Moyie and Kootenay Rivers to Bonners Ferry, where it turns south and roughly parallels the route of the Great Northern to Sandpoint and Spokane.

85. The Canadian portion of the Kootenay Basin is served by two lines of the Canadian Pacific Railway. One of these is the trans-provincial Kettle Valley Railway which is interconnected to the Great Northern Railway at Nelson and to the Spokane International Railway near Yahk. The second of these lines is the Kootenay Central Railway which serves the eastern portion of the basin and links the Kettle Valley Railway in the south with the Canadian Pacific Railway main line north of the basin.

86. U.S. Highway No. 95 enters the basin from the south at Elmira, Idaho, passes through Bonners Ferry, and continues north to cross the international boundary at Eastport, Idaho. This highway is continued in Canada, as B.C. Highway No. 95, through Cranbrook and leaves the basin at Canal Flats. State Highway No. 1 connects Porthill with this highway near Copeland.

87. State Highway No. 37, from its junction with U.S. Highway No. 2 at Libby, follows Kootenay River upstream to join U.S. Highway No. 93 at Eureka, Montana, 5 miles south of the international boundary.

88. U.S. Highway No. 93 follows down the Tobacco River valley to Eureka, then turns north, crosses the international boundary at Roosville and, in Canada, as B.C. Highway No. 93, it continues up the Kootenay valley to Elko, where it joins B.C. Highway No. 3. Highway No. 3 enters the basin over the Crowsnest Pass and goes through Fernie and Elko to Cranbrook. From Cranbrook it goes through Yahk, crosses over to Creston, and continues along the east shore of Kootenay Lake. After crossing the lake by the Kootenay Bay - Balfour Ferry, it continues down the West Arm and the Kootenay River through Nelson to Brilliant at the confluence of the Kootenay and Columbia Rivers.

89. No commercial air lines serve the Kootenay Basin in the United States. The closest major terminal is at Spokane, through which there are numerous flights daily by several commercial air lines. Airfields have been built at Troy, Libby, and Eureka, Montana, and Bonners Ferry, Idaho. They are used for private and chartered flights, and by Forest Service planes. In British Columbia, Canadian Pacific Airlines operates a daily service between Vancouver, Penticton, Castlegar, Cranbrook, and Calgary. The lakes and rivers are used extensively by float planes.

PUBLIC LANDS AND RESERVATIONS

90. Of the 4,800 square miles contained within the Kootenay Basin in the United States, 68 per cent is publicly owned. Of this, about 2,990

square miles are National Forest land, and other federally-owned land and State forests amount to 287 square miles. Of the 14,500 square miles contained within the Kootenay Basin in Canada, more than 90 per cent is publicly owned. Most of this is unreserved Crown land, but about 625 square miles are Provincial and National parks or recreational land reserves and 54.6 square miles are occupied by 13 Indian Reservations.

III PROBLEMS

GENERAL

91. The development of this basin involves projects which affect both Canada and the United States. Because the Kootenay River flows from Canada through the United States, and back into Canada, developments in one country or the other may have beneficial or detrimental effects in the other country. Backing up of water across the international boundary by development in the downstream country could cause damages in the upstream country. Diversion of waters out of the basin by the upstream country would reduce the volume of natural flows and in some cases might adversely affect some developments in the downstream country. On the other hand, the downstream effect might be beneficial in providing flood control and facilitating the reclamation of wet lands. That these downstream benefits should be shared in some manner between the two countries is a reasonable premise, if the maximum utilization of the water resources of the basin is to be achieved. The problem of how these benefits can be shared should be resolved, in order that the basin development can proceed in an orderly and efficient manner.

LIBBY

92. By an Act of the United States Congress, approved by the President on May 17, 1950, the Libby project on Kootenay River in Montana was authorized for construction. The construction of Libby dam to a pool elevation of 2459 would incur flowage damage in Canada for a distance of 42 miles north of the international boundary. Approval by Canada would be required under the Treaty of 1909 before this project could be constructed. Also, the problem of recompense for this damage and sharing of the benefits resulting from water stored in the area would be a subject for international agreement.

POWER

93. The present power requirements in the Kootenay Basin are adequately supplied by existing plants in United States and Canada (see Table 12, Page 30). Sufficient hydro-electric reserves are available for development to satisfy the needs of the foreseeable future.

94. The main power problem of the Kootenay Basin is not that of meeting the needs of the local economy but, instead, is that of economically developing the hydro-electric power capabilities to satisfy the growing power needs of the Pacific Northwest both in Canada and the United States. To develop the maximum power potential of the river, co-operative operation and interconnection of all the power-producing facilities are required. A major problem of obtaining optimum basin development is the allocation of costs and benefits by international arrangements and agreements.

95. The three plans of development considered herein contemplate varying degrees of diversion of the Kootenay River flows into the Columbia. Any diversion of the flow of the Kootenay River to the Columbia would reduce the power outputs from downstream developments. Complete diversion below the confluence of the Elk River could make power development uneconomic on the Kootenay River in the United States. Accordingly, the international effects of the various diversions of the Kootenay River flow would have to be considered in arriving at a plan of development.

FLOOD CONTROL AND DRAINAGE

96. Floods have been a major problem in the Bonners Ferry area, where overflow bottom lands have been reclaimed by dyking. Serious damage has occurred in this area on numerous occasions due to failure or overtopping of dykes. The town of Bonners Ferry and surrounding agricultural areas have

suffered damages of major proportions. It has been estimated that the maximum non-damaging flow at Bonners Ferry is 60,000 cubic feet per second.

97. Any development of the Kootenay River, either by the Libby project, by diversion in Canada or by a combination of both, would have flood-control benefits in the Bonners Ferry - Creston area of the Kootenay River valley. The determination and recompense for these benefits would be of international concern.

98. Under the selected plans of development, the storage range on Kootenay Lake would be increased from the presently authorized six feet to nine feet. Such an increase might result in increased pumping costs in the reclaimed lands upstream from Kootenay Lake.

99. In the area between Bonners Ferry and Kootenay Lake, 55,300 acres of wet lands have been reclaimed. An additional 15,700 acres in Canada could be reclaimed but would require international agreement. The control of the river flow by any of the selected plans would facilitate this reclamation.

IRRIGATION

100. Additional lands exist in both Canada and the United States which are suitable for irrigation; however, pump lifts for many of these are relatively high, which would result in high costs. The creation of reservoirs would reduce these pumping lifts in some instances. No feasibility studies have been carried out to determine the practicability of irrigating the major portion of these lands. However, the water supplies are more than adequate. The stream flows used in the power studies were reduced to allow for the ultimate development of irrigation in the basin.

RECREATION

101. In general terms, the recreational facilities within the basin, or in close proximity, appear to be adequate at present. It is expected that access to more remote recreational areas and accommodations will be provided as the need becomes apparent. The main problem to be expected is the conflict that may arise, in some cases, where development of the water resource for hydro-electric purposes inhibits, or destroys, an area which has been in use for game range, wildfowl nesting grounds, or fish spawning. However, hydro-electric projects may improve the recreational aspects by providing access and by creating lakes which can be used for boating, fishing, and swimming. In some cases, the operation of reservoirs with large drawdowns may be detrimental to the scenic values of an area.

LEGAL CONSIDERATIONS

102. In the United States the laws governing the control and use of waters stem from both the federal government and from each of the Columbia Basin states. The national government has the authority to deal with waters which are navigable, interstate waters, and, of course, international waters. In addition, the national government has responsibility with respect to waters relating to the public lands and other areas held by the national government in its proprietary capacity, such as Indian lands and waters. Power installations on navigable streams are required to be licensed by the federal government, although the licensee is required to conform to state water laws. The several states of the basin have established systems of laws under which use rights to waters may be obtained.

103. No interstate compacts have been formulated regarding any of the streams of the Kootenay Basin in the United States, although a Columbia River Compact Commission has been at work on an over-all compact for several years.

104. In Canada the legal control of surface water in British Columbia is vested in the Crown in the right of the Province of British Columbia subject to certain federal government provisions respecting navigation and

fisheries, and is administered under the Provincial Water Act. Also, the Kootenay River falls within the definition of an "international river" under the International River Improvements Act of the Government of Canada. River improvements in Canada on this stream would be subject to licensing by the Government of Canada.

105. Trans-boundary projects in the Kootenay Basin fall within the purview of the Boundary Waters Treaty of 1909.

IV PLANS OF DEVELOPMENT

INVESTIGATION AND OFFICE STUDIES

106. The field work for investigation of dam sites on the Kootenay River and tributaries in Canada was initiated in 1945, when the lower parts of the Lardeau and Duncan Rivers were mapped. In the next few years Gibralter, Copper Creek, Torrent, Bull River, Wardner, Plumbob and Dorr dam sites were studied. In 1946, a study of the ground-water table was started in the Kootenay Flats area near Creston, and a program of subsurface investigation at some of the various dam sites was initiated. Subsurface investigations were carried out on the Kootenay River at Dorr, Plumbob, Wardner, Bull River, Torrent and Gibraltar sites, at Duncan site on the Duncan River, at St. Mary Lake site on the St. Mary River, and at Natal site on the Elk River. The valleys of the Elk and St. Mary Rivers and the Kootenay River from Newgate to the border of Kootenay National Park were covered by soil surveys which commenced in 1947. Underwater soundings were made of Kootenay Lake. Geodetic survey, reconnaissance, and topographic mapping were also carried out at each of the dam sites selected for study. Preliminary designs were made for dams, powerhouses, spillways, intakes and other necessary works. Costs of these items were estimated. In most cases, various types of structures were studied to determine the most favourable.

107. The entire reach of the Kootenay River within the United States was investigated by geological and engineering reconnaissance to locate potential dam sites and ascertain the general flowage problems involved in each. Aerial photographs were taken over the full length of the river and an aerial topographic map was prepared and used in preliminary studies for site locations, estimates, and determination of area-capacity curves for the numerous potential dam sites. Various sites and axes were drilled, including three axes at the Katka site, three sites and axes for Libby, four axes at Tunnel No. 8, and one at Moyie. Subsurface investigation was performed by seismic methods to supplement the drilling, and topographic dam-site surveys were made at all of the sites. Geology of the area was developed and delineated on site maps for the same four sites. Existing topographic maps were relied on for estimates at Long Meadows and Yaak Falls on the Yaak River, and at Meadow Creek and Moyie Canyon on the Moyie River. Site maps and area-capacity curves were obtained from available aerial maps. Preliminary estimates were made of the cost of railroad and highway relocations and the necessary land acquisition and community relocations for the various plans based on the aerial topographic maps. Topographical surveys were made of the broad agricultural flat between Bonners Ferry and the international boundary. Estimates of a number of methods of channel improvement for flood control in this reach of the river were studied and their economics compared. Flood-damage surveys were made for both this area and the area subject to damage on Libby Creek.

108. Office studies have been undertaken to determine the more favourable combinations of possible alternate developments on the Kootenay River, the economics of developing these alternatives, and the power output that could be expected from the various combinations when considered as parts of plans of development for the entire Columbia River basin.

PROPOSED PLANS

109. Many projects on the Kootenay River were studied for possible development of the hydro-electric resources, assuming co-ordinated operation with plants on the other tributaries and main stem in the Columbia River Basin. Of these, seven were included in the alternative plans presented in the main report. These plans are called Non-Diversion, Copper Creek Diversion, and Dorr Diversion Plans. The Non-Diversion Plan would develop the Kootenay River in its own channel. The projects that would be included are Bull River, Libby,

Kootenai Falls, Long Meadows, Duncan Lake, the Canal Plant at South Slocan, and an additional powerhouse at Brilliant. In the Copper Creek Diversion Plan, all the flow of the Kootenay River at the Copper Creek site would be diverted into the Columbia River by a reservoir extending from Copper Creek site over a low divide at Canal Flats to Luxor site on the Columbia River. This diversion would average 3,600 cubic feet per second. The projects that would be included in the Kootenay Basin in the Copper Creek Diversion Plan are Copper Creek, Libby and Kootenai Falls (with smaller installations than in the Non-Diversion Plan), Long Meadows, Duncan Lake, the Canal Plant, and an additional powerhouse at Brilliant. In the Dorr Diversion Plan most of the inflow of the Kootenay River between Bull River and Newgate would be pumped into the Bull River - Luxor reservoir for release down the Columbia. The flow that would be diverted would average 8,000 cubic feet per second. The projects that would be included in the Kootenay Basin are Bull River (with Luxor), Dorr, Long Meadows, and Duncan Lake. In all three plans, it has been assumed that a fourth unit would be installed in an existing setting at the Brilliant plant. Table 13 lists and gives pertinent data on the elements in the plans of development for the Columbia River basin that are located in the Kootenay Basin. It should be noted that these elements do not comprise a complete plan of development in themselves but are part of comprehensive plans for the Columbia Basin.

PROJECT DATA

110. The following descriptions of elements are supplemental to those in the main report. The cost estimates are based on January 1957 prices and additional information regarding the basic assumptions in compiling the estimates is given in Appendix VI. Those projects on the Kootenay River that are required to divert Kootenay River water into the Columbia River are described in Appendix I and mentioned only briefly here. Descriptions of the improvement elements for the further development of the water resources of the Kootenay River basin are given in the following paragraphs. Descriptions of additional installations at the hydro-electric plants now in operation on the Kootenay River between Kootenay Lake and the Columbia River are included also.

111. BULL RIVER. The site is on the Kootenay River, 42 miles upstream from the international boundary and 1-1/3 miles upstream from the confluence of the Bull and Kootenay Rivers. The crest height of Bull River dam would not be as high in the Non-Diversion Plan as it was in the Dorr Diversion Plan, for which a description is given in Appendix I. At Bull River there would be 2,794,000 acre-feet of usable storage between full-pool elevation, 2660 feet, and elevation 2589 feet, which amounts to a 35 per cent drawdown.

112. Plate 3 shows the topography and exploration data, and Plate 4 shows a geological section and logs of drill holes. At the site the Kootenay River flood plain is about 1,600 feet wide with the river against the right bank in a channel 400 feet wide. The right bank is rocky and quite steep to about elevation 2,730. The left bank is not as steep as the right bank and is covered with unconsolidated deposits. There are rock outcrops above maximum pool elevation. Drilling has disclosed bedrock 140 feet beneath the ground surface near the left abutment. The rock outcrops in the area are massive grey, crystalline limestone, which would serve satisfactorily for dam abutments. Most extensive and widespread unconsolidated deposits consist of interbedded sand, silty sand, sandy silt, and silt with minor gravelly sand and clay beds. The drill-hole records indicate that the unconsolidated deposits contain enough silt or clay throughout to be impervious for all practical purposes and should serve as satisfactory abutments.

113. Plate 5 shows the general arrangement for Bull River project to elevation 2,660 and Plate 6 shows elevations and sections giving more details of the parts of the project. This site would be developed by constructing an earth-fill dam in the river channel with a spillway and powerhouse on rock on the right bank.

TABLE 13

Elements for the Plans of Development in the Kootenay Basin

Project	Full Pool Elevation Feet	Usable Storage 1000 Ac.Ft.	Gross Head Feet	Installed Capacity Mw	Investment Cost $1000
Non-Diversion Plan					
Bull River	2,660	2,794	201	134	83,632
Libby	2,459	4,045	340	344	324,800
Kootenai Falls	2,060	Nil	160	240	98,000
Long Meadows	3,100	400	193	9	26,933
Duncan Lake	1,892	1,402	Nil	Nil	24,755
Kootenay Lake	1,748	355 additional	Nil	Nil	Nil
Canal Plant	1,748	Nil	263	213	32,959
Brilliant Additions	1,470	Nil	80	50	7,797
Copper Creek Diversion Plan					
Libby	2,459	4,045	340	258	312,760
Kootenai Falls	2,060	Nil	160	180	92,500
Long Meadows	3,100	400	193	9	26,933
Duncan Lake	1,892	1,402	Nil	Nil	24,755
Kootenay Lake	1,748	355 additional	Nil	Nil	Nil
Canal Plant	1,748	Nil	263	213	32,959
Brilliant Additions	1,470	Nil	80	50	7,797
Dorr Diversion Plan					
Dorr Power	2,513	Variable 1/	164	12	1,970
Long Meadows	3,100	400	193	9	26,933
Duncan Lake	1,892	1,402	Nil	Nil	24,755
Kootenay Lake	1,748	355 additional	Nil	Nil	Nil
Brilliant Addition	1,470	Nil	80	25	2,399

1/ At Dorr only enough storage released down the Kootenay River to maintain a minimum flow of 1,000 cubic feet per second. The remainder of the storage pumped into Bull River - Luxor reservoir.

114. To commence construction, two 35-foot-diameter tunnels would be driven in the right bank and lined with concrete; then the cofferdams would be built. The upstream cofferdam would have a crest elevation of 2,525 feet and the downstream cofferdam a crest elevation of 2,480 feet. The area between the cofferdams would be dewatered, stripped where necessary, and the main earth dam would be built. At the same time work would be proceeding on the chute spillway, intake tower, surge tank, and powerhouse. The upstream cofferdam would be incorporated in the dam, but the downstream cofferdam would be removed. Both the diversion tunnels would be closed by gates at their upstream end, then plugged. Part of one tunnel would be used to convey water from the intake to the penstocks. It has been estimated that about 2,280 cubic yards of earth excavation, 2,800,000 cubic yards of rock excavation, 14,600,000 cubic yards of fill, and 200,000 cubic yards of concrete would be required.

115. The spillway, which would be equipped with six radial gates 35 feet wide and 30 feet high, operated by individual hoists, would be capable of passing a design flood of 120,000 cubic feet per second. Two Francis turbines rated at 92,200 horsepower under a design head of 158 feet would be connected to 67,000-kw. generators. Two cranes each with a capacity of 175 tons would be needed in the powerhouse. A gantry crane of 25 tons capacity would be needed for the intake emergency gates, and one of 35 tons capacity for the tailrace closure gate. The transformers would be located between the powerhouse and the river with the switchyard downstream from the powerhouse.

116. The total reservoir area at full pool would be 49,700 acres, of which 6,300 acres are now river channel (See Plate 7). Of the remaining 43,400 acres, there are 10,700 acres which would not require any clearing. The settlements of Fort Steele, Wasa, and Skookumchuck would be inundated. Because the Kootenay Central Railway follows a water grade throughout the reservoir area, all the existing track between Bull River and Canal Flats would be flooded. It is proposed to relocate the railway on benches to the east of the reservoir. Seven and one-half miles of the Canadian Pacific Railway Kettle Valley Line would have to be relocated as would four and one-half miles of the Trans-Provincial Highway (No. 3). Also one-half mile of highway near Rampart would have to be raised. Twenty-eight miles of the Banff-Windermere Highway (No. 95) between Ta Ta Creek and Canal Flats would be relocated on the benches to the west of the reservoir area and 21 miles of new road would be needed to complete a road link between Bull River and Canal Flats on the east side of the reservoir. There are some sections of transmission line and telephone line to be relocated.

117. Detailed cost estimates for the Bull River project are given in Table 14. It is estimated that the Bull River project would take five years to build.

118. DORR. This project would provide a small amount of at-site power in the Dorr Diversion plan, utilizing a minimum release of 1000 cubic feet per second. A detailed description and cost estimate is given in Appendix I.

119. LIBBY. The site is at river mile 217 on the Kootenay River about 15 miles upstream from Libby, Montana, and 51 miles downstream from the international boundary. In the Non-Diversion Plan, the installed hydro-electric generating capacity would be 344,000 kilowatts and in the Copper Creek Diversion Plan the installation would be 258,000 kilowatts, utilizing 86,000-kw. units in each case. The project would provide 4,045,000 acre-feet of storage for power and flood control. The project layout is shown on Plate 8.

120. The mean annual natural discharge is about 10,000 cubic feet per second, but would be reduced to about 6,400 cubic feet per second in the Copper Creek Diversion Plan. The maximum flood peak of record occurred in 1894 and has been estimated at 130,000 cubic feet per second at the dam site. The maximum probable flood is estimated to be 275,000 cubic feet per second, and the resulting reservoir outflow, 260,000 cubic feet per second, has been used for spillway design.

TABLE 14

Cost Estimate for Bull River

River Diversion	$12,256,000	
Spillway	6,508,000	
Powerhouse	12,209,000	
Intake	2,891,000	
Penstocks	948,000	
Earth Dam	9,388,000	
Operator's Colony	300,000	
Access Roads	180,000	
Surge Tank	1,034,000	
Sub-Total	$45,714,000	
Engineering and Contingencies (15%)	6,857,000	
Sub-Total	$52,571,000	
Interest at 3% for ½ of 5 years	3,943,000	
Insurance and Administration (2½%)	1,183,000	
Total Construction Cost		$57,697,000

Flowage

Relocation: Railways	$10,685,000	
Highways	2,420,000	
Roads	525,000	
Transmission & Telephone Lines	457,000	
		$14,087,000
Dyke at Canal Flats		90,000
Buildings and Land		1,020,000
Indian Reservations		1,719,000
Reservoir Clearing		4,435,000
Miscellaneous or Special Contingencies		261,000
Sub-Total		$21,612,000
Engineering, Overhead, and Contingencies (20%)		4,323,000
Total Flowage Cost		$25,935,000
Total Investment Cost		$83,632,000

Annual Cost

Amortization (.00887) $83,632,000		$ 742,000
Interest (.03) $83,632,000		2,509,000
Operation and Maintenance:		
(a) Generating Units (2) $80,000	$ 160,000	
(b) Spillway (6) $15,000	90,000	
(c) General (.00185) $83,632,000	155,000	405,000
Interim Replacement (.0015) $57,697,000		87,000
Total Annual Cost		$ 3,743,000

121. The Kootenay River at the damsite lies in rugged terrain with a total relief of about 3,000 feet. Bedrock is of the pre-Cambrian Belt series of argillite and quartzite. Two or more ancient basalt flows, varying up to 100 feet in thickness, were extruded concurrent with the displacement of the sand and mud and have been folded with the other rock. Drill holes indicate that the bedrock is approximately level and about 30 feet below the river bed. The steep right abutment is exposed rock from the river to well above the top of the dam with some scattered small pockets of overburden. The left abutment is a terrace remnant of silty sand and gravel up to 130 feet in depth. Rock outcrops at about elevation 2,440 form a pronounced knob behind which are four low saddles.

122. The dam would be a concrete gravity structure rising about 400 feet above bedrock, with a total crest length of approximately 2,700 feet. A short earthfill embankment would be required for the left abutment. In addition to the main dam, it would be necessary to construct four earthfill saddle dams behind the left abutment. These saddle dams would total about 3,200 feet in length and would have a maximum height of approximately 120 feet. An eight-bay, concrete overflow spillway controlled by tainter gates would be provided with fourteen sluices in the spillway monoliths to provide drawdown for flood control. The hydraulic capacity of the outlets at minimum pool, elevation 2,287, would be 33,000 cubic feet per second. The power plant would be located on the left bank near the toe of the dam. Initially the power plant would consist of four 86,000-kw. units. As many as eight such units may be installed ultimately. Gross head for initial development of power would be 344 feet between a normal operating pool at elevation 2,459 and a tailwater elevation 2,115.

123. The reservoir, shown on Plate 9, would extend about 42 miles into Canada to the Bull River damsite. Gross storage would be 5,985,000 acre-feet of which 4,045,000 would be usable storage with a 35-percent drawdown. Minimum pool would be at elevation 2,287. The reservoir would occupy an area of about 48,000 acres. Most of the land required in the United States consists of timber and cut-over lands along the river and a few small farms. The towns of Warland, Stonehill, and Rexford would be inundated. In addition, the reservoir would inundate portions of the Great Northern Railway, which follows along the east bank of the Kootenay River, Montana State Highway No. 37, which parallels the railroad along the west bank of the river, and portions of county and Forest Service roads.

124. Major relocations would include about 70 miles of the main line of the Great Northern Railway and approximately 58 miles of State Highway No. 37. County and Forest Service roads, telephone and power lines and other utilities would require relocation also. A detailed cost estimate of the project is given in Table 15.

125. KOOTENAI FALLS. The site is on the Kootenay River 12.5 miles downstream from Libby, Montana. The installed capacity in the Non-Diversion Plan would be four 60,000-kw. units and in the Copper Creek Diversion Plan three 60,000-kw. units. It would be a run-of-the-river development.

126. The damsite at river mile 189.5 is immediately below Kootenai Falls where an area of exposed rock is found. The rock is argillite and quartzite of the pre-Cambrian Belt series. The concrete gravity dam would be about 943 feet long, rising about 153 feet above bedrock on the right bank. The conventional powerhouse would be at the toe of the intake dam. A concrete non-overflow structure would complete closure on the left bank and the spillway structure containing six 40-by 45-foot tainter gates would be set in the right bank. Steel-lined penstocks through the intake dam would convey water to the turbines. Plan and sections are shown on Plate 10.

127. The dam would create a 15-mile reservoir backing water to the Mile 204.9 site. The total water-surface area would be 2450 acres. Drawdown would be limited to pondage requirements. The reservoir would be in a scenic and wooded area parallel to U.S. Highway No. 2.

TABLE 15

Cost Estimate for Libby

1.	In Non-Diversion Plan (4 units)		
	Flowage Cost in Canada		$ 7,610,000
	Lands and Damages in U.S.		7,917,000
	Relocations		
	Roads	$25,130,000	
	Railroads	75,029,000	
	Other	1,083,000	101,242,000
	Reservoir		5,591,000
	Dams		
	Main Dam	86,165,000	
	Outlet Works	1,509,000	
	Power Intake	13,593,000	
	Auxiliary Dams	1,095,000	102,362,000
	Power Plant		
	Powerhouse	$ 9,104,000	
	Turbines and Generators	17,386,000	
	Switchyard and Miscellaneous Equipment	5,768,000	32,258,000
	Roads, railroads, and bridges		1,026,000
	Recreation facilities		117,000
	Building grounds and utilities		967,000
	Permanent operating equipment		301,000
	Preauthorization studies		100,000
	Engineering and design		11,728,000
	Supervision and administration		15,331,000
	Construction facilities		10,160,000
	O & M during construction		1,270,000
	Total construction cost (including contingencies)		$297,980,000
	Interest at 3% for ½ of 6 years		26,820,000
	Total investment cost		$324,800,000

Annual Cost

Amortization (.0088)		$ 2,858,000
Interest (.03)		9,744,000
Operation and Maintenance:		
a. Generating Units (4) $80,000	$ 320,000	
b. Spillway (8) $15,000	120,000	
c. Sluices (14) $ 8,000	112,000	
d. General (.001)	325,000	877,000
Interim replacement (.0008)		260,000
		$ 13,739,000

TABLE 15 (Continued)

Cost Estimate for Libby

2. In Copper Creek Diversion Plan (3 units)		
Construction cost for 4 units		$297,980,000
Less cost of one unit		11,044,000
Total construction cost (including contingencies)		$286,936,000
Interest at 3% for ½ of 6 years		25,824,000
Total investment cost		$312,760,000

Annual Cost

Amortization (.0088)		$ 2,753,000
Interest (.03)		9,384,000
Operation and Maintenance:		
a. Generating Units (3) $80,000	$ 240,000	
b. Spillway (8) $15,000	120,000	
c. Sluices (14) $ 8,000	112,000	
d. General (.001)	313,000	785,000
Interim replacement (.0008)		250,000
		$ 13,172,000

128. The major relocations would be about 16.5 miles of Great Northern Railway main line, seven miles of U.S. Highway No. 2 and ten miles of forest roads. A detailed cost estimate of the project is given in Table 16.

129. LONG MEADOWS. This project would be a multiple-purpose project on the Yaak River, 30 miles upstream from the confluence of the Yaak and Kootenay Rivers. The damsite is in a narrow gorge. The river valley along the dam axis is about 100 feet wide at river level, and is confined between steep rock slopes. The left bank rises steeply about 100 feet to a gravel-mantled rock terrace approximately 400 feet wide and then continues to above elevation 3,200. On the right bank, a rock ridge rises to about elevation 3,150 and then drops 60 feet to form a saddle. Beyond this saddle the rock slope extends upward to above elevation 3,200. Overburden covers rock to a shallow depth in the right bank saddle and along the left bank terrace. The valley fill, 45 to 85 feet deep, is of boulders and sand and minor amounts of silt. It is generally semi-pervious but has a few highly pervious zones. The bedrock in the river channel slopes gently away from the axis both upstream and downstream. The rock is composed primarily of quartzite and high siliceous argillite, bedded and quite massive, with widely spaced joints generally normal to the bedding.

130. The dam would be a straight, non-overflow, concrete gravity structure having a maximum height of 280 feet above bedrock, top elevation 3,108, top length of 1,450 feet, and top width of 30 feet. (See Plate 11). The powerhouse would be founded on rock on the right bank. Two penstocks, ten feet in diameter, installed in the dam, would serve the turbines. Flow would be controlled at each intake by fixed-wheel gates. One penstock would be bulkheaded for future use.

131. The powerhouse would have an initial installation of one 9,000-kw. generating unit. A skeleton structure would be provided for future installation of a second unit of the same size to provide greater peaking capability for low hydro-system load factors anticipated in the future. Gross head for power would be 193 feet.

132. Sluice capacity for maintaining flood-control storage in the reservoir would be provided for installing two 8-foot-diameter conduits through the dam. These sluices would be regulated by 72-inch Howell-Bunger valves, adjacent to the powerhouse, and would have a capacity of 4,000 cubic feet per second at minimum pool elevation 3,040. The sluices would discharge into the natural channel.

133. A concrete gravity spillway, crest elevation 3,085, would be founded on rock in the saddle on the right bank, and would be connected to the main dam by a roadway 800 feet long excavated across the rock ridge separating these structures. The spillway would be 60 feet wide, and flow would be controlled by two tainter gates, each 30 feet wide by 15 feet high. The total outflow for the spillway-design flood, with the reservoir at elevation 3,105.7, would be 28,000 cubic feet per second, with 23,000 cubic feet per second flowing over the spillway and 5,000 cubic feet per second passing through the sluices. The spillway would discharge into an unlined rock channel excavated along the downstream side of the rock ridge to enter the river about 1,100 feet below the dam. No stilling basin or paving of the chute would be required, as the spillway channel would be remote from the dam and such erosion as might occur in the channel would not be serious. Use of the channel for spillway flows would be infrequent and of short duration.

134. Concrete aggregates are available in ample quantities at Spread Creek about 4.3 miles downstream from the damsite. The quality is satisfactory, although processing would be required to remove soft materials from the sand. A quarry site, 3.5 miles downstream from the site, would be an excellent source for riprap and for manufacturing aggregates from rock.

135. The dam would be served by the Great Northern Railway, with the railhead located at Troy, Montana. Access from Troy would be by U.S. Highway No. 2, west to the Yaak Valley, thence on Forest Service and county roads

TABLE 16

Cost Estimate for Kootenai Falls

1. In Non-Diversion Plan (4 units)		
Land and Land Rights	$ 1,171,000	
Relocations: Railroad	23,595,000	
Highway	4,730,000	
Other	110,000	
Reservoir Clearing	712,000	
Dam	29,998,000	
Power Facilities	30,082,000	
Access Road	380,000	
Miscellaneous, including buildings grounds and construction facilities	1,722,000	
Total Project Cost		$92,500,000
Interest at 3% for ½ of 4 years		5,500,000
Total Investment Cost		$98,000,000

Annual Cost

Interest and Amortization	$ 3,802,000
Interim Replacement	147,000
Operation and Maintenance	502,000
Total Annual Cost	$ 4,451,000

2. In Copper Creek Diversion Plan (3 units)		
Total project cost for 4 units	$92,500,000	
Less cost of one unit	4,959,000	
Total project cost		$87,541,000
Interest at 3% for ½ of 3¾ years		4,959,000
Total Investment Cost		$92,500,000

Annual Cost

Interest and Amortization	$ 3,589,000
Interim Replacement	139,000
Operation and Maintenance	417,000
Total Annual Cost	$ 4,145,000

along the Yaak River to the site. Of the 40 miles of haul distance, 28 miles would require improvements to provide all-weather hauling.

136. The reservoir would have an area of 7,740 acres and a gross storage of 726,000 acre-feet at full pool elevation 3,100. Drawdown to the minimum operating pool at elevation 3,040 would provide 400,000 acre-feet of usable storage. It would extend twenty miles upstream to a point about 3.5 miles below the international boundary, as shown on Plate 12. Buildings and improvements within the reservoir consist of 231 buildings, 76 of which are residences. Included in these improvements are the cantonment of the Yaak Air Force Station, the town of Yaak, two Forest Service camp grounds, and the Upper Ford Ranger Station. The total population within the reservoir area is estimated to be 249 persons, exclusive of military personnel. The reservoir would inundate 27 miles of United States Forest Service roads and 16.5 miles of telephone lines.

137. Three years would be required for project construction. Relocation of the cantonment of the Yaak Air Force Station would be completed in the first year. Construction of project structures which could be accomplished in the dry would also begin during the first year. An unlined diversion tunnel 21 feet in diameter and approximately 400 feet long would be driven through rock on the right bank. Diversion would be accomplished in the first high-water period. The construction area would be dewatered after the high-water period for construction of the concrete dam. In the second and third years, the concrete structures and the spillway channel excavation would be completed. In-service operation of the powerhouse unit would begin about 2½ years after beginning project construction.

138. The estimated construction cost of the project with one generating unit installed is $26,933,000. A summary of project costs is given in Table 17.

139. DUNCAN LAKE. This site, which is on the Duncan River about 8½ miles upstream from Kootenay Lake and a half-mile upstream from the confluence of the Lardeau and Duncan Rivers, would be used for storage only. Between maximum pool elevation of 1,892 feet and minimum pool elevation of 1,800 feet, there would be 1,402,000 acre-feet of usable storage. The valley bottom is about 2,000 feet wide at the site with the river channel about 200 feet wide on the south side of the valley.

140. Plate 13 shows the topography and exploration data at the site, and Plate 14 shows a geological section and logs of the drill holes. The rocks in the area may be divided into two main groups, one predominantly limestone and the other predominantly chloritic, calcareous, and micaceous schists. However, this division was made on a quantitative basis only; rocks of either group occur throughout the section. The limestones would probably be satisfactory for dam abutments. The schists are not particularly good rocks for dam sites. They are relatively weak and susceptible to decay, and are difficult rocks through which to tunnel, tending to overbreak on blasting and to slump and slip on planes of schistosity and shear. There would be a tendency for leakage along the planes of schistosity and the schists would also be unsatisfactory for rockfill and riprap. The drill logs indicate that the dam site axis is underlain by more than 200 feet of unconsolidated deposits, of which all but 20 feet of gravel at the surface would appear to be impervious.

141. The general arrangement of the dam, diversion works, spillway and outlet works is shown on Plate 15, and elevations and sections are shown on Plate 16. Two 23-foot-diameter tunnels would be driven through the rock abutment on the right bank, lined with concrete, and the intake and outlet structures built. These tunnels were designed to divert a flow of 27,000 cubic feet per second without overtopping the upstream cofferdam. This cofferdam, which would be built across the valley bottom, would have a crest elevation of 1,830 feet and would be incorporated in the main dam. The downstream cofferdam, which would be built only across the existing river channel,

TABLE 17

Cost Estimate for Long Meadows

Lands and Damages		$ 867,000
Relocations		
Roads (including Bridges)	$2,919,000	
Cemeteries, Utilities & Structures	1,793,000	4,712,000
Reservoir		980,000
Dam		12,512,000
Fish & Wildlife Facilities		251,000
Power Plant		
Powerhouse	1,674,000	
Turbines & Generators	744,000	
Accessory & Miscellaneous Equipment	465,000	2,883,000
Roads & Bridges		299,000
Buildings, Grounds & Utilities		173,000
Permanent Operating Equipment		55,000
Engineering & Design		672,000
Supervision & Administration		1,569,000
Construction Facilities		684,000
Operation & Maintenance during Construction		116,000
Total Construction Cost including contingencies		$ 25,773,000
Interest during construction at 3%		1,160,000
Total Investment Cost		$ 26,933,000

Annual Cost

Interest & Amortization on investment at 3%	$ 1,045,000
Operation & Maintenance	260,000
Interim Replacements	40,000
Total Annual Cost	$ 1,345,000

would have a crest elevation of 1,800 feet and would be used to carry a permanent access road to the outlet structure. The main dam would be constructed on the valley floor and an impervious blanket would be laid for about 400 feet upstream to reduce the amount of leakage under the dam.

142. The diversion tunnels, which would be used for outlet and spillway works upon completion of the project, would pass 45,000 cubic feet per second at full pool, elevation 1,892, which is greater than the design flood of 35,000 cubic feet per second. At minimum pool, elevation 1,800, these tunnels would be capable of discharging a flow of 6,000 cubic feet per second. The flow through the two spillway-outlet tunnels would be controlled by two individually operated radial-type gates 20 feet high and 23 feet wide. At the upstream end of each tunnel, a 28-foot-square emergency roller gate could be lowered behind the trashracks. While the tunnels are being driven and the inlet and outlet structures are being built, a start could be made on the upstream cofferdam and on the main dam on the broad flood plain on the right side of the river channel. On completion of the inlet and outlet works, a temporary diversion dam and the downstream cofferdam would be built to divert the flow of the Duncan River through the tunnels, so that the upstream cofferdam and the main dam could be completed in the dry.

143. For the cofferdams, main dam, diversion tunnels, spillway and outlet works, the following approximate volumes of excavation, fill and concrete would be required: earth excavation, 2,000,000 cubic yards; rock excavation, 600,000 cubic yards; fill, 6,800,000 cubic yards; and concrete, 32,000 cubic yards. It is estimated this project would take four years to construct.

144. At full-pool level the reservoir would extend about 27 miles upriver to a point about a mile upstream from Sob Creek (See Plate 17). The village of Howser would be inundated. The major item of flowage would be reservoir clearing. Details of the investment and annual costs are shown in Table 18.

145. KOOTENAY LAKE STORAGE. At present there is six feet of controlled storage on Kootenay Lake between elevations 1739.32 feet and 1745.32 feet, providing 673,000 acre-feet of usable storage. During the high-water period, when the outflow from Kootenay Lake is controlled by natural constrictions in the river between Proctor and Corra Linn dam, in all but two of the last 22 years the elevation of Kootenay Lake has been above 1,750 feet; in two years during this period, the elevation has been over 1,760 feet. In these studies, it was assumed that there would be no additional construction required to use nine feet of storage on Kootenay Lake between elevations 1739.32 and 1748.32 feet to provide 1,028,000 acre-feet of usable storage. However, there would have to be minor modification to the gates on the spillway of Corra Linn dam which now have a top elevation of 1748.0 feet. There may be additional pumping costs in reclaimed areas caused by this increased storage.

146. CANAL PLANT. Although the head of the Kootenay River between Nelson and South Slocan, British Columbia, is now being utilized by five hydro-electric plants at four dams, the hydraulic capacity of these plants is less than half the average flow of the Kootenay River at Nelson. With the advent of additional storage on the Kootenay River and its tributaries upstream from Kootenay Lake, the low flows that now occur in the winter months would be increased and it would become economical to increase the installed capacity at these plants. However, rather than to add powerhouse and equipment at each of the four existing dams, investigations by the International Columbia River Engineering Board showed that it would be more economical to construct a canal bypassing the existing developments and to concentrate the head at the Canal Plant to be located at the upstream end of the Brilliant pool. Plate 18 shows the general arrangement and profile for the project.

147. The general plan is to replace the southeast end of the gravity dam at Corra Linn with a headwork structure and build 6,600 feet of concrete-lined canal along the left bank of the river. Then, on the hillside above the City of Nelson plant, four earth embankments would be built to contain

TABLE 18

Cost Estimate for Duncan Lake

Preliminary	$ 225,000	
Dewatering	5,136,000	
Spillway & Outlet Works	3,486,000	
Earth Dam	5,671,000	
Access Roads	285,000	
Operators Colony	150,000	
Sub-Total	$14,953,000	
Engineering & Contingencies (15%)	2,243,000	
	$17,196,000	
Interest at 3% for ½ of 4 years	1,032,000	
Insurance & Administration (2¼%)	387,000	
Total Construction Cost		$18,615,000
Flowage		
Relocation: Trail	$ 36,000	
Reservoir Clearing	4,883,000	
Property	170,000	
Miscellaneous	28,000	
Sub-Total	$ 5,117,000	
Engineering Overhead & Contingencies (20%)	1,023,000	
Total Flowage Cost		$ 6,140,000
Total Investment Cost		$24,755,000
Annual Cost		
Amortization (.00887) $24,755,000		220,000
Interest (.03) $24,755,000		743,000
Operation and Maintenance:		
a. Spillway (2) $15,000	$ 30,000	
b. General (.002) $24,755,000	50,000	80,000
Interim Replacement (.0015) $18,615,000		28,000
Total Annual Cost		$ 1,071,000

the bypassed water for the next 4,000 feet. One of these would be very small; and the other three would be respectively: 700 feet long and 50 feet high; 1,800 feet long and 100 feet high; and 900 feet long and 140 feet high. From the artificial lake, formed by these earth embankments joining rock knolls on the hillside, the water would pass through a horseshoe-shaped, concrete-lined tunnel 2,600 feet long to enter a concrete-lined canal section 1,200 feet long. At the exit of this section, the water would flow into the forebay area, then either into the intakes to the powerhouse or over a surge spillway.

148. Plate 19 shows additional details of many of the various items comprising the Canal Project. The canal intake at Corra Linn dam would have four openings 15 feet wide and 35 feet high that could be closed with step logs by a gantry crane. The canal section between Corra Linn and the intermediate pool would be 6,600 feet long and 38 feet wide at the bottom with sides having a slope of 1½ to 1. The minimum depth of water in the canal would be 19 feet. The canal, which would be concrete lined throughout, would convey 9,000 cubic feet per second at a velocity of about seven feet per second at minimum Corra Linn forebay elevation.

149. The horseshoe-shaped tunnel section between the intermediate pool and the downstream canal would be 35 feet wide at the bottom with vertical walls 17½ feet high, above which the semi-circular ceiling would have a 17½-foot radius. This tunnel would be concrete lined throughout its 2,600-foot length. A second canal section 1,200 feet long would convey water from the tunnel to the forebay area. This canal would be 35 feet wide at the base with sides having a slope of 1½ to 1, and would have a minimum water depth of 29 feet. This canal would be lined with concrete and would carry a flow of 9,000 cubic feet per second, with a maximum water velocity of four feet per second under minimum Corra Linn forebay conditions. At its downstream end this canal would widen to form a forebay pool for the intake works and spillway.

150. Three intake gates 25 feet high and 20 feet wide would be operated by a gantry crane with a 50-ton capacity. Penstocks, 18 feet in diameter, would convey water to three Francis turbines, each rated at 101,000 horsepower at a design head of 262 feet and connected to generators rated at 71,000 kilowatts. An outdoor powerhouse was assumed for the design and cost estimate. A powerhouse gantry crane with a capacity of 290 tons, and a tailrace-gate gantry crane with a capacity of 10 tons would be needed. The transformers would be on a deck between the powerhouse and the penstocks, with the switchyard across the river. It is estimated that this project would take three years to construct. The design and the cost estimate were prepared by the Board without consultation with the owners of the existing developments on the Kootenay River. Details of the investment and annual costs are shown in Table 19.

151. ADDITIONS TO BRILLIANT PLANT. When the Brilliant plant was constructed in 1944, a setting for a fourth unit was included. In the three plans of development it has been assumed that the fourth unit would be installed. The additional cost for this turbine and generator and appurtenant works has been estimated by the Board to be $2,399,000. Details are shown in Table 20.

152. In the Non-Diversion and Copper Creek Diversion Plans, a fifth unit could be utilized at Brilliant. This would require a new powerhouse and alterations to the south end of the existing spillway, as shown on Plate 20. The most easterly of the eight existing spillway bays would be reconstructed to provide the intake works for the penstock for the fifth unit.

153. The construction work would be carried out by building two timber crib cofferdams and dewatering the spillway tailrace area. A spillway training wall at the east end of the revised spillway, the piers for an access bridge to the east powerhouse, and the east powerhouse tailrace piers and gate would have to be constructed before the downstream cofferdam could be

TABLE 19

Cost Estimate for Canal Plant

Preliminary	$ 500,000	
Access Roads	150,000	
Canal and Tunnel	8,509,000	
Powerhouse and Intakes	4,573,000	
Powerhouse Equipment	12,715,000	
Surge Spillway	141,000	
Flowage	160,000	
Operators' Colony	100,000	
Sub-Total	$26,848,000	
Engineering and Contingencies (15%)	4,027,000	
Sub-Total	$30,875,000	
Interest at 3% for ½ of 3 years	1,389,000	
Insurance and Administration (2¼%)	695,000	
Total Investment Cost		$32,959,000

Annual Cost

Amortization (.00887) $32,959,000		$ 292,000
Interest (.03) $32,959,000		989,000
Operation and Maintenance:		
a. Generating Units (3) $80,000	$ 240,000	
b. Canal Headgate (1) $8,000	8,000	
c. General (.002) $32,959,000	66,000	314,000
Interim Replacement (.0015) $32,959,000		49,000
Total Annual Cost		$ 1,644,000

TABLE 20

Cost Estimate for Additions to Brilliant

Fourth Unit

Field Construction Cost (Includes Turbine, Generator, Transformer, Switching Equipment, Switchyard, and Intake Gates)	$2,010,000	
Engineering and Contingencies (15%)	302,000	
Sub-Total	$2,312,000	
Interest at 3% for ½ of 1 year 1/	35,000	
Administration and Insurance (2¼%)	52,000	
Total Investment Cost		$2,399,000

Annual Cost

Amortization (.00887) $2,399,000		$ 21,000
Interest (.03) $2,399,000		72,000
Operation and Maintenance:		
a. Generating Unit (1) $80,000	$ 80,000	
b. General (.002) $2,399,000	5,000	85,000
Interim Replacement (.0015) $2,399,000		4,000
Total Annual Cost		$ 182,000

1/ In estimate for Canal Plant and fourth and fifth unit at Brilliant, a two-year construction period was assumed, which would make the fourth unit investment cost $2,433,000 and annual cost $184,000.

removed. This work would have to be carried out during the low-flow winter months. On completion of the east training wall and the tailrace works, they could be used as a cofferdam during construction of the draft tubes, scroll case, penstock, and turbine setting.

154. The Francis turbine would have an output of 38,000 horsepower at full gate at a head of 78 feet, for which the generator output would be 27,000 kilowatts. Included in the cost estimates are provisions for a 260-ton-capacity powerhouse gantry crane and a 23-ton-capacity tailrace gantry crane. It is estimated that this addition would take two years to complete. The cost is shown in Table 21. The design and cost estimate were prepared by the Board without consultation with the owner of the existing power plant.

155. OTHER PROJECTS. Projects which were studied in possible alternative plans for development in the Kootenay Basin but for various reasons were not included in the selected plans of development are Gibraltar, Torrent, Wardner, Plumbob, Mile 204.9, Tunnel No. 8, and Katka. Brief descriptions of these projects follow.

156. Gibraltar. - This site is 17 miles upstream from Canal Flats in the narrow valley through which the river flows from the broad inter-mountain trench, through the western range of the Rocky Mountains to the Rocky Mountain Trench. On the left bank rock rises steeply from the river bank for 250 feet, then gradually for 400 feet. On the right bank rock rises abruptly from the water's edge for 500 feet, then dips to a saddle 300 feet above river level, thus providing a favourable spillway location. Beyond the saddle the rock again rises steeply. Bedrock in the river channel is covered by more than 200 feet of overburden. Advantages of the Gibraltar site are the possibility of a high-head project and the absence of relocation problems. Disadvantages are: a lower flow in the Kootenay River here than at sites farther downstream, hence less possibilities for flood control; unfavourable foundation conditions; and insufficient suitable construction material obtainable locally.

157. Torrent. - This site is 17 miles downstream from Canal Flats. A development over 90 feet high at Torrent would have to include a dam at either Canal Flats or more probably at Fairmont Hot Springs, north of Columbia Lake, to prevent waters of the Kootenay River from flowing north down the Columbia River. The Kootenay valley at Torrent is approximately 1,000 feet wide with rock on both sides. From the results of subsurface drilling the rock appears to slope downwards from the river banks in a shallow "V" shape, with about 200 feet of overburden at the centre. There is a possible spillway location on the right bank, but no subsurface exploration has yet been undertaken therein. The inclusion of Bull River project in the Non-Diversion Plan and Bull River - Luxor project in the Dorr Diversion Plan would flood out the Torrent project.

158. Wardner. - This site is one mile downstream from the settlement of Wardner. The valley bottom is about 3,000 feet wide and although there are numerous rock outcrops on both sides of the river, sand and gravel extend at least 200 feet below the ground surface. Investigations at Wardner were discontinued in favour of more intensive studies at the Bull River and Plumbob sites.

159. Plumbob. - This site is nine miles downstream from Wardner, where the Kootenay River flows south on the western edge of a flood plain about 2,000 feet wide and cut about 200 feet below the floor of the Rocky Mountain Trench. Although rock outcrops are found on both banks near the site as well as in the river, overburden is over 200 feet deep in places. This site would be flooded by either the Libby or the Dorr project in the three selected plans of development.

160. Mile 204.9. - This site is on the Kootenay River about 3 miles upstream from Libby, Montana. It would develop a gross head of 60 feet but in the selected plans of development favourable economic feasibility was not indicated.

TABLE 21

Cost Estimate for Additions to Brilliant

Fifth Unit

Preliminary	$ 30,000	
Dewatering	260,000	
Spillway Dam Alterations	141,000	
Headworks	310,000	
Penstock and Training Wall	214,000	
Powerhouse	887,000	
Powerhouse Equipment	1,869,000	
Switching	320,000	
Auxiliary Systems	80,000	
Access Bridge	320,000	
Sub-Total	$4,431,000	
Engineering and Contingencies (15%)	665,000	
Sub-Total	$5,096,000	
Interest at 3% for ½ of 2 years	153,000	
Insurance and Administration (2¼%)	115,000	
Total Construction Cost		$5,364,000

Annual Cost

Amortization (.00887) $5,364,000		$ 48,000
Interest (.03) $5,364,000		161,000
Operation and Maintenance:		
a. Generating Unit (1) $80,000	$ 80,000	
b. General (.002) $5,364,000	11,000	
		91,000
Interim Replacement (.0015) $5,364,000		8,000
Total Annual Cost		$ 308,000

161. Tunnel No. 8. - This site is at river mile 172.0 on the Kootenay River. It was investigated for high dams backing water into Canada; however these proposals would so seriously disrupt the economy of the valley that they were given no further consideration.

162. Katka. - This site is on the Kootenay River about three miles upstream from the mouth of the Moyie River. It would develop a gross head of 102 feet. In the selected plans of development, favourable economic feasibility was not indicated for this project.

DISCUSSION

163. The principal benefits of the projects selected for the Kootenay Basin would be the development of large blocks of hydro-electric power in the Columbia Basin system, and the contribution by storage to the control of major floods on the Kootenay River between Bonners Ferry and Kootenay Lake and on the Columbia River downstream from The Dalles. These benefits are considered in detail in the Main Report and in Appendix VI. There would also be incidental effects which, though of minor importance in the over-all system, would be of importance in the Kootenay Basin. These effects are discussed briefly in the following paragraphs.

164. The construction of storage projects on the Kootenay River would provide some benefit to navigation on Kootenay Lake and the West Arm by decreasing to some degree the annual variation in lake levels.

165. There would be very minor benefits to flood control in the basin, except in the Bonners Ferry area, where any one of the selected plans would reduce flood flows to about 60,000 cubic feet per second, the estimated maximum non-damaging flood flow.

166. The possibilities for reclaiming additional wet lands along the Kootenay River between Bonners Ferry and Kootenay Lake would be facilitated to some extent after the upstream storage in the basin had been developed.

167. No detailed studies were made of other water uses. Water requirements for domestic, industrial, and irrigation uses are very minor at present; and, even with major expansion, these uses would be small compared with the available supply.

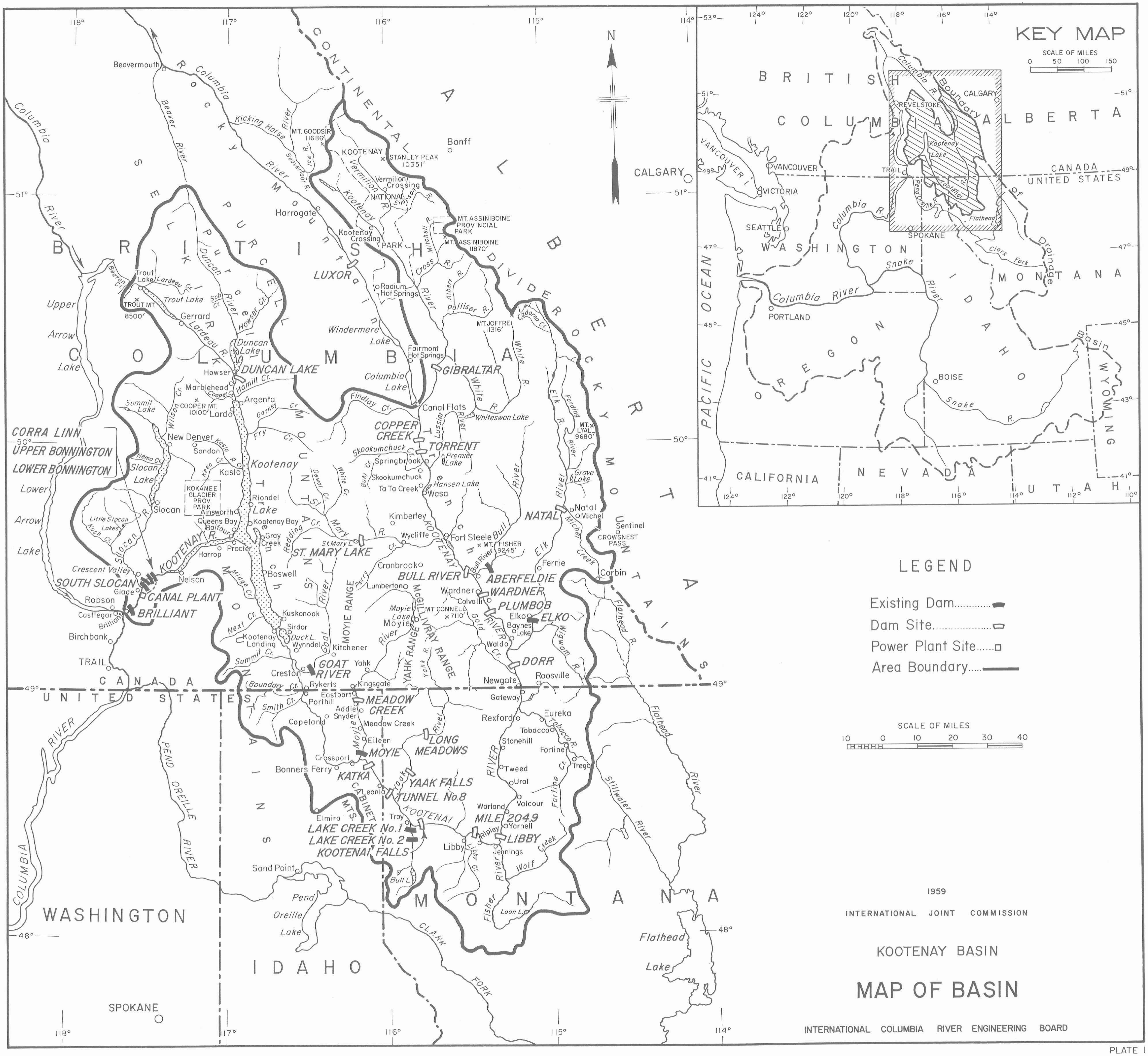
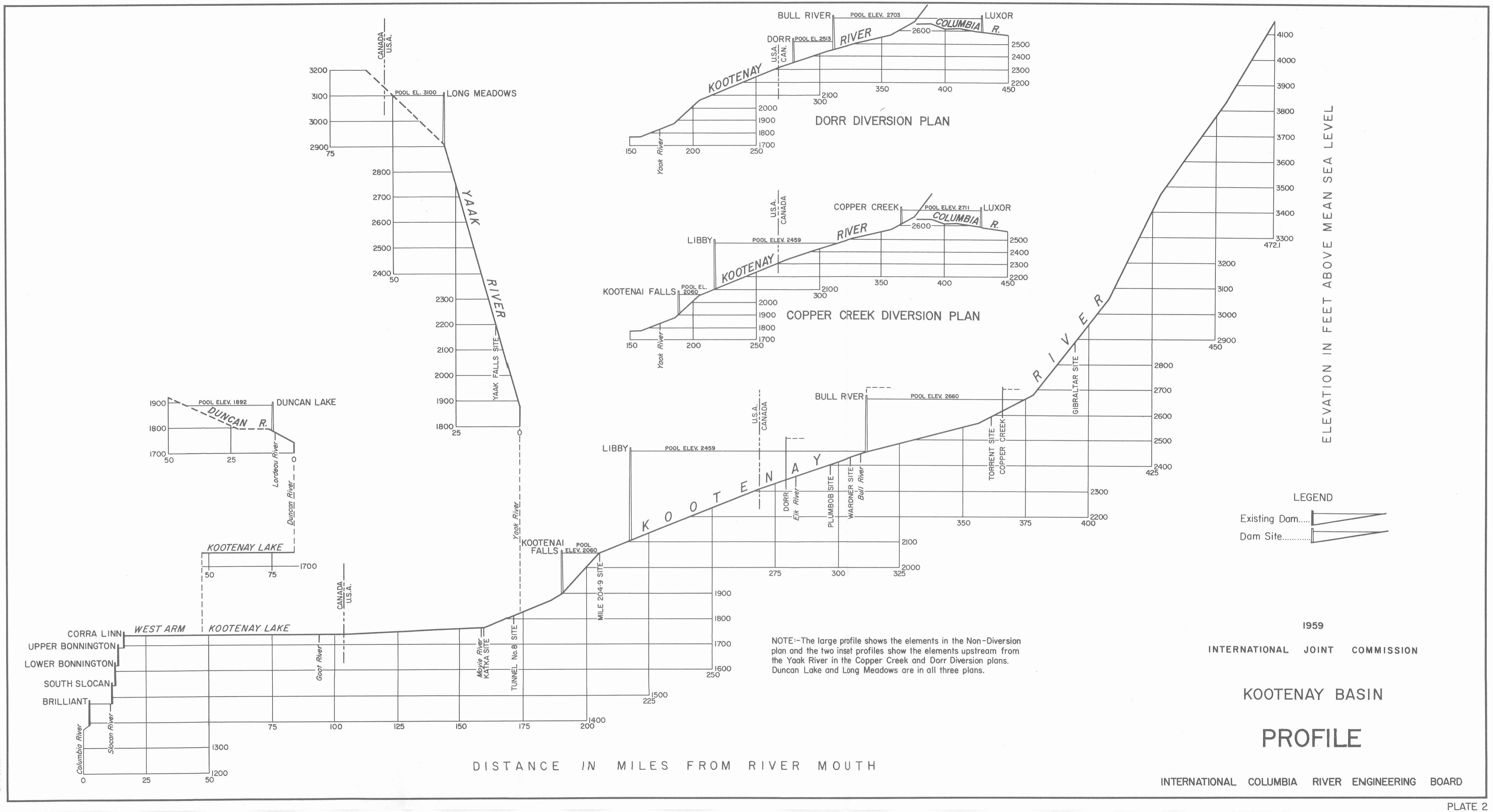
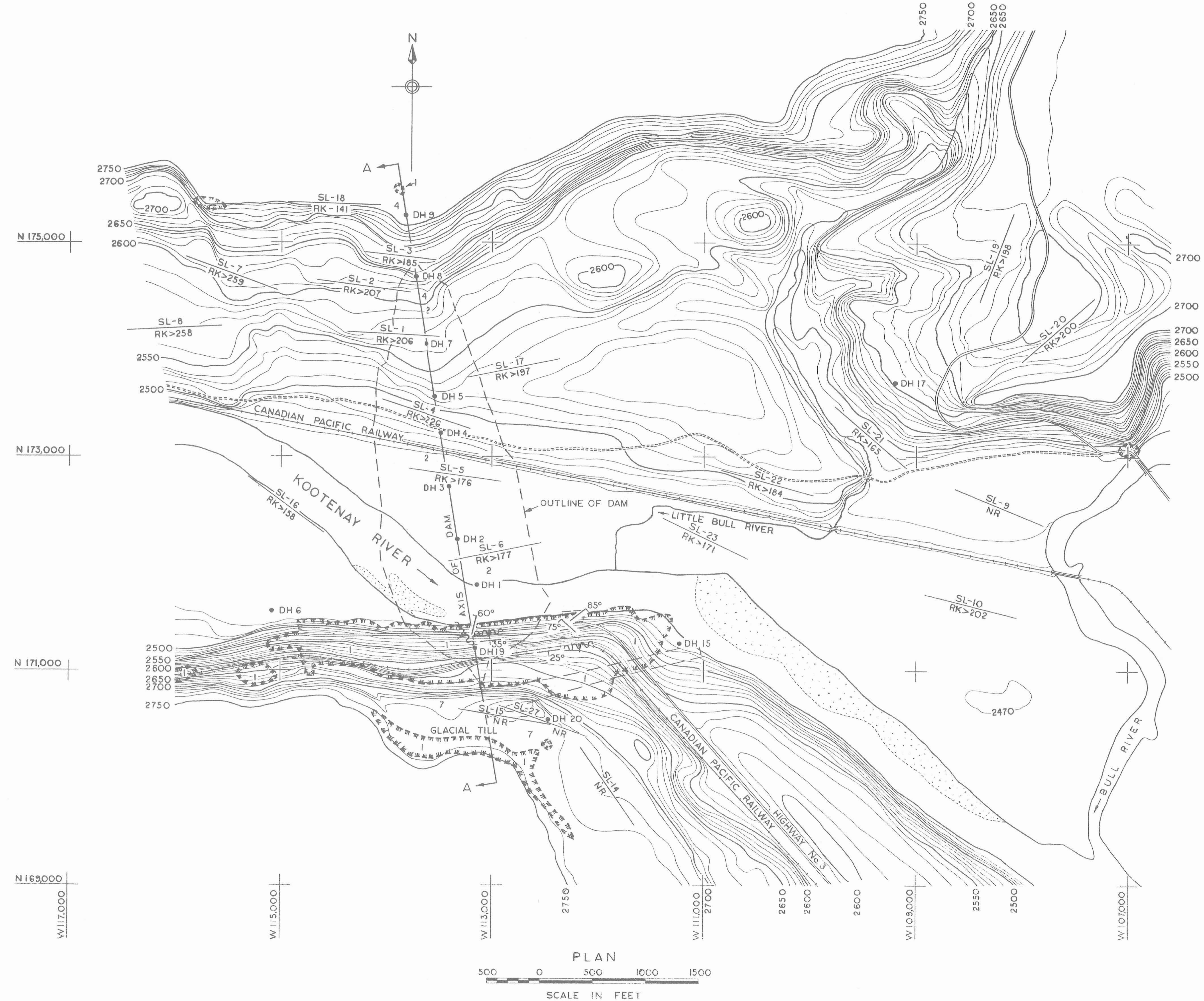

KEY MAP
SCALE OF MILES
0 50 100 150
BRITISH COLUMBIA
ALBERTA
CANADA
UNITED STATES
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
CALIFORNIA
NEVADA
UTAH
PACIFIC OCEAN
VANCOUVER
VICTORIA
SEATTLE
PORTLAND
SPOKANE
BOISE
CALGARY
REVELSTOKE
TRAIL
Columbia R.
Snake R.
Clark Fork
Kootenay Lake
Boundary of Columbia Drainage Basin
LEGEND
Existing Dam
Dam Site
Power Plant Site
Area Boundary
SCALE OF MILES
10 0 10 20 30 40
1959
INTERNATIONAL JOINT COMMISSION
KOOTENAY BASIN
MAP OF BASIN
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD
BRITISH COLUMBIA
ALBERTA
CONTINENTAL DIVIDE
ROCKY MOUNTAINS
SELKIRK MOUNTAINS
PURCELL MOUNTAINS
CANADA
UNITED STATES
WASHINGTON
IDAHO
MONTANA
CABINET MTS.
CALGARY
Banff
SPOKANE
DUNCAN LAKE
CORRA LINN
UPPER BONNINGTON
LOWER BONNINGTON
SOUTH SLOCAN
CANAL PLANT
BRILLIANT
LUXOR
GIBRALTAR
COPPER CREEK
TORRENT
ST. MARY LAKE
BULL RIVER
ABERFELDIE
WARDNER
PLUMBOB
ELKO
NATAL
DORR
GOAT RIVER
MEADOW CREEK
LONG MEADOWS
MOYIE
KATKA
YAAK FALLS
TUNNEL No.8
MILE 204.9
LIBBY
LAKE CREEK No.1
LAKE CREEK No.2
KOOTENAI FALLS
Kootenay Lake
Columbia Lake
Windermere Lake
Upper Arrow Lake
Lower Arrow Lake
Pend Oreille Lake
Flathead Lake
Nelson
Kaslo
Cranbrook
Kimberley
Fernie
Creston
Bonners Ferry
Libby
Troy
Eureka
TRAIL

PLATE I



DORR DIVERSION PLAN
BULL RIVER
POOL ELEV. 2703
LUXOR
COLUMBIA R.
DORR
POOL EL. 2513
KOOTENAY RIVER
U.S.A. CAN.
Yaak River
COPPER CREEK DIVERSION PLAN
COPPER CREEK
POOL ELEV. 2711
LIBBY
POOL ELEV. 2459
KOOTENAI FALLS
POOL EL. 2060
U.S.A. CANADA
CANADA U.S.A.
LONG MEADOWS
POOL EL. 3100
YAAK RIVER
YAAK FALLS SITE
DUNCAN LAKE
POOL ELEV. 1892
DUNCAN R.
Lardeau River
Duncan River
KOOTENAY LAKE
WEST ARM
CORRA LINN
UPPER BONNINGTON
LOWER BONNINGTON
SOUTH SLOCAN
BRILLIANT
Columbia River
Slocan River
Goat River
Moyie River
KATKA SITE
TUNNEL No.8 SITE
MILE 204.9 SITE
KOOTENAI FALLS
POOL ELEV. 2060
LIBBY
POOL ELEV. 2459
DORR
Elk River
PLUMBOB SITE
WARDNER SITE
Bull River
BULL RIVER
POOL ELEV. 2660
TORRENT SITE
COPPER CREEK
GIBRALTAR SITE
KOOTENAY RIVER
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
DISTANCE IN MILES FROM RIVER MOUTH
LEGEND
Existing Dam.....
Dam Site..........
NOTE:-The large profile shows the elements in the Non-Diversion plan and the two inset profiles show the elements upstream from the Yaak River in the Copper Creek and Dorr Diversion plans. Duncan Lake and Long Meadows are in all three plans.
1959
INTERNATIONAL JOINT COMMISSION
KOOTENAY BASIN
PROFILE
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD
GPO 994250

PLATE 2



GEOLOGICAL LEGEND

UNCONSOLIDATED DEPOSITS
-ALLUVIAL AND GLACIAL DEPOSITS

GLACIAL TILL	7
GRAVEL AND SANDY GRAVEL; MINOR SAND, SILT AND CLAY	4
UNCONSOLIDATED DEPOSITS, UNCLASSIFIED	2

BEDROCK
-MISSISSIPPIAN

WARDNER FORMATION; GREY CRYSTALLINE LIMESTONE WITH CHERT NODULES	1
BEDDING	35°
SHEARING AND FAULTING VERTICAL	
JOINTING INCLINED	60°

LEGEND

DRILL HOLE	• DH 1
ROCK OUTCROP	
SEISMIC LINE AVERAGE DEPTH TO BEDROCK IS 141 FEET	SL-18 / RK-141
DEPTH TO BEDROCK GREATER THAN 177 FEET	SL-6 / RK>177
RESULTS ERRATIC	SL-14 / NR

1959

INTERNATIONAL JOINT COMMISSION

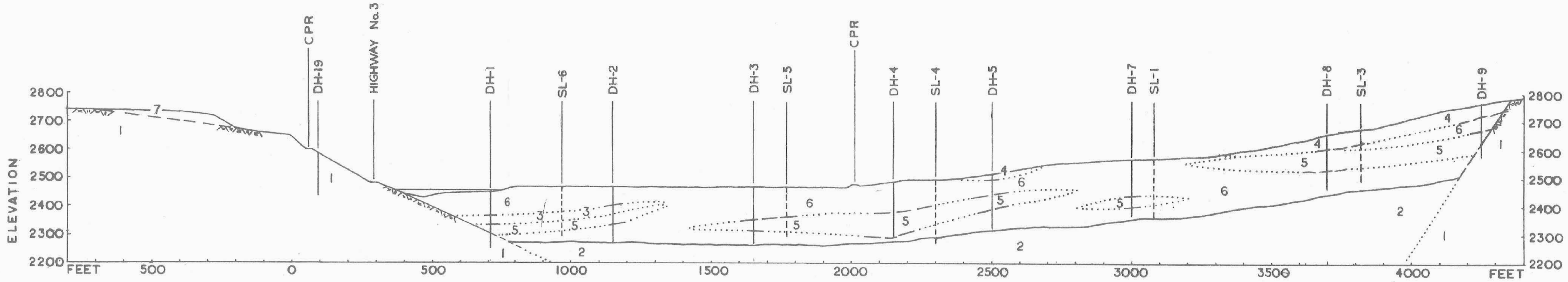
KOOTENAY BASIN

BULL RIVER

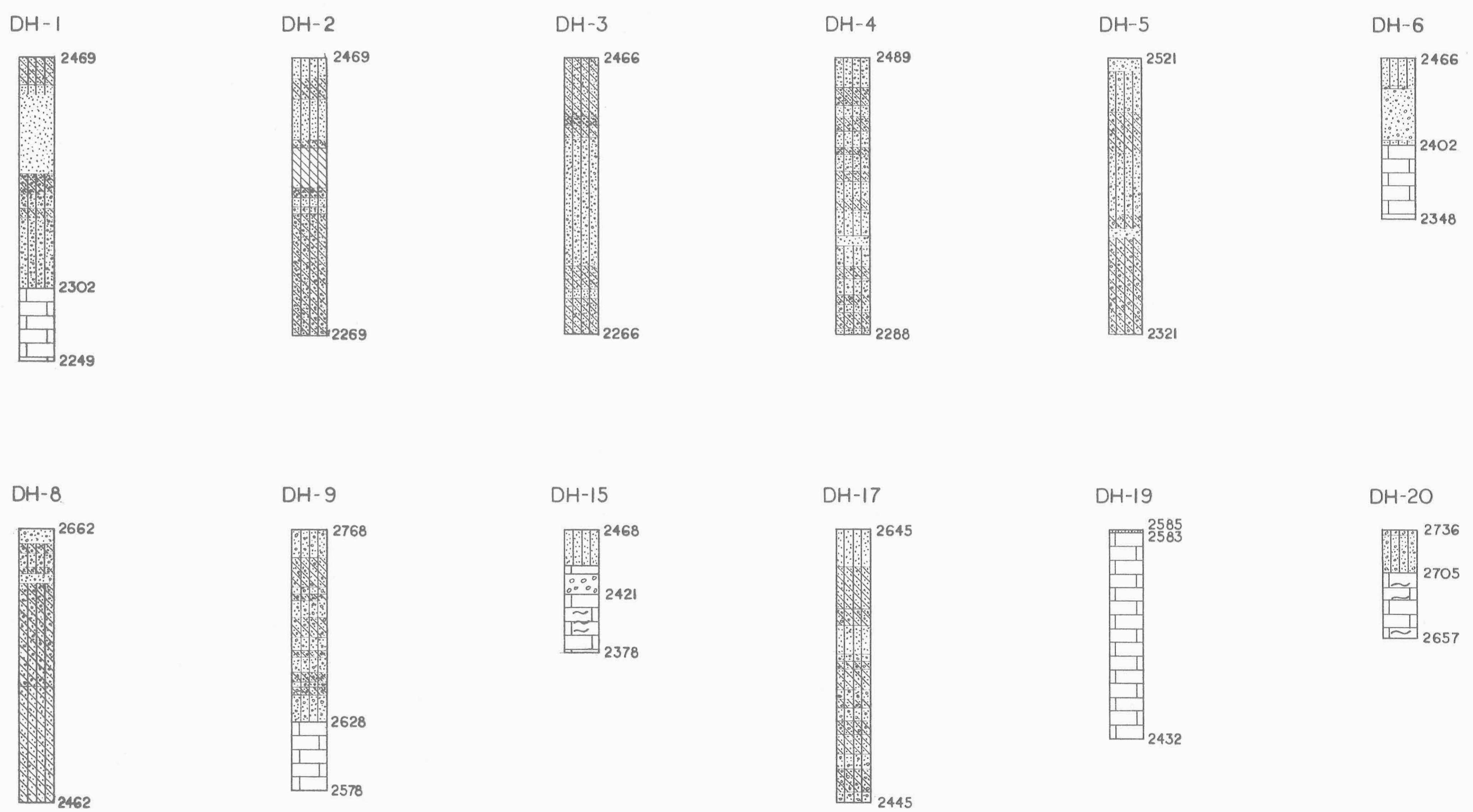
TOPOGRAPHY & EXPLORATION DATA

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

PLATE 3



SECTION A—A



LOGS OF DRILL HOLES

DRILL HOLE LEGEND

- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- CHERT AND SILICEOUS LIMESTONE

GEOLOGICAL LEGEND

UNCONSOLIDATED DEPOSITS
(ALLUVIAL AND GLACIAL DEPOSITS)

GLACIAL TILL	7
SAND, SILTY SAND, SANDY SILT, AND SILT; MINOR GRAVEL AND CLAY	6
SAND AND GRAVELLY SAND; MINOR GRAVEL, SILT AND CLAY	5
GRAVEL AND SANDY GRAVEL; MINOR SAND, SILT AND CLAY	4
CLAYEY SILT AND SILTY CLAY, MINOR SILT, SAND AND GRAVEL	3
UNCONSOLIDATED DEPOSITS UNCLASSIFIED, PROBABLY INCLUDES ALL DEPOSITS LISTED ABOVE	2

BEDROCK
(MISSISSIPPIAN)

WARDNER FORMATION; GREY CRYSTALLINE LIMESTONE WITH CHERT NODULES	1

GEOLOGICAL BOUNDARY

- DEFINED
- APPROXIMATE
- ASSUMED

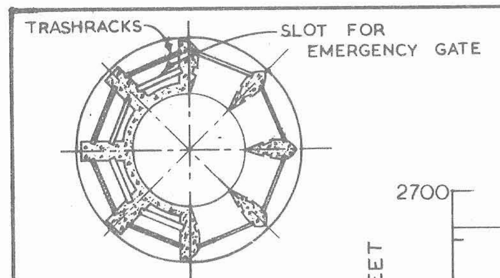
1959
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

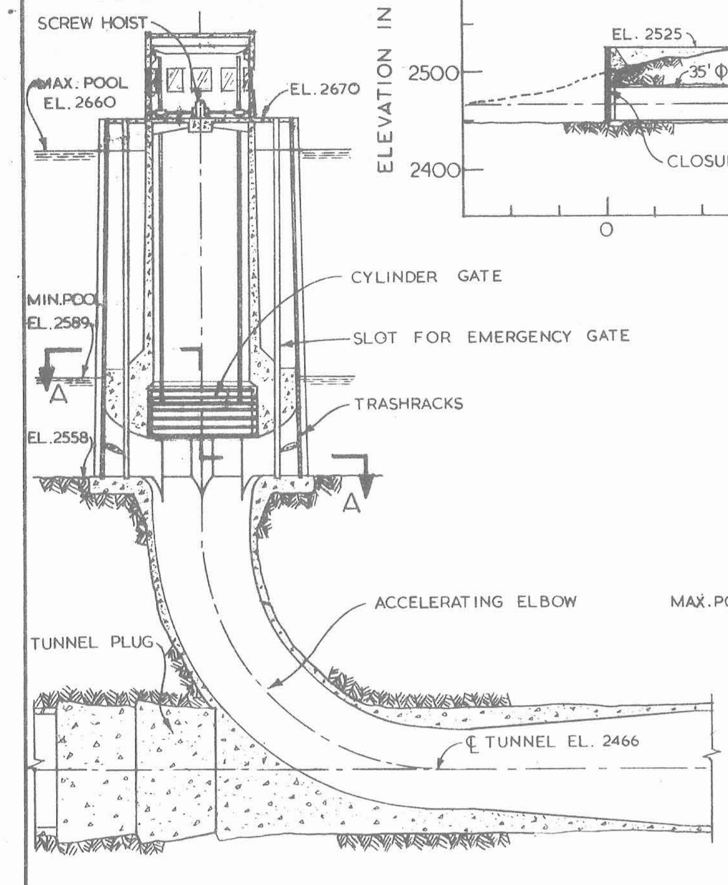
BULL RIVER GEOLOGICAL SECTION & LOGS OF DRILL HOLES

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

AREA IN 10,000 ACRES
MAX. POOL EL. 2660
AREA
STORAGE
MIN. POOL EL. 2589
2,794,000 AC-FT. USABLE
ELEVATION IN FEET
STORAGE IN 1,000,000 ACRE-FEET
AREA-STORAGE CURVES
LIBBY POOL EL. 2459
ELEVATION IN FEET
DISCHARGE IN 1000 C.F.S.
TAILWATER RATING CURVE
PROJECT DATA
NO. OF UNITS....2
TURBINE RATING......92,200 H.P.@158' NET DESIGN HEAD
GENERATOR RATING......67,000 K.W., 97.3 R.P.M.
PLANT CAPABILITY.....NP. 134,000 K.W., O.L. 154,000 K.W.
SPILLWAY DESIGN FLOOD......120,000 C.F.S.
USABLE STORAGE......2,794,000 AC.-FT.
N 175,000
N 173,000
N 171,000
N169,000
W 117,000
W 115,000
W 113,000
W 111,000
W 109,000
W 107,000
MAXIMUM POOL EL. 2660
MINIMUM POOL EL. 2589
UPSTREAM COFFERDAM TOP EL. 2525
EARTHFILL DAM TOP EL. 2670
DOWNSTREAM COFFERDAM TOP EL. 2480
LITTLE BULL RIVER
SWITCHYARD
TAILRACE
EL. 2445
TUNNEL PLUGS
INTAKE TOWER
EL. 2558
POWERHOUSE
2-35'Φ CONCRETE-LINED DIVERSION TUNNELS
TUNNEL PLUGS
CHUTE SPILLWAY
BRIDGE OVER SPILLWAY
ACCESS BRIDGE
EL. 2615
HIGHWAY NO. 3 (RELOCATED)
35'Φ CONCRETE-LINED POWER TUNNEL
C.P.R. (KETTLE VALLEY LINE) (RELOCATED)
SPILLWAY INTAKE
DIFFERENTIAL SURGE CHAMBER
21'Φ PENSTOCKS STEEL-LINED
RAILWAY SPUR
ACCESS ROAD
KOOTENAY RIVER
BULL RIVER
PLAN
SCALE IN FEET
1959
INTERNATIONAL JOINT COMMISSION
KOOTENAY BASIN
BULL RIVER
GENERAL ARRANGEMENT
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

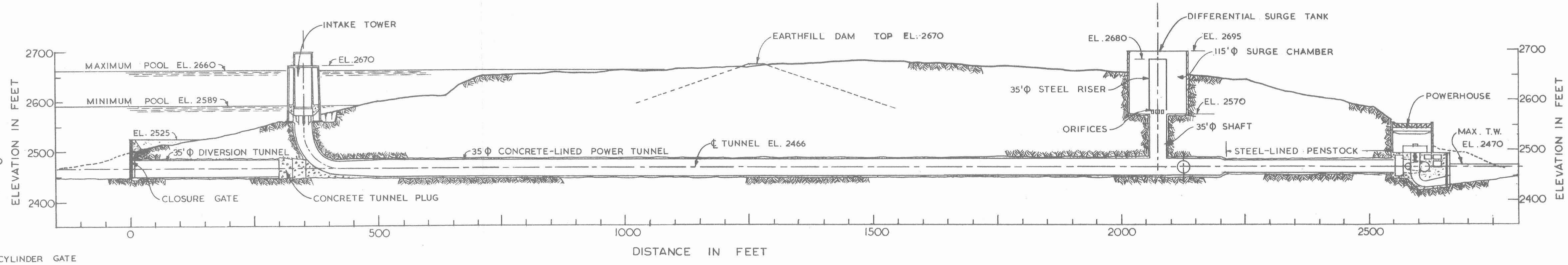


SECTION A-A



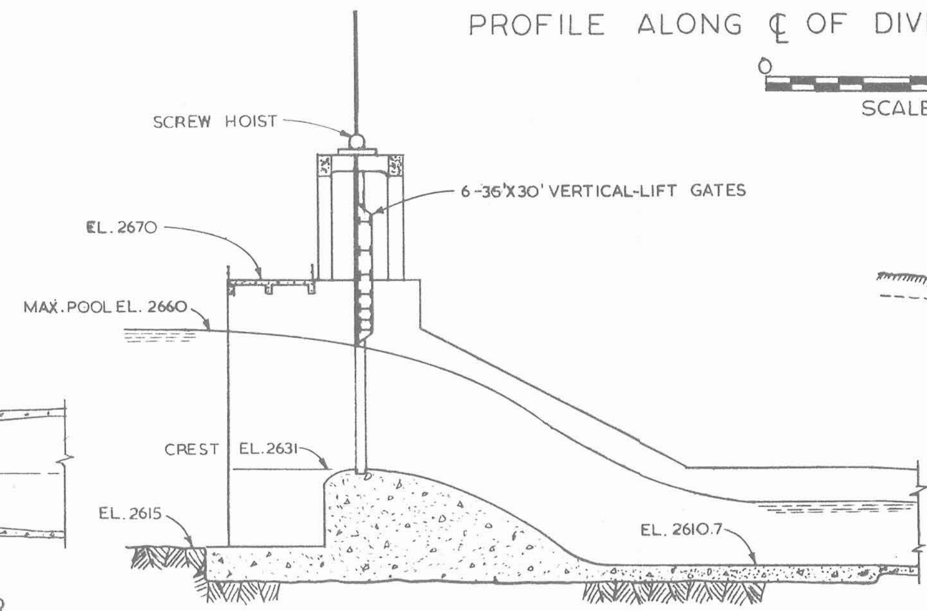
SECTION THROUGH INTAKE TOWER

0 60 120
SCALE IN FEET



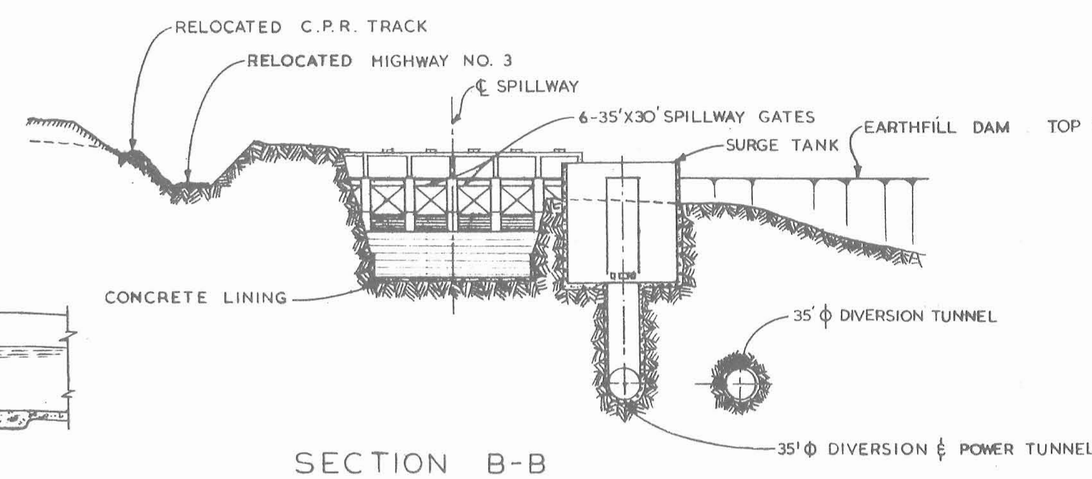
PROFILE ALONG ℄ OF DIVERSION AND POWER TUNNELS

0 200 400
SCALE IN FEET

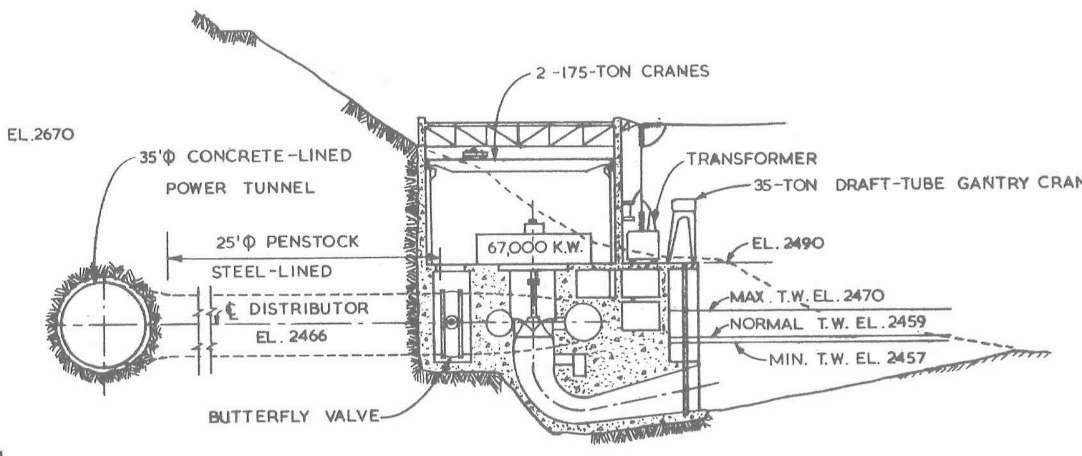


SPILLWAY CREST SECTION

0 40 80
SCALE IN FEET

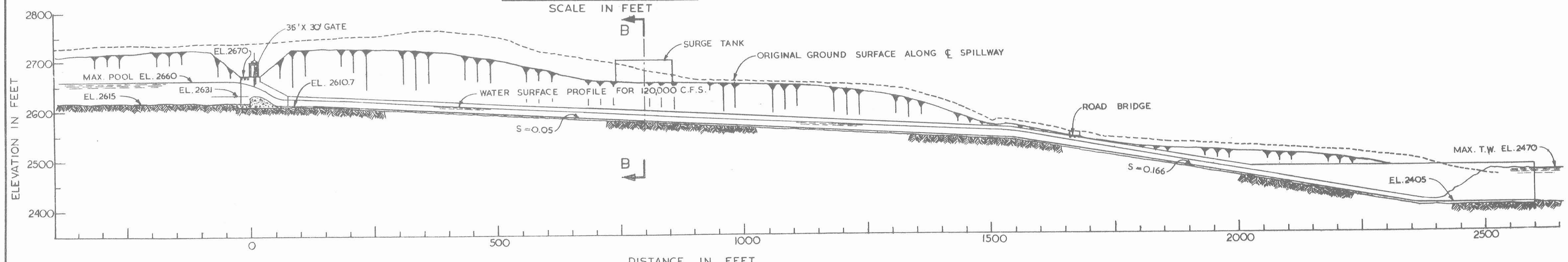


SECTION B-B



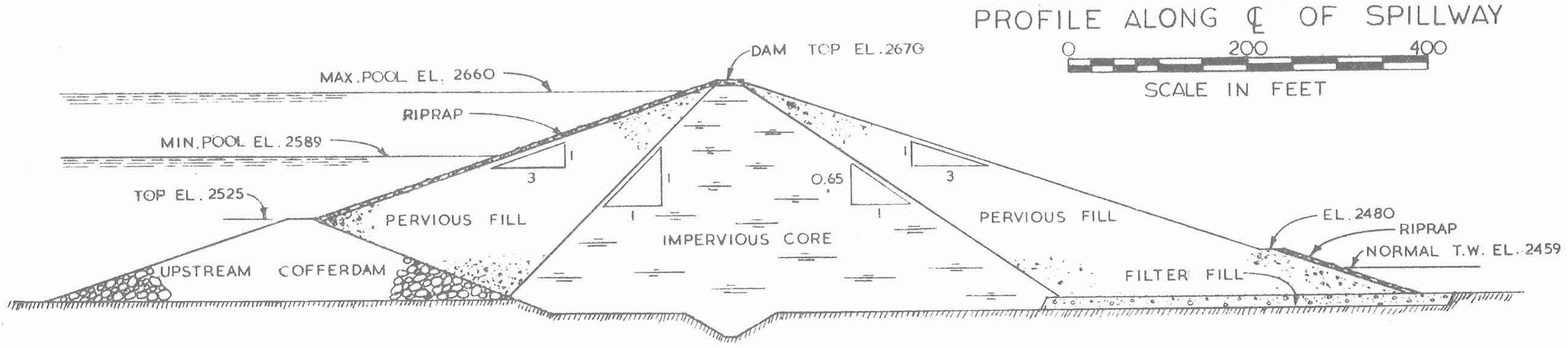
SECTION THROUGH POWERHOUSE

0 80 160
SCALE IN FEET



PROFILE ALONG ℄ OF SPILLWAY

0 200 400
SCALE IN FEET



TYPICAL EARTHFILL DAM SECTION

0 200 400
SCALE IN FEET

PROJECT DATA

NO OF UNITS	2
TURBINE RATING	92,200 H.P. @ 158' NET DESIGN HEAD
GENERATOR RATING	67,000 K.W. 97.3 R.P.M.
PLANT CAPABILITY	N.P. 134,000 K.W.; O.L. 154,000 K.W.
SPILLWAY DESIGN FLOOD	120,000 C.F.S.
USABLE STORAGE	2,794,000 AC-FT.

1959

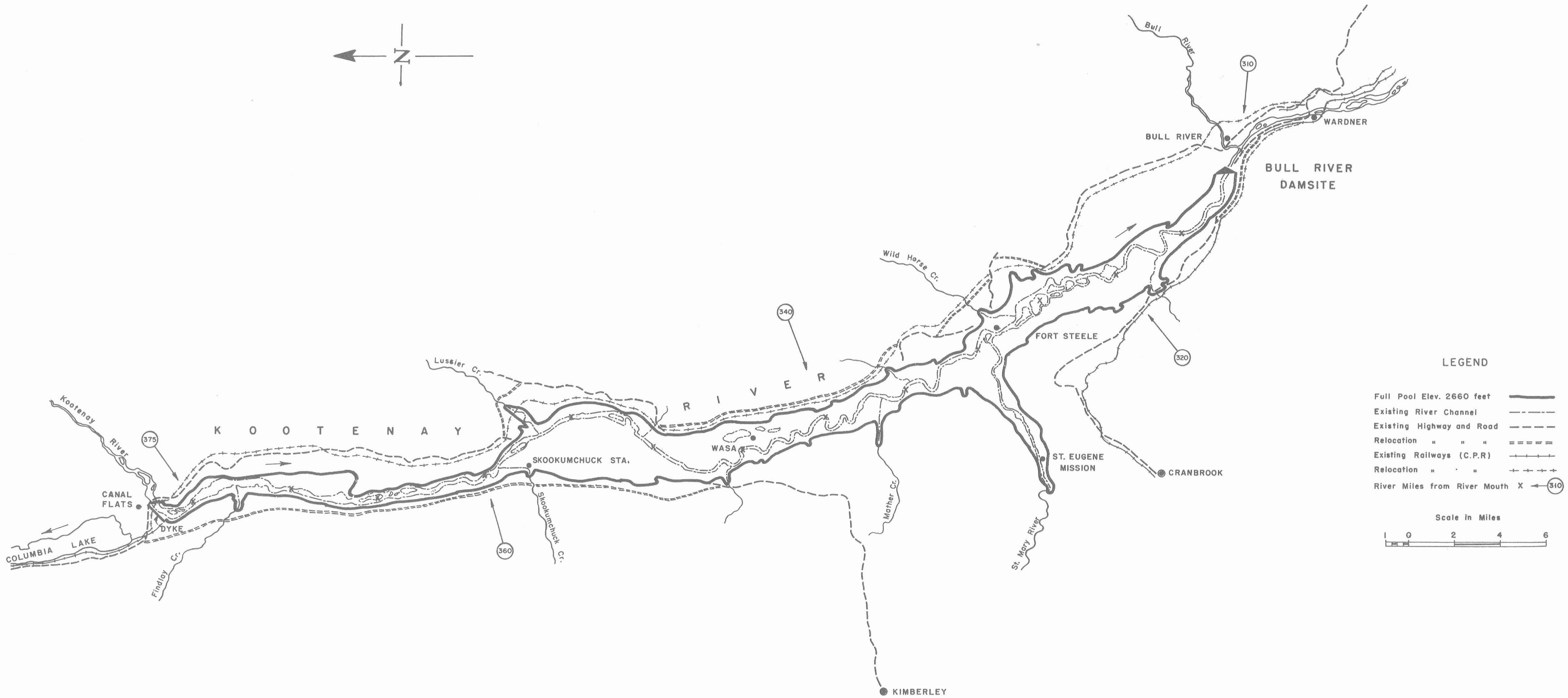
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

BULL RIVER

ELEVATIONS AND SECTIONS

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



Note: In Appendix II, Bull River Site is 311.0 river miles upstream from the mouth of the Kootenay River. In Appendix I, this site is 557.6 river miles from the International Boundary at Waneta.

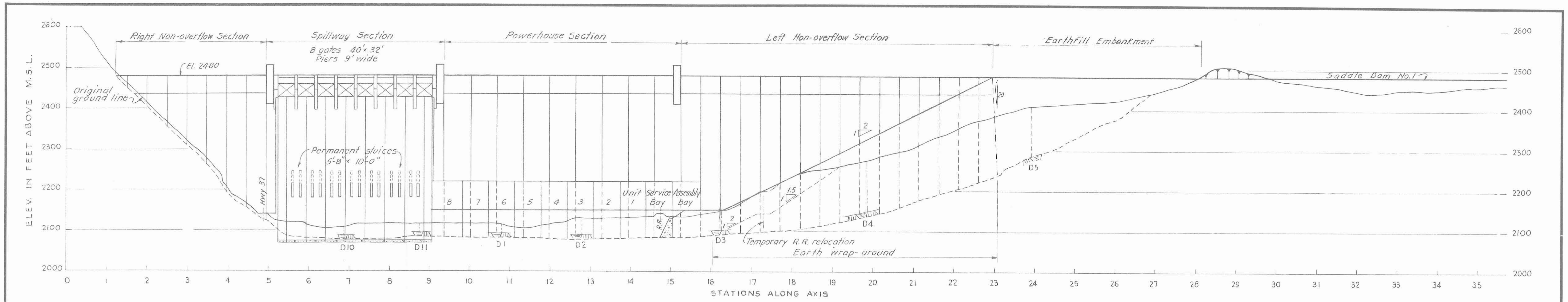
1959

INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

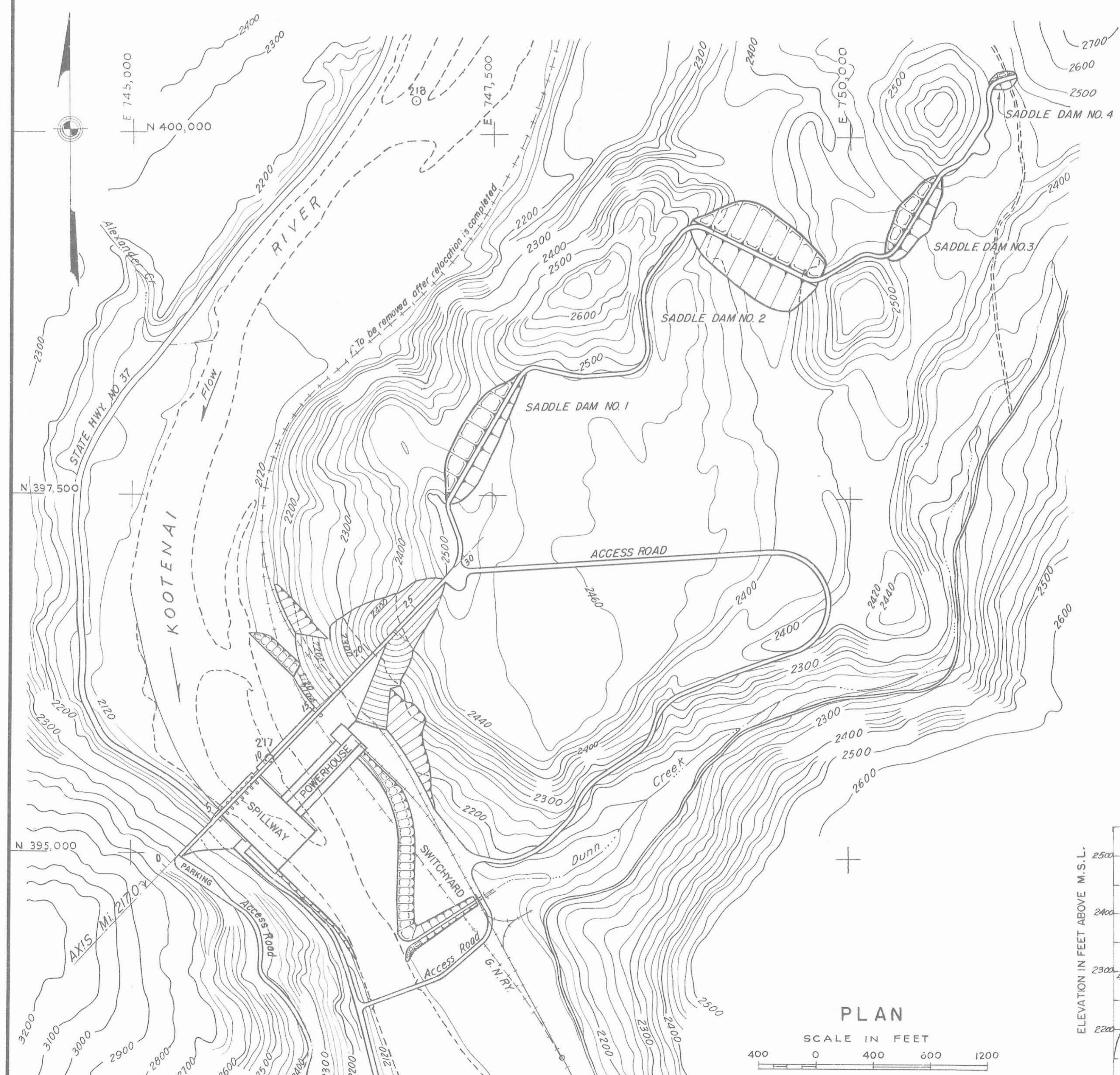
BULL RIVER RESERVOIR MAP

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



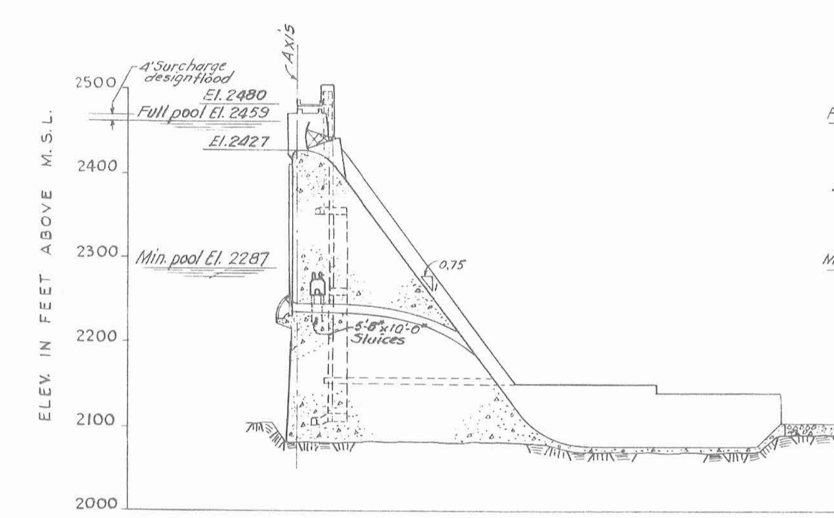
DOWNSTREAM ELEVATION

SCALE IN FEET
100 0 100 200 300

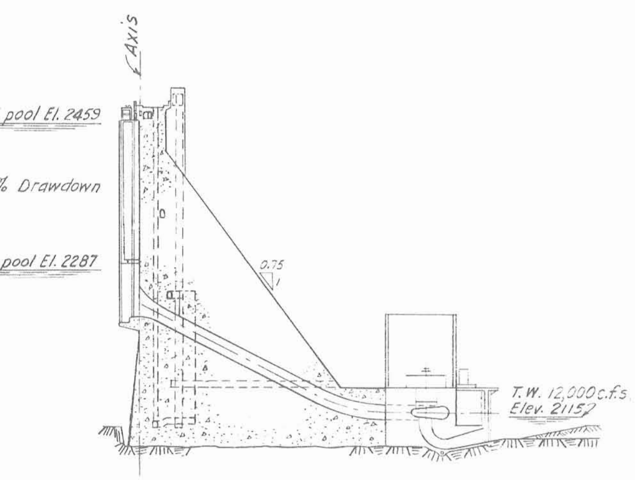


PLAN

SCALE IN FEET
400 0 400 800 1200

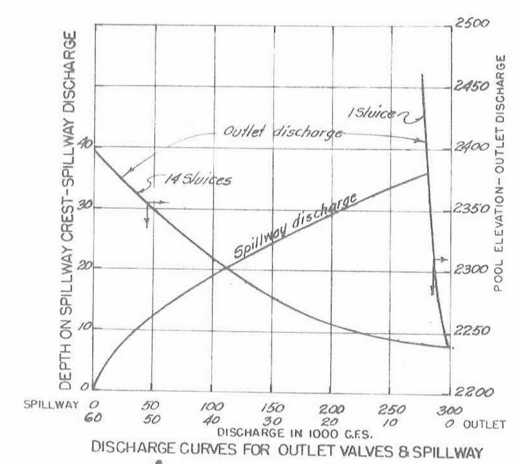


SECTION THRU SPILLWAY

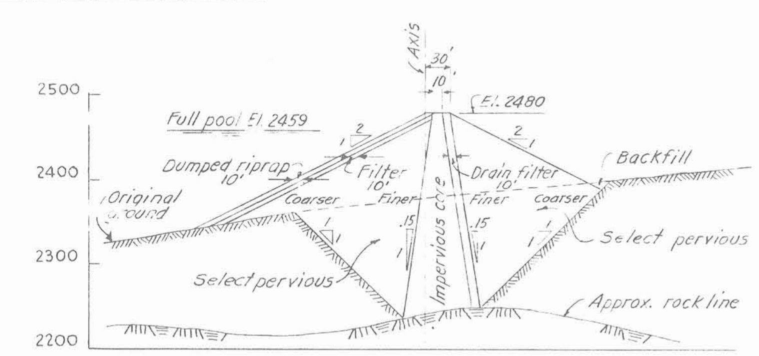


SECTION THRU INTAKE AND POWERHOUSE

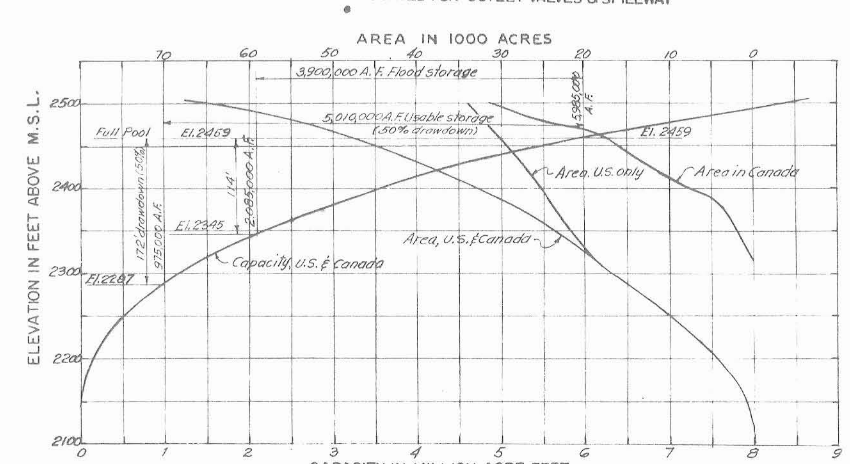
SCALE IN FEET
100 0 100 200 300



DISCHARGE CURVES FOR OUTLET VALVES & SPILLWAY



SECTION THRU EARTHFILL EMBANKMENT MAIN DAM



AREA - CAPACITY CURVES

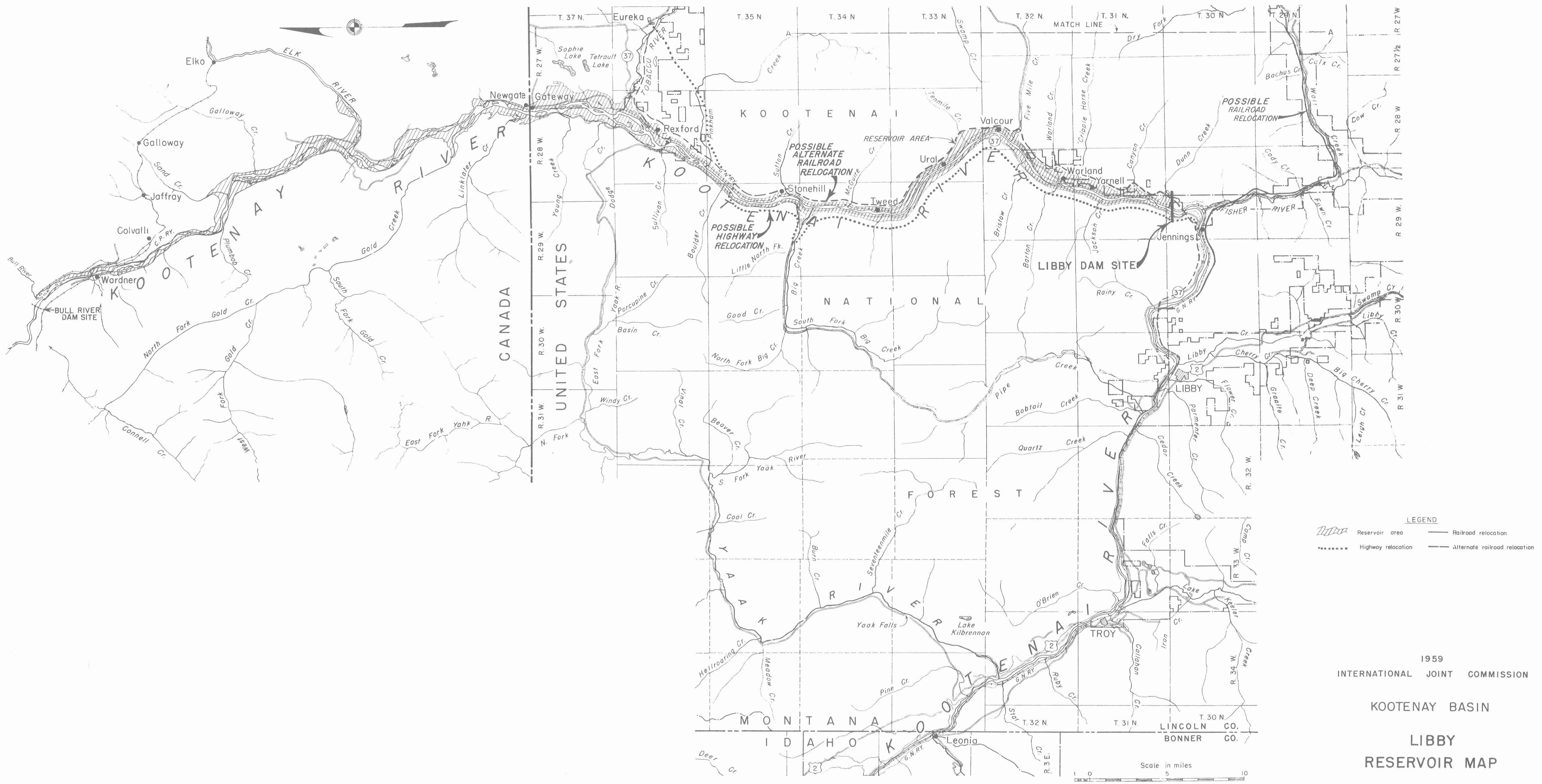
1959

INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

LIBBY
PLAN AND SECTIONS

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



1959

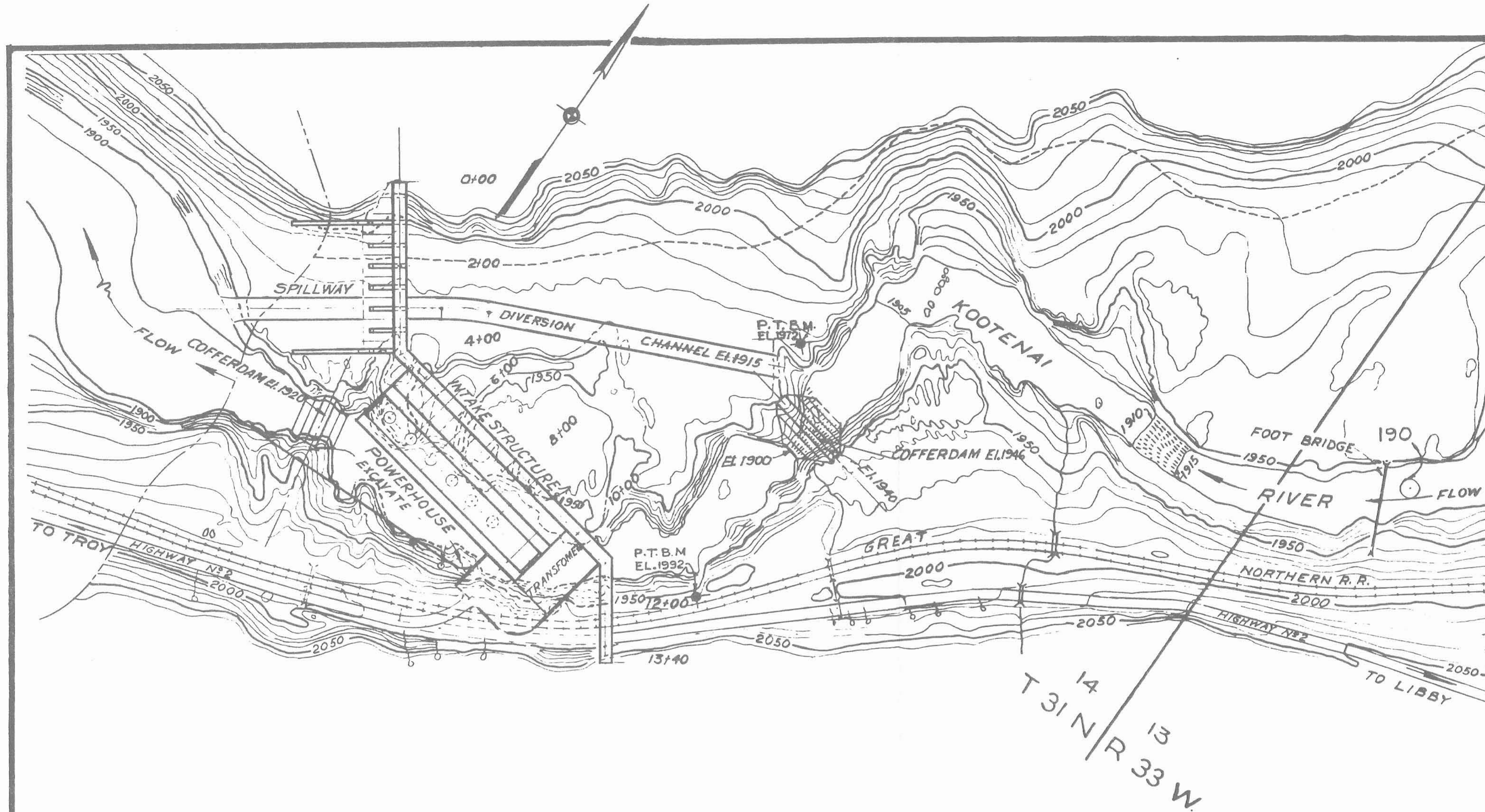
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

LIBBY RESERVOIR MAP

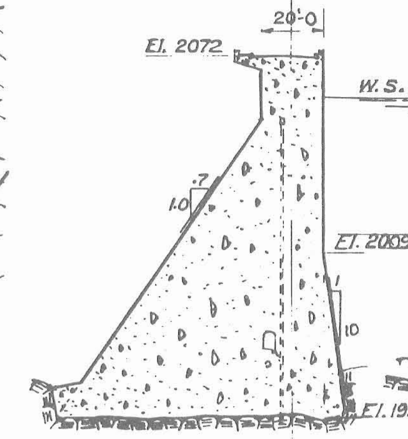
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

PLATE 9

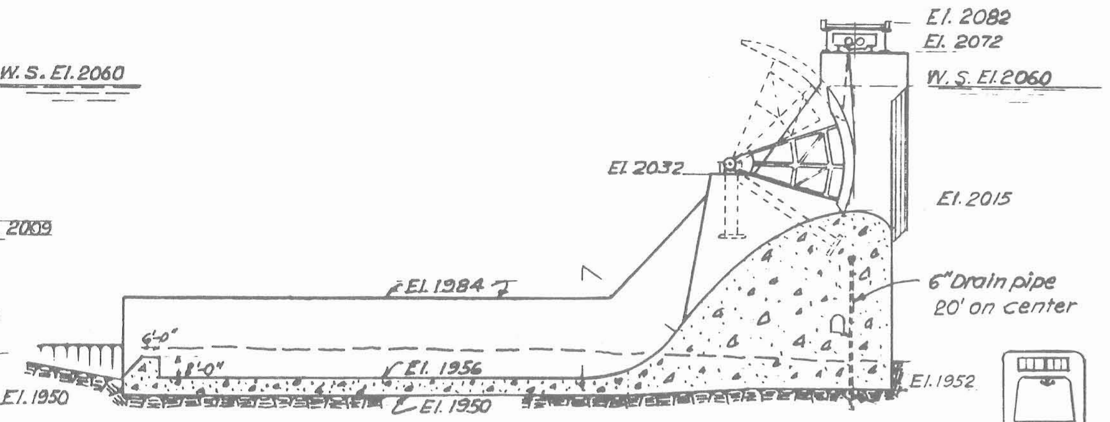


PLAN

Scale: 1" = 200'

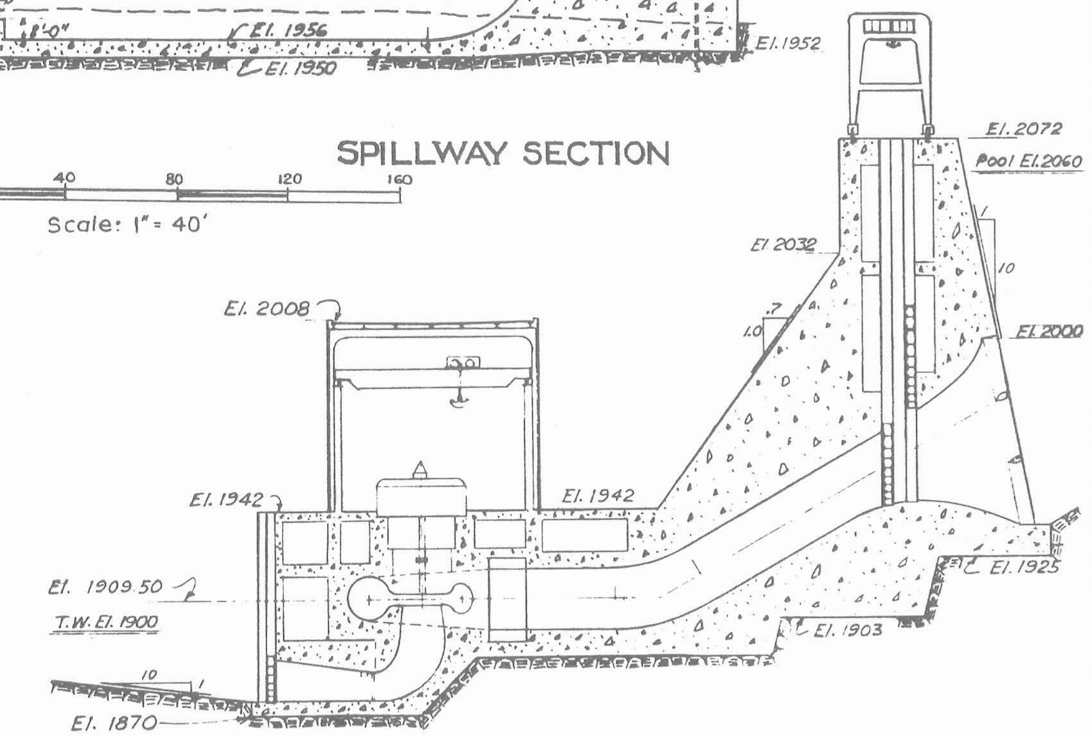


NONOVERFLOW SECTION



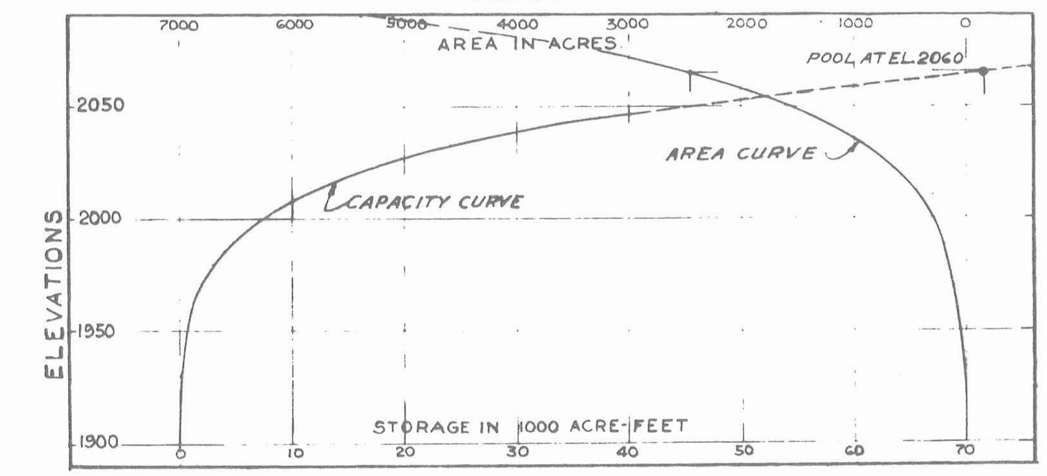
SPILLWAY SECTION

Scale: 1" = 40'

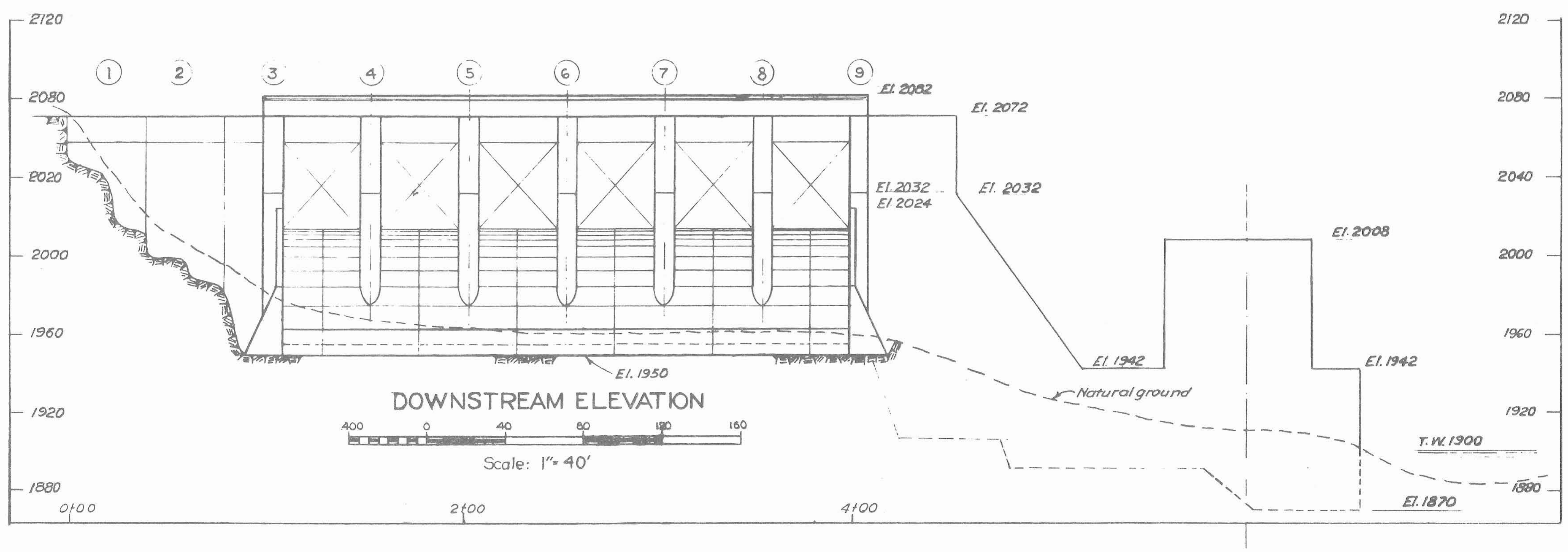


POWERHOUSE SECTION

Scale: 1" = 40'



AREA-CAPACITY CURVES.



DOWNSTREAM ELEVATION

Scale: 1" = 40'

LEGEND:
(5) Indicate No of Monolith

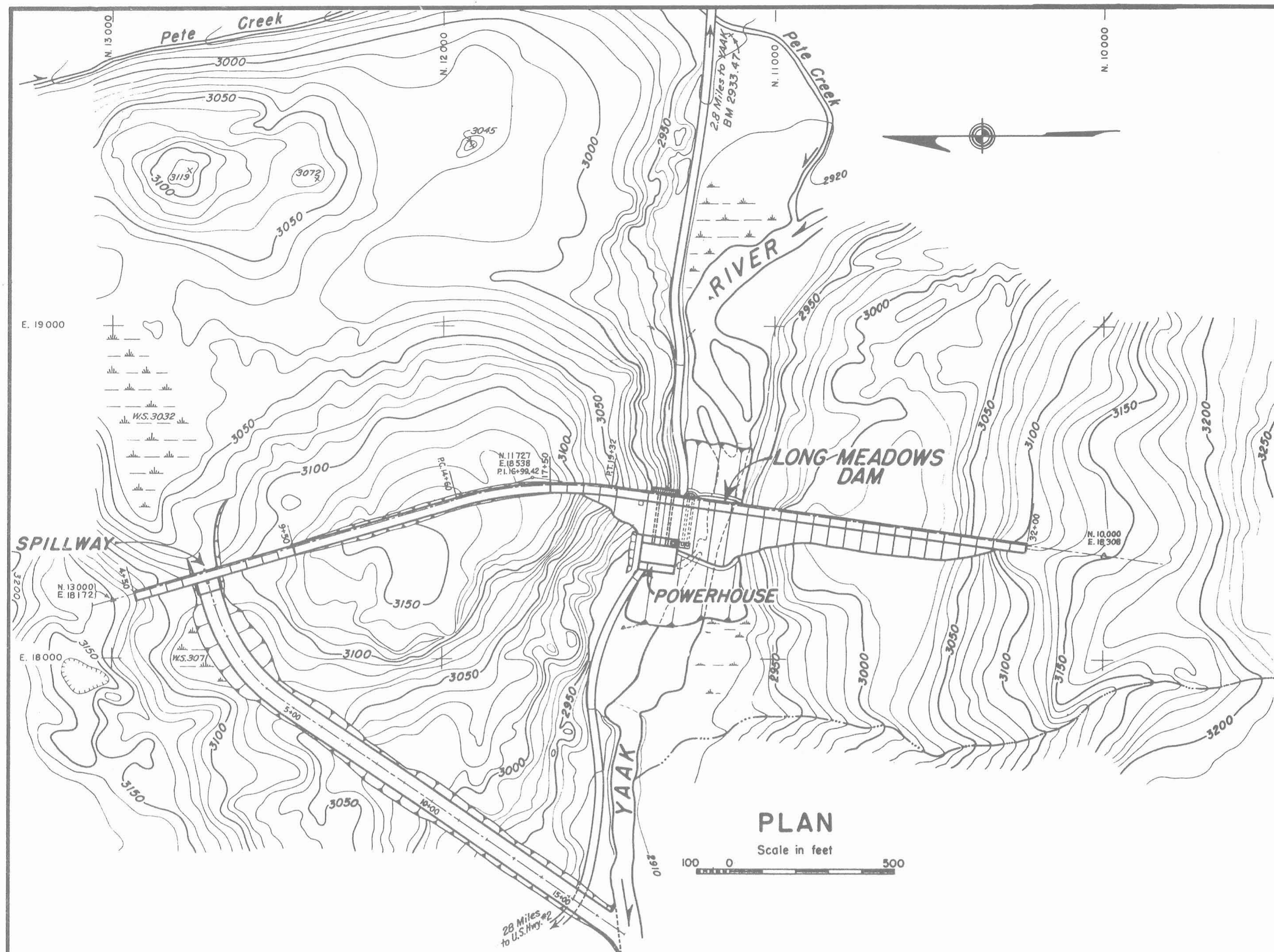
1959

INTERNATIONAL JOINT COMMISSION

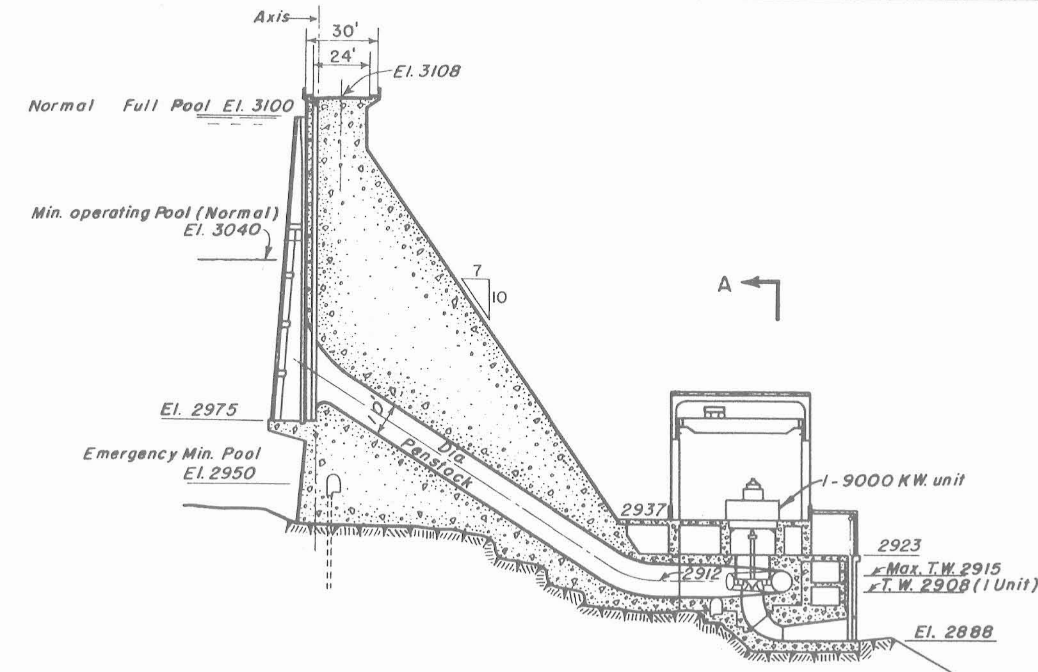
KOOTENAY BASIN

KOOTENAI FALLS
PLAN AND SECTIONS

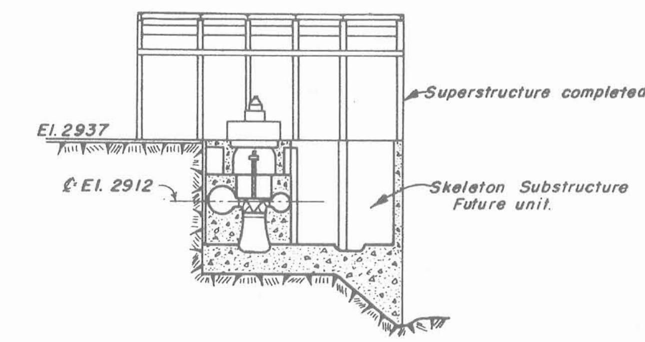
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



PLAN



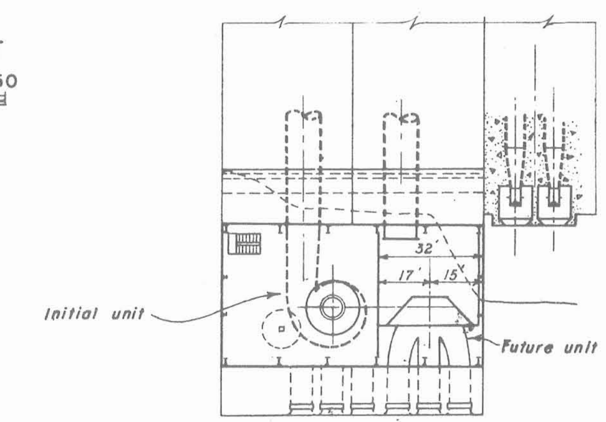
POWERHOUSE AND INTAKE DAM



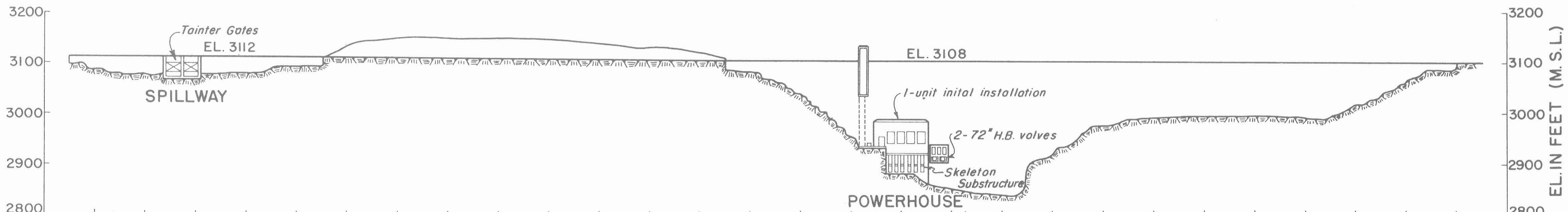
SECTION A-A

Note:
Topography (1956) taken from U.S.G.S. Yaak River, Montana, Sheets 2 & 3. Modified by Seattle District Axis Survey 1956 Dwg. D-8-8-236

SCALE IN FEET
50 0 50



PLAN
POWERHOUSE



DOWNSTREAM ELEVATION
SCALE IN FEET
100 0 500

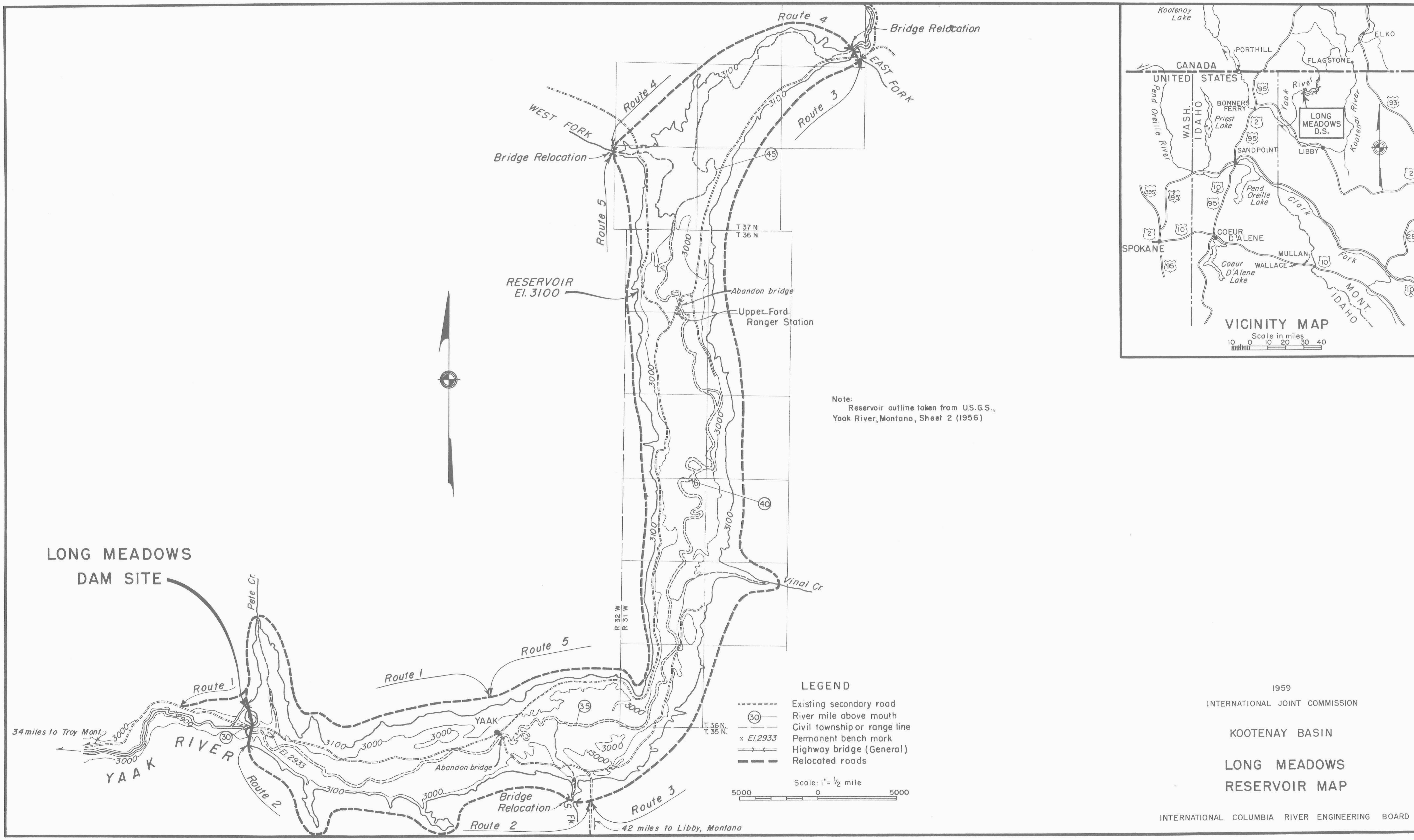
1959
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

LONG MEADOWS
PLAN AND SECTIONS

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

PLATE 11

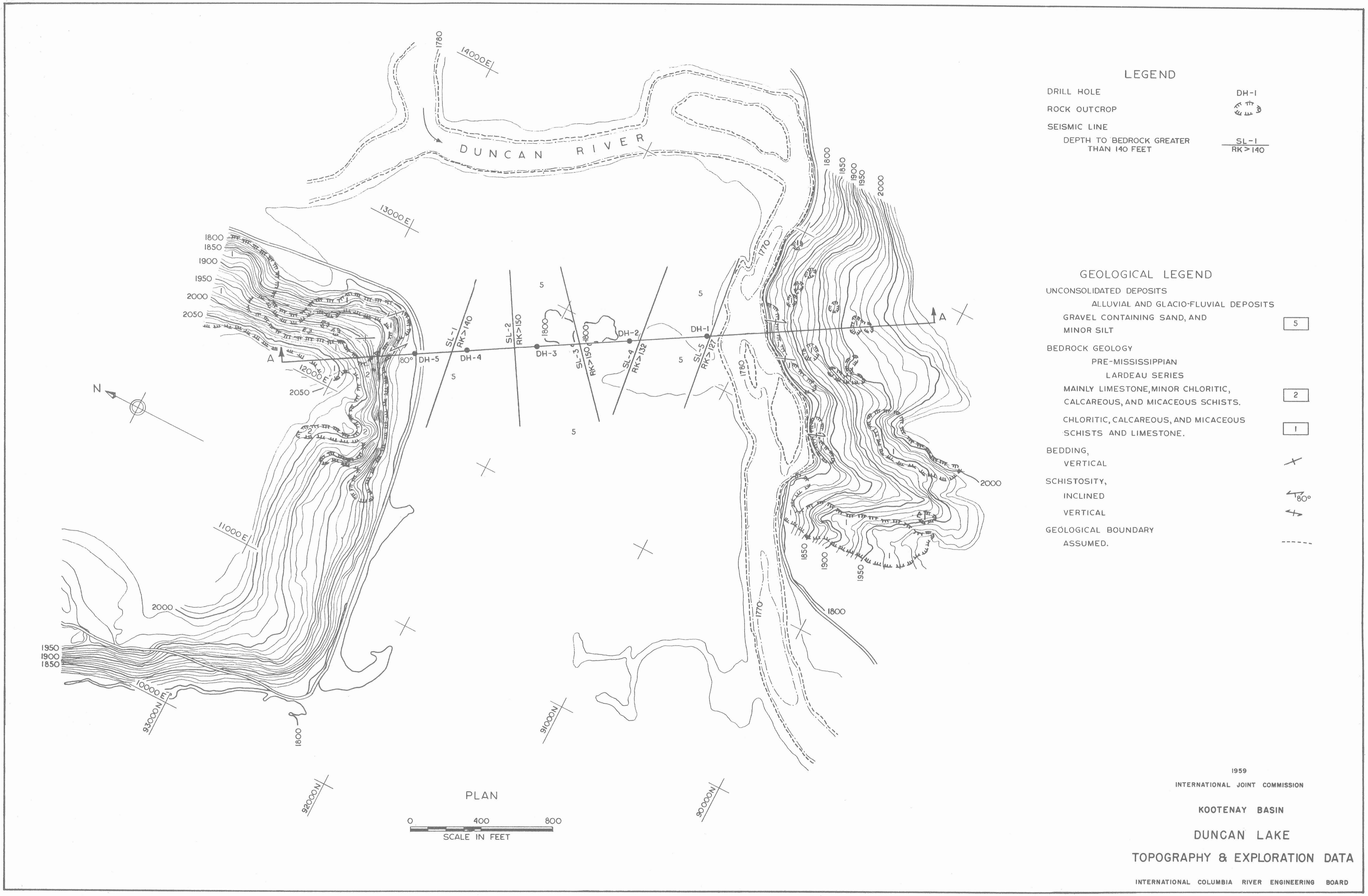


1959
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

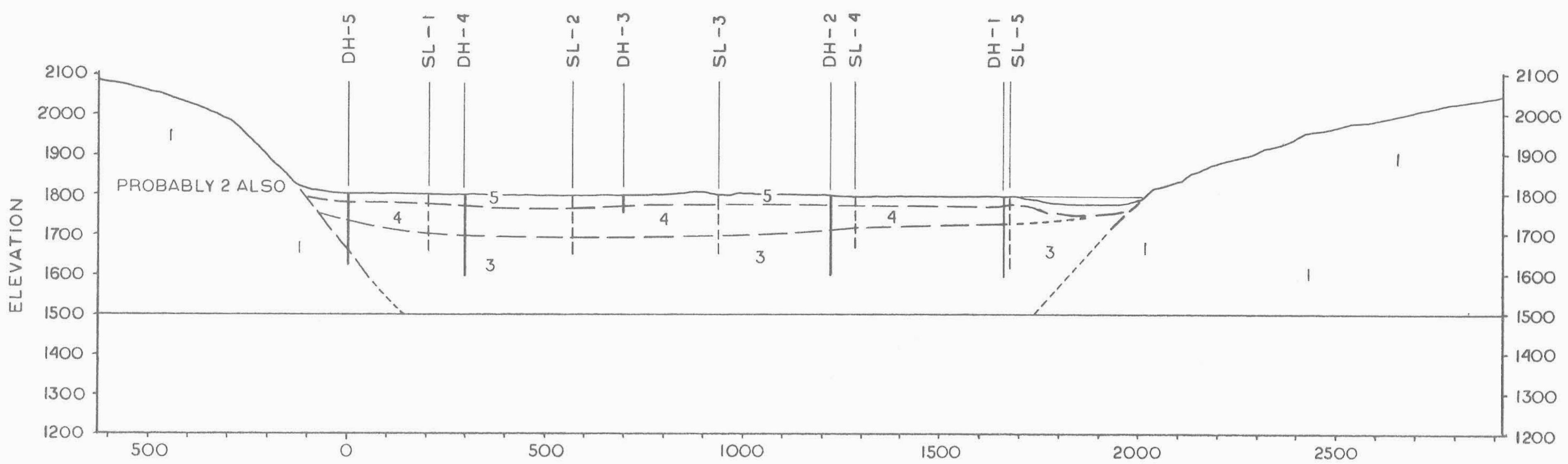
LONG MEADOWS
RESERVOIR MAP

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



DUNCAN RIVER
LEGEND
DRILL HOLE DH-1
ROCK OUTCROP
SEISMIC LINE
DEPTH TO BEDROCK GREATER THAN 140 FEET SL-1 RK>140
GEOLOGICAL LEGEND
UNCONSOLIDATED DEPOSITS
ALLUVIAL AND GLACIO-FLUVIAL DEPOSITS
GRAVEL CONTAINING SAND, AND MINOR SILT 5
BEDROCK GEOLOGY
PRE-MISSISSIPPIAN
LARDEAU SERIES
MAINLY LIMESTONE, MINOR CHLORITIC, CALCAREOUS, AND MICACEOUS SCHISTS. 2
CHLORITIC, CALCAREOUS, AND MICACEOUS SCHISTS AND LIMESTONE. 1
BEDDING, VERTICAL
SCHISTOSITY, INCLINED 80°
VERTICAL
GEOLOGICAL BOUNDARY ASSUMED.
SL-1 RK>140
SL-2 RK>150
SL-3 RK>150
SL-4 RK>132
SL-5 RK>127
DH-1
DH-2
DH-3
DH-4
DH-5
A
A
PLAN
0 400 800
SCALE IN FEET
1959
INTERNATIONAL JOINT COMMISSION
KOOTENAY BASIN
DUNCAN LAKE
TOPOGRAPHY & EXPLORATION DATA
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

PLATE 13



SECTION A-A

GEOLOGICAL LEGEND

UNCONSOLIDATED DEPOSITS
(ALLUVIAL AND GLACIO-FLUVIAL DEPOSITS)

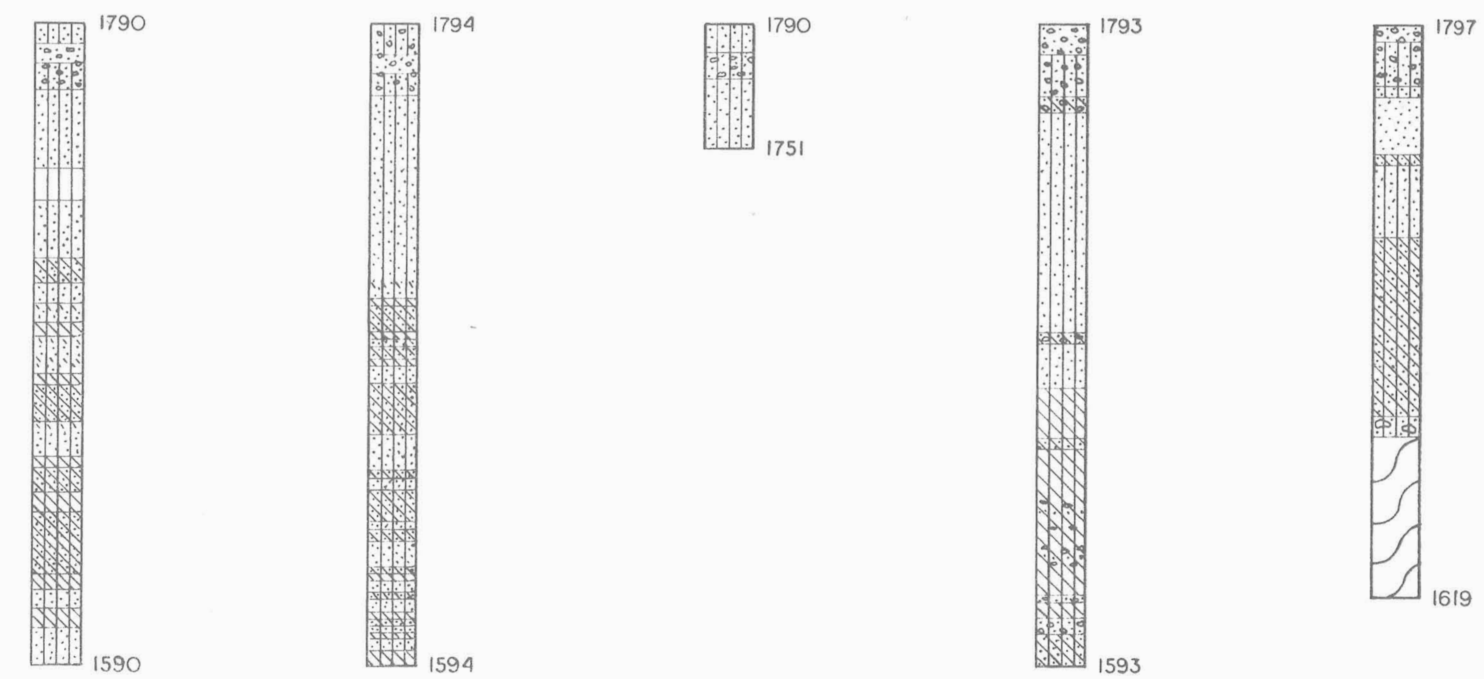
- GRAVEL CONTAINING SAND, AND MINOR SILT — 5
- SANDY SILT AND SILTY SAND — 4
- SILT, SANDY SILT, CLAYEY SILT, SILTY CLAY, AND SILTY SAND. — 3

BEDROCK GEOLOGY
PRE-MISSISSIPPIAN
LARDEAU SERIES

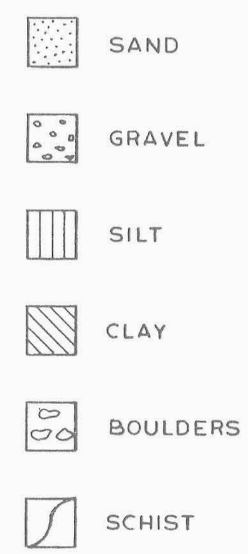
- CHLORITIC, CALCAREOUS, AND MICACEOUS SCHIST, AND LIMESTONE — 1
- MAINLY LIMESTONE, MINOR CHLORITIC, CALCAREOUS AND MICACEOUS SCHISTS. — 2

GEOLOGICAL BOUNDARY

- APPROXIMATE — — —
- ASSUMED - - - - - -



DRILL HOLE LEGEND



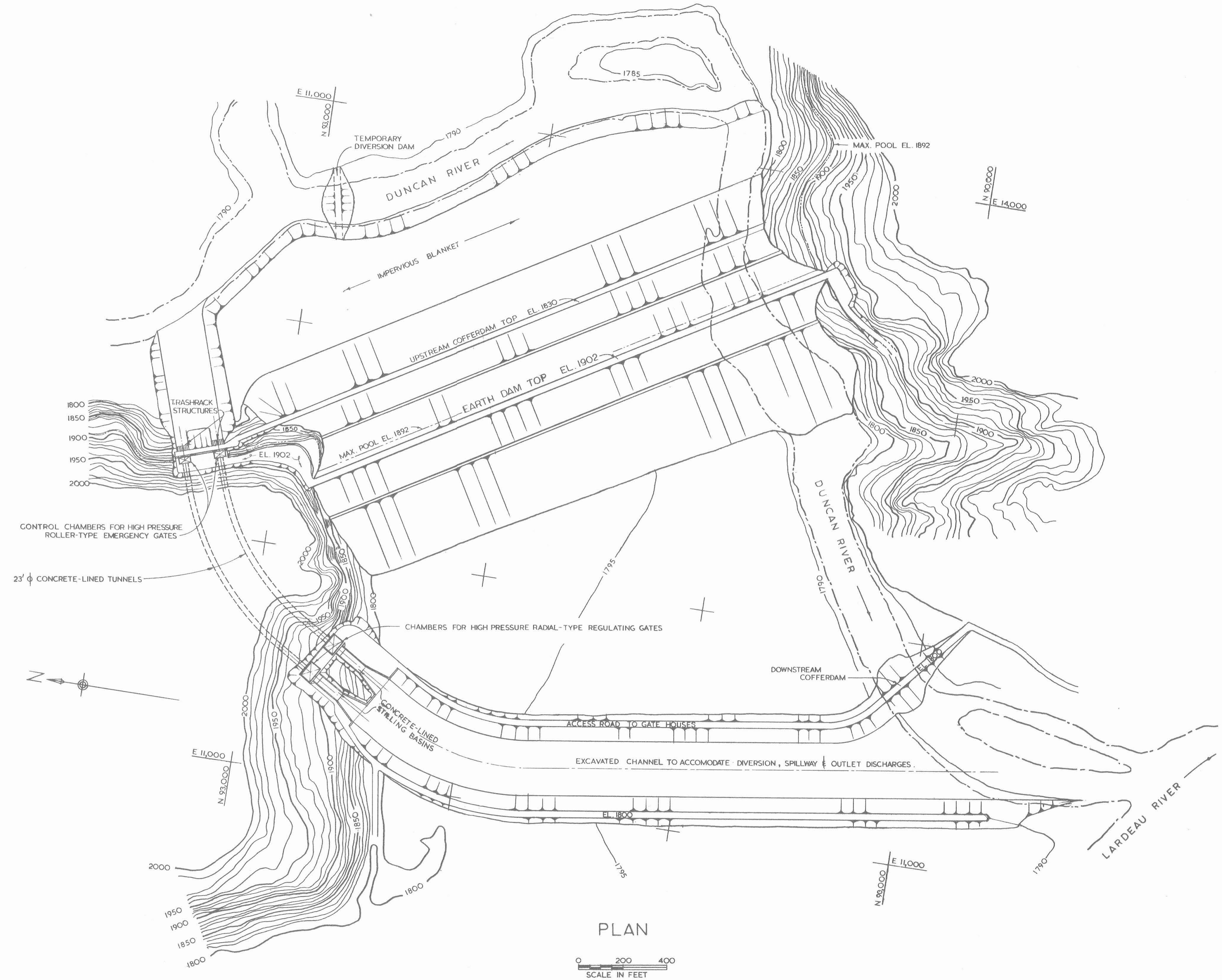
LOGS OF DRILL HOLES

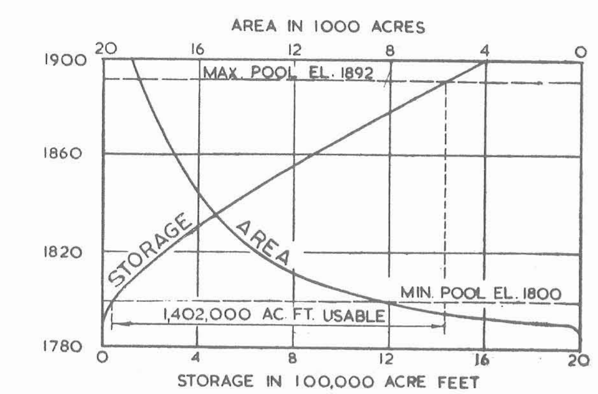
1959
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

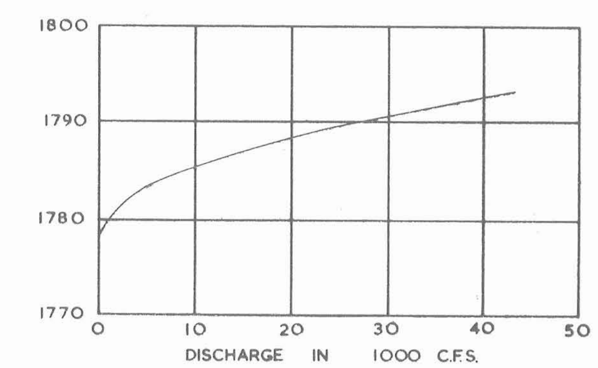
DUNCAN LAKE GEOLOGICAL SECTION & LOGS OF DRILL HOLES

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

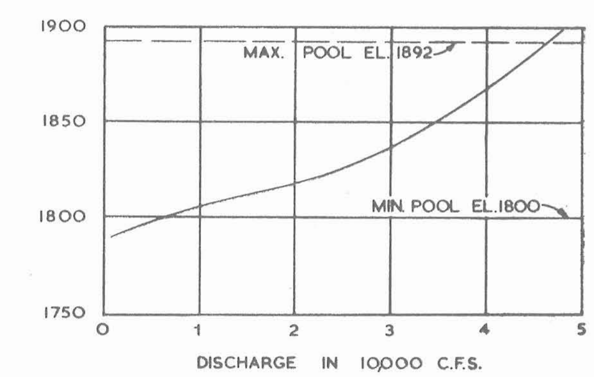




AREA-STORAGE CURVES



TAILWATER RATING CURVE



SPILLWAY & OUTLET RATING CURVE

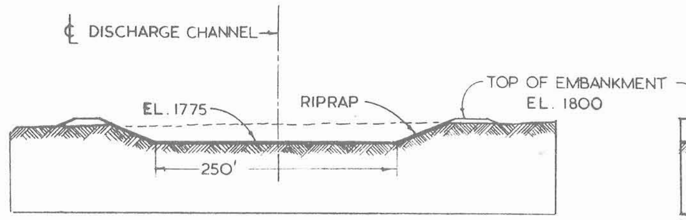
1959

INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

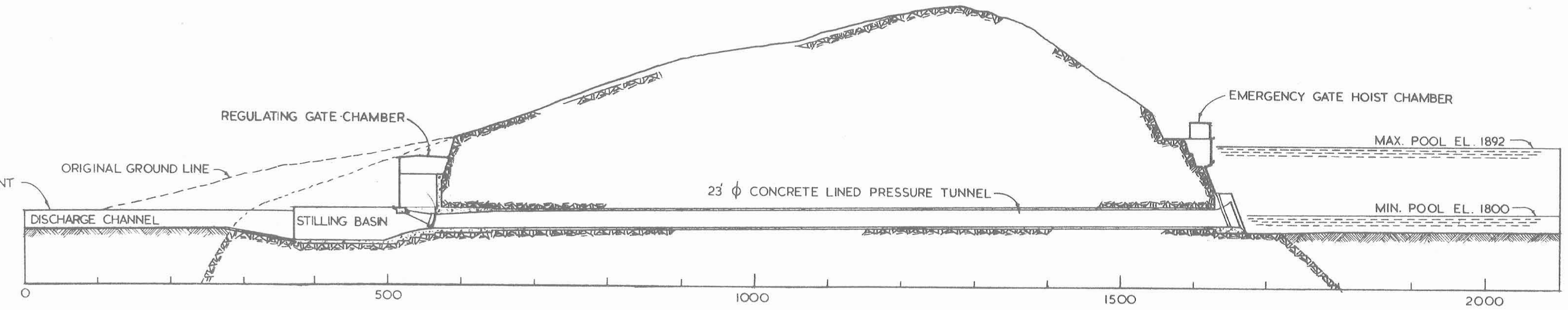
DUNCAN LAKE
GENERAL ARRANGEMENT

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



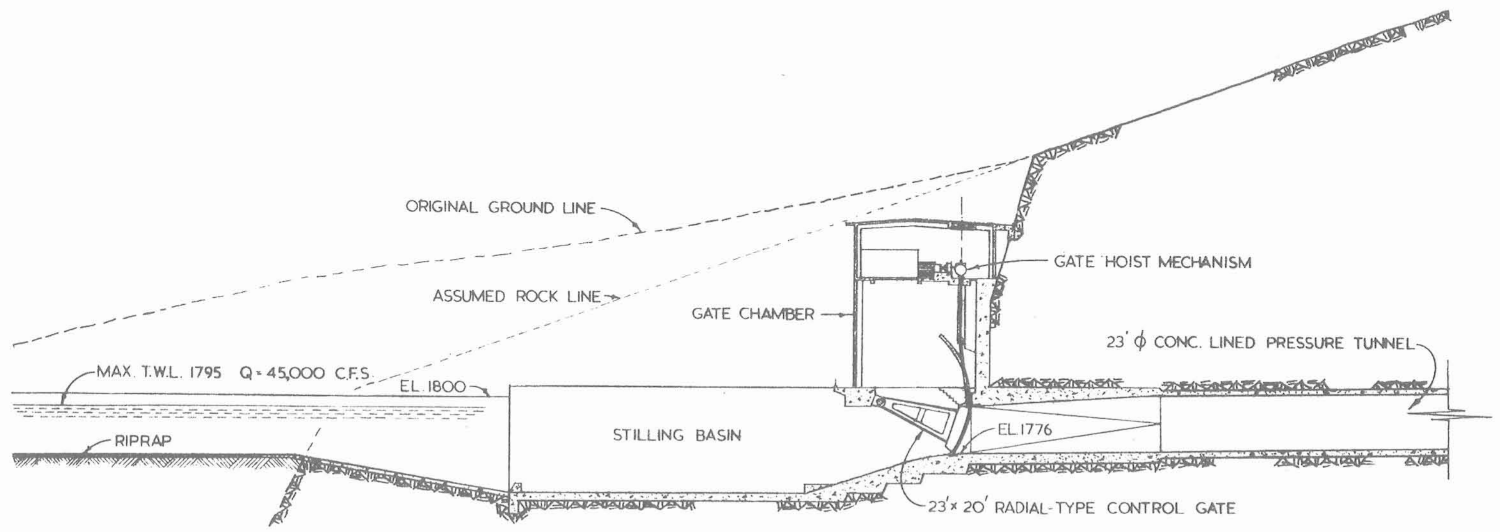
TYPICAL DISCHARGE CHANNEL SECTION

0 100 200
SCALE IN FEET



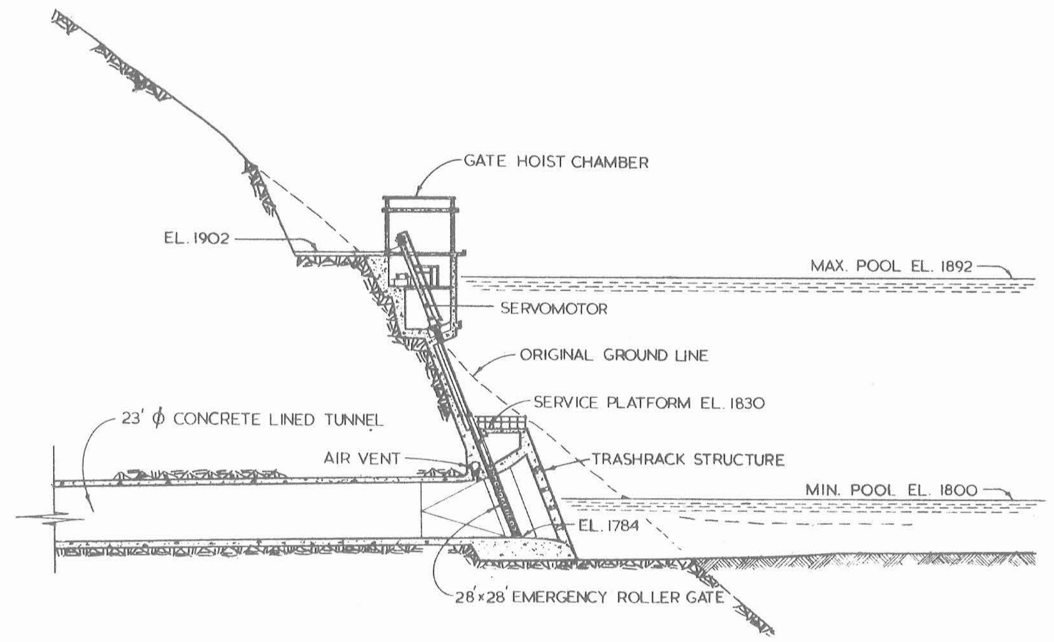
PROFILE OF SPILLWAY, OUTLET & DIVERSION STRUCTURE

0 100 200
SCALE IN FEET



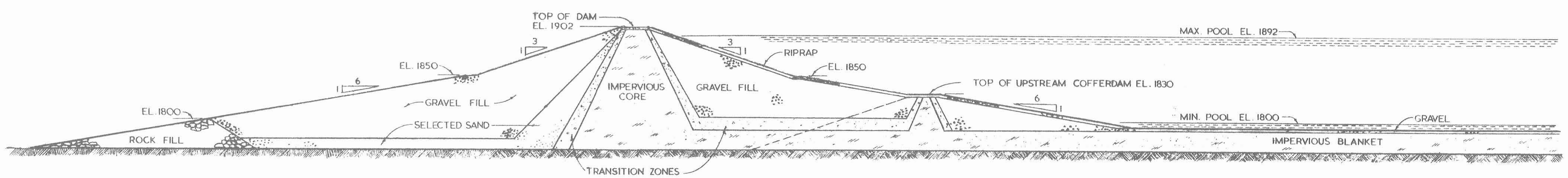
SECTION THROUGH REGULATING PORTION OF SPILLWAY & OUTLET STRUCTURE

0 40 80
SCALE IN FEET



SECTION THROUGH INTAKE PORTION OF SPILLWAY & OUTLET STRUCTURE

0 40 80
SCALE IN FEET



MAXIMUM SECTION THROUGH EARTH DAM

0 60 120
SCALE IN FEET

1959

INTERNATIONAL JOINT COMMISSION

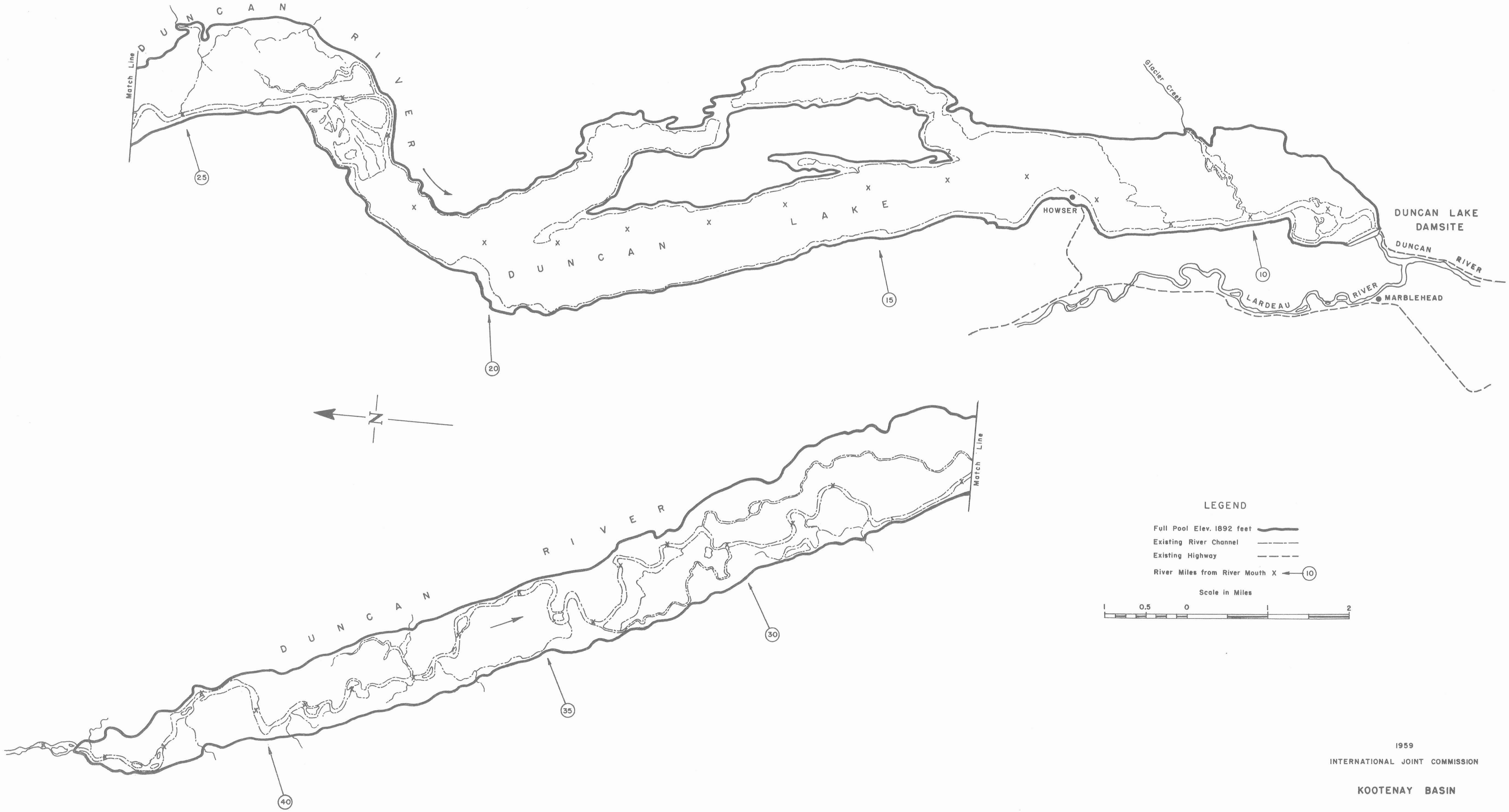
KOOTENAY BASIN

DUNCAN LAKE

ELEVATIONS AND SECTIONS

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD

PLATE 16



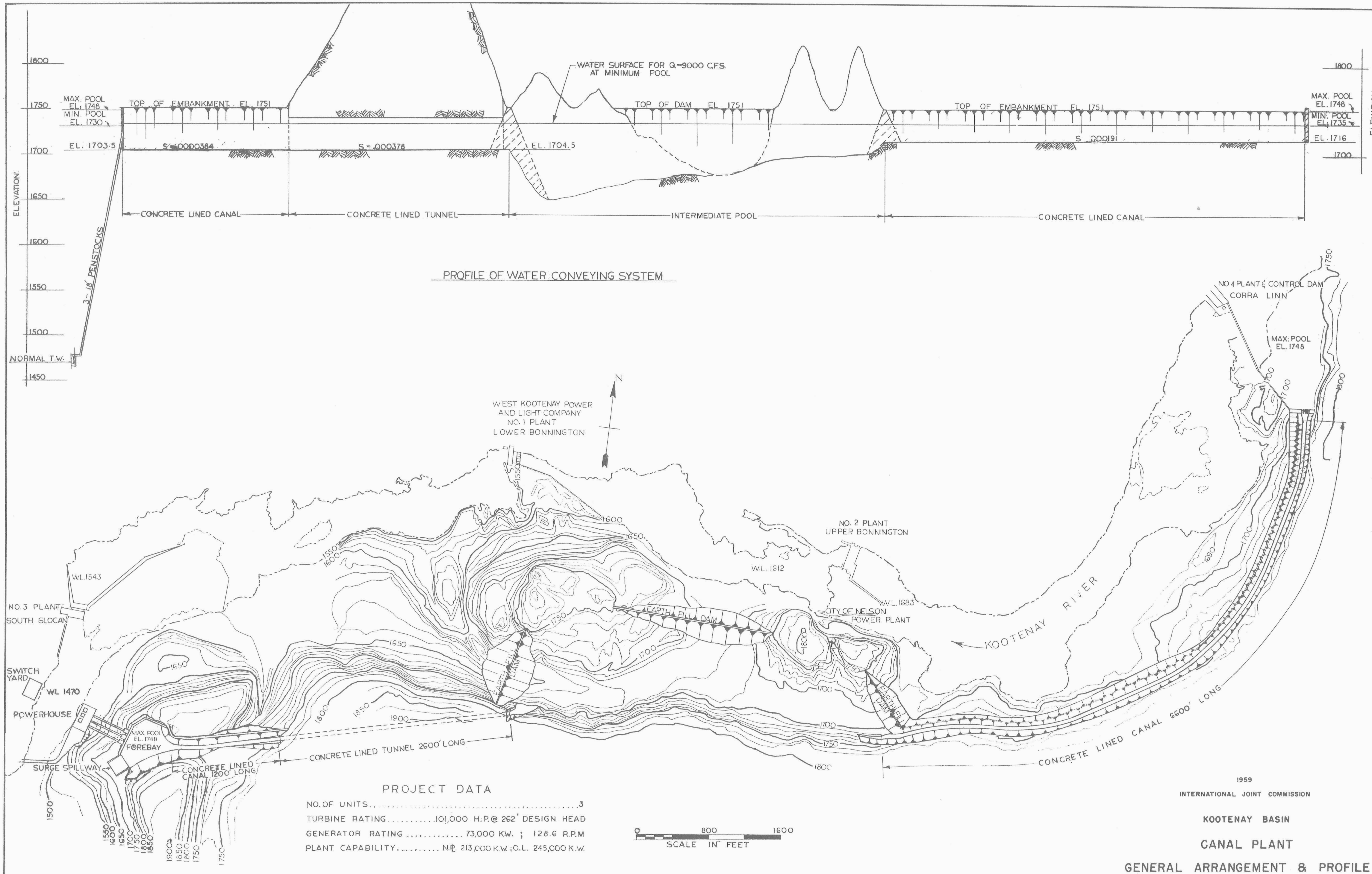
1959

INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

DUNCAN LAKE RESERVOIR MAP

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



PROJECT DATA

NO. OF UNITS..3
TURBINE RATING..........101,000 H.P. @ 262' DESIGN HEAD
GENERATOR RATING............73,000 KW. ; 128.6 R.P.M.
PLANT CAPABILITY.........N.P. 213,000 K.W.; O.L. 245,000 K.W.

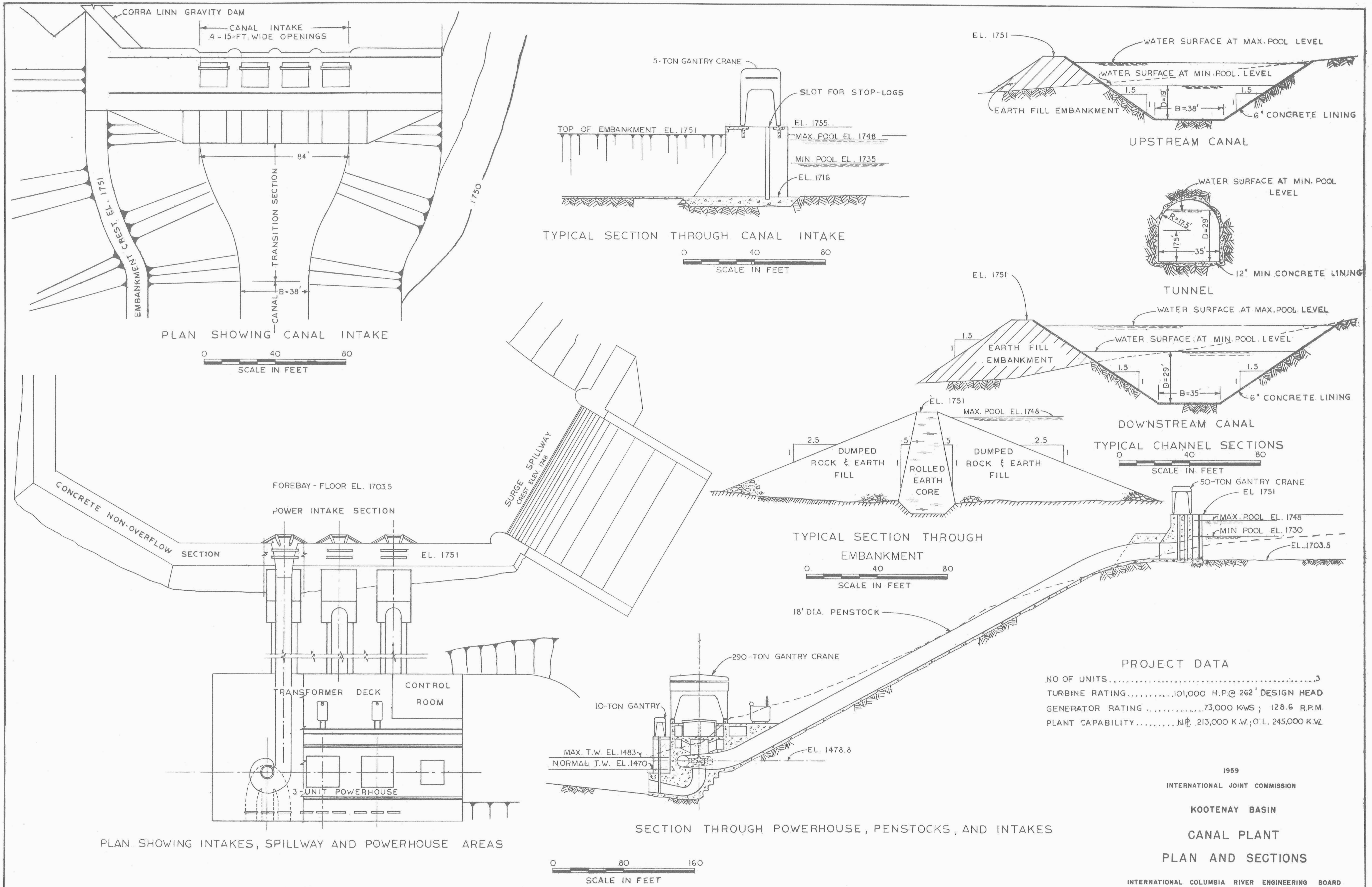
1959
INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

CANAL PLANT

GENERAL ARRANGEMENT & PROFILE

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



PROJECT DATA

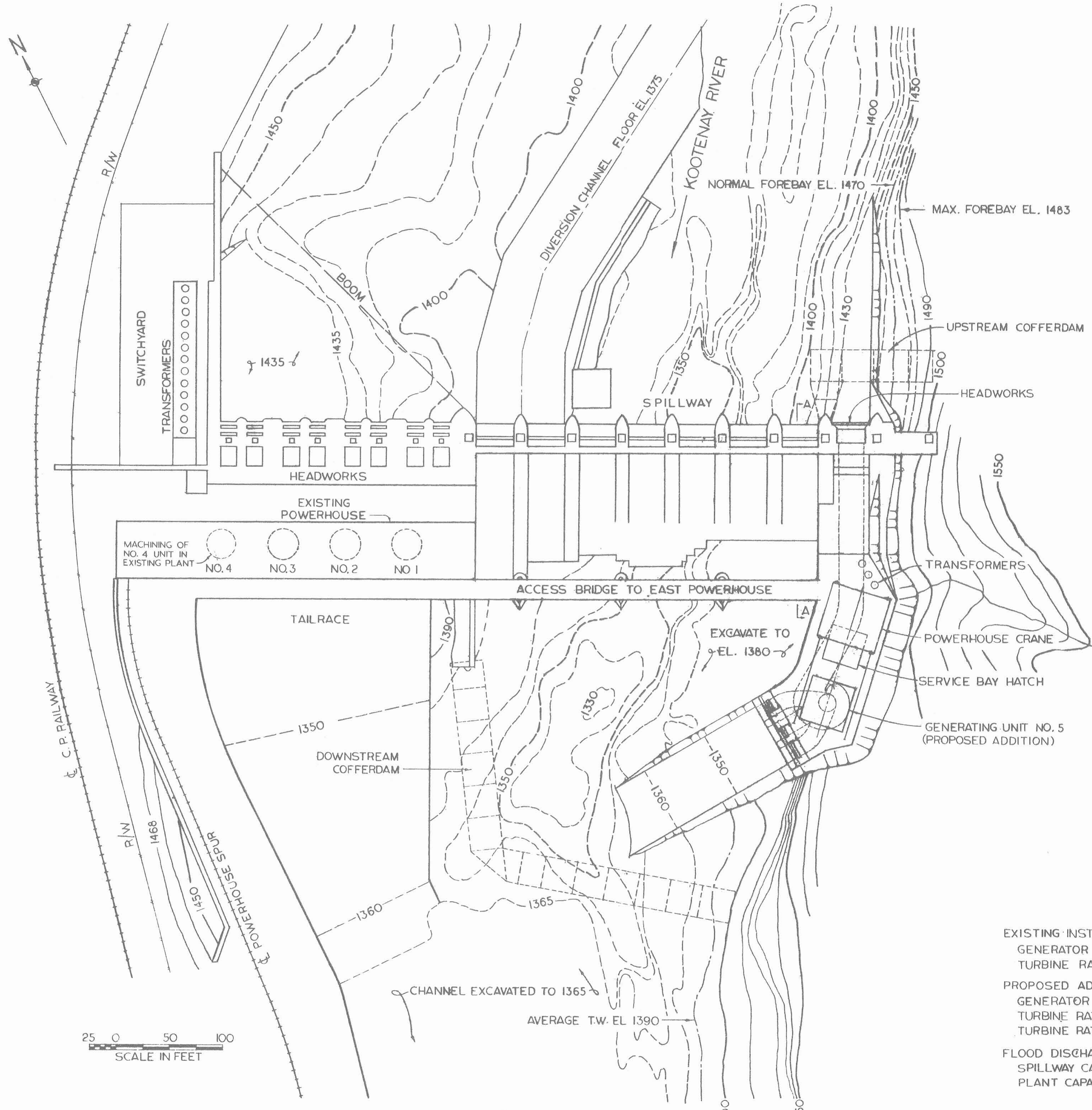
NO OF UNITS 3
TURBINE RATING .... 101,000 H.P.@ 262' DESIGN HEAD
GENERATOR RATING .... 73,000 KWS ; 128.6 R.P.M.
PLANT CAPABILITY .... N.P. 213,000 K.W.; O.L. 245,000 K.W.

1959
INTERNATIONAL JOINT COMMISSION

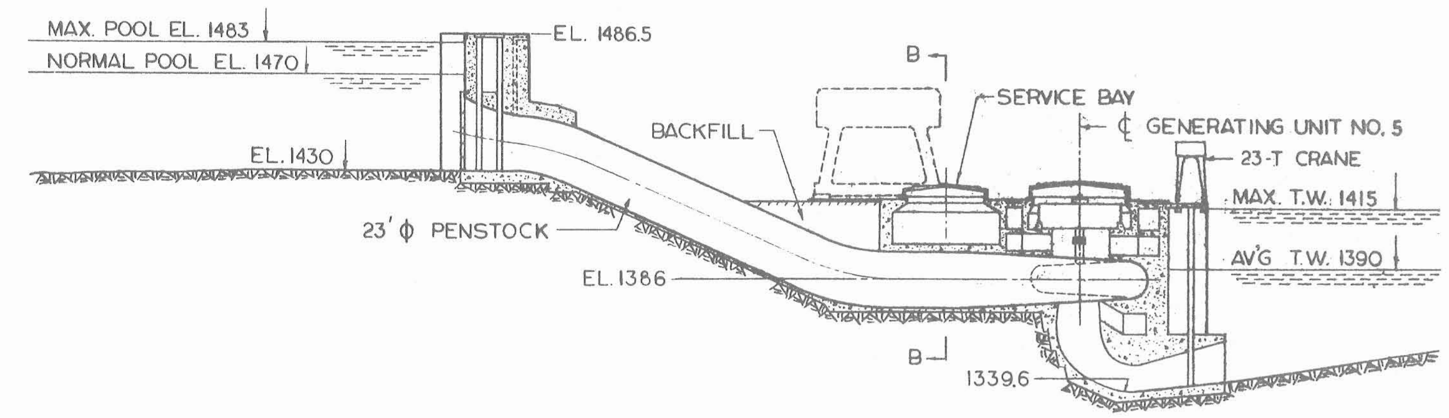
KOOTENAY BASIN

CANAL PLANT
PLAN AND SECTIONS

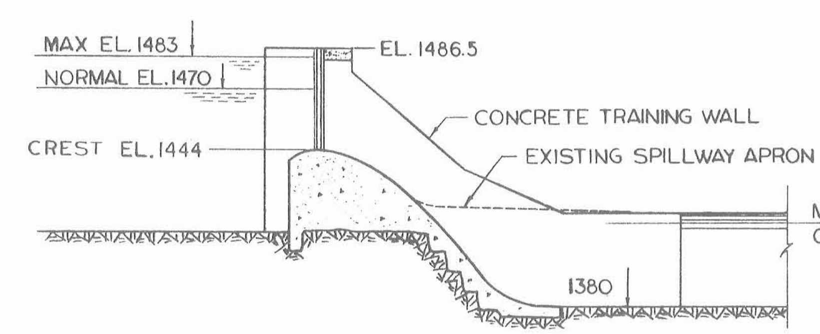
INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD



GENERAL LAYOUT

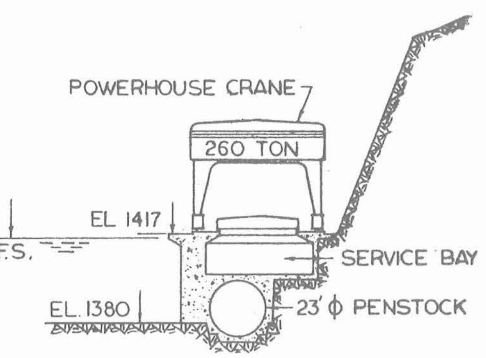


DEVELOPED SECTION ALONG HEADWORKS AND POWERHOUSE
UNIT NO. 5



SECTION A-A

25 0 50 100
SCALE IN FEET



SECTION B-B

PROJECT DATA

EXISTING INSTALLATIONS .... UNIT NO.'S 1, 2, & 3
GENERATOR RATING .... 32,000 K.V.A. @ 85 % P.F.
TURBINE RATING .... 37,000 H.P. @ 90' HEAD, 100 R.P.M.

PROPOSED ADDITIONAL INSTALLATIONS .... UNIT NO.'S 4 & 5
GENERATOR RATING (UNITS 4 & 5) .... 32,000 K.V.A. @ 85 % P.F.
TURBINE RATING, UNIT NO. 4 .... 37,000 H.P. @ 90' HEAD, 100 R.P.M.
TURBINE RATING, UNIT NO. 5 .... 38,000 H.P. @ 78' HEAD, 87.8 R.P.M.

FLOOD DISCHARGE CAPACITY @ ULTIMATE DEVELOPMENT .... 247,000 C.F.S.
SPILLWAY CAPACITY 7 - 34'x36' SLUICES WITH 3' SURCHARGE .... 224,000 C.F.S.
PLANT CAPACITY .... 23,000 C.F.S.

1959

INTERNATIONAL JOINT COMMISSION

KOOTENAY BASIN

ADDITIONS TO BRILLIANT PLANT DETAILS

INTERNATIONAL COLUMBIA RIVER ENGINEERING BOARD