International Joint Commission

International Kootenay Lake Board of Control

Kootenay Lake Information Paper

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Executive Summary

The International Kootenay Lake Board of Control (IKLBC) mandate and 1938 Order of Approval for Kootenay Lake (1938 Order) established a framework that has been used to manage Kootenay Lake for over 80 years. Many significant changes have occurred during this period, including the construction and operation of two large upstream dams that altered the hydrology and water quality, and the implementation of many actions in the Kootenay River Basin for flood risk management, improving the ecosystem and other considerations. This paper assembles factual information to support potential further research and study to inform the decision of whether to recommend a review of the 1938 Order, including:

- Climate Change: Many future changes are expected to the meteorology and hydrology of the basin that could affect lake regulation and the ability of Corra Linn Dam to operate in accordance with the IJC Order. These changes include warmer temperatures, more extremes and increased variability in precipitation, potentially higher winter and spring streamflows, and lower summer streamflows. The changes could lead to higher winter and early spring lake levels due to shifted freshet timing, lower summer lake levels, and warmer summer water temperatures in the lake.
- Socioeconomic Setting: The population and development in the areas affected by lake operations have increased significantly, and this trend could continue in the future, depending on how development is managed. This could increase the frequency of flood damage from high lake levels, with increased pressure to address flood risk concerns.
- Agricultural Impacts: The backwater effect from the regulation of the lake can impact drainage in upstream agricultural areas during spring and summer months. This issue has become more critical as agricultural uses have expanded, levees and dykes protecting these agricultural areas have degraded, and the pumping costs for draining the lands have increased.
- Grohman Narrows Hydraulics: A natural constriction at Grohman Narrows limits the hydraulic capacity of the lake's outlet during certain conditions, and will

continue to be a key factor in regulating the lake. Although the hydraulic capacity of this constriction remains unchanged since the most recent dredging in 1939, interest has been expressed in performing additional dredging to increase the hydraulic capacity (BC Hydro, 2014). This could have both positive and negative effects. The positive effects could include reduced flood risk during high water years and better control of the lake to mitigate agricultural impacts (reduced pumping) while enabling increased hydropower generation. The negative effects could include temporary environmental impacts during the construction period and higher peak outflows from the lake. Grohman Narrows is a constraint to Corra Linn Dam operations and typically limits outflows from Kootenay Lake for about 5 months each year, as early as February and through the end of June, but can be the control point at any point of the year.

- <u>Ecological and Fisheries Concerns</u>: The regulation of the lake plays a significant role in the ecology, water quality, and fisheries of the lake and surrounding area. Conditions in these areas have changed significantly since the 1938 Order was approved. Upstream dams have further altered the hydrology and ecology of the lake and surrounding area. The 1938 Order incorporates some flexibility that has been used to periodically alter Corra Linn Dam operations. However, there are possible actions that would be in conflict with the existing Order. An example of such an action would be raising the lake water level higher in the spring, which has been suggested in the past to benefit Kootenai River white sturgeon spawning and more recently for the protection of kokanee shoal spawning. However, higher levels in the spring than those currently allowed by the 1938 Order could be detrimental to flood risk management due to the limited storage on Kootenay Lake.
- <u>Flood Risk Management</u>: Flood risk management provisions of the 1938 Order have been very effective for managing flood risk. The construction of the two upstream dams has greatly reduced the peak lake levels and frequency of flooding, though the total inflow into Kootenay lake during the freshet is largely unregulated and accounts for approximately 75 percent of the total inflows. Continued development in the floodplain around the lake and in surrounding

areas, combined with the Grohman Narrows constraint on lake discharge, have led to increased flood risk during high water years. The lake is normally regulated to achieve the maximum Grohman Narrows flow capacity each spring until the lake level peaks in June to minimize flood risk impacts on the lake, though this is not explicitly required in the 1938 Order.

- Other Considerations: Corra Linn Dam is operated for many other purposes such as hydropower generation, recreation, and navigation. Changes in the lake regulation can also affect these operating purposes.
- Issues and Future of 1938 Order: Future research and review could be conducted in the following areas:
  - The Order pre-dates the existence of the upstream dams which have contributed to altered basin hydrology. The Order could be reviewed to see whether any adjustments to the Order are warranted given changed hydrology.
  - The provision for reimbursement of agricultural pumping costs could be reviewed to determine if annual reimbursement limits should be changed to cover current and expected future pumping costs.
  - Consider whether the procedures used to declare the timing of spring freshet need to be updated to reflect current hydrology and future climate conditions.
  - Many other potential changes to the lake's regulation have been suggested, such as establishing minimum lake levels during certain conditions, raising or lowering the lake during certain periods, and other changes that are described in this paper.

Finally, this review has identified many different studies that have been completed and actions that have been implemented since the 1938 Order was first approved. These have been done to address various issues at Kootenay Lake and other areas in the basin that are related to the lake regulation. However, most of these did not involve a systematic approach where all aspects of the lake regulation and basin management were integrated together.

1. Purpose and Background.

a. Purpose. The purpose of this work is to evaluate historical records, to analyze recent and historical data, to assess current issues likely to recur, and to document potential future issues related to the 1938 Order and the ability of the International Kootenay Lake Board of Control (IKLBC) to deliver on its mandate (Attachment 1). The final objective is to produce this information paper for use by the IKLBC as a basis for formulating specific further research and study efforts.

b. Background.

i. Kootenay Lake. Kootenay Lake is a large fjord-like lake that is located on the Kootenay River in British Columbia, Canada, 25.7 kilometers (16 miles) upstream of the confluence with the Columbia River. The level of Kootenay Lake is regulated by Corra Linn Dam, and is also influenced by a natural constriction upstream of the dam at Grohman Narrows. Grohman Narrows has a backwater effect that can extend about 80 kilometers (50 miles) upstream, to near the town of Bonners Ferry, Idaho.

ii.1909 Boundary Waters Treaty. The Boundary Waters Treaty (BWT) is an international treaty between the United States and Canada that was signed in 1909, and provides the principles and mechanisms to help prevent and resolve disputes over the use of the waters shared by Canada and the United States and to settle other transboundary issues. The Kootenay (known as Kootenai in the United States) River flows across the boundary between the two countries. Pursuant to Article IV of the BWT, obstructions or dams in rivers flowing across the boundary which raise the natural level of waters on the other side of the boundary require approval by the International Joint Commission, except in cases provided for by special agreement between the two countries. The works on Kootenay Lake cause a backwater effect that extends into the United States and are subject to the BWT.

iii. International Joint Commission. The BWT established the International Joint Commission (IJC) to help the two countries carry out its provisions. Canada and the United States each appoint three of the six IJC Commissioners, including one chair from each country. The IJC sets conditions for projects through Orders of Approval, such as dams, diversions or bridges, which affect the natural level or flow of boundary waters, or dams on transboundary streams that would raise the level across the boundary in the upstream country. The IJC also investigates transboundary issues upon request of the two governments and recommends solutions. In 1938, the IJC issued an Order of Approval for Kootenay Lake.

iv.1938 Kootenay Lake Order of Approval and IKLBC. In November 1938, in response to an application submitted by the Government of Canada on behalf of the West Kootenay Power and Light Company (WKPL), which operated Corra Linn Dam, the IJC issued the 1938 Order. WKPL originally applied through Government of Canada to the IJC for permission to construct and operate Corra Linn Dam in 1929. Objections to this initial application were raised by agricultural interests in an area near the international border between the United States and Canada who were concerned about the impact of the higher lake levels on their farms. Despite the fact that the application to build the dam had not been approved, WKPL proceeded with construction, and began operating the dam in 1932 as a run-of-river project without utilizing the 1.8 meters (6 feet) of storage that they had requested in their application. Further negotiations between WKPL and the IJC led to provisions being included in the Order regarding the concerns from these agricultural interests, such as reducing the lake levels during key agricultural periods and providing reimbursement for additional pumping costs that may be incurred. The Order was issued in 1938, about six years after Corra Linn Dam was constructed and began operations.

The 1938 Order has several provisions, including:

- Establishing the maximum elevation limits and operational criteria for the lake
- Appointing the IKLBC to monitor the regulation of the lake to assure the provisions of the order are followed

- Requiring excavation of the outlet of the lake at Grohman Narrows to expand the hydraulic capacity
- Providing for reimbursement of increased pumping costs resulting from flooding of agricultural lands caused by Corra Linn Dam operations

The maximum lake elevation limits are described in the Kootenay Lake rule curve, described in more detail in Section 2. Since it was first implemented, the 1938 Order has been supplemented by four Special Orders in 1941-42, 1942-44, 1949-54, and 1966-67. These special orders allowed the lake to be operated to increase the storage by an additional 0.6 meters (2 feet) to increase power generation, and are no longer in effect.

The IKLBC consists of four members appointed by the IJC, currently one each from USACE Seattle District, United States Geological Survey, Environment and Climate Change Canada, and the British Columbia Ministry of the Environment. The USACE Seattle District Engineer is the United States Co-Chair of the IKLBC. A USACE Seattle District Hydrology, Hydraulics, and Coastal Branch employee is the United States Secretary of the IKLBC. The Canadian Co-Chair and Canadian Secretary are both employees of Environment and Climate Change Canada. Generally, the IKLBC acts as the local representative of the IJC. The principal duties are to:

- Monitor regulation of Kootenay Lake to ensure Corra Linn Dam operation is in accordance with the provisions of the 1938 Order.
- Interface with the public including holding public meetings and providing the Commission with meeting reports and other reports necessary to keep the Commission informed.
- Annually specify the time of “commencement of the spring rise” which in accordance with Condition 2(6) of the Order defines the computation of the maximum allowable lake elevation during the spring/summer period of peak lake inflow.
- Provide general advice and assistance to the Commission on issues relating to the 1938 Order.

v. Duck Lake Orders of Approval and IKLBC. Between 1927 and 1970, the Creston Reclamation Company, the Duck Lake Dyking District and the Creston Valley Wildlife Management Authority received approvals (Orders of 12 October 1950, 3 April 1956 and 31 March 1970) from the IJC to construct and improve dykes adjacent to the channel of the Kootenay River and in the Duck Lake area for the reclamation of flooded lands. Duck Lake is located just north of the United States-Canadian border at the south end of Kootenay Lake and has the potential to increase water levels on the Kootenay River in the United States under certain extreme flood conditions. The IKLBC was responsible for the monitoring of these Orders. However, in December 2003 the IJC terminated the Duck Lake Orders based on a determination that flood protection afforded by Libby Dam reduced the likelihood of extreme flood conditions to near zero and, as such, minimized the potential for Duck Lake's dykes to cause backwater effects upstream at the Canada/United States border (IJC, 2003).

vi. Columbia River Treaty. The Columbia River Treaty (CRT) is an international treaty between the United States and Canada that entered into force in 1964. The 1938 Order predates the CRT, and therefore the conditions described in it make no reference to the CRT. The CRT required the construction of one dam upstream of Kootenay Lake, and allowed for the construction of another. The first is Duncan Dam, which was completed in 1967 and is located on the Duncan River in Canada, and the second is Libby Dam, which was completed in 1973 and is located on the Kootenai River in the United States. The operations of both dams have significantly altered the inflow and other aspects of Kootenay Lake, and are described in more detail in Section 2. In particular, their operation has greatly reduced the flood risk and peak lake levels at Kootenay Lake.

The CRT does not make reference to how the operation of Duncan Dam relates to Kootenay Lake. The CRT does make a reference to the operation of storage by the United States at Libby Dam in relation to Kootenay Lake. It states under Article XII, Paragraph (6) that: "The operation of the [Libby Dam] storage by the United States of America shall be consistent with any order of approval which may be in force from time to time relating to the levels of Kootenay Lake made by the International Joint Commission under the Boundary Waters Treaty, 1909."

The CRT has no end date, but it includes an option for either country to terminate most treaty provisions any time after 60 years, given that they provide at least 10 years advance notice. Since the CRT was ratified in 1964, the earliest date that it could have been terminated was 2024, with notice given by 2014. Neither nation has provided a notice of termination. The governments began formal negotiations regarding the future of the CRT in 2018 and negotiation status is ongoing. Related to this, in 2024, the 60-year term for pre-purchased flood control storage in Canada ends, and the CRT provisions governing flood control will transition to a less-defined approach. Further discussion is provided in Section 9.

2. Project and Basin Description.

a. Kootenai/Kootenay River System Overview. The Kootenay River is the third largest tributary to the Columbia River, and includes a part of a large system of dams that is operated by multiple owners and for multiple purposes. It begins in British Columbia, and then flows into northwestern Montana and the Idaho panhandle, before returning to British Columbia, where it joins with the Columbia River 25.7 kilometers (16 miles) downstream of Kootenay Lake at the town of Castlegar. It is 780 kilometers (485 miles) long, has a drainage area of more than 50,000 square kilometers (19,420 square miles), and falls 1,740 meters (5,840 feet) in elevation (Virtualmuseum, 2020). The map in Figure 2-1 shows the Kootenay River Basin and some of the key features.

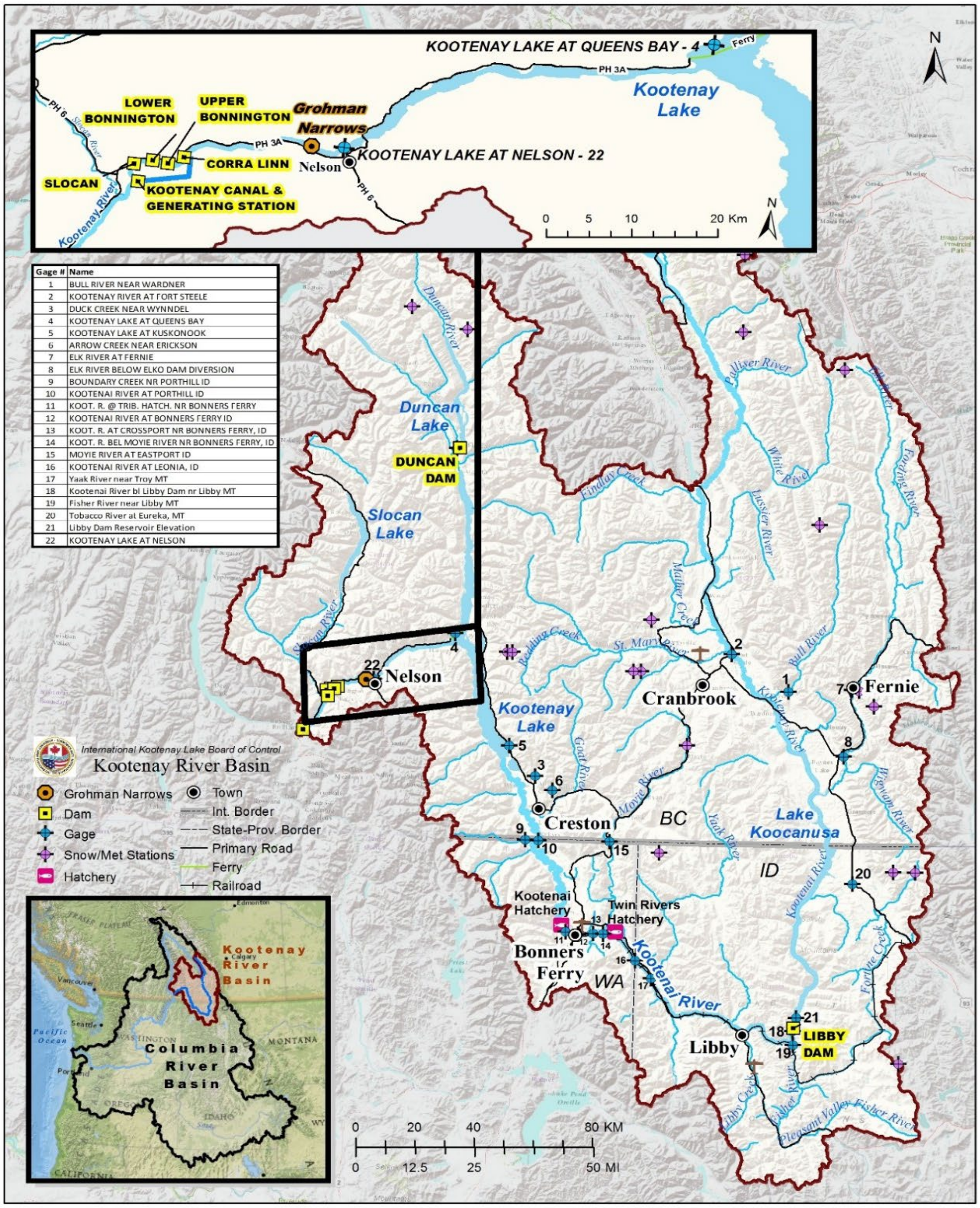


Figure 2-1 Kootenay River Basin

b. Kootenai/Kootenay River System Water Resource Projects. There are numerous water resource projects in this large and complex river system. Only those that are most pertinent to the regulation of Kootenay Lake are described. These are summarized in upstream to downstream order in Table 2-1.

Table 2-1. Key Project Characteristics

Dam	Owner/Operator	River	Year Completed
Libby	United States Army Corps of Engineers, Seattle District	Kootenai	1973
Duncan	British Columbia Hydro and Power Authority (BC Hydro)	Duncan	1967
Corra Linn	Fortis BC	Kootenay	1932
Kootenay Canal Plant	BC Hydro	Kootenay	1976
Upper Bonnington/Nelson Plant	Fortis BC/Nelson Hydro	Kootenay	1907
Lower Bonnington	Fortis BC	Kootenay	1925
South Slocan	Fortis BC	Kootenay	1928
Brilliant	Columbia Power Corporation (CPC)/FortisBC	Kootenay	1947
Brilliant Expansion	CPC	Kootenay	2007

The two upstream dams, Libby and Duncan, were constructed after the 1938 Order was established. Libby Dam is operated by the USACE and Duncan Dam is operated by BC Hydro. The reservoir formed by Libby Dam has 6.2 cubic kilometers (5 million acre-feet [MAF]) of active storage, and the reservoir formed by Duncan Dam has 1.7 cubic kilometers (1.4 MAF) of active storage. That compares to about 0.97 cubic kilometers (0.79 MAF) of active storage for Kootenay Lake (USACE, 2020a). The operation of these upstream dams has significantly altered the inflow and other characteristics of the lake. These two projects are operated as part of a large coordinated system of dams in the Columbia River basin and provide benefits such as flood risk management to the local area, as well as to areas in the lower Columbia River. The other projects listed in Table 2-1 are not operated as a part of that system; however, they are operated as a part of a regional power system that interconnects power generation sources throughout the region.

The regulation of Kootenay Lake itself is managed using the Corra Linn project, which was constructed in 1932. It is currently owned and operated by Fortis BC, a privately held natural gas and electric utility. The reservoir regulation is performed by BC Hydro through an agreement that was signed between the two organizations. BC Hydro is a Crown Corporation that is owned by the government of British Columbia. In 1976, BC Hydro constructed the Kootenay Canal Plant, which is a hydropower generating plant that is owned and operated by BC Hydro and is hydraulically connected to the Corra Linn dam forebay on the Kootenay River through a constructed canal. There are six projects that are located immediately downstream of Kootenay Lake. They are operated by either Fortis BC, or the Columbia Power Corporation (CPC), and are all primarily operated for hydropower generation. Like BC Hydro, CPC is a British Columbia Crown Corporation. The photograph in Figure 2-2 is looking downstream from Kootenay Lake, and shows the various dams in the vicinity of Kootenay Lake.

Figure 2-2 Photograph of Kootenay Lake and Surrounding Area

i. Operating Purposes. The dams in the Kootenay/Kootenai River system are operated for a variety of purposes. The operating purposes and procedures for these various dams are generally described in documents known as water control plans and manuals in the United States, and water use plans in Canada. The operating purposes can include flood risk management, hydropower generation, recreation, environmental stewardship, and others. Some dams are operated for multiple purposes, while others are operated for a single purpose. For example, some of the dams immediately downstream of Kootenay Lake are operated for the single purpose of hydropower generation, while the regulation of Kootenay Lake itself is for flood risk management, hydropower generation, and in consideration of other purposes such as agriculture and the ecosystem. Dam operations may be focused on the needs in a local area, or they can be integrated as a part of the operation of a large system of dams. An example of this is Libby Dam, which is operated for system flood risk management that benefits areas as far downstream as the lower Columbia River near Portland, Oregon, but is also operated for local flood risk management that benefits the area just downstream of the dam. In addition to flood risk management, Libby Dam is operated for hydropower generation, recreation, and environmental stewardship. Duncan Dam is operated to provide storage for local and system flood risk management, downstream hydropower generation, recreation, and environmental stewardship.

ii. Interrelation of Upstream and Downstream Projects to Kootenay Lake. Kootenay Lake is in the middle of a complex river system that includes many upstream and downstream dams. Because of this, the operations of the dams are interrelated. The upstream projects are discussed first, followed by the downstream projects.

One issue that relates to the upstream project operation occurs during periods when the Kootenay Lake IJC rule curve is being exceeded. Prior to the spring of 2007, in these circumstances, the releases from the upstream projects, Libby and Duncan Dams, were both limited to be no higher than the natural inflow to avoid exacerbating rule curve exceedances at Kootenay Lake. This process led to Libby and Duncan Dams sometimes not being drafted as deeply for flood risk management as they would have been otherwise. This resulted in what is known as “trapped storage” at these upstream projects. However, starting in 2007, the operation of Duncan Dam, and in 2011 the operation of Libby Dam, were changed such that releases would be above the natural inflow if needed to draft storage for flood risk management, even during periods when the Kootenay Lake IJC rule curve was being exceeded. The impact of Duncan and Libby Dams releasing water as needed for prescribed flood risk management regardless of whether the IJC rule curve at Kootenay Lake is exceeded or not, is a reduction in the peak stage at Kootenay Lake, or at worst, no change in the peak stage, relative to the previous operating practice of reducing Libby and Duncan outflows to no greater than inflows so as not to exceed the water levels in Kootenay Lake mandated by the IJC rule curve (USACE, 2012a). The effect on other purposes such as agriculture is uncertain. To resolve this issue, the IKLBC submitted a letter to the IJC requesting the IJC position on the operating requirements for upstream dams relative to the 1938 Order (IKLBC, 2008a). The IJC response to this letter was that the 1938 Order is directed solely to the operator of Corra Linn Dam, and therefore does not pertain to the operation of the upstream dams (IJC, 2008). This operational change with the upstream projects has continued since it first began in 2007 at Duncan Dam and in 2011 at Libby Dam.

A related issue that the IKLBC has discussed regarding the operation of Libby and Duncan Dams is how the inflows into Kootenay Lake from these dams should be computed. When the 1938 Order was first established, neither Libby nor Duncan Dams were constructed, and the inflow to the lake from the Duncan and Kootenai(y) Rivers was “natural,” in that it was not influenced (or regulated) by the operation of the upstream dams. Once operations at these dams began, the inflow changed from “natural” inflow to “regulated” inflow. This raised questions about whether the date when Kootenay Lake should begin filling later in the spring (commencement of the spring rise), should be based on the “natural” inflow, or the “regulated” inflow. After discussions between the IJC, IKLBC, and the Treaty Entities, the IKLBC determined that since this determination was originally based on the “natural” inflow prior to the construction of the projects, it should continue to be based on the “natural” inflow among other factors (IKLBC, 2008b).

Other issues related to the operation of the upstream dams are discussed in Sections 6 and 8.

The regulation of Kootenay Lake and the projects downstream are also very interrelated. There are six projects (Upper Bonnington, Nelson Plant, Lower Bonnington, South Slocan, Brilliant, and Brilliant Expansion) located immediately downstream of the lake that are directly affected by the regulation of the lake because their inflow comes from it. The details of this are described in Section 2.c. There are also numerous dams on the Columbia River influenced by the regulation of Kootenay Lake, although the effect is minimal due to the fact that they are located a great distance downstream from Kootenay Lake and because it has limited storage.

c. Kootenay Lake. Kootenay Lake was originally a natural lake whose level was controlled by shallow constrictions in the river near the outlet of the lake. Some of these constrictions have been excavated over time to increase the release capacity of the lake. However, under certain flow and lake level conditions, a constriction at a location known as Grohman Narrows just upstream of Corra Linn Dam still controls the maximum releases that can be made from the lake. This is discussed in more detail in Section 7.

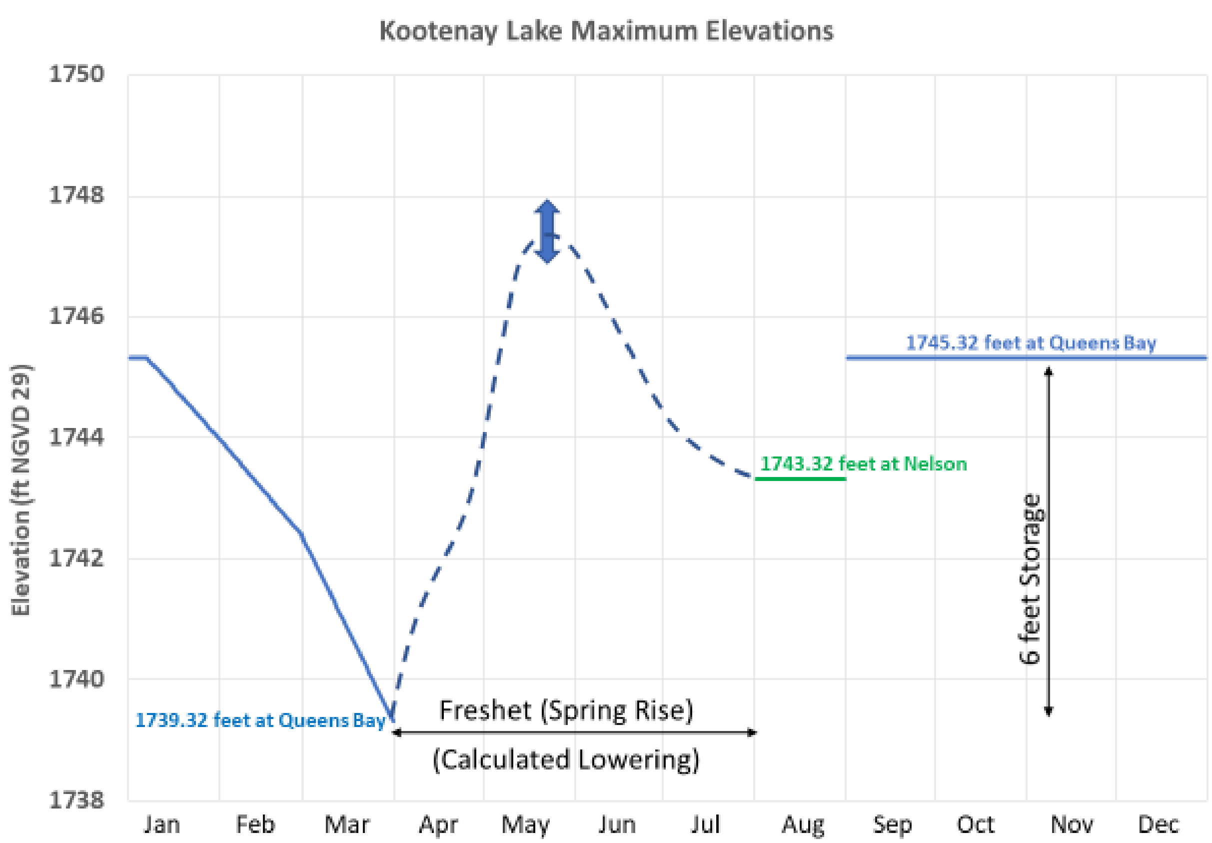
The lake has a surface area of approximately 400 square kilometers (154.4 square miles) and drains a watershed of over 50,000 square kilometers (19,305 square miles). The total active storage volume is about 0.97 cubic kilometers (0.79 MAF). The main body of the lake is comprised of the north and south arms and is about 104 kilometers (64.6 miles) long, and 3-5 kilometers (1.9-3.1 miles) wide. The average depth is 94 meters (308 feet), and the maximum depth is 154 meters (505 feet) (Bassett et al., 2015).

The overall operating guidelines for Kootenay Lake are described in the 1938 Order. It has a rule curve that specifies lake levels for periods through the year such as:

- A maximum lake elevation of 532.0 meters (1,745.32 feet) (at Queens Bay) from September 1 through January 7, and drawing down through the winter-early spring period (lake drawdown period) to a maximum of 530.1 meters (1,739.32 feet) (at Queens Bay) on or about April 1.

- After the declaration of spring rise, the lake is allowed to refill in accordance with a lowering formula during the spring freshet period.
- Once the lake level peaks and then returns to a level of 531.4 meters (1,743.32 feet) at Nelson, typically in late July or early August, this becomes the maximum lake level and compliance point through August 31.
- A maximum lake level back to 532.0 meters (1,745.32 feet) (at Queens Bay) beginning in September and continuing through January 7 to reduce backwater from the lake and provide other benefits during these periods.

A graph showing the maximum lake elevations under the rule curve in the 1938 Order is provided in Figure 2-3. The difference between the April 1 low level of 530.1 meters (1739.32 feet) and the fall storage level of 532.0 meters (1745.32 feet) represents the 1.8 meters (6 feet) of storage that was allowed in the 1938 Order.



The majority of the time when there are not high or low flow conditions, Corra Linn Dam is used to control the water releases from Kootenay Lake. When water is released through Corra Linn Dam, it provides inflow to four projects (Upper Bonnington, Nelson Plant, Lower Bonnington, and South Slocan) located immediately downstream, enabling them to generate power. However, when water is diverted into the Kootenay Canal and released through the Kootenay Canal Plant, it bypasses these four downstream dams because the canal starts upstream of and ends downstream of these four plants. Releasing water through the Kootenay Canal Plant is the preferred mode of operation, when possible, because its generating units are much newer and more efficient than the units in the other plants. The general operating plan is to release the first 142 cubic meters per second (5,000 cubic feet per second) through Corra Linn Dam. Any additional water releases go through the Kootenay Canal Plant, until its powerplant capacity of about 849 cubic meters per second (30,000 cubic feet per second) is reached, at which point any additional releases are made from Corra Linn Dam. All of the detailed operating procedures are described in an operating agreement between Fortis BC and BC Hydro.

3. Watershed and Hydrology. The watershed and hydrology of Kootenay Lake and the surrounding area is very complex. The details are described in the following sections.

a. Hydrometeorology of the Basin.

i. Meteorology. The Kootenay Lake basin has a relatively moist climate, with four distinct seasons. Average minimum and maximum daily temperatures vary from -5C to 5C (23F to 41F) in winter to 15C to 27C (59F to 80F) in the summer. The annual precipitation, even at low elevations, generally exceeds 500 millimeters (20 inches). Warm, wet air masses from the Pacific Ocean bring abundant rainfall that averages around 25 millimeters (0.98 inches) per month from March through October (Daley et al., 1981). At the lower elevations, snowfall occurs from November through March, with December and January averaging 700 millimeters (27.5 inches) each in Nelson, British Columbia.

There are much higher amounts in the mountains nearby, averaging between 1,016 to 7,620 millimeters (40 to 300 inches) annually (USACE, 2012b).

ii. Hydrology. The headwaters of the Kootenay River in British Columbia consist primarily of the main fork of the Kootenay River and the Elk River. Libby Dam Reservoir (Lake Koocanusa), and its tributaries receive runoff from 47 percent of the Kootenay River drainage basin. Three Canadian rivers, the Kootenay, Elk, and Bull, supply 87 percent of the inflow into Libby Dam. The Tobacco River and numerous small tributaries flow into the reservoir south of the international border. Major tributaries to the Kootenai River below Libby Dam include the Fisher, Yak, and Moyie Rivers. The inflow to Kootenay Lake from the other major tributary, the Duncan River, is primarily comprised of releases from Duncan Dam, and flows from the Lardeau River, which is a tributary that joins the Duncan River just downstream of Duncan Dam then flows into the north arm of Kootenay Lake. At the confluence with the Columbia River near Castlegar, British Columbia, the Kootenay River has an average annual discharge of about 868 cubic meters per second (30,650 cubic feet per second) (Kootenai River Network, Inc., 2020).

Kootenay River tributaries are characteristically high-gradient mountain streams with bed material consisting of variying mixtures of sand, gravel, rubble, boulders, and drifting amounts of clay and silt, predominantly of glacio-lacustrine origin. Fine materials, due to their instability during periods of high stream discharge, are continually abraded and redeposited as gravel bars, forming braided channels with alternating riffles and pools (Kootenai River Network, Inc., 2020).

The streamflows in the Kootenay Basin are dependent on precipitation in the form of rainfall as well as snow. Rainfall is the dominant form of precipitation in the lower elevation areas, and snowfall in the mid to higher elevation areas. As described above, it is a highly variable basin with many very remote areas with relatively limited data collection sites, and streamflows can be difficult to predict given these conditions. As described previously, approximately 50 to 60 percent of the inflow to the lake comes from streams that are not regulated by dams. Of the remaining 40 to 50 percent of the inflow that is regulated, the majority comes through Libby Dam, with only about 10 percent coming through Duncan Dam (Daley et al., 1981).

Streamflows in the Kootenay Lake basin are generally highest during the peak snowmelt season in early spring, and lowest during the late summer, early fall, and very cold periods in the winter. The water levels in Kootenay Lake also vary seasonally, with the peak historically occurring in May or June, and the lowest water levels generally occurring in March or April. Flow rates through Corra Linn Dam average 788 cubic meters per second (27,826 cubic feet per second), and range as low as 104 cubic meters per second (3,673 cubic feet per second) to as high as 4,930 cubic meters per second (174,101 cubic feet per second) (Environment and Climate Change Canada, 2019).

There are six main surface water hydrologic data collection gages that are most pertinent to the operation of Kootenay Lake. These are listed below in downstream to upstream order in Table 3-1.

Table 3-1. Pertinent Surface Water Data Collection Gages

Gage Name	Maintaining Agency	Identification Number
Kootenay Lake Outflow near Corra Linn, BC	FortisBC	08NJ158
Kootenay River above Corra Linn, BC	FortisBC	08NJ113
Kootenay Lake at Nelson, BC	FortisBC	08NJ009
Kootenay Lake at Queens Bay, BC	FortisBC/ Water Survey of Canada	08NH064
Kootenai River at Porthill, Idaho	U.S. Geological Survey	12322000
Kootenai River at Bonners Ferry, Idaho	U.S. Geological Survey	12309500

The first four gages are directly referenced in the 1938 Order, and the last two on the Kootenai River are on the upper end of the lake where it has a backwater effect reaching as far upstream as the vicinity of Bonners Ferry, Idaho. The site at Porthill is important because it is in the area with agricultural developments that are considered in the 1938 Order. The site at Bonners Ferry is a key consideration in flood risk management, agriculture, and habitat conditions for the endangered Kootenai River white sturgeon. In addition to these surface water collection sites, there are numerous snowpack data collection sites, since it is such an important component of the inflow.

b. Lake Regulation History and Charts. A chart showing the historical lake elevations based on daily data from 1931 to 2020 is provided in Figure 3-1. This chart graphically illustrates several important points regarding the history of lake regulation. One key observation that can be made from the data is that the annual maximum lake elevations have been much lower after Libby and Duncan Dams became operational than they were previously, averaging about 1.8 meters (6 feet) lower. Another key observation is that the range of fluctuation between the maximum and minimum lake levels has also been reduced from about 7.3 meters (24.5 feet) prior to the dam construction, to about 5.0 meters (16.4 feet) after the dams were constructed. Detailed yearly charts showing the water surface elevations, inflow, and outflow based on daily data for the available historical period of record are provided in Attachment 2. The water surface elevation data in Attachment 2 is for the Kootenay Lake at the Queens Bay measuring site, and the period of record is from 1931 to 2020 (USACE, 2020b). The inflow data is calculated and is for the period of available record from 1976 to 2020. The outflow data is for a location near Corra Linn Dam and is for the period of record from 1938 to 2020. Another key observation about this data is that the peak outflows from the lake have also decreased since the upstream dams were constructed due to the regulation of the peak inflows by these dams. Other statistics on maximum and minimum operating parameters are provided in Section 3.c.

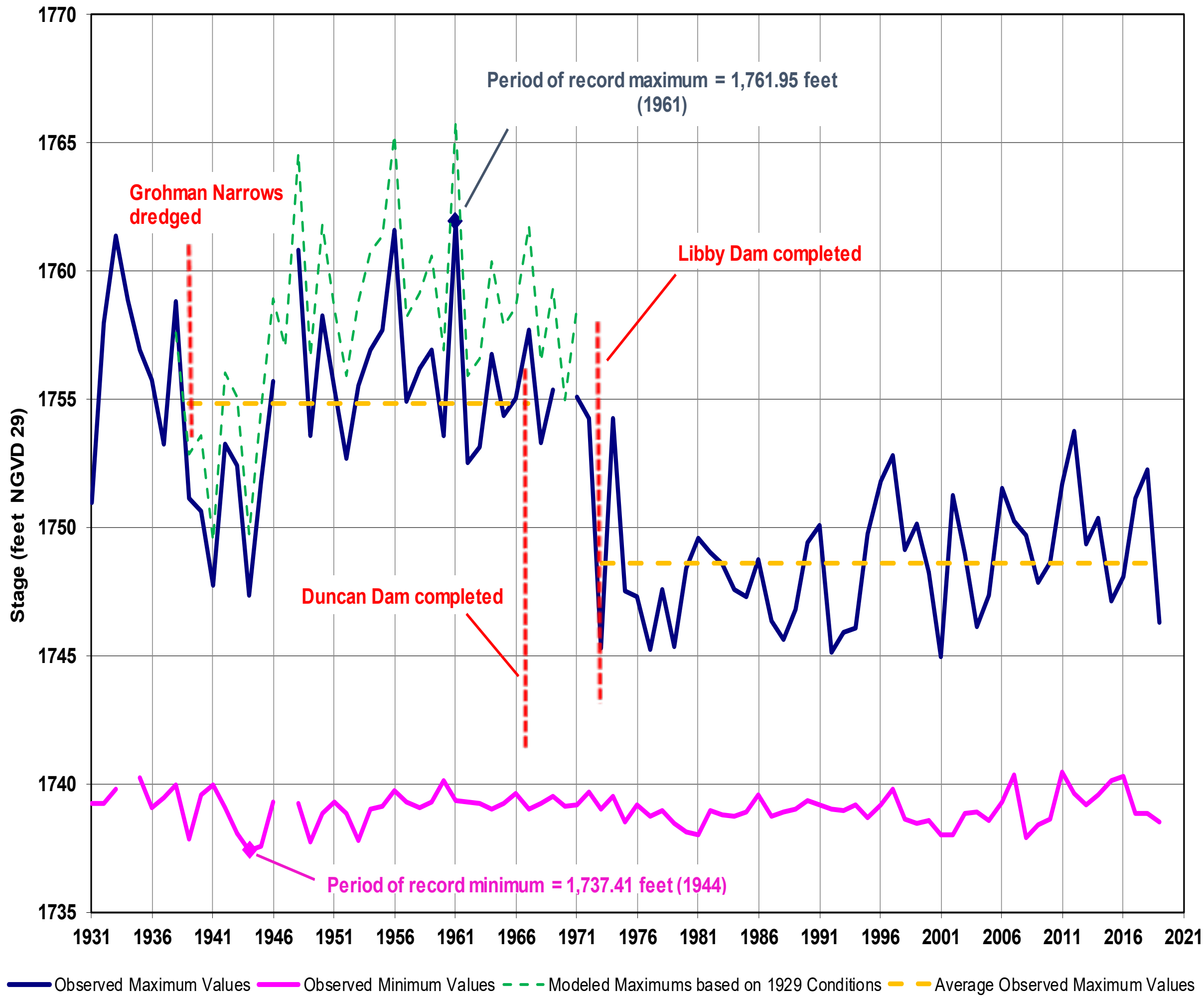


Figure 3-1. Kootenay Lake Historical Lake Levels

c. Lake Regulation Summary Tables. Tables 3-2, 3-3, and 3-4 show the maximum and minimum daily lake levels, inflow, and outflow for the available period of record. Similar to what is shown in the graphical charts included in Attachment 2 and described above, one key observation about the data is that the Kootenay Lake peak elevations have been much lower since Libby and Duncan Dams became operational. As shown below in Table 3-2, all of the highest ten peak water surface elevations on record occurred prior to 1973, before Libby and Duncan Dams were operational. The lowest annual peak water surface elevations all occurred in 1973 or later. Table 3-4 also shows that the highest ten outflows from Kootenay Lake all occurred prior to these two upstream projects becoming operational.

Table 3-2. Maximum and Minimum Kootenay Lake Peak Water Surface Elevation at Queens Bay (1931-2020)

Rank	Date	Maximum Peak Water Surface Elevation (ft)(1)	Rank	Date	Minimum Annual Peak Water Surface Elevation (ft)(1)
1	June 9, 1961	1,762.00	1	May 30, 2001	1,745.00
2	June 6, 1956	1,761.60	2	June 7, 1992	1,745.10
3	June 23, 1933	1,761.00	3	October 23, 1977	1,745.20
4	June 12, 1948	1,760.90	4	November 15, 1973	1,745.40
5	June 3, 1934	1,758.60	5	December 27, 1979	1,745.50
6	June 8, 1938	1,758.50	6	June 1, 1988	1,745.60
7	June 25, 1950	1,758.30	7	May 23, 1993	1,745.90
8	June 98, 1955	1,757.80	8	June 28, 1994	1,746.10
9	June 24, 1967	1,757.80	9	June 14, 2004	1,746.10
10	June 19, 1932	1,757.70	10	May 18, 1987	1,746.30

(1) Data obtained from USACE Seattle District, data sources are a combination of Environment and Climate Change Canada and Corps of Engineers Water Management System.

Table 3-3. Maximum and Minimum Kootenay Lake Peak Inflow (1976-2020)

Rank	Date	Maximum Annual Peak Inflow (cfs) (1)	Rank	Date	Minimum Annual Peak Inflow (cfs) (1)
1	May 22, 2006	122,500	1	June 10, 1977	50,500
2	June 2, 1997	122,220	2	May 28, 1979	53,600
3	June 7, 2012	119,700	3	June 7, 2004	58,400
4	May 18, 2018	118,700	4	May 15, 1988	59,610
5	June 1, 2020	114,600	5	May 9, 1992	60,810
6	June 18, 1999	112,820	6	May 13, 1994	60,810
7	May 21, 2008	110,900	7	May 29, 2001	63,410
8	June 9, 1996	107,500	8	June 19, 2005	64,500
9	May 23, 2002	106,100	9	June 18, 1984	65,680
10	May 14, 2013	101,500	10	May 13, 1989	66,410

(1) Data obtained from USACE Seattle District, data source is computer modeling with the Corps of Engineers Water Management System, calculations are based on water year (October 1 to September 31).

Table 3-4. Maximum and Minimum Kootenay Lake Outflow (1938-2020)

Rank	Date	Maximum Annual Peak Outflow (cfs) (1)	Rank	Date	Minimum Annual Peak Outflow (cfs) (1)
1	June 8, 1961	174,101	1	September 8, 1957	3,673
2	June 6, 1956	169,157	2	September 5, 1960	4,414
3	June 10, 1948	163,860	3	November 2, 1971	4,803
4	June 22, 1967	140,906	4	September 5, 1955	4,838
5	June 25, 1950	139,140	5	April 9, 1980	4,944
6	June 28, 1955	135,961	6	November 24, 1957	4,944
7	June 27, 1959	131,017	7	December 13, 1963	5,015
8	1954 (multiple dates)	128,899	8	December 25, 1960	5,262
9	June 17, 1964	127,839	9	October 3, 1975	5,300
10	May 30, 1958	119,010	10	August 17, 1966	5,333

(1) Data obtained from USACE Seattle District, data source is Environment and Climate Change Canada, calculations are based on water year.

<u>4. Climate Change</u>. This section of the paper provides information on projected changes to the meteorology, hydrology, and operations of Kootenay Lake. This information is based on climate change research conducted by several different entities. It also provides information on the relevance of these changes to the 1938 Order, and key information gaps and areas for potential additional research and study.

a. Summary of Projected Changes to Meteorology and Hydrology. There are several important factors to consider when evaluating the potential effects of climate change on Kootenay Lake. One is that since snowmelt is an important source of inflow to the lake, any reductions or changes in the amount or timing of snowpack or snowmelt play a key role in the hydrology of the lake. Another is that this watershed is highly variable in terms of hydrology and geography, and therefore changes in the climate will affect the watershed in different ways. For example, the northernmost part of the watershed is the coldest and the most snowmelt dominant part of the basin. Therefore, the snowpack in those areas is probably less sensitive to temperature changes than it is in other parts of the basin that are at lower elevations. The lower elevation areas are more susceptible to increased temperatures and a change in precipitation falling in the form of rain than snow. Finally, climate change impacts at the two upstream dams will also have a direct effect, since the dams release a large percentage of the annual inflow to Kootenay Lake. This section describes the climate change research utilized in this analysis, followed by the projected changes to the meteorology and hydrology.

i. Summary of Key Climate Change Research Utilized. Various studies and analyses have been conducted regarding the potential impacts to the meteorology and hydrology of the Columbia River basin and its watersheds due to climate change. These studies and analyses have used different assumptions and approaches to predict potential changes to the meteorology and hydrology in the Kootenay Lake watershed. The two key climate change research projects utilized for this paper are summarized below.

- *River Management Joint Operating Committee (RMJOC) Climate Change Assessment*: The RMJOC is a group of federal agencies in the United States that operate dams in the Columbia River Basin which are part of the Federal Columbia River Power System (FCRPS). The RMJOC is comprised of the Bonneville Power Administration (BPA), USACE, and the United States Bureau of Reclamation (USBR). Since 2009, they have performed a wide range of ongoing climate change assessments and analysis in the basin. A recent report summarizing their results was published in 2018 (RMJOC, 2018). They have conducted these efforts in collaboration with numerous entities such as the University of Washington and Oregon State University. They were very extensively reviewed, and have been well accepted as a key source of information throughout the region. Their assessments include a large ensemble of unique projections of future hydrology, and focus on potential future changes to hydropower generation and reliability, flood risk management, water supply, recreation, cultural resources, fisheries, navigation, and functioning of the ecosystem.

- *BC Hydro and Pacific Climate Impacts Consortium (PCIC) Research Project*: In Canada, BC Hydro has led various efforts to project the potential impacts of climate change on the hydrology and reservoir operations across the province of British Columbia. Their research is being done in collaboration with others such as the Pacific Climate Impacts Consortium at the University of Victoria. Their research has also been reviewed extensively and is well accepted. A report summarizing some of their key conclusions for the Columbia River basin was published in 2011 (PCIC, 2011).

ii. Projected Meteorological Changes. The climate change research suggests that several relevant meteorological changes are anticipated, including:

- Temperatures are projected to continue increasing.
- Precipitation is projected to increase, and more of it will be in the form of rain, rather than snow (Hamlet et al. 2013). The exception is that the snowfall will remain about the same in the coldest, most snowmelt-dominant areas in the basin.
- Precipitation will be more variable, and there will be more extreme precipitation events. In a snowmelt dominated system such as Kootenay Lake, warming temperatures and changes in the precipitation such as those described could have a significant impact on the hydrology and management of the lake in accordance with the 1938 Order and other objectives.

Although these projected meteorological changes are based on the best available information regarding possible global warming and climate change scenarios, information gaps exist regarding the expected meteorological changes. These are described in Section 4.c.

iii. Projected Hydrologic Changes. The projected meteorological changes described above could lead to many different hydrologic changes that are relevant to the regulation of Kootenay Lake and surrounding projects, including:

- There will be more overall variability in the streamflows and more extreme hydrologic events. This is related to the increased variability in the winter and spring precipitation, changed evapotranspiration and runoff conditions, and overall warming temperatures.

- There will be higher winter streamflows due to warmer temperatures and more of the winter precipitation falling as rain. This will also be exacerbated by more rain-on-snow events.
- There will be more uncertainty in spring streamflows due to more of the precipitation falling as rain and warmer temperatures during this period.
- There will be lower late summer and fall streamflows due to the warmer temperatures during these periods, as well as changes in glacier cover. Higher summer temperatures and lower late summer and fall streamflows could also lead to higher water temperatures and evaporation in Kootenay Lake, particularly during the summer and fall.

Key information gaps and areas for potential research and study regarding the hydrologic effects of climate change are described in Section 4.c.

b. Relevance of Climate Change and Potential Impacts to Kootenay Lake and 1938 Order. The projected changes described above in the meteorology and hydrology of the watershed could result in some additional challenges regulating Kootenay Lake in accordance with the 1938 Order and rule curve, including:

- Winter and early spring lake levels may be higher than in the past due to higher streamflows during these periods. If this occurs, it will make it more difficult to regulate the lake in accordance with the 1938 Order to achieve the lake levels specified in the rule curve.
- If streamflows become more extreme and variable in the spring, it will also make it more difficult to implement some provisions of the rule curve used to manage the lake, such as drafting the lake from January 7 through April 1 and determining the commencement of the spring rise.
- Lake levels in the summer may decrease due to lower streamflows and increased evaporation from warmer air temperatures.

Specific effects of climate change on the various operating purposes are described in further detail in Sections 6 through 9.

c. Summary of Key Information Gaps and Areas for Future Research and Study. The key climate change topics for potential future research and study are summarized below.

i. Projected Meteorological Changes. More details are needed on changes in the magnitude and timing of the projected precipitation. In particular, the projected changes in precipitation vary depending on the assumptions used for climate change scenarios, and could continue to be refined. For example, a key area of uncertainty is the proportion of the precipitation that will occur as rainfall versus snow, and how this relates to the magnitude and timing of the expected runoff. In addition, as new information is developed on global warming and associated changes, additional research may be needed to determine how this affects the meteorology.

ii. Projected Hydrologic Changes. Key information gaps still exist regarding the hydrologic effects of climate change such as how much the magnitude and timing of the streamflow will change due to the meteorological changes. Changes in glacier cover and contribution to streamflow are an important aspect that could also be considered. Additional research and study could be conducted in all these areas, as well as to determine how this affects lake regulation.

iii. Relevance of Climate Change to Kootenay Lake and the 1938 Order. If research is done to fill the information gaps on meteorological and hydrologic changes, additional studies could also be done to see how these affect the lake level and if the lake can be managed within the existing provisions of the 1938 Order, or if adjustments may be needed. Specific research and study recommendations include:

- Performing additional hydroregulation studies for the Kootenay River system to determine the specific impacts of climate change on the system
- Performing additional studies to determine how effectively Kootenay Lake can be managed to meet objectives within the existing provisions of the 1938 Order

- Determining adjustments to lake regulation and the 1938 Order that may be needed given the most likely climate change scenarios and other changing requirements

5. Socioeconomic Setting. This section of the paper summarizes the pertinent recent, current, and potential future socioeconomic information and trends for the Kootenay Lake area most affected by lake regulation. It also identifies key information gaps and areas for potential additional research and study.

a. Population. The area surrounding Kootenay Lake was originally inhabited by several different indigenous peoples, and is an important part of their history. In Canada, the Kutenai (also known as Ktunaxa) and Sinixt tribes inhabited the area and used the lake and associated river systems as part of their seasonal migration and trading routes. Two federally recognized tribes represent the Kutenai people in the United States. These are the Kootenai Tribe of Idaho, and the Confederated Salish and Kootenai Tribes in Montana. The area around Kootenay Lake that is most affected by lake regulation is comprised mainly of rural areas and a number of small towns and villages located around the lake. Approximately 19,700 people live within 2.5 km (1.6 mi) of the Kootenay Lake shoreline, and about 10,660 of those live in the City of Nelson, which is the largest city in the area and is located on the West Arm of the lake (Statistics Canada, 2016). Tourism is an important industry, with approximately 200,000 tourists visiting the area each year (Duc, 2020). It is unclear what percentage of these visits are directly related to Kootenay Lake, but it is a major tourist attraction in the area that probably contributes significantly to tourist visitation.

The upstream area most affected by regulation of the lake is comprised mainly of agricultural areas and a number of small towns and villages. The largest towns in the area are Creston, British Columbia, population about 5,300 (Statistics Canada, 2016), and Bonners Ferry, Idaho, population about 2,673 (World Population Review, 2020).

The downstream area between the lake and the confluence of the Kootenay and Columbia Rivers is comprised mainly of rural areas, with one small village at Glade, British Columbia, which has a population of about 300 (Waymarking, 2020). The city of Castlegar (population about 8,000) is located at the confluence of the Kootenay and the Columbia Rivers (Statistics Canada, 2016). There are also a number of other cities, towns, and villages in this general area that are affected by the flows from the Kootenay River.

b. Development. Numerous developments and facilities have been constructed around Kootenay Lake and the surrounding area, and are affected by lake regulation. These range from individual residences to larger commercial developments and facilities such as water treatment plants and others. There is also a ferry service that transports vehicles and passengers across the lake. This section describes these developments and how lake regulation affects them. Specific details about the economic impacts from flooding are covered in Sections 6 and 9.

<u>i. Residential Development</u>. Many different types of residences have been built around the shoreline of Kootenay Lake, as well as in upstream and downstream areas affected by the regulation of the lake. Home prices vary widely, but in 2019 the median price for homes around the lake in more rural areas was over CDN$500,000, and well over CDN$1,000,000 for homes in Nelson (Goertz, 2020). Many of these residences have boat docks, decks, and other facilities that are affected by both high and low water levels. The impacts vary depending on the time of the year, the lake elevation, and the duration of the event. There are many different and conflicting sources of data on residential flood damages. However, the Regional District of Central Kootenay (RDCK), which is the local agency responsible for floodplain management around the lake, estimates that flood impacts generally begin when the lake reaches an elevation of about 533.4 meters (1,750 feet) (RDCK, 2007). These impacts include flooding of a water supply pumping station and minor flooding of approximately 15 homes. Concerns about low lake levels usually begin when the lake is below an elevation of about 1,738

feet, and involve impacts to water wells, boat docks, and other facilities (Nelson Star, 1981).

The developments in the upstream area most affected by the lake regulation are the agricultural areas that are discussed in Section 6, and the areas in the towns and villages that are in the floodplain. The backwater from Kootenay Lake can contribute to flooding of residential properties in these areas. The backwater effect varies depending on the lake level and flow in the river. The United States National Weather Service (NWS) established the flood stage for the Kootenai River at Bonners Ferry at 537.7 meters (1,764 feet) (National Weather Service, 2020). Since 1996, local officials requested the NWS to reduce the flood stage down to 537.1 meters (1,762 feet) because of flood damage that was occurring to properties and agricultural areas in the floodplain when the river was at 537.7 meters (1,764 feet). In 2007, the NWS decided to leave the flood stage at 537.7 meters (1,764 feet) based on information they received during a public comment period (RuralNorthwest, 2007). Further details on development and flood risk in the upstream areas are provided in Section 9.

There are some residences along the downstream reach of the river between the lake and the confluence with Columbia River, but no information was available on the relationship between river flows and impacts to developments in this area. As the third largest tributary to the Columbia River, the flows from the Kootenay River can have a major effect on the flood risk for developments in the Columbia River floodplain. However, the storage volume in Kootenay Lake is relatively small compared to the average flow in the Kootenay River, so that the lake operation has a limited effect on regulating river flows.

ii. Commercial Development. Many commercial developments around the shoreline of the lake can be affected by lake operations. Some have also been constructed in the upstream and downstream areas. In the shoreline area, for example, there are close to 20 different public and private boat launching facilities and marinas that are located around the lake (Kootenay Lake Sustainable Boating Society, 2020). There are also many other developments such as hotels and other businesses that are affected. An example is the Prestige Lakeside Resort located in Nelson, British Columbia. It begins to experience flooding when the lake reaches approximately elevation 534.5 meters (1753.5 feet) (IKLBC, 1997). In total, there are over 180 tourism-related businesses in the area (Duc, 2020). It is unclear what percentage of these businesses are directly related to Kootenay Lake, but it is known to be a major tourist attraction in the area that probably helps attract many of the tourism-related businesses.

Limited information was available regarding the commercial developments in the upstream areas, aside from the agricultural developments. The Kootenai River Inn Casino and Spa in Bonners Ferry, Idaho is an example of a commercial development that can be affected by the lake operations. It is located adjacent to the Kootenai River, and according to the NWS, water begins to encroach upon the lawn of this hotel at a river stage of 538.3 meters (1,766 feet) at the Bonners Ferry gage (National Weather Service, 2020).

No information was available about commercial developments in the downstream area between the lake and the confluence of the Kootenay and Columbia Rivers, other than the dams and hydroelectric plants that are located in this reach.

<u>iii. Other Facilities</u>. Numerous other facilities around the shoreline of the lake are affected by the lake level and water quality of the lake. These include public parks, swim beaches, water wells, water pumping plants and treatment facilities, storm drainage and sewer facilities, and many others. Many of these can be impacted by unusually high or low lake levels and poor water quality. Limited information was available about other facilities that are affected by lake regulation in the upstream and downstream areas.

<u>iv. Ferries</u>. There are two ferries that provide transportation across Kootenay Lake, and one that provides transportation across the Kootenay River downstream of Kootenay Lake. The Kootenay Lake Ferry is operated by the British Columbia Ministry of Transportation and Infrastructure to transport vehicles and passengers across the west

arm of the lake. This ferry route connects the towns of Balfour and Kootenay Bay, carries up to 80 cars and 250 passengers, and makes crossings each way as often as 15 times per day in the summer (British Columbia Ministry of Transportation and Infrastructure, 2020a). The Harrop Cable Ferry transports up to 24 cars and 98 passengers across Kootenay Lake between the towns of Harrop and Longbeach and operates on demand (British Columbia Ministry of Transportation and Infrastructure, 2020b). The routes for both ferries cross relatively shallow areas in the lake, and both of the ferries touched the bottom of the lake in April 2008 when the lake level was around 529.7 meters (1,738.0 feet) (personal communication with BC Hydro staff, 2020). The route for the Kootenay Lake Ferry has recently been dredged so that the lake level is not expected to be an issue in the future (Tanasichuk, 2020). The Glade Cable Ferry transports vehicles and passengers across the Kootenay River to the town of Glade, which is downstream of the lake and approximately 22.5 km (14.0 miles) west of Nelson (British Columbia Ministry of Transportation and Infrastructure, 2020c). It is possible that if outflows from the lake are higher in the future the service could be disrupted, however this has not been an issue to date (Tanasichuk, 2020).

c. Economic Value of Recreation and Other Commercial Uses. Information about the economic value of recreation and other commercial uses in the area around Kootenay Lake is somewhat limited. Approximately 200,000 tourists visit the area each year. The approximate annual economic value of tourism in the area, just in terms of lodging sales, is CDN$21,000,000 (Duc, 2020). There are also significant economic benefits from the other tourism-related expenditures for food, tours, and other items.

d. Summary of Key Information Gaps and Areas for Future Research and Study. The key socioeconomic topics for potential future research and study are summarized below.

i. Population. Further research could be done to determine the current and projected population and tourist visitation associated with the lake given different growth scenarios.

ii. Development. Further research could be done to assess available floodplain mapping information showing the current and projected development around the shoreline of the lake and in the pertinent upstream and downstream areas, such as information created by the Regional District of Central Kootenay. This information could be supplemented with additional information if gaps exist. Research could also be done on the economic effects of lake regulation on tourism, developments, and facilities in shoreline, upstream, and downstream areas.

6. Agricultural Impacts. Agriculture impacts related to the backwater effect from the regulation of Kootenay Lake were a key consideration in the 1938 Order. This section summarizes recent, current, and potential future issues in the Kootenay Lake basin related to agriculture, agricultural pumping costs for drainage issues, reimbursement for pumping costs, and other related topics.

a. Agricultural Development in Kootenay Lake Area. There is a total of about 26,101 hectares (64,500 acres) of agricultural land that is affected by the regulation of Kootenay Lake. Approximately 12,141 hectares (30,000 acres) of the land are in Canada (Toyota, 2020), and 13,960 hectares (34,500 acres) are in the United States (IKLBC, 2014). This agricultural land is located in a very flat valley known as the “Kootenay Flats” that is adjacent to the river. A photograph of the area is shown in Figure 6-1. It begins just upstream of the town of Bonners Ferry, Idaho, and extends downstream to about 30 miles south of the international border. A variety of crops are grown in this area, including alfalfa, barley, canola, hops, oats, mustard, and wheat (Darden et al., 2001.) About 1,700 acres of hops are grown at the Elk Mountain Farm owned by Anheuser-Busch InBev, making it the single largest hop farm in the world and an important economic asset in the area (Anheuser-Busch InBev, 2020).

Figure 6-1. Photograph of Kootenai Flats (looking downstream toward Kootenay Lake).

There are a total of about 45 kilometers (27 miles) of levees in Canada and 170 kilometers (100 miles) of levees in the United States that are designed to reduce the flood risk in the City of Bonners Ferry, Idaho and the agricultural areas (IKLBC, 2014). There are also many miles of dykes within the agricultural areas that are used to control water intrusion into the agricultural areas. These dykes, and related facilities such as gates and pumps, are managed by various dyking districts and the federal Kootenai National Wildlife Refuge.

b. Effect of Kootenay Lake Regulation on Agriculture. The backwater from the regulation of the lake can increase water seepage into agricultural lands. The backwater effect varies depending on the location, flow in the river, and lake levels. At the upstream end of the agricultural area, the water seepage begins when the Kootenai River at the Bonners Ferry gage is at about elevation 535.8 meters (1,758 feet), but at the downstream end it can begin when the Kootenai River at the Porthill gage is at about elevation 533.4 meters (1,750 feet) (IKLBC, 2012).

Agricultural impacts result from either having too much water on the land to plant crops during the planting season, or having too much water on crops after they have been planted (Darden et al., 2001). The majority of the planting begins in April, and the majority of the harvesting is done by September (Merkle, 2015). It is estimated that damage begins when water is on the crops for over one week. Crop damage estimates vary widely, depending on factors such as the type of crop, the time of year, and the extent of the damage. The estimates range from as low as about US$210 to US$440 per acre for most crops, to over US$5,100 per acre for hops (USACE, 2005). The total agricultural economic losses due to flooding and drainage problems can exceed US$7,000,000 in a high water year like 1961 (USACE, 2005).

c. Provisions of Kootenay Lake Order Pertaining to Agriculture. The key provisions in the 1938 Order pertaining to agriculture are the lowering of lake levels during key agricultural periods and providing for reimbursement to agricultural interests for additional pumping costs that may be incurred due to lake regulation. The maximum elevation limit of 531.4 meters (1,743.32 feet) (at Nelson) in the late summer was included to reduce the backwater effects on upstream agricultural areas during key periods. The other provision pertaining to agriculture requires the operator of Corra Linn Dam to pay a total up to US$3,000 per year to agricultural interests for increased pumping required to drain the lands affected by the backwater from the lake. This reimbursement was not indexed for inflation or other changes that might warrant increases in the limit. This has been an issue, because the pumping costs have increased over time due to higher electricity prices and other factors. Previously, the Kootenai Valley Reclamation Association (KVRA) and others have suggested to the IKLBC and the IJC that the reimbursement limit needs to be increased to make it commensurate with the actual increased pumping costs. To date, the reimbursement limit in the Order has not been changed, and the IKLBC and IJC have instead encouraged the operator of Corra Linn Dam to negotiate financial settlements with the agricultural interests to provide additional reimbursement where justified. Annual settlements have been negotiated over the years, resulting in recent average annual reimbursements ranging from US$30,000 to $US40,000. This is an important current and future issue that will be described in further detail below.

d. Potential Future Issues Related to Kootenay Lake Regulation and Agriculture. There are many potential future issues related to Kootenay Lake regulation and agricultural impacts. These are summarized below, along with key information gaps and areas for potential additional research and study.

i. Magnitude, Frequency, and Causes of Agricultural Impacts. Agricultural impacts in the backwater areas affected by Kootenay Lake vary depending on many factors such as:

- Water levels in the river and lake
- Condition of dykes, levees, pumps, and other related facilities used to protect agricultural areas
- Groundwater conditions
- Unusual weather events
- Crop type and time of year

The construction of the upstream dams significantly reduced agricultural impacts by reducing the peak lake levels and fluctuations in the lake. However, the operations of these dams have changed significantly over time. For example, starting in about 1995, changes have been made to move toward more natural, pre-dam conditions in the basin to provide biological benefits. These include higher releases from Libby Dam in the spring to early summer to augment lower basin runoff entering the Kootenai River downstream of Libby Dam to enhance conditions for the endangered Kootenai River white sturgeon (USACE et al, 2002). Under the VARQ procedure, in most water years, less water is released during the fall-winter period, and more water is released during the spring-summer period to benefit downstream fish. When analyzed for the Upper Columbia Alternative Flood Control and Fish Operations EIS, peak Kootenay Lake elevations under VARQ flood control were stated as likely to increase relative to the previous flood control operation, but increases were expected to typically be one foot or less in most years (USACE, 2006). Evaluations from that time stated that the increased water levels under VARQ flood control could also result in increased backwater effects in upstream agricultural areas. It is unknown if this has occurred, and therefore whether it would occur in the future. Even with these changes the peak lake levels and inflows to

Kootenay Lake are still lower than they were prior to the construction of the upstream dams. A study by BGC Engineering concluded that the implementation of VARQ flood control has not had a significant negative impact on dyke infrastructure adjacent to the Kootenay River between the international border and Kootenay Lake (BGC, 2012). These changes are described in more detail in Sections 8 and 9.

The magnitude and frequency of agricultural impacts from lake regulation is influenced by factors such as:

- Fishery and flood risk management flows from Libby Dam.
- Continued erosion and maintenance issues with dykes and levees.
- Potential climate change effects such as more variable spring streamflows and lake levels.

ii. Levee and Dyke Conditions and Maintenance. The levees and dykes located throughout the agricultural areas are key facilities that help reduce flood risk in these areas. Many of them have deteriorated over time due to erosion and other factors, and are not as effective as they once were in protecting the agricultural areas from the backwater effect of Kootenay Lake as well as high river flows. Surveys and inspections conducted to assess the conditions of the levees and dykes indicate that they are generally not being well maintained and are in poor overall condition. For example, an inspection report prepared in 1995 determined that out of about 80 levees inspected, 20 were in imminent danger of failure, 25 had the potential for failure, and 35 were in satisfactory condition (USACE, 1995).

iii. Reimbursement for Agricultural Impacts. It can be difficult to determine the economic losses associated with agricultural flooding and drainage problems. This is because there are many components, such as the crop damages and losses, operation and maintenance costs for pumps and other facilities, and other related costs. There is no provision in the 1938 Order for indexing or making adjustments to the pumping cost reimbursement limit of US$3,000 per year. Therefore, unless the Order is modified, the only option for increasing the reimbursement is through negotiated financial settlements or similar actions, which is currently taking place. It is well recognized that this limit is outdated and too low to cover most additional pumping costs that are now incurred. Electricity costs alone have increased significantly since the time of the Order. For example, in 2000, after extensive discussions, a settlement was reached in which the owner of Corra Linn Dam (West Kootenay Power and Light at the time) agreed to pay the agricultural interests about US$27,000 per year for pumping costs incurred in 1999 and 2000 (IKLBC, 2000). Similarly, FortisBC (the current owner of the dam), paid farmers US$30,000 for their pumping costs in 2012 (IKLBC, 2013).

iv. Climate Change. Climate change could negatively impact agriculture in the spring if it results in more uncertainty about lake and/or river levels and causes more flooding during agricultural planting periods. This could increase agricultural pumping requirements and associated costs. Conversely, climate change is expected to result in lower lake levels during the summer, which could reduce the flood risk to agriculture during this period.

e. Summary of Key Information Gaps and Areas for Future Research and Study. The key agricultural topics for potential future research and study are summarized below.

i. Magnitude, Frequency, and Causes of Agricultural Impacts. Additional research and study are needed to better understand the role and relationship of variables pertaining to the agricultural impacts from the Kootenay Lake backwater. This would improve the understanding of agricultural impacts and actions that could be taken with lake operations to reduce these impacts. The potential research topics include:

- Analyzing agricultural areas to determine the current and projected future agricultural uses in the areas most prone to flooding and drainage issues
- Monitoring shallow groundwater levels.
- Performing detailed hydraulic modeling to determine the relationship between river flows, lake levels and the backwater effect, and how this relates to flooding and drainage in the agricultural areas.

- Analyzing potential future operational and hydrologic scenarios to determine how the agricultural impacts may change in the future, including the general viability of area agriculture under changed climate conditions.

ii. Levee and Dyke Conditions and Maintenance. Additional research and study are needed to better understand the current and expected future conditions of the levees and dykes and the flood risk management they provide in agricultural areas. Although the issues with the conditions and maintenance of dykes and levees are outside of the current mandate of the IKLBC, this research could be performed by other stakeholder groups or agencies. The potential research topics include:

- Assessing the condition and maintenance of the key dykes and levees in the area and identifying improvements that might be warranted.
- Analyzing potential future operational and hydrologic scenarios to determine how changes in these scenarios may affect the dyke and levee conditions and their ability to protect key areas (BGC Engineering, 2012).

iii. Pumping Cost Reimbursement Limit in 1938 Order. The $3,000 pumping cost reimbursement limit in the 1938 Order is inadequate to cover actual costs and could be revised to cover current and expected future costs. These issues with reimbursement for agricultural impacts are another area of possible research and study. The potential research topics include:

- Analyzing the current and projected frequency and magnitude of the pumping under various conditions.
- Determining if pumping is the best option to address the drainage issues, or if there are other better options such as improving dykes and/or levees.
- If it is determined that pumping will continue to be the best solution, determining the appropriate reimbursement limit and a mechanism for indexing future pumping reimbursement.

7. Grohman Narrows Hydraulics. This section summarizes the hydraulics of Grohman Narrows, the relevant history of Grohman Narrows dredging, investigations of further dredging, and potential future impacts of decisions to expand or not to expand the hydraulic capacity of Grohman Narrows. It also identifies key information gaps and areas for potential additional research and study.

a. Background. Grohman Narrows is a natural hydraulic constriction on the Kootenay River which is located approximately 3 kilometers (1.9 miles) downstream of the town of Nelson, British Columbia. The constriction is primarily due to a naturally high river bed elevation through the reach. In this area, the river narrows to an approximate width of 175 meters (574 feet) at the upstream end of the reach. The river bed elevation through the reach varies between approximately elevation 520 meters (1,706 feet) and elevation 530 meters (1,739 feet) (BC Hydro, 2014).

Grohman Narrows is a very important consideration in the regulation of the lake, because during both high and low flow conditions it can control the total outflow from the lake. Figure 7-1 shows the location of Grohman Narrows constriction relative to Corra Linn Dam, as well as the relationship between the hydraulic control provided by Corra Linn Dam versus Grohman Narrows. During high flow events or other times when the lake is projected to exceed the IJC rule curve elevations and outflow is reaching the Grohman Narrows channel capacity, the gates at Corra Linn Dam are lifted out of the water as needed to maximize water conveyance past the dam. This condition is depicted in the lower image in Figure 7-1. In these circumstances, the hydraulic control of the lake shifts upstream from the dam, to Grohman Narrows. If the lake is being regulated in this manner, and the lake elevation still exceeds the maximum level allowed by the rule curve, it is considered an exceedance of the rule curve but not a violation of the 1938 Order, because the control of the lake has shifted to the natural constriction at Grohman Narrows.

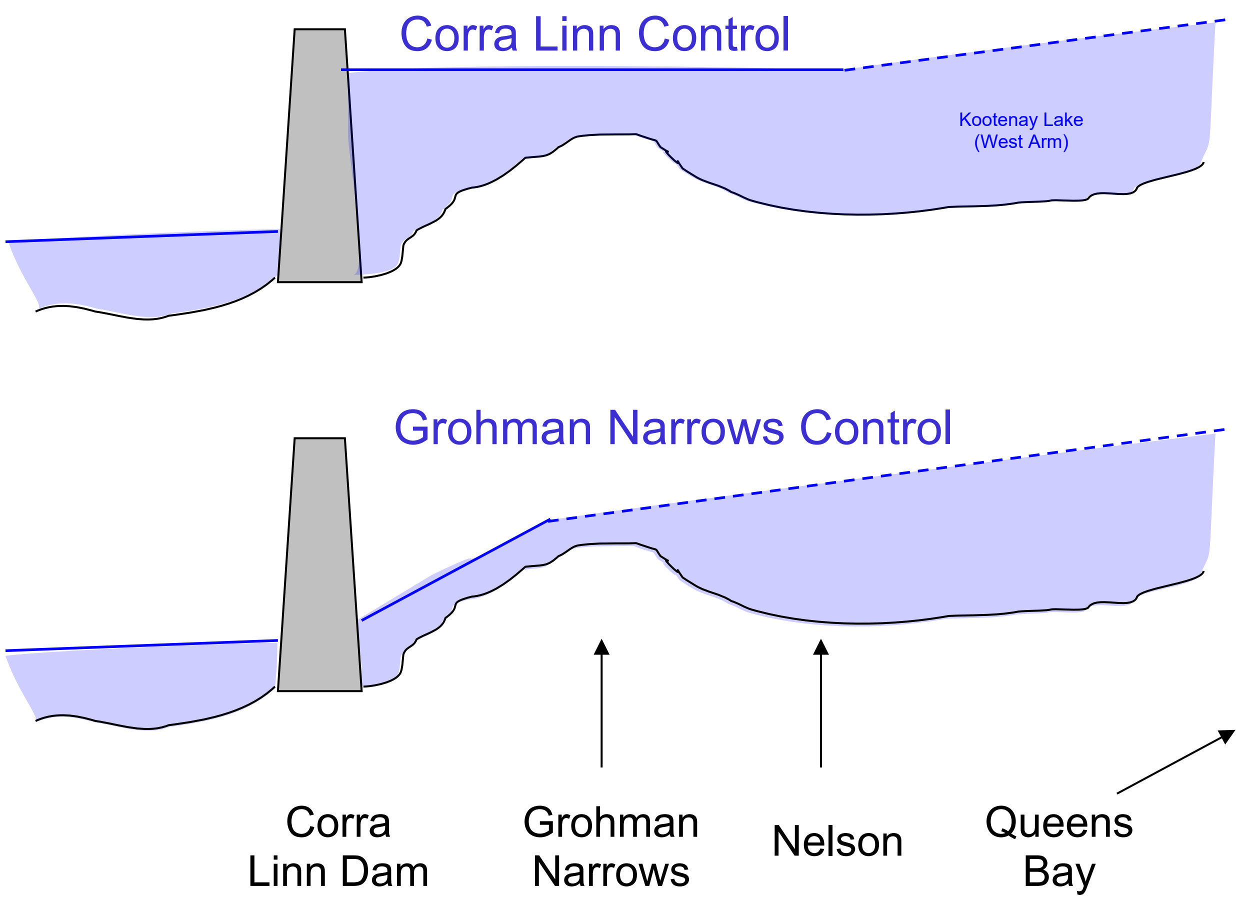


Figure 7-1. Corra Linn Dam and Grohman Narrows Control of Kootenay Lake.

b. History of Grohman Narrows Dredging. The hydraulic benefits of channel improvements from dredging Grohman Narrows have been recognized since the 1890's, and there is a long history of dredging the channel. Dredging began in 1890, when an estimated 13,760 cubic meters (18,000 cubic yards) of blasted rock, boulder and gravel were removed from the riverbed. This was followed by dredging in 1931, when approximately 350,000 cubic meters (457,780 cubic yards) of rock and 200,000 cubic meters (261,590 cubic yards) of boulders and gravel material were removed from six locations between Corra Linn Dam and Grohman Narrows (BC Hydro, 2014). The most recent dredging was done in 1939 by the West Kootenay Power and Light company as a requirement of the 1938 Order. In this 1939 effort, approximately 14,000 cubic meters (18,310 cubic yards) of rock were removed from the left bank of the river opposite Grohman Creek, and 256,000 cubic meters (334,835 cubic yards) of boulders and gravel were removed from Grohman Creek fan and from either side of the wooded island in an area known as the Narrows. It is estimated that this excavation increased the hydraulic capacity of Grohman Narrows by 425 to 708 cubic meters per second (15,000 to 25,000 cubic feet per second), depending on the lake elevation and flow conditions (IKLBC, 1997). The photograph in Figure 7-2 shows Grohman Narrows constriction.

Figure 7-2. Photograph of Grohman Narrows.

c. Current Status of Hydraulic Capacity of Grohman Narrows. Over the years since the 1938 Order went into effect, there have been concerns that the hydraulic capacity of

Grohman Narrows has been reduced due to sediment accumulation or other factors. Local citizens have offered as evidence, for example, the apparently expanding sediment bar at the outlet of Grohman Creek, claiming that it is restricting flow and causing more flooding. Despite the apparent sediment aggradation, comparison of the most recent stage-discharge curve developed in the 1950s for Grohman Narrows area with the actual daily water levels and discharges during the snowmelt periods of the subsequent decades indicate that the discharge capacity of Grohman Narrows is essentially unchanged since the last update of the stage-discharge curve (Merkle, 2011). As further confirmation of this, during the relatively high water year of 2011, the IKLBC closely monitored the operation of Corra Linn Dam to ensure that the hydraulic control point for the lake was at Grohman Narrows in advance of, and during, the spring rise. The discharge for almost all days that year plotted within 5 percent of the most recent stage-discharge curve drawn in the 1950s. This is strong evidence that, although there may be small perturbations from time to time, Grohman Narrows is still the control point for the lake, and that it is neither significantly aggrading nor degrading.

d. Investigations of Further Dredging. Although there has been no dredging of Grohman Narrows since 1939, during this period many suggestions have been made to undertake additional dredging to further improve the hydraulic capacity of the lake. This is particularly common in high runoff years when flooding occurs in the area. As a result, investigations such as those summarized below have been conducted to analyze costs and effects of further dredging.

<u>i. BC Hydro Investigations</u>. Starting in about 2005, BC Hydro began conducting various types of analysis regarding the potential for additional dredging of Grohman Narrows. A high water event in 2012 resulted in the highest levels at Kootenay Lake since 1974, and this put a renewed focus on the potential for dredging to increase the hydraulic capacity at Grohman Narrows. About this time, BC Hydro conducted several more detailed studies on the effects of various dredging scenarios to consider the feasibility, costs, and benefits of different levels of excavation as part of the Grohman Narrows Channel Improvement Project (GNCIP). In this study, they considered three different

excavation alternatives that involved low, medium, and high excavation volumes (BC Hydro, 2014). Their analysis indicated that the excavation could be completed with just dredging, and that bedrock removal by blasting would not be needed. Their preliminary cost estimates for the project ranged from about CDN$21,000,000 for the “low excavation volume” alternative, to CDN$68,000,000 for the “high excavation volume” alternative. However, the costs for the project are very uncertain, and could be as low as 5 percent below these estimates, to as high as 100 percent over. These studies showed that peak levels of the freshet, which usually occur in June, would be reduced by anywhere from 22 to 60 centimeters (0.7 feet to 2 feet) for the low to high excavation levels, respectively. They also showed that hydropower generation could be increased by the ability to pass more water through the constriction, but that it would only be increased for the high excavation scenario. Several public meetings were held throughout the region to share information about this project and to determine if there was support. BC Hydro discontinued any further efforts in 2015 because the project was not considered justified based on the benefits, costs, and other factors (Nelson Star, 2015).

ii. 2012 BPA Investigation. In 2012, the Bonneville Power Administration (BPA) conducted a preliminary hydraulic modeling study to evaluate the effects of various dredging scenarios on the lake levels. This effort was focused on determining how additional dredging would affect the backwater produced by the lake in the Kootenai River near Bonners Ferry, Idaho. This study was done because this area provides important habitat for the endangered Kootenai River white sturgeon, and/or significant increases in water depths and decreases in water velocities in this area could have a negative effect on fish spawning conditions. The study utilized a variety of different operational scenarios and water conditions to evaluate the potential effects of additional dredging on the water depth and velocity in the spawning area. It did not consider the effect of dredging on other aspects such as agriculture. The results showed that under most of the scenarios that were evaluated, there was expected to be an average reduction in the peak lake levels of less than 15 centimeters (0.5 feet), and a maximum reduction of 45 centimeters (1.5 feet) at the Queens Bay gage (Bonneville Power

Administration, 2012). The study determined that the effects of dredging on the key fish habitat area near Bonners Ferry would be minimal.

e. Potential Future Effects of Expanding Hydraulic Capacity of Grohman Narrows. Additional dredging to expand the hydraulic capacity of Grohman Narrows could have both positive and negative effects on the regulation of the lake and implementation of the 1938 Order. These are described in further detail below.

<u>i. Increased Ability to Manage Lake Levels</u>. A key result of expanding the hydraulic capacity of the lake through additional dredging would be improving the ability to control the lake. This could also improve the ability to adhere to the requirements of the 1938 Order and manage the lake to the rule curve. The increased hydraulic capacity would allow more water to be released from the lake during high flow periods and result in lower lake levels. Potential effects on the various operating purposes from expanding the hydraulic capacity are described below:

- Flood Risk Management: Flood risk around the lake and in the upstream areas would be reduced due to lower lake levels and reduced backwater from the lake. The benefits of this could be even greater in the future, given the potential for climate change to increase the variability and magnitude of peak streamflows, and the potential for increased population growth and development. Flood risk in downstream areas could increase slightly due to higher outflows that could occur from the lake with the increased hydraulic capacity.
- Ecology and Fisheries: There could be both positive and negative effects on the ecology and fishery of the lake and surrounding area. Lower lake levels in the spring could have a slightly negative effect on spawning conditions for shore-spawning kokanee and the Kootenai River white sturgeon. Other negative effects could include higher total dissolved gas levels in downstream areas due to higher releases. Higher releases could have a positive effect by providing higher flows for downstream species such as salmon and steelhead.

- Agricultural Impacts: Lower lake levels in the spring and summer would be beneficial for agriculture because this would reduce flooding and drainage issues. This could also reduce agricultural pumping requirements and costs.
- Other Uses: Increased hydraulic capacity could increase the hydropower generation during periods when the releases were higher. However, hydropower generation could also be reduced if the lake levels were lower, due to decreased head at the generating plants. If lake levels were kept lower in the summer, it could have a negative effect on recreation.

f. Summary of Key Information Gaps and Areas for Future Research and Study. The key topics related to Grohman Narrows that may warrant future research and study all pertain to potential additional dredging in the future. They include:

- Reviewing past dredging studies performed by BC Hydro to determine if they adequately addressed key issues such as the preferred dredging option, future lake regulation, the effects of dredging, and any operational changes
- Performing any additional analysis if needed to fill in key information gaps

8. Ecological and Fisheries Concerns. This section of the paper summarizes recent, current, and potential future issues and concerns related to the ecology and fishery of Kootenay Lake and the other pertinent water resources in the area. It also identifies key information gaps and areas for potential additional research and study.

a. Summary of the Ecological and Fisheries Issues and Operational Effects of Kootenay Lake. The ecology, fishery, and water quality of Kootenay Lake and the surrounding area are very complex and interrelated since it is a part of a large watershed and on a major tributary to the Columbia River. Because of this, it is important to consider these issues for the lake, as well as the related upstream and downstream areas. The regulation of the lake plays a significant role in the ecology, water quality, and fisheries of the lake and surrounding areas. The key issues, concerns, and operational effects related to the ecology and fishery will be described below.

i. Ecological Concerns and Operational Effects. Kootenay Lake is what is known as an oligotrophic lake, which means that it has fairly low productivity and a relatively low nutrient content (Golder Associates, 2009). It is generally very clear and has adequate oxygen content and other characteristics to support a good fishery. It has a medium residence time, which means that the physical and chemical characteristics of the lake are strongly influenced by the characteristics of the two major tributaries that flow into it, the Duncan and Kootenay Rivers (Daley et al., 1981). The supply and availability of nutrients to support phytoplankton is a key factor in the ecological health of the lake. This is because phytoplankton is an important food source for kokanee in the lake, and limitations in nutrients are thought to drive the food web in Kootenay Lake.

The upstream dams have had numerous ecological effects on the lake that need to be considered in planning the future management of the lake (Daley et al., 1981). The most significant of which is the removal of nutrients that go into the lake, and changes in the timing of when any nutrients go into the lake (Ashley et al., 1997). An additional upstream development which impacted the ecology of the lake was the Cominco fertilizer plant located on the St. Mary's River near Kimberley, British Columbia (Ashley et al., 1997). When it went into operation in 1953, significant quantities of phosphates were released, which caused nutrient eutrophication in Kootenay Lake. The phosphate pollution from the plant began to decrease when pollution abatement equipment was installed in 1972, and then it stopped when the plant closed in 1977. The construction of the upstream dams also trapped much of the sediment that previously went into Kootenay Lake and replenished beaches and were inputs of nutrients into Kootenay Lake (Daley et al., 1981). Lake regulation can also have other effects such as increased shoreline erosion. These, and other similar activities, led to significant changes that also affected the ecology of the lake.

Operations can affect ecological considerations around the shoreline of the lake such as aquatic nursery habitat and shoreline erosion. For example, lower lake levels can decrease aquatic nursery habitat (IKLBC, 2008c). Conversely, when lake levels are kept the same for relatively long periods of time, shoreline erosion can be increased, particularly in areas like the West Arm of the lake (IKLBC, 2009). Erosion can also be a concern in upstream areas, depending on the river flows and lake levels.

Similar ecological concerns exist in upstream and downstream areas that are affected by the regulation of the lake. For example, the backwater from the lake affects the water quality and fishery in the upstream areas. The timing and quantity of water released from Kootenay Lake also affects the water quality and fishery in downstream areas. These will be discussed in further detail below.

ii. Fishery Concerns and Operational Effects. Many different species of fish inhabit Kootenay Lake, including white sturgeon, burbot, kokanee, Gerrard rainbow trout, and bull trout. The Gerrard rainbow trout and kokanee are particularly important to the sport fishery in the lake. The kokanee is also a primary food source for the Gerrard rainbow trout and the bull trout. The kokanee population was impacted by phosphate eutrophication that occurred in the lake starting in the 1980s, because it reduced the phytoplankton in the lake, a major food source for the fish (Ashley et al, 1997). The introduction of Mysid shrimp into the lake in about 1949 is another fishery concern (Ashley et al, 1997). This was done to provide a supplementary food source for rainbow trout. However, the shrimp compete with fish for zooplankton, and their introduction reduced the average size and abundance of the kokanee. Kokanee is also one of the species that are most affected by the lake levels, because some of them ("shore-spawners") spawn in an area along the shoreline of the West Arm of the lake in the fall (Ecosociety, 2019). Successful egg incubation requires that the redds where eggs are laid in the fall be covered in water until the fry emerge in the spring. Flood risk management operations to draw down the lake level in the spring can dewater the redds. Burbot is another fish species in the lake whose population has declined significantly starting in about 1970 (KVRI, 2005). They are known to have spawned in certain areas of the lake and have been affected by lake regulation and the operation of Libby Dam (KVRI, 2005). Higher winter flows from Libby Dam, combined with the lower winter lake levels at Kootenay Lake, have impacted burbot spawning by increasing velocities in their spawning areas in the Kootenai River. Higher Kootenay lake levels that would slow river velocities during their spawning period might improve conditions for the burbot (KVRI, 2005). While the current burbot population in the lake is very low, hatchery reared burbot have recently been released into the lake as part of an effort to restore the population (British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2019).

The winter drawdown of the lake for flood risk management is an example of a Corra Linn Dam operation that can be detrimental to fish species such as kokanee that spawn along the shoreline of the lake. To reduce this impact, the lake has periodically been drawn down earlier than usual in the fall, so that the fish lay their eggs at a lower elevation that is not as susceptible to dewatering during the winter drawdown of the lake. The objective is to keep the lake elevation at no higher than 531 meters (1,742 feet) from about September 15 through October 15 every third year. This was done with great success in 2012, 2015, and 2018 (Thorley, 2019).

There are also fishery concerns related to the regulation of Kootenay Lake in the upstream tributaries and the Kootenay and Columbia Rivers downstream of the lake. For example, the endangered Kootenai River white sturgeon spawns in upstream habitat in the Kootenai River near Bonners Ferry, Idaho. Since the lake levels cause a backwater effect in the areas where these fish may spawn, the regulation of the lake is an important consideration in their survival. The winter and spring drawdown for flood control reduces the lake level and water depth in the sturgeon spawning area, which reduces their spawning success. Since Libby Dam began operating in 1973, the lake levels at Kootenay Lake in the spring, when the sturgeon spawn, have been much lower. According to the agencies responsible for the recovery of the sturgeon, this has had a detrimental effect on the water depths, water velocity, and substrate relationships needed in spawning areas during the sturgeon recruitment period (USFWS, 1997). In 1997, these same agencies requested the IKLBC to consider increasing the lake level during May and June back up to previous levels to facilitate sturgeon spawning. The IKLBC response to this request indicated that it was beyond their authority to make these changes, and that it was a matter for the IJC (IKLBC, 1997a). The records do not indicate that the agencies ever pursued this further with the IJC.

Various fish species of concern such as endangered salmon and steelhead reside in downstream areas in the Columbia River and are also affected by the regulation of the lake. As an example of this, the correspondence described previously regarding higher lake levels for sturgeon also described potential benefits to endangered salmon and steelhead in the downstream areas. This was mentioned because the additional water stored in May and June could potentially be released in August to help achieve downstream flow objectives for these species (USFWS, 1997). Although there is not an extensive fishery in the river and reservoirs immediately downstream of the lake, the operation can also affect the fishery in this area. For example, rapid fluctuations in the releases can result in the stranding of fish in some of these reservoirs such as Upper Bonnington (Golder Associates, 2009). Total dissolved gas in the water downstream of the hydroelectric dams on the Kootenay River is known to reach dangerously high levels as a result of high discharge over the spillways.

<u>iii. Water Quality Concerns and Operational Effects</u>. Limited information is available regarding water quality concerns due to the regulation of Kootenay Lake. This is an area that might warrant further research. The primary water quality concern related to lake regulation is that high water releases from the lake may result in high total dissolved gas levels from spill at downstream projects (Golder Associates, 2009). This situation has been improved by the addition of the Kootenay Canal Plant, but it still can be an issue when high releases occur at Corra Linn Dam spillway. The dams that produce the highest dissolved gas levels from spill are Brilliant, Lower Bonnington, and Upper Bonnington. High dissolved gas levels from spill at Lower Bonnington may also affect fish survival in the reservoir above the South Slocan Dam (Golder Associates, 2009). Dissolved gas limits may also be exceeded at other downstream dams, but are not believed to have measurable impacts on aquatic life (Golder Associates, 2009).

The upstream dam operations have had a number of effects on the water quality of Kootenay Lake. For example, they have significantly reduced the nutrient supply to Kootenay Lake. This has had a negative effect on the aquatic productivity of the lake.

The “Kootenay Lake Nutrient Restoration Program” was established in 1992 in an effort to address this problem (Ashley et al, 1997). It involves adding nitrogen and phosphorous to the lake to improve aquatic productivity and the fishery. This program has been successful in increasing zooplankton and kokanee populations. Another effect of the upstream dam operations is that water temperatures in the winter have increased (KVRI, 2005). This can have both positive and negative effects on the environment. An emerging water quality concern involves higher than normal selenium levels that have been detected in the Kootenai River downstream of Libby Dam (EPA, 2019). This study found elevated levels of selenium in water and fish, and elevated nitrates in the water. These elevated levels are associated with upstream sources in Canada’s Elk Valley and Lake Koocanusa. It is unclear at this time if this has resulted in higher selenium levels in Kootenay Lake.

b. Potential Future Issues Related to Kootenay Lake Regulation on the Ecology and Fishery. Many of the issues with the ecology, fishery, and water quality of the lake and surrounding area will likely continue to be future lake management considerations. Although the 1938 Order does not specifically include provisions for the ecosystem, it has some flexibility that has allowed operational changes for the ecosystem. For example, since the Order does not establish any minimum lake levels, the lake has recently been operated at levels that are lower than usual in the fall to enhance conditions for shore-spawning kokanee. However, other ecosystem-related operations that have been requested by stakeholders, such as holding the lake higher in the spring to enhance spawning conditions in upstream areas for white sturgeon, have not been implemented. Specific future issues related to the ecology, fishery, and water quality of the lake are described below.

<u>i. Ecological Issues</u>. Many of the ecological issues will likely continue or expand in the future. Factors such as increased development and demand for water, climate change, and others have made ecological considerations increasingly important in water resource management throughout the Columbia River basin. For example, the 2013 BC decision on the Columbia River Treaty includes a principle noting, “ecosystem values are currently, and will continue to be, an important consideration in the planning and

implementation of the Treaty” (BPA, 2013). Similarly, BPA, USACE, and US Bureau of Reclamation recently completed the “Columbia River System Operations Environmental Impact Statement” to review and update the management of the system (BPA et al, 2020). An important aspect of this includes operational changes for the ecosystem to benefit threatened and endangered species. These examples reflect the trend toward including more ecosystem considerations in water resource management.

Finally, the ecosystem-related impacts of climate change need to also be considered in future planning of lake regulation. Projected changes such as higher lake levels in the winter, lower lake levels in the summer, and warmer water temperatures in the summer could have both positive and negative effects on the ecology of the lake. For example, lower lake levels in the summer could reduce the aquatic nursery habitat around the shoreline of the lake.

ii. Fishery Issues. Fishery issues will continue to be an important consideration in the planning of future lake regulation. The populations of many of the key sport fish species in the lake such as kokanee, Gerrard rainbow trout, and others have been declining for some time (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2016). Action plans to improve conditions for these fish have been developed, but it is projected that it will take more time for these to show results. One of the key actions that can improve the kokanee fishery is to continue the plan of keeping the lake elevation at no higher than 531 meters (1,742 feet) in the fall to encourage shore-spawning kokanee to spawn at lower lake elevations. This is allowable within the 1938 Order, and it reduces the impact of winter drawdowns for flood risk management.

The fishery issues described previously in the upstream and downstream areas will also likely continue or may expand in the future. Some entities have suggested that anadromous salmon and resident fish be reintroduced into the upper Columbia River (United States Columbia River Tribes and Canadian First Nations, 2015). If this were to occur, it could involve fish passage at dams in the vicinity of Kootenay Lake, such as the Brilliant Dam. This could lead to changes in the regulation of Kootenay Lake as well.

Climate change could also affect the fishery in the lake and surrounding area. For example, warmer water temperatures in the lake and rivers during the summer months could have a negative effect on the cold-water fish species that inhabit the lake and spawn in upstream areas. Higher lake levels in the winter could be beneficial to shore-spawning kokanee because their eggs might not be as susceptible to dewatering.

iii. Water Quality Issues. Limited information is available regarding water quality issues pertaining to the regulation of Kootenay Lake water levels. The primary water quality concern related to lake regulation is high total dissolved gas levels at downstream projects that can result from water being spilled when high water releases are made from the lake (Golder Associates, 2009). The water quality in the lake is largely dependent upon the quality of the inflow. Since 40 to 50 percent of the inflow comes from Libby and Duncan Dams, changes in the future operation or water quality of those lakes could have an impact on the water quality of Kootenay Lake. Future operations planning will likely need to factor in continuing issues with nutrient and sediment retention caused by the upstream lakes. Mitigation efforts such as the Kootenay Lake Fertilization Experiment could also be considered. New issues such as the elevated selenium and nitrate levels detected in the Kootenai River upstream of the lake could also be considered.

Climate change considerations such as warmer water temperatures in the summer could also affect the water quality such as by increasing algal blooms. Higher releases that could result from higher peak flows in the winter could increase spill and total dissolved gas levels in the reach of the river downstream of the lake.

c. Summary of Key Information Gaps and Areas for Future Research and Study. The key ecological and fisheries topics for potential future research and study are summarized below.

i. Ecological Issues. Future studies could be considered to:

- Evaluate the effectiveness of lake regulation in addressing current and projected ecological, fishery, and water quality objectives in the lake and in pertinent upstream and downstream areas.
- Identify potential lake regulation adjustments that may be needed to better meet these objectives.
- Identify changes to the 1938 Order which might facilitate these types of lake regulation.

ii. Water Quality. Further research could be considered regarding:

- The impacts and future plans for addressing nutrient depletion and increased winter water temperatures in the lake due to the operation of upstream dams.
- Elevated levels of selenium and nitrates that have been found in water and fish upstream of Kootenay Lake to determine if this has impacted the water quality in the lake.

iii. Fisheries. Further research could be considered regarding future plans for fisheries-related activities that might affect lake levels such as the fall lake drawdown for shore-spawning kokanee and any plans for other species of concern such as burbot and the Kootenai River white sturgeon.

9. Flood Risk Management. The 1938 Order includes provisions such as dredging Grohman Narrows and drawing the lake down to 530.1 meters (1,739.32 feet) (at Queens Bay) during the winter-early spring lake drawdown period to mitigate operations of Corra Linn Dam. This section summarizes recent, current, and potential future concerns related to Kootenay Lake flood risk management. It begins with a summary of flood risk management and issues related to Kootenay Lake. This is followed by a description of the effect of Kootenay Lake regulation on flood risk management and potential future issues with flood risk management.

a. Summary of Flood Risk Management Issues Related to Kootenay Lake and the Surrounding Area. Flood risk management at Kootenay Lake and the surrounding area affects three main areas, which will be described below. These include flood risk around the shoreline of the lake, in the upstream area that is affected by the backwater from the lake, and in the Kootenay and Columbia Rivers downstream of Kootenay Lake.

i. Kootenay Lake Shoreline Issues. Since 1993, the RDCK, which is the primary regulatory agency responsible for development around Kootenay Lake, has had a bylaw in place that required the Flood Construction Level (FCL) of the underside of floor systems used for habitation, business or storage of goods damageable by floodwaters to be above elevation 536.5 meters (1760.2 feet) in the main body of the lake at the Queens Bay gage (BC Hydro, 2005). Slightly lower elevation levels were established in the bylaw for the downstream areas of the lake such as the West Arm and Grohman Narrows area. Other similar requirements regarding development around the lake have been in existence since the late 1980s, however, they have all been provided as guidelines, and were not strictly enforced by local authorities. As a consequence, there are many homes and other related developments that are built at levels below this FCL that sustain various types of flood damage during elevated lake levels. In addition, there are different estimates regarding the lake levels at which flood damages begin and the economic consequences of these damages. While the RDCK bylaws established the FCL of 536.5 meters (1760.2 feet), the RDCK estimated that flood damage begins to affect about 15 homes in the West Arm of the lake at about elevation 533.4 meters (1,750 feet), which is over 3.0 meters (10 feet) below the FCL (RDCK, 2007). The results of a 2007 RDCK study on the expected flood damages to residential structures around Kootenay Lake at various lake elevations are shown in Table 9-1. The flood damage information in this table is based on rough order-of-magnitude estimates. The table shows that at elevation 533.4 meters (1,750 feet), 15 residences are flooded by water up to 0.3 meters (1 foot) deep, whereas 20 residences are flooded at this depth at elevation 534.0 meters (1,752 feet). At elevation 534.9 meters (1,755 feet), 5 residences are flooded by water up to 0.9 meters (3 feet) deep. The economic damages from flooding are as high as CDN$15,000,000 at elevation 534.9 meters (1,755 feet).

Table 9-1. Estimated Kootenay Lake Flood Damages (RDCK, 2007)

Kootenay Lake Elevation at Queens Bay (meters)	Kootenay Lake Elevation at Queens Bay (feet)	Number of Residences Impacted (water depth on residences of 1 foot, 2 feet, and 3 feet	Estimated Total Economic Damages (CDN$)
533.4	1,750	15, 0, 0	0 - 2,000,000
534.0	1,752	20, 10, 0	2,000,000 – 5,000,000
534.9	1,755	40, 30, 5	5,000,000 – 15,000,000

The RDCK is undertaking a regional update of floodplain mapping that is expected to be completed later in 2020 (RDCK, 2019). The CRT Flood Control Operating Plan that guides CRT flood risk management provides another example of conflicting information on flood damages. It states that flood damage begins when the lake reaches elevation 534.9 meters (1,755 feet) (at the Nelson gage), and that major flood damage begins to occur at elevation 536.1 meters (1,759 feet) (USACE, 2003).

ii. Upstream Area Issues. The regulation of Kootenay Lake also affects flood risk in the upstream areas extending up to near Bonners Ferry, Idaho, due to the backwater effect from the lake. There is a risk of flooding agricultural areas, as well as residential and commercial developments and facilities. The effects of flooding on other developments in the upstream area are described in Section 5. The agricultural flood risks are described in Section 6. While much of the upstream area is protected by dykes and levees, poor maintenance and erosion from high flows has diminished their effectiveness in managing flood risk. However, this has been offset by the construction and operation of the upstream dams.

iii. Downstream Area Issues. There are a number of homes and small communities immediately downstream of Kootenay Lake that can be impacted by flooding due to high flows in the Kootenay River. One example that was mentioned previously is the town of Glade, British Columbia, which is approximately 22.5 km (14.0 miles) west of Nelson. This community can only be reached by a cable ferry that transports vehicles and passengers across the river. While this has not happened in the past, during very high flow conditions, it is possible this ferry service could be disrupted due to safety concerns, leaving residents with no access to their homes. High flows on the Kootenay River can also contribute to flooding in the downstream areas along the Columbia River in towns like Castlegar and Trail, British Columbia. This occurs when flows in the Columbia River are already high and the high flows in the Kootenay River exacerbate the problem.

<u>iv. Effect of Construction and Operation of Columbia River Treaty Dams.</u> Flood risk management for Kootenay Lake and the surrounding area has evolved significantly since the 1938 Order was established. No upstream dams with storage for flood risk management existed when the 1938 Order was established. This changed when Duncan and Libby Dams were constructed as part of the CRT. The operation of these dams reduced the average annual peak levels at Kootenay Lake by about 1.8 meters (6 feet). The maximum annual peak water level prior to the construction of these upstream projects was 537.0 meters (1,761.8 feet), in 1961, and the maximum annual peak water level since the construction of the upstream dams is 534.5 meters (1,753.7 feet), in 2012, which is over 2.4 meters (8 feet) lower. The peak outflows from the lake have also been much lower since the upstream dams were constructed, which has further reduced flood risk in downstream areas. The flood risk management benefits from the upstream projects is a key factor to consider in current and future flood risk management decisions related to Kootenay Lake. This is an area where further research might be done to see if Corra Linn’s regulation of Kootenay Lake under the 1938 Order should be updated to take into account upstream reservoir regulation.

From the start of operations through 2002, Libby Dam flood risk management operations were based upon what were known as “Standard Flood Control” procedures. However, in response to United States Endangered Species Act requirements for the recovery of endangered fish species in the United States, the operation of Libby Dam was changed to an interim alternative flood control procedure known as “VARQ” (Variable Flow). In most water years, Libby Dam discharges less water during the fall-winter period under the VARQ regime (compared to the Standard regime) and more water during the spring/summer period to benefit downstream fish. When analyzed for the Upper Columbia Alternative Flood Control and Fish Operations EIS, peak Kootenay Lake elevations under VARQ flood control were stated as likely to increase relative to the previous flood control operation, but increases were expected to typically be one foot or less in most years (USACE, 2006). In June 2008, USACE adopted the VARQ flood control regime for Libby. The operation of Libby Dam provides significant flood risk management benefits for Canada, however, Canada alleged that the VARQ flood control regime caused a reduction in FRM benefits around Kootenay Lake. The Canadian CRT representatives notified the U.S. that it was their position that compensation would be required for the reduced levels. The CRT parties have used agreements known as the Libby Coordination Agreement (LCA) and the Short-term Libby Agreement (STLA) to set aside this issue while maintaining their respective positions.

b. Effect of Kootenay Lake Regulation on Flood Risk Management.

<u>i. Kootenay Lake Shoreline Effects</u>. The drawdown of the lake to elevation 530.1 meters (1,739.32 feet) during the winter-spring period, and the refill of the lake after these to peak levels below the natural (pre-Grohman Narrows excavation) conditions, are the key operations that affect the shoreline flood risk management. Minor flood damage to developments around the shoreline of Kootenay Lake begins to occur at about elevation 533.4 meters (1,750 feet) even though this is below the FCL of 1,760.2 feet. The operation of the upstream dams has greatly decreased the flood risk around the shoreline of the lake by reducing the average annual peak lake level by about 1.8 meters (6 feet). The average peak lake elevation in the years since the construction of the upstream dams is 533.0 meters (1,748.7 feet). During that period, the peak level has exceeded elevation 533.5 meters (1,750 feet) in only about 26 percent of the years, and it is usually only for relatively short periods of time. The highest peak lake elevation since the upstream projects were constructed is 534.6 meters (1,753.8 feet), which occurred in 2012.

ii. Upstream Area Effects. The river stage in the upstream areas affected by flooding from the lake is dependent on both the elevation of Kootenay Lake and the flow in the Kootenai River. The river gage at Bonners Ferry is used for flood risk management in this area. The United States National Weather Service (NWS) has established 537.7 meters (1,764 feet) as the flood stage for this gage (NWS, 2020). Due to the backwater effect from Kootenay Lake, this stage is dependent on both the river flow and lake level, and can occur at various flow and lake level conditions. For example, a stage of 537.7 meters (1,764 feet) can occur when the flow in the Kootenai River at Bonners Ferry is approximately 1,416 cubic meters per second (50,000 cubic feet per second) and the Kootenay Lake elevation at Queens Bay is about 534.9 meters (1,755 feet) (USACE, 2003). This same stage can also occur when the river flow is about 963 cubic meters per second (34,000 cfs) and the lake elevation is 536.4 meters (1,760 feet). The NWS states that when the Kootenai River at Bonners Ferry gage is at 537.7 meters (1,764 feet), there will be minor flooding due to seepage along the agricultural lands, as well as on private roads along levees (NWS, 2020). At a river stage of 538.3 meters (1,766 feet), flooding will begin to cut off access to some homes on private roads (NWS, 2020). Major flooding occurs at a river stage of 540.7 meters (1,774 feet) at Bonners Ferry, Idaho, and 537.4 meters (1,763 feet) at Creston, British Columbia (USACE, 2003). The damages that can occur in agricultural areas are discussed in more detail in Section 6. No information was available on the relationship between river flows and flood damages for residential and other developments in the upstream area. However, prior to 2007, public officials and farmers in the area requested that the NWS lower the flood stage from 537.7 meters (1,764 feet) down to 537.1 meters (1,762 feet) in order to reduce flood damage to properties and agricultural areas (RuralNorthwest, 2007.) The NWS evaluated this proposal and decided against it based on input they received from various entities during a public comment period.

iii. Downstream Area Effects. As the third largest tributary to the Columbia River, the flows from the Kootenay River can have a major effect on the flood risk in the downstream areas. The magnitude and duration of outflows from the lake are the primary consideration in downstream flood risks. With only 0.96 cubic kilometers (0.78

MAF) of storage, the ability to store flood water in Kootenay Lake and reduce downstream flood risk is fairly limited. As a consequence, the outflows from the lake are generally fairly similar to the inflows. For example, in 2012 the peak inflow to the lake was about 3,390 cubic meters per second (119,700 cubic feet per second), and the peak outflow was about 2,733 cubic meters per second (96,500 cubic feet per second). This was a reduction in the peak outflow of about 657 cubic meters per second (23,200 cubic feet per second). The peak outflows have been much lower since the upstream dams were constructed, which has further reduced the flood risk in these areas. No information was available on the relationship between river flows and flood damages in the reach of the river between the lake and the confluence with the Columbia River. This is a topic that may warrant further research if significant changes are anticipated in the outflows from the lake. Information on the relationship between flood damages and river stage in the downstream area near the confluence of the Kootenay and Columbia Rivers and areas downstream of that is available in the FCOP (USACE, 2003). For example, it states that flood damages begin at Trail, British Columbia when the Columbia River flow measured at the nearby Birchbank, British Columbia gage exceeds 6,371 cubic meters per second (225,000 cubic feet per second).

c. Potential Future Challenges Related to Kootenay Lake Regulation on Flood Risk Management.

<u>i. CRT Flood Risk Management</u>. In September 2024, the current flood risk management provisions in the Columbia River Treaty change from specific flood risk management procedures with a defined amount of flood storage in Canadian reservoirs to a less defined approach. The United States and Canada began formal negotiations on modernizing the Columbia River Treaty in May 2018. Negotiations are ongoing, and flood risk management is among the topics under discussion. The outcome of these discussions and how Kootenay Lake may or may not be affected are unknown at this time, and it is a topic that warrants further monitoring.

ii. Climate Change. Climate change could affect flood risk management at Kootenay Lake and the surrounding area in many ways. Winter lake levels are projected to be higher than in the past due to the higher streamflows during this period. This would make it more difficult to keep the lake below the levels specified in the rule curve, potentially increasing flood risk around the lake and surrounding areas. Projections for more extreme and variable streamflows could also affect flood risk due to higher lake levels and outflows.

iii. Kootenay Lake Shoreline Effects. The shoreline flood risk could increase if floodplain bylaws are not enforced in the future and development is allowed to occur in flood prone areas.

iv. Upstream Area Effects. Flood risk in the upstream areas could be affected as described in the above section that discusses shoreline effects. The continued degradation of the dykes and levees due to erosion and a poor maintenance is also an additional factor that could increase flood risk. Additional agricultural and residential development that could occur in the area if floodplain development is not managed would exacerbate the problem.

v. Downstream Area Effects. Flood risk in the downstream areas would increase if increases in peak inflows and lake levels lead to higher peak outflows.

d. Summary of Key Information Gaps and Areas for Future Research and Study. The key flood risk management topics for potential future research and study are summarized below.

i. Flood Risk and Damages. Additional research and study could be undertaken to improve the understanding of the flood risk and damages that occur around Kootenay Lake and in the surrounding area affected by lake regulation. Specific topic for potential research include

- Analyzing currently available flood risk and flood damage information for Kootenay Lake shoreline and surrounding areas.
- Determining if additional information is needed to fill any important gaps.
- Performing studies and analysis to fill in these gaps.

ii. Effect of Construction and Operation of CRT Dams. Additional research and study could be done in several areas to account for the effect of the construction and operation of CRT dams. A specific topic for potential research includes evaluating changes in the Kootenay Lake inflow due to the construction of Libby and Duncan Dams to determine if the procedures and information in the 1938 Order could be improved in light of changed conditions.

10. Key Information Gaps and Areas for Future Research and Study. Many significant changes have occurred in the Kootenay Lake watershed since the IKLBC mandate and 1938 Order were established, including the construction of two large upstream dams that have significantly changed the hydrology of the downstream rivers. During this time, many different studies and analyses have been conducted on various aspects of the lake and the surrounding area, such as climate change, Grohman Narrows dredging, flood risk management, ecosystem enhancements, and others. However, there has not been a comprehensive study of the lake and watershed that integrates all of these considerations. Many considerations, such as the socioeconomic setting and issues involving the entire watershed, are outside of the current mandate of the IKLBC. Therefore, further analysis of these topics by the IKLBC would require additional IJC directives and guidance or would be performed by other stakeholder groups or agencies. One overall recommendation for future research is to support a study that integrates the current and future goals and objectives for Kootenay Lake with those in the pertinent upstream and downstream areas that are affected by the operation of the lake. The results of this study could be used to determine if any changes are needed in lake regulation and the 1938 Order. Key information gaps and areas for future research and study are summarized below. More detailed information on these topics is provided in Sections 4 through 9, and in Attachment 3. A reference may be needed from the two federal governments in order to conduct the studies outlined above in a robust and comprehensive manner.

a. Climate Change. There are key gaps regarding information about the expected meteorological and hydrologic changes resulting from likely future climate change scenarios. These gaps, and the potential research needed to address them, are described below.

<u>i. Expected Meteorological Changes</u>: The type, magnitude, and timing of the projected precipitation vary depending on the climate change assumptions used and could continue to be refined. Additional research could be conducted as new information becomes available to refine and provide more details on precipitation, as well as potential temperature changes.

<u>ii. Expected Hydrologic Changes</u>: Further information is needed on how meteorological changes will affect the hydrology of the lake. Additional research should be conducted on changes in the timing and magnitude of streamflow patterns. This could include research into the effect of glacier changes on streamflows.

<u>iii. Lake Regulation Changes</u>: Further details are needed on how projected changes in the meteorology and hydrology will affect lake regulation and the 1938 Order. Specific recommended studies include:

- Hydroregulation studies to evaluate changes to the lake regulation and effects on the surrounding area.
- Studies to determine if adjustments are needed to the 1938 Order based on expected changes in lake regulation.

b. Socioeconomic Setting. There are important socioeconomic information gaps regarding the current and projected population and development around the shoreline of the lake and in the pertinent upstream and downstream areas. These gaps, and the potential research that could be done to address them, are described below.

i. Population and Development: Additional information is needed, and data could be collected or developed on the current and projected population and development around the lake and in surrounding area. Data could be collected and developed as needed on the population and development.

ii. Economic Effects of Lake Operations: Additional information is needed, and data could be collected or developed on the current and projected economic effects of lake operations on developments and facilities in shoreline, upstream, and downstream areas.

c. Agricultural Impacts. There are many important information gaps pertaining to agricultural impacts resulting from lake regulation. These gaps, and the potential research needed to address them, are described below.

i. Causes of Agricultural Impacts: The role and interrelationship of the factors that may cause the agricultural impacts, such as high groundwater, unusual weather events, high river levels, and others are poorly understood. This would require additional research and study that could include the following:

- Analyzing agricultural areas to determine the current and projected future agricultural uses in the areas most prone to flooding and drainage issues.
- Performing detailed hydrologic modeling to determine the causes of flooding and drainage in the key agricultural areas.
- Analyzing potential future operational and hydrologic scenarios to understand changes in future agricultural impacts.

ii. Dyke and Levee Conditions: Further information is needed on the current and projected condition and maintenance of dykes and levees designed to protect the agricultural areas. Although the issues with the conditions and maintenance of dykes and levees are outside of the current mandate of the IKLBC, this research could be performed by other stakeholder groups or agencies. Research to address this gap could include the following:

- Assessing the condition and maintenance of the key dykes and levees in the area and identifying warranted improvements.
- Analyzing potential future operational and hydrologic scenarios to determine the effect of potential changes on the dyke and levee condition and their ability to protect key areas.

<u>iii. Pumping Cost Reimbursement</u>: Further information is needed about the cost of reimbursement for pumping water from agricultural areas that results from the lake backwater. The research to address this gap could include the following:

- Analyzing the current and projected frequency and magnitude of the pumping requirements.
- Determining if pumping is the best option to address the drainage issues, or if there are other better options such as improving dykes and/or levees.
- Determining the appropriate reimbursement limit, and a method to index future pumping cost reimbursement if it is determined that pumping will continue to be the best option.

d. Grohman Narrows Hydraulics. Previous dredging studies performed by BC Hydro could first be reviewed to determine if they adequately addressed key issues such as the preferred dredging option, future lake regulation, and the impacts of the dredging and any Corra Linn Dam operational changes. Additional analysis could be performed if needed to fill any key information gaps.

e. Ecological and Fisheries Concerns. There are many important information gaps pertaining to ecological and fisheries concerns resulting from lake regulation. These gaps, and the potential research needed to address them, are described below.

<u>i. Lake Regulation Effectiveness</u>: The ecological and fisheries concerns and objectives at the lake and surrounding area have changed considerably since the 1938 Order was

approved. Many incremental changes have occurred at the lake and surrounding area but there has not been a comprehensive evaluation of the effectiveness of lake regulation in achieving current and expected ecological and fisheries requirements. This is an important overall gap that could be addressed by studies to:

- Evaluate the effectiveness of lake regulation in addressing current and projected ecological, fishery, and water quality objectives in the lake and in pertinent upstream and downstream areas.
- Identify potential adjustments in lake regulation to better meet these objectives.
- Identify changes needed in the 1938 Order to achieve these adjustments in lake regulation.

<u>ii. Water Quality Issues</u>**:** Additional information could be developed regarding water quality issues such as nutrient depletion, increased winter water temperatures, and selenium and nitrate pollution. Further research could address:

- Impacts and future plans for addressing nutrient depletion and increased winter water temperatures in the lake due to the operation of upstream dams.
- Impacts of elevated levels of selenium and nitrates that have been found in water and fish upstream of the lake.

<u>iii. Fisheries Issues</u>. Further research could be conducted regarding future plans for fisheries-related activities that might affect lake operations such as the fall lake drawdown for shore-spawning kokanee, the timing and magnitude of the spring drawdown, and any plans for other species of concern such as burbot and the Kootenai River white sturgeon.

f. Flood Risk Management. There are many important information gaps pertaining to flood risk management concerns. These gaps, and the potential research that could be conducted to address them, are described below.

<u>i. Flood Risk and Damages</u>: More detailed information is needed about the current and projected flood risk and damages around the shoreline of Kootenay Lake and in the

pertinent upstream and downstream areas. Different types of analyses and information are available on this topic but much of it is outdated, incomplete, or conflicting. This is an important gap that could be addressed by additional research and study to:

- Compile available information about current and projected flood risks in all pertinent areas.
- Determine additional information needed to address key gaps in this information.
- Perform studies and analysis needed to fill in those gaps such as flood damages and effects of future changes in the operation of upstream dams, as warranted.

ii. Effect of CRT Dams: Additional research and study could be done to take into account the effect of changes in the Kootenay Lake inflow due to the construction of Libby and Duncan Dams. This information could be used to determine if the procedures and information in the 1938 Order need to be updated to reflect the impacts of upstream dam operation.

g. 1938 Order. Many aspects of the regulation and management of Kootenay Lake have changed since the approval of the 1938 Order. This trend is expected to continue and possibly increase in the future. Because of this, the 1938 Order could be reviewed to determine if changes are needed. Specific areas for consideration are described below.

i. Upstream Dam Operation: The 1938 Order does not reference the upstream dams. With regard to the upstream dams, the Board has determined that it has no authority to direct their operations, whether through the 1938 Order or the Columbia River Treaty (IKLBC, 2008d). The Commission (IJC) supported this conclusion, stating that the Order is directed solely to the Applicant, and operation of the upstream dams is a matter for the two federal governments to determine.

ii. Operational Flexibility and Adaptive Management: Many aspects of the regulation and management of Kootenay Lake have changed since the approval of the 1938 Order. This trend is expected to continue and possibly increase in the future. Because of this, it may be important that future plans are designed with as much flexibility as possible to adapt to changing conditions. The Order could be reviewed based on current requirements and expected changes to determine if changes are needed to improve the flexibility of the document and the procedures within it to adapt to changing conditions. Some potential changes that might be considered based on past experience include:

- Establishing minimum lake levels that could apply during certain conditions to address concerns about low lake levels.
- Raising the lake level during the spring to improve spawning conditions for Kootenai River white sturgeon and other species such as burbot.
- Lowering the lake level during the fall to improve spawning conditions for kokanee.
- Changing the lake drawdown period in the winter and spring if needed to respond to earlier and more variable runoff conditions.

11. Summary and Conclusions. The IKLBC mandate and 1938 Order have been very effective for managing Kootenay Lake for over 80 years. There have been many changes in the configuration of the watershed and operating conditions during this period. These include:

- Construction of two large upstream dams that significantly changed the hydrology and ecosystem.
- Construction of a new lake control structure consisting of the Kootenay Canal Powerplant and a diversion canal from the Corra Linn Dam.
- Significant population growth and development around the shoreline of the lake and surrounding areas.
- Implementation of many changes for flood risk management, the ecosystem and other considerations.

The IKLBC mandate and 1938 Order have demonstrated the flexibility to adapt lake regulation to many of these changing conditions. A summary of the key points and conclusions for the pertinent topics presented in this paper is provided below.

a. Climate Change. There are many projected changes to the meteorology and hydrology of the basin, and many of these are expected to have an effect on Kootenay Lake. Projected meteorological changes include:

- Warmer temperatures, particularly in summer.
- More extreme precipitation events and more variability in precipitation.
- More precipitation in the form of rain than snow.

Projected hydrologic changes include:

- Higher winter and spring streamflows.
- More variable spring streamflows.
- Lower summer and fall streamflows.
- More overall variability in streamflows.

These projected meteorological and hydrologic changes could have the following effects on Kootenay Lake:

- Higher and more variable winter and early spring streamflows may result in earlier and higher peak outflows and higher lake levels in the winter and early spring.
- Lower summer and fall streamflows and warmer air temperatures may result in lower summer and fall lake levels and warmer water temperatures.

b. Socioeconomic Setting. The population and development around the lake and the surrounding area have increased significantly since the Order was first established, and these trends are expected to continue, though with more regulation than occurred in the past. These developments are affected by lake regulation, particularly those that have occurred in the floodplain around the lake and surrounding area.

c. Agricultural Impacts. The backwater from the regulation of the lake can affect drainage in upstream agricultural areas, and was a key consideration in the 1938 Order. It includes provisions for agriculture such as lowering lake levels during key agricultural periods and providing for reimbursement to agricultural interests for additional pumping costs that may be incurred due to lake regulation. Conditions in the agricultural areas have changed considerably since the Order was first established. For example, the areal extent of the agricultural land and type of crops grown has changed. The magnitude and frequency of the drainage issues has increased due to deterioration of dykes and levees that protect these areas from flooding and other factors. The provision in the Order that limits reimbursement for pumping costs to US$3,000 is also very outdated based on recent reimbursements that have been negotiated for amounts well over this amount.

d. Grohman Narrows Hydraulics. The hydraulic capacity at the Grohman Narrows constriction is a key factor in managing the lake. Although evaluations of the hydraulic capacity show that it has not declined since the last dredging occurred in 1939, suggestions have been made to perform additional dredging to further increase the hydraulic capacity. Studies on this have been performed, but no additional dredging has been undertaken.

e. Ecological and Fisheries Concerns. The regulation of the lake plays a significant role in the ecology, water quality, and fisheries of the lake and the surrounding area. The ecological and fisheries conditions and objectives at the lake and the surrounding area have changed considerably since the 1938 Order was approved. For example, the upstream dams have changed the hydrology of the lake and reduced the nutrients and sediment going into the lake. Upstream developments such as fertilizer plants, mines, and others have changed the ecology and water quality by introducing pollutants. As a result of these and other factors, numerous fish species in the lake and surrounding area have declined and/or been listed as threatened or endangered. The lake level affects the habitat for species in the lake as well as in upstream areas affected by the backwater from the lake. The timing and magnitude of water released from the lake affects the ecology, water quality, and fishery in the downstream areas. Although the 1938 Order does not specifically include provisions for the ecosystem, it only specifies maximum lake levels which has allowed operational changes for the ecosystem. Other requested operational changes such as holding the lake higher in the spring for endangered species like the Kootenay River white sturgeon have not been implemented.

f. Flood Risk Management. Although not specifically for flood risk management, the 1938 Order includes provisions to mitigate operations of Corra Linn Dam such as:

- The lake lowering formula.
- Drawing the lake down to 1,739.32 feet (at Queens Bay) during the winter-early spring lake drawdown period.

Flood risk management for the lake and surrounding area has changed significantly since the 1938 Order was established. Examples include:

- Upstream dams were constructed with significant storage for flood risk management as part of the CRT. The operation of these dams has reduced the peak lake levels by an average of about 1.8 meters (6 feet), and the peak outflows from the lake have also been much lower. Both of these changes have reduced the flood risk around the lake and in surrounding areas.
- Development in the floodplain areas was allowed, prior to current regulations.

Several factors could change the flood risk management for Kootenay Lake and the surrounding areas in the future, including:

- The topic of CRT flood risk management, currently under discussion as part of Treaty modernization negotiations, may or may not result in an outcome that affects water levels and flood risk management at Kootenay Lake.
- Changes in the meteorology, hydrology, and lake operations due to climate change could also affect flood risk management in the future.

g. Other Considerations. The regulation of Kootenay Lake affects many other considerations, such as hydropower generation, recreation, and navigation. For example, higher lake levels can increase hydropower generation, but can have a negative effect on recreation and navigation on the lake if docks, beaches, parks, and other facilities become inaccessible. Unusually low lake levels can also have a negative effect on recreation by making facilities inaccessible and exposing shoreline areas.

h. Issues and Future of the IKLBC Mandate and 1938 Order. The fact that Kootenay Lake has been managed successfully for more than 80 years under the same mandate and operating rules is a testament to their effectiveness, especially given the many significant changes that have occurred in the watershed during this period. A major reason for this success is that they incorporate the flexibility of no specified minimum lake levels to adapt to changing conditions. For example, this flexibility has been used during recent periods to regulate the lake at lower elevations in the fall to improve fish spawning conditions. The Order has also been periodically supplemented as needed by special orders that allowed the lake to be regulated to increase the storage by 0.6 meters (2 feet) to increase power generation during certain periods.

While the mandate and Order have been very effective for managing the lake, based on the evaluation of historical records, analysis of current issues likely to recur, and evaluation of potential future issues related to lake regulation, they should be reviewed to determine if revisions are warranted. Some potential changes that might be considered based on stakeholder concerns include:

- Establishing minimum lake levels during certain conditions to address concerns about low lake levels during droughts and other situations.
- Raising the lake level during the spring to improve spawning habitat for endangered Kootenai River white sturgeon.
- Lowering the lake level in the fall to improve conditions for shore-spawning Kokanee.
- Changing the winter-spring lake drawdown period in response to projected earlier and more variable spring runoff conditions.
- Additional dredging of Grohman Narrows to increase the hydraulic capacity and reduce peak lake levels.

This review could begin with individual studies or a comprehensive study that integrates current and future regulation objectives for Kootenay Lake with those in the pertinent upstream and downstream areas that are affected by the regulation of the lake. The results of this study could then be used to determine if any changes are needed in lake regulation and the 1938 Order.

Attachment 1 – 1938 Order and IJC Rule Curve

1. Sections 2(4), 2(5), and 2(6) of the 1938 Order are the most pertinent to the rule curve and specific operation of Kootenay Lake. They are summarized below:
a. Section 2(4). The Applicant shall be permitted to store water in the main body of Kootenay Lake to a maximum elevation of 1745.32, Geodetic Survey of Canada datum, 1928 adjustment (i.e. six feet above zero of the Nelson gauge), in accordance with the rule curve detailed in Sub-section (5).
b. Section 2(5). That after the high water of the spring and early summer flood and when the lake level at Nelson on its falling stage recedes to elevation 1743.32, Geodetic Survey of Canada datum, 1928 adjustment, the gates of the dam may be so operated as to retain it at said level until August 31st, and after said date, the level of the main body of the lake may be raised to elevation 1745.32, which shall be the maximum storage level until January 7, and thereafter it shall be lowered so that it shall not exceed elevation 1744 on February 1, elevation 1742.4 on March 1, and elevation 1739.32 (i.e. zero of the Nelson gauge) on or about April 1, 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.
c. Section 2(6). That following the completion of all of the excavation provided for in Sub-section (1) of Section 2 of this Order, and throughout the period of flood flow in each and every year, (i.e. from the commencement of the spring rise in March or April until the level of the lake at Nelson returns to elevation 1743.32, Geodetic Survey of Canada, 1928 adjustment, on the falling stage), a sufficient number of gates and sluiceways of the dam shall be opened to provide, in conjunction with the flow through the turbines, for the lowering of the main body of Kootenay Lake, as a result of the Applicant's completed and proposed excavation, by at least the amounts indicated in Table 2, page 21 of the Canadian Government Exhibit No. 1, dated June 1, 1933, on file in the offices of the Commission in Ottawa and Washington as follows:

> Discharge from Kootenay Lake under original conditions (in second feet) [vs.] amount of lowering to be affected on the main body of Kootenay Lake (in feet)

10,000	1.0
25,000	1.3
50,000	1.7
75,000	2.1
100,000	2.6
125,000	3.0
150,000	3.2
175,000	3.5
200,000	3.8
225,000	4.0

2. A summary of the annual lake operations according to the rule curve is provided below:

a. September 1 - January 7: the maximum geodetic elevation is 1,745.32 feet.

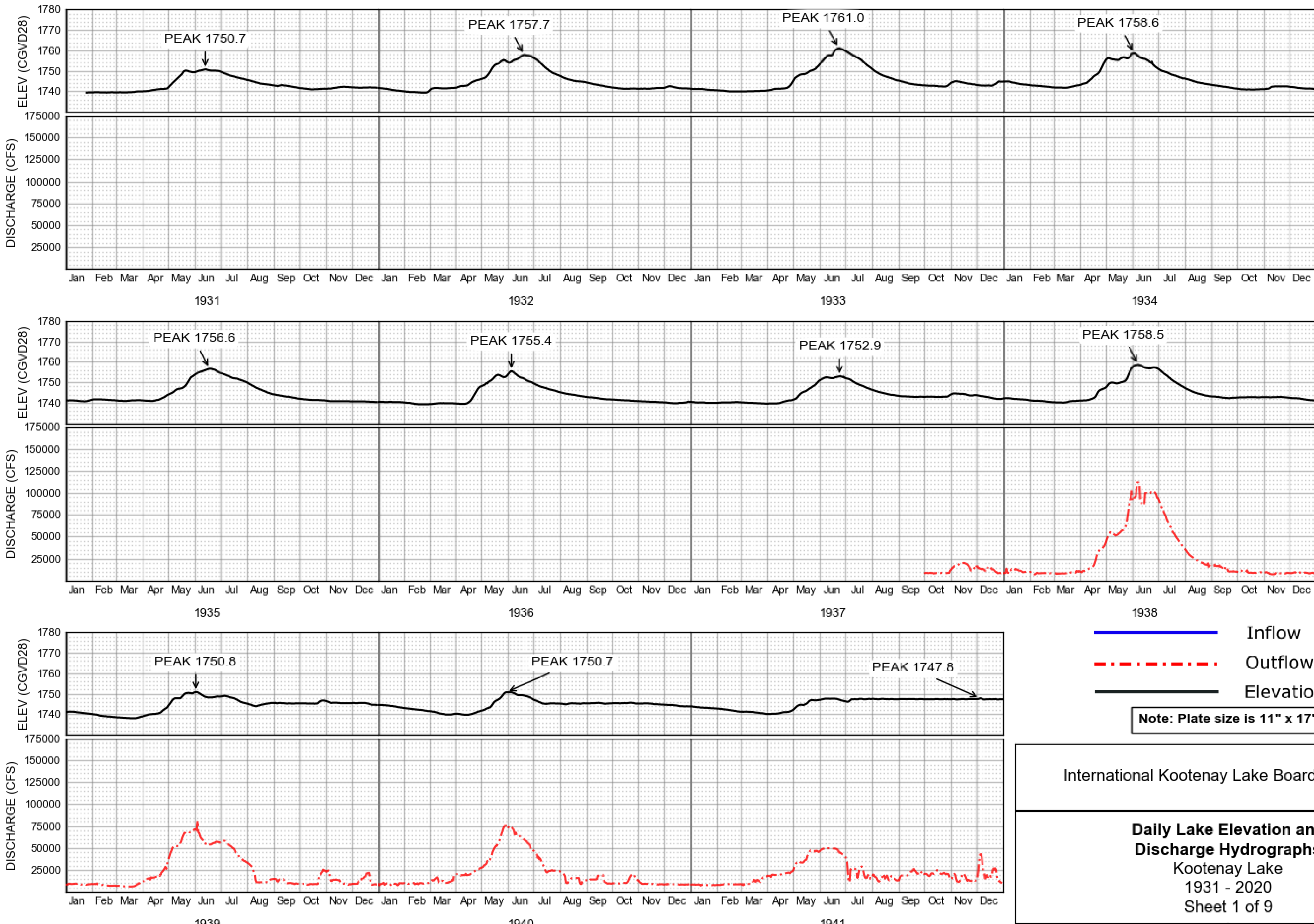
b. January 7 - January 31: the elevation gradually declines to a maximum of 1,744.00 feet.

c. January 31 - February 28: the elevation gradually declines to a maximum of 1,742.40 feet.

d. February 28 - March 31: The elevation gradually drops to a maximum of 1,739.32 feet.

e. After March 31: Rise in the lake, endeavouring to keep the elevation below 1,739.32 feet. When the elevation is forced above 1,739.32 feet, lake levels rise and fall based on a calculated maximum allowable elevation, which is based on actual lake inflow, calculated lake elevation given original discharge conditions prior to the excavation of Grohman Narrows and a certain lowering below the calculated lake elevation. Once the flood peak passes and lake levels recede to 1,743.32 feet at Nelson, the control becomes an upper elevation of 1,743.32 feet at Nelson until September 1.

Attachment 2 – Kootenay Lake Pool Elevation, Inflow, and Discharge Charts



International Kootenay Lake Board of Control

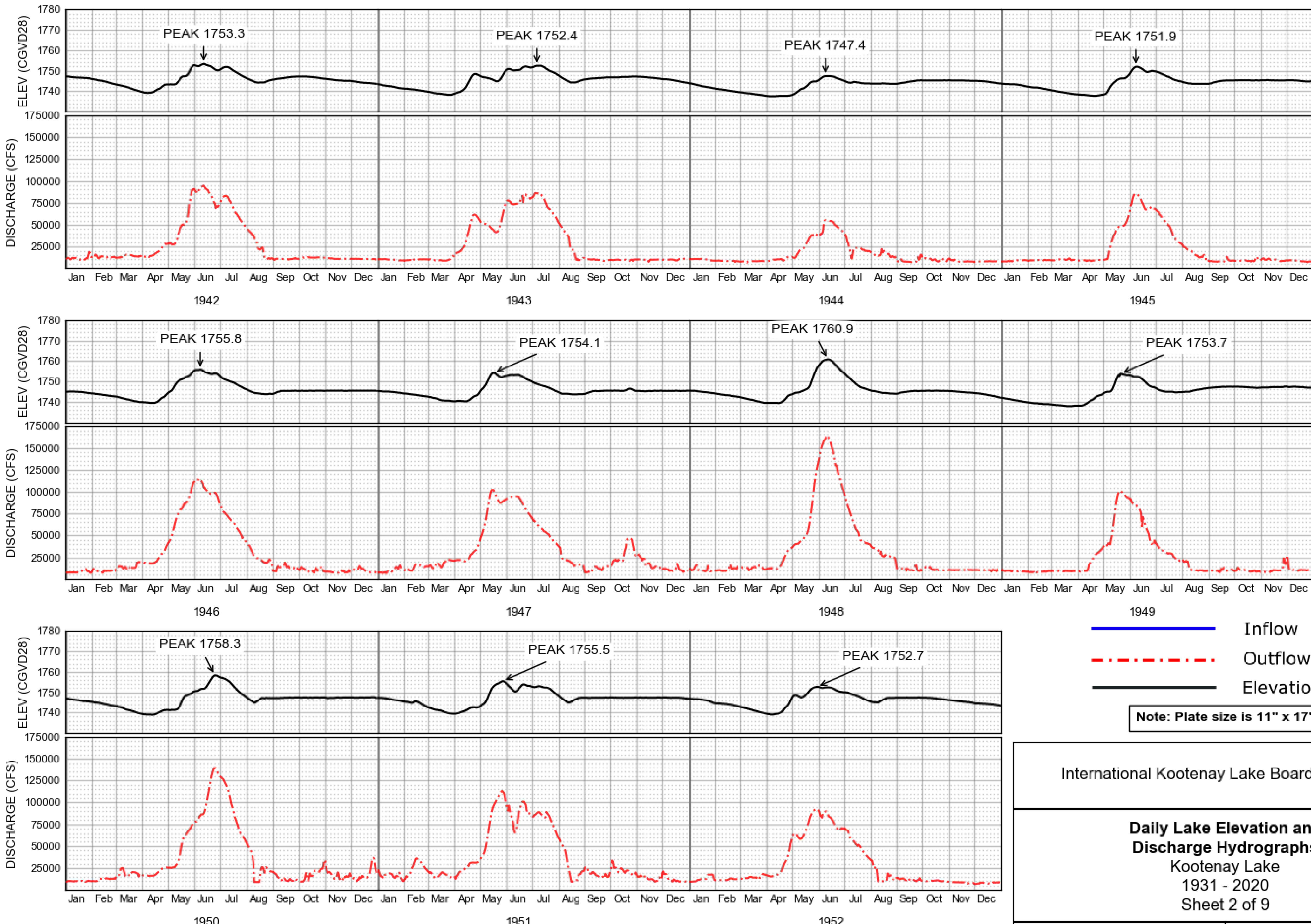
Daily Lake Elevation and Discharge Hydrographs

Kootenay Lake

1931 - 2020

Sheet 1 of 9

Completed by: WEST	July 2020



International Kootenay Lake Board of Control

Daily Lake Elevation and Discharge Hydrographs

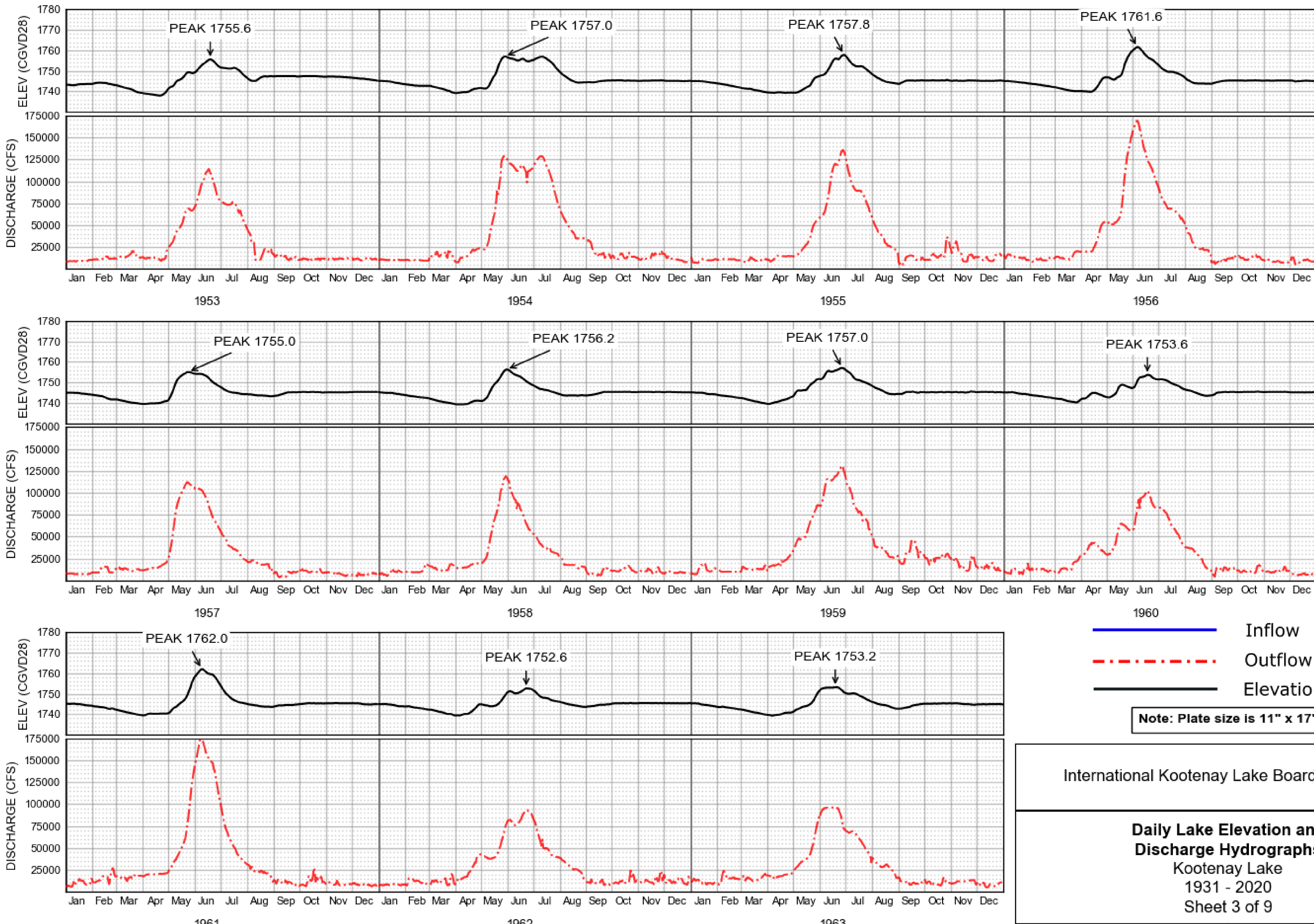
Kootenay Lake

1931 - 2020

Sheet 2 of 9

Completed by: WEST

July 2020



International Kootenay Lake Board of Control

Daily Lake Elevation and Discharge Hydrographs
Kootenay Lake
1931 - 2020
Sheet 3 of 9

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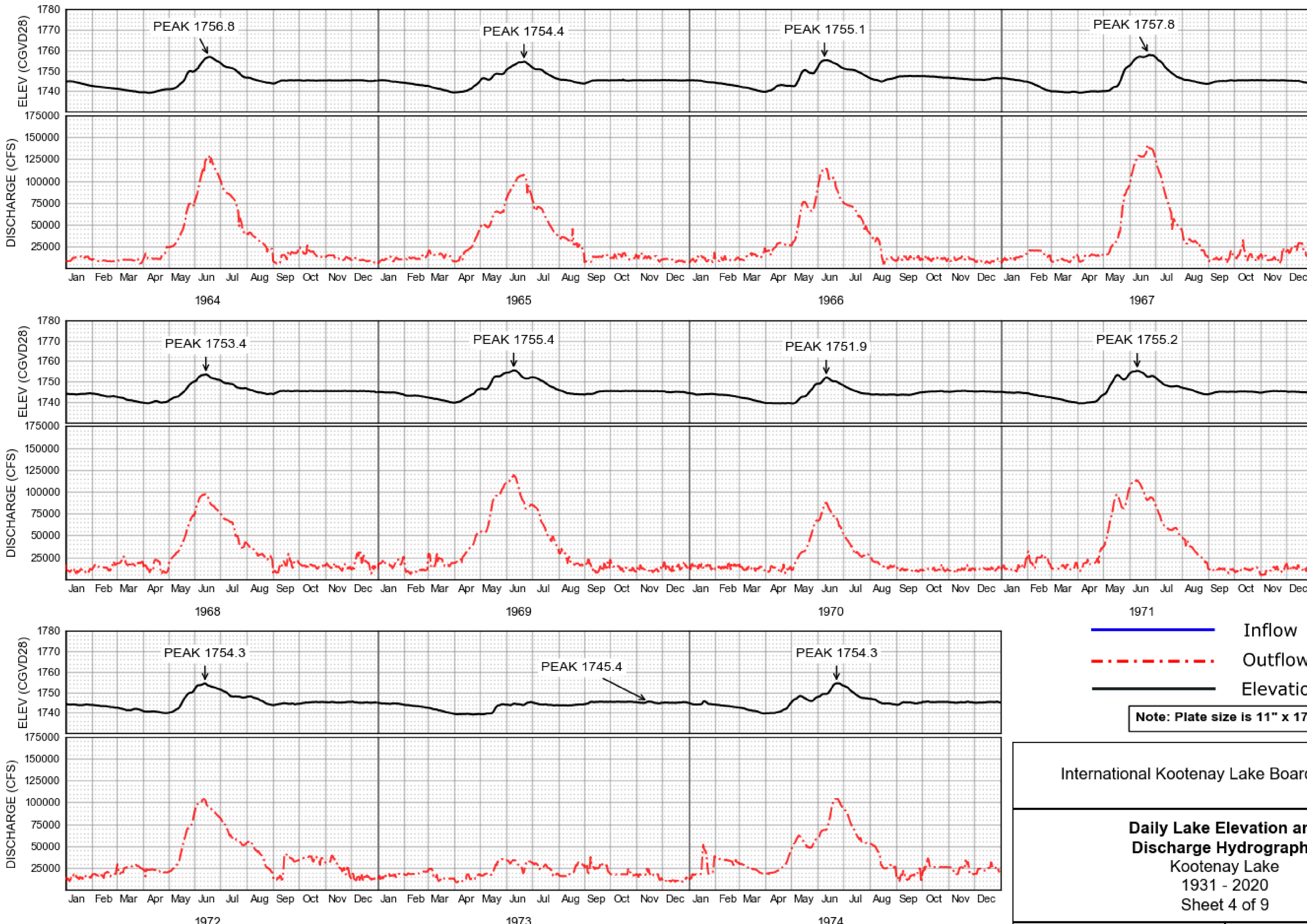

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Daily Lake Elevation and Discharge Hydrographs
Kootenay Lake
1931 - 2020
Sheet 4 of 9

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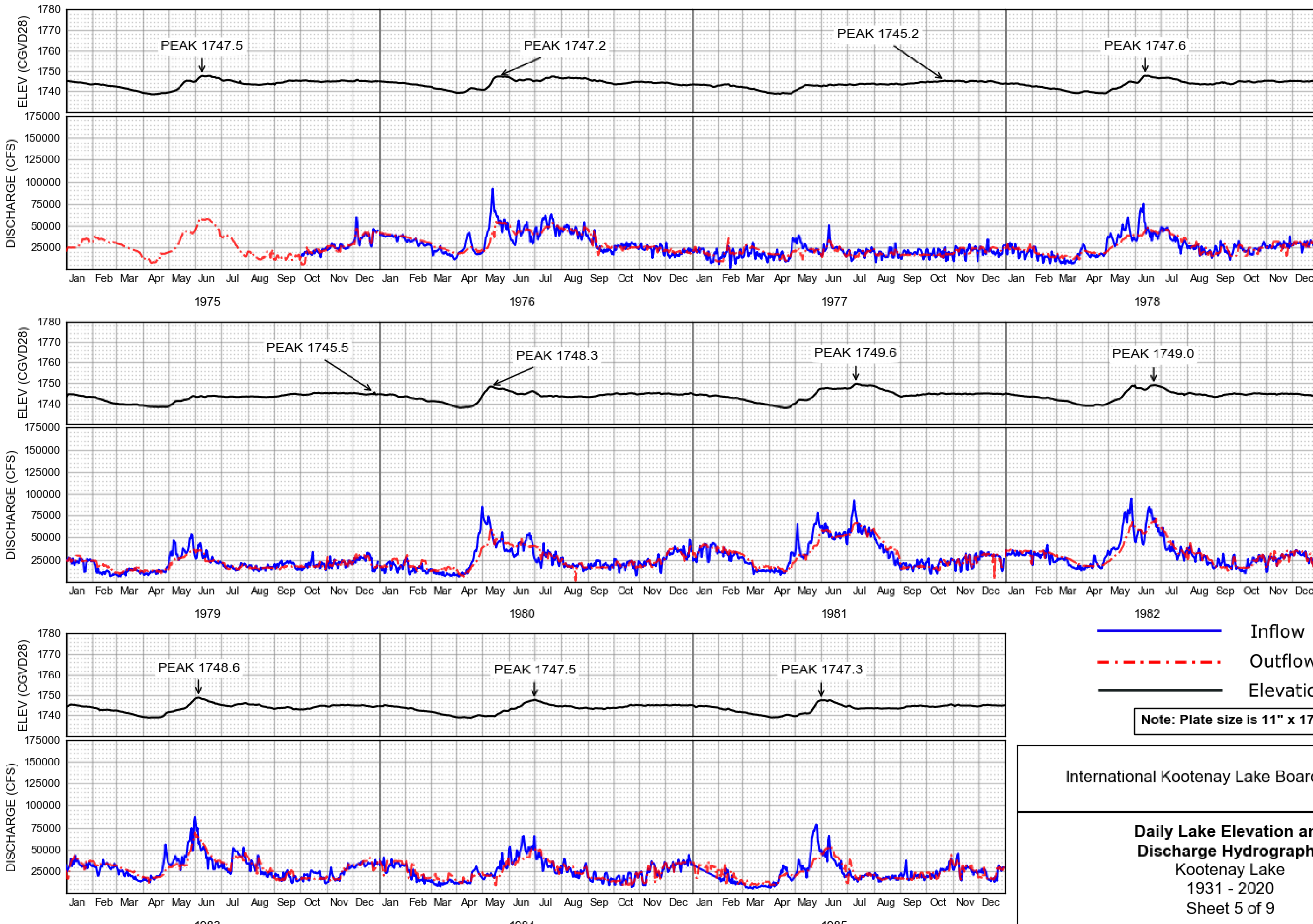

Note: Plate size is 11" x 17"

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Daily Lake Elevation and Discharge Hydrographs
Kootenay Lake
1931 - 2020
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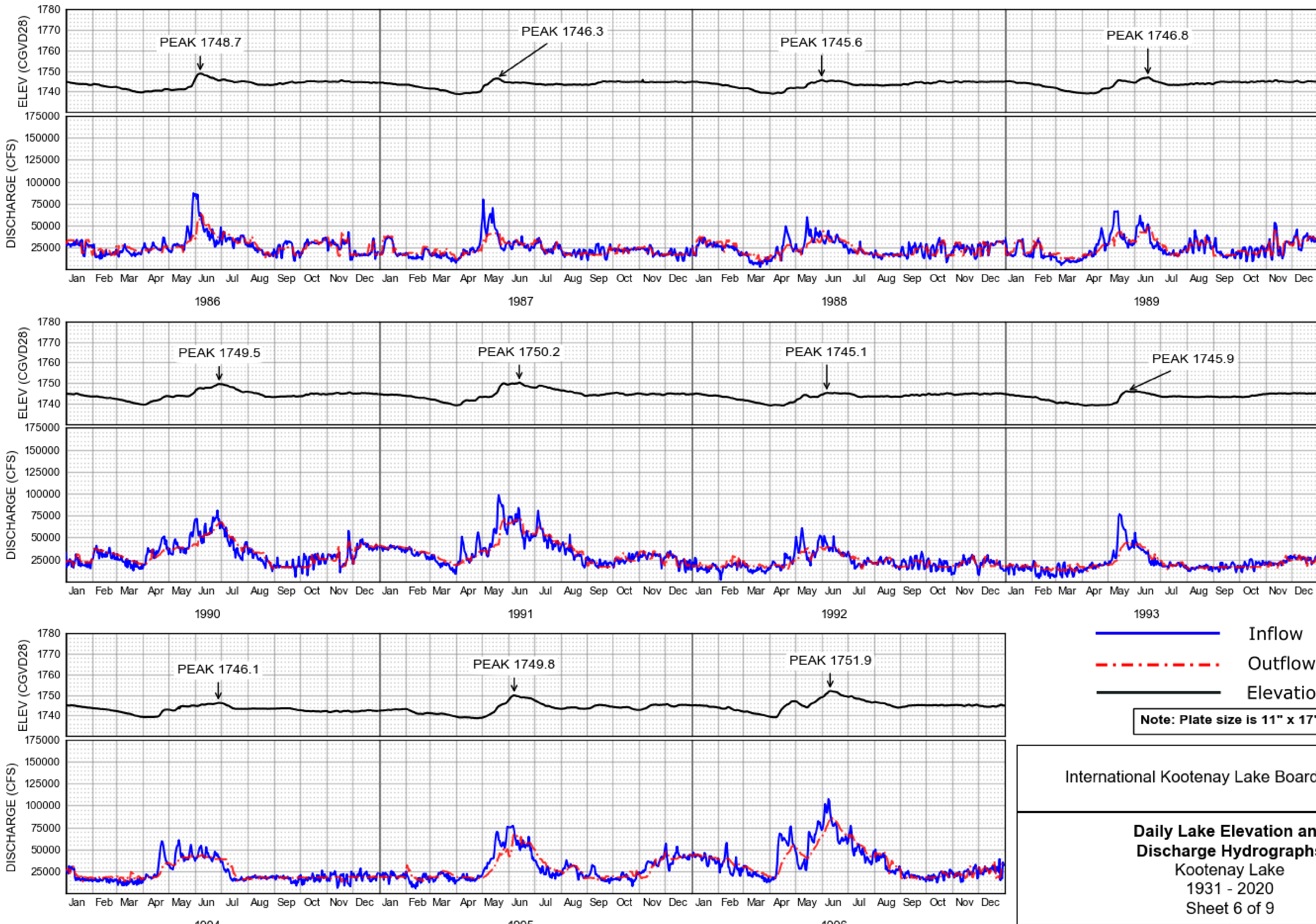
Completed by: WEST	July 2020



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Daily Lake Elevation and Discharge Hydrographs

Kootenay Lake

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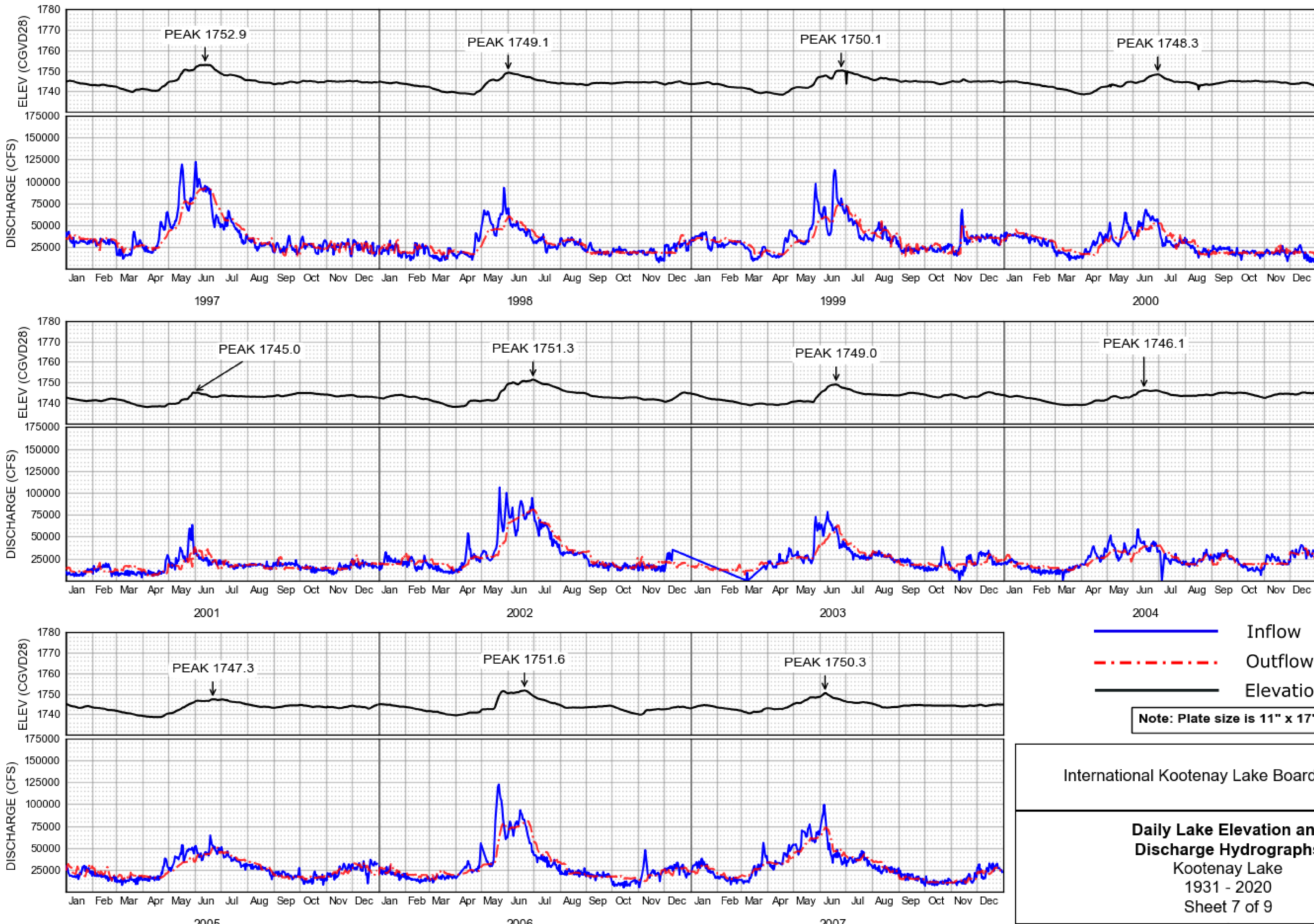
Sheet 6 of 9

Completed by: WEST	July 2020



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Daily Lake Elevation and Discharge Hydrographs
Kootenay Lake
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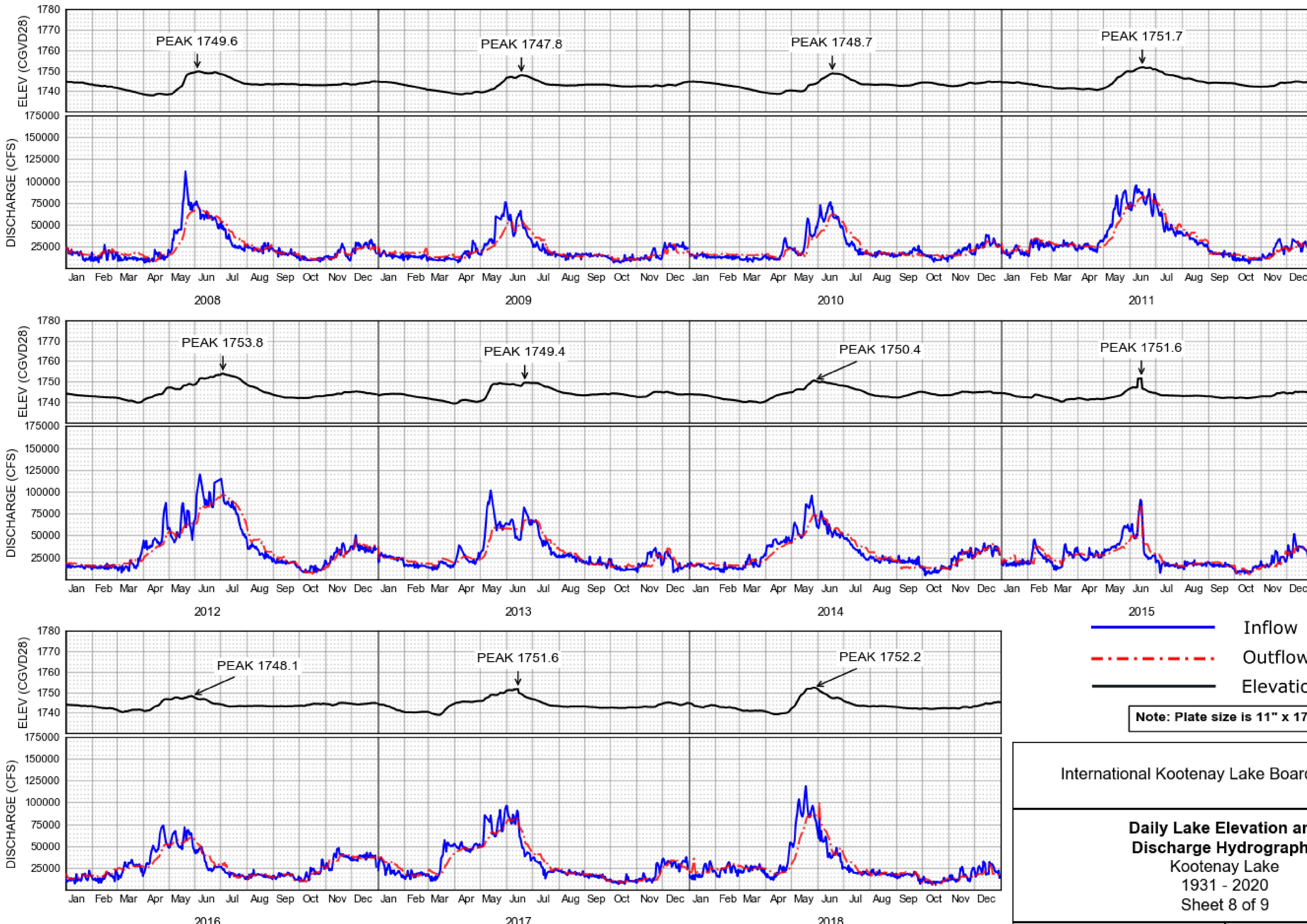
Completed by: WEST	July 2020



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Daily Lake Elevation and Discharge Hydrographs
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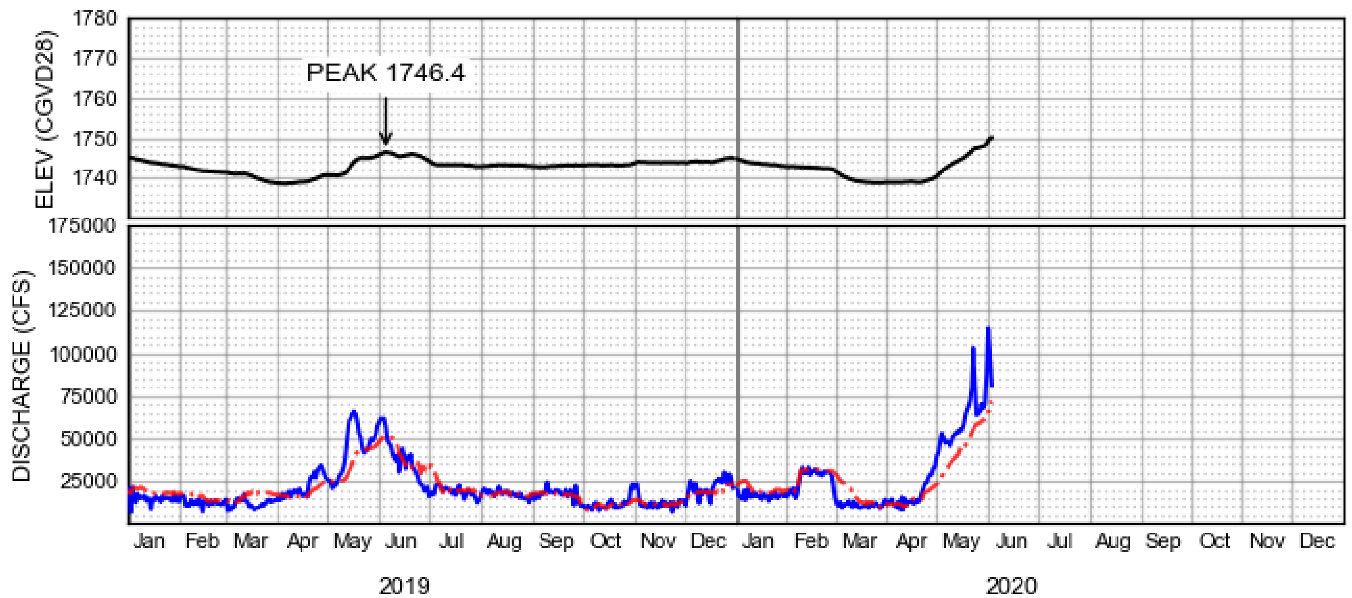

Inflow

Outflow

Elevation

Note: Plate size is 11" x 17"

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Daily Lake Elevation and Discharge Hydrographs

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Attachment 3 – Summary of Key Issues, Information Gaps, and Areas for Potential Further Study

Category	Issue/Topic	Information Gap	Potential Research or Study
General	Future Kootenay Lake regulating requirements	No recent comprehensive review that integrates current and expected conditions and regulation goals for the lake and surrounding affected area affected	Study that integrates current and future conditions and regulation goals for the lake and surrounding area
Climate Change	Expected meteorological changes	Further details needed on projected meteorological changes such as the type, magnitude, and timing of precipitation	Refine and provide more details about expected precipitation and temperature changes.
Climate Change	Expected hydrologic changes	Further details needed about how the expected meteorological changes will affect the hydrology	Refine and provide more details about expected hydrologic changes such as in the timing and magnitude of streamflow patterns.
Climate Change	Glacier cover	Further details needed on how climate change will affect glacier cover and streamflows	Refine and provide more details about expected changes in glacier cover and how this will affect streamflow.
Climate Change	Lake regulation and implementation of 1938 Order	Further details needed on how projected climate changes will affect lake regulation and the 1938 Order	(1) Hydroregulation studies for the Kootenay River system to determine specific climate change effects on lake, and (2) determine if adjustments are needed to the 1938 Order based on climate change effects

Category	Issue/Topic	Information Gap	Potential Research or Study
Socioeconomic Setting	Current and projected population and development around Kootenay Lake and surrounding area	Additional information needed on current and projected population and development around Kootenay Lake and surrounding area.	(1) Assess data on the current and projected population and development around the lake and in surrounding areas, and (2) supplement this data as needed
Socioeconomic Setting	Current and projected economic effects of lake regulation by Corra Linn Dam	Additional information needed on the current and projected economic effects of lake regulation.	Collect data on the current and projected economic effects of lake regulation in the shoreline and surrounding areas
Agricultural Impacts	Causes of agricultural impacts by Corra Linn Dam operation	Additional details needed on the causes of agricultural impacts such as high river levels, high groundwater levels, high lake levels, etc.	(1) Analyze agricultural areas to determine the current and projected future agricultural uses in most flood-prone areas, (2) monitor shallow groundwater levels, (3) perform detailed hydrologic modeling to determine causes of flooding and drainage problems in key areas and (4) analyze potential operational and hydrologic scenarios to understand future agricultural impacts
Agricultural Impacts	Current and projected condition and maintenance of dykes and levees protecting agricultural areas	Additional details needed on the current and projected condition and maintenance of dykes and levees protecting agricultural areas.	(1) Assess condition and maintenance of key dykes and levees and identify needed improvements, and (2) analyze potential future operational and hydrologic scenarios to determine the effect of potential changes on dykes and levees

Category	Issue/Topic	Information Gap	Potential Research or Study
Agricultural Impacts	Reimbursement for pumping costs	Provisions in 1938 Order for reimbursement of agricultural pumping costs need to be updated to reflect current and future pumping costs	(1) Analyze the current and projected frequency and magnitude of pumping requirements and costs, (2) determine if pumping is the best option, or if other better options exist to address the problems, and (3) determine the appropriate reimbursement limit and a method to adjust future reimbursement limits
Grohman Narrows Hydraulics	Details about additional dredging options, such as lake regulation changes, costs, benefits, and impacts	If additional dredging is considered, further information may be needed on the best dredging option, costs, benefits, and impacts of dredging	(1) Review previous dredging studies performed by BC Hydro to determine if key issues are adequately addressed, and (2) perform additional analysis if needed to fill any key information gaps
Ecological and Fishery Concerns	Effectiveness of lake regulation in meeting fishery and ecological requirements	Comprehensive analysis may be needed on the effectiveness of lake operations in meeting fishery and ecological requirements	(1) Evaluate the effectiveness of lake operations in addressing current and projected ecological, fishery, and water quality objectives in the lake and pertinent surrounding areas, (2) identify potential adjustments that may be needed to better meet objectives, and (3) identify changes needed in the 1938 Order to achieve these adjustments

Category	Issue/Topic	Information Gap	Potential Research or Study
Ecological and Fishery Concerns	Water quality issues such as nutrient depletion, increased winter water temperatures, and selenium and nitrate pollution	Need to better understand water quality issues such as nutrient depletion, increased winter water temperatures, and elevated selenium and nitrate levels in upstream areas	Research impacts and future plans for addressing water quality issues such as nutrient depletion, increased winter water temperatures, and elevated levels of selenium and nitrates in upstream areas
Ecological and Fishery Concerns	Fisheries issues such as operations for kokanee, burbot, Kootenai River white sturgeon, and other species in the lake and surrounding area	Need to better understand issues and future plans for fisheries-related activities that might affect lake regulation	Research impacts and future plans for fisheries-related activities that might affect lake regulation such as the fall drawdowns for shore-spawning kokanee and any plans for other species such as burbot and the Kootenai River white sturgeon
Flood Risk Management	Current and projected flood risk at Kootenay Lake and in surrounding area	Additional and consistent information may be needed about the current and projected flood risk around the shoreline of Kootenay Lake and in pertinent upstream and downstream areas. Key gaps may include data on when flood damage occurs, and the magnitude of those damages	(1) Analyze available information about current and projected flood risks in all pertinent areas, (2) determine additional information needed to address key information gaps, and (3) perform analysis required to fill those gaps

Category	Issue/Topic	Information Gap	Potential Research or Study
1938 Order	Effect of operation of upstream dams	*(1) Upstream dams were not constructed when the 1938 Order was approved, and have changed the hydrology of the inflow to the lake from the natural inflow that was used when the original order was developed to regulated flow. Information is needed on how this change may lead to changes in the Order.*	(1) Take into account the effect on the 1938 Order from the changes in the lake inflow due to the construction of Libby and Duncan Dams and use this information to determine if the procedures and information in the 1938 Order need to be updated to reflect upstream dam regulation, (2) Review the 1938 Order to determine if other changes are needed based on the existence of those dams and their effect on Kootenay Lake

Category	Issue/Topic	Information Gap	Potential Research or Study
1938 Order	Flexibility and adaptive management	Many changes have occurred since the 1938 Order was approved such as construction of upstream dams and implementation of many changes for the ecosystem. The 1938 Order may need to be modified to include more flexibility and ability to adapt to changing conditions.	The 1938 Order could be reviewed based on current and expected changes to determine if modifications are needed to improve the flexibility and ability to adapt to these changes. Some potential changes based on past experience include: (1) establishing minimum lake levels during certain conditions to address concerns about low lake levels, (2) raising the lake level during the spring to improve spawning habitat for sturgeon, (3) lowering the lake level during the fall to improve spawning conditions for kokanee, and (4) changing the winter-spring lake drawdown period if needed for earlier and more variable future runoff conditions.

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