Lake Koocanusa:

Management for Recreation

on a Popular International Reservoir

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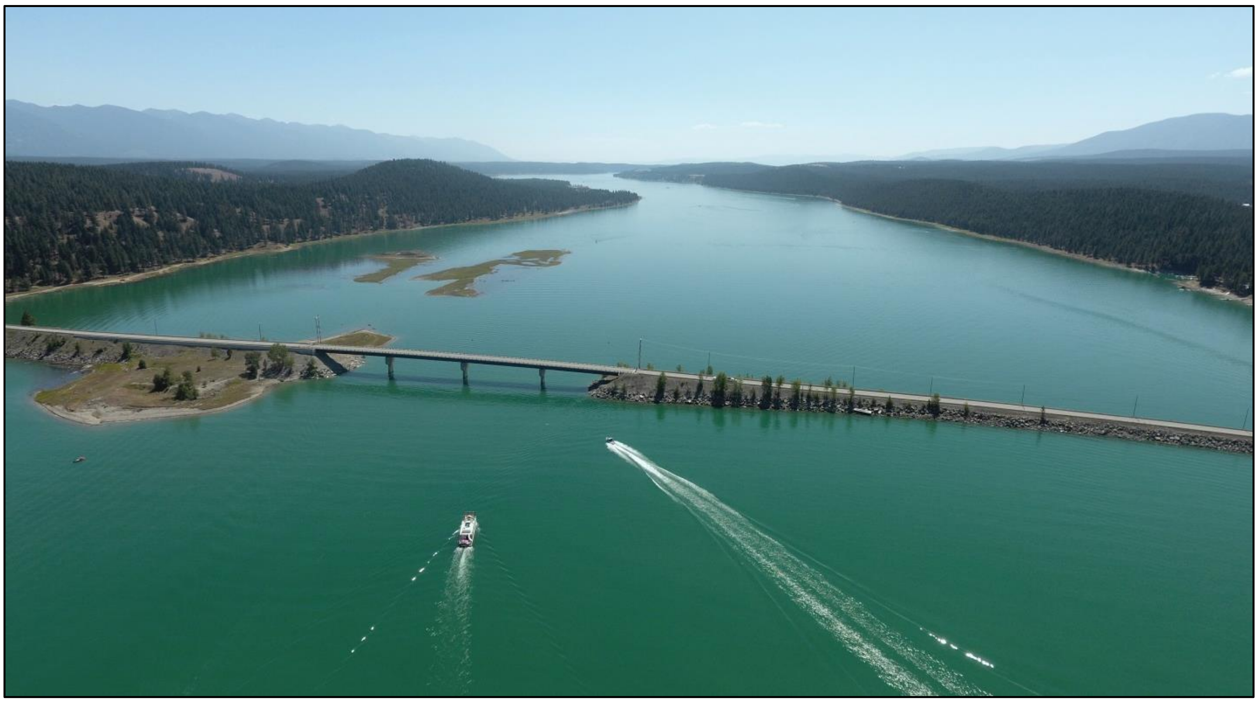

Figure 1. The Lake Koocanusa reservoir in southeastern British Columbia, facing south toward Montana, USA. A houseboat, motorboat and the Kikomun Bridge are in the foreground with a sparse band of black cottonwood trees along the causeway shoreline.
(August 15, 2020; level: 2451'; all photographs by Stewart Rood).

Submission to: BC Ministry of Energy, Mines and Low Carbon Innovation,
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Summary

Libby Dam was constructed around 1972 as one of four large dams that followed the Columbia River Treaty between Canada and the USA. It created the 145 km long Lake Koocanusa reservoir, which straddles the international border. During summer, warm and dry weather and clear, clean water, provide ideal conditions for reservoir recreation. The reservoir is annually drawn down through the winter for hydroelectric power generation and to create capacity for flood control. The reservoir is refilled with the spring freshet but in some years, floating woody debris and lower reservoir levels limit recreational use when the summer season commences.

In response, to raise levels of the Canadian portion of the reservoir for recreational benefit, the ‘Koocanusa Weir’ was proposed to be built near the international border. This would require a major dam about 60 m tall x 1500 m wide (~150 ft x ~1 mile) and there would be unique design challenges to accommodate varying water levels upstream and downstream and seasonal submergence. Subsequently, the project cost would probably substantially exceed $1 billion.

The dam would interrupt navigation, fragment the lake ecosystem and impede fish passage, including kokanee salmon and bull trout that are designated as threatened in Montana. Other environmental issues include water quality with current international concerns for selenium and other coal mine contaminants. Maintenance of a full pool year-round would substantially reduce flood control as well as hydroelectric power generation at Libby Dam and downstream through hydropower facilities along the lower Kootenay River and the Columbia River in the USA.

As an alternate measure, enhanced woody debris management could provide a practical, near-term approach to advance the recreational season on Lake Koocanusa reservoir. Additionally, in some years with lower flood risk, modest changes in Libby Dam operations might advance refilling to enhance early summer recreation in Montana as well as in British Columbia, providing international benefits.

To explore the options and consequences, analyses of prospective refinements to reservoir regulation could be undertaken, such as to achieve 2435’ (ft, 742.2 m) by June 15 or 2445’ by July 1. Hydrological variation and operational constraints including flood control and downstream flows would be recognized, and implementation might emphasize low flow years and would be facilitated with expanded runoff forecasting. Additionally, the new OASIS model could consider environmental impacts around the reservoir and downstream, and the broader consequences for the Columbia River Treaty system of rivers, dams and reservoirs.

Figure 2. The 129 m tall Libby Dam in Montana, USA, which created and regulates Lake Koocanusa reservoir.

1. The Reservoir and Seasonal Draw Down

Libby Dam is one of four large dams built following the Columbia River Treaty (CRT) between Canada and the USA. These were initially intended for two primary purposes: flood control and hydroelectric power generation. Behind the dams, the four storage reservoirs are filled through the summer and drawn down through the winter for hydropower generation when electricity demand is highest. For this objective, the water released at Libby Dam passes through turbines at that dam and then through the hydropower facilities on the Kootenay River downstream of Kootenay Lake. The Kootenay River subsequently joins the Columbia River and the regulated flows pass through the sequential hydropower dams in Washington and Oregon, with some shared benefits from the power production. Importantly, the winter draw down also creates storage capacity for subsequent flood flow attenuation.

As a consequence and similar to the other three CRT reservoirs, Duncan Lake, Kinbasket Lake and Arrow Lakes Reservoir, the dam operations result in lower reservoir levels in early summer, when recreational demands increase (Figure 3, following). The scheduling of draw down and refill represents a management consideration for all four reservoirs and this has been a repetitive concern for the Lake Koocanusa reservoir, which provides a highly valued recreational resource. The concern even prompted a major article in the *New York Times* in 1988 (1).

Following from this concern, in the mid-2010's a regional group proposed the 'Koocanusa Weir' (2). This structure would be slightly north of the international border and would retain a water pool upstream to an elevation of 2440' or 2450', ~20 or 10 ft below full pool, either year-round (Option A) or seasonally (Option B). This was intended to extend the interval for recreational use with boating and fishing, and for aesthetics (Figure 4).

This concept gained momentum following the very low flow year of 2019, which delayed reservoir filling. The Koocanusa Weir group initially suggested that the project might only cost 'a few million dollars' (3) and the concept was raised at the 2019 BC CRT community meetings in Cranbrook and Jaffray (3). The concept was somewhat endorsed by regional groups including the Regional District of East Kootenay (4).

Subsequently, the Province of BC contracted a preliminary 'high level assessment' by BGC Engineering Inc. ('BGC') with a report released in January, 2021 (5). BGC recognized that the structure would be a large dam rather than a weir, which is commonly regarded as a low head dam with lower height, smaller size and generally simple design.

Initial consideration for a major natural resource project often involves a 'pre-feasibility' or 'scoping' study to identify the range of major concerns and considerations (6). This may also provide guidance if a proposed project appeared very impractical, such as was the case for the rejected Meridian Dam near the Alberta/Saskatchewan border (7).

Guidance from the BGC report is ambiguous relative to the Koocanusa Dam concept and somewhat recommends advancement to consider engineering (5, p. 42). While the BGC report recognized some challenges with the prospective dam, there are a number of substantial issues, and potentially more practical alternatives for recreational enhancement.

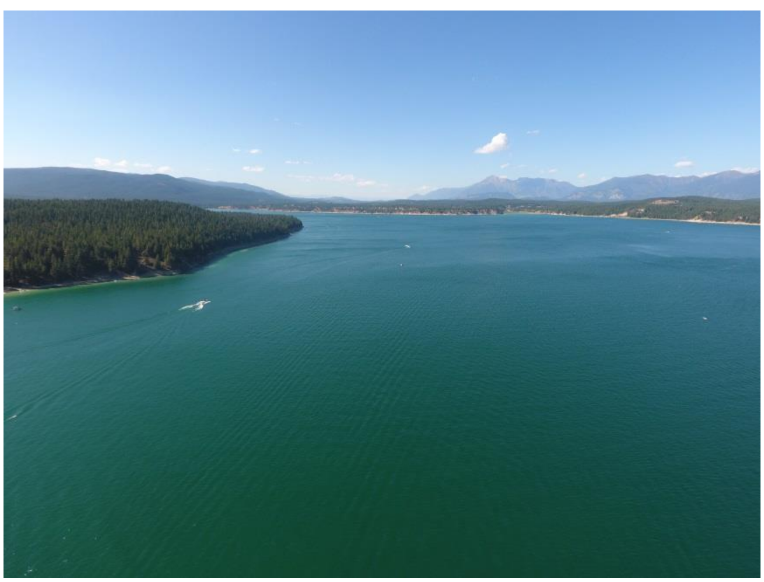


Figure 3. Seasonal conditions of the Lake Koocanusa reservoir in 2020, a fairly typical year. These aerial views face northward over the 'Kikomun pool' from above the reservoir near the causeway bridge.

In spring (left top, April 24, 2404' - ft), the reservoir is drawn down and the exposed Kootenay River is gradually rising prior to the freshet from snow melt and spring rains.

In early summer (left middle, July 9, 2449') the conditions are favorable as the reservoir has risen to the preferred level but the water may be cool and somewhat turbid after the spring freshet.

Optimal conditions are provided from mid-July into August (left bottom, August 15, 2451') with warm and clear water, and typically warm and dry weather.

There is limited recreational use when the reservoir partially freezes in winter (below, January 20, 2021 – 2410').

2. Seasonal Reservoir Recreation

The BGC report assessed the reservoir recreational season as from mid-May to the end of September (5, p. ii and Table E-1). This is a slightly longer interval than the commonly assessed period from the Victoria Day (~May 24) to the Labor Day (~Sept. 8) long weekends (8). For either interval, recreation on Lake Koocanusa in May is limited since the weather is often cool, the water is cold, woody debris and turbidity can be substantial, and this is not the primary interval for family holidays since schools are in session.

Even June is unreliable since the weather is variable during this wet month (5, Fig. 2-2). By mid-June, the weather is often warming and there is increasing interest in lake recreation. However, through June, the flows from the Kootenay and Elk Rivers into Lake Koocanusa reservoir are generally cold and turbid. For lake recreation in June, swimmers are probably more likely to go to Surveyor's Lake in Kikomun Provincial Park (9) or another small, natural, regional lake. These are clear year-round and warm much earlier. As recognized in the BGC presentation (10), the Koocanusa Weir development might benefit boating, aesthetics (Figure 4) and possibly fishing, but would provide limited benefit for swimming.

Figure 4. Views across the Lake Koocanusa reservoir to Koocanusa Village, a major and expanding recreational and residential development. Along with recreational consequences, the reservoir is generally assessed as more attractive (aesthetic) when higher and this also avoids blowing dust (top: May 10, 2018; 2379'- bottom: Aug 15, 2020; 2451').

July and August provide the primary interval for reservoir recreation on Lake Koocanusa. The weather is commonly warm and dry, the water warms, schools are generally out and residents and visitors often have summer holidays. Thus, the analysis should emphasize the seasonality of demand for reservoir recreation. Lower reservoir levels in mid-May are much less important than low levels in mid-June. This seasonality is recognized in the BGC report (5, p. 33) but deserves greater emphasis.

To consider some of the seasonal factors influencing reservoir recreation, columns are added to content from the BGC summary Table E-2 (Table 1, below). These indicate that the priority interval for seasonal extension would commence around mid-June. This interpretation is consistent with a recommendation of Bob Cutts, the long-time operator of the Koocanusa Campsite & Marina (personal communication).

Table 1. Factors influencing the suitability of the Canadian portion of Lake Koocanusa reservoir for recreational use. The table includes the numbers of days that the reservoir would be below the proposed dam elevation of 2440 ft (744 m ASL, right columns), as assessed in the BGC analysis (5, Table E-2). Red lettering indicates recreational limitations and the blue band indicates the primary recreation interval of July and August.

		Daylength h[1]	Max Air Temp[2] C	Water Temp[3] C	Woody Debris[4]	Turbidity[4]	Recreational Demand[5]	Average	Wet	Dry
								Days < 2440'		
May	15-31	15.8	19	20.6	XX	XXX	medium-low	16	17	17
June	1-14	16.1	22	21.7	XXX	XXX	medium	12	14	14
June	15-30	16.3	23.5	23.9	XX	XX	medium-high	8.5	0	16
July	1-14	16	26	25.3	X	X	high	3	0	14
July	15-31	15.5	27.5	25.8	-	-	very high	2	0	12
August	1-14	14.8	27.5	24.4	-	-	very high	0	0	0
August	15-31	14	26	23.3	-	-	high	0.5	0	0
Sept	1-14	13	22.5	22.8	-	-	medium-high	2.5	0	0
Sept	15-30	12	19	21.7	-	-	medium-low	4	0	0

[1]Values for Cranbrook, BC. Insolation (sunshine warming) is positively correlated.
[2]For Baynes Lake, from BGC Figure 2-2 – average daily maximum temperature (Temp).
[3]Interpolated from data posted by Sunshine Houseboats (11). Water Temp is also measured at the international border (11). For reference, Olympic swimming events require water 25 to 28^{o}C.
[4]These vary considerably across years, associated with river flow patterns.
[5]This assessment reflects the various measures and the vacation season.

3. Reservoir Levels for Recreation

Along with the recreational season, the second major variable is the reservoir level. The reservoir may be less favored when filled to the full pool elevation of 2459’ (ft, 749.5 m, Figure 5). This raises the water level to the shoreline with permanent vegetation, reducing barren beach areas that are favored for some activities. Reservoir elevations from about 5 to 15 ft (1.5 to 5 m) below full pool could be preferred, consistent with a prior survey (8). The bank slopes vary substantially around the reservoir, with corresponding variation in the width of the exposed band.

The Koocanusa Weir proposal initially sought an elevation of 2440’ (743.7 m) (Figure 5) and this was revised to 2450’. These would be ~20 ft or 10 ft below full pool. Assessments suggest that the reservoir level is sufficient but not optimal down to ~30 ft below full pool (~2430’). Splitting these criteria and recognizing the recreational season, an objective of 2435’ by June 15 would advance the boating season into the interval of higher demand. There would generally be further filling to raise the level to the favored 2445’ by July 1.

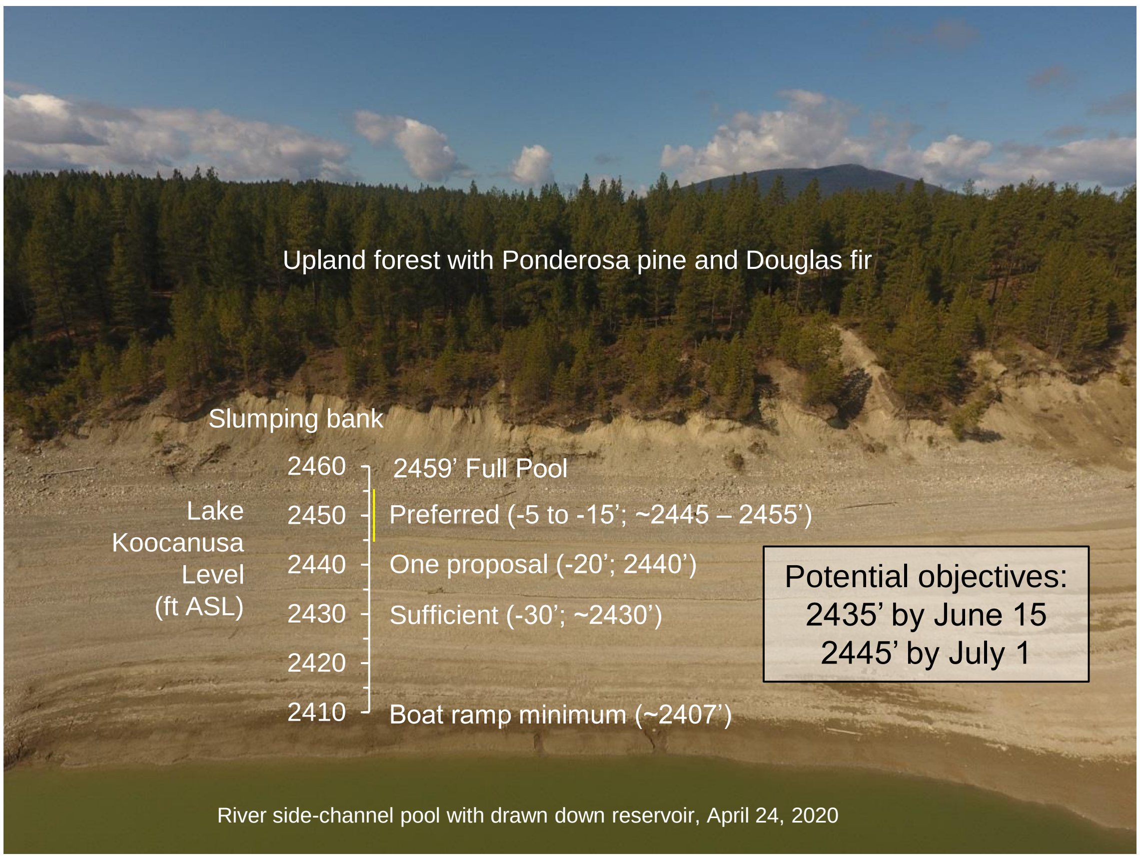


Figure 5. The exposed profile of the foreshore or draw down zone of Lake Koocanusa reservoir, along the west bank shortly north of the main boat ramp. This is a fairly typical shoreline but there are locations with more gradual slopes that are better suited for boat landing and recreational use. Recreational preferences are approximate and corresponding water level positions are estimated (1 ft = 0.3048 m; 2459 ft = 749.5 m; 2435 ft = 742.2 m).

Boat ramps and beaches provide additional elevational considerations. The main boat ramp at the Kikomun causeway requires ~2407’, ~50’ below full pool (5). This is minimal and the function improves ~2426’, when the adjacent dock becomes usable (5, p. 36) and a second lane is accessible. Suitability improves further up to the preferred levels (Figures 4, 5, 6 and 7). There are a number of other boat ramps and many undeveloped launch locations and these often require higher reservoir levels than the main ramp (5, p. 11).

Figure 6. Two major developments along Lake Koocanusa reservoir during the prime recreational season (Saturday, August 15, 2020; 2451’).

The main boat ramp at the Kikomun causeway (left, top) with about 75 boat trailers and 50 other vehicles at the boat ramp parking lots and adjacent roadway. Anticipating about 4 people per boat this would result in ~300 boaters from this ramp at this time. There is turn-over with boats launched and landed throughout the day and thus ~500 boaters from this ramp/day during the prime recreational season. Surveys would be worthwhile and the total numbers of boats and boaters over the full Canadian and American portions of Lake Koocanusa would be many times higher.

The popular Koocanusa Campsite & Marina (left, bottom) is across the causeway with travel trailers for seasonal camping, a marina, beach, store, and boat fuel. Similar amenities are being developed at Koocanusa Village.

Canoes and especially touring kayaks are increasing on Lake Koocanusa along with stand-up paddleboards and other boats and floats. These don’t require boat ramps and access is widespread. There are some sailboats, especially moored at Waldo Cove, and these may require deeper launches. The Waldo Cove development was acquired by the Regional District of East Kootenay in 2019 (12) and there are a range of other existing and generally expanding public and private developments. A major and popular public resource is Kikomun Provincial Park, which has an older boat ramp that extends lower than the main ramp at the Kikomun causeway.

Following from these considerations, a favourability curve is proposed (Figure 7, below). The values follow from reported preferences (8), communication with individuals familiar with the reservoir (Acknowledgements), and the author's observations and boating at varying levels. The specific curve will vary somewhat with activities, user preferences and locations - there is no single 'perfect' reservoir level.

There are four approaches that could be applied to verify this curve:
1. Expert Opinion – survey individuals with extensive experience,
2. User Survey – survey users such as exiting boaters at ramps,
3. Comparison – common users or observers provide assessments at different levels, and
4. Physical Assessment – analyses of features within the draw down zone such as gradual slopes for beaches.

The full pool elevation is 2459' (749.5 m) and the dots in the figure indicate rated reference elevations that could be modeled as performance measures relative to reservoir recreation. Levels of 2435' or 2440' could be objectives to commence the primary recreational season by June 15. Subsequent filling would raise the reservoir to very good to excellent levels by July 1, when recreational demand further increases. An annual operational target for reservoir regulation has reportedly been 2454' (23).

These assessments emphasize the Canadian portion of Lake Koocanusa. There could be similar analyses for the American locations including Rexford and the Koocanusa Resort and Marina closer to Libby Dam - a similar function is expected. Along the American portion and the southern Canadian portion, the river valley is lower and reservoir boating is possible substantially below 2410'.

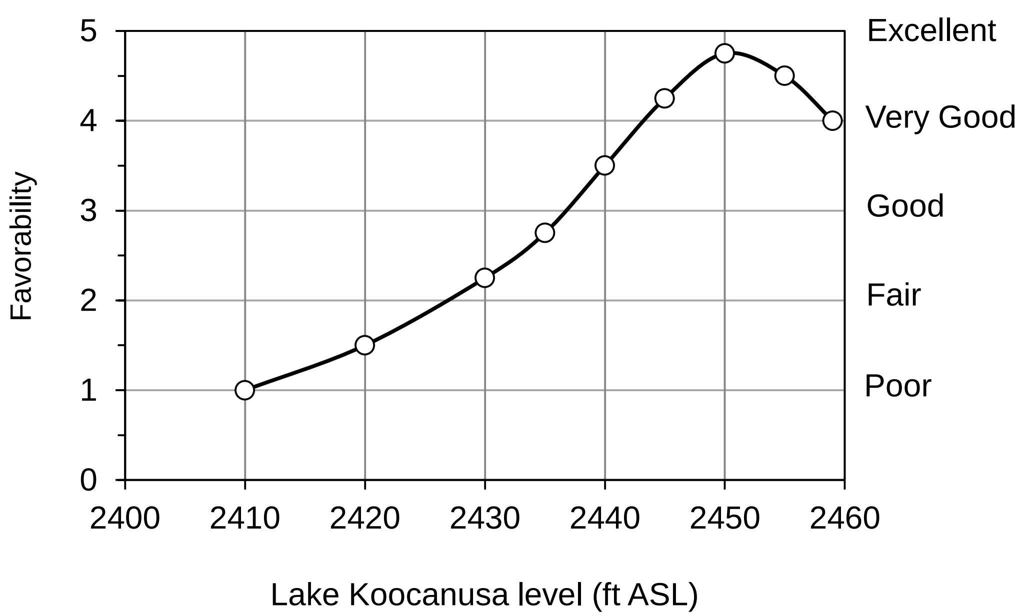


Figure 7. A favourability curve for recreational boating on Lake Koocanusa reservoir (ASL – above sea level).

4. The Koocanusa Weir - A Major Dam with Major Cost

The Koocanusa Weir concept proposed a dam near the international border. There, the pre-reservoir or draw down river elevation is ~2290’ (ft, 698 m). Consequently, a 150 or 160 feet (46 or 49 m) tall structure would be required to provide the upstream pool at 2440’ or 2450’ (744 or 747 m). As recognized in the BGC report (5), this would be a major dam rather than a weir, which indicates a smaller and simpler low-head structure.

At the border, the reservoir is almost a mile wide (~1.5 km) and consequently the dam would be a very large structure. As recognized by BGC, there would probably be requirements for a gate system to permit flow regulation and a structure or system for fish passage. These would substantially increase the complexity and cost of a dam and would be especially challenging due to the changing downstream and upstream water levels, and the submergence of the structures for a few months annually. BGC suggest that a taller dam that matches Libby Dam in the crest elevation might provide an alternate design to deal with these complexities, and this would require an even larger structure.

Related to the dam design, the suggestion in the BGC report that a complexity would be the need for the structure to deal with bidirectional flow seems incorrect (5, p. 41). The Kootenay and Elk Rivers are perennial and there will always be downstream flow southward to Libby Dam.

As the BGC report recognizes, without more detailed design the dam cost is very uncertain. The BGC report includes a comparison with various dams in Australia, which provide a broad range of values, leading to an estimate of ‘in excess of $400 million’ (5, p. 42).

Alternate cost comparisons could consider recent and current regional dams. Across the Alberta border, the zoned earth-fill Oldman River Dam was fairly similar in height but about one-half the width (76 m height to enable ~ 50 m drop from reservoir to river in a location with ~ 0.6 km wide valley). Built three decades ago, that structure cost ~ $350 million (13), but with environmental analyses, mitigation, litigation and compensation, the full project cost would have been closer to $500 million. (No comprehensive cost analysis was undertaken, which would be complicated by the extensive unbudgeted contributions from municipal, federal and especially provincial agencies).

Major water project costs are likely to about double per decade, as displayed for the Site C Dam currently under construction on the Peace River in BC (14). Consequently, the Oldman Dam project might cost ~$1.5 billion today. The vastly smaller, anticipated Springbank Dam on the Elbow River upstream of Calgary has a current cost estimate of >$400 million, although that includes land acquisition to allow a temporary offstream reservoir (15). The prospective Kootenay Lake dam might even approach the size of the Site C Dam, which has a current cost estimate of ~$11 billion, but this includes the major hydropower plant and that project encountered site instability (14). Relative to these regional comparisons, the $400 million minimum for the Lake Koocanusa Dam appears very low and it is likely that the full project cost would be substantially more than $1 billion.

In addition to the initial cost, as recognized by the BGC report (5, p. 41), there would substantial annual costs for operation and maintenance. The dam's longevity might also be shortened due to the varying water levels upstream and downstream and seasonal submergence, and subsequent reconstruction or removal would be costly.

There would also be substantial costs with the loss of hydropower generation (5). This would especially be the case for the year-round full pool Scenario A. The loss of hydropower without the winter draw down would include the reduced generation at Libby Dam and also downstream through the sequential hydropower facilities along the lower Kootenay River after the outflow from Kootenay Lake. The loss might then extend downstream through the hydropower facilities along the Columbia River in Washington and Oregon, USA. There could be compensations with altered management especially of the three other Columbia River Treaty (CRT) dams in BC, but that would influence the management opportunities for those dams, reservoirs and river reaches.

The full pool option would also substantially limit flood flow attenuation and the economic and external costs of the full-pool scenario would thus be extensive, disfavoring Scenario A. The seasonal pool would have much less impact on flood control or hydropower generation (5, p. 42, etc.). It would also have less influence on management for the downstream Kootenai River and back into Canada, and for management of the other CRT dams and Kootenay Lake, which is also regulated. The BGC report somewhat encouraged further study (5, p. 42), possibly for the seasonal pool Scenario B but other major impacts could further oppose a large dam.

Figure 8. Sandy beaches near Newgate (July 9, 2020; 2449'), shortly north of the border, where the proposed dam could be located. Most of the foreshore (draw down) zones around Lake Koocanusa are covered with gravels while sandy beaches are often preferred for recreation. The Newgate area provides the largest sandy beaches and there are also other popular beaches such as 'Gilligan's Island' at Waldo Cove. An opposite physical feature is the bedrock cliffs that provide another popular location (right, Aug 29, 2016; 2447').

5. Fish, Including a Threatened Species

There would be substantial challenges for the Koocanusa Weir project due to impacts on fish. A dam would impede passage, as recognized by the BGC report, and impact the aquatic ecosystem.

The primary sport fish in Lake Koocanusa is kokanee salmon, freshwater sockeye salmon (*Oncorhynchus nerka*, 98% of sport fish caught in 1996, 17). This fish was accidentally introduced during the early filling of the reservoir (17) but is regionally native, occurring naturally downstream of Libby Dam in the Kootenai/y River and Kootenay Lake. Thus, the distribution of this salmon has substantially expanded following the Libby Dam project.

The abundant Kokanee salmon of Lake Koocanusa spawn in the inflowing rivers and their tributaries, especially the Lussier River, and in the reservoir side creeks such as Sand Creek (Figure 9, 17). For example, they are conspicuous in Kikomun Creek with a popular viewing location below the Baynes Lake Road culvert (Figure 9). Bears are common at this and other migration and spawning locations, and the salmon carcasses contribute to the riparian and upland ecosystems as well as to the aquatic food web.

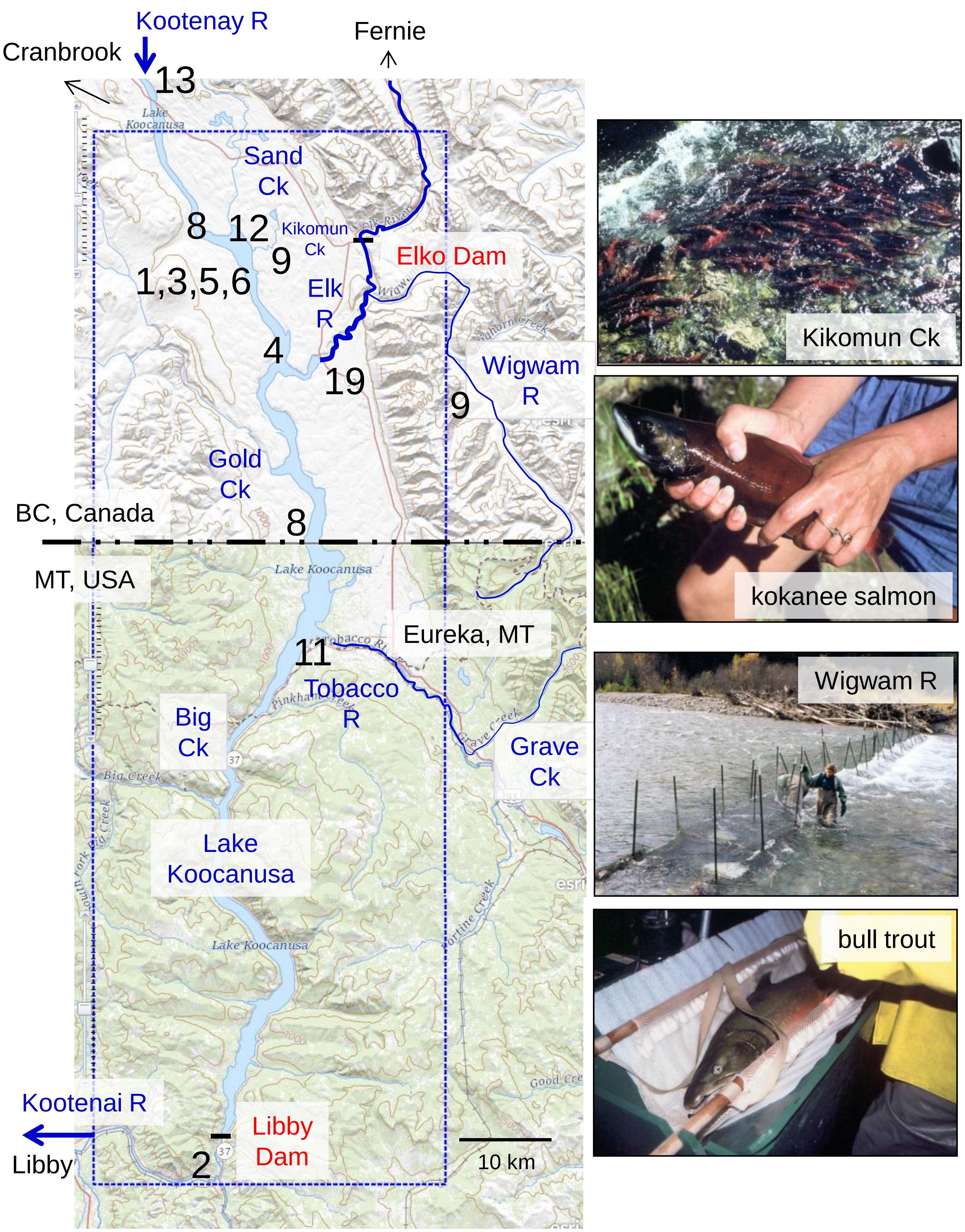
Bull trout (*Salvelinus confluentus*) are native and another sport fish. These are the largest fish and the top-level carnivore (piscivore) in Lake Koocanusa (18). Bull trout are listed as a threatened species in accordance with the American Endangered Species Act, and this listing is important since Lake Koocanusa straddles the international border. With concerns for the population, in 2020 the Montana Fish and Wildlife Commission closed the harvesting of bull trout from Lake Koocanusa (18). Issues of connectivity and population fragmentation were regarded as contributing factors. This recent assessment contrasts with the more favorable interpretation in the older report referred to in BGC Table 2-2, based on data from 1975 to 2002.

Like the kokanee salmon, the bull trout spawn in autumn in the stream tributaries, thus requiring migration (Figure 9). While there is some spawning in other creeks, Graves Creek, a small tributary branching from the Tobacco River near Eureka, MT is the most productive bull trout spawning stream from the MT side of Lake Koocanusa (17). A larger and much more productive spawning tributary is the Wigwam River (17, Figure 9). This is a tributary of the Elk River that flows into Lake Koocanusa. The bull trout swim up the Elk River but are blocked by the 10 m 'Leap of Faith' waterfall and subsequently migrate up the Wigwam River system to spawn.

The Wigwam River commences in Montana and consequently there is international involvement in both the spawning tributary and in Lake Koocanusa where the bull trout grow vigorously to exceed one m in length (40 inches, Figure 9).

In addition to the autumn spawning bull trout and kokanee salmon, the native, spring-spawning westslope cutthroat trout and rainbow trout could also be challenged by the Lake Koocanusa Dam. The spring interval involves major reservoir draw down, and a dam would impede spawning migration. While the Lake Koocanusa Weir project would be intended to benefit recreational fishing, negative impacts to fish populations would oppose that intended outcome.

Figure 9. Map of Lake Koocanusa reservoir with tributaries and other features.
Numbers indicate locations of the report photos by Figure #. Important fish are displayed (right) and the blue outline indicates a USGS selenium study area
https://www.sciencebase.gov/catalog/item/imap/58ecf623e4b0b4d95d335366.



6. Water Quality – Coal Mine Contaminants

A current transboundary issue related to the Elk River, Lake Koocanusa and the Kootenai River downstream involves selenium and other aquatic contaminants (19). These originate from the large mountain-top metallurgical coal mines in the Elk Valley between Elkford and Sparwood. Contaminant levels are sufficient to cause fish deformities especially in the Fording River near the mines, with impacts extending to the Elk River and downstream (20). This introduces a major concern for aquatic health and for the contamination of drinking water from riverside wells. Remediation projects for selenium removal are underway in the mine areas but outcomes are uncertain.

Studies are underway to explore the dynamics of selenium and the other contaminants and these have extended to Lake Koocanusa (Figure 9, 21). These water quality studies are intensive and also provide detailed measurements of water temperature and turbidity, which relate to reservoir recreation.

The flow of mining contaminants from BC to MT, downstream to ID, and then back to BC near Creston provides a current international friction that would probably invoke the International Joint Commission relative the Boundary Waters Treaty. The water quality consequences would need analyses prior to any development such as the prospective Lake Koocanusa dam. Water pooling and warming influence selenium speciation and bioaccumulation, and would thus require assessments prior to any prospective development.

7. International Trade-offs Along Lake Koocanusa Reservoir

Another likely challenge is underemphasized in the BGC report. The dam could result in a trade-off between an advancement of the recreational season in Canada versus reduced recreational suitability along the American portion of Lake Koocanusa, south of the proposed dam. This important point is only recognized with a short statement at the end of the analysis of Reservoir Level and Recreation (5, p. 35).

Along the American portion of Lake Koocanusa, the most extensive recreational developments are around Rexford, MT, near the outflow of the Tobacco River. This is a short distance west of Eureka, MT, which is only 14 km south of the Canadian border. There are a number of projects and boat ramps around Rexford, including the Abayance Bay Marina (Figure 11) with adjacent homes, cabins and campgrounds. Many Canadians, especially from Alberta and BC, own property or vacation in this area. For example, at the nearby Wilderness Club Resort about three quarters of the visitors are Canadians, especially from Calgary (22).

The international consequences would require further analyses, including more detailed digital elevation modeling (DEM) of the reservoir zones. A crude estimate can be derived with an assumption of relatively similar upper reservoir areas in the Canadian and American portions, although it is recognized that the reservoir pool is a wedge (Figure 10). While the American portion is slightly longer, the valley is generally narrower from Libby Dam north to the Tobacco River, where it widens as it reaches the southern Rocky Mountain Trench (Figure 9).

If the upper surface areas were fairly similar, redistributed filling to raise the upper Canadian portion by 40’ in mid-May might result in a drop of ~20’ to 30’ in the American portion (Figure 10). The river valley slopes progressively downwards from north to south and consequently the reservoir pool is deeper in the American versus Canadian portion. However, the difference is only modest between the Canadian area at Newgate, near the international border, and Rexford, which provides the focus for recreational development in Montana (Figures 9, 11).

Further, while the reservoir pool is deeper at the downstream locations, the recreational developments along the full reservoir similarly emphasize the upper band. Thus, the favored level is commonly ~10 ft (~3 m) below the full pool shoreline (Figure 11). This principle was confirmed in 2019 when there were similar concerns for the delayed filling of the Lake Koocanusa reservoir in Canada and the USA (23).

For Americans or Canadians, reduced recreational favourability south of the international border for recreational benefit north of the border seems counter-productive. A proposal for a major dam near the border would certainly trigger international assessment and recreational loss would provide one more risk to American support and project approval.

Figure 10. A simplified longitudinal profile of Lake Koocanusa reservoir with the proposed Koocanusa Lake dam. Prospective changes in reservoir levels upstream versus downstream are indicated with the seasonal pool Scenario B and spring filling of the upstream Canadian pool.

This figure is illustrative and scaling is inaccurate.

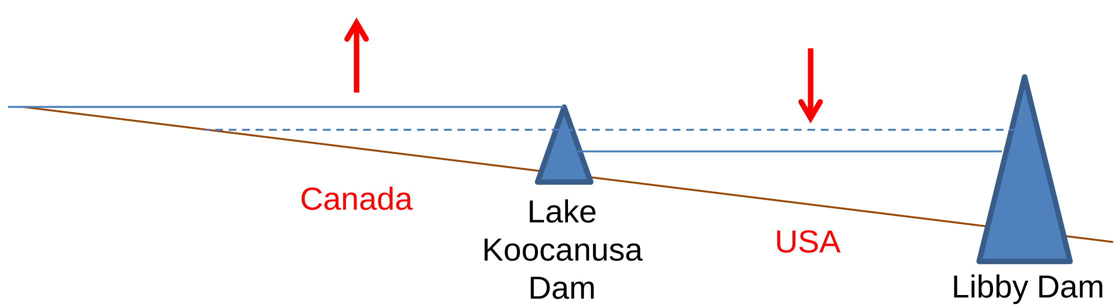


Figure 11. The marina (top) and shoreline (bottom) of Lake Koocanusa reservoir at Abayance Bay, in Rexford, Montana. These photos are from June 7, 2017 (2413’), which approaches the popular recreational season but few boats had been launched. The American and Canadian developments are probably intended for generally similar reservoir levels and early season filling benefits recreation along the full international reservoir.

Situated downstream, the American portion is deeper than the Canadian portion and consequently boatable at lower reservoir elevations. The American portion is also further from the major inflowing tributaries, the Kootenay and Elk Rivers, which deliver suspended sediments and woody debris.

8. Woody Debris Management to Advance the Boating Season

As indicated, with long days and warmer and drier weather, demand for reservoir recreation increases through June as the holiday season advances. This prompted the alternative reservoir level objective of 2435’ by June 15. However, at that time Lake Koocanusa has sometimes been unsuitable for motor boating and especially for towing of inflatables, water skis and wakeboards, and the increasingly favored wake surfing. In June, woody debris floating in from the Kootenay and Elk Rivers often creates substantial hazard.

The woody debris is increased with higher river flows and dramatically increased with flood flows such as in 2013 (33). In timing, woody debris is primarily floated with river rise and the debris load drops abruptly after the flow peak, which is typically in early June on the Elk River and slightly later on the Kootenay River (*Peak Flow Hydrology* section 12, following).

There is a program to remove the woody debris from Koocanusa but the timing has varied. In some years, there is still substantial floating debris into July and this discourages recreational boating when the reservoir level and other conditions would otherwise be favorable. The annual debris removal budget is ~ $110 to 130K, with contracting by BC Hydro (26). Revised woody debris management might provide a practical, near-term measure to advance the boating season on Lake Koocanusa. This would avoid a costly dam or the complexities of revisions to reservoir regulation. The operators who have managed woody debris will have more familiarity and aspects might be considered such as interception at the Elko Dam head-pond, a second boom on the Elk River arm or offset debris traps on the Kootenay River that would allow boat passage.

While floating debris is a hazard to boating, woody debris along the shoreline provides wildlife habitat and interest for recreational users, and sunken debris contributes to the aquatic ecosystem (27). This could invite broader consideration of woody debris management. There are also interesting aspects such as the natural circulation of woody debris from the Kootenay River into the aptly named Driftwood Bay, where Lake Koocanusa widens near Sand Creek (Figure 12).

Figure 12. Driftwood Bay of Lake Koocanusa reservoir (July 9, 2020, 2449’), where woody debris from the Kootenay River naturally accumulates.

(inset) The woody debris boom and anchor at the Elk River outflow below the Hwy 93 Bridge.

9. Reservoir Turbidity

Through the spring, the Canadian portion of Lake Koocanusa is turbid due to suspended silts. This hinders fishing and reduces the aesthetic appeal but provides less impediment to motor boating than woody debris. The BGC report attributes the turbidity to the slowly submerging mudflats (5, p. 11 and elsewhere), citing a broad overview report ('BC Hydro 2013').

This interpretation is at least incomplete and may be incorrect. The spring outflows from the Kootenay and Elk Rivers are turbid with the suspended sediments increasing with the freshet (Figure 13, below). Subsequent settling of the fine sediments is gradual and there are substantial differences in the sediment textures (particle size distributions) between the Kootenay and Elk Rivers. There would be some local sediment suspension from the mudflats, and longitudinal assessment could be instructive to resolve the relative sources and prospective influence from reservoir regulation.

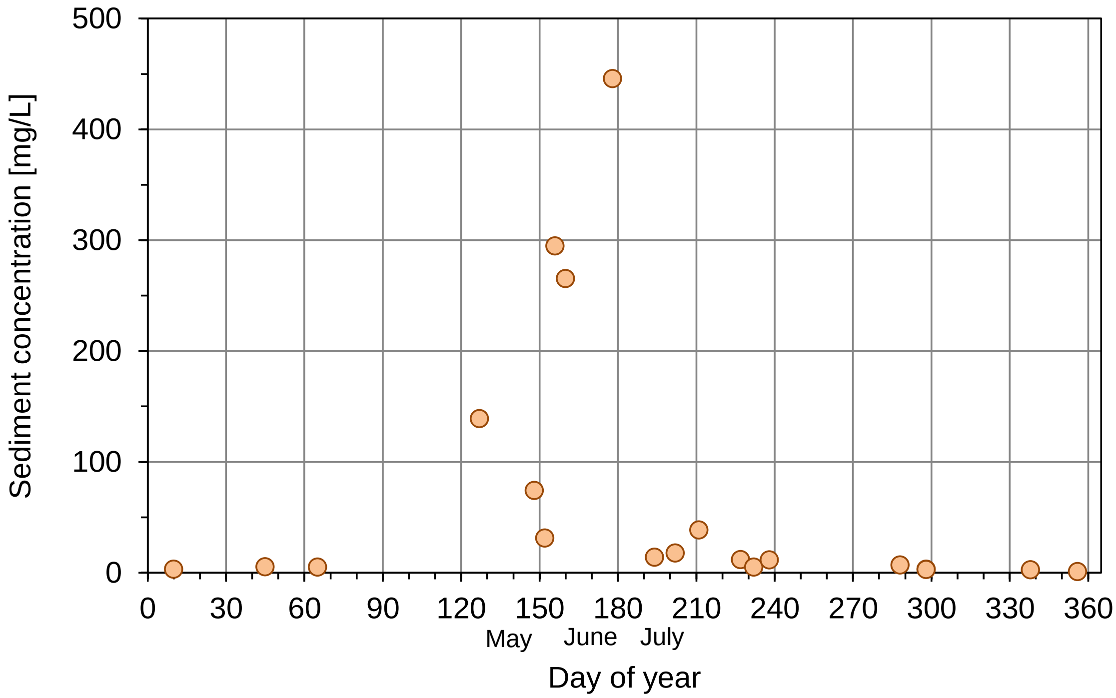


Figure 13. (Above) Suspended sediment concentrations in the Kootenay River at Fort Steele, with sampling accompanying flow peaks in 1989 to 1992 (day 150 = May 30; instantaneous, WSC #08NG065). Accompanying the new water quality monitoring for coal mine contaminants from the Elk River, more detailed suspended sediment sampling is underway.

(Right) Turbid Kootenay River flow at Hwy #3 bridge, June 3, 2019, a very low flow year.

10. Hydrology and Climate Change

The BGC report presents hydrographs for the three inflowing tributaries in Figure 4-1 (5). As indicated, the current Elk River gauge is at Fernie (5, Table 4-1). However, the run-of-river Elko Dam is situated downstream (Figure 9) and thus the Elk River is slightly regulated.

Downstream from the Fernie gauge, the Elk River is joined by a number of creeks and then the Wigwam River. A prior gauge had been below these at Phillips Bridge, a short distance upstream from Lake Koocanusa. The seasonal flow regimes of the tributaries are quite similar to the Elk River, and the combined discharge is ~60% higher than at Fernie (28). Thus, the Elk River provides proportionally larger flow contribution than represented in BGC Figure 4-1 (5).

As recognized by the BGC analysis, the regional impacts of climate change on river flows will influence future patterns of Lake Koocanusa. The BGC report emphasizes projections from regionally downscaled global circulation (or climate) models, as undertaken by the Pacific Climate Impacts Consortium (PCIC, 5, Figure 4-8).

Empirical trend projection provides a second approach that assesses statistical trends in the actual historical data. A reasonable interpretation is that the near future will extend patterns from the recent past. For the Elk, Kootenay and Bull Rivers, we have spliced the hydrometric records across sequential gauges to develop century-long time series for trend analyses (28, Figures 17 & 18). These indicate that annual and peak flows display substantial year-to-year variation but have not revealed progressive trends over the past century. This suggests that the regional hydrologic changes may be more gradual than the PCIC projections (5).

While more moderate in magnitude, the directions of historical trends for regional rivers (28) are generally consistent with the PCIC projections. Winter flows are slightly increasing, probably due to an increase in the winter rain versus snow proportion. A greater increase in spring flows follows from the advancement of snow melt, accompanying warming spring weather. Following the earlier snow melt, mid- to late summer river flows are declining (28).

With some convergence between the climate modeling and the historical trends, it is likely that these changes will continue through the twenty-first century. The advancement of the spring freshet could advance the filling of Lake Koocanusa, benefiting the objective of 2435' by June 15. Declining late summer and autumn inflows might advance the commencement of draw-down, but recreation in that interval is less commonly limited by reservoir level.

The historical analyses also reveal correspondences with the Pacific Decadal Oscillation (PDO, 28), which has a period of around four decades. This reversing climate oscillation complicates shorter hydrologic patterns such as displayed in the BGC Report Figure 4-7 (5) or in the recent Morrisey Ridge snow packs (Figure 20).

As well as advancing snow melt, spring warming will advance reservoir warming. This will provide another influence from climate change on Lake Koocanusa recreation.

11. Reservoir Regulation

The target of 2440’ by mid-May, as assessed by BGC, would require substantial change in the seasonal regime. Conversely, the alternative objective of 2435’ by mid-June has been reached in many recent years. Increased compliance might be achieved through fairly modest changes in dam operations rather than the costly construction of a major new dam.

This is demonstrated in Figure 14 (below), which is revised from BGC Figure 4-4 with plots of the two target elevations and timing. As indicated with the ‘X’, much more revision would be required to satisfy the proposal of 2440’ by mid-May. In contrast, the slightly lower and substantially later alternate objective is 2435’ by June 15 is nearly satisfied in average years.

The plots of historical patterns also reveal that over recent decades, Libby Dam operations have reduced the annual draw down (red and blue lines) and advanced reservoir filling to levels more suitable for recreation (black line). These changes have substantially improved conditions for reservoir recreation over the interval when there were numerous developments and substantially increasing recreational use on the Canadian and American portions.

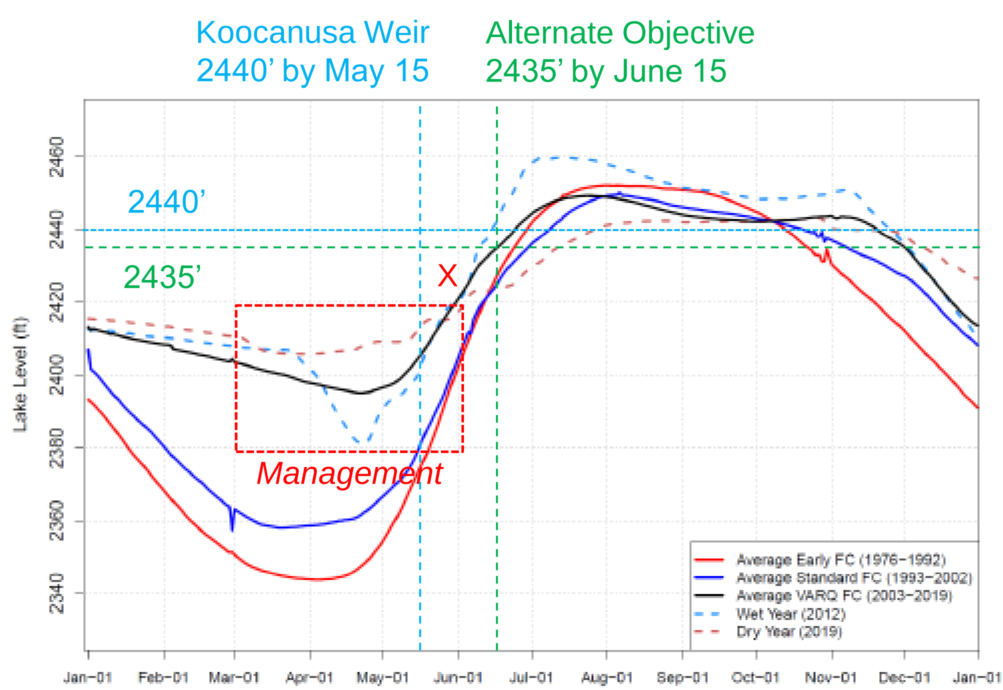


Figure 4-4. Average daily reservoir level for each operational period measured in the reservoir forebay.

Figure 14. Figure 4-4 from the BGC Report, with additions including dashed lines for the proposal of 2440’ by mid-May, and an alternate objective of 2350’ by mid-June. Dry years provide a challenge and dam operations have varied between dry, wet and normal years, especially within the ‘Management’ interval. Advancement in the commencement of differential management from April to March might be enabled by refined flow forecasting.

The prospects for refinements to dam operations to slightly advance filling are demonstrated by prior hydrologic modeling (24, Figure 15). In this case study, management Alternative 3 commenced with higher reservoir levels and provided about a two-week filling advancement, thus satisfying the objectives of 2435' by June 15 and 2445' by July 1. However, averages are plotted in the model outcomes in Figure 15, and dry years may continue to provide a challenge.

Any alternatives will impose trade-offs, with some reduction in hydropower generation and other consequences (24). The modeling could be expanded and the newer OASIS model (Operational Analysis and Simulation of Integrated Systems) could also consider the broader impacts relative to the Columbia River Treaty system of rivers, dams and reservoirs.

The recreational performance measures of preferred level for recreation and sufficient level for boat launching were already implemented with the prior modeling (24). These could be refined and expanded with the newer OASIS modeling including different objectives.

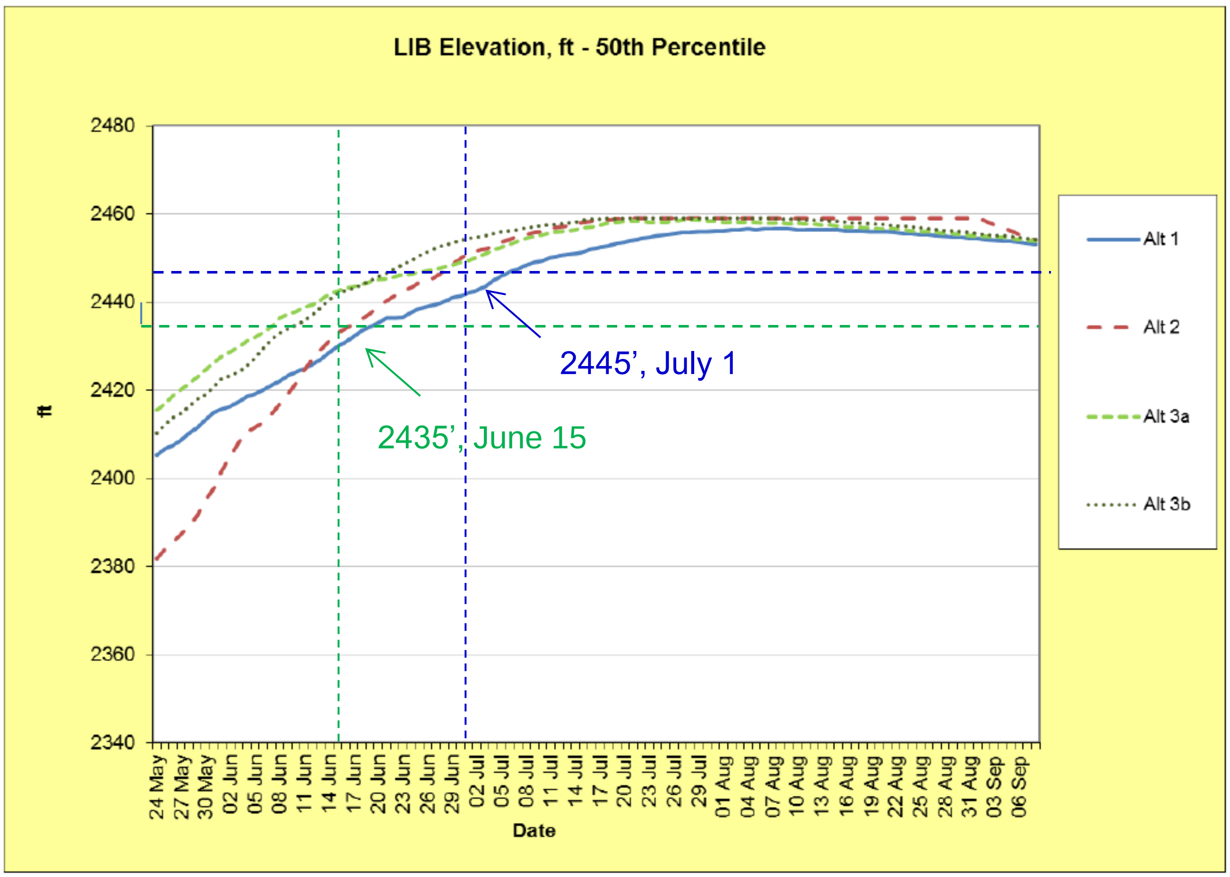


Figure 15. Sheet #52, Figure 1 from the CRT model report (24) with the possible objectives plotted. Alternative 3 commences with a higher reservoir, following less draw down. https://engage.gov.bc.ca/app/uploads/sites/6/2012/07/Appendix-G-Kootenay-Performance-Measure-Information-Sheets-FINAL.pdf - PM Info Sheet # 52 –Lake Koocanusa: Recreation and Tourism, p. 3.

The operation of Libby Dam must consider multiple factors and these will constrain the extent of reservoir regulation for recreation. The priorities of flood control and hydropower generation persist and fish including downstream sturgeon and salmon and the broader downstream riverine ecosystems provide additional factors. These and other aspects must be considered, requiring comprehensive analysis of environmental, social and economic costs, benefits and risks.

Despite these complexities, there is promise. In many years, Lake Koocanusa has reached preferred levels for recreation, especially through the peak recreational season of July and August.

For example, seasonal reservoir levels are plotted in Figure 16 (right) for recent normal, low flow and flood years. Of these, favorable reservoir levels were provided in the normal and flood year, but sufficient filling for recreation was delayed in the low flow year of 2019.

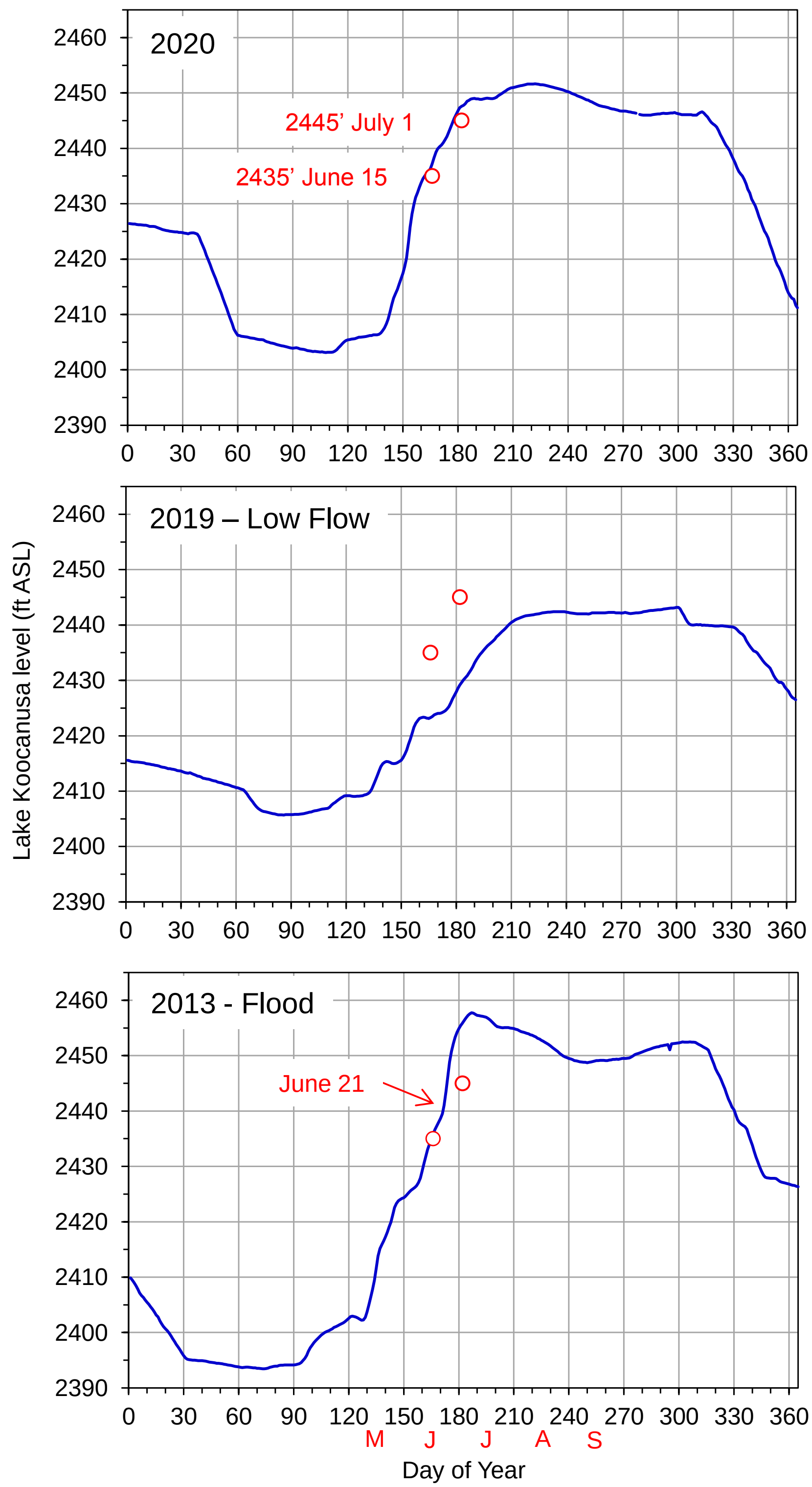


Figure 16. Levels of Lake Koocanusa reservoir in recent years with different inflow patterns. The prospective recreational objectives are plotted with red circles.

12. Peak Flow Hydrology

A practical challenge for woody debris management and for reservoir regulation is the variation in timing of the spring peak (Figure 17). This is commonly in June but has varied by two months over the past century. The seasonality of recreational demand led to the mid-June objective but this is sometimes prior to the spring peak along the Elk River and commonly prior to the Kootenay River peak (Figure 17). Consequently, woody debris removal has been delayed in some years, potentially favoring increased interception.

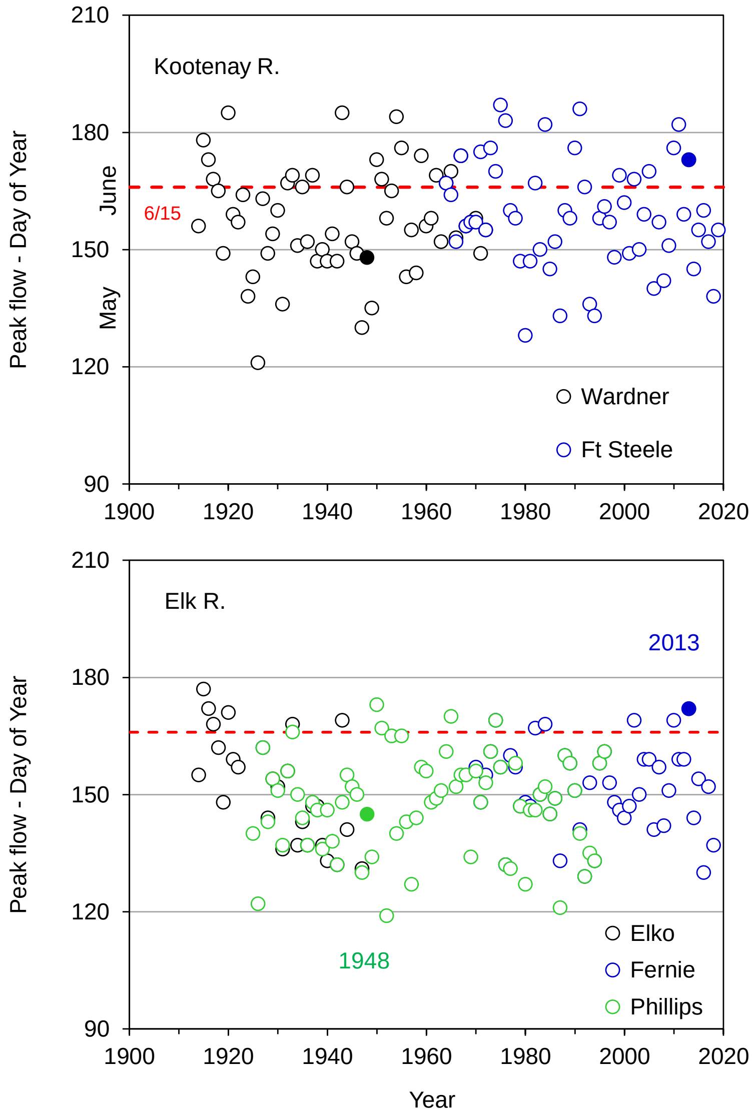


Figure 17. Timing of peak flows along the Kootenay (top) and Elk (bottom) Rivers, with values from the sequential WSC hydrometric gauges.

There were no significant trends over the past century (e.g. Kootenay: Peak flow DoY vs Year: r = 0.017; r = ; not significant), but the PDO pattern emerges (28).

This natural variation in the timing of the spring peak also imposes a challenge for dam operations and especially reservoir regulation for flood control. The uncertainty about rain events requires caution but snow pack patterns are instructive both for snow melt contributions and for potential rain-on-snow that accelerates snow melt, contributing to major regional floods (34).

Data splicing across these sequential gauges provides century long records to further explore historical trends (28). While the 'climate intensification' hypothesis would propose increasing flood frequency, severity and/or duration, these have not been observed for the Kootenay or Elk Rivers (Figures 17 and 18; 28). Across the Continental Divide, peak flows along some rivers have actually been declining, in association with a decline in annual flows and earlier snow melt that reduces the snow pack and watershed saturation when heavy rains typically occur in late spring (28).

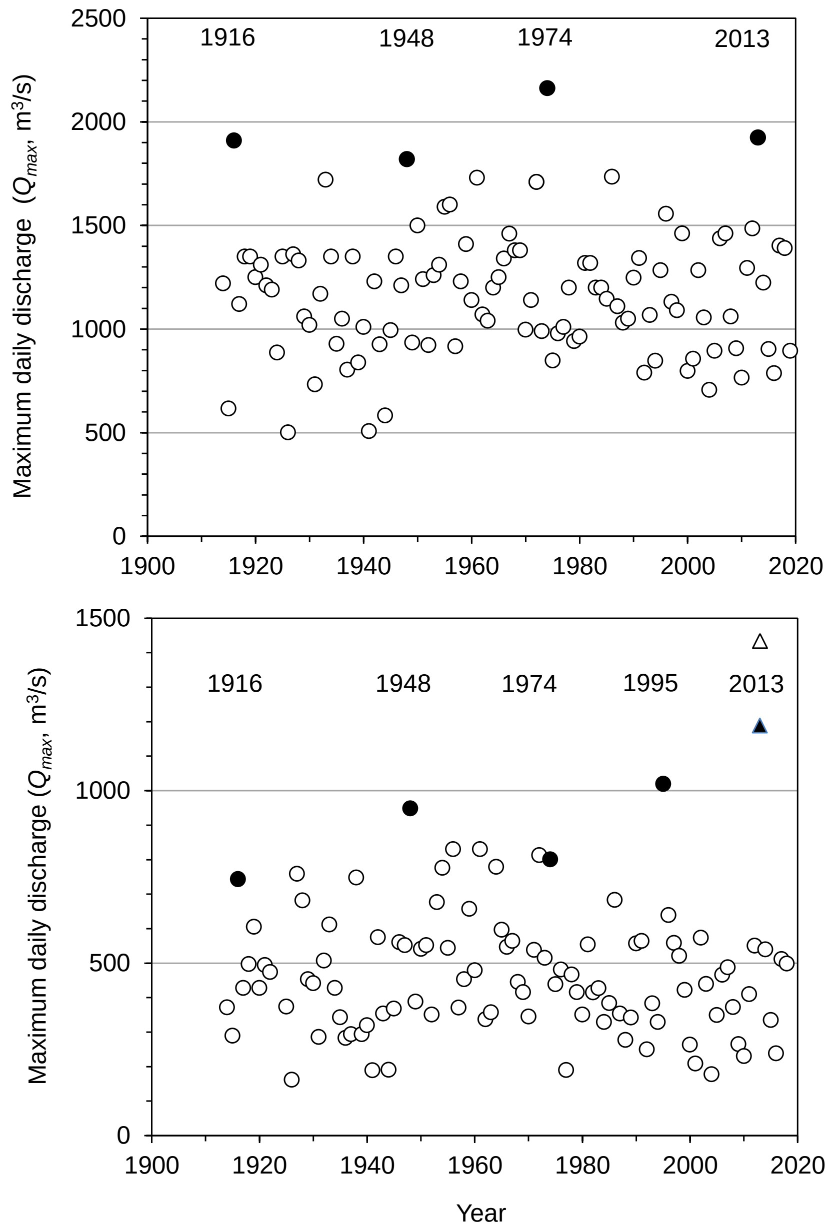
The 2013 flood in the upper Kootenay River basin was exceptional and it would be instructive to further analyze that year relative to flow forecasts and dam operation. Lake Koocanusa reservoir levels were favorable for recreation in 2013 (Figure 16) but woody debris was extensive (26).

Figure 18. Annual peak flows of the Kootenay (top, Wardner) and Elk Rivers (bottom, Phillips Bridge).

Adjusted values from sequential WSC hydrometric gauges were derived by regression, with two estimates for the 2013 Elk River flood.

There was no apparent trend over the past century (e.g. Kootenay: Q_{max} vs. Year: r = 0.017, not significant).

And there was slight correlation between the peak flow magnitude and timing (Kootenay: Q_{max} vs. DoY: r = 0.148, not significant; and a weak positive correlation for the Elk, 28).



13. Flow Forecasting

Accurate river flow forecasting is essential for informed dam operations. However, forecasting for the Lake Koocanusa reservoir and Libby Dam is hindered by sparse snow pack monitoring within the Canadian portion of the upper Kootenay River Basin (Figure 19, following). Only two snow pillow sites exist in BC but there are seven complementary snow pillows along the Continental Divide in Alberta. Southern Alberta provides the Canadian national focus for irrigation agriculture and snow pack monitoring is essential for water supply projections, which prompted those installations.

Current flow forecasting for Lake Koocanusa and Libby Dam incorporates three of the Alberta snow pillows (Table 2, following). It also includes two BC snow pillow sites but Moyie Mountain relates to the Moyie River that flows into the Kootenai River downstream of Libby Dam, and is less directly related to Lake Koocanusa reservoir. The other assessed BC snow pillow is East Creek, which contributes to the Duncan River that provide the northern tributary into Kootenay Lake. Inclusion of the BC snow pillows within the upper Kootenay watershed, Morrisey Ridge (Figure 19) and Floe Lake, might improve the accuracy and confidence of inflow forecasting for Lake Koocanusa reservoir. Additionally, the Upper Gray Ck. snow pillow could provide information relative to the upper Kootenay River tributary, the St. Mary River.

As an example, the weather tracking for the February 2021 forecast is provided in Table 2. Precipitation or snow pack assessments are reported, with regressions to estimate water contributions. At that time, these measurements derived an aggregate estimate of 102% of normal runoff from April or May through July. Conversely, the Morrisey Ridge snow pack was substantially lower, at 72%, although the Floe Lake snow pack was above average. Morrisey Ridge is situated in a high snow pack zone, with proportionally increased water contribution to Lake Koocanusa. Additionally, the Elk River is flashier than the Kootenay River, and this relates to flood risk. Along with the inclusion of additional snow pillow measures, there could be refinements to model weightings to reflect the spatial variation in runoff patterns.

Additional monitoring resources might include winter river discharges and snow data from the regional ski hills at Fernie and especially Kimberley for the St. Mary River watershed. Snow records are maintained and if the locations are constant these should reveal interannual patterns. Supporting validity, the annual maximum snow depth at Fernie Alpine Resort is strongly correlated with the maximum snow water equivalent at the Morrisey Ridge snow pillow across the Elk River valley (S.Rood, unpublished).

Emerging approaches consider snow depths for whole watersheds following repetitive LiDAR imaging. For example, a project in the adjacent West Castle River watershed across the Continental Divide may contribute to calibrated models that incorporate elevation, slope, aspect and forest cover (25). The subsequent model could enable spatial and temporal projections based on initial watershed mapping and calibration, and subsequent weather and snow site monitoring.

Figure 19. A map of the upper Kootenay River watershed in BC (brown) that contributes runoff to the Lake Koocanusa reservoir and downstream. Snow survey stations are indicated with snowflakes, and snow pillow sites along the Continental Divide in Alberta are indicated with '*'. Red indicates inclusion in current flow forecasting, and purple indicates additional sources that could strengthen forecasts. For this map, annotations are added to the BC Gov't map: https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=c15768bf73494f5da04b1aac6793bd2e

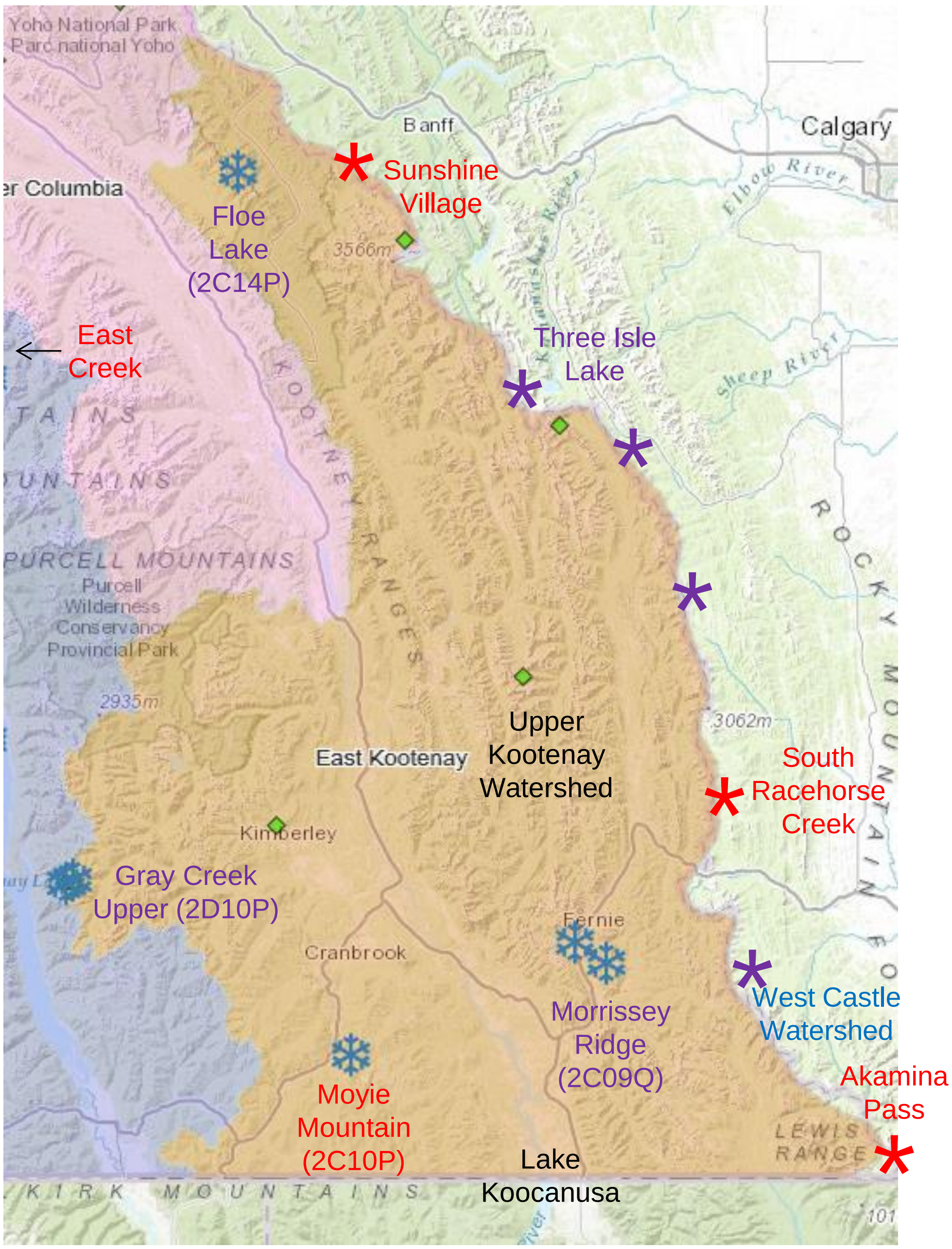


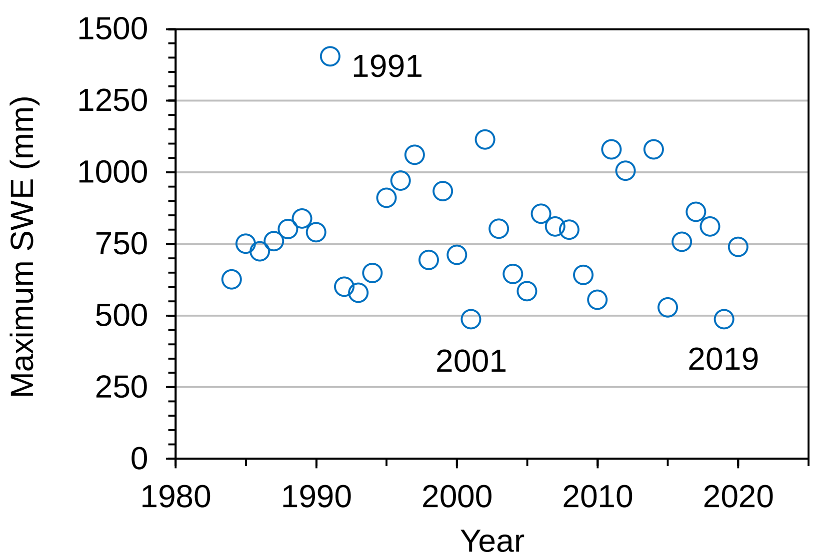
Table 2. Data sources and analyses for the February, 2021 runoff forecast and flood risk management calculation for Libby Dam, as undertaken by the U.S. Army Corps of Engineers, Seattle District. ('LIB_WSF_WY2021_FEB_updated.pdf').

Variable	Month(s)	Units	Observed Value A	Percent of Average	Regression Coefficient	Marginal Runoff (kaf) =A*B
SOI	∑Jun:Jul					
Eureka RS, MT	∑Oct:Jan Prcp	inches	4.04	94%	78.5	317.0
West Glacier, MT	∑Oct:Jan Prcp	inches	14.10	115%	31.0	436.4
Cranbrook A, BC	∑Oct:Jan Prcp	millimeters	110.00	95%	2.8	312.4
Fernie, BC	∑Oct:Jan Prcp	millimeters	493.21	100%	0.7	355.1
Hawkins Lake, MT	1-Feb SWE	inches	15.60	95%	30.6	477.4
Stahl Peak, MT	1-Feb SWE	inches	20.90	89%	23.0	480.5
East Creek, BC	1-Feb SWE	millimeters	715.00	117%	0.8	536.3
Moyie Mountain, BC	1-Feb SWE	millimeters	235.00	82%	1.5	347.8
Sunshine Village, AB	1-Feb SWE	millimeters	422.41	109%	1.5	620.9
Akamina Pass, AB	1-Feb SWE	millimeters	316.27	99%	1.3	401.7
South Racehorse Creek, AB	1-Feb SWE	millimeters	262.99	94%	1.5	402.4
Intercept			1.00		1291.5	1291.5
February Forecast	April - August	kaf				5979.3

Each year provides another informative data extension that could improve modeling and forecasting. Flood years such as 1995 and 2013 (Figure 18) contribute to flood risk analyses while dry years such as 2001 and 2019 (Figure 20) are especially instructive relative for the objective of sufficient reservoir filling for early summer recreation. These suggest opportunities to refine flow forecasting and subsequent reservoir regulation for sufficient refilling for recreation in low snow and flow years, when the flood risk is lower.

Figure 20. The Morrisey Ridge snow pillow data display substantial interannual variation, and forewarned the low flow years of 2001 and 2019.

No temporal trend is revealed but the measurement interval is only four decades (SWE = snow water equivalent).



14. Downstream and Environmental Consequences

Impact assessments for possible refinement to reservoir regulation must consider the environmental consequences. This would consider the reservoir and the downstream Kootenai River in Montana and Idaho, and then back to British Columbia and into Kootenay Lake.

Within this downstream system, the Kootenai River White Sturgeon was listed as an endangered species in the USA (29). This prompted changes in flow regulation from Libby Dam, including higher flow pulses in late spring to promote sturgeon spawning. While the responses of the long-lived sturgeon are emerging, there were rapid benefits for the broader riverine ecosystem, including unanticipated seedling recruitment of riparian cottonwoods (30). Further changes in the environmental flow regime included ramping, gradual flow recession after the sturgeon pulse. This ecological flow pattern provides a very promising precedent for the ecosystem function objective for the broader Columbia River Treaty system.

The environmental flows for sturgeon spawning and ecosystem replenishment may focus on high flow years. These might consequently be less limiting in low flow years that could provide the focus for revised reservoir regulation for recreation.

A slight advancement in reservoir filling would probably have slight consequences for vegetation development in the foreshore or draw down zones around the reservoir. Alternate changes in reservoir regulation for ecosystem function might focus on the delta zones where the rivers and creeks flow into Lake Koocanusa.

The Elk River outflow delta supports an extensive riparian wet meadow complex with sedges and other plants (Figure 21). The consequences of reservoir regulation on this system and the delta zones from Sand, Kikomun and Gold creeks (Figure 9) could be explored. There could also be assessments relative to the American tributaries including the Tobacco River and Big Creek (Figure 9).

Figure 21. The cleared Elk River delta into Lake Koocanusa reservoir (Aug. 15, 2020; 2449’).

Another environmental consideration relates to Lake Koocanusa reservoir regulation and recreation. The annual draw down excludes littoral vegetation, the plants that occupy the fringes around the shoreline. It also discourages aquatic plants that are common in shallow zones of some regional lakes including Columbia Lake and Lake Windermere (31). Those aquatic plants provide important contributions to the aquatic ecosystem but are often disfavored for boating.

15. An International Waterway

Four dams and reservoirs were developed following the Columbia River Treaty (CRT). Three reservoirs elevated natural lakes but there was no prior lake that was flooded with the Lake Koocanusa reservoir behind Libby Dam. While initially intended as a storage reservoir with the two primary objectives of flood control and hydroelectric power generation, this reservoir has become a very popular water body for summer recreation. The recreational use and developments have progressively expanded and Lake Koocanusa reservoir now contributes a major and increasing social, economic and environmental asset. While Lake Koocanusa is an artificial reservoir that submerged a rich river valley, it should be recognized as a highly valued recreational resource that followed from the CRT.

There have been repetitive concerns for insufficient levels of Lake Koocanusa reservoir in early summer. As a possible operational adjustment, slight advancement in reservoir filling in low flow years could enhance conditions for recreation in Montana as well as British Columbia; this would provide shared international benefits.

This principle of international cooperation for shared benefit could be extended. There are reciprocal mechanisms to permit recreational boaters to cross between Canada and the USA (32), such as on the Great Lakes. There are registration and reporting requirements and the nearby Roosville border crossing may simplify aspects such as interviews and pre-registration. Repetitive crossing may be simplified with on-line or phone reporting (32).

Permitted border crossing would about double the extent of reservoir navigation and further invite multiple day boat trips. International touring might include houseboats, sailboats, cruisers, touring kayaks or other craft. Even for day trips, Newgate, BC is near Rexford, MT, and these and the other locations provide different features and a broader range of amenities. Most recreational boating on Lake Koocanusa reservoir will probably continue to involve a group of family and friends for a warm afternoon but an international waterway would expand the range of opportunities.

For afternoon outings or for longer trips, a slight advancement of suitable conditions to mid-June in would be beneficial. This could involve woody debris management and in low flow years, slight changes in reservoir regulation could be considered. Both of these would enhance the recreational opportunities and the corresponding social and economic values of the Lake Koocanusa reservoir.

Acknowledgements

Dianne Fitzgerald (Chinook Environmental Resources) assisted with the field assessments. Our analyses of environmental impacts from Libby Dam have extended for two decades (30), especially with Mary Louise Polzin (Fig. 9; VAST Resource Solutions, Cranbrook; and a resident near Lake Koocanusa reservoir). Greg Hoffman (U.S. Army Corps of Engineers, Libby Dam) provided valuable feed-back, along with Bill Green (Kimberley, engaged in the CRT renegotiation). There were very helpful communications with other regional residents, Ken Bettin, Bob Cutts, Steve Kuijt and Mario Scodellaro. These seven individuals generously provided feedback, but not endorsement and their views varied considerably. The interpretations in this report are solely the author’s responsibility.

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Biosketch
Stewart Rood is a Professor of Environmental Science at the University of Lethbridge (AB) and has instructed courses including *River Science* and *Environmental Impact Assessment*. He was involved in the implementation of three river dams in Alberta (Oldman, Pine Coulee, Twin Valley) and contributed to the operational regimes of other dams in Alberta and Nevada and to the FERC relicensing of hydropower dams in Idaho and Washington. He has studied environmental flow regimes in BC (Bridge and Duncan Rivers) and has contributed ~200 journal papers, book chapters, conference proceedings and technical reports.
https://scholar.google.com/citations?user=lEVbfWcAAAAJ&hl=en&oi=ao

Disclosure/Conflict of Interest
Lake Koocanusa reservoir is the primary location for recreation by the author's family and friends on his motor boat (Figure 22).

Figure 22. Family recreation on Lake Koocanusa reservoir (Sept. 2, 2012; 2452').

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