DECEMBER 2022

PERFORMANCE MEASURE INFORMATION SHEET

KOOTENAY LAKE: FLOODING

SUMMARY

Goal: Minimize flooding of property and infrastructure.

Recommended Performance Measure:

Objective/ Location	Performance Measure	Details	Description
Initial flooding/ Kootenay Lake	Flooding of low-lying areas	Median number of days per year when Kootenay Lake water levels ≥ 1750ft to <1752ft (534 m). Less is better.	Duration of flooding in low lying areas.
Structure damage and transportation limits/Kootenay Lake	Structure damage and transportation limits	Expected annual damage (in $) when water levels ≥ 1752ft (534m). Less is better.	Impact of flooding based on elevation and frequency resulting in structure damage and impacts on ferry operations.

Further consideration of the best statistics (e.g. median, mean and what years to include) is ongoing and may result in some revision to the first measure.

Sub-measures of the number of days and number of years that flooding is estimated to occur, by one foot elevation increments, will inform detailed scenario evaluation.

Introduction

Flooding of property and public infrastructure is a major concern around Kootenay Lake. Frequency of flooding events is a function of property elevation and location within the reservoir flood plain and, specifically, inflow rate because the ability to evacuate water is restricted by the downstream hydraulic constriction at Grohman Narrows. When inflow rate exceeds the ability for water to pass Grohman Narrows, regardless of whether Corra Linn (and Kootenay Canal) discharge is maximized, Kootenay Lake levels rise.

Inflows to Kootenay Lake are both regulated and unregulated (i.e., natural). Regulated inflows come from Duncan Dam (~16% of total annual inflows) and Libby Dam (~44% of total annual inflows). Unregulated, natural inflows originate from the Lardeau River (~10% of total annual inflows), which flows into the Duncan River below the Duncan Dam, and local inflow below Libby Dam and along Kootenay Lake (~30% of total annual inflows).

Kootenay Lake levels are regulated by the 1938 International Joint Commission (IJC) Kootenay Lake Order. Fortis BC holds one half of the water licence for Kootenay Lake, with the other half held by Brilliant Power Corporation (a Columbia Power Corporation/Columbia Basin Trust joint venture that owns the Brilliant Dam, located near the confluence of the Kootenay River and the Columbia River near Castlegar). These licenses do not specify lake elevations as operations must be subject to the IJC Order.

The Columbia River Treaty requires that the operation of Libby Dam be consistent with the Kootenay Lake IJC Order. Prior to 2007, it was normal practice for BC Hydro to reduce discharges from Duncan Dam and the US Army Corps of Engineers to do the same from Libby Dam in March-April, if needed, to allow Kootenay Lake to draft below its IJC Order level of 1739.32ft (530.15m). However, in some years, this practice 'trapped water' in the upstream reservoirs which then reduced their ability to provide flood risk management for Kootenay Lake during the spring freshet.

The current agreed-to operation allows BC Hydro and the US Army Corps of Engineers to draft the upstream reservoirs as needed for flood control and other purposes and this operation has been shown to reduce flood peaks for Kootenay Lake.

However, the current Libby dam operations include legally required surges during the freshet to support downstream sturgeon and bull trout in the Kootenay River within the U.S. and Canada. These surges can increase Kootenay Lake levels when Grohman Narrows is limiting the rate of outflow, thus raising Kootenay Lake levels.

BC Hydro has identified the following historical elevations when flooding has occurred:

- in 1961, the pre-regulation peak level of Kootenay Lake is estimated to have been at 1761.95ft (537m);
- in 1974, a high inflow year, the level of Kootenay Lake peaked at 1754.24ft (534.7m); and
- in June 2012, the most recent high inflow year, the lake level reached 1753.8ft (534.6m).

Since the construction of the Duncan Dam in 1967 and the Libby Dam in 1975, the lake elevations have stabilized somewhat, with less frequent inundation of higher elevation areas. This has resulted in vegetation growth and other conditions that have allowed the Surveyor General of BC to approve 'accretions' or additions to private property around the lake. This has often been accompanied by applications for developments on these areas.

From the early 1980s to 1993, flood construction levels and setbacks from the natural water line of water bodies were provided as provincial guidelines. The first RDCK floodplain bylaw was adopted in 1993 with specified flood construction levels and setback requirements. In 2003 and 2004, provincial legislative changes granted local governments the authority to manage land use in flood hazard areas. The most recent RDCK floodplain management bylaw (2009) sets minimum elevations and setbacks for floodproofing and identifies alluvial fan hazard areas. This bylaw applies to all persons who apply for a building permit to construct on lands designated as 'floodplain' by the RDCK and all buildings within 49.2ft (15m) of the 'present natural boundary' of waterways. The floodplain bylaw and maps are incorporated into building bylaws, subdivision approvals by the Ministry of Transportation and Infrastructure, official community plans and zoning bylaws. Specific requirements for Kootenay Lake include:

- floodplain setback of 49.2ft (15m), measured from the present natural (lake) boundary, including any accretions; and
- flood construction level of 1760ft/ 536.6m (at Queens Bay) which was determined by the province as 10ft/ 3m above the level the lake is expected to rise to in the event of a flood equal to the 1894 flood plus a freeboard. The freeboard allowance of 2.5ft/ 0.76m is to account for, among other things, wave action and wind setup. This level includes consideration of the storage effect of the Duncan and Libby dams. Habitable space cannot be constructed below this elevation.

Some inhabitable structures are exempt from the floodplain bylaw requirements.

The approval of accretions by the BC Surveyor General, which moves the present natural boundary into the floodplain and variances based on hardship by the Regional District has resulted in more lakeside developments with flooding risks.

Past Performance Measures

In *A Stakeholders Summary of Preferred and Potential Negative Reservoir Levels and River Stages on the Kootenay River System in Canada* (CBT 2004), the following flooding concerns were identified (Table 1):

Table 1 Flooding concerns according to CBT report A Stakeholders Summary of Preferred and Potential Negative Reservoir Levels and River Stages on the Kootenay River System in Canada

Elevation	Description
1754ft (534.6m)	Detrimental flooding as identified by participants.
1750ft (533.5m)	The beginning of flood effects as identified by BC Hydro.
1749.26ft (533.17m)	15 homes and one water supply pumping station along the West Arm flooded according a 1996 survey as shared by the Ministry of Water, Land and Air Protection, Dike Inspection Office and Flood Hazard Management Section. It was estimated that an additional rise of 2ft would flood another 20 to 30 homes.

In the CRT Review Technical Studies (2013) BC Hydro created performance measures (PMs) for Kootenay Lake. The process of creating these PMs is described in Appendix H of the Technical Studies Report and Appendix G contains the PMs that were used in these studies. Two flooding-related performance measures were defined (Table 2). The location of the elevation measurement is not included; however BC Hydro has confirmed that Queen's Bay is used operationally for these measurements.

Table 2 Performance measures used in the CRT Review Technical Studies (2013)

Objective/ Location	Performance Measure	Units	Description
Flooding/ Kootenay Lake	% of years above 1752ft	% of Years	Percent of years with at least one day at or above 1752ft (533.7m). Lower is better
Flooding/ Kootenay Lake	% of years above 1760ft	% of Years	Percent of years with at least one day at or above 1760ft (536.4m). Lower is better.

New Information

In 2020 the Regional District of Central Kootenay commissioned a *Kootenay Lake Flood Impact Analysis* by BGC Engineering. The purpose of the analysis was to broaden the understanding of potential Kootenay Lake geohazard impacts to support decisions that prevent or reduce economic loss from elevated lake levels.

The analysis estimated flood-related economic losses to property development fringing Kootenay Lake, across a range of potential lake elevations from 1752ft (534m) to 1760ft (536.5m) (measured at the Queen's Bay gauge). Economic losses resulting from flooding of transport and utility infrastructure were not considered. Damages from other reservoir flood geohazards such as storm surge, wind- and boat-generated waves, and landslide-generated waves were also not considered.

Potential economic losses per vertical-meter of lake rise are recorded at 1752ft (534m), the lowest elevation that was evaluated, and increase markedly above 1755.25ft (534.9m). This evaluation does not account for wave action, or flooding impacts on transportation and utility infrastructure, although it is noted that at 1752ft (534m), the Harrop cable ferry approach ramp and the Canadian Pacific Rail Line, between 5 Mile Point and 7 Mile Point along the West Arm, and at the south end of the lake near the Kootenay River Bridge are at risk. The Ministry of Transportation and Infrastructure has confirmed that the elevation limit for the Harrop ferry ramp is 1752ft (534m), and that the upper elevation operational limit for the Balfour-Crawford Bay ferry is 1752ft (534m). RDCK staff have also noted that this analysis does not account for the cumulative flooding impacts of high lake levels and high stream flows in tributaries during the freshet.

During the Columbia River Treaty Local Governments Committee (LGC) and Columbia Basin Regional Advisory Committee (CBRAC) review of the initial performance measures it was stated that lake levels above 1760ft (536.5m) would be “disastrous with extreme financial and safety consequences”.

The following details the LGC and CBRAC feedback on the draft recommendation for the addition of one performance measure for initial flooding at either 1749ft (533m) or 1750.3ft (533.5m), with the team’s research findings where this was requested:

- “Check out the Kootenay Lake Partnership survey of what 1752ft looks like along the shoreline and down the west arm which shows that 1752ft (534m) looked like a good threshold of risk for operations, which is similar to the outcomes for an earlier boat survey by the province.”
    - The survey presentation was reviewed by the team, with findings confirmed regarding structural damage.

- “Contact IHA [Interior Health Association] and RDCK re: flooding impacts on septic fields and consider having a separate PM.”
    - The team contacted the RDCK and IHA who indicated that they have not had any concerns raised regarding flooding impacts on septic fields.

- “The number of days the lake levels cause flooding is important.”
    - The team is recommending that sub-measure document this by compiling the number of days and number of years that lake levels exceed one foot increments in elevation above the low lying area flooding threshold.

- “Significant waves during major storms can increase damage from high lake levels.”
    - The team considered this to recommend the initial flooding level of 1750ft (533.5m).

- “The Surveyor General of BC’s approval of accretions makes it difficult for local governments to effectively regulate against developments that create flood risks.”
    - The team has added a section in the introduction explaining accretions and local government tools.

- Several members supported setting the flood risk level at 1752ft (534m), noting that lake levels often exceed 1750ft (533.5m). The team considered this and given there are ‘initial flooding’ PMs for the Lower Duncan River and Lower Columbia which document

the level at which low-lying areas are flooded, and there is evidence of flooding at 1749.26ft (533.17m) in the 2004 report described above, and flooding of low-lying areas in 2022 (described below), the team recommends establishing PMs for **low-lying area flooding** level at 1750ft (533.5m) and **structure damage and transportation limit** level at 1752ft (534m).

- "Contact Ministry of Transportation and Infrastructure (MOTI) re: setbacks for subdivisions."
    - The Team contacted the Ministry and confirmed that they currently follow the RDCK setbacks and had no comments on flooding impacts.

The current (May 2022) Flood Risk Management (FRM) performance measure provided by BC Hydro for the Columbia River Treaty Planning Model (CRTPM) tracks the number of days (rather than the % of years as in the CRT Review Technical Studies PMs) that lake elevations (measured at Queens Bay gauge) are:

- equal to or above 1752ft (534m)
- equal to or above 1755ft (m) – onset of flood damage
- equal to or above 1760ft (m) – RDCK Flood Construction level

In early June 2022, Kootenay Lake levels at the Queens Bay gauge were above 1750ft (533.5m) for 17 days, reaching a maximum of 1751.6ft (533.9m) for four days. The RDCK Emergency Program Coordinator noted "There were a few close calls reported as the water was getting closer to structures, but the water receded and did not reach homes." The team confirmed that this indicates that low-lying areas are flooded below the maximum elevation of 1751.6ft (533.9m) that was reached.

Recommended Performance Measure

The team makes the following recommendations, shown in the table below:

1. Change the measure from % of years used in the CRT Review Technical Studies to units that are more sensitive measures of flood risk.

2. Define thresholds for flooding of low-lying areas at 1750ft (533.5m) and for structure damage and transportation limits at 1752ft (534m), measured at the Queens Bay gauge.

3. For flooding of low lying areas, the PM should be the median number of days per year across all years in the scenario.

4. For structure damage and impacts on ferry operations, the PM should be the estimated annual damage across all years in the scenario, based on the damage estimates by elevation provided in the 2020 *Kootenay Lake Flood Impact Analysis* as revised in Nov 2022.

5. Do not use the performance measure at 1755ft (535m) as this is above the onset of flood damage documented in the 2020 *Kootenay Lake Flood Impact Analysis.*

6. Do not use the performance measure at 1760ft (536.4m) from the CRT Review Technical Studies as this elevation is well beyond the level when flooding impacts become detrimental. This measure is based on the RDCK Flood Construction Level

which is the elevation below which habitable areas cannot be constructed, however other above-ground structures are permitted provided they meet other flood related bylaw allowances.

Objective/ Location	Performance Measure	Details	Description
Initial flooding/ Kootenay Lake	Flooding of low lying areas	Median number of days per year when Kootenay Lake water levels ≥ 1750ft (533.3m) to <1752ft (534m). Less is better.	Duration of flooding in low lying areas
Structure damage and transportation limits/Kootenay Lake	Structure damage and transportation limits	Expected annual damage (in $) when water levels are ≥ 1752ft (534m) Less is better.	Impact of flooding based on elevation and frequency resulting in structure damage and impacts on ferry operations

The 2020 *Kootenay Lake Flood Impact Analysis* provides estimated economic losses due to property damage based on the flooding elevation, as shown in Figure 1. *Please note that a revised version of this report, submitted by BGC in November 2022, is currently being reviewed by the RDCK board. Approval of the revised report is expected in early 2023. .*

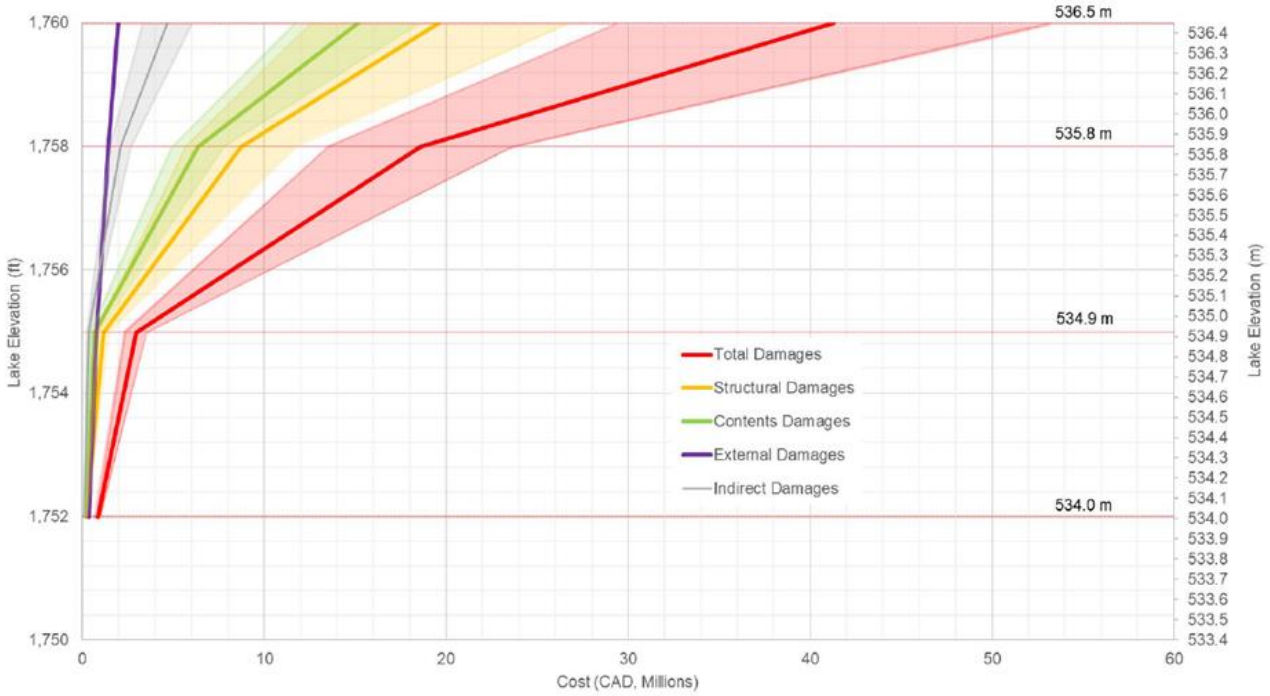

Figure 1. Elevation-damage relationships for economic losses to properties along Kootenay Lake.

The team also recommends that sub-measures be reported on the number of days and number of years that the that lake levels exceed one foot increments in elevation above the low lying area flooding threshold:

Elevation	Total no. of days elevation is reached	No. of years when elevation is reached
≥1755'		
1754-1755'		
1753-1754'		
1752-1753'		
1751'-1752'		
1750'-1751'		

The team recommends that during future high water events on Kootenay Lake, the RDCK document:

- lake levels at the Queens Bay gauge;
- wave action conditions;
- specific properties and infrastructure where flood risk concerns occur;
- what structures, activities and operations are at risk, ideally with photographs; and
- whether structures are consistent with development bylaws, or variances were approved that increase flooding risk.

This information will inform refinements to these performance measures over time.

If there is a desire to understand flooding impacts below the 1752ft (534m) level assessed in the 2020 *Kootenay Lake Flood Impact Analysis*, the team recommends that further analysis which is beyond the scope of this initiative include:

- expanding the 2020 Kootenay Lake Flood Impact Analysis to include 1749ft (533m) to 1752ft (534m) to capture the full range of elevations where flooding has been previously identified;
- as recommended in the BGC Engineering report, examine the impact of wave action on flood impacts;
- include transportation, utility and water infrastructure at all elevations;
- consider whether high freshet flows in tributaries can be factored into the analysis of flood impacts; and
- where possible, the analysis should account for developments that have occurred within areas of known flood risk.

Comparison of Proposed Performance Measure with Historical Operations

During 1995-2020, the low lying areas flooding threshold was exceeded in many years between mid-May and late July (Figure 2), during the annual freshet when there are high inflows from unregulated tributaries and Libby dam flows include pulses to support endangered species recovery in Kootenay River, and the rate of outflow from Kootenay Lake is limited by Grohman Narrows, located just downstream of Nelson. During this period the structure damage and transportation limits threshold was exceeded approximately one in ten years during the same freshet period.

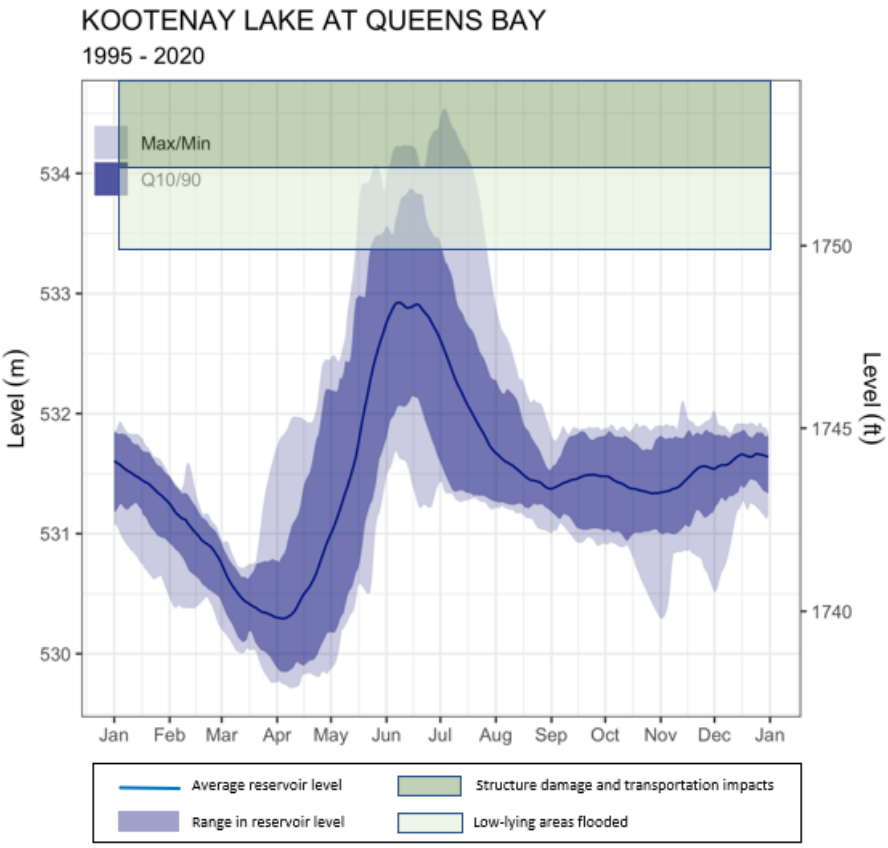

Figure 2. Comparison of proposed performance measures with historical operations.

Calculations

For each alternative:

1. Assemble the simulated results for reservoir elevations over the years.
2. For the low-lying area flooding PM – count the number of days within the defined elevations each year, then calculate the median number of days per year across all years in the scenario.
3. For the structural damage and transportation limits PM – for years when the elevation is equal to or above the threshold, look up the estimated damage from the 2020 study, then calculate the estimated average damage across all years in the scenario.
4. Prepare stacked bar graphs of the number of days above 1750ft, by one foot increments and the number of years each one foot increment is exceeded.

Key Assumptions and Uncertainties

Key assumptions include:

- The frequency of flooding is directionally similar across alternatives with other important flooding metrics such as maximum elevation, average and maximum flood durations etc.
- In each of the scenarios, modellers have applied the same flooding risk tolerance when

balancing other modelling objectives.

- The 2020 *Kootenay Lake Flood Impact Analysis* adequately reflects economic losses due to property damage along Kootenay Lake.

References

Columbia Basin Trust (2004) A Stakeholders Summary of Preferred and Potential Negative Reservoir Levels and River Stages on the Kootenay River System in Canada - Interest Group Response Summary to proposed VarQ Alternative Flood Control Operation. (*Link will be added to the CRT LGC website for public review)*

BGC Engineering (2020) Kootenay Lake Flood Impact Analysis. (*Link will be added once it's posted on the RDCK site)*

RDCK Floodplain Regulation presentation (2016). Columbia River Treaty Review Technical Conference. Note: updated links within the presentation:

Floodplain Bylaw:
https://www.rdck.ca/assets/Government/Bylaws/Land~Use-Planning/2080-Floodplain_Consolidated_2695.pdf

Floodplain Bylaw Mapping via Property Information Webmap:
https://www.rdck.ca/EN/main/services/mapping-gis.html

RDCK Brochure: Flooplains Alluvial Fans and Geotechnical Hazards
https://www.rdck.ca/assets/Services/Land~Use~and~Planning/Documents/2016-PLN-Floodplain-Brochure.pdf