Appendix F

Columbia Performance Measure Information Sheets

PM Info Sheet #	Location	Topic
50	Koocanusa Reservoir	Vegetation
51	Koocanusa Reservoir	Aquatic Ecosystem
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PERFORMANCE MEASURE INFORMATION SHEET #50
LAKE KOOCANUSA: RESERVOIR VEGETATION AND WILDLIFE

Objective / Location	Performance Measure	Units	Description	MSIC
Vegetation and Wildlife, Flooded Vegetation / Lake Koocanusa	Area flooded for more than 10 weeks	Hectares	Hectares of vegetation flooded for more than 10 weeks. Lower is better.	10%

Description

Lake Koocanusa has not been studied as extensively as others in the Kootenay and Columbia systems, and so data is relatively sparse. Pre-impoundment maps (Ketcheson 2005) show a floodplain vegetation community (cottonwood and wetland) extending well below the current full pool elevation. These areas now have compromised wildlife values because they are underwater for prolonged periods. When they are exposed, the substrate is mud and sand.

Reducing the period of inundation during the growing season at the Kootenay-Koocanusa confluence (near full pool) could potentially produce a similar community to that observed in the Revelstoke Reach of the upper Arrow Reservoir. Surveys of tributary confluences in the Koocanusa area (Sand Creek, Elk River, Gold Creek) would provide a better picture of what could be obtained. Therefore, strategies which do not fill Koocanusa to full pool, and limit flooding to 8-10 weeks at lower elevations during the growing season, have the potential to achieve the desired vegetation objective.

Calculations

- Digital Elevation Models were used to estimate the potentially vegetated area associated with each 25cm elevation band above 707m (2319.55’). **Note: At the time of this analysis, there was no DEM data over 744m (2440.94’). Contour areas for up to 750m (2460.60’) are being developed for the CRTR process and this document will be amended accordingly.** These results should therefore be considered preliminary only, though it is likely that although the absolute amount of flooded area may increase when these ranges are added, the relative changes between alternatives shown in this analysis will not change.
- For each day of the year between April 1 to October 15, the number of days each band was fully submerged under each alternative was calculated. The combined area flooded for a) more than 18 weeks, b) between 10 weeks and 18 weeks, and c) less than 10 weeks was calculated.
- Results were summarized for all years.

Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.

- Assumes frequency, duration and extent (timing, duration and depth) of inundation are the only drivers of vegetation survival/establishment.
- No assumptions are made about the relationships between elevation and vegetation types, nor species associated with these wildlife types.

Results

Full pool on the Koocanusa reservoir is considered to be 2459'. In terms of hydrology for the median results, Alternative 1 does not reach full pool as a result of the current Libby dam operations (Figure 1). Alternatives 2, 3a, and 3b reach full pool at similar times and are discussed further below.

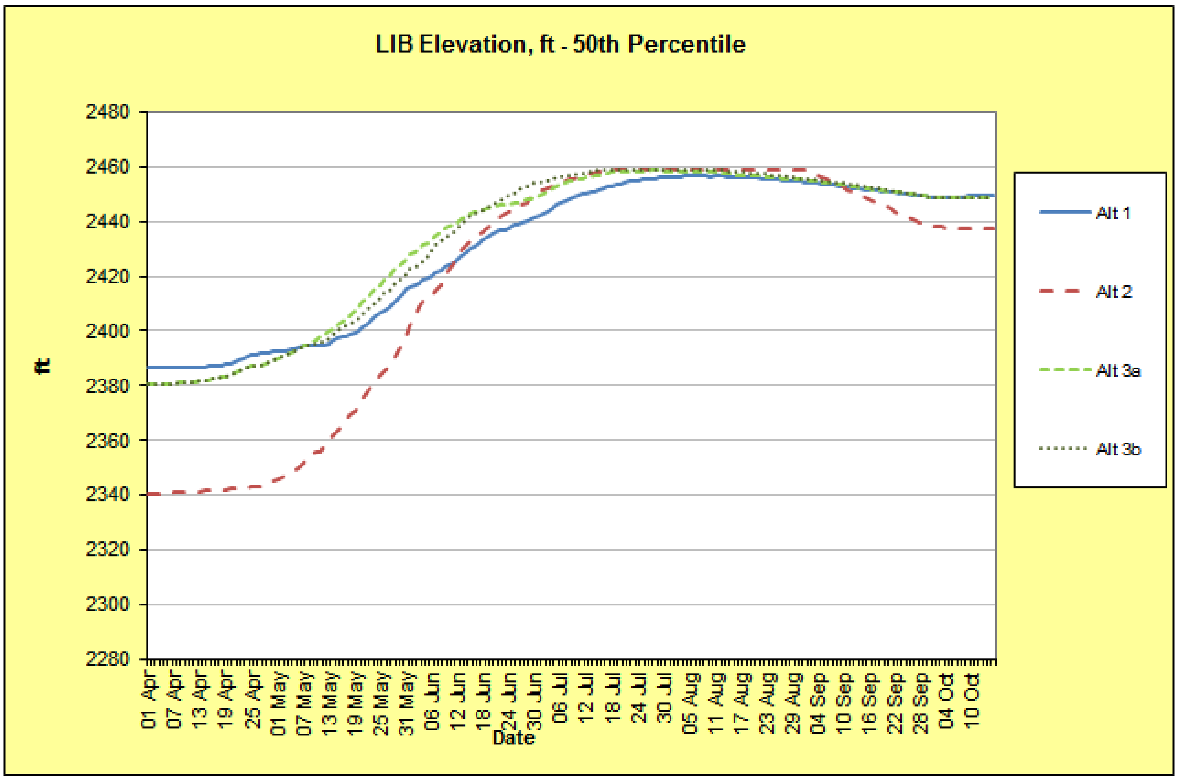


Figure 1. Lake Koocanusa, elevation levels from April 1 to October 15 using median daily values.

Figure 2 shows the flooded hectares of potentially vegetated areas by duration category for Koocanusa reservoir.

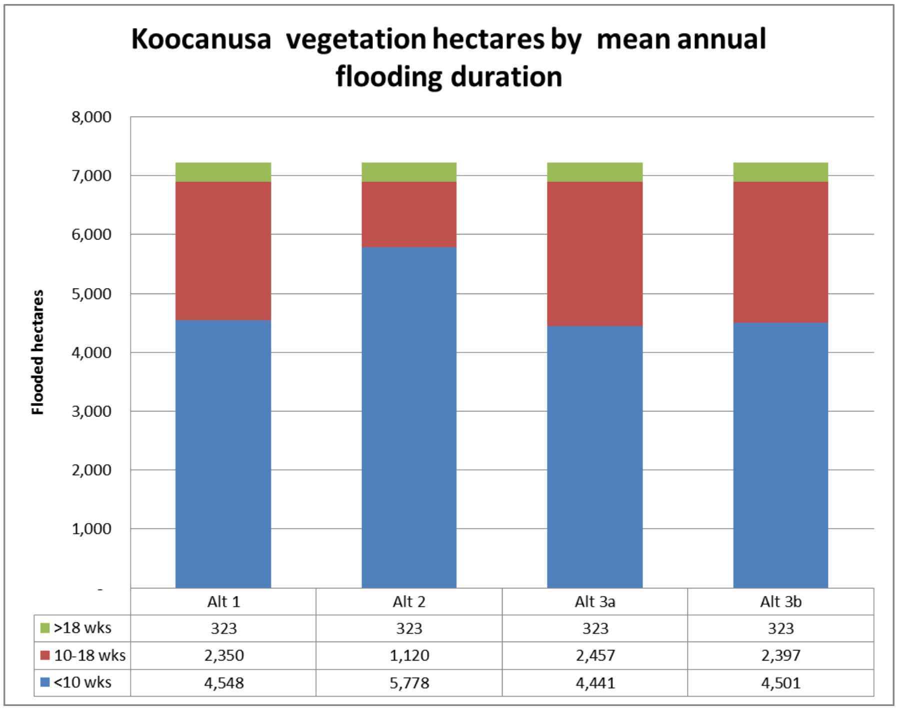


Figure 2. Koocanusa Reservoir flooded hectares by flooding duration

The alternatives do not differ in terms of the area inundated for more than 18 weeks, but Alternative 2 has a lower area flooded for between 10 and 18 weeks.

For the consequence table, the area in each of these two categories were added to create the numbers shown in

Table 1: Mean annual hectares flooded for more than 10 weeks on Koocanusa reservoir (1 April to 15 October)

Alt 1	Alt 2	Alt 3a	Alt 3b
2,673	1,443	2,780	2,720

PERFORMANCE MEASURE INFORMATION SHEET #51
LAKE KOOCANUSA: FISH AND AQUATIC ECOSYSTEM HEALTH

Objective / Location	Performance Measure	Units	Description	MSIC
Ecosystem Productivity Koocanusa	Primary Production	Tons	Primary Production generated by a model using seasonal changes in reservoir area and Libby Dam discharge. Higher is better.	10%

Description

Two of the most important factors limiting lake productivity are flushing rate and nutrient supply. Storage reservoirs such as Koocanusa have high drawdown as well as high flushing rates. These two factors limit the generation and retention primary production by two main mechanisms: entrainment of algal and zooplankton biomass in the outlet flow, and large reductions in the area available for photosynthesis as the reservoir is drawn down. Koocanusa Reservoir has both large drawdowns and high flushing rates. Reservoir area varies from a minimum of 61 km^2 to a maximum of 188 km^2. Theoretical residence times for mean annual discharge range from a minimum of 0.15 yr at low pool to 0.76 yr at maximum pool.

The interplay between the seasonal discharge and drawdown cycle and seasonal variation in primary production is an important factor in determining the amount of primary production that is generated and retained in the reservoir. Algal biomass and production per unit area are typically low in the winter, peak in the spring with a secondary peak in late summer. The impact of small areas and high flushing rates is highest in the spring and summer, when primary production, algal biomass and zooplankton standing crops are all at seasonal maximums. The calculation of this performance measure is driven by daily inflow, outflow and reservoir area data from Koocanusa Reservoir combined with seasonal variation in phytoplankton production represented by 1977 estimates from Kootenay Lake.

The performance measure is a relative measure of the impacts of changes in reservoir size and residence times on the production and retention of carbon in the reservoir. The change in algal biomass at each time step involves the addition of new production and the loss of biomass in discharge water. New production is proportional to the current reservoir area and the current seasonal production per unit area. The loss of biomass is proportional to amount of water discharged and the biomass per unit volume of discharge. The model provides a relative measure across moderate operational scenarios because it fails at both extreme operational scenarios. For very high residence times, primary production accumulates without being depleted by zooplankton or seasonal die offs, which results in unrealistically high algal biomass concentrations. At very low residence times, primary production continues at the same rate, which results in unrealistic production:biomass ratios because dilution reduces algal biomass concentration to very low levels. However, at the intermediate residence times, such as those in Koocanusa reservoir, this model provides a simple method of linking changes in operational regimes to changes in ecosystem productivity.

Performance Measures

The performance measure the biomass of algae measured in metric tons of carbon, which is an indicator of the amount of carbon available to higher trophic levels at a given point in time.

Calculations

For each day, the amount of primary production in the reservoir is calculated from the seasonal variation in primary productivity per unit area, and the area of the reservoir. The loss of algal biomass is calculated using algal concentration in the top 20 m of the water column (gC/m3) and the proportion of the entrained water volume that contains algae. The proportion containing algae is calculated by assuming that half of the discharge originates from deep water below the intake level and therefore contains no algae (because the intake depth is rarely less than 20m).

For each Day:
Algal Biomass Exported = 0.5 *Daily Discharge * Algal Concentration*20/Intake Depth
Algal Biomass = Previous Biomass - Algal Biomass Exported + Reservoir Area * Production/m2

For each scenario:

1. Assemble the data for daily inflows of water over 50 years (1948-1997).
2. Apply the flow and elevation management rules for the scenario to give daily reservoir areas, elevation and discharge.
3. Compute the average algal biomass over the year.
4. Summarize all statistics.

Key Assumptions and Uncertainties

1. Primary production is a simple function of reservoir area.
2. The pattern of primary productivity is similar to that measured in Kootenay Lake by Jasper et al. 1983. Seasonal variation in light, nutrient availability and cropping by zooplankton are incorporated into this seasonal pattern.
3. Algal concentration in water flowing into the reservoir is zero.
4. Algal concentration is uniform across the entire reservoir.
5. Algal concentration in water flowing out of the reservoir depends the depth of water withdrawal relative to the depth of algal biomass in the reservoir.
6. All algal biomass is uniformly distributed at depths of 0-20 m.
7. Thermal stratification occurs at a depth of 20 m, starting May 15 and ending Oct 15.
8. Water withdrawal volumes from above and below the intake centerline are equal. The proportion of algal biomass that lies in upper the 50% of water is fully entrained.
9. From May1 to Aug 31, the selective withdrawal intake centerline is assumed to be 60 ft below reservoir elevation. From Sept 1 to Nov 30, intake depth is 110 ft below reservoir elevation. From Dec 1 to Apr 30, the selective withdrawal intake is not in use; the penstock intake centerline is at 2247 ft elevation.
10. Dilution of reservoir water by Inflow water occurs daily and uniformly across all depths.

Results

In terms of hydrology in the median year, Alternatives 1, 3a and 3b overlap broadly in elevation, which results in similar algal biomass across most of the growing season. Alternative 2 has much lower elevations during the peak algal production period in the spring and this results in a consistently lower algal biomass through much of the summer under Alternative 2 (Figure 1.).

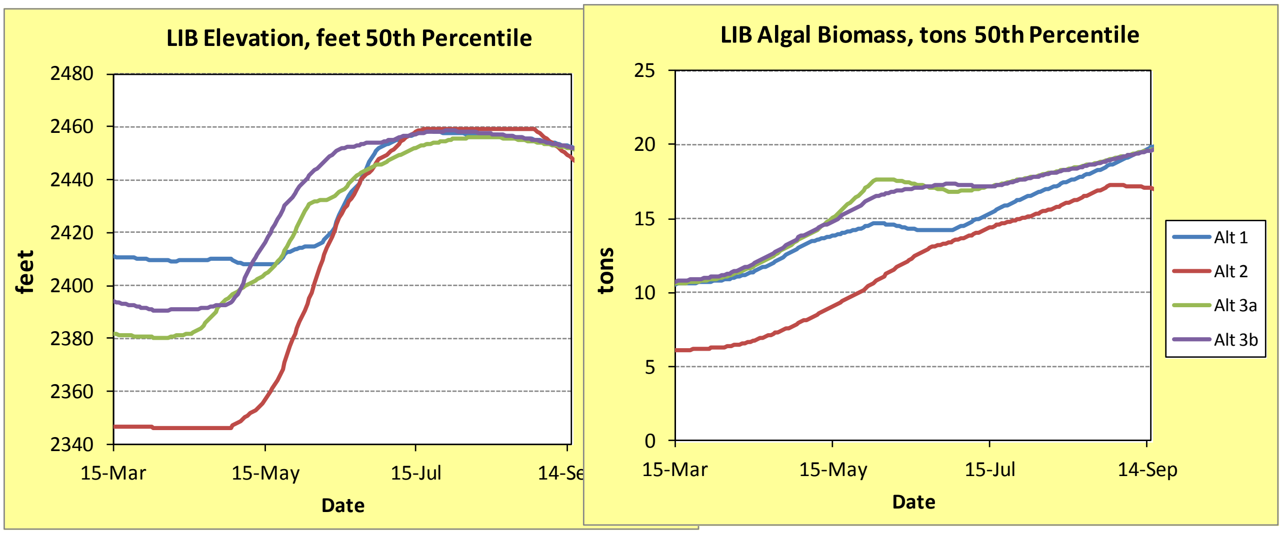


Figure 1. Koocanusa Reservoir elevation and algal biomass across the algal growing season.

	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	24.8	24.0	24.8	26.0
90th	20.6	18.7	20.6	22.8
Median	15.2	11.7	15.2	15.7
Mean	14.5	12.6	14.5	15.2
10th	7.3	7.7	7.3	6.5
Min	6.1	6.6	6.1	5.5

In median year, modelling results of Alternatives 1, 3a and 3b are 30%, 30% and 34% higher respectively, than Alt 2 (Figure 2.). Alternatives 2 and 3b have the narrowest and widest range of outcomes, respectively, but the distributions of all four Alternatives overlap broadly.

References

Jasper, S, E C Carmack, RC Daely, C B J Gray, C H Pharo and R C Wiegand. 1983. Primary productivity in a large, temperate lake with river interflow: Kootenay Lake. British Columbia. Can. J. Fish. Aquat. Sci. 48: 319 - 327.

PERFORMANCE MEASURE INFORMATION SHEET #52
LAKE KOOCANUSA: RECREATION AND TOURISM

INTRODUCTION

CBT (2004) note that a wide variety of recreational interests are affected by reservoir elevation changes in Koocanusa reservoir. These include swimming, boating, fishing and the use of beaches. Koocanusa reservoir is a camping destination, with numerous forestry and private campgrounds; there are 105 campsites at Kikomun Creek Provincial Park, close to Fernie. Beaches are popular and are protected from the wind. Several local businesses cater to tourists. Kikomun Creek Provincial Park is open from May 1 to September 30, but as with most of the province Labour Day to Victoria Day is the primary window for outdoor activities. The park has a boat ramp available during the off season, and in 2011 a new boat access point opened adjacent to the Kikomun Bridge with a much wider operational depth range.

Fisheries in Koocanusa and Kootenay Lake reservoirs focus on the same species: rainbow trout, bull trout and kokanee. On the Canadian side of Koocanusa reservoir the fishery is almost entirely directed at kokanee and is more intensive in years when kokanee are bigger and water levels are higher.

Open house participants proposed objectives that provided for water access for boating and fishing, and that generally improved the quality and diversity of recreational activities. Recreation performance measures on Koocanusa reservoir are captured through three performance measures, two of which are presented in the consequence table.

a) General Recreation and Tourism

Objective / Location	Performance Measure	Units	Description	MSIC
Recreation and Tourism / Lake Koocanusa	Preferred elevation days	# days per year in range	Days in range, 2445’(745.2m)-2455’(748.3m), May 24 to Sept. 8 Higher is better.	10%

Description

CBT (2004) found that a range of recreation stakeholders generally preferred a reservoir level range of 2445’ (745.2m) - 2455’ (748.3m), Victoria Day (May24) – Labour Day (September 8). This preferred range incorporates several negative factors that emerge at lower elevations, including the emergence of sand bars, the potential for dust mobilization during wind storms, and unpleasant aesthetics. Negative effects from high reservoir levels begin approximately 4 feet (1.2m) below the full pool mark of 2459’ (749.5m). This range was confirmed at public meetings as part of this review.

Boat access is considered as a separate performance measure below for this analysis.

Performance Measure

Preferred elevation days are calculated as the number of days when the reservoir level is within the range 2445’ (745.2m) - 2455’ (748.3m) during the 24 May to 8 September period. A higher number of days counted in this range is better.

Calculations

For each alternative:

1. Assemble the simulated results for daily elevations (1948 - 1997; Figure 1 shows the median daily values for each alternative in this time period).
2. Count the number of days in each year that the reservoir water levels are between the critical elevation range for each site.
3. Summarize all statistics (Figure 2).

Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.
- Assumes that the critical elevations for each site are accurate.

Results

In terms of hydrology, Alternatives 3a and 3b start from a higher initial reservoir level and reach the preferred elevation threshold on June 20. Alternative 2 begins the period from the lowest elevation of the 4 alternatives yet reaches the threshold on June 27, eight days before Alternative 1 (Figure 1).

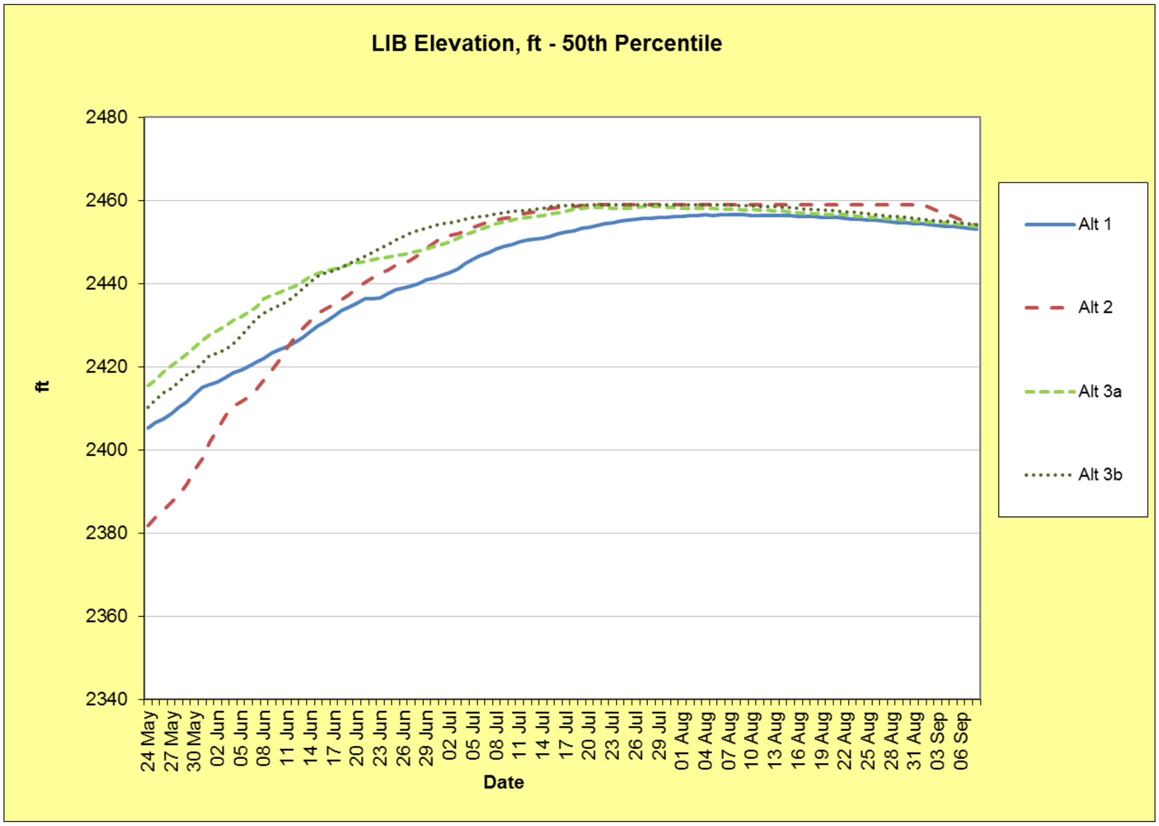
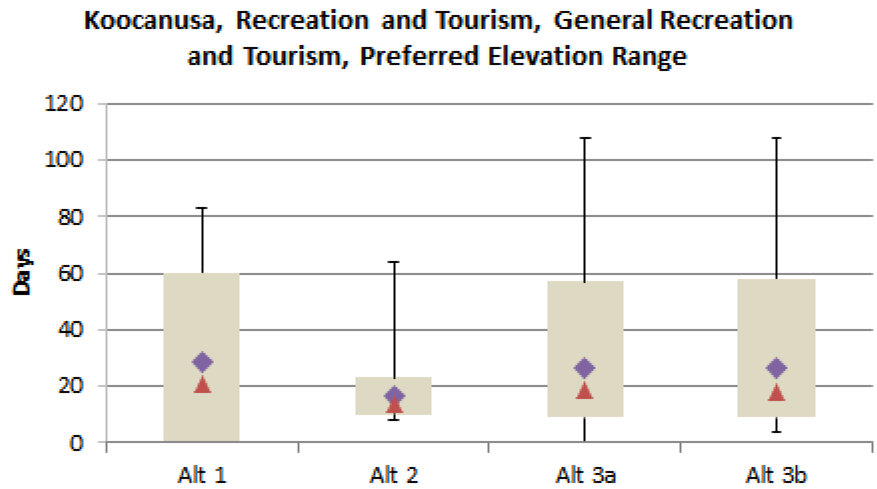


Figure 1. Lake Koocanusa, reservoir elevation levels May 24 to Sept. 8.

Figure 2 illustrates the performance of each alternative on this performance measure.



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	83	64	108	108
90th	60	23	57	58
Median	21	14	19	18
Mean	29	16	26	27
10th	-	10	9	9
Min	-	8	-	4

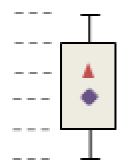


Figure 2. Lake Koocanusa, preferred elevation range for recreation (number of days).

b) Boat Access at Kikomun Bridge

Objective / Location	Performance Measure	Units	Description	MSIC
Recreation: Boat access at Kikoman Bridge / Lake Koocanusa	Preferred elevation days	# days per year in range	Days lake elevation is above 2407' Victoria Day to Labour Day Higher is better.	10%

Description

A new boat ramp, constructed in 2011 adjacent to the Kikomun Bridge, is usable for reservoir levels down to 2407.15' (733.7m). Since the boat ramp was constructed only in 2011, there is not yet enough data to ascertain how heavily the ramp is used.

Figure 3 - Aerial view of the Kikomun boat launch and surrounding area.

Performance Measures

Boat access days will be calculated as the number days above 2407.15’ (733.7m) from 24 May to 8 September. A higher number of days counted in this range is better.

Calculations

For each alternative:

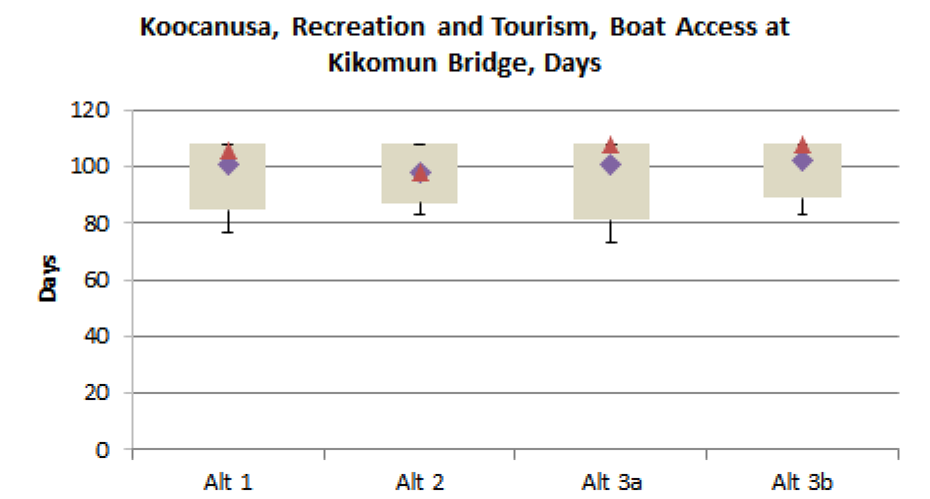
1. Assemble the simulated results for daily elevations (1948 - 1997).
2. Count the number of days in each year that the reservoir water levels are above the threshold elevation
3. Summarize the results (Figure 4).

Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1948 - 1997).
- Assumes that there is minimal recreational use outside the defined recreation season.
- Assumes that the preferred season and elevations are accurate.

Results

Because of the depth of of this boat ramp, access to the reservoir would not significantly be affected by the alternatives; this performance measure was not carried forward to the consequence table.



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	108	108	108	108
90th	108	108	108	108
Median	106	98	108	108
Mean	101	98	101	102
10th	85	87	81	89
Min	77	83	73	83

Figure 4. Lake Koocanusa, boat access days at Kikomun Bridge from May 24 to September 8.

c) Kokanee Angling

Objective / Location	Performance Measure	Units	Description	MSIC
Recreation: Fish / Lake Koocanusa	Angler Days	# days per year	Angler Days between May 24 and Sept 8 using an empirically-derived relationship between reservoir elevation and kokanee length. Higher is better.	10%

Description

Kokanee account for 98% of the recreational harvest of Koocanusa reservoir. Parkinson (see below) has developed an empirical relationship relating angling days for kokanee in the Canadian portion of Koocanusa reservoir to kokanee length and reservoir elevation. When the elevation is high there is more fishing effort, and at very low elevations there is little reservoir area remaining in Canada for fishing. The reservoir is typically drawn down by about 100' (30 m) by the beginning of May (elevation 2360' (719.3m)). In most years, the reservoir reaches near full pool (2459' (749.5 m)) sometime in July. At full pool, the reservoir is 145 km long and extends 77 km into Canada. Anglers start fishing at about 2420' (737.6m) but the reservoir is not fully fishable until 2435' (742.2m) at approximately June 30 because of high sediment concentrations from the slowly submerging mudflats. Kokanee move out of the reservoir in early September, resulting in a two month season that can support up to 25,000 angler-days/year.

Performance Measures

Angler Days between May 24 and Sept 8 using an empirically-derived relationship between reservoir elevation and kokanee length. Higher is better.

Calculations

Parkinson (2012, appended below) describes a rule curve for angler days vs. filling date for Koocanusa reservoir. Effort is calculated as:

Effort (Angler Days) = Days* (112.5 + 4.7*(0.824 * Len - 189)) = 328 * Days

Where Days is the number of days with elevation > 2440 ft between May 24 & Sept 8. [A kokanee length of 285 mm (avg length of kokanee caught , 1988-2007) is assumed.]

For each alternative:

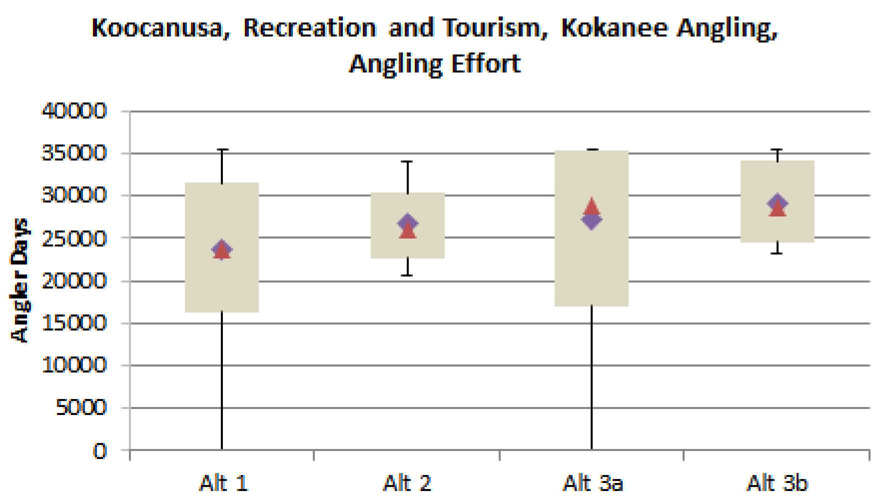
1. Assemble the simulated results for daily reservoir elevations over (1948 – 1997)
2. Calculate Angler Days as above
3. Summarize all statistics (Figure 5).

Key Assumptions and Uncertainties

- A kokanee length of 285 mm (avg length of kokanee caught , 1988-2007) is assumed
- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1938 - 1998).
- Assumes that there is minimal recreational use outside the defined recreation season
- Assumes that the preferred season and elevations are accurate

Results

In terms of hydrology in the median year, Alternative 2 begins the period at roughly 2380' resulting in the largest fluctuation of reservoir level between May 24 and Sept. 8, however Alternative 1 has the lowest reservoir recharge rate resulting in the fewest number of days where the reservoir elevation exceeds 2440 ft. Alt 3a and Alt3b conversely have the longest period in which the threshold is met and/or exceeded, thereby providing the greatest number angler days as modelled.



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	35,424	34,112	35,424	35,424
90th	31,521	30,373	35,424	34,112
Median	23,780	26,076	28,864	28,536
Mean	23,629	26,627	27,158	29,008
10th	16,334	22,632	16,990	24,567
Min	-	20,664	-	23,288

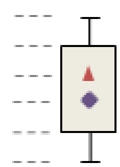


Figure 5. Lake Koocanusa, Angling effort as a relationship between reservoir depth and length of Kokanee (Parkinson, 2012).

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

Reservoir Elevation and Angling Effort on the Canadian Portion of Lake Koocanusa

ERIC PARKINSON (2012)

BACKGROUND INFORMATION

Angling effort often exhibits strong seasonal pattern that can be associated with seasonal variation in catch and non-catch components of angling quality. Angling effort on both the Canadian (CLK) and American (ALK) portions of Lake Koocanusa varies seasonally pattern (Figure 1). One of the reasons for this seasonality are changes in reservoir elevation, which reduces boat ramp access and the lake area of CLK, especially in May and June. The objective of this report is to develop a method of quantifying the effect of reservoir elevation that is independent of seasonal effects.

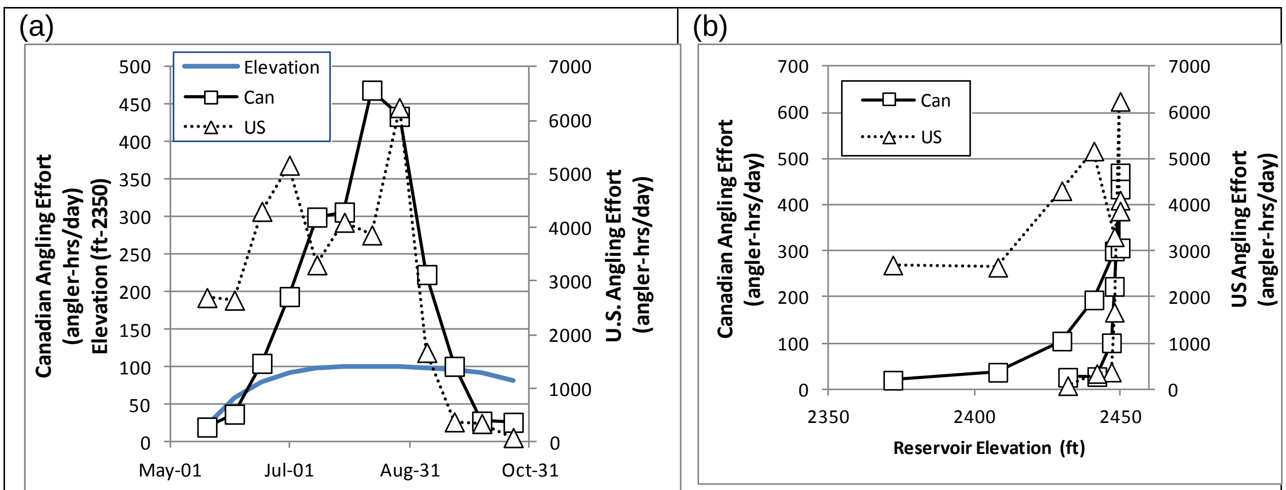


Figure 1. (a) Seasonal pattern of elevation and angler effort on the Canadian and American portions of Lake Koocanusa in 1985. (b) Angler effort as a function of reservoir elevation on the Canadian and American portions of Lake Koocanusa.

Creel surveys on CLK have noted on the importance of reservoir levels in determining total angler effort (Hartman and Martin 1987, Parnell 1997). The 1996 survey did not encounter any anglers at reservoir levels below 2422 ft and suggested that the reservoir was not “fishable” under the 2435 ft level because of combination of low reservoir levels and high silt loads (Parnell 1987). At full pool, 47% of the reservoir length is in Canada, however 94% of the May-October fishing effort in 1985 was on the US portion (Chisholm and Hamlin 1987).

Index boat counts on Koocanusa Reservoir from 7 years (1989, 90, 91, 96, 2003, 04, 05) also indicate that CLK angling effort is strongly dependent on reservoir elevation. These counts utilize aircraft that follow set flight lines between 10AM and 3PM on 20 weekend days per year between May and October (Tredger 1992). Boat counts on CLK are close to zero at elevations of less than 2420 ft with a plateau starting at 2440 ft with some suggestion that peak boat counts occur at the full pool elevation of 2458 ft (Figure 2).

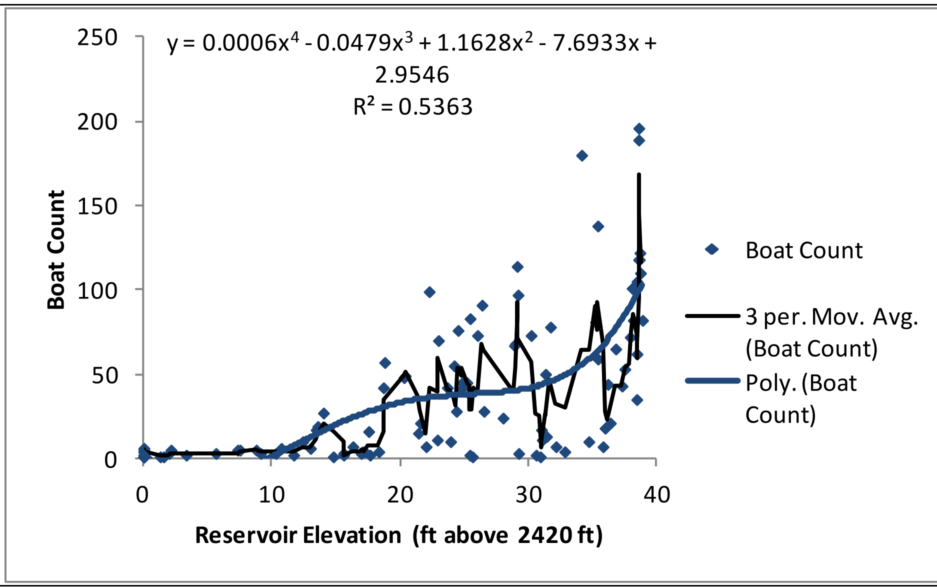


Figure 2. Aerial boat counts of the Canadian portion of Koocanusa Reservoir from the Provincial fisheries data base described by Tredger (1992). Reservoir elevations are down loaded from http://www.nwd-wc.usace.army.mil/report/columbia.htm#upcol . Boat counts are available from 1989-91, 1996 and 2003-2005.

In addition to reservoir elevation, angling effort is expected to be a function of kokanee abundance and size because kokanee make up most of the harvest on both CLK (90%, Parnell 1997) and ALK (96% Chisholm and Hamlin 1987). However, kokanee angling effort is expected to peak at an intermediate kokanee density because of the effects of density dependent growth and catchability, combined with a preference by anglers for larger fish (Reiman and Maiolie 1995). Data from Lake Koocanusa indicates that growth is strongly density dependent (Figure 3a) and that kokanee anglers respond strongly to fish size (Figure 3b).

The effects of reservoir elevation and kokanee size are confounded in the available data. Years with small kokanee are also years with generally higher reservoir levels (2003-2005, Figure 3b larger symbols) and when time of filling is plotted against angling activity, years in which reservoir elevation rose earlier are associated with low, rather than high, angling activity (Figure 4). Taken together, the data from the fishery on Lake Koocanusa suggest that elevations >2430 ft are essential to maintaining the fishery on CLK but it is not clear that high water levels in spring and fall will result in more angling activity.

Seasonal patterns on other BC lakes offer some insight into the seasonal distribution of effort on lakes where lake elevation is not a factor. In contrast to both CLK and ALK, angling activity on these lakes is almost independent of the time of year between the beginning of May and the end of September. Assuming that that angling activity on CLK would follow a similar pattern, then the total angling activity can be estimated as a function of the size of kokanee and the date at which the elevation reaches a target elevation.

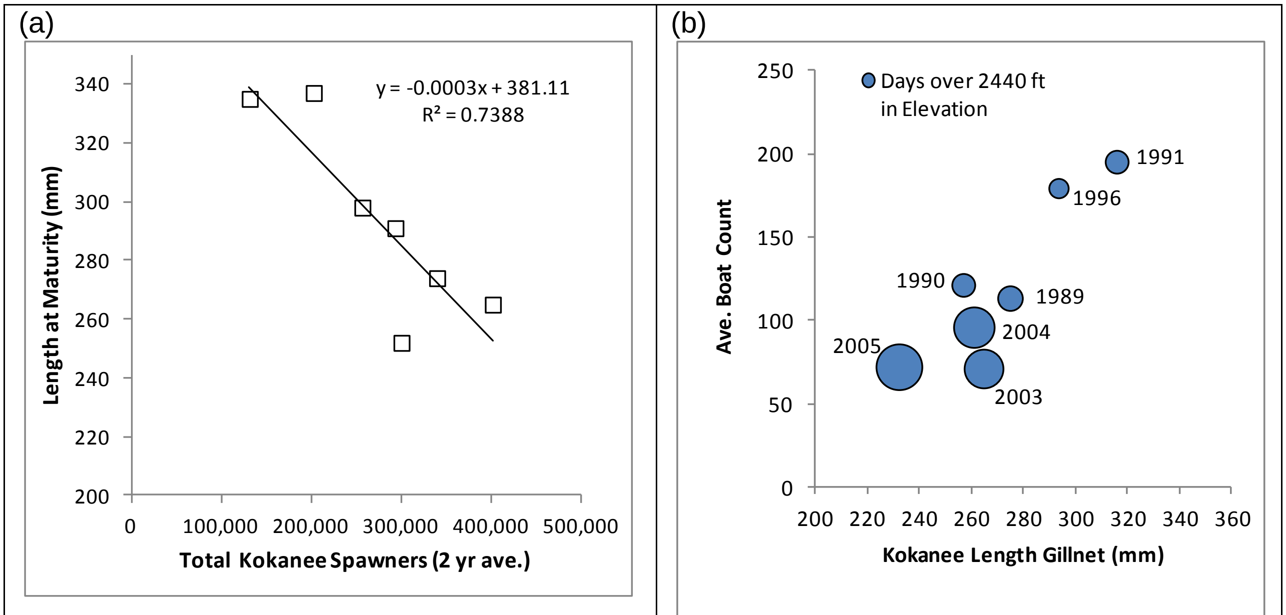
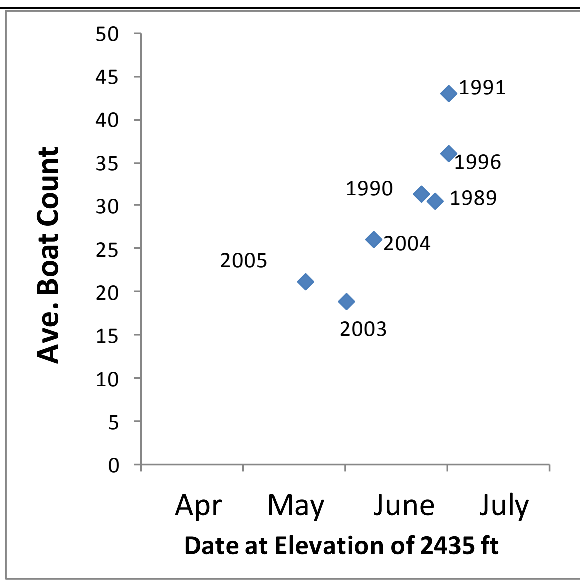


Figure 3. (a) Length at maturity versus 2 year running average of escapement. Data is from Westover (2003). (b) Average boat count versus length of kokanee in standardized gillnet monitoring in Lake Koocanusa. Gillnet data from Dunnigan et al. (2009). The diameter of the symbols in (b) is proportional to the number of days where elevation was >2440 ft.



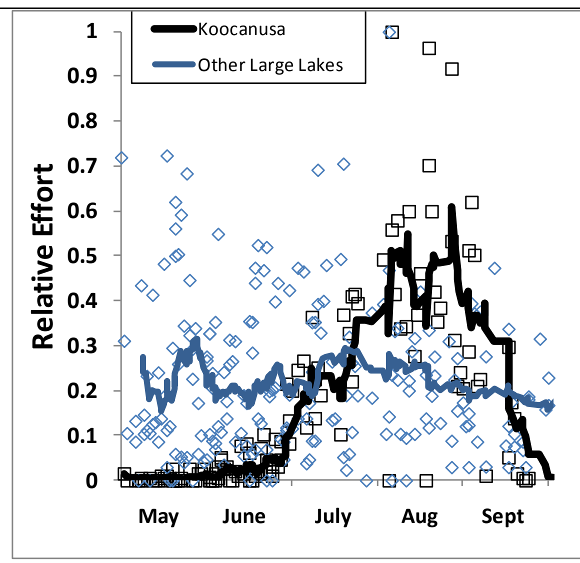


Figure 4. Boat count as a function of the date

Figure 5. Seasonal patterns of boat counts on

at which reservoir elevation exceeded 2435 ft (=minimum fishable Parnell 1997).	CLK and a combination of 8 other large (>930 ha), low elevation lakes in southern BC (Kalamalka, Mabel, Christina, Okanagan, Osoyoos, Sugar, Windermere, Wood). Lines are running averages of 10 (Koocanusa) and 20 (other lakes) data points.

METHODOLOGY

The data consists of seven years of standardized boat counts (Tedger 1992), average length of gillnetted kokanee (Dunnigan et al. 2009) and reservoir elevation data from the US Corps of Engineers, NW Division website (http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=lib).

Boat counts were first filtered to remove those below 2440 ft, which is the elevation where boat counts on CLK become independent of reservoir elevation (Figure 2). The average of the remaining counts was used to calculate angler days for each year using May 1 to Sept 15 season using Tredger's (1992) methodology. The end of the fishing season is assumed to be September 15, the approximate date at which angling activity declines rapidly on CLK (Figure 5). The actual effort in each year was estimated by multiplying the full season effort estimate by fraction of days between May 1 and Sept 15 where reservoir elevation was greater than 2440 ft.

Predicted effort was modeled as a function of 2 components. Baseline effort is a constant amount of angling activity per day over 2440 ft, independent of kokanee size. Kokanee dependent effort is a linear function of kokanee length above a minimum length of 189 mm, which is the length where kokanee catchability approaches zero (Rieman and Maiolie 1995). These 2 parameters were estimated using data from the seven years of boat counts that were available.

RESULTS

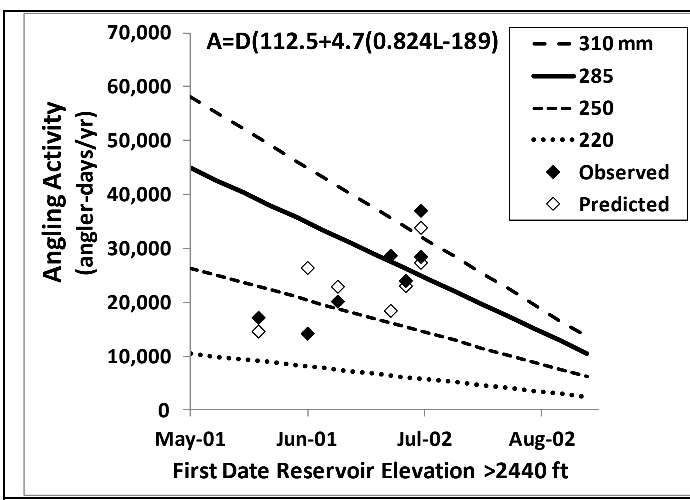


Figure 6. The proposed rule curves for effort as a

function of filling dates and kokanee size. The average kokanee length between 1988 and 2007 was 285 mm.

Baseline angling activity that was independent of kokanee length was estimated to be 112.5 angler days for each day where reservoir elevation was over 2440 ft. In addition to baseline effort, angling activity was predicted to increase with kokanee length:

$$A = D(112.5 + 4.7(0.824L - 189)) \quad \text{Eqn. 1}$$

where A is angling activity in angler days per year, D is season length in days and L is kokanee length in mm in standardized gillnet monitoring. D is the number of days between the date where reservoir elevation equals 2440 ft and September 15. The predicted angling activity is highest when kokanee are large and the reservoir is filled early in the spring (Figure 6). If the average length of kokanee from 1988-2007 (285 mm) is used, Eqn. 1 simplifies to A=328D. Note that for both the predicted and observed data points, angling activity is higher for later filling dates, which is the result of the underlying correlation between filling dates and the size of kokanee.

Discussion

Although fitting a 2 parameter model to 7 data points is questionable, the results are consistent with other studies of kokanee fisheries and angler behavior. Kokanee anglers respond to kokanee size because an exponential increase in catchability between 200 and 300 mm outweigh the effects of the lower density needed to generate larger sizes (Rieman and Maiolie 1995). The net result of this interaction is much kokanee angling activity and higher harvest rates when kokanee are larger (Martinez and Wiltzus 1995).

Reservoir operations also have two less direct impacts on the kokanee fishery on CLK. Kokanee are the most common species entrained through turbines at Libby Dam and entrainment clearly affects population densities in the reservoir (Skarr et al. 1996). Reservoir operations also affect kokanee food density via effects on both primary production per unit area and the total area available for primary production. These effects are propagated up the food chain and influence the growth rate of kokanee at a given density (Chisholm et al. 1989). The linkages between these 2 factors and kokanee angler effort are complex and therefore difficult to quantify. Entrainment decreases, and total primary production increases, at high reservoir levels and low discharge, which means that entrainment tends to complement changes in primary productivity in balancing kokanee populations with their food supply. If bathymetry data is available, a simple version of these effects could be incorporated into the model of angler response to reservoir elevation.

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PERFORMANCE MEASURE INFORMATION SHEET #53

CRESTON VALLEY FLOOD PLAIN:

DYKE MANAGEMENT OPERATIONS

Objective / Location	Performance Measure	Units	Description	MSIC
Farming and wetland protection, water pumping / Creston Valley Floodplain	Preferred operational days	# of days	# Days below 1750' (533.4m) 1 Jan to 15 June Higher is better	10%
	Spring dry days	# of days	# Days below 1739.32' (530.1m) in Kootenay Lake, March 1 – April 30 Higher is better	10%

Description

Prior to dyking and impoundment, the Creston Valley was a very large wetland with a healthy and large kokanee population (Goat Creek) and other fish species (sturgeon, burbot, etc). The area is currently managed for farming (Kootenay Indian Reserve) and wildlife (Creston Valley Wildlife Area or CVWA). In farmed areas, the key is to drain fields in June so farmers can plant the hay crop. Wildlife areas in the CVWA are managed for different species (e.g. Duck Lake for waterfowl and leopard frog). Inundation of these dyked-off floodplain areas is controlled by gravity drainage when the Kootenay River level is low enough, and by pumping when the river levels are higher. River elevations adjacent to these areas are controlled by the combined backwater effect of Kootenay Lake (which depends on lake elevation) and flow in the Kootenay River. High water elevations in June and July make it more costly, difficult, or impossible to drain dyked-off areas of floodplain that are inundated by local inflows. In some years when water elevations are low these areas can be drained mostly by gravity (little cost). In years with higher river levels or greater local inflows these areas can be drained using pumps, but this increases costs and not all areas currently have the infrastructure to do this. In years with high local runoff and high water elevations it is not possible to drain all areas to meet wildlife and farming objectives given the current infrastructure. In high water years such as 2012, some dyked-off areas such as Leach Lake could not be drained due to concerns about dyke integrity (must limit the extent of head differences between the river and dyked-off areas or the dykes could fail).

Performance Measure: Preferred Operational Days

CBT (2004) found that a wide range of recreational, commercial and ecological interests would be captured by the preferred elevation levels of 1744' (531.6m) to 1746' (532.2m) measured at Duck Lake (Figure 1).

Figure 1 - Aerial view of Kootenai River and Creston Valley Flood Plain.

Estimating elevations at Duck Lake is beyond the scope of this preliminary survey, for two reasons:

- If unregulated, Duck Lake levels are a function of both Kootenay River flows and Kootenay Lake levels. Although estimates for both of these parameters are available, a detailed hydrological model would be required to calculate elevations at Duck Lake from these inputs. It may be possible to adapt models from other processes (e.g. a recent Creston Valley Floodplain Management Plan), but this was not possible within the time available.
- Duck Lake levels are controlled by a gate between the Duck Lake outlet and Kootenay River. Predictions of Duck Lake levels would also need to assume management responses.

Following a technical meeting including floodplain operators, it was agreed that the number of days with Kootenay Lake level below 1750’ (533.4m) prior to mid-June would be a coarse indicator of the implications of system water management choices on floodplain operations. Generally, whenever the Kootenay Lake level is above 1750’ (533.4m), the floodplains’ system of dykes, gates and pumps becomes more complex and costly to manage.

Calculations

For each alternative:

1. Assemble the simulated results for Kootenay Lake elevations over 60 years (1948 - 1997; Figure 2).
2. Count the number of days between January 1 and June 15 that the reservoir is at or above the elevation threshold for each of the 60 years.
3. Summarize all statistics (Figure 3).

Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.

Results

The operation of the Kootenay system of dams is such that the median year of the model remains below the elevation of 1750' for all Alternatives (Figure 2).

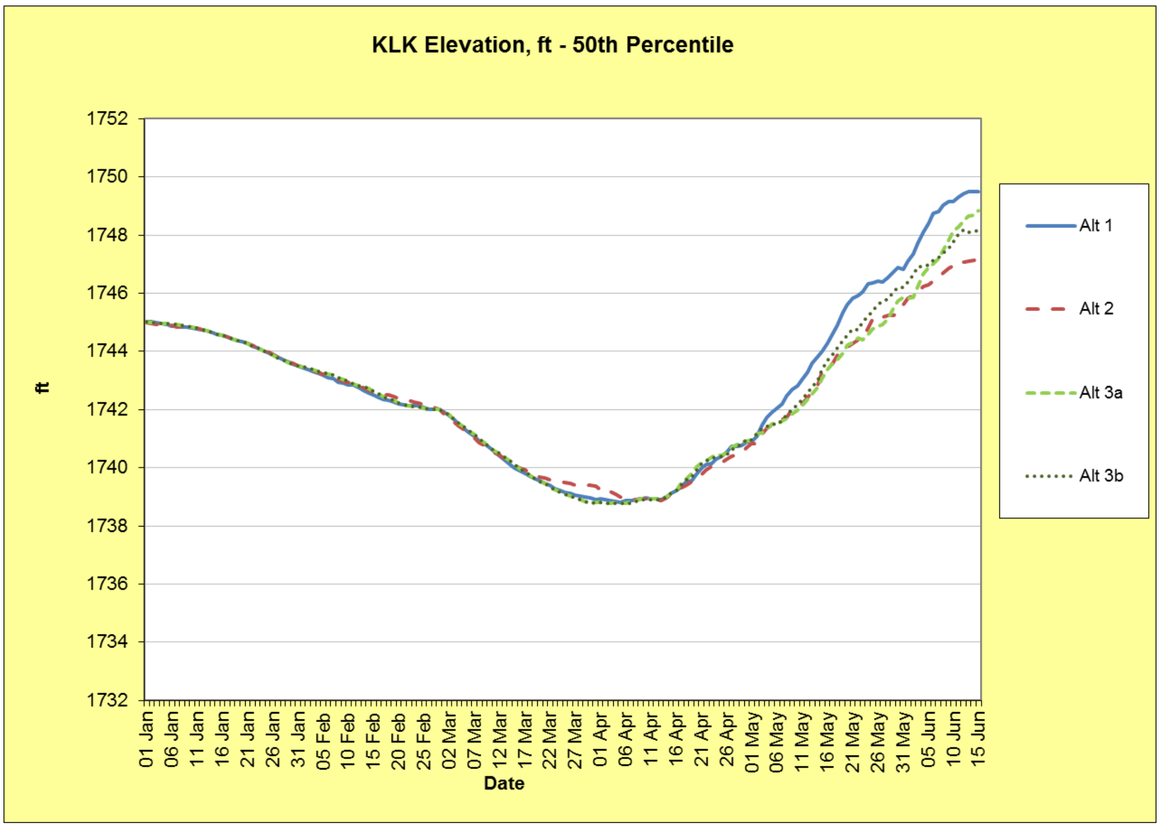
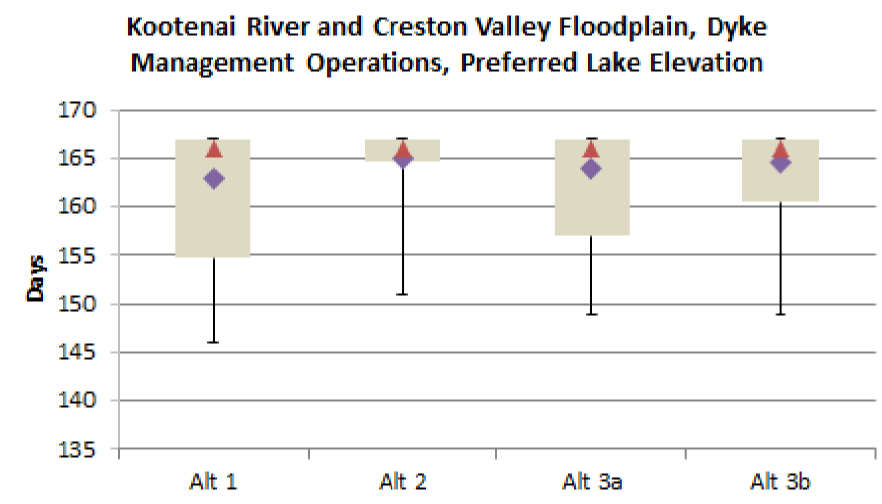


Figure 2. Kootenay Lake, reservoir elevation from January 1 to June 15.

Alternative 2 exhibits a fractionally improved performance (Figure 3), though this difference does not appear to be significant.



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	167	167	167	167
90th	167	167	167	167
Median	166	166	166	166
Mean	163	165	164	165
10th	155	165	157	161
Min	146	151	149	149

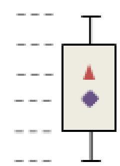


Figure 3. Kootenay Lake, Creston Valley Floodplain, preferred lake elevation days

Performance Measure: Spring dry days

Description

A second operational performance measure concerns the need for relatively dry farmland during March and April in order to move farming equipment to desired locations. Although pumps may help mitigate the effects of high reservoir levels to some extent, there are costs associated with doing so.

Calculations

The number of days when the Kootenay Lake level is below 1739.32’ (530.1m) in March 1 and April 30 will be counted. A higher number of days below this threshold is better.

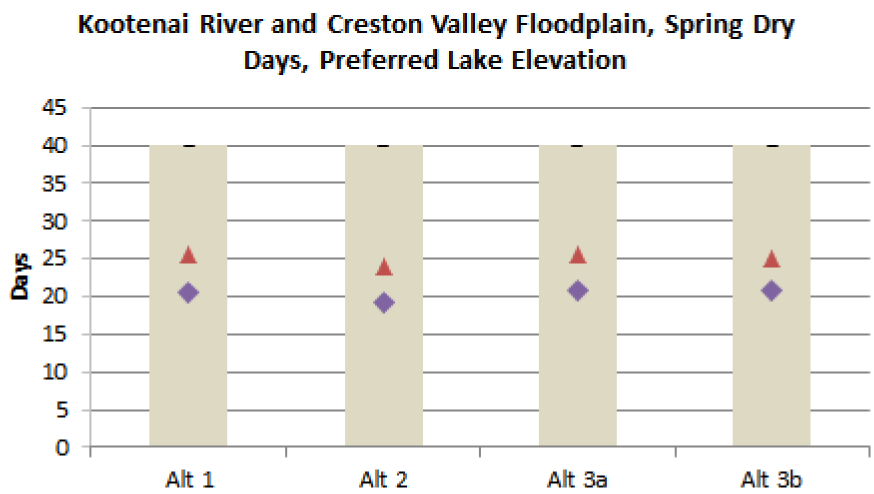
For each scenario:

1. Assemble the simulated results for Kootenay Lake elevations over 60 years (1948 – 1997);
2. Count the number of days between January 1 and June 15 that Kootenay Lake is at or above the elevation threshold for each of the 60 years.
3. Summarize all statistics (Figure 4).

Key Assumptions and Uncertainties

- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.

Results



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	40	40	40	40
90th	40	40	40	40
Median	26	24	26	25
Mean	21	19	21	21
10th	-	-	-	-
Min	-	-	-	-

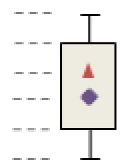


Figure 4. Kootenay Lake, Creston Valley Floodplain, Spring dry days

Discussion

For both of these performance measures, there does not appear to be a significant difference between the alternatives. Moreover, impacts of operations on the Creston Valley Floodplain are best addressed via infrastructure.

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

PERFORMANCE MEASURE INFORMATION SHEET #55
KOOTENAY LAKE: FISH AND AQUATIC ECOSYSTEM HEALTH

Objective / Location	Performance Measure	Units	Description	MSIC
Kootenay Lake: Fish and Aquatic Ecosystem Health / Recreation	West Arm Kokanee Spawner Length	cm	Average annual kokanee spawner length	10%

Description
Productivity is one aspect of Kootenay Lake fish and aquatic ecosystem health. Productivity is influenced by operations in several ways. For the CRTR process, investigations focused on the relationships between 1) Operations and mysis biomass in the West Arm and 2) Mysis biomass in the West Arm and kokanee spawner length. As a result of these relationships, a performance measure was developed that linked operations to kokanee spawner length in the West Arm. This measure of lake productivity was preferred over Mysis biomass alone because it is easier to understand, and also because it additionally functions as a recreation performance measure.

Theses linkages are discussed in the appended discussion document.

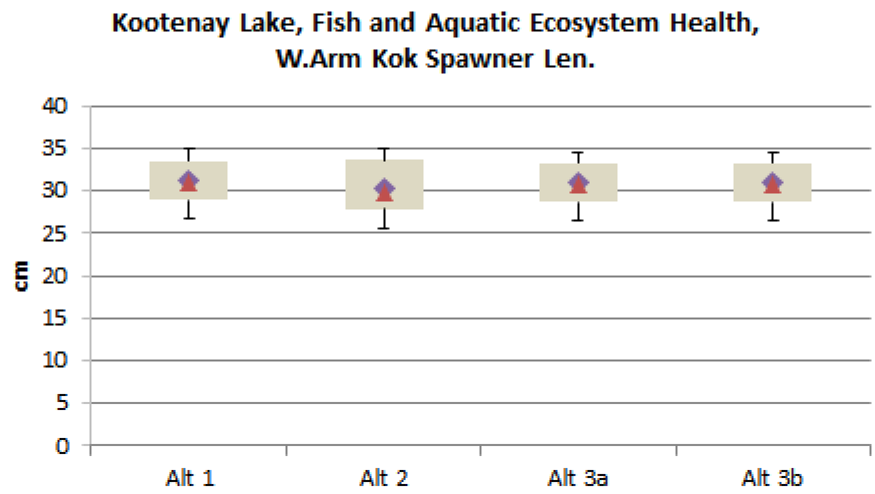
Performance Measure
This measure is based on the empirical relationship between discharges at Corra Linn dam and West Arm kokanee spawner length shown in Figure 3 below.

Calculations
For each alternative:

1. Assemble the daily discharges of Corra Linn dam (i.e. Kootenay Lake Outflows)
2. For each of the years 1929 – 1998, calculate the average discharge between 1 April and 30 September and convert to cms
3. Calculate the average annual spawner length using the relationship:
    - Length =0.0087 * [Ave annual discharge in cms] +21.5449
4. Calculate statistical measures across the years.

Key Assumptions and Uncertainties
- Each scenario is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1929 - 1998).
- The relationships discussed below are accurate

Results



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	34.9	35.0	34.5	34.5
90th	33.5	33.6	33.2	33.2
Median	30.9	29.8	30.8	30.7
Mean	31.1	30.2	31.0	30.9
10th	28.9	27.8	28.7	28.7
Min	26.7	25.6	26.6	26.5

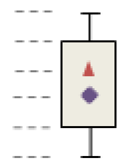


Figure 1. West Arm Kokanee Spawner Length

Figure 1 indicates no significant differences between the water management alternatives

The Effects of Discharge on Mysis Supply to the West Arm of Kootenay Lake

For many years, Mysis relicta (mysis) has been recognized as an important food resource for fish populations, particularly kokanee, in the West Arm of Kootenay Lake (Lasenby et al 1986, Martin and Northcote 1991). Mysis spend the day in deep water, but at night they migrate to the surface to feed on zooplankton. On Kootenay Lake, surface-feeding mysis can be swept over a shallow sill at the outlet of the lake and in to the much shallower West Arm, where they are vulnerable to predation by kokanee and other fish. High discharge, particularly during the spring and summer growing season, is believed to enhance mysis export in the West Arm and result in higher growth rates for West Arm kokanee.

A time series of mysis and kokanee data have been collected as part of ongoing spawning channel operations and fertilizer treatments (see Schindler et al 2011). The data presented here were provided by the BC Ministry of Forest Lands and Natural Resource Operations.

A comparison of mysis densities in the West Arm and the main part of Kootenay Lake suggest that discharge is an important factor controlling the supply of mysis to the West Arm (Figure 1). Mysis densities are much lower in the West Arm than in the Main Lake, particularly during the growing season when fish predation is expected to be the most intense. Feeding rates for many species of fish decline with temperature and therefore West Arm mysis densities are expected to be higher during the winter at comparable discharges. Mysis densities in the Main Lake are lower in high discharge years ($N=19$, $p=0.02$), which suggests that higher discharge is detrimental to Main Lake mysis populations. There is also some indication of a lower threshold (~1000 cms) where mysis supply approaches zero during the growing season (Figure 1).

Higher mysis densities appear to result in faster growth of West Arm kokanee. In years with inorganic fertilizer treatments, higher discharges during their final growing season (April – August) are associated with larger sizes in mature West Arm kokanee ($N=19$, $p=0.0047$) but not in Main Lake kokanee ($N=19$, $p=0.36$) (Figure 2, 3). Declining growth with discharge in the main lake kokanee may be the result of reduced standing stocks of algae and zooplankton in the main lake in years with high flushing rates. Below about 500 cms, growth rates are similar, which suggests that 500 cms may be a threshold where these effects become noticeable.

If high May-August discharge enhances mysis supply and kokanee growth, then water storage in the upper Columbia might be expected to have negative impacts on these values. The historical hydrograph of discharge to the West Arm peaked sharply in June but following the construction of Libby and Duncan dams, this peak is much broader and winter flows are much higher (Figure 3).

References

Lasenby, D. C., T. G. Northcote, M. Fürst. 1986. Theory, Practice, and Effects of Mysis relicta Introductions to North American and Scandinavian Lakes. Canadian Journal of Fisheries and Aquatic Sciences, 1986, 43(6): 1277-1284

Martin, A. D., & Northcote, T. G. 1991. Kootenay Lake: an inappropriate model for Mysis relicta introduction in north temperate lakes. In American Fisheries Society Symposium 9:23-29.

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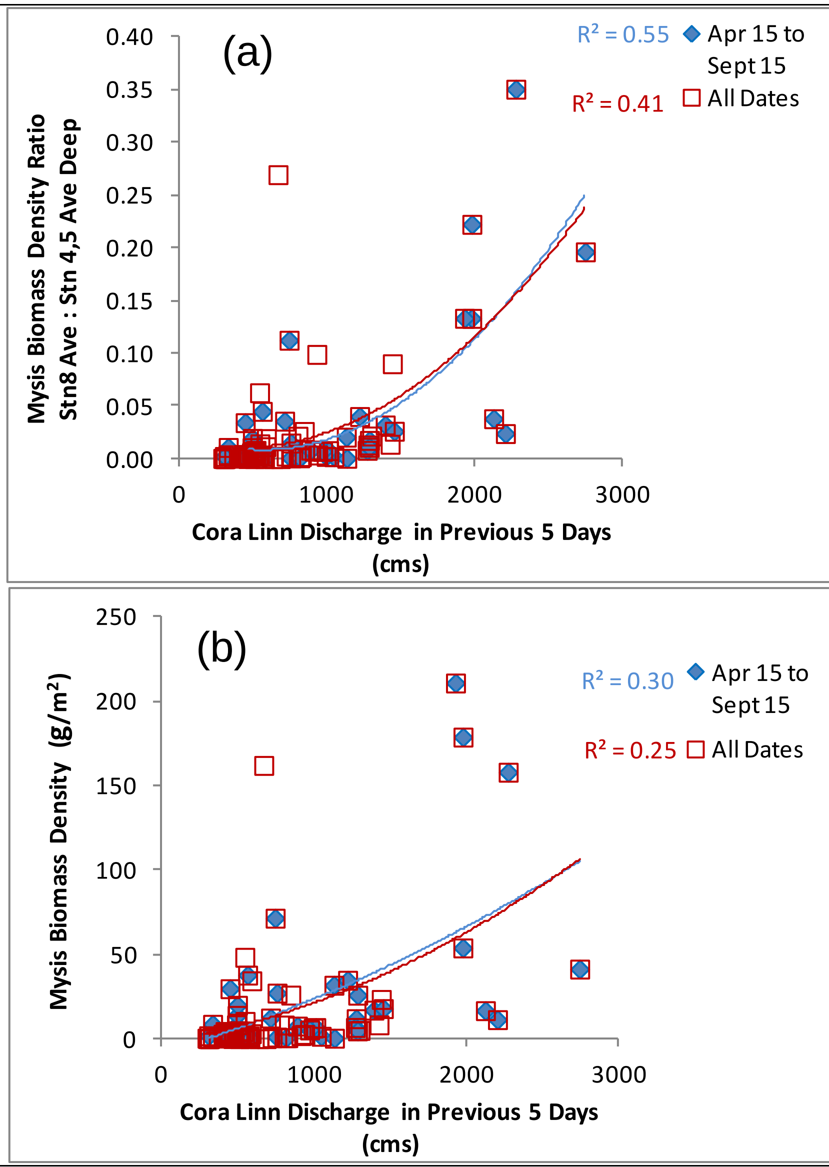


Figure 1. (a) Relative densities of mysis in the West Arm (Stn 8) as compared to the Main

Lake (Stns 4,5) versus average discharge at Cora Linn Dam in the previous 5 days. (b) Densities of mysis in the West Arm (Stn 8) versus average discharge at Cora Linn Dam in the previous 5 days. The strength of the correlations declined steadily with longer averaging periods.

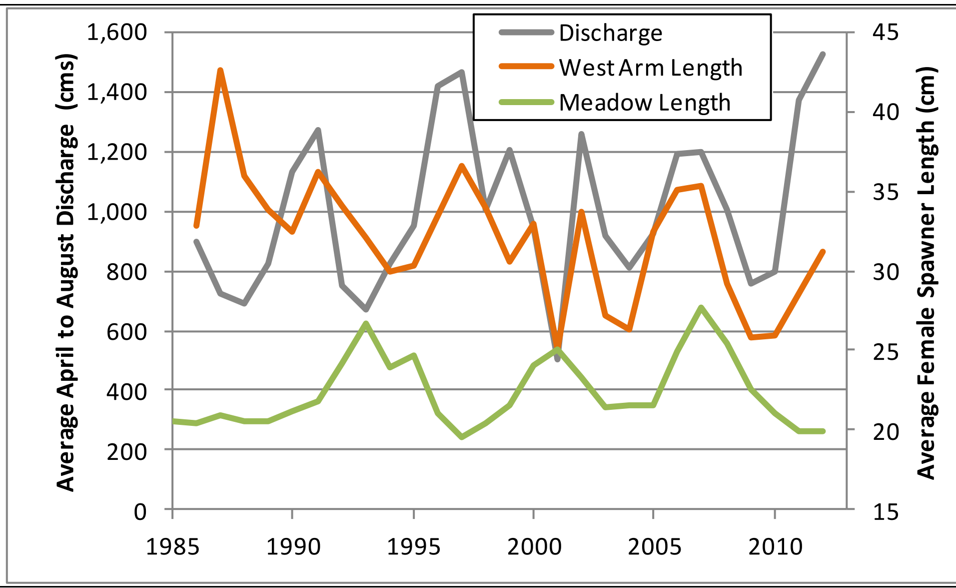


Figure 2. Time series of discharge versus spawner lengths for Kokanee Creek (West Arm) and Meadow Creek (main body of Kootenay Lake. The correlation between length and discharge is tightest during the period of fertilizer application (1993-2012).

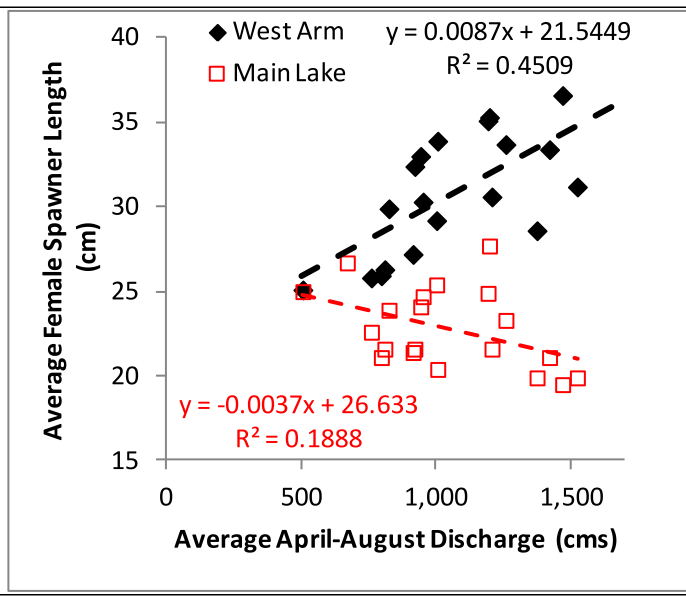


Figure 3. The relationship between discharge at Cora Linn Dam during the growing season

and female kokanee spawner lengths for the West Arm (Kokanee and Redfish Creeks) and the Main Lake (Meadow Creek). Each point is a single year between 1993 (start of fertilization) and 2012. Male kokanee lengths are similar to female lengths but were not available for all sites in all years.

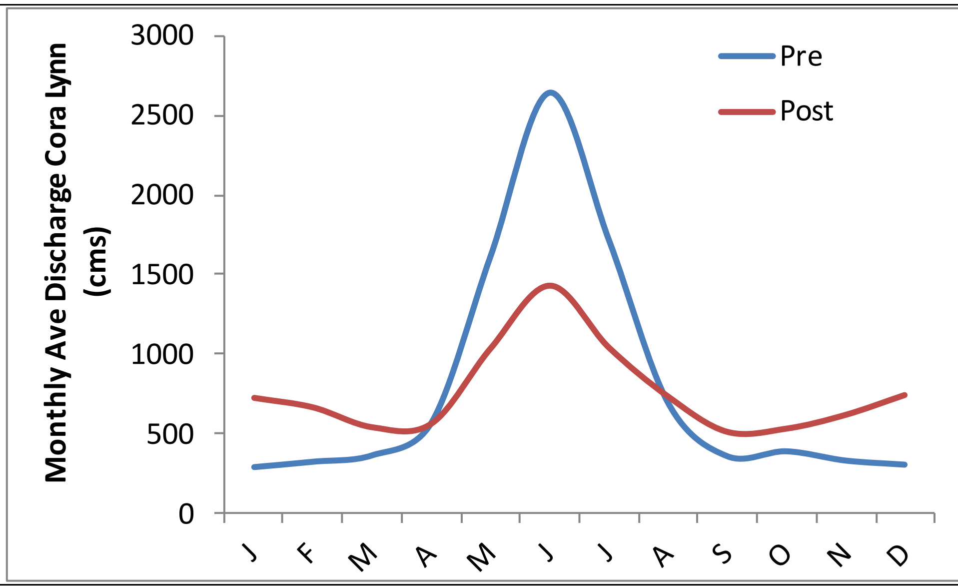


Figure 4. Annual average monthly discharges for the period before (1938-1967) and after (1974-2011) the construction of Libby and Duncan dams.

PERFORMANCE MEASURE INFORMATION SHEET #56
KOOTENAY LAKE: RECREATION, TOURISM, AND INDUSTRY

Objective / Location	Performance Measure	Units	Description	MSIC
Recreation and tourism / Kootenay Lake	Preferred recreation days	# of days	Days between 1744' (531.6m) and 1750' (533.4m) at Queens Bay during the recreation season Higher is better	10%

Description
A wide variety of Spring recreational activities occur on or around Kootenay Lake, including boating, sailing, water-skiing, swimming, fishing (fly, shore, trolling), canoeing/kayaking, and beach use for multiple activities; these were identified in a Columbia Basin Trust study (Columbia Basin Trust, 2004). A broad range of preferred lake levels, 1740' (530.4m) to 1752' (534m), was identified across a broad range of stakeholder interests. BC Hydro notes that a narrower range of preferred lake levels is more consistent with recent stakeholder feedback; hence the selection of the range, 1744' (531.6m) to 1750' (533.4m), for this analysis.

Performance Measures
This performance measure tracks the number of days in a preferred elevation range for recreation during the recreation season.

Calculations
The number of days when Kootenay Lake levels are between 1744' (531.6m) and 1750' (533.4m) between 24 May and 8 September will be counted. A higher number is better.

For each alternative:
1. Assemble the simulated results for month-end reservoir elevations over (1948 – 1997); Figure 1).
2. Count the number of days over each year that the reservoir water levels are between the critical elevation range.
3. Summarize all statistics (Figure 2).

Key Assumptions and Uncertainties
- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows.
- Assumes that there is reduced recreational use outside the defined recreation season.
- Assumes that the preferred season and elevations are accurate.

Results
In terms of hydrology Alternative 1 reaches the preferred threshold on May 15 with Alternative 3b on May 17 and May 19 for Alternatives 2 and 3a. Thereafter all alternatives in the median year remain within the preferred elevation range for the period (Figure 1).

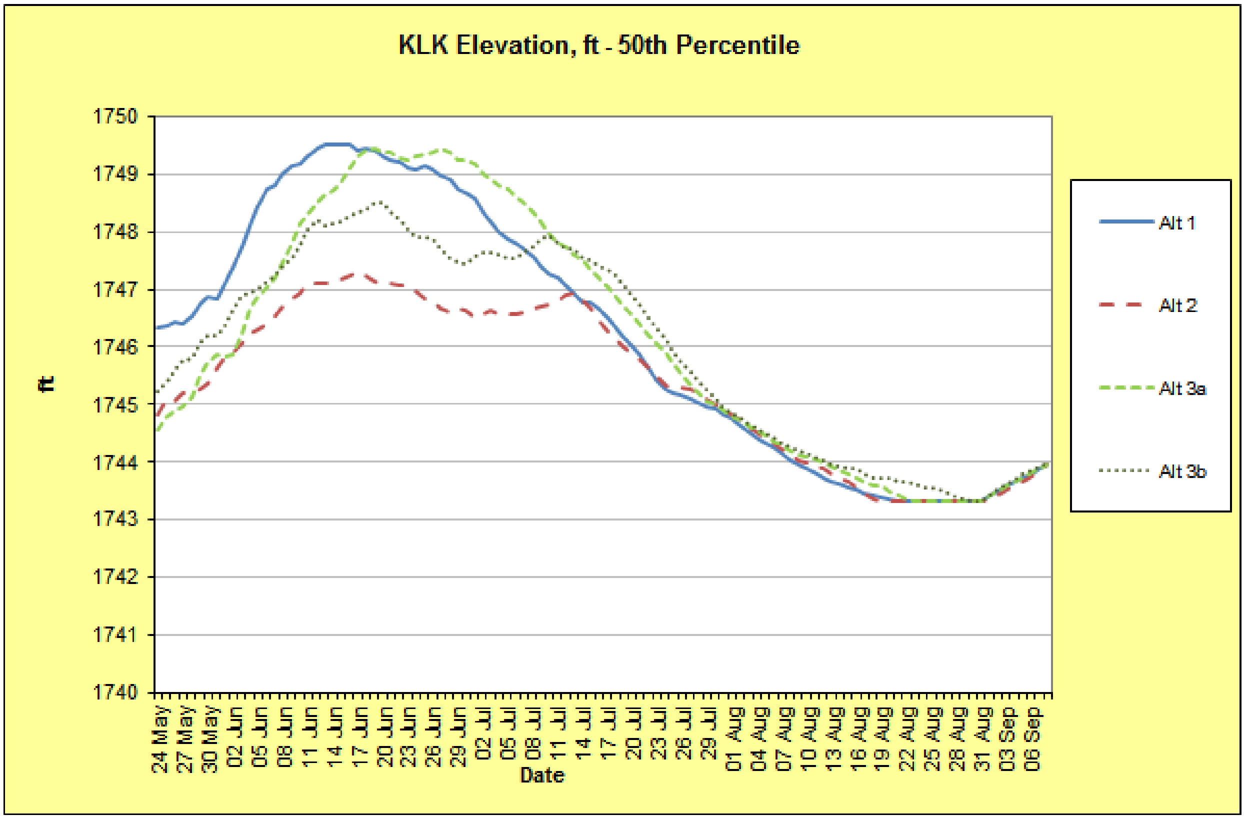
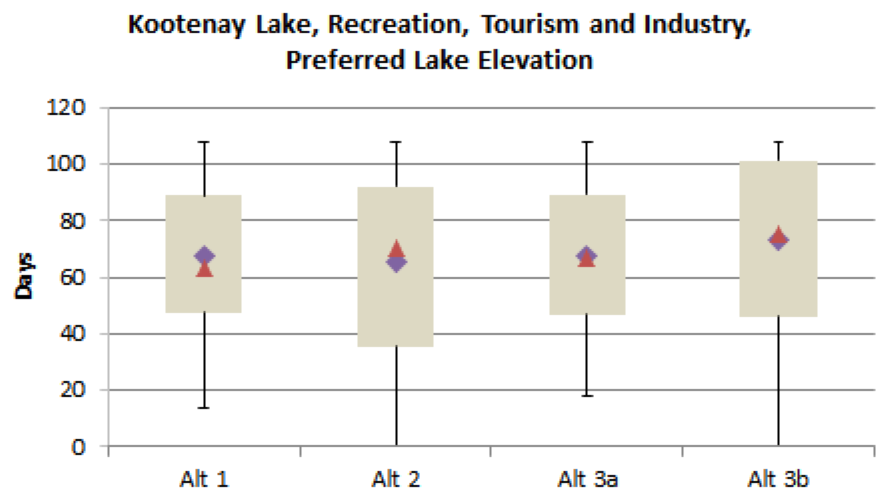


Figure 1. Kootenay Lake, daily elevation from 24 May to 8 September

For the median year Alternative 1 has the greatest number of days which fall within the preferred elevation range for the suite of recreation activities (Figure 2).



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	108	108	108	108
90th	89	92	89	101
Median	64	70	67	75
Mean	67	65	68	73
10th	48	36	47	46
Min	14	-	18	-

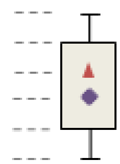


Figure 2. Kootenay Lake, number of days Kootenay Lake is within preferred elevation range from 24 May to 8 September

LITERATURE CITED

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.

PERFORMANCE MEASURE INFORMATION SHEET #57
KOOTENAY LAKE: FLOODING

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

Description

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 will rise.

On an annual basis regulated Kootenay Lake inflows come from Duncan Dam (~16%) and Libby Dam (44%). Unregulated inflow originating from Lardeau River (~10%) and local inflow between Libby Dam and Kootenay Lake (~30%) make up the balance. It should be noted that BC is only able to directly influence 16% of the inflow in any given water year through operations at BC Hydro’s Duncan Dam. Fortis BC holds the water licence for Kootenay Lake, but no elevation is specified other than operations must be subject to the IJC.

Peak pre-regulation levels of Kootenay Lake were estimated to be 1761.95’ (1961). In 1974, the level of Kootenay Lake peaked at 1754.24’ (534.7 m) and resulted in flooding damage around the lake. In June 2012, the lake level reached 1753.8’ (534.6 m).. The RDCK Flood Construction Level is 1,760’, approximately 6’ greater than the onset of observed minor flooding issues.

Performance Measures

This measure indicates the expected frequency of years in which the elevation of Kootenay Lake is expected to exceed 1752’ and 1760’. 1760’ was selected as it is the Flood Construction Level used by the RDCK. A second measure, to reflect the onset of incidental flooding expected below the Flood Construction Level is 1,752’. This level has been exceeded on few occasions since 1984 and is one foot higher than the high lake alert elevation of 1751’ (533.7m).

Calculations

For each alternative:

1. Assemble the simulated results for reservoir elevations over the years (1948 - 1997).
2. Flag each year that has at least one day at or above i) 1760’ and 1752’

3. Sum the flagged years and divide by the number of years:

Key Assumptions and Uncertainties

Key assumptions include:

- The frequency of flooding is a proxy for the onset of nuisance damage > 1752') and significant damage (>1760') associated with flooding events;
- 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.

This latter point may not be the case, and the performance of Alternative 1 may be relatively under represented. See results below for further discussion.

Results

Throughout the modelled data set, there are no examples of water levels reaching 1760'

For 1752', the results appear to indicate that Alternative 2 is the best performer, followed by 3b, then Alternatives 1 and 3a (Figure 1).

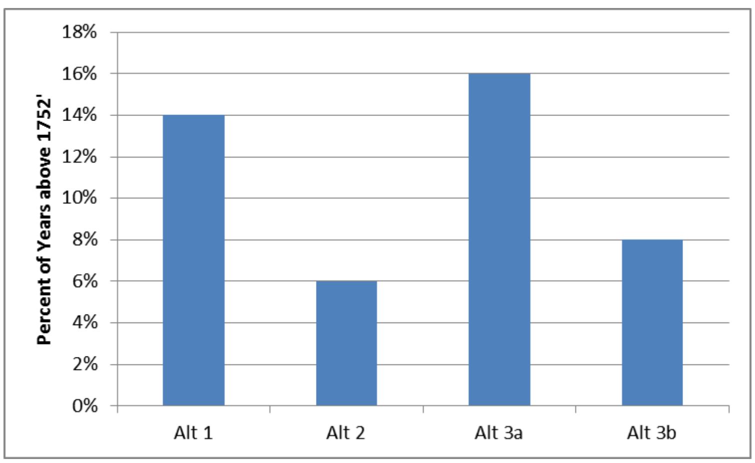


Figure 1. Kootenay Lake, percent of years where water levels exceed 1752'.

While it should be expected that Alternative 2 performs best, these results may be exaggerating the benefit of Alternative 3b over Alternative 1.

Under the current Alternative 1 operation, Libby releases a large volume of water for US sturgeon operations. The actual volume depends on the forecast, and the timing of the start date normally varies from around mid-May to mid-June. Modelling had assumed that this volume of water would be released at a rate up to maximum turbine flow (25 kcfs) starting on 1

Jun for usually around 3-4 weeks, and is assumed to be completed no later than 30 June. This volume of water drafts Lake Koocanusa, and coincides and contributes to the peak runoff at Kootenay Lake, thereby resulting in a higher peak level, peak flow and longer duration.

In Alternative 3b, the Libby operation is targeting refill to within 5 ft of full by 30 June. This target operation was assumed to have a higher priority over the sturgeon operation, and so, in years where the sturgeon operation drafts Libby below this target (most years), the sturgeon outflow volume was scaled down (as far as minimum flows in some years) to reach (or to get as close as possible to) the target. This results in lower Libby outflows in June and defers the peak outflows into July, when Kootenay Lake levels have already peaked and have started to recede. With the deferred peak flows from Libby, peak Kootenay Lake levels and outflows are lower and for a shorter duration.

It may generally be concluded that Alternative 2 performs best, and Alternative 1 and 3b likely perform similarly.

In all alternatives, Duncan simulation is similar to current operations (e.g. little or no contribution during peak freshet inflow).

PERFORMANCE MEASURE INFORMATION SHEET #58

KOOTENAY RIVER: VEGETATION AND WILDLIFE

Objective / Location	Performance Measure	Units	Description	MSIC
Multiple environmental objectives Wetland Habitat / Kootenay River	Cumulative habitat loss	Hectare days	Area calculated as a function of Corra Linn dam spills Lower is better	

Description

A high value wetland habitat exists immediately downstream of Corra Linn Dam on the Kootenay River. This wetland is comprised of a variety of habitat types that are used by a broad variety of obligate and facultative aquatic animals. The flood-affected wetland and pond habitats total 7.92 ha with maximum generation at Corra Linn Dam. During periods of spill at Corra Linn, this wetland area is at risk of inundation. As spills approach 63,500 cfs (1800 m3/s), the wetland habitat becomes fully inundated and no further impact occurs (other than the potential for erosion). Animals at greatest risk when the wetland is inundated are nesting birds, which either lose potential nesting sites or have their nests flooded out (potentially losing their chicks).

Performance Measure

Cumulative habitat loss: Area calculated as a function of Corra Linn dam spills, Lower is better

Calculations

From a series of habitat surveys carried out in the summer of 2012, wetland habitat inundation can be approximated using the following linear equation:

Wetland habitat lost (ha) = 7.92* Q_SpillCorraLinn/1800 if Q_SpillCorraLinn < 1800 m^3/s
= 7.92 if Q_SpillCorraLinn ≥ 1800 m^3/s

It is assumed that the greater the magnitude, duration and frequency of wetland habitat inundation, the greater the impact on wetland vegetation and wildlife. For the purposes of this performance measure, it is also assumed that wetland vegetation and wildlife risk is highest from April 1 to Oct 31.

It is assumed that, as the number of ha·days of inundated habitat increases, so does the risk to wildlife populations, including changes in wetland habitat structure. Therefore, the metric chosen to evaluate relative differences in wetland inundation risk between flow alternatives is the average number of ha·days of inundated wetland habitat (1 April to 31 Oct) per year.

Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1938 - 1998).

Results

For the median year, Alternative 2 results in the lowest spill rate for the period, while Alternatives 1 and 3a result in prolonged periods of high spill rates which are calculated to contribute to wetland habitat damage (Figure 1).

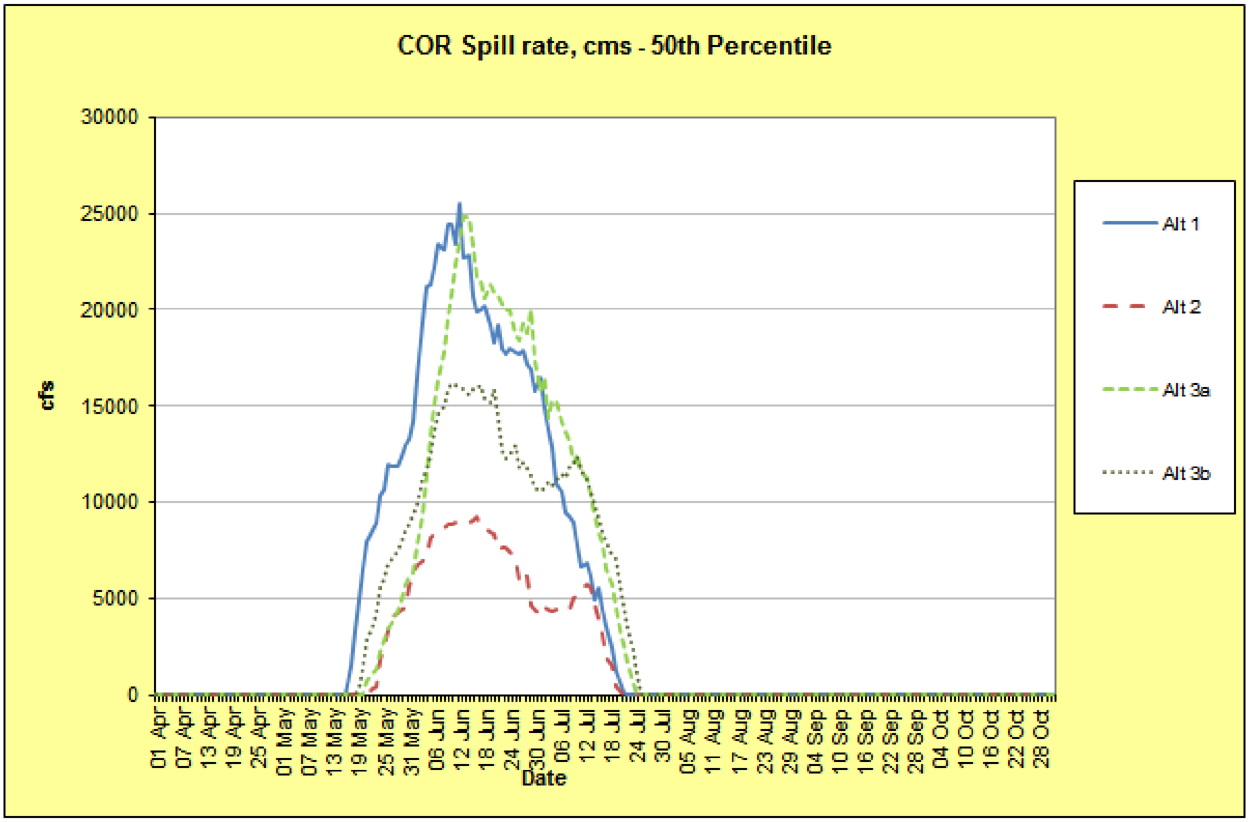
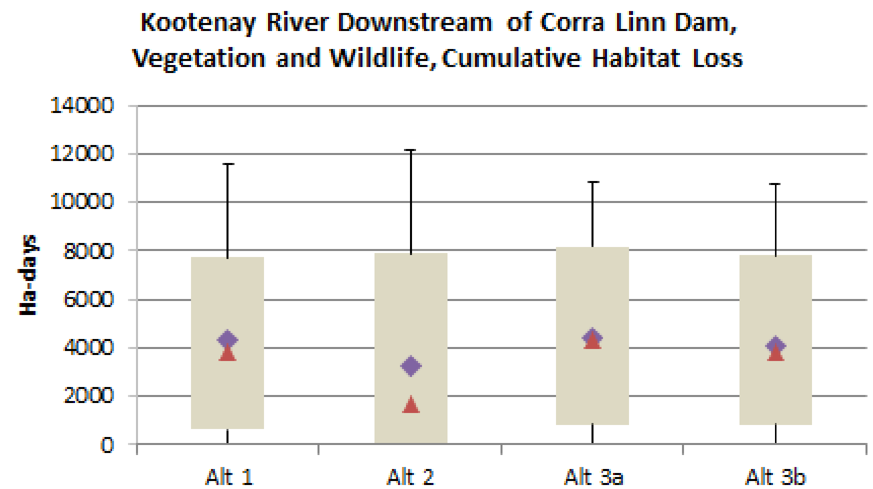


Figure 1. Kootenay River, Corra Linn Dam spill from April 1 to October 31.

In the average year, Alternative 2 results in the lowest hectare days of affected wetland habitat; (Figure 2).



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	11,595	12,152	10,854	10,783
90th	7,741	7,914	8,192	7,804
Median	3,830	1,703	4,338	3,796
Mean	4,307	3,242	4,400	4,089
10th	643	-	862	826
Min	-	-	-	-

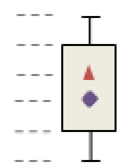


Figure 2. Cumulative habitat loss downstream of Corra Linn Dam

PERFORMANCE MEASURE INFORMATION SHEET #59
KOOTENAY RIVER: FISH AND AQUATIC ECOSYSTEM HEALTH

Objective / Location	Performance Measure	Units	Description	MSIC
Fish / Kootenay River	Total Dissolved Gases	# of days gases exceed 115% pressure threshold (1 Jan to 31 Dec)	Function that relates TDG to spills at Corra Linn dam Lower is better	

Description

Air supersaturation in water can lead to gas bubble trauma in fish if exposed to gas pressures above 115% saturation. This trauma is the result of bubble formation in tissues that can impair body function (swimming ability, respiration, vision, etc.) and, hence, foraging success or predator avoidance. In vital tissues such as the brain and heart, high gas levels can lead to direct mortality.

The duration of exposure, as well as the frequency of episodic exposure events, has also been shown to be a critical factor governing the degree and extent of gas bubble trauma in fish.
Total gas pressure measurements taken downstream of Slocan Dam have shown that spill discharges at the upper four Kootenay River plants (Corra Linn spill is used as the proxy) can create air supersaturation conditions that exceed the 115% threshold.

Calculations

The relationship between spill and gas supersaturation is linear and is characterised by the following regression equation (assuming full generation at the 4 Kootenay River plants and the Kootenay Canal plant):

% Saturation = 112.4 + 0.01 * Q_SpillCorraLinn (in m3/s) (Max Q_SpillCorra Linn = 2000 m3/s)

The metric to evaluate relative differences in gas bubble trauma risk between flow alternatives is:

- average number of %Sat·Days per year when total dissolved gas exceeds 115% Saturation
  (It is assumed that as the number of %Sat·Days increases, so does the risk of gas bubble trauma.)

The %Sat·Days variable was averaged across all years of simulation; other summary statistics are possible.

Key Assumptions and Uncertainties

- Each alternative is simulated using the same set of system constraints, input assumptions (e.g., load forecasts) and historic basin inflows (1948 – 1997).

Results

For the median year the spillage from the Corra Linn Dam begins in early May and finishes before the end of July. However, spills may occur in winter months also.

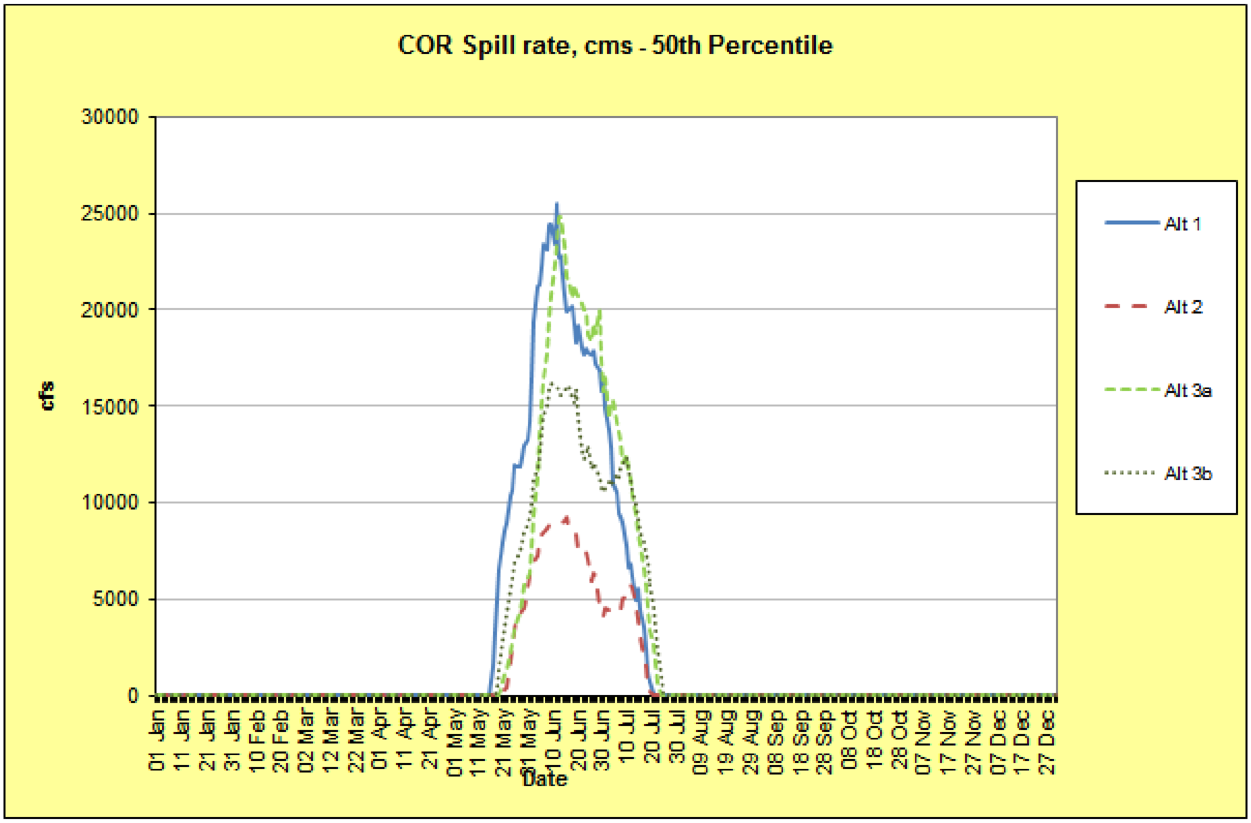
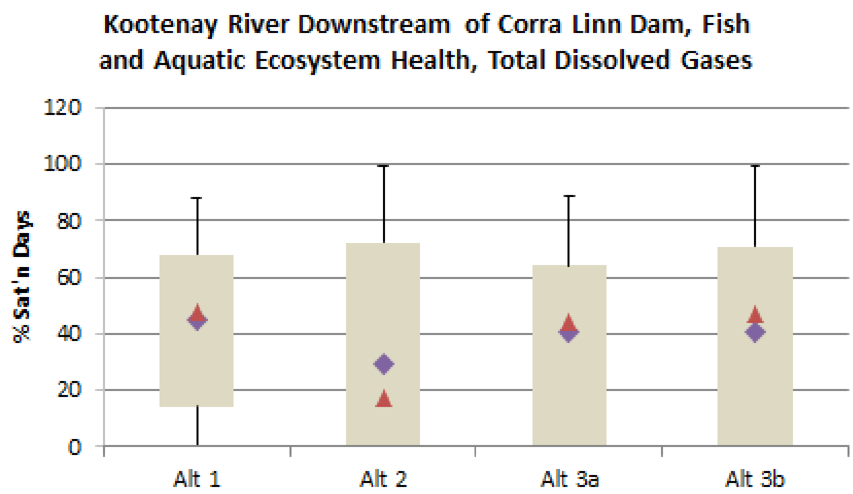


Figure 1. Kootenay River, Corra Linn Dam spill rates from May 1 to July 31.

Alternative 2 exhibits the lowest percent of saturation days for the median year (Figure 2).



	Alt 1	Alt 2	Alt 3a	Alt 3b
Max	88	99	89	99
90th	68	72	64	71
Median	48	18	45	47
Mean	45	29	41	40
10th	14	-	-	-
Min	-	-	-	-

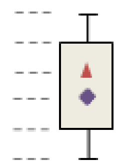


Figure 2. Kootenay River, percent saturation days between January and December, median year.

PERFORMANCE MEASURE INFORMATION SHEET #60
KOOTENAY: VALUE OF POWER

System Wide – Value of Energy

Objective / Location	Performance Measure	Units	Description	MSIC
Average annual value of Kootenay system energy in Canada	Average Increase in Value of Canadian Electricity Generation Relative to Alt 1	$ millions / yr	The relative increase in Canadian power value relative to Alternative 1 Higher is better	NA

Description

The primary driver of changes to water management alternatives in the Kootenay system come from changes in Libby dam operations, the financial consequences of which to the United States are outside the scope of this analysis. However, the water management alternatives in this review could affect the ability of BC to generate electricity through Canadian dams in the Kootenay system. This performance measure tracks the financial value associated with this change in Canadian electricity generation.

Performance Measures

The performance measure is the Average Increase in Value of Canadian Electricity Generation Relative to Alt 1. It is measured in $millions / yr.

Calculations

Monthly estimates of Canadian Kootenay River generation (in GWh) are multiplied by average assumed monthly values for energy in $ / MWh

For each alternative:

1. Assemble values for Canadian Kootenay River generation (in GWh) from model
2. Multiply 1. by assumed values of electricity per month in 2024
3. Sum the monthly values
4. Calculate the difference of each alternative relative to Alternative 1.

Key Assumptions and Uncertainties

- Monthly pricing values are quite uncertain, but the relative ordering of the alternatives will be unaffected by this assumption.

Results

Alternative 2 has deeper drafts associated with flood control curve results in greater flows from Dec-Apr and less spill in May-Jul, resulting in more generation than Alternative 1 (Figure 1)

Alternative 3a and 3b have higher performance than Alternative 1 primarily due to spill reduction in May and higher generation in Jul-Oct.

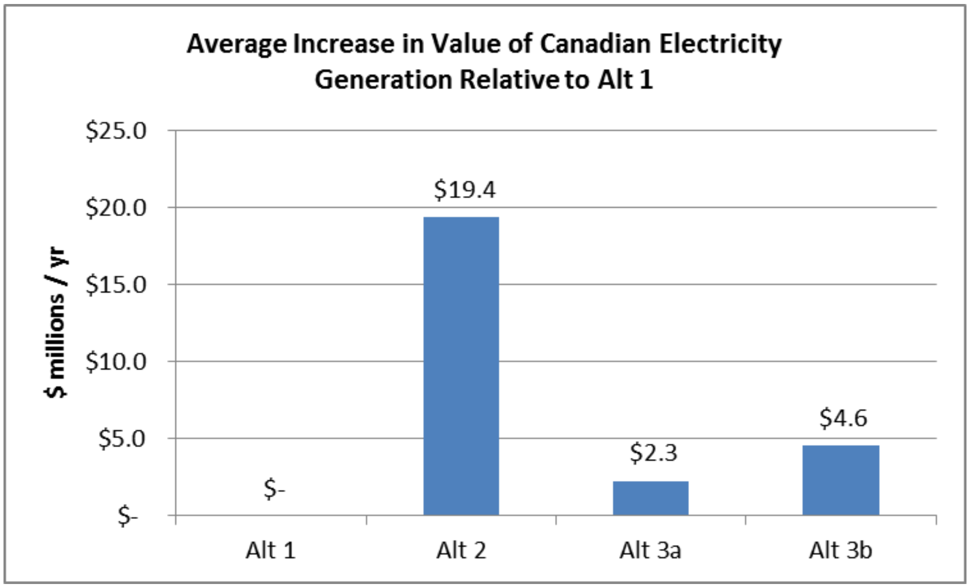


Figure 1: Average Increase in the Value of Electricity Generated in Canada