BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

MINISTRY OF ENERGY, MINES AND NATURAL GAS

LIBBY VARQ FLOOD CONTROL IMPACTS ON KOOTENAY RIVER DIKES

FINAL

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November 7, 2012
Project No: 0640-002

Chris Trumpy
Ministry of Energy, Mines and Natural Gas
PO Box 9053 Station Provincial Government
Victoria, BC V8W 9E2

Dear Mr. Trumpy,

Re: Libby VARQ Flood Control Impacts on Kootenay River Dikes

Please find enclosed a FINAL report for the above-referenced study. If you have any questions or comments, please contact the undersigned at (604) 629-3850.

Yours sincerely,

BGC ENGINEERING INC.
per:

Hamish Weatherly, M.Sc., P.Geo.
Senior Hydrologist

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LIMITATIONS

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1.0 INTRODUCTION

Under the terms of the Columbia River Treaty, Canada permitted the U.S. to build the Libby Dam on the Kootenai River (U.S. spelling) in Montana. The dam was completed in 1973 and the reservoir, flooding approximately 70 kilometers into Canada, filled for the first time in 1974. Under the Treaty, operation of Libby Dam was to be coordinated with Canada. Operations of Libby Dam from 1973 through 1992 were managed to optimize power generation and flood control in the two countries.

Since construction of Libby Dam, average mean annual peak floods on the Kootenay River, as measured at the Canada-US Border, have decreased by more than a factor of two, while fall and winter mean discharges have increased by a factor of three to four times. Similarly, Kootenay Lake peak water levels have decreased on average by about 2 m. This result is not unexpected as Libby Dam regulates about 70% of the total Kootenay River runoff at the border and about 45% of the total inflow into Kootenay Lake.

In 1993, the U.S. Army Corps of Engineers, responding to U.S. regulatory agency concerns, began to operate Libby in a manner designed to benefit downstream sturgeon spawning, with less water released from Libby during the fall and winter and more water released during the spring and summer. This operation resulted in power losses, including additional spill and reduced seasonal value, at downstream Canadian hydropower plants on the Kootenay River system. The Canadian Entity objected to this unilateral operating change. The dispute was set aside with the signing of the Libby Coordination Agreement.

In return for Libby Dam operations that meet U.S. regulatory requirements for fish, the Libby Coordination Agreement gives Canada the flexibility to self-compensate for its Kootenay River power value losses. Canada has the option to release water from the Arrow Lakes Reservoir and receive the resulting power generated at U.S. federal plants during periods of high power value. Canada returns the power to the U.S. during times of lower power value, with the value difference being the net compensation to Canada. Under the Libby Coordination Agreement, Canada also obtains some non-power benefits, including more favourable Treaty requirements on Arrow discharges during January, which benefits mountain whitefish spawning, and an option to exercise an Arrow-Libby “storage swap” agreement when beneficial to Canada. This “storage swap” agreement has been used in several years to improve recreational conditions for the communities on Koocanusa Reservoir.

Until 2002, Libby Dam operations continued to observe the “Standard Flood Control” regime that had been in place since dam operations began. However, in response to a 2000 Biological Opinion, under the U.S. Endangered Species Act, Libby began operating to an interim alternative flood control procedure referred to as “Variable Flow” or “VARQ”. Libby dam began discharging less water during the fall/winter period and more water during the spring/summer to benefit downstream fish. However, this new flood control operating regime also resulted in slightly higher frequencies of peak water levels on Kootenay Lake and on the Columbia River downstream of Castlegar.

In June 2008, the U.S. Entity permanently adopted VARQ Flood Control (FC) for Libby which, while still providing significant energy benefits and flood protection for Canada, does so at a reduced level compared to the terms expected by Canada when it ratified the Columbia River Treaty. The Canadian Entity notified the U.S. that compensation would be required for the reduced levels. The Columbia River Treaty Operating Committee has made some good progress on this issue, but has not yet reached final agreement.

Local residents of the Creston Valley have recently expressed concern that implementation of VARQ FC has resulted in increased bank erosion along the Kootenay River, which in turn has impacted diking infrastructure as a significant proportion of the dikes are located immediately adjacent to the river. The Columbia River Treaty Review Team (CRTRT), a branch of the Ministry of Energy, Mines and Natural Gas (MEM), has retained BGC Engineering Inc. (BGC) to evaluate the concerns of the local residents, who are amalgamated into a number of Diking Districts. The proposed scope of work is to investigate whether implementation of VARQ FC has had a significant negative impact on diking infrastructure adjacent to the Kootenay River between the Canada-US border and Kootenay Lake.

2.0 STUDY AREA

2.1. Kootenay River Basin

The Kootenay River basin is located in southeast British Columbia, northwest Montana, and northern Idaho (Figure 2-1). At its confluence with the Columbia River near Castlegar, British Columbia, the Kootenay River (spelled Kootenai in the US) drains an area of approximately 50,027 km^2.

The Kootenay River originates at the continental divide along the British Columbia-Alberta border and flows south into Montana. In Montana, the Kootenai River is impounded by Libby Dam: an 880 m wide, 132 m high structure completed in 1972 (Corps, 1984). The impoundment behind Libby Dam, known as Lake Koocanusa, is approximately 145 km long, a little less than half of which extends into British Columbia at full pool. Libby Dam has a drainage area of 23,270 km^2.

Downstream of Libby Dam, the river flows to the northwest passing through the towns of Libby, Troy, and Bonners Ferry, Idaho, before reaching the international border near Creston, BC. Major tributaries along this reach of the river include the Fisher and Yaak Rivers in Montana and the Moyie River in Idaho.

About 45 km north of the border, the Kootenay River discharges into the south end of Kootenay Lake, near the town of Kuskonook, British Columbia. The watershed area of the basin is about 37,000 km^2 at this point. Kootenay Lake is 100 km long and 3 to 5 km wide, and is oriented in a north-south alignment. Other major tributaries to Kootenay Lake include the Duncan and Lardeau Rivers, which join the lake at the north end. Flow from the Duncan River is regulated by Duncan Dam, which was completed in 1967. Kootenay Lake drains through the West Arm near Nelson, BC, eventually flowing into the Columbia River at Castlegar.

Kootenay Lake is a naturally formed lake whose levels have been regulated following construction of Corra Linn Dam and the excavation of Grohman Narrows near the lake's outlet near Nelson. Depending on how Corra Linn is operated, the hydraulic control for the lake outlet can either be the dam itself or a natural constriction known as the Grohman Narrows, located approximately 10 km upstream of the dam. The operation of Corra Linn is in accordance with the Kootenay Lake International Joint Commission (IJC) Order.

2.2. Study Area

The study area is confined to the reach of Kootenay River situated within the Creston Valley, which extends from the international border to Kootenay Lake, a straight line distance of approximately 30 km. The Kootenay River distance is significantly greater, 46 km, due to the meandering morphology of the river (Figure 2-2).

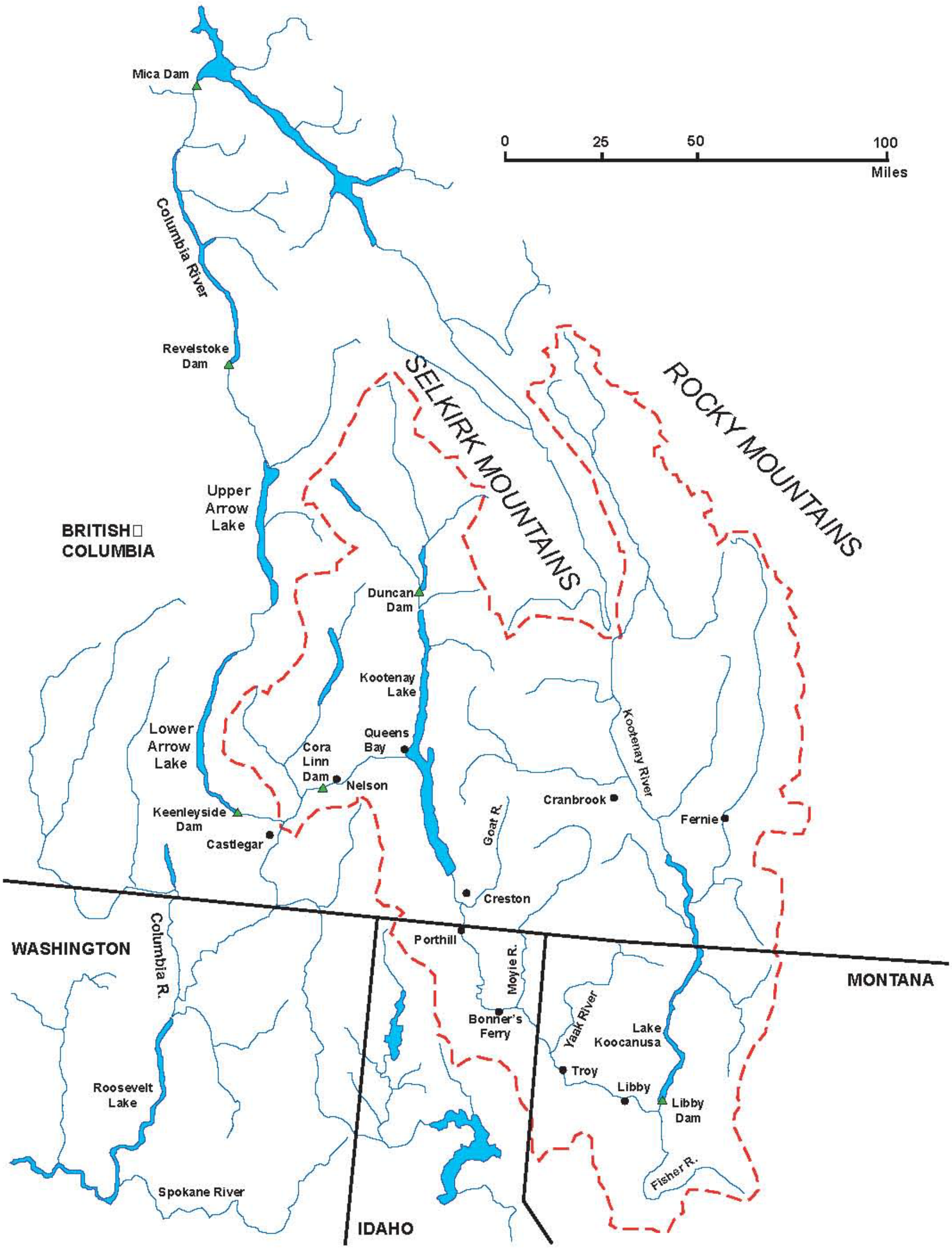

Figure 2-1. Kootenay River Basin

The Kootenay River is extensively diked and the floodplains behind the dikes have been used predominantly for agriculture, although they are also used for transportation corridors (Highway #3 and #21), and residential and commercial development. Construction of the main dikes commenced in the early 1930's, with significant damage incurred in both 1938 and 1948, during major freshet floods. Significant reconstruction of the diking system occurred after 1948 and ongoing annual maintenance has been required since then.

The floodplain of the Kootenay River is up to 6.5 km wide, and the river has an average width of 180 m and an average depth of 20 m. Prior to dike construction, flooding of the valley floor was common and the Lower Goat River flowed parallel to the Kootenay River before discharging into Kootenay Lake. The natural channel regime created a large inter-connected wetland ecosystem that was rich in aquatic and terrestrial habitat and species diversity. This diversity was significantly reduced following dike construction and a diversion of the Lower Goat River into the Kootenay River.

The dikes are managed and maintained by a total of five diking authorities and the Lower Kootenay Band (LKB) on Kootenay River, and one dike authority on the Goat River (Figure 2-2):

Table 2-1. Dike Authorities and Dike Length

Dike Authority	Dike Length (km)
Lower Kootenay Band	9.0
Reclamation Diking District	27.9
Creston Diking District	12.8
Nicks Island Diking District	16.1
Duck Lake Diking District	8.8
Creston Valley Wildlife Management Area	18.6
Goat River Residents Association	3.7

3.0 HYDROLOGY

3.1. General

Table 3-1 lists the main Canadian and American hydrometric stations that have operated in the study area. Critical stations for this study include the Kootenay River at Porthill, Idaho and Kootenay Lake at Kuskonook. The Porthill gauge is maintained jointly by the US Geological Survey (USGS) and Water Survey of Canada (WSC). This station has operated continuously since 1928 and includes pre- and post-Libby Dam conditions. While discharge data have been gathered since 1928 at Porthill, approved water level measurements are only available since 1961.

A number of water level gauges were operated along the Kootenay River between the international border and Kootenay Lake in the 1940's and 1950's. However, most of these stations were discontinued after a few years of operation. Stations that are currently active are highlighted in light grey in Table 3-1.

Table 3-1. Kootenay River and Tributaries Hydrometric Stations

Station	ID	Lat	Long	Type	Period of Record
Kootenay River at Kootenay Crossing	08NF001	50-53-10	116-02-35	Q	1939 – present
Kootenay River at Fort Steele, BC	08NH065	48-36-43	115-38-04	Q	1963 – present
Kootenai River at Libby Dam, MT	12301933	48-24-03	115-19-11	Q	1971 – present
Kootenai River at Bonners Ferry	12309500	48-42-00	116-18-45	W	1929 – present
Kootenai River near Copeland, ID	12318500	48-54-43	116-24-59	Q, S	1928 – 1992
Boundary Creek near Porthill	08NH032	48-59-50	116-34-05	Q	1925 – present
Kootenai River at Porthill, ID	12322000	49-00-00	116-30-10	Q	1928 – present
Kootenay River at Creston Ferry	08NH028	49-05-06	116-34-45	W	1925 – 1973
Goat River near Erickson	08NH004	49-05-21	116-27-20	Q	1914 – 1995
Kootenay River at Nicks Island	08NH129	49-07-02	116-34-39	W, S	1970 – 1987
Kootenay River near Creston (Well No. 436)	08NH094	49-09-01	116-35-55	W	1946 – 1950
Kootenay River at Goat Slough (inside dike)	08NH095	49-09-22	116-35-17	W	1946 – 1950

Station	ID	Lat	Long	Type	Period of Record
Kootenay River at Goat Slough (outside dike)	08NH096	49-09-22	116-35-17	W	1946 – 1950
Kootenay River at Duck Slough (inside dike)	08NH092	49-10-21	116-33-33	W	1946 – 1950
Kootenay River at Duck Slough (outside dike)	08NH093	49-10-21	116-33-33	W	1946 – 1950
Kootenay River (East Branch) near Sirdar	08NH098	49-11-13	116-37-38	W	1947 – 1955
Duck Creek near Wynndel	08NH016	49-12-10	116-31-56	Q	1921 – 1925, 1945 – 1954, 1979 – present
Kootenay River at Six Mile Lake	08NH060	49-15-10	116-40-41	W	1930 – 1931, 1946 – 1950
Kootenay River at Kootenay Landing	08NH062	49-15-08	116-40-59	W	1930 – 1938, 1944 – 1971
Kootenay River near Slough Bridge	08NH026	49-15-40	116-38-52	W	1925 – 1938, 1944 – 1971
Kootenay Lake at Kuskonook	08NH067	49-17-56	116-39-31	W	1936 – present
Kootenay Lake at Queens Bay	08NH064	49-39-16	116-55-47	W	1931 – present

W = water level, Q = discharge, S = suspended sediment concentration

Table 3-2 summarizes the mean annual discharge at various locations along the river. Values shown are for the common period of record of 1972 to 1994. Because mean annual discharge is averaged over the entire year, the comparisons are not impacted by seasonal flow regulation effects from Libby Dam.

Table 3-2. Mean Annual Discharge on Kootenay River (1972 – 1994)

Location	Gauge	Drainage Area (km^2)	Discharge (m^3/s)	Unit Flow ($m^3/h/km^2$)
Fort Steele, BC	08NH065	11,400	171	54
Libby Dam, MT	12301933	23,290	301	47
Porthill, ID	12322000	35,510	437	44
Goat River at Erickson	08NH004	1,180	24	74

Several observations can be made from Table 3-2:

- About 57% of the runoff into Koocanusa Reservoir (impounded by Libby Dam) originates upstream of Fort Steele, BC.
- Libby Dam regulates about 70% of the total Kootenay River runoff at Porthill, Idaho. The remaining 30% is generated from reaches downstream of the dam.
- The Goat River, which discharges into the Kootenay River just upstream of Creston, increases the mean flow by about 5%.

Because of the location and size of the Kootenay River watershed, runoff and peak flows are dominated by snowmelt. The spring freshet typically commences in April with peak flows occurring in May and June. In an unregulated scenario, flows generally decline gradually through the late summer and fall, with minimum flows occurring in March. The impacts of flow regulation by Libby Dam are analyzed further in the next section.

3.2. Libby Dam Flow Regulation

Discharges on the Kootenay River have been regulated since March 21, 1972 when Libby Dam became operational. Figure 3-1 illustrates the impact of the dam as observed at the Porthill, Idaho hydrometric station. Average daily discharge is plotted on this figure for two different periods: pre-Libby Dam (1929-1971) and post-Libby Dam (1973-2011).

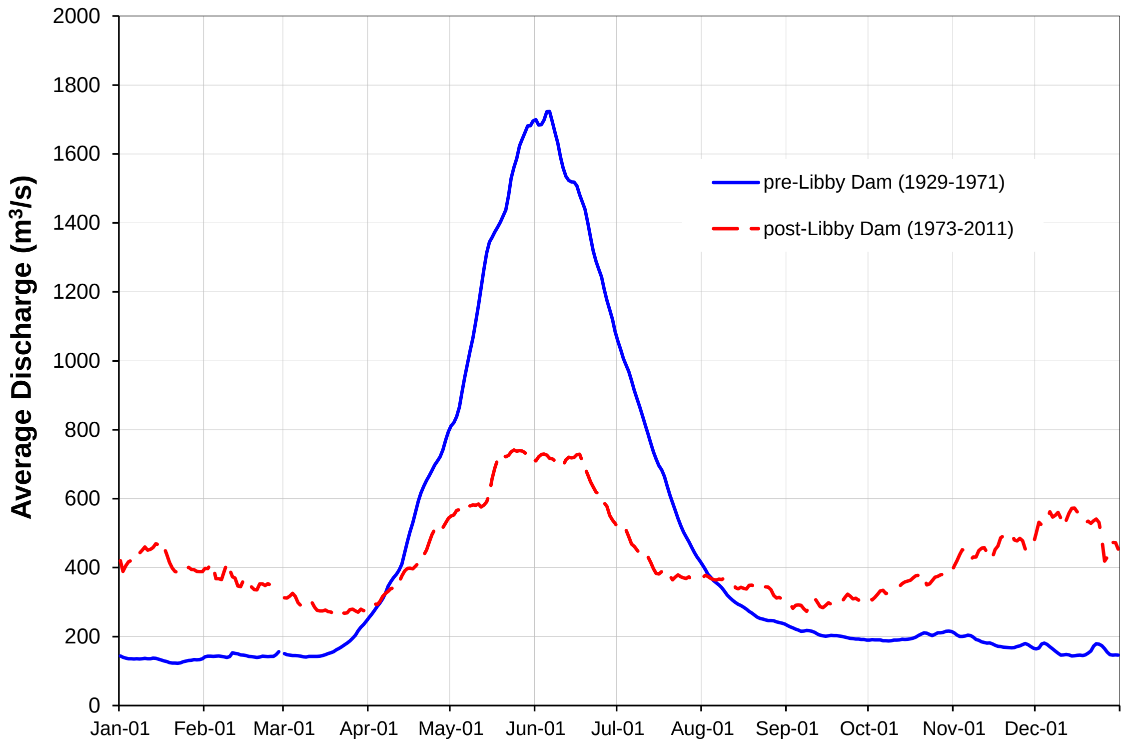

Figure 3-1. Average Discharge of Kootenay River at Porthill, Idaho

Average mean annual floods (MAF) have decreased by more than a factor of two, while mean discharges in the fall and winter have increased by a factor of three to four times due to hydropower releases. These trends are also presented as a frequency histogram (Figure 3-2).

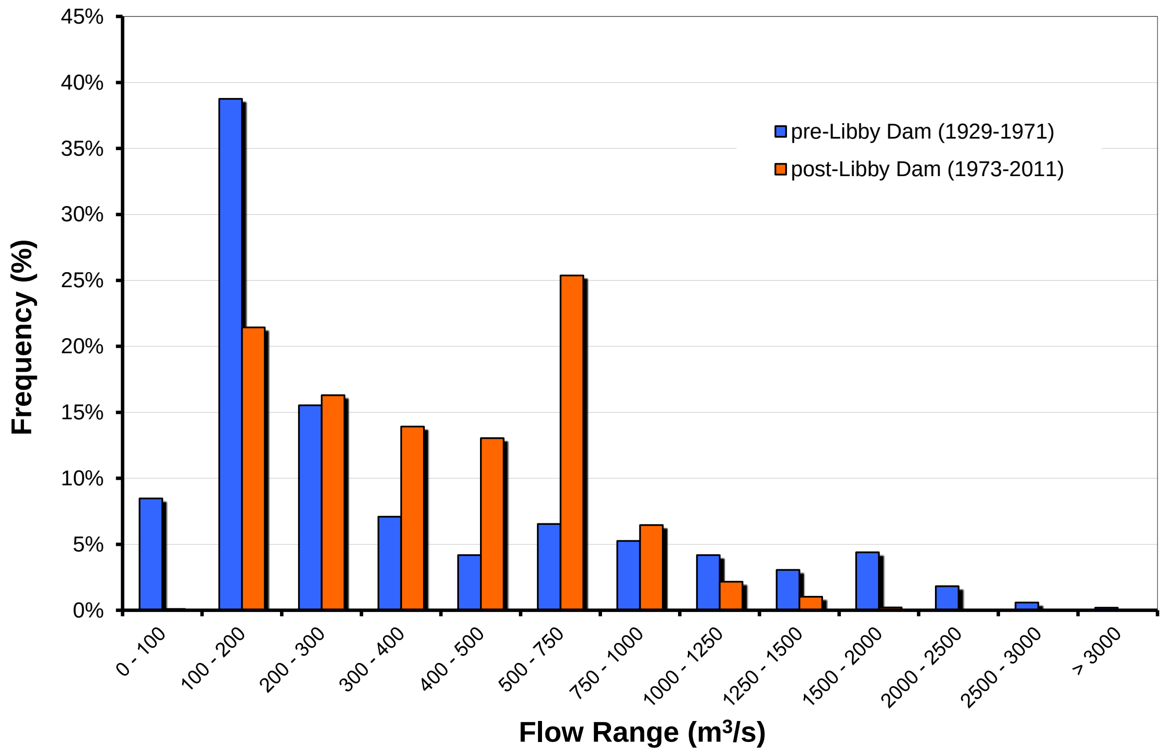

Figure 3-2. Histogram of Kootenay River Discharge at Porthill, Idaho

Both the pre- and post-Libby Dam duration curves indicate that for about 75% of the record, discharge remains below 650 m^3/s. However, the tails of the two periods are significantly different. Prior to Libby Dam, Kootenay River flows were below 200 m^3/s about 50% of the time, compared to 20% after dam construction. At the other end of the spectrum, flows used to exceed 1000 m^3/s 14% of the time. Since dam construction, this percentage has reduced to 3%.

Table 3-3 summarizes pre- and post-regulation statistics on peak and average flows. Average annual flows are similar for the two periods, which is expected as Libby Dam only regulates peak flows not runoff volumes. The MAF has decreased by a factor of 2.2 due to dam construction, while the highest recorded flood has decreased by a factor of 2. In fact, the highest recorded flood at Porthill (1,775 m^3/s on June 20, 2006) since dam construction is less than the MAF for the 1929-1971 period (2,222 m^3/s).

Table 3-3. Pre- and Post-Libby Dam Kootenay Flow Statistics at Porthill, Idaho

	Pre-Libby Dam 1929-1971	Post-Libby Dam 1973-2011
average flow (m^3/s)	456	432
mean annual flood (m^3/s)	2,222	1,110
highest recorded flood (m^3/s)	3,540	1,775

The impact of flow regulation on peak flows is also illustrated by Figure 3-3, which plots peak annual flows at the Porthill gauge for the period 1929-2011. The significant impact of Libby Dam in reducing peak annual flows at Porthill is obvious on this figure.

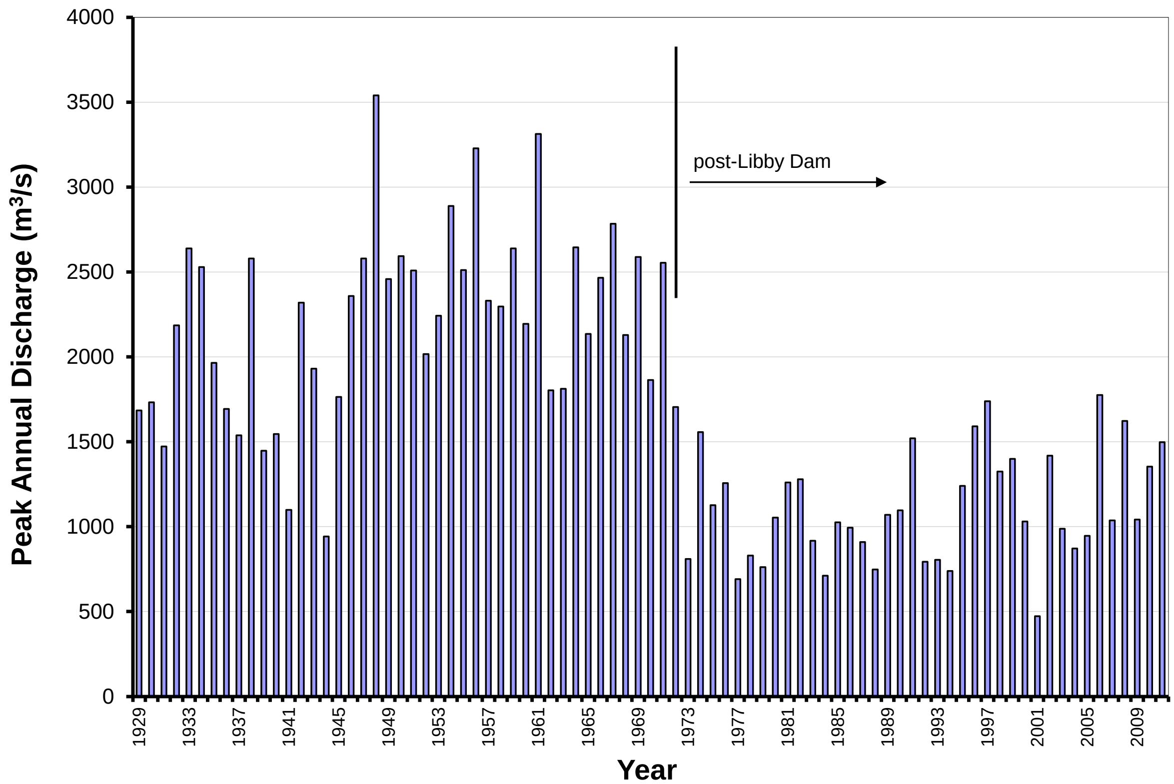

Figure 3-3. Annual Peak Flows on Kootenay River at Porthill, Idaho

3.3. Kootenay Lake Levels

Outside of climatic factors, Kootenay Lake levels are controlled by a number of factors including:

- Corra Linn Dam and Kootenay Canal Project operations
- Grohman Narrows – west arm channel restriction
- Duncan Dam operations
- Libby Dam operations.

The operations of Corra Linn Dam has an impact on lake levels, as the dam provides up to 6 feet (1.8 m) of storage (or 987 Mm^3). However, there are a number of restrictions that place a limit on dam operations during the spring freshet. These restrictions are per a 1938 Order from the International Joint Commission and are intended to limit the potential backwater effect of lake levels impacting farmers in Idaho. The Kootenay Canal Project, built in parallel with Corra Linn in the 1970's, has increased the turbine, but not the total (turbine plus spill), discharge capability for the lake.

Grohman Narrows was a natural constriction of the West Arm of Kootenay Lake and is located about 10 km upstream of Corra Linn Dam (Figure 3-4). The feature is named after William Adolph Baillie-Grohman who, late in the 19^{th} century, attempted to deepen the narrows in an early (and unsuccessful) effort to reclaim the farmlands of the Creston Valley and Kootenai Flats in the US. The narrows remained intact until the West Kootenay Power and Light Company dredged the constriction as a condition of the International Joint Commission's 1938 Order for Kootenay Lake. The Order stipulated that at least 250,000 yd^3 of rock, gravel and boulders were to be removed from Grohman Narrows and at least 14,000 yd^3 of a rock bluff jutting into the narrows on the south side. Excavation of Grohman Narrows reportedly lowered potential flood levels on Kootenay Lake by about 1 m. To this day, during the rising limb of the spring freshet and, normally, until after the peak annual level has occurred, water levels in Kootenay Lake continue to be controlled by the Narrows.

Duncan Dam was completed in 1967; one of the three storage projects built in Canada as a result of the Columbia River Treaty (CRT). Duncan Lake is a storage reservoir that does not generate hydro power. Rather it:

- improves the amount and timing of power generation for downstream hydro projects
- provides some downstream flood control benefits
- provides fish flow regulation in the Duncan River below the dam.

The dam has a watershed area of 2,410 km^2 and regulates approximately 13% of runoff in the Kootenay Lake basin (BC Hydro, 2007).

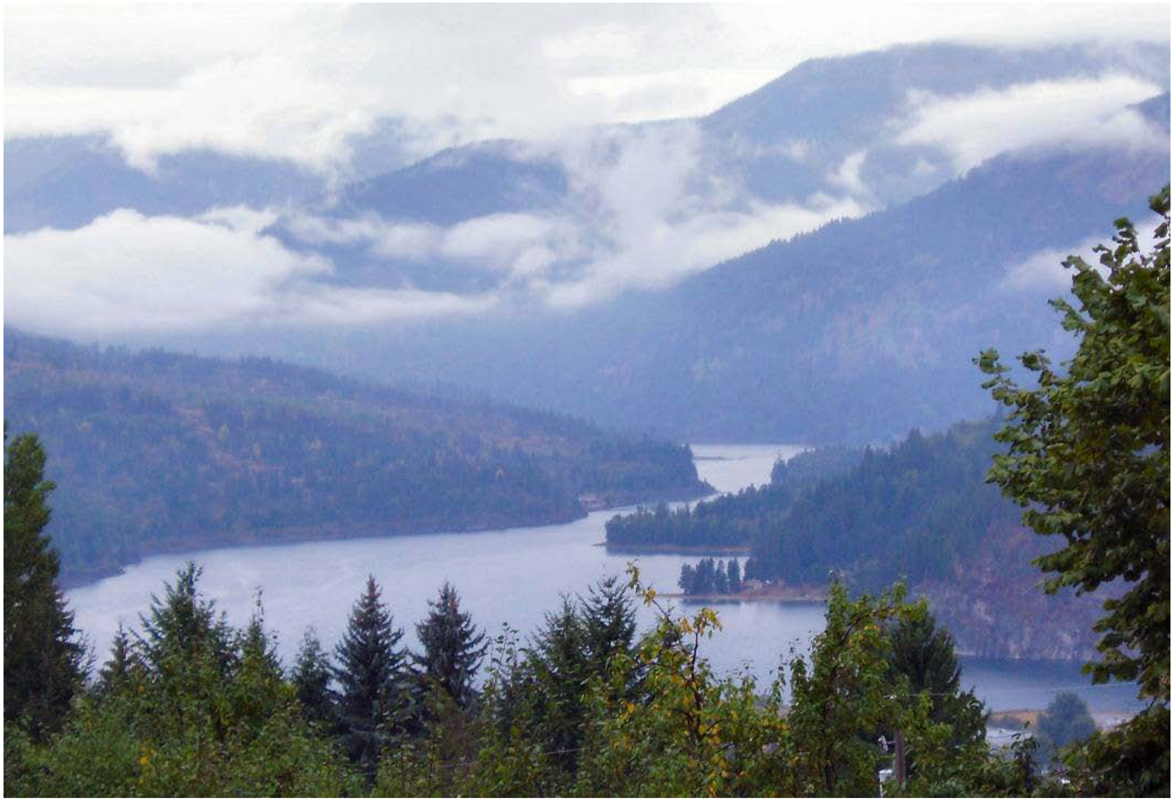

Figure 3-4. Upstream View of Grohman Narrows (IJC, 2007)

While all these controls have had an impact on Kootenay Lake levels, the impacts of Libby Dam have been the most significant. Figure 3-5 shows average lake levels[1] at Kuskonook for two different periods: pre-Libby Dam (1938-1971) and post-Libby Dam (1973-2010). Winter lake levels are similar between the two periods, but peak lake levels have decreased by 2 m. Given that Libby Dam regulates approximately 40% of runoff to Kootenay Lake (BC Hydro, 2007), this result is not surprising.

Figure 3-6 plots peak annual lake levels at Kuskonook for the period 1936-2010: the difference between the pre- and post-regulation period is striking.

[1] Note that Kootenay Lake levels are reported to Canadian Geodetic Vertical Datum (CGVD) 1928.

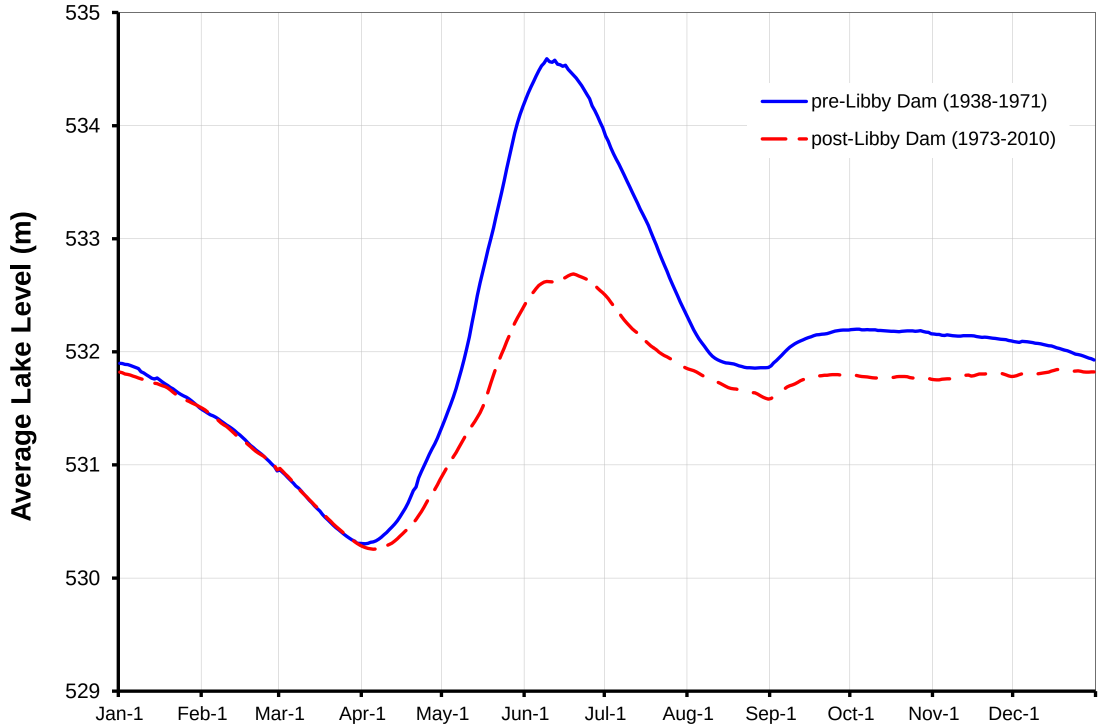

Figure 3-5. Kootenay Lake Levels at Kuskonook

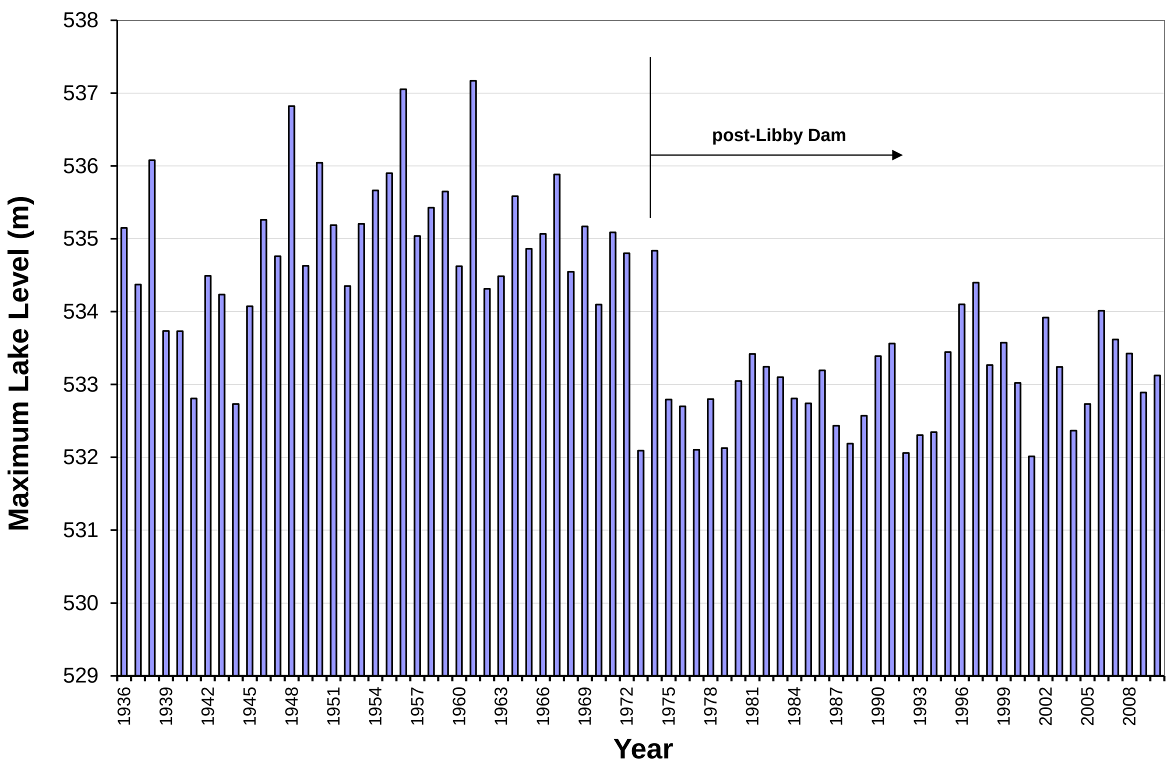

Figure 3-6. Annual Maximum Kootenay Lake Levels at Kuskonook (1936 to 2010)

Table 3-4 summarizes pre- and post-regulation statistics on peak and average lake levels. Average annual lake levels have decreased on average by 0.5 m, while the mean annual flood level has decreased on average by 2 m due to dam construction. In fact, the highest recorded level at Kuskonook (534.8 m on June 24, 1974) since dam construction is less than the mean annual peak level for the 1936-1971 period (535 m).

Table 3-4. Pre- and Post-Libby Dam Kootenay Lake Levels at Kuskonook, BC

	Pre-Libby Dam 1938-1971	**Post-Libby Dam 1973-2010**
average level (m)	532.1	531.6
mean annual peak level (m)	535.0	533.0
highest recorded level (m)	537.2	534.8

3.4. Operation of Libby Dam

Libby Dam is a multi-purpose storage project that: provides storage for flood control on the lower Columbia River; local flood control on the Kootenay River and Kootenay Lake; hydroelectric power generation at site (525 MW capacity); and, increased power production at downstream powerplants in both countries. The dam is operated by the US Army Corps of Engineers (Corps).

Since it went into operation, the operating regime for Libby Dam has changed several times. Releases from the dam have varied over the years due to changing flood storage requirements and flow releases for different fish species. There have been three major operating regimes for Libby Dam:

- **1973 to 1992** – Standard Flood Control regime with operation of the dam driven almost exclusively by flood control and power.
- **1993 to 2002** – Standard FC regime continues and flood control remains a top priority. However, operations for downstream fisheries has a higher priority than power operations. During this period, discharge ramping rate restrictions were also adopted in the late 1990’s.
- **2003 to Present** – Variable Flood Control regime is adopted. With this regime there are higher flood control curves for most water conditions, although flood control remains a top priority. Operations for downstream fisheries continues to have higher priority than operations for power.

More detail for each of these periods is provided below.

3.4.1. Standard Flood Control – 1972 to 1992

The procedure for Libby Dam flow releases originally authorized for use is referred to as Standard Flood Control (FC) (Corps, 2004). Under Standard FC, Libby Dam was regulated according to the Columbia River Treaty Flood Control Operating Plan

(Corps, 1972), as amended by the review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63 (Corps, 1991). A storage reservoir diagram (SRD) specific to Libby Dam was used in combination with Libby's seasonal water supply forecasts to determine how much space in Libby Dam needed to be made available by March 15 for flood control (Corps, 2004). As the season progressed and forecasts changed, so did the storage requirements. Under this regime, Libby Dam had a minimum outflow requirement of 4,000 cfs (113 m^3/s) throughout the year.

3.4.2. Standard Flood Control – 1993 to 2002

Under Standard FC, Libby Dam would generally release high flows from January through April in order to increase storage capacity to capture the spring runoff in May, June and July (Corps, 2006). This process of reducing reservoir levels is called drafting. Because Lake Koocanusa drafted a large amount of water storage under Standard FC, Libby Dam historically released little water from May to July in order to refill.

Eventually it was realized that this strategy was detrimental to several fish species. From 1993 to 2002, while Standard Flood Control procedures remained in place, the operation of Libby Dam was altered to provide more water for fish particularly during the freshet, with operations for power taking a lower priority.

Prior to the mid-1990's, aggressive Libby discharge changes, normally caused by "load following" needs in the Pacific Northwest electrical system, caused rapid changes in Kootenay River flows and significant changes in water level over a period of several hours. Such fluctuations were eventually found to be detrimental to fish and invertebrates, and have also been identified as a major factor in increased bank erosion rates observed in the Creston Valley (NHC, 1999). As a result of the fisheries findings, the Corps began to institute limits on the ramping rate for Libby discharge changes in the late 1990's.

3.4.3. VARQ Flood Control – 2003 to Present

In December 2000, the US Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS)[2] each issued a Biological Opinion outlining measures to protect endangered species including sturgeon, bull trout, salmon and steelhead. Recommended measures included implementation of VARQ (variable flow) Flood Control procedures at Libby Dam. The intent of VARQ Flood Control (VARQ FC) is to provide additional flows for downstream fish while increasing the likelihood of reservoir refill and continuing to provide adequate downstream flood protection. VARQ FC allows for more assured provision of flows for endangered Kootenai River white sturgeon, threatened bull trout in the Kootenai River, and various listed stocks of salmon and steelhead in the Columbia.

[2] Also known as NOAA Fisheries.

With VARQ FC, the release during refill varies according to the reservoir level, water supply forecast and the estimated duration of flood control. VARQ FC is intended to provide a similar level of flood protection as Standard FC, but with improved flow augmentation for fish. Standard and VARQ Flood Control have the same storage space for flood control when the water supply forecast is greater than 120% of normal. In practice, there is only a difference between the two methods when the inflow forecast falls between 80% and 120% of normal (Corps, 2004). Within this range some of the water that would be stored during the refill period under Standard FC is instead passed through the dam under VARQ FC. Further details on the differences between Standard and VARQ FC are provided in Corps (2004).

An Environmental Assessment (EA) for interim implementation of VARQ FC with fish flows (including sturgeon flows up to powerhouse capacity plus 1 kcfs spill) received a finding of No Significant Impact in December 2003 (Corps, 2002). Since then, the Corps has operated Libby Dam according to VARQ FC procedures and has continued to provide fish flows.

In 2006, the Corps in cooperation with the Bureau of Reclamation prepared a final Environmental Impact Assessment (EIS) on the Upper Columbia Alternative Flood Control and Fish Operations, Columbia River Basin. This final EIS addressed the long-term implementation of VARQ FC at Libby Dam and evaluated the potential effects of fish flow operations involving discharges greater than the existing powerhouse capacity[3] of 25,000 cfs (708 m^3/s), actions which were beyond the scope of the interim decision-making process. The EIS includes input from a revised Biological Opinion submitted by the USFWS on February 18, 2006.

The Canadian Entity under the Columbia River Treaty (BC Hydro) continues to object to the Corps' unilateral adoption of VARQ FC on the grounds that Libby, while still providing significant energy benefits and flood protection for Canada, does so at reduced levels compared to the terms expected by Canada when it ratified the Treaty. The Treaty Operating Committee has made progress towards resolving this issue, but there is not, as yet, a final agreement.

3.4.4. 2006 USFWS Biological Opinion

The USFWS Biological Opinion (2006) includes recommendation for flow ramping rates (up and down), flow augmentation, minimum flows, and habitat improvements in the Kootenai River. The first three items are discussed in more detail below.

Table 3-5 summarizes proposed ramp rates for Libby Dam.

3 Powerhouse capacity actually ranges from 19,000 cfs (538 m^3/s) to 27,600 cfs (782 m^3/s), depending on the reservoir pool elevation (i.e. hydraulic head).

Table 3-5. Proposed Daily and Hourly Ramp Rates for Libby Dam (USFWS, 2006)

Summer (May 1 to September 31)			
	Flow Release (m^3/s)	**Max Hourly Change (m^3/s)**	**Max Daily Change (m^3/s)**
Ramp Up	113 – 170	71	1 unit
	170 – 255	71	1 unit
	255 – 453	71	2 units
	> 453	142	2 units
Ramp Down	113 – 170	14	14
	170 – 255	14	28
	255 – 453	28	71
	> 453	99	1 unit
Summer (October 1 to April 30)			
Ramp Up	113 – 170	57	1 unit
	170 – 255	57	1 unit
	255 – 453	99	2 units
	> 453	198	2 units
Ramp Down	113 – 170	14	28
	170 – 255	14	71
	255 – 453	28	1 unit
	> 453	99	1 unit

1 generating unit is ~ 140 m^3/s

Flow augmentations (or "fish flows") recommended by the USFWS (2006) are as follows:

Sturgeon

During the spring freshet, flows are released from Libby Dam for sturgeon spawning and recruitment in the Bonners Ferry reach. The recommended flow augmentation volume varies between 0.8 and 1.6 million acre feet (MAF) as a function of the seasonal water supply forecast. If the seasonal water supply forecast for the April-August period is less than 4.8 MAF (5,921 Mm^3), no flow augmentation is provided for sturgeon.

Table 3-6 is a summary of the recommended flow releases, including probability of occurrence.

Table 3-6. Libby Dam VARQ FC Sturgeon Flow Augmentation Volumes (USFWS, 2006)

Tier	Runoff Forecast April-August (MAF)	Augmentation Volume (MAF)	Probability of Occurrence
1	< 4.8	0	0.12
2	4.8 – 6.0	0.8	0.30
3	6.0 – 6.7	1.12	0.14
4	6.7 – 8.1	1.2	0.33
5	8.1 – 8.9	1.2	0.07
6	> 8.9	1.6	0.04

These flow augmentations would be used in May, June and July, and are measured as a volume out of Libby Dam above a minimum flow of 4,000 cfs (113 m^3/s).

Based on the April-August flow forecast (final May forecast), sturgeon flow augmentation would commence on or about May 15[4], targeting use of 45% of the tiered volume by June 1. Maximum discharge should occur during the last week of May and first week of June. Maximum flow releases would occur for a maximum duration of 14 days and minimum of 2 days. The maximum augmentation flows are intended to initiate migration and spawning behaviour of sturgeon. Maximized flows would include pulses, which refer to slight reductions in flow, as Kootenai sturgeon spawn on the declining limb of the hydrograph.

The remaining volume will be shaped over June (45%) and July (10%), targeting a final ramp down to reach minimum bull trout tiered flows by July 15. Higher tier years will have a more gradual ramp-down from powerhouse capacity, while lower tier years will have a more pronounced rise in May towards a peak. The post-peak augmentation flows are for the benefit of sturgeon incubation and rearing. Figure 3-7 is a schematic of the recommended Libby Dam release hydrograph during the freshet. Sturgeon augmentation flows would be curtailed if required for downstream flood control purposes.

[4] If possible, flow releases would be delayed so as not to substantially decrease river temperatures downstream of the dam. Ideally, water temperatures in the top 20 feet of the forebay would be within 2°C of the river temperature at Bonner's Ferry.

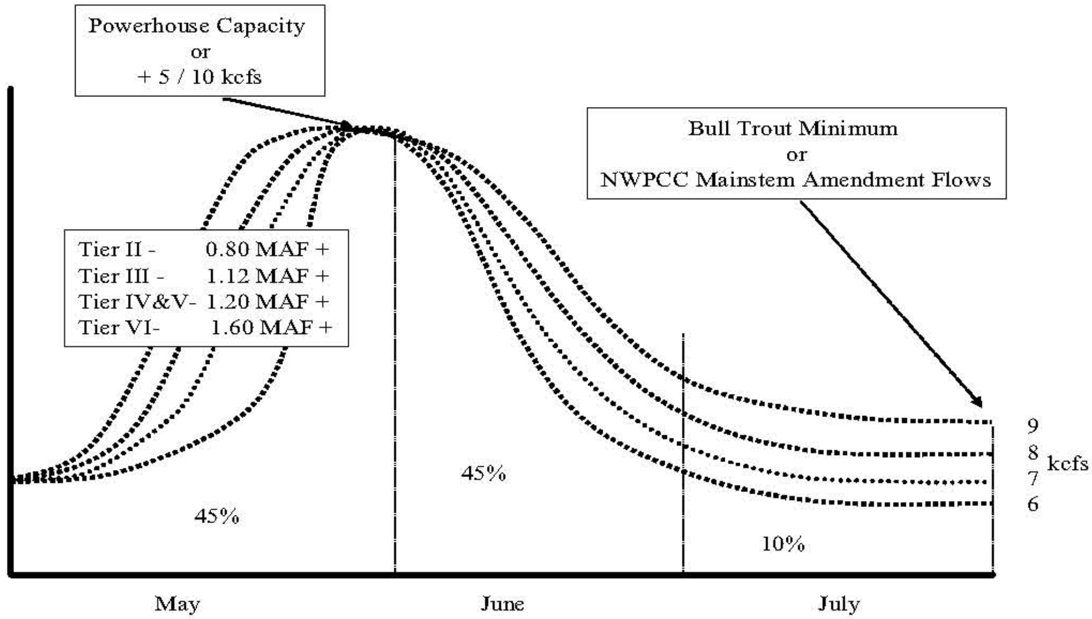

Figure 3-7. Schematic of USFWS (2006) Recommended Spring Freshet Hydrograph from Libby Dam (not to scale)

<u>Bull Trout and Salmon</u>

Between May 15 and September 30, a minimum bull trout flow of 6,000 cfs (170 m^3/s) is also required. The bull trout flow augmentations vary up to 9,000 cfs (255 m^3/s) depending on the April-August flow forecast volume. The remainder of the year a minimum flow release of 4,000 cfs (113 m^3/s) is maintained from Libby Dam for resident fish.

Steady-state outflows in August and September also benefit salmonid habitat in the Lower Columbia. If water for salmon is released only in August, there is the potential for a double-peak of outflows in the summer. In that scenario, a drop in outflows following sturgeon operations reduces the wetted perimeter of the channel and impacts aquatic invertebrates and juvenile fish. It is preferred to keep the river margins consistently submerged between the period of flow augmentation for sturgeon and salmonids.

In order to minimize loss of river productivity in October, the USFWS (2006) recommends that river elevations should gradually decrease from September elevations towards the target baseflow. If September flows are at the bull trout minimum, then following the general ramping rates is acceptable. However, if flows are greater than the minimum bull trout flows, then a slower ramping should be considered.

In theory, sturgeon augmentation flows are ramped up to powerhouse capacity and are held constant for whatever duration is necessary so that the full sturgeon volume is released before the end of the ramp-down to bull trout flows. In reality, the sturgeon operations called for by USFWS have not always been at full powerhouse capacity.

Powerhouse Capacity + 10 kcfs

The 2006 USFWS Biological Opinion recommends that maximum sturgeon augmentation flows should be 35 kcfs (990 m^3/s): powerhouse capacity of 25 kcfs (708 m^3/s) plus 10 kcfs (283 m^3/s). Higher flows are recommended in order to achieve desired habitat attributes of depth, velocity and temperature for successful sturgeon spawning and recruitment. Currently, the only means available to provide up to 10 kcfs above the powerhouse capacity of Libby Dam is by spill. However, spill of up to 10 kcfs will increase total dissolved gas (TDG) above the Montana water quality standard of 110%. The Corps and USFWS are co-ordinating with the State of Montana on the TDG effects of spilling up to 10 kcfs. The Corps did investigate retrofitting Libby Dam so that 10 kcfs could be released without using the spillway, but all identified options were considered too costly.

Because the release of 35 kcfs can not easily be achieved in all years, the USFWS Biological Opinion (2006) provided Reasonable and Prudent Alternatives (RPA) to meet sturgeon habitat objectives. The RPA calls for annual operations to be based on a scientific approach with different releases from Libby Dam being tested to determine their effectiveness on meeting sturgeon habitat objectives. Specifically, a flow test of powerhouse capacity plus 10 kcfs is to occur three or more times during the next 10 years and three times within the next 4 years if conditions allow.

2006 EIS

As written in the final EIS for the Upper Columbia Alternative Flood Control and Fish Operations (Corps, 2006), the preferred alternative for sturgeon flow augmentation is:

- Maximum peak augmentation flows of up to 35 kcfs will be provided for up to 14 days, when water supply conditions are conducive, during the peak of the spawning period.
- After the peak augmentation flows, the remaining water would be provided to maximize flows for up to 21 days with a gradually receding hydrograph.

For this alternative, the reservoir elevation would have to greater than 2415 ft in order to release 10 kcfs through the Libby Dam spillway, which has an invert elevation of 2405 ft. Reservoir inflows would also need to be sufficient to maintain the reservoir at or above elevation 2415 ft in order to maintain this maximum release for a two-week period. Dam releases would also be optimized to provide temperatures of approximately 50°F with no more than a 3.6°F drop. When reservoir elevations are insufficient to utilize the spillway, the maximum release would be the powerhouse capacity. This option is consistent with the USFWS (2006) RPA for Libby Dam operations. The Corps (2006) estimate that flow releases through the spillway could potentially occur in approximately 50% of years (for some period of time).

The 2006 USFWS RPA also recognizes that maximum flow releases of 35 kcfs may not be the only means to achieve the desired sturgeon habitat attributes. Habitat enhancement actions may reduce the need for releases above the powerhouse capacity in the future. As information is gained on the biological response to providing the habitat attributes, flows may be adjusted under the adaptive management approach provided for in the 2006 USFWS Biological Opinion (Corps, 2006).

2009 Water Management Plan

Each year the Bonneville Power Administration (BPA), the Corps and Bureau of Reclamation, collectively referred to as the Action Agencies (AA), issue a Water Management Plan (WMP) for the operation of the dam and reservoir projects in the Federal Columbia River Power System (FCRPS). The WMP includes consultation on listed species with NOAA Fisheries and the USFWS. The purpose of the WMP is to describe how the Action Agencies plan to implement specific operations identified in the NOAA Fisheries 2008 Biological Opinion during the current water year. The Action Agencies are the final authorities on the content of the WMP, although review, comment and recommendations are solicited from the Technical Management Team (TMT) and NOAA Fisheries.

The 2009 WMP for Libby Dam is consistent with the 2006 USFWS Biological Opinion.

4.0 NHC BANK EROSION ASSESSMENT

In October 1998, Northwest Hydraulic Consultants (NHC) and Thurber Engineering were retained by the Association of Kootenay Valley Drainage Districts[5] to investigate riverbank erosion along the Kootenay River between Kootenay Lake and the international border. The concern was that greater water level fluctuations and higher discharges in the fall and winter due to the operation of Libby Dam were resulting in increased rates of bank erosion. NHC was requested to assess the causes of bank erosion and to develop solutions for bank stabilization.

Initially, NHC compared the historic channel planform from a number of sources:

Table 4-1. Map Information for NHC (1999) Bank Erosion Assessment

Date	Source	Data Type	Scale
1961	Canadian Hydrographic Service	hydrographic survey chart	1:20,000
1968	BC MELP	cross-section survey	n/a
1972	BC MELP	orthophoto	1:10,000
1988	BC MELP	TRIM mapping	1:20,000
1997	BC MELP	cross-section survey	n/a
1998	BC Province	air photo	1:15,840

Visual comparisons of these data indicated that the banklines had not changed appreciably since 1961. NHC concluded that the rate of progressive bank erosion and meander pattern shifting has been very low downstream of the Canada-US border for the last 40 years due to the low, lake-controlled river gradient and partially cohesive bank sediments

NHC then conducted a field survey to identify eroding banks, which were then classified as: very high (VH) – attention and protection required in the next 5 years, high (H) – monitor and plan on protecting in the next 5 to 10 years, and moderate (M) – monitor for further bank loss.

4.1. Erosion Types

While overall rates of bank erosion were found to be low, the NHC site inspections indicated that localized erosion was continuing to occur and was threatening the stability of the dikes in several locations. NHC classified the localized erosion into five categories:

1. erosion at the outside of sharp bends
2. erosion at the inside of river bends resulting in steep banks – these situations generally show deep scour holes adjacent to the banks

5 This association has since disbanded although a loose coalition remains.

3. rotational arc slumps generally located opposite tributary inflows such as near Summit Creek
4. long reach vertical slumps – the slumped material has not moved down or been washed into the river
5. progressive slumps showing several scarps and large areas of disturbed ground. This type of slumping is probably due to weak soil properties.

Erosion on the inside of meander bends is counterintuitive at first, but is in fact dependent on the degree of bank curvature. Paraphrased by NHC(1999):

Due to a curved flow path, the river current has both a downstream velocity component and a weaker sideways component. The sideways component creates a secondary circulation pattern, with flow toward the outer bank on the water surface and toward the inner bank along the channel bottom. This lateral velocity component is typically 10 to 20% of the downstream component. Material slumping into the channel by bank caving from the outer bank is carried by the secondary flow circulation and is deposited on the inner bank to form a point bar.

In most meandering channels, maximum flow velocities are usually found near the steep outer bank, just downstream from the axis of the bend. The increase in velocity depends on the degree of bend curvature (Rc/W ratio), where Rc = radius of curvature of the bend and W is the top channel width. Relatively straight channels have a Rc/W ratio of 10 to 20, while highly curved channels have Rc/W ratios of between 3 and 5. On most rivers, the rate of meander shifting tends to increase as the Rc/W ratio decreases, with the erosion rate reaching a maximum when the Rc/W ratio is between 2 to 3. When the bend becomes more curved (Rc/W < 2), the flow tends to separate along the outer bank, which may cause a back eddy to develop. Development of flow separation not only causes the rate of channel shifting to decrease, but it causes the deepest portion of the channel to shift from the outer bank toward the inner bank. As a result, in very curved bends, bank erosion and bank sloughing may occur along the inner or outer bank of the river.

4.2. Bank Erosion Mechanisms

Scour at bends can have an important impact by bank stability by undercutting and oversteepening the toe of the bank (Photo 4-1). NHC (1999) compared Ministry of Environment surveys of 1968 and 1997, and observed that there had been no change in the deep scour holes along the river. It was therefore concluded that the overall stability of the underwater slopes has probably not changed substantially since Libby Dam regulation commenced.

Photo 4-1. Bank instability at outside of meander bend adjacent to IR5 (2005). Photo courtesy of Dwain Boyer, Ministry of Environment.

NHC noted that shallow slumping was the most significant contributor to bank erosion along the Kootenay River. During the field survey it was observed that the Kootenay River had developed a “notch” at normal river level, with associated slumping of the soil to form a steep bare face above the normal river level. The slumped material deposits as a narrow underwater shelf that is then typically removed by river erosion or deeper slumping. The notch initially develops due to wave action, pore water pressure and release of capillary tension, or freeze-thaw action that causes very shallow sloughing. The reduction in lateral constraint allows longitudinal fissures to open. Water enters these fissures, and during rapid drawdown and heavy rain, this results in added hydraulic force, which further opens the fissures. This eventually leads to detachment of the stiff clay, which together with accelerated weathering at the water level allows the block to topple. NHC and Thurber concluded:

“It is considered probable that the development of this notch is more pronounced now that the river level is controlled by Libby Dam in comparison to pre-Libby Dam, when the river level fluctuated over a wider range and the short duration releases from Libby Dam did not occur. The more limited range of water levels, greater fluctuations in flows during the winter season, and more frequent cycles of wetting and drying appears to induce a weakening of the banks resulting in toppling of soil wedges.”

The Corps (2006) have also concluded that past practices of load following (fluctuations in dam releases that correspond to changes in power demand) at Libby Dam contributed to the erosion of the toe slope of much of the levee system in the Kootenai Valley, making the levees unstable. At the same time, the levees are becoming stabilized by vegetation due to the curtailment of load following, especially daily fluctuations, since the late 1990's (Corps, 2006). The recently prescribed maximum ramp rates from Libby Dam (Table 3-5) were not only implemented to protect resident fish and prey organisms in the Kootenay River, but also to help minimize dike/levee erosion along the river.

5.0 EROSION ASSESSMENT

5.1. Overall Impact

Overall the impacts of Libby Dam operation have been favorable from a flood management perspective in the study area. Peak discharges and peak water levels in Kootenay Lake have been reduced significantly (Figure 3-3 and Figure 3-6). Flow velocities, which impact bank erosion and dike maintenance, have also been reduced significantly (Figure 5-1).

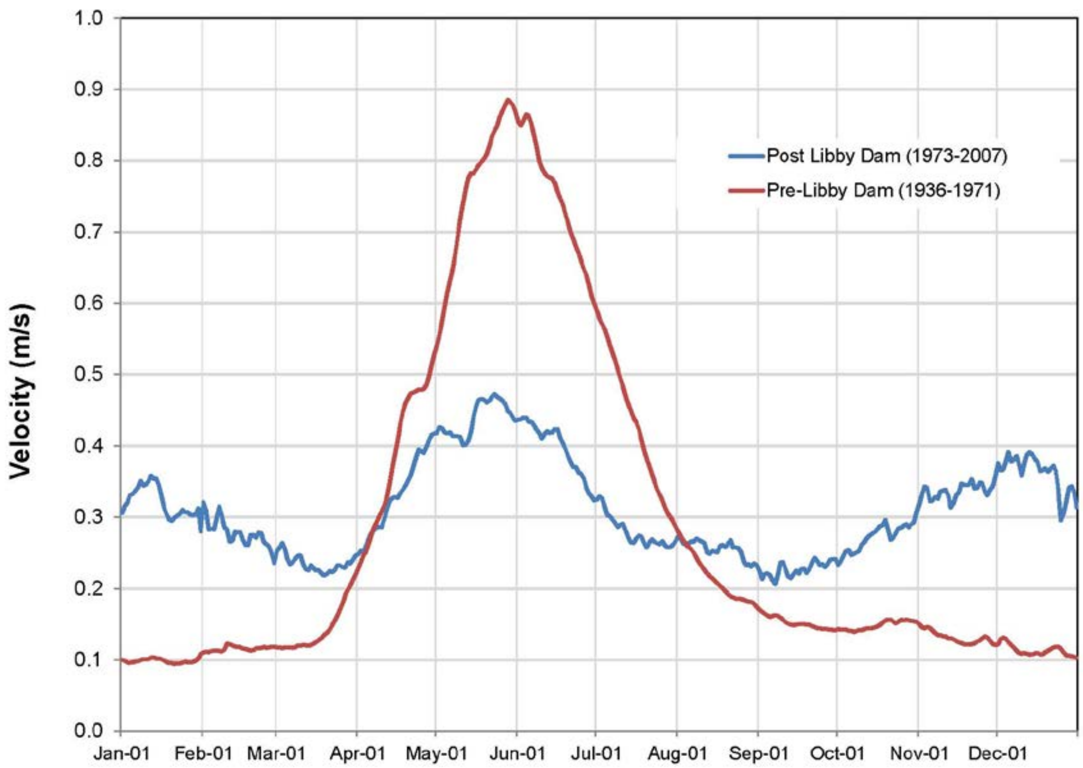

Figure 5-1. Average Flow Velocity of Kootenay River at Porthill, Idaho

However, as noted by NHC (1999), rapid fluctuations in flow releases from Libby Dam until the late 1990's have induced a cycle of wetting and drying that appears to weaken the banks and result in bank erosion from toppling of soil wedges. This aspect is considered in the next section.

5.2. Water Level Fluctuations

5.2.1. Daily Fluctuations

Figure 5-2 shows releases from Libby Dam in 1980 and 2010. Flow releases in 1980 varied considerably throughout the year, as the dam was operated to maximize hydroelectric potential. Similar hydrographs are observed until the late 1990's, when it was realized that the variable flow releases were having a significant impact on downstream fish habitat (see Section 4.4). This variability is contrasted by the 2010 hydrograph, where there is considerably less variability due to Libby Dam operating with more stringent ramping procedures. Implementation of more stringent ramping flows is roughly coincident with the implementation of VARQ FC, but the two procedures are independent of one another from an operational perspective.

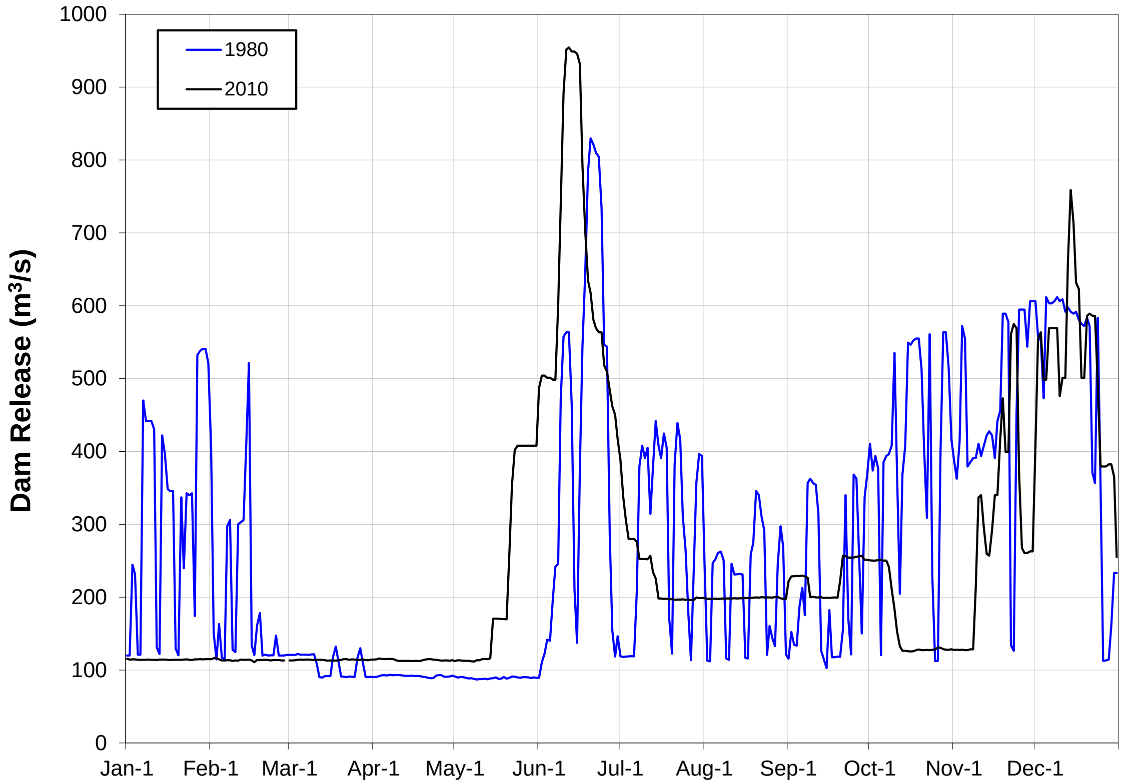

Figure 5-2. Daily Flow Releases from Libby Dam, 1980 and 2010

While the fluctuating flow releases from Libby Dam are significant and obvious, of importance to this study is their impact on flows and water levels in the vicinity of Kootenay Lake. Figure 5-3 plots Kootenay River water levels and discharge at Porthill, Idaho for 1980.

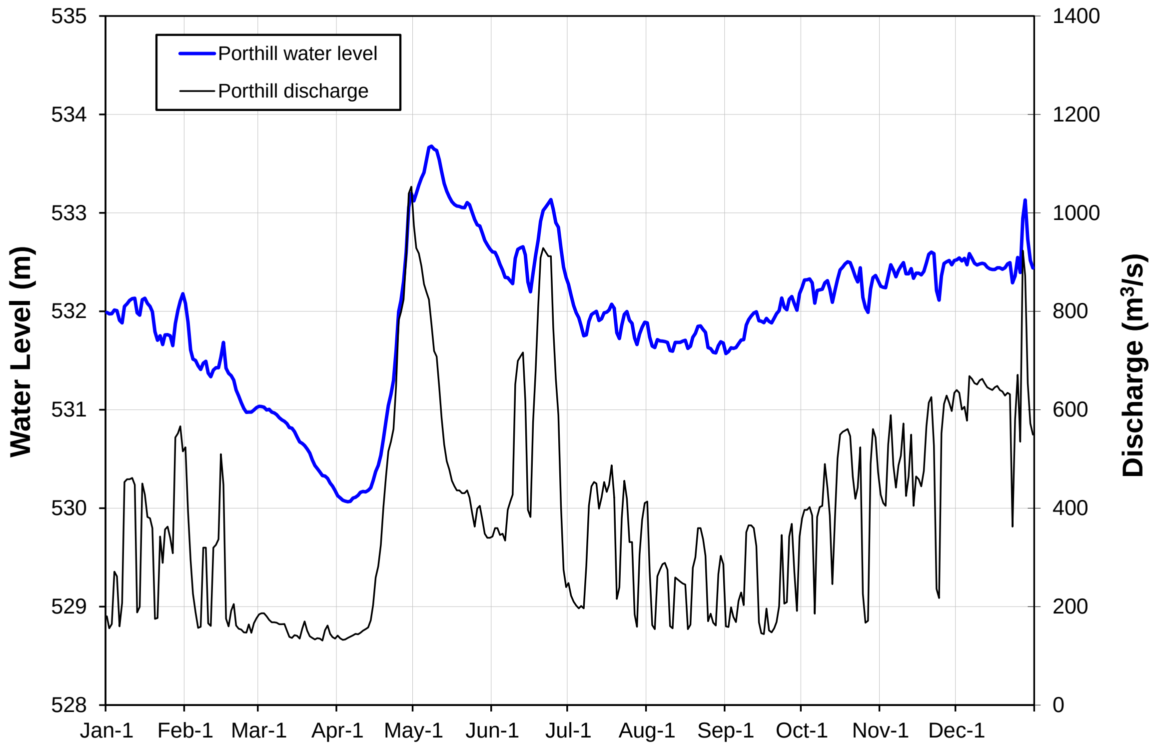

Figure 5-3. 1980 Kootenay River Daily Water Levels and Discharge at Porthill, Idaho

This figure demonstrates that the Kootenay River hydrograph at Porthill, Idaho closely follows flow releases from Libby Dam, as expected given that dam outflows make up 70% of the runoff at Porthill. An exception is the snowmelt period, where flow releases are curtailed at Libby Dam while downstream tributaries contribute significant flow. When discharge is variable, particularly during the late fall and winter, average daily Kootenay River water levels tend to vary from about 0.2 to 0.4 m due to the changes in flow releases. For example, the difference in water level at Porthill for a discharge of 200 m^3/s versus 400 m^3/s is about 0.4 m.

Of note is that the lake creates a backwater effect such that Kootenay River water levels in the Creston Valley are higher than they would be if the lake was not present and velocities are reduced. This backwater effect can extend as far upstream as Bonner's Ferry in the US. The lake backwater effect makes it difficult to develop a unique stage-discharge rating curve at a given location because a given stage can be achieved with different combinations of lake elevation and flow. Figure 5-4 shows the backwater influence for the Kootenay River gauge at Porthill, Idaho. The backwater influence is such that for a given discharge the stage can vary by 2 m.

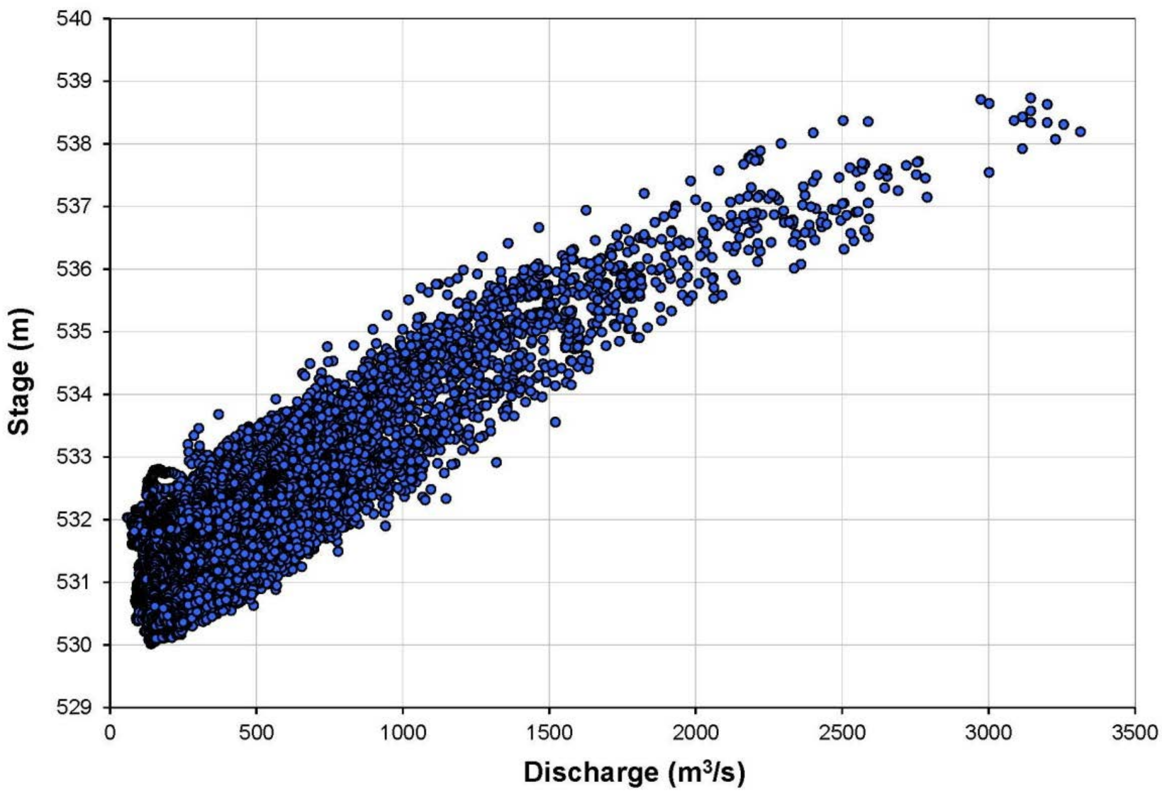

Figure 5-4. Stage Discharge Curve for Kootenay River at Porthill, Idaho

5.2.2. Hourly Fluctuations

Figure 5-3 is actually misleading in that daily average values are plotted rather than hourly. Actual water fluctuations can be considerably greater than shown on Figure 5-3. For example, NHC (1999) notes that in January 1974, the discharge at Porthill surged suddenly up to 1560 m^3/s in one day and then dropped abruptly to 325 m^3/s. The corresponding river level fluctuation was about 2 m near the Canada-US border, while average channel velocities ranged from 0.25 m/s during the low flow up to 1 m/s at the peak. Similarly in January 1990, discharge at Porthill jumped to 1030 m^3/s and then dropped abruptly to 310 m^3/s. This event resulted in a 1 m river level fluctuation at the border and 0.3 m near the lake. Neither of these events is captured in the averaged daily record. The range in water level and average flow velocity during the January 1990 flow release is summarized below.

Table 5-1. Range in Water Level and Velocity During January 1990 Flow Release (NHC, 1999)

Distance from Lake (km)	Water Level (m)			Average Velocity (m/s)		
	Max	Min	Range	Max	Min	Range
42.6	532.95	531.95	1.0	0.69	0.23	0.46
27.2	532.60	531.92	0.68	0.67	0.22	0.45
24.9	532.52	531.91	0.60	0.68	0.24	0.44
20.5	532.41	531.90	0.51	0.66	0.22	0.44
7.2	532.17	531.88	0.29	0.82	0.25	0.57

Note: discharge fluctuated between 1,030 m^3/s and 310 m^3/s during the release.

Figure 5-5 shows hourly water levels on the Kootenay River at Porthill in 1989. Of note is the considerable flow fluctuations during the fall and winter months that result in water level fluctuations on the order of 0.5 m. These hourly water level fluctuations are much more noticeable in comparison to the daily average values illustrated in Figure 5-3.

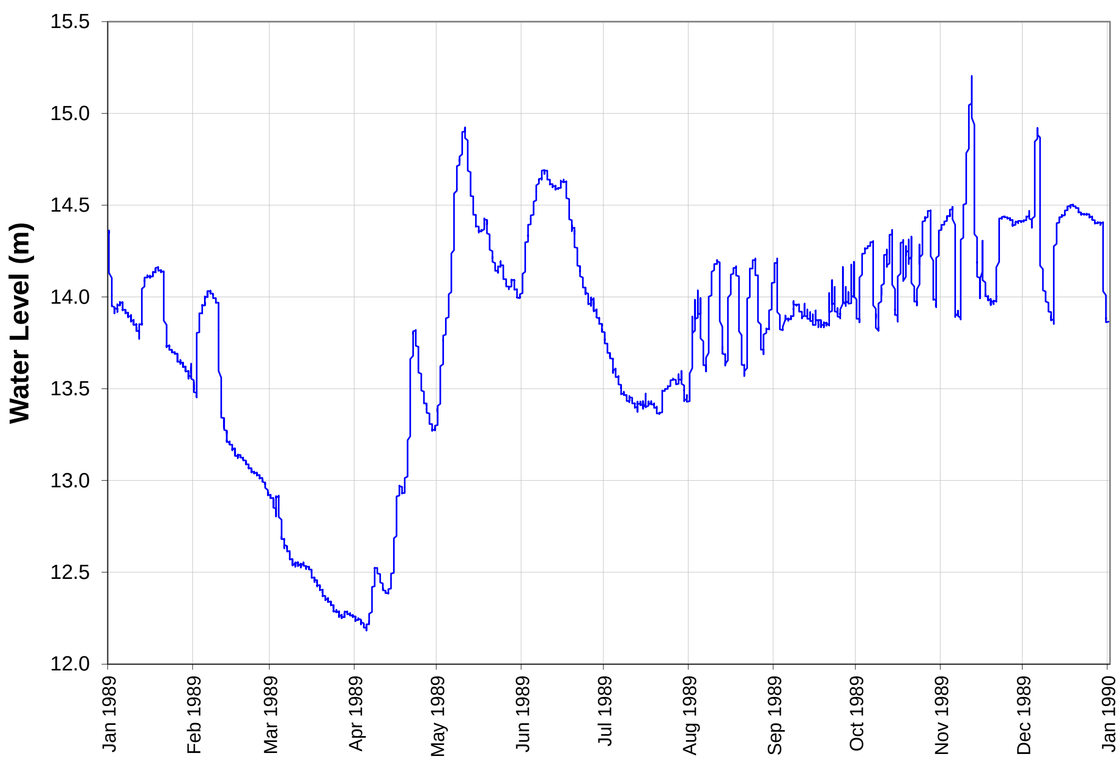

Figure 5-5. 1989 Hourly Kootenay River Water Levels at Porthill, Idaho

In contrast, Figure 5-6 shows hourly Kootenay River water levels for 2006 and 2008. While a significant amount of hourly data is missing, the trend toward a more stable hydrograph is evident and is consistent with the updated flow release practices from Libby Dam.

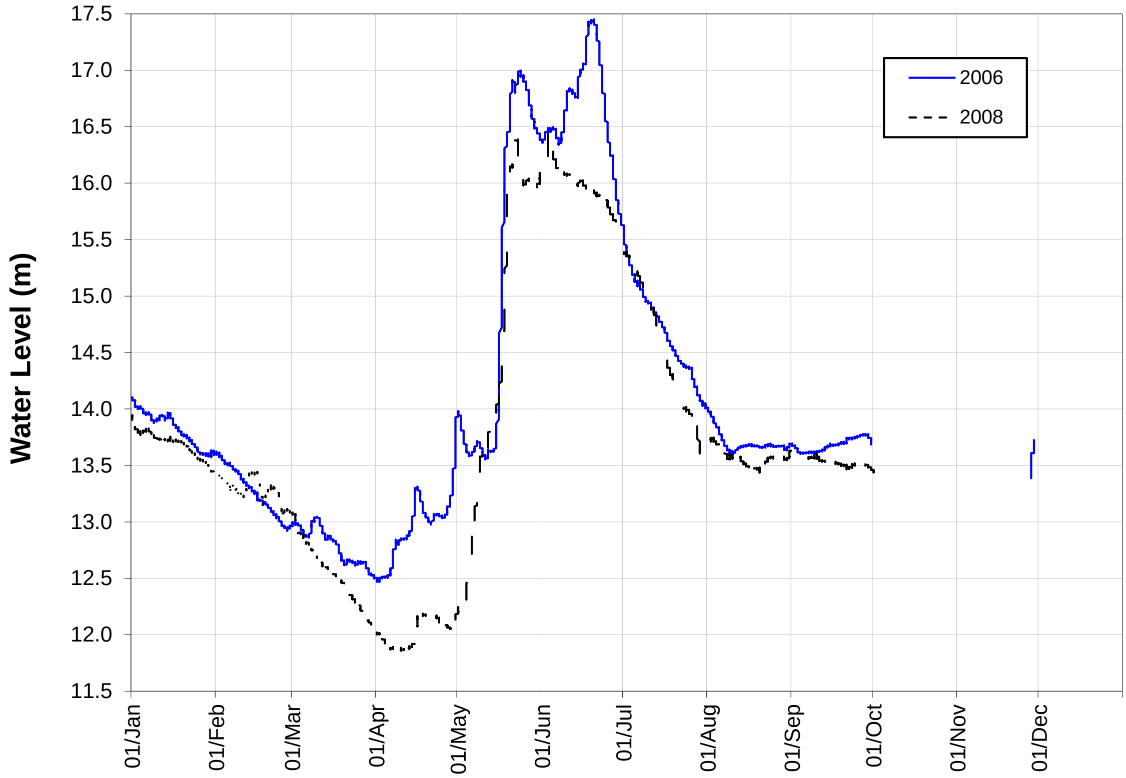

Figure 5-6. 2006 and 2008 Hourly Kootenay River Water Levels at Porthill, Idaho

5.2.3. Range in Water Level

Flow regulation at Libby Dam has also resulted in a more limited range of water levels. Figure 5-7 shows average water levels at Porthill, Idaho for two different periods: pre-Libby Dam (1938-1971) and post-Libby Dam (1973-2011). The annual range in water levels is 5.5 m for the pre-Libby Dam period and only 2.7 m for the post-dam period.

[Note: Water level data at Porthill, Idaho actually only extend back to 1961. However, Kootenay River discharge data at Porthill and Kootenay Lake level data extend back to 1938. These data were input into a calibrated hydraulic model (HEC-RAS) to extend the Porthill water level dataset back to 1938.]

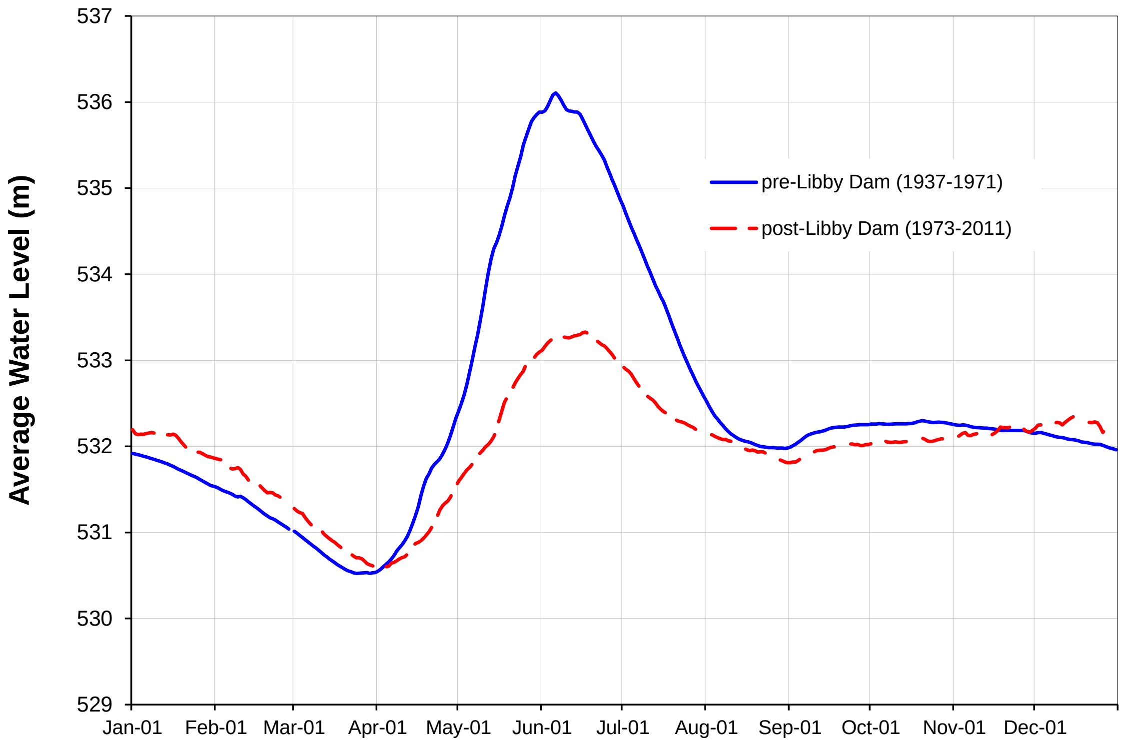

Figure 5-7. Average Daily Water Levels at Porthill, Idaho for pre-Libby Dam (1937-1971) and post-Libby Dam Conditions (1973-2011)

5.2.4. Summary

Figure 5-5 and Figure 5-7 are consistent with the conclusion of NHC (1999) that "the more limited range of water levels, greater fluctuations in flows during the winter season, and more frequent cycles of wetting and drying appears to induce a weakening of the banks resulting in toppling of soil wedges".

A lack of riparian vegetation is also likely to be a significant factor in the observed erosion. Many of the banks with protective dikes are either vegetated with grasses and shrubs only. In contrast, the right bank adjacent to IR1A, IR1 and portions of IR1B is not protected by either riprap or a dike and as such, the riparian vegetation is well established (with cottonwoods in particular) providing a stabilizing influence against bank erosion.

However, the observations of NHC (1999) were made very soon after the adoption of restricted flow ramping practices, which have eliminated the rapid water level fluctuations of the past, as demonstrated by Figure 5-6. Therefore, it is not unrealistic to expect bank erosion rates to decrease over the next several decades, as long as flow releases from Libby Dam continue to be managed for both fish habitat and bank erosion. This expectation is consistent with observations by the Corps who have noted that Kootenay River levees in the

US are becoming stabilized by vegetation due to the curtailment of load following, especially daily fluctuations, since 2000 (Corps, 2006).

5.3. **Standard vs VARQ FC**

The previous section has demonstrated that restricted flow ramping practices have significantly reduced water level fluctuations, which have been identified as a primary contributor to "recent" bank erosion in the study area. However, seasonal differences in flow releases between Standard and VARQ Flood Control practices may also be a contributor to erosion, as investigated further in this section.

5.3.1. Differences in Flow and Water Level

There have been three different phases of flood control in place on Libby Dam since 1973:

- from 1973 to 1992, operation of Libby Dam was flood centric and power centric (Standard FC);
- between 1993 and 2002, the Standard FC regime continued, but operations for downstream fisheries had a higher priority than power operations ;
- since 2003, Libby Dam has operated with VARQ FC (fish priority) and restricted flow ramping practices.

The Kootenay River hydrograph differences between these three operating periods are illustrated in Figure 5-8 and Figure 5-9.

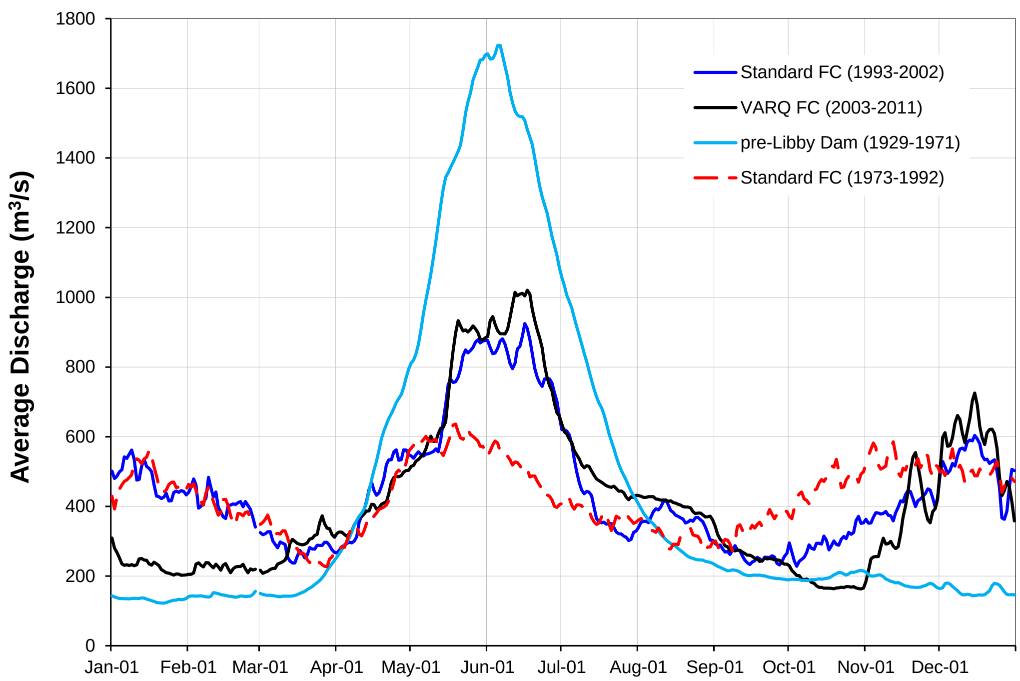

Figure 5-8. Average Daily Discharge at Porthill, Idaho for Various Time Periods

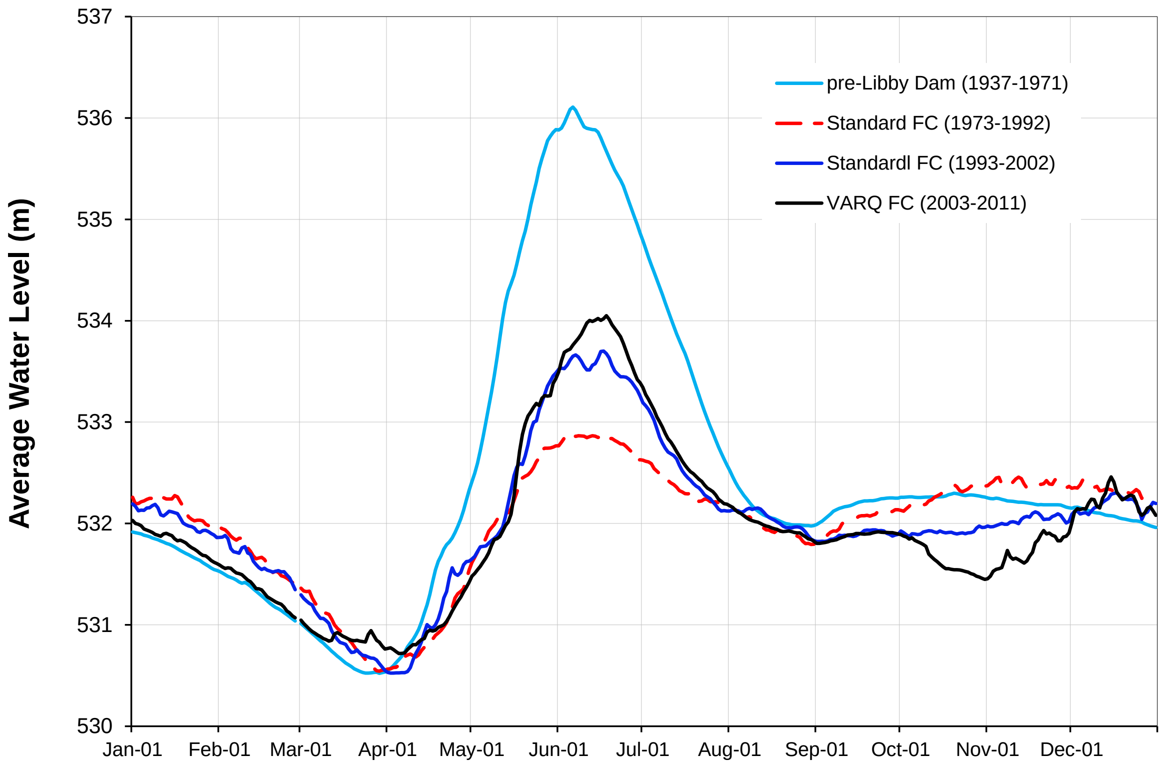

Figure 5-9. Average Daily Water Levels at Porthill, Idaho for Various Time Periods

Differences between the various operating periods can be summarized as follows:

- Since 1993, fish flow releases during the spring freshet result in a hydrograph that is more representative of pre-dam conditions; however, the difference during the peak of the spring freshet is still significant.
- Flow releases associated with power generation and to evacuate space for flood control during the subsequent freshet have occurred in the late fall since Libby Dam became operational. However, the total flow released between September 1 and March 31 is significantly lower for VARQ FC when compared to both Standard FC periods.
- The discharge and water level regime during the winter period under VARQ FC is closer to the pre-dam regime than is the regime associated with Standard FC (1973-1992) and Standard FC (1993-2002).

None of these results suggest that VARQ FC has resulted in increased bank erosion when compared to Standard FC. Discharges are increased during the freshet under VARQ FC with fish flows, but peak discharges are still considerably lower than pre-dam freshet conditions. Channel velocities are a better indicator of potential bank erosion and these are discussed below.

5.3.2. Channel Velocities

Water velocity is a fundamental factor for bank erosion. Water velocities are driven by many local and regional factors. Locally the shape of the river, its cross sectional area, bed roughness and many other factors contribute to variations in channel velocity. On a regional level, the quantity of flow released from Libby Dam and the downstream Kootenay Lake levels are the most significant factors. Assuming that local conditions along the Kootenay River are relatively consistent, and beyond the scope of this assessment, any changes in erosion may be attributed to changes in flow regime

As detailed above, the construction of Libby Dam radically altered the flow regime along the Kootenay River. These alterations were ongoing with modifications in the management of flows from Libby Dam. The complex interactions of downstream lake levels and upstream flow release are too complex to understand by observation alone. In order to illustrate the impacts of the different management scenarios, a numerical hydraulic model of the Kootenay River between Porthill and Kootenay Lake was created.

BGC used an existing 1-D hydraulic model (HEC-RAS) for the analysis. This hydraulic model was created by BGC (2012) for a risk-based Floodplain Management Plan of the Kootenay River. Inputs to the model include 1997 cross-section data, Kootenay Lake levels, and flows from the Porthill USGS gauging station. Details of model set-up and calibration are provided in BGC (2012). The available record of lake levels and inflows allow a simulation of river hydraulics from 1936 to 2012. This length of record allows an assessment of how different flow management scenarios may have affected flow velocities.

The analysis is partially limited by the complexity of bank erosion and the relative simplicity of the 1-D hydraulic model: the HEC-RAS model only provides average channel velocities as output. However, for the purposes of this report, it is the relative differences in channel velocities between the different management periods that are of importance.

For this assessment a location at km 17[6] (as measured downstream of Porthill) was chosen to demonstrate the changes in average stream velocity for different scenarios. Several high and medium risk bank erosion locations have been noted over the years at this location, which is at a complex bend (BGC, 2012). Three time periods were simulated to understand the historic average velocities at this location: pre-Libby Dam, Standard FC (1973-1992) and VARQ FC (2003-2012). The results are plotted on a cumulative flow frequency graph below.

[6] This section is located about 1 km downstream of the confluence with Goat River.

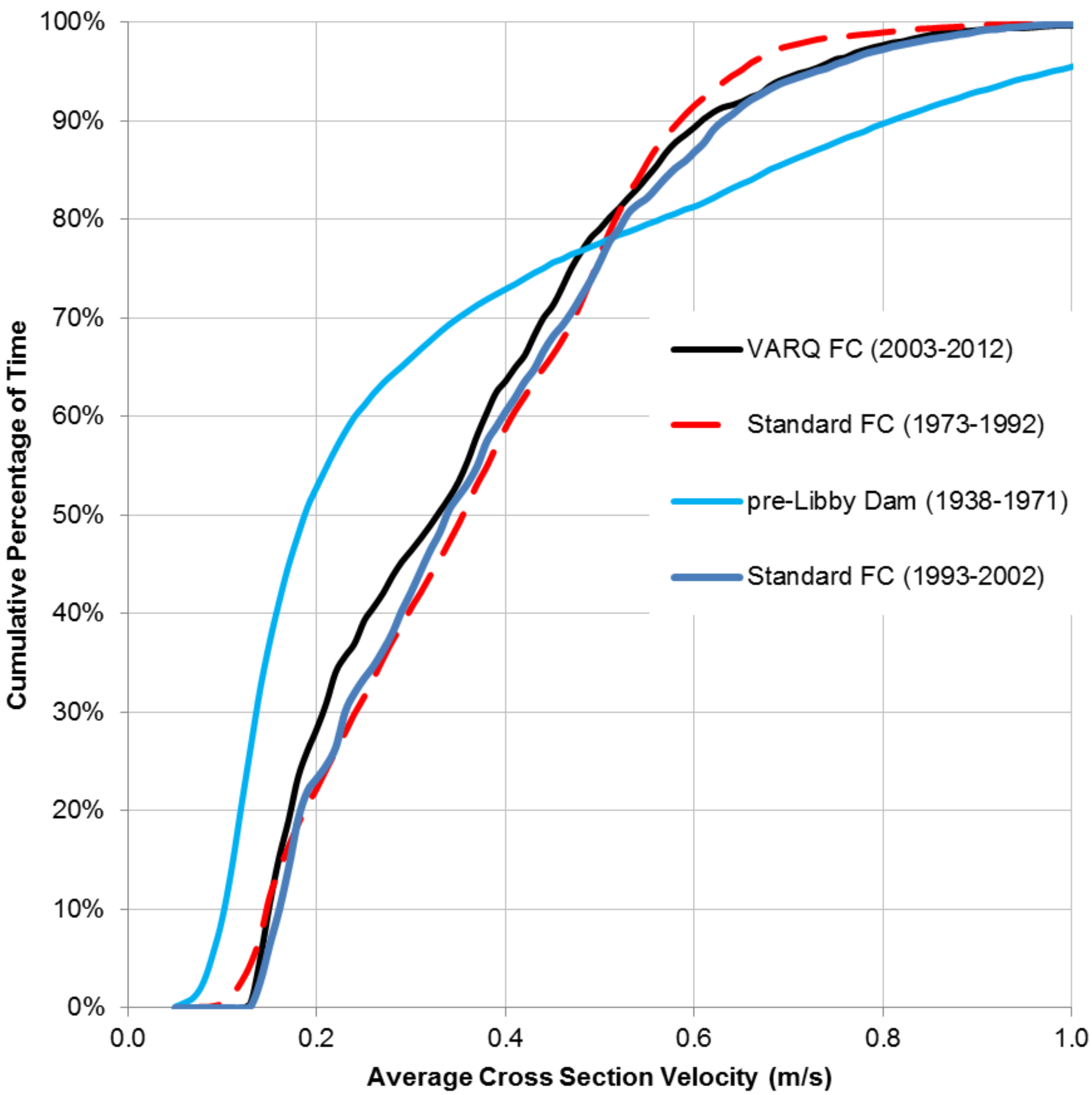

Figure 5-10. Cumulative Average Velocity for the Kootenay River at km 17 for Various Time Periods

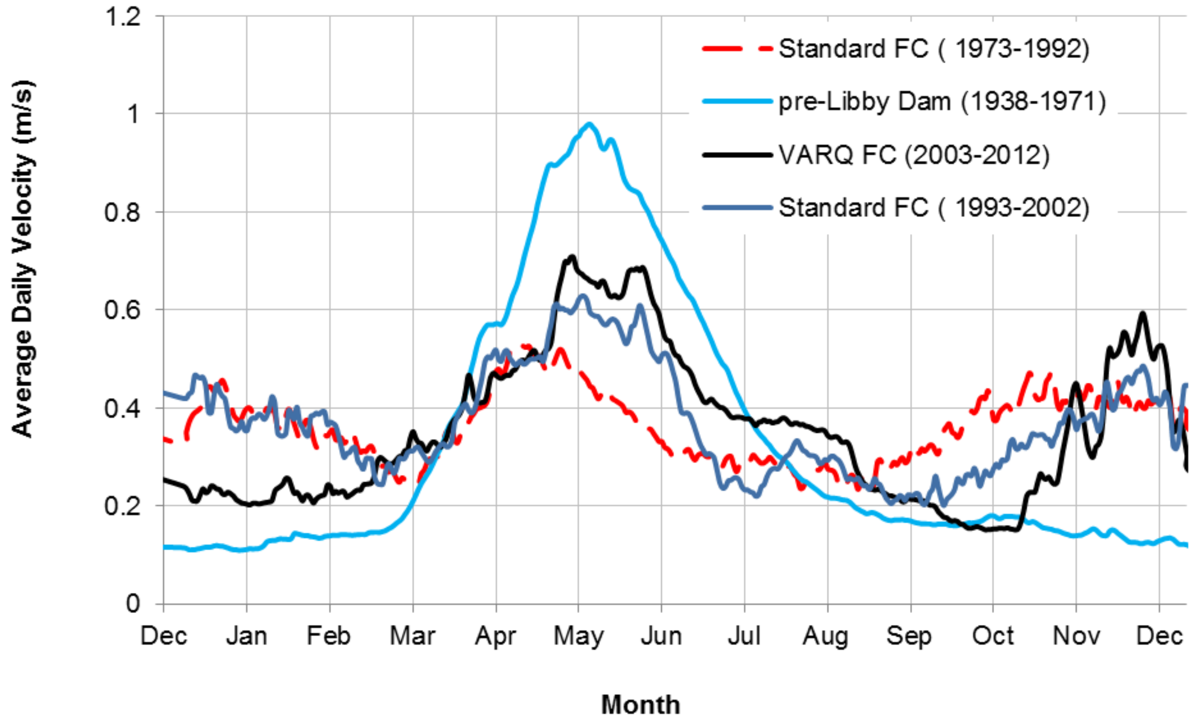

Figure 5-11. Daily Average Velocities for the Kootenay River at km 17 for Various Time Periods

Based on this assessment, the velocity regimes between Standard FC (1973-1992), Standard FC (1993-2002) and VARQ FC are not significantly different on a cumulative basis. What can be seen is that the post-dam releases have significantly decreased both the percentage of slowest velocities (<0.4 m/s) and fastest velocities (>0.6 m/s), while more than doubling the percentage of moderate velocities (0.4 to 0.6 m/s). Implementation of VARQ FC has partially recaptured some of the very fast flows (>0.6 m/s) in an attempt to meet the habitat requirements for fish species. However, peak flow velocities remain well below the pre-Libby Dam period (Figure 5-11).

The lack of a significant difference between average channel velocities for Standard FC and VARQ FC is not surprising. VARQ FC is intended to provide the same level of flood protection as Standard FC, but with improved flow augmentation for fish. In practice, there is only a difference between the two methods when the inflow forecast falls between 80% and 120% of normal (Corps, 2004). Within this range some of the water that would be stored during the refill period under Standard FC is instead passed through the dam under VARQ FC.

Figure 5-11 does indicate that the peak monthly average velocity during freshet is about 30% higher when comparing VARQ FC (~0.65 m/s) and Standard FC (~0.50 m/s). However, this peak average velocity associated with VARQ FC is still considerably reduced when compared to the pre-Libby Dam period. The peak monthly average velocity during the pre-

Libby Dam period (~0.95 m/s) is 50% higher compared to VARQ FC. The average peak velocity during the pre-Libby Dam period is considered to be a better measure of typical shear stresses that induce meaningful channel changes (i.e. scour and bank erosion) along this section of the Kootenay River. The Standard FC period is an exception to this statement, as weakening of the banks was induced by rapid changes in flow releases at Libby Dam.

6.0 RECENT CLIMATE

The recent concerns raised by local residents of increased bank erosion along the Kootenay River may be influenced by the climate. In the last few years, there have been several years where Kootenay River flows and Kootenay Lake levels have been above average: 2006, 2011, and 2012 (Figure 6-1).

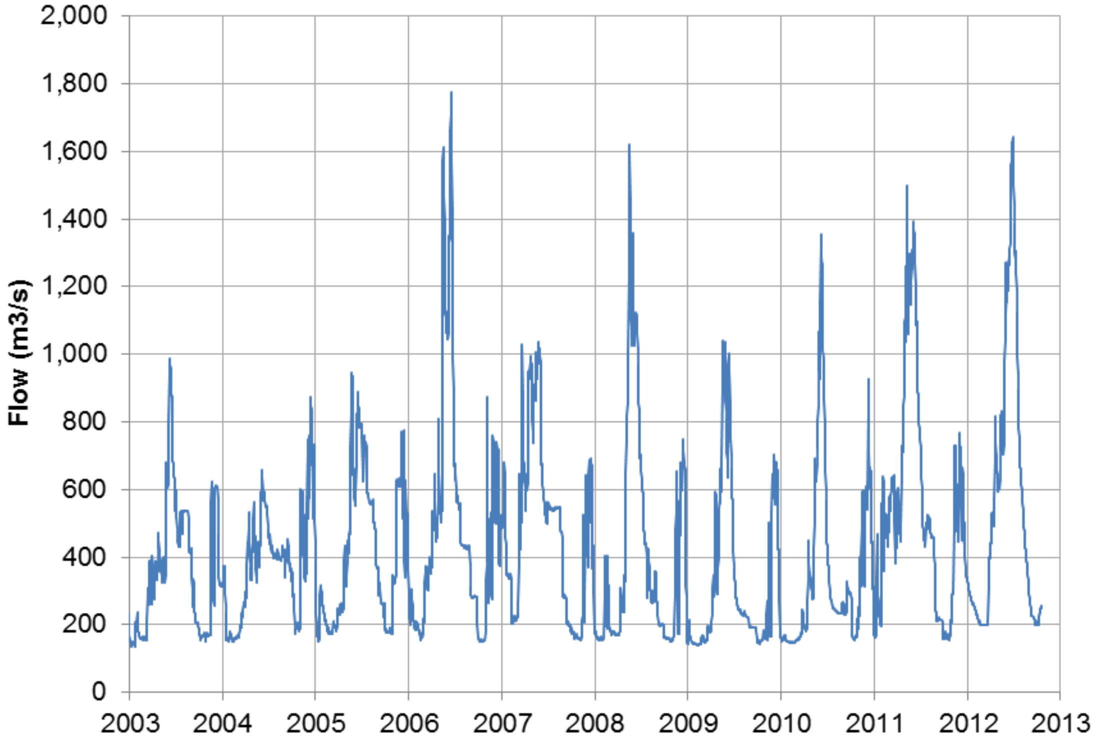

Figure 6-1. Gauged flow at USGS station 12322000 Kootenai River at Porthill. Data for 2012 have been extrapolated from water elevations at the station and are preliminary only.

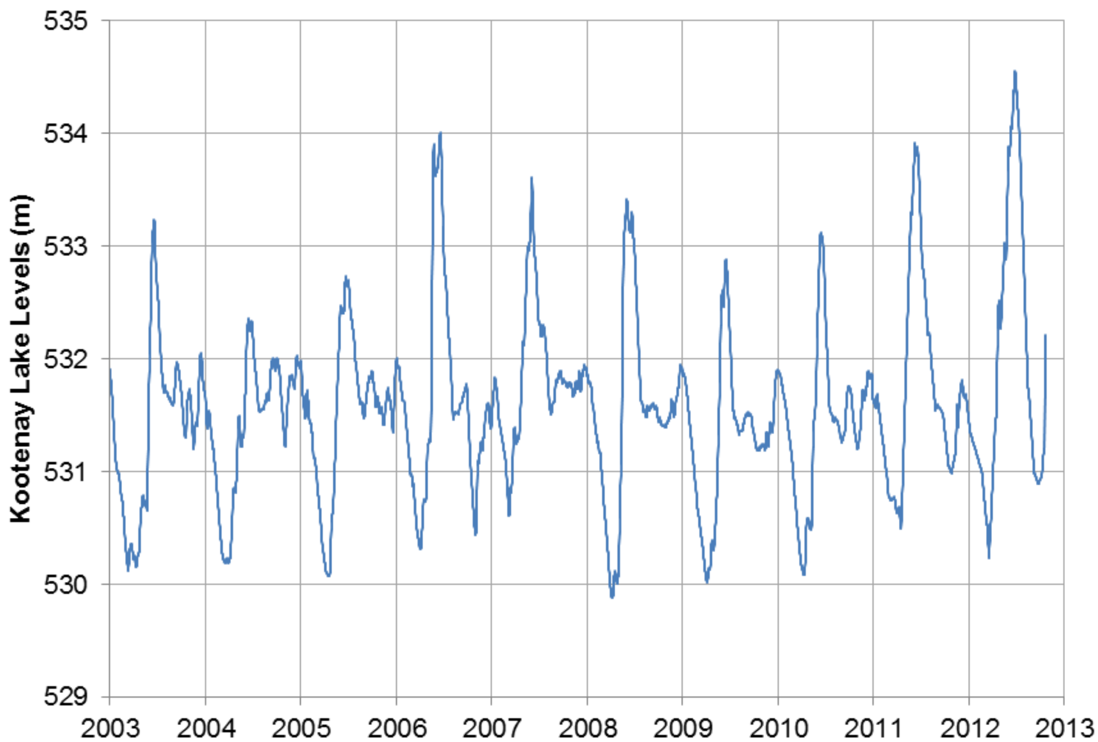

Figure 6-2. Gauged lake elevations for Kootenay Lake. Data for 2011 and 2012 have been extrapolated from preliminary water elevations.

Higher than average flows result in a greater likelihood of bank erosion, which may bias local opinions as to the impacts of Libby Dam operation. A high level assessment indicates that the past two years have had a delayed freshet along with some significant spring rainfall.

6.1. Snowpack

Five snow pillow stations are maintained by the British Columbia River Forecast center upstream of Libby Dam. Two of these stations: Morrissey Ridge (2C09Q) and Moyie Mountain (2C10P) were examined to explain the, 2011 and 2012 flow regimes.

Table 6-1 summarises the source of the snow pillow data and Figure 6-3 shows their relative locations.

Table 6-1. Snow Pillow Stations

ID	Region	Station	Elevation (m)	Lat	Long	Period of Record
2C09Q	E. Kootenay	Morrissey Ridge	1800	49°27'	114°58'	1983-2012
2C10P	E. Kootenay	Moyie Mountain	1930	49°15'	115°46'	1971-90, 1997-2012

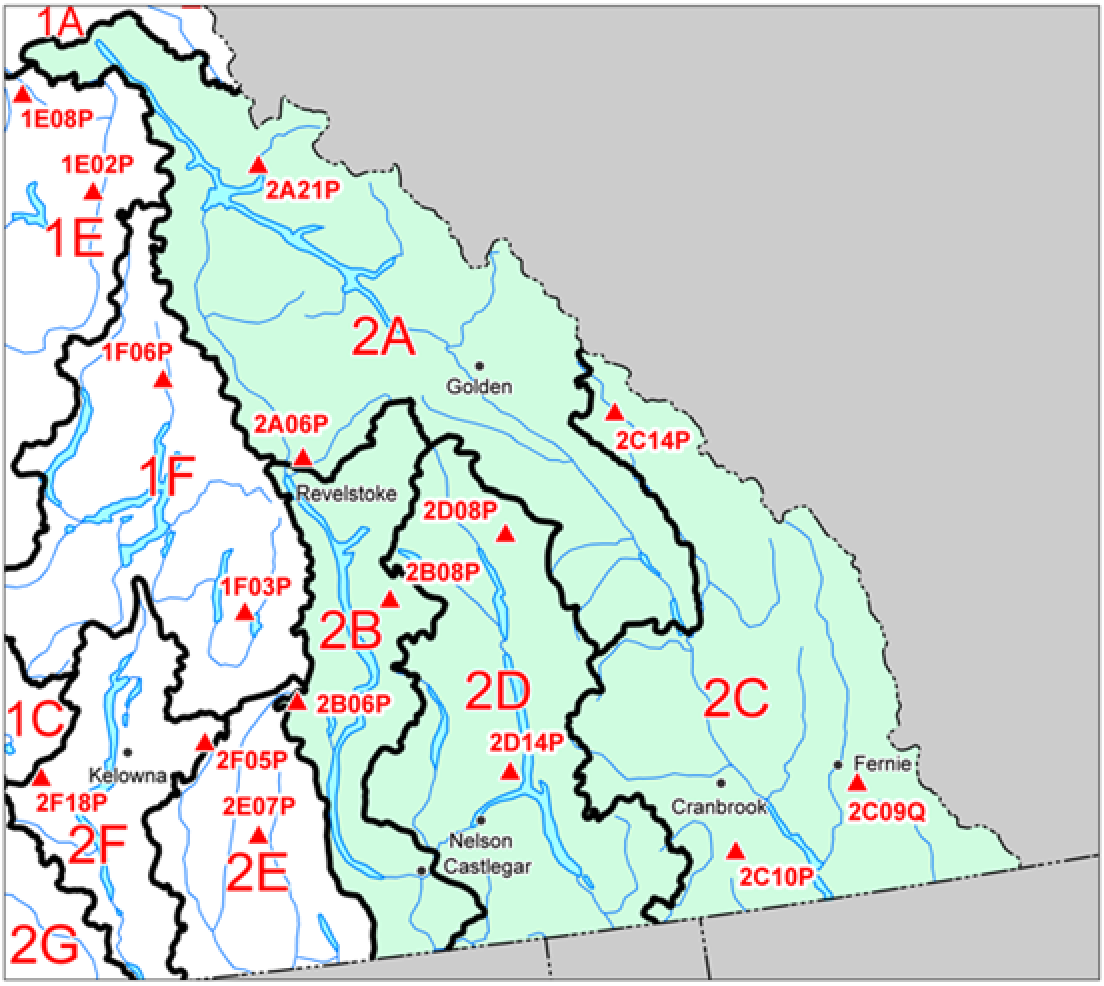

Figure 6-3. British Columbia River Forecast Centre regional snowpack stations. (http://bcrfc.env.gov.bc.ca/data/asp/realtime/basin_columbia_kootenay.htm**)**

The most recent data for 2C10P south of Cranbrook shows the severity of the 2011 and 2012 snowpack. Figure 6-4 below provided by the BC River Forecast Centre for station 2C10P indicates that the 2012 snowpack (labelled as current year) was near record levels and that 2011 (labelled as previous year) was the most significant and latest to melt in the season snowpack on record.

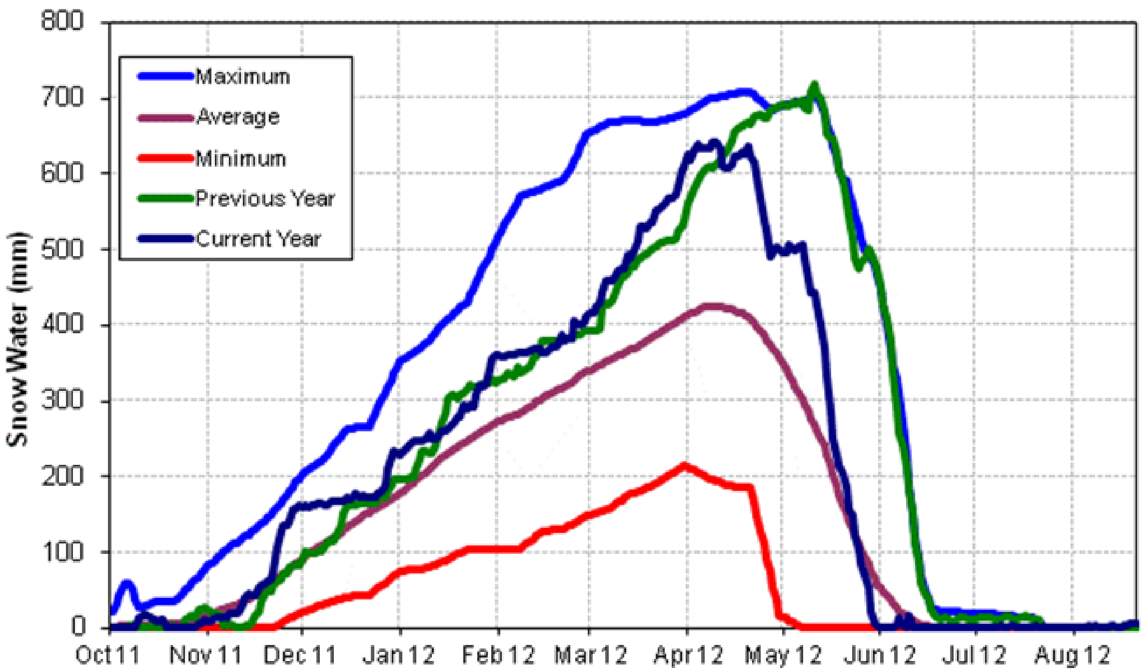

Figure 6-4. Snow pillow measurements for station 2C10P (downloaded from the British Columbia River Forecast Centre).

A review of all historical snow packs on record reveals that the 2011 and 2012 snow packs were some of the largest on record and had the latest freshet. Figure 6-5 and Figure 6-6 illustrate the peak snowpack date and water equivalent for stations 2C10P and 2C09Q, respectively.

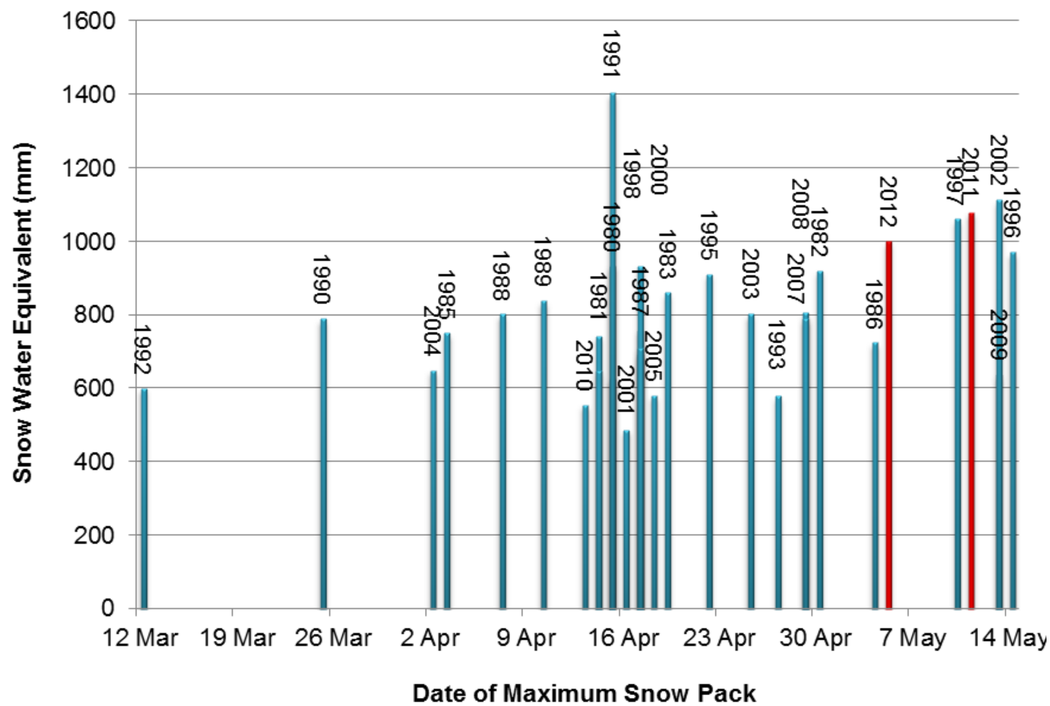

Figure 6-5. Peak snowpack day and water equivalent depth for all recorded years from station 2C10P. 2011 and 2012 are highlighted on the graph.

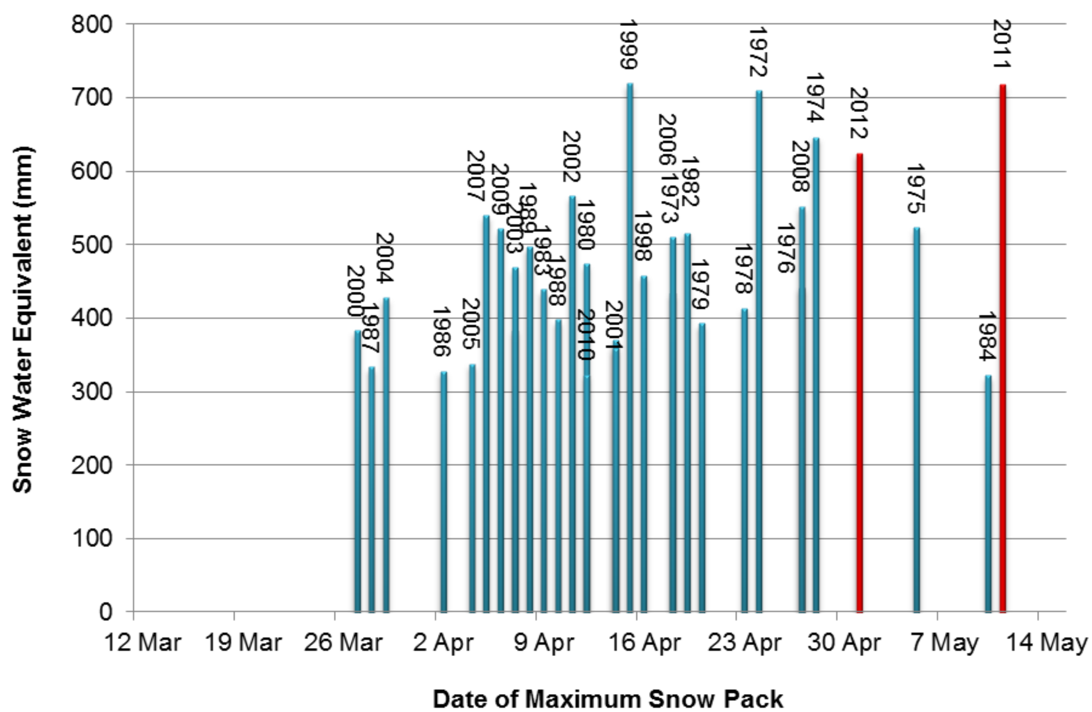

Figure 6-6. Peak snowpack day and water equivalent depth for all recorded years from station 2C09Q. 2011 and 2012 are highlighted on the graph.

Independent of the high snowpack in 2012, the region had significant rainfall in June and July. At a climate station in Creston (#1142160) maintained by Environment Canada, 148 mm and 74 mm of rain was recorded in June and July respectively, compared to a long-term (1912-2012) averages of 56 mm and 29 mm. The combined two-month rainfall of 222 mm is the largest on record. The high snowpack and June/July rainfall resulted in the highest Kootenay Lake level recorded in 38 years.

The snow water equivalents and above average rainfall in June and July are a strong indicator of the extent of the likely severity of the flood season. In 2011 and 2012 the snowpack accumulated to high levels late in the spring season. The lateness of the freshet combined with the snowpack's significant snow water equivalent and high rainfall would have combined to create an exaggerated freshet. The timing and extent of the flows could have led to an increase in flows downstream of Libby Dam and therefore an increase in the risk of erosion to the dikes along the Kootenay River. Yet, the actual flow is a result of dam management. To understand the actual relative impacts, the numerical model was used to simulate the 2011 and 2012 flow regimes using provisional published data.

6.2. 2011 and 2012 Flow Velocities

A significant snowpack and a late freshet do not necessarily imply higher flows, increased velocities and an increased risk of erosion in the study reach. Downstream lake levels and flows from Libby Dam are both highly managed processes which directly affect the quantity and velocity of flows along the Kootenay River. To estimate relative impact, the 2011 and 2012 flows at Porthill and Kootenay Lake levels were included in the 1-D hydraulic model. Typically there is up to a two-year gap before lake levels and flow data are published for use. Prior to that however, provisional data are available and these provisional data have been used to estimate average channel velocities at km 17 of the Kootenay River. Figure 6-7 and Figure 6-8 provide a quantitative comparison of the 2011 and 2012 flow regimes to the VARQ FC average. As shown in Figure 6-7, VARQ FC velocities were less than 0.6 m/s 90% of the time while the 2011 and 2012 velocities were less than 0.6 m/s for only 80% of the time.

Furthermore, as illustrated in Figure 6-8, average channel velocities for 2011 and 2012 are consistently above the VARQ FC historical average, most notably during the freshet. While the actual level of erosion cannot be quantified by this approach, the graphs do illustrate that flow velocities during the past couple of years have been above average. In the US, the Corps observed some levee damage along the Kootenai River in 2011 and 2012 (pers. comm., 2012). The Corps attributed this damage to a long duration snowmelt in 2011 and above average snowmelt in 2012 compounded by above average rainfall in June. In both years, these conditions resulted in saturated dikes that were more susceptible to erosion. Operation of Libby Dam was not identified as a factor in the observed erosion.

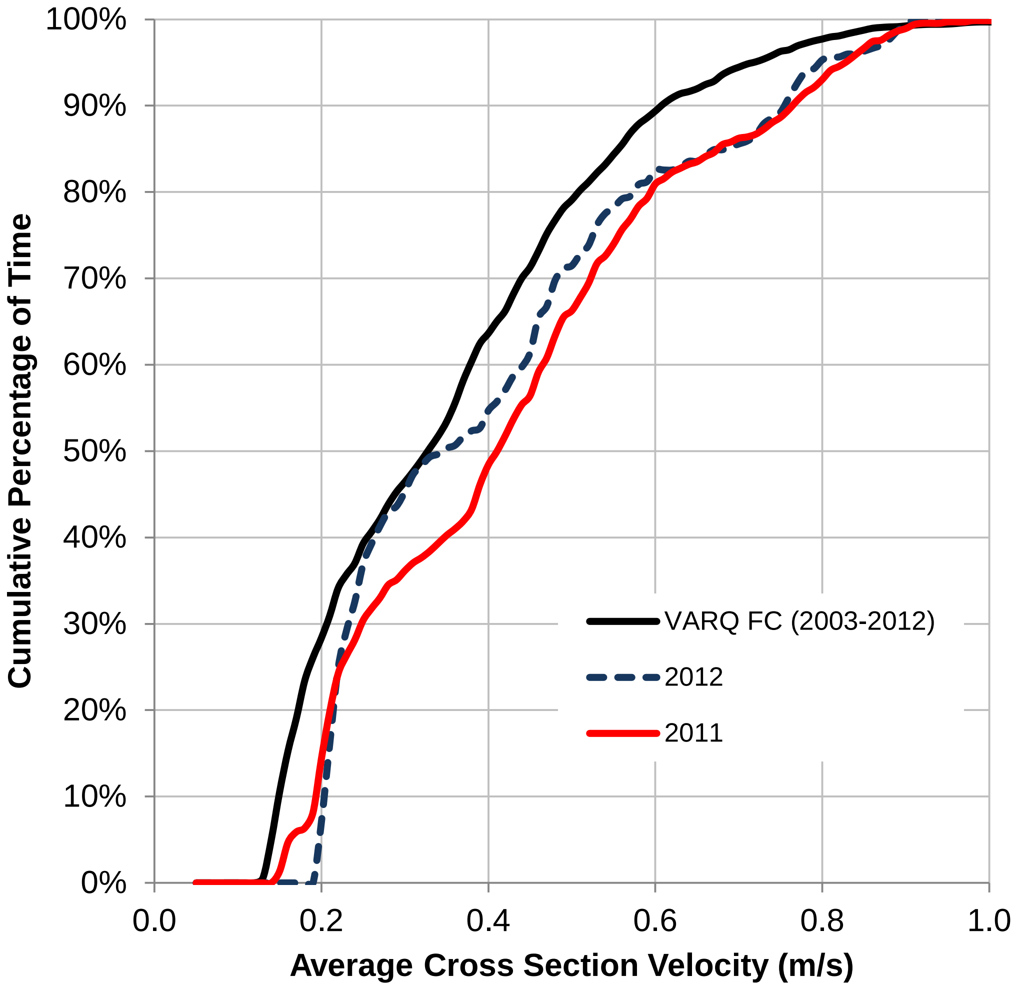

Figure 6-7. Cumulative Average Velocity for the Kootenay River at km 17 for 2011 and 2012 Relative to the VARQ FC Average (2003-2012)

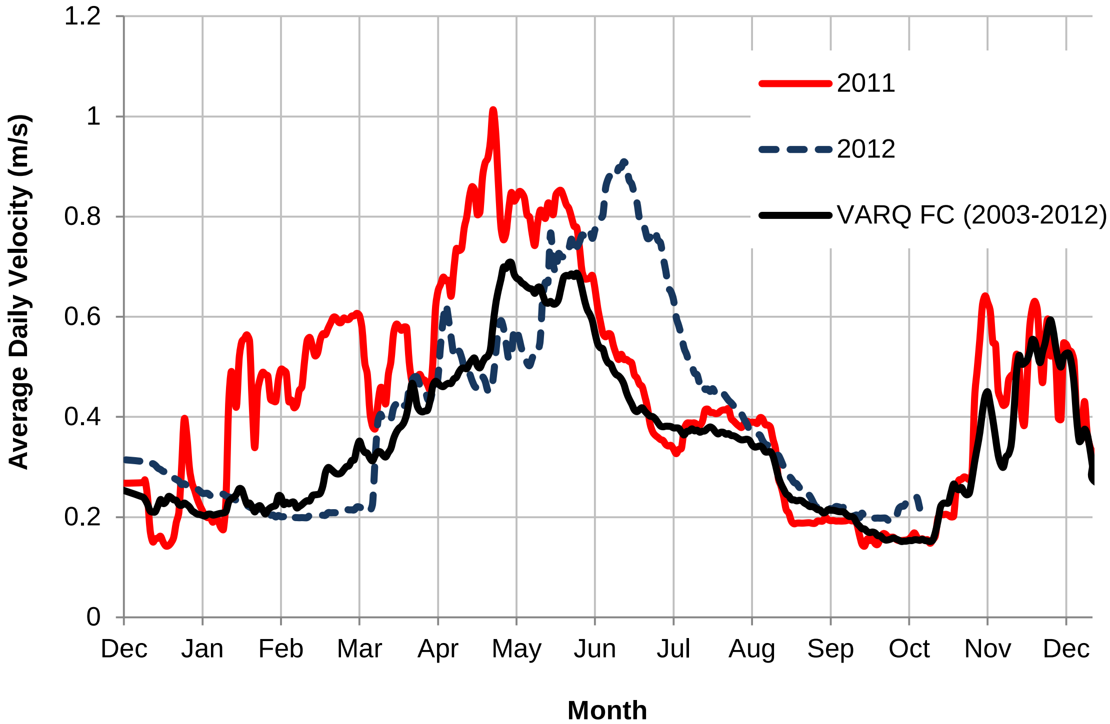

Figure 6-8. Daily Average Velocities for the Kootenay River at km 17 for 2011 and 2012 Relative to the VARQ FC Average (2003-2012)

7.0 SUMMARY AND CONCLUSIONS

This study has investigated whether implementation of variable flow flood control (VARQ FC) has had a negative impact on diking infrastructure adjacent to the Kootenay River between the Canada-US border and Kootenay Lake. In this study reach, there are approximately 93 km of dike, which are maintained by five different diking authorities and the Lower Kootenay Band.

Prior to the construction of Libby Dam, major freshet floods caused extensive damage to the diking system (e.g. 1948). However, since Libby Dam operation commenced in 1973, average mean annual floods on the Kootenay River, as measured at the Canada-US Border, have decreased by more than a factor of two. Peak channel velocities also decreased by a factor of about 2 following dam construction.

<u>Flow Ramping and Load Following</u>

Conversely, bank erosion rates appear to have increased following dam construction, perhaps stabilizing in the late 1990's when flow ramping restrictions were instituted. Up until 1992, operation of Libby Dam was driven primarily by flood control and power needs. Flow ramping during the fall and winter months was a common practice, when the dam was operated to maximize hydroelectric power values. During load-following operations, it was not unusual to observe daily fluctuations in water level on the order of 0.5 to 1.0 m in the study reach. Similarly, daily fluctuations in average channel velocity on the order of 0.5 m/s also occurred.

In a 1999 study, NHC observed that a notch had developed along the Kootenay River banks, which they attributed to load following (fluctuations in dam releases that correspond to changes in power demand). NHC concluded that "It is considered probable that the development of this notch is more pronounced now that the river level is controlled by Libby Dam in comparison to pre-Libby Dam, when the river level fluctuated over a wider range and the short duration releases from Libby Dam did not occur. The more limited range of water levels, greater fluctuations in flows during the winter season, and more frequent cycles of wetting and drying appears to induce a weakening of the banks resulting in toppling of soil wedges." The Corps (2006) have also concluded that past practices of load following at Libby Dam contributed to the erosion of the toe slope of much of the levee system in the Kootenai Valley, making the levees less stable.

Load following at Libby was common practice until the late 1990's, when it was realized that this practice may be having a significant impact on downstream fish habitat. Since the late 1990's, Libby Dam has operated with restricted flow ramping procedures. By prescribing maximum ramp rates from Libby Dam, there has been a considerable reduction in daily flow fluctuations in the study reach. These measures were implemented not only to protect resident fish and prey organisms in the Kootenay River, but also to help minimize dike/levee erosion along the river. Analysis of Kootenay River hydrographs shows that post-1999 hydrographs are more stable and the rapid water level fluctuations of the past have been eliminated. Therefore, it is not unrealistic to expect bank erosion rates to decrease in the future, as long as flow releases from Libby Dam continue to be managed for both fish habitat and bank erosion. This expectation is consistent with observations by the Corps who have noted that Kootenay River levees in the US are becoming stabilized by vegetation due to the curtailment of load following, especially daily fluctuations, since 2000 (Corps, 2006).

A lack of riparian vegetation was also likely a significant factor in the observed erosion. Many of the banks with protective dikes are either vegetated with grasses and shrubs only. In contrast where the bank is not protected by either riprap or a dike, the riparian vegetation is well established (with cottonwoods in particular) providing a stabilizing influence against bank erosion.

Standard FC

Under Standard FC (1973-1992), Libby Dam would generally release high flows from January through April in order to increase storage capacity to capture the spring runoff in May, June and July. Because Lake Koocanusa drafted a large amount of water storage under Standard FC, Libby Dam historically released little water from May to July in order to refill. Eventually it was realized that this strategy was detrimental to several fish species. Between 1993 and 2002, Libby Dam was operated with increased flow releases during the freshet to accommodate different fish species, several populations of which have been listed for protection under the Endangered Species Act (ESA). In this transitional period Standard FC procedures continued to be used, but power operations were secondary to operations for fish.

VARQ FC

In December 2000, the USFWS and NOAA Fisheries each issued a Biological Opinion formalizing measures to protect endangered species including sturgeon, bull trout, salmon and steelhead. Recommended measures included implementation of VARQ FC at Libby Dam with the intent of ensuring reservoir refill in years when flood control allows it. As a consequence, VARQ should allow more assured provision of flows for endangered Kootenai River white sturgeon, threatened bull trout in the Kootenay and Flathead Rivers, and various listed stocks of salmon and steelhead in the Columbia.

With VARQ FC, the release during refill varies according to the reservoir level, water supply forecast and the estimated duration of flood control. VARQ FC is intended to provide a similar level of flood protection as Standard FC, but with improved flow augmentation for fish. Standard and VARQ Flood Control have the same storage space for flood control when the water supply forecast is greater than 120% of normal. In practice, there is only a difference between the two methods when the inflow forecast falls between 80% and 120% of normal (Corps, 2004). Within this range some of the water that would be stored during the refill period under Standard FC is instead passed through the dam under VARQ FC.

Using a calibrated hydraulic model, BGC has evaluated the difference in channel velocities between the Standard FC (1973-1992) and VARQ FC (2003-2012) periods. This assessment indicates that the velocity regimes between Standard FC and VARQ FC are not significantly different on a cumulative basis. On a seasonal basis, the peak monthly average velocity during freshet is about 30% higher when comparing VARQ FC (~0.65 m/s) and Standard FC (~0.5 m/s). This increase in velocity is a result of increased flow releases during the freshet to augment fish habitat.

However, peak flow velocities during VARQ FC remain well below the pre-Libby Dam period (~0.95 m/s). The pre-dam period is considered to be a better measure of typical shear stresses that induce meaningful channel changes (i.e. scour and bank erosion) along this section of the Kootenay River. It is therefore our opinion that the implementation of VARQ FC has not had a significant negative impact on diking infrastructure adjacent to the Kootenay River between the Canada-US border and Kootenay Lake.

In contrast, the past practice of load following did have a significant negative impact on diking infrastructure. Hence the curtailment of load following in the late 1990's has significantly reduced the erosion potential on the diking infrastructure.

It is also noted that peak freshet flows and channel velocities were well above average in 2011 and 2012. These above average flows may have resulted in some bank erosion along the study reach, increasing the perception that VARQ FC has had a negative impact on diking infrastructure. In the US, the Corps observed some levee damage along the Kootenai River in 2011 and 2012 (pers. comm., 2012). The Corps attributed this damage to a long duration snowmelt in 2011 and above average snowmelt in 2012 compounded by above average rainfall in June and July. In both years, these conditions resulted in saturated dikes that were more susceptible to erosion.

8.0 CLOSURE

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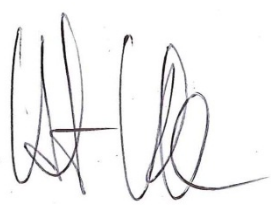

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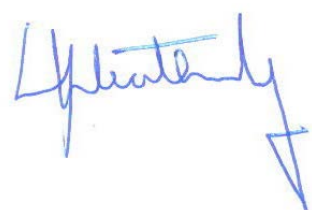

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