Kootenai River Habitat Restoration Project Master Plan

Appendix A – Hydraulic Analysis

Kootenai Tribe of Idaho

July 2009

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Appendix A – Hydraulic Analysis

Introduction

The Kootenai River in the project area is strongly influenced by the operation of Libby Dam and Corra Linn Dam as discussed in Section 2.3.5. The following sections detail the hydraulic analysis that was completed to investigate how river regulation has influenced discharge, river velocities, and stream power. In short, river regulation has simplified the Kootenai River's hydrograph and influenced the relationship of river discharge and the Kootenay Lake backwater effect. Additional analysis was completed to evaluate how hydraulic response is affected by river discharge and backwater effect in the five reaches of the project area.

Simulation of Hydraulic Response

As discussed in Section 2.4, the long term effects of both upstream and downstream regulation of the governing boundary conditions (i.e., Libby Dam discharge and Kootenay Lake stage) has resulted in departure of the historical hydraulic conditions under which the Kootenai River developed. Because river hydraulics are closely related to geomorphic processes/response and ecological function, the magnitude and variability of select hydraulic parameters were synthesized such that their departure could be evaluated for the dominant historical hydrologic regime periods as listed in Table A-1 below.

Table A-1. Summary of Regime Periods of Interest.

Regime Period	Period of Record Synthesized	# of Mean Daily Records for Discharge and Backwater Controlled Stage.
Pre-Dam	10/1/1960 - 12/31/1971	4,109
Post-Dam	1/1/1972 - 12/31/2007	13,081
Pre-BiOp	1/1/1972 - 9/30/1993	7,923
Post-BiOp	9/30/1993 - 12/31/2007	5,158

The historical hydrologic periods are broadly divided as Pre/Post Libby Dam, coincident with the completion and initial filling of Libby Dam in 1972. In order to evaluate the hydraulic response resulting from dam operations, the post-dam regime period was further divided as Pre/Post BiOp, coincident with the implementation of a variable flood control (VarQ) strategy. Under the Pre-BiOp regime, the upper rule curves governing Libby Dam operations primarily considered flood control and power generation. The "BiOp VarQ" strategy was designed to allow more assured flow provision and integrate relevant biological requirements into the existing VarQ operations. For average or low water years with moderate to low flood projections, the BiOp VarQ allows Libby Dam to store more water prior to spring runoff such that a more natural flow pattern can be maintained in the Kootenai river downstream via higher spring outflows (spring freshet) and summer flow augmentation. On average, the additional available outflow for the spring freshet is around 10kcfs, and the median summer flow augmentation is up to 5 kcfs. The BiOp VarQ continues to evolve, and discharge shaping has been further refined to consider input from a broad base of stakeholders such that more variable seasonal factors such as temperature, local inflow below the dam, hydrologic forecasts, fish behavior and special circumstances can be considered.

Departure in Boundary Conditions

At cross sections influenced by the Kootenay Lake backwater, hydraulic response is not solely a function of discharge and thus traditional single predictor stage-discharge relationships cannot be accurately used. This is because the magnitude of a hydraulic response parameter of interest such as water surface elevation or velocity can occur for multiple combinations of discharge and lake level at cross sections subjected to the backwater influence. In general, as a result of the downstream Kootenay Lake level, the water-surface elevation at the Porthill, Idaho stream gage tends to be lower on the rising limb (as a result of previous Kootenay Lake drafting) than on the falling limb of the hydrograph at the same discharge, essentially producing a "looped" rating curve for stage. The general departure in the pre-dam and post-dam boundary conditions is reflected in the scatter plot of discharge and stage at Porthill (Figure A-1). The overall trend of a looped rating curve is reflected in the point density.

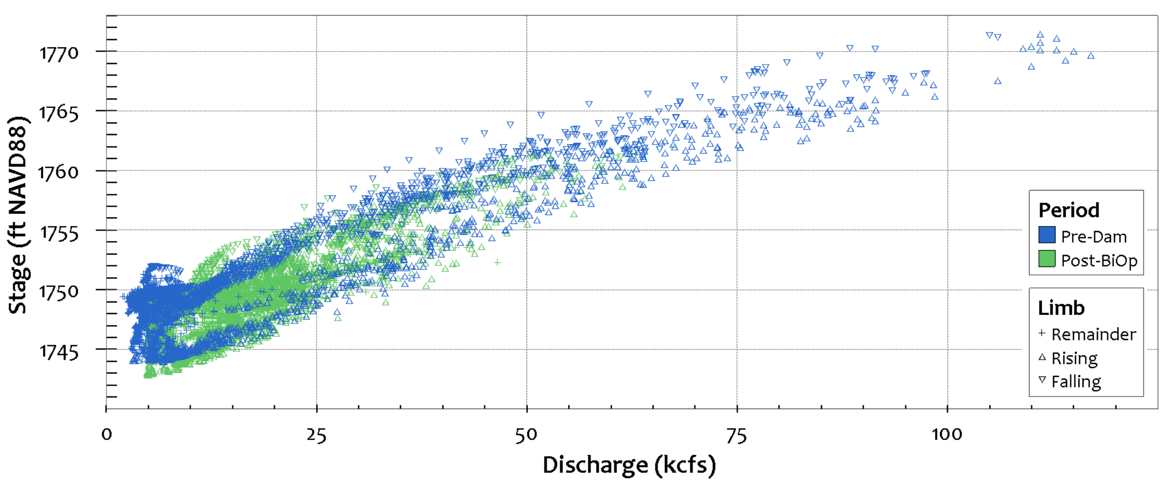

Figure A-1. Stage and discharge for pre-dam/post-dam regimes on the Kootenai River at Porthill (USGS Station #12322000).

The magnitude and variability of backwater stage for select discharges and regimes is illustrated the clustered box plot below (Figure A-2). In short, the combination of discharge and backwater elevation as measured in stage, exhibited a wider range of results during the pre-dam period compared to the post-dam BiOp period. The difference in results is due to regulation of the Kootenai River by both Libby Dam and Corra Linn Dam operations, which regulate the elevation of Kootenay Lake and corresponding backwater extent in the study reach.

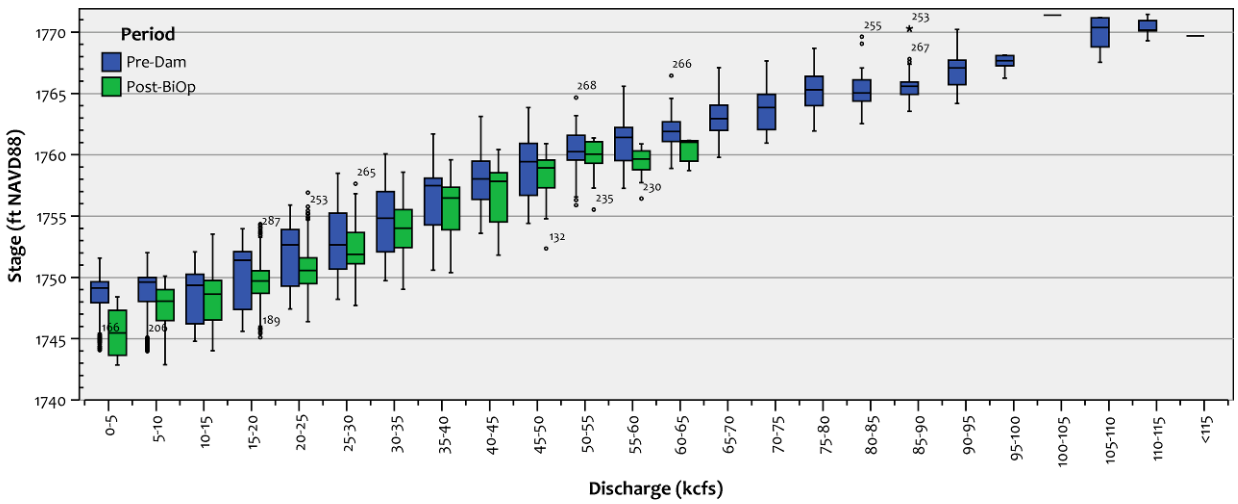

Figure A-2. Variability in downstream boundary conditions for select binned discharges under pre-dam and post-BiOp hydrologic regimes. Kootenai River at Porthill (USGS Station #12322000). Outliers are labeled by DWY.

The historical departure of boundary conditions and dominant energy regime for the study reach was further evaluated by plotting the joint probability density function (PDF) for periods of interest. Figure A-3 shows a standard multi-normal distribution fit to historical stage and discharge data at Porthill (USGS Station #12322000). The median or 50th percentile, is plotted as an ellipse depicting the probability density of the joint occurrence of discharge and Kootenay Lake level effect for a regime period, with a shaded region representing the inner quartile range (IQR) between the 25th and 75th percentiles. Combinations of stage and discharge nearest to the spatial mean at the ellipse center have the largest joint probability density for the given period of record. For a historical combination of discharge and stage, the inner shaded range represents the 25th percentile, a value which exceeds 25% of the spread in the target variable and is exceeded by 75% of the spread. The outer shaded range represents the 75th percentile, a value which exceeds 75% of the spread in the target variable and is exceeded by an additional 25% of the spread. Simply, the combinations of stage and discharge that have occurred the most frequently are at the center of the graphic, rarer combinations of stage and discharge are located in the extreme portions of the graphic.

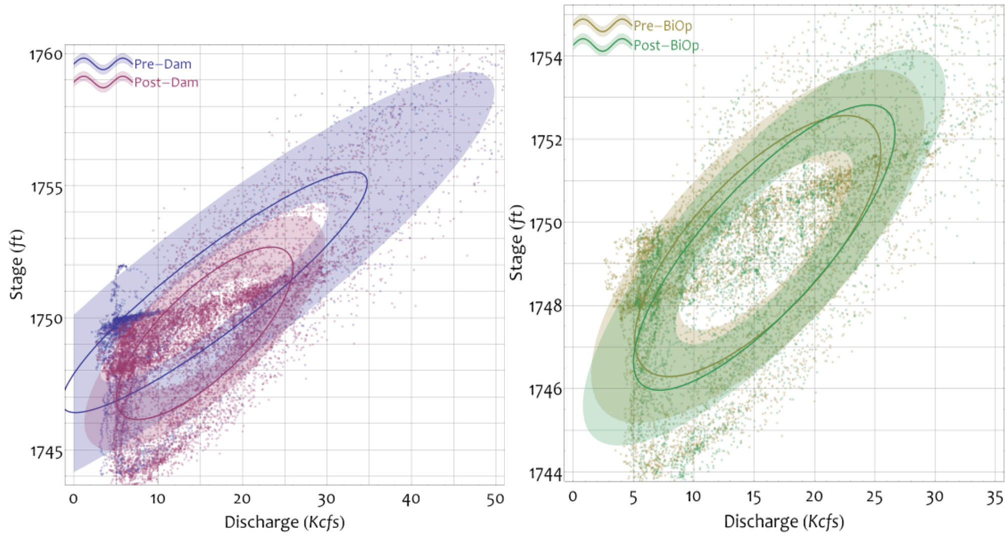

Figure A-3. Multinormal fit of stage and discharge for pre-dam versus post-dam hydrologic regimes (left) and post-dam regime split by pre-BiOp versus post-BiOp (right). Kootenai River at Porthill (USGS Station #12322000).

Table A-2 includes summary statistics for the joint probability metrics for stage and discharge for discharge data and backwater elevation measured at Porthill.

Table A-2. Joint probability metrics for Stage & Discharge at USGS Station #12322000.

Regime Period	Spatial Mean	Spatial Standard Deviation
Pre-Dam	16.4 kcfs , 1750.9 ft	19.9 kcfs, 5.0 ft
Post-Dam	15.4 kcfs , 1749.4 ft	9.0 kcfs, 2.8 ft
Pre-BiOp	15.2 kcfs , 1749.2 ft	8.7 kcfs, 2.7 ft
Post-BiOp	15.7 kcfs , 1749.4 ft	9.5 kcfs, 3.0 ft

Overall, the departure in post-dam boundary conditions and corresponding energy regime for the study reach is reflected by the shift in the joint frequency centroid of the various quantiles and the ratio between the major and minor axes. The PDF centroid for discharge and stage was around 15kcfs and 17kcfs for pre-dam and post-dam regimes with respective backwater stages of 1749 ft and 1751 ft. Median peak discharge decreased from 35kcfs to 25kcfs accompanied by a shift in downstream median stage by approximately 2 ft. In the post-dam regime, variability in discharge with stage decreased as reflected by the magnitude of the major quartile axis, while variability in stage with discharge increased under the post-dam regime as reflected by the minor quartile axis. The subtle shift in boundary conditions under the Post-Dam BiOp-VarQ is reflected by a slight increase in the median discharge as well as increasing the outer 75th percentile to around 30kcfs. Evaluation of the normalized frequency for discharge and stage between the pre-dam and post-BiOp regimes (Figure A-4) also illustrates the minor difference in the highest discharge frequency versus stage, further illustrating the larger range of variability for discharge and stage in the pre-dam regime.

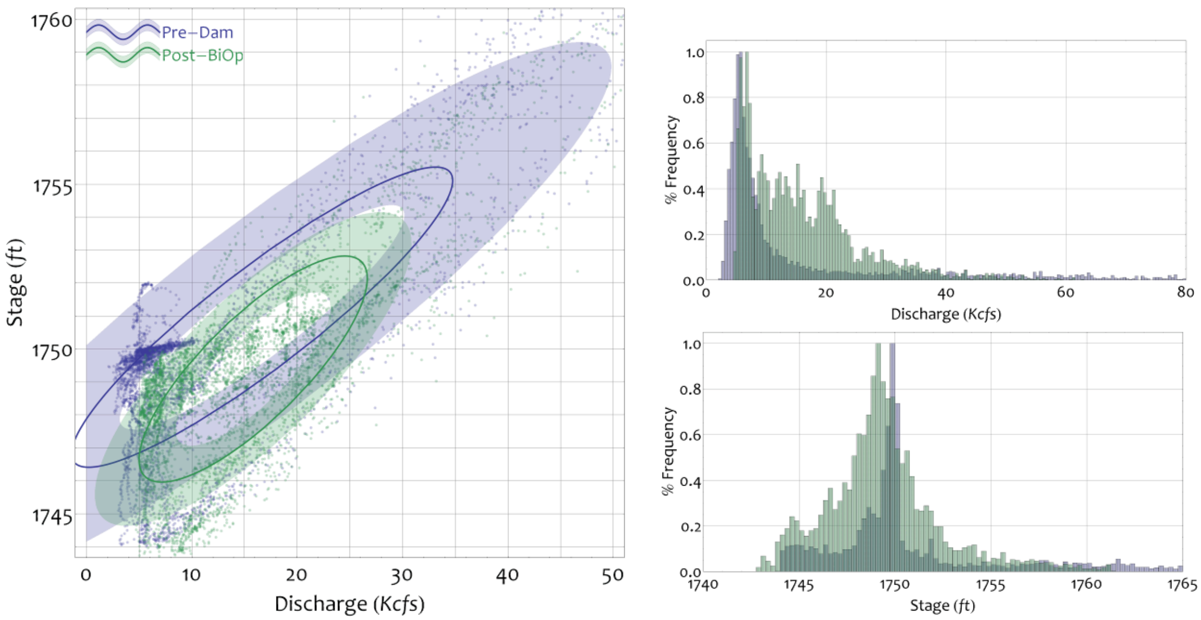

Figure A-4. Variability in downstream boundary conditions for select discharges between pre-dam versus post-BiOp hydrologic regimes. Kootenai River at Porthill (USGS Station #12322000).

Seasonal departure in boundary conditions between the pre-dam and post-BiOp regimes is characterized by a 50% reduction in median annual peak flows coincident with a nearly 10 ft reduction in river stage at Porthill, ID. Variability about the annual median under the pre-dam regime is limited primarily to the period of the spring peak (DWY 175-300) while under the post-BiOp regime, a larger degree of variability is present throughout the entire year. During the fall drafting period when dam operations are traditionally governed by power generation (DWY 1-175), post-BiOp discharge is higher than pre-dam with a median peak of about 20kcfs occurring mid-December (Figure A-5). These unseasonably high outflows combined with lower downstream lake levels as governed by the IJC has substantially increased the stream energy in the study reach during this period, resulting in a corresponding departure of the channel hydraulics and accompanying geomorphic response.

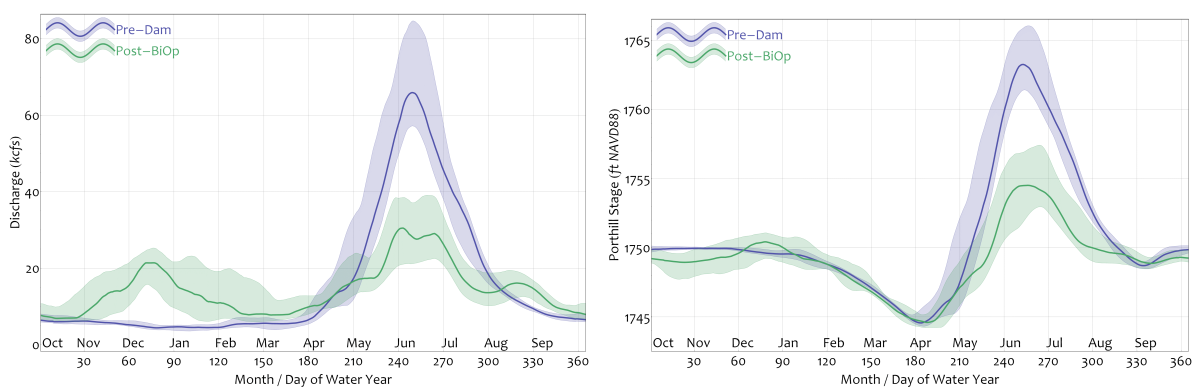

Figure A-5. Seasonal variation in discharge (left) and stage (right) for pre-dam versus post-BiOp hydrologic regimes. Kootenai River at Porthill (USGS Station #12322000).

The decrease in downstream lake level for the post-dam regimes represents a decrease in backwater stage of up to 2 ft for equivalent discharges between 5kcfs and 25kcfs; this indicates that the frequency of moderate post-dam discharges below bankfull (~30kcfs) has increased during periods of lower lake levels which may be attributed to increased flows for hydro-peaking operations during the first half of the water year (October to March). These higher winter flows result in the transport of fine sediment, bank erosion, and detrimental spawning habitat conditions for burbot.

Methods

In order to evaluate the historical hydraulic response and departure within the study reach, synthetic hydraulics were developed utilizing the one-dimensional U.S. Geological Survey (USGS) backwater model (Berenbrock 2005) for the four regime periods of interest provided in Table A-2 above. The backwater model geometry was based on 164 cross sections surveyed in 2002-2003 over 66 river miles between Porthill, ID downstream (USGS Station #12322000) and Leonia, ID upstream (USGS Station #12305000). Model runs were performed over a broad range of historical boundary conditions in order to synthesize mean daily hydraulic parameters at each station in the study reach for the period of interest.

It is important to note that the hydraulic modeling approach utilized for this analysis is based on a number of simplifying assumptions about the Kootenai River system. Most significant are the inherent assumptions of steady streamwise gradually varied flow, and an immobile channel bed. Also notable is the assumption that the model geometry based on the 164 cross sections surveyed in 2002-2003 could be used to represent the nominal channel geometry present during prior time periods. Historical planform analysis (as discussed in § 2.4.3) indicates that the Kootenai River has generally not experienced significant change in alignment (and corresponding channel slope) since 1928; one exception is in the Braided reaches were it is possible that the dominant channel may have historically adjusted in response to large discharge events, or changes in sediment supply. Historical changes in channel bed elevations and roughness, related to annual cyclical changes in sediment transport (e.g. formation/washout of dunes, armor deposition/breakup, etc.), are also expected to differ. As such, these simplifications may cause the model to calculate water-surface elevations and corresponding hydraulic parameters that differ somewhat from actual conditions in the study reach. However, considering the relatively gentle channel slopes (<0.001), the significant channel size (conveyance area > 5000 sq ft) and uniformity, and large inertia (Fr << 1) resulting from the dominant backwater influence of Kootenay Lake, such assumptions were not necessarily expected to limit the model applicability for use in evaluating the response/departure of section averaged hydraulic parameters for the general planning assessment required of this study.

The USGS backwater model was calibrated to a nominal tolerance of 0.1 ft using flow dependent channel roughness values at four gage stations as shown in Table A-3 below.

Table A-3. Stations used for backwater model calibration.		
Station#	**Station Name**	**Station RM**
1230500	Kootenai River at Leonia, ID	RM 171.875
12309500	Kootenai River at Bonner's Ferry, ID	RM 152.79
12314000	Kootenai River at Klockman Ranch	RM 139.469
123122000	Kootenai River at Porthill, ID.	RM 105.63

Regime departure was evaluated by synthesizing mean daily hydraulic parameters at each cross section in the model over a period of nearly 50 years. Section averaged results were further grouped into similar geomorphic reaches for comparison (Table A-4).

Table A-4. Summary of Kootenai River Geomorphic Reach Breaks used to evaluate Hydraulic Response.		
Reach	**Station Range**	**# of Cross Sections**
Canyon	RM 171.875 - 160.44	30
Braided 1	RM 160.44 - 156.209	12
Braided 2	RM 156.129 - 152.79	17
Straight	RM 152.69 - 151.686	11
Meander 1	RM 151.438 - 141.99	41
Meander 2	RM 141.68 - 105.63	45

Figure A-6 and Figure A-7 illustrate the cross section distribution in the Braided and Straight Reaches and Meander Reach 1 and a portion of Meander Reach 2, respectively.

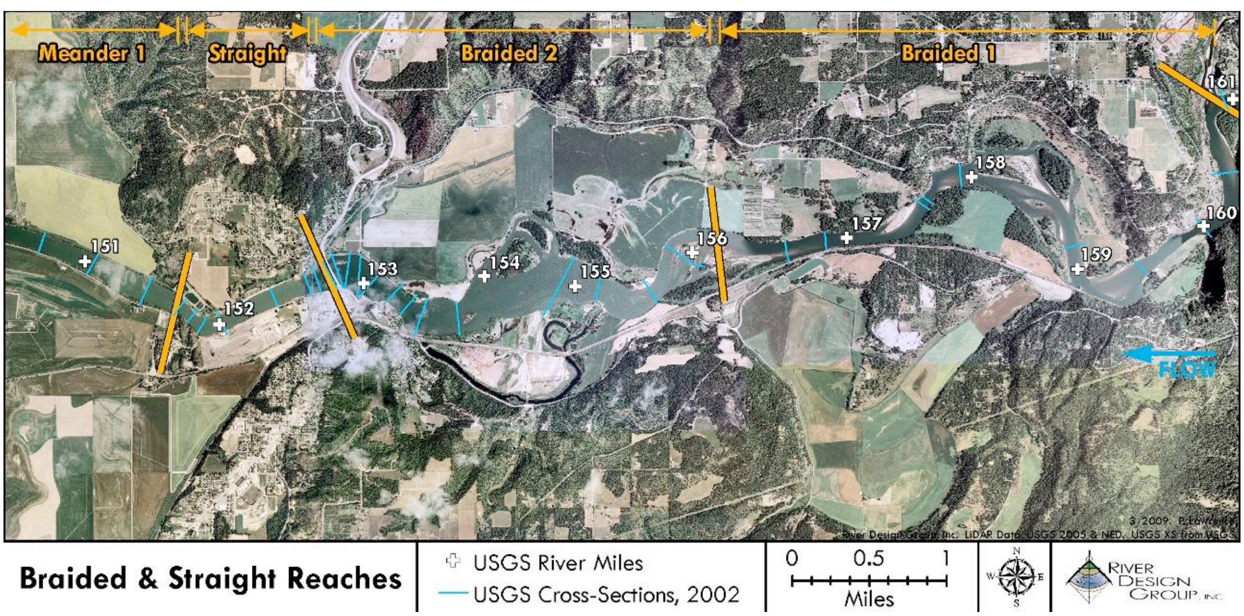

Figure A-6. Model cross sections in the Braided and Straight Reaches.

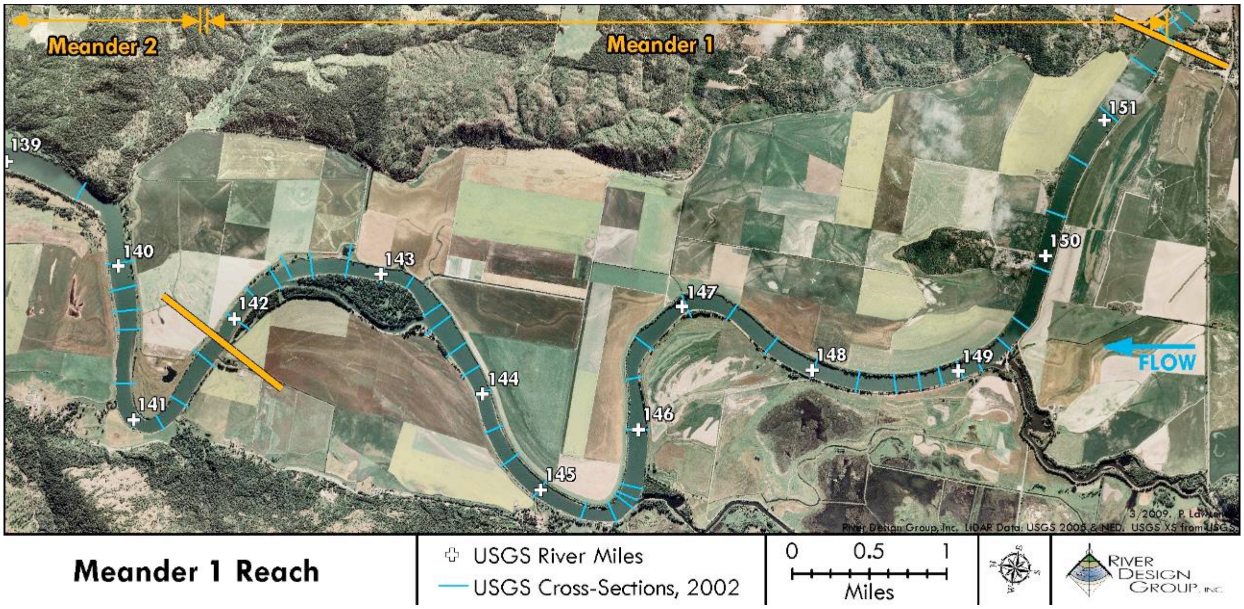

Figure A-7. Model cross sections in the Meander Reaches.

The operating level of Kootenay Lake and corresponding backwater effect can have a significant effect on the water surface elevation and corresponding hydraulic response below RM 157 (Figure A-8). The net result is a general decrease in available energy with river mile, regardless of discharge.

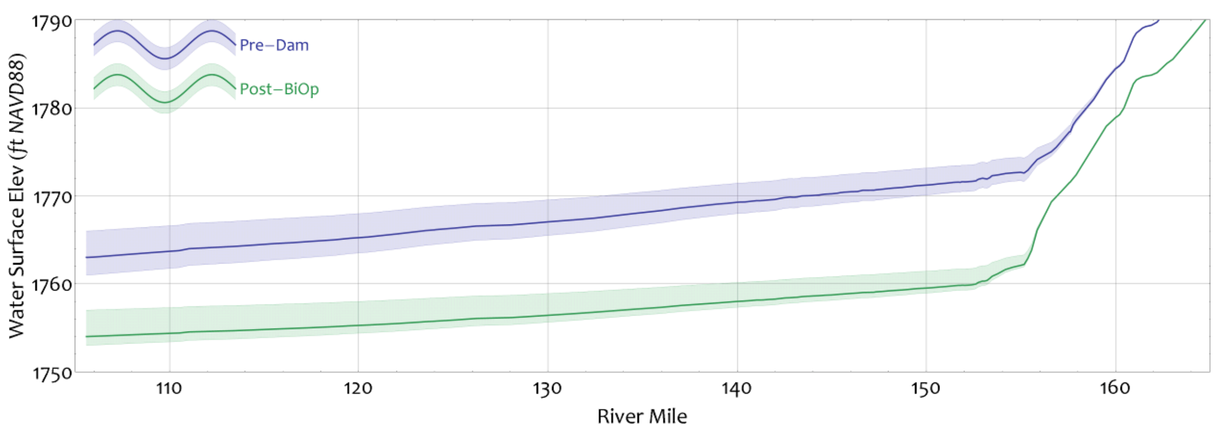

Figure A-8. Longitudinal median bankfull water surface profile for pre-dam (65 kcfs) and post-BiOp (30 kcfs) regimes through the study reach over IQR of downstream backwater influence.

To accurately account for the variable backwater effect in the departure analysis, USGS Sta#12322000 at Porthill, ID (RM 105.63) was set as the downstream limit of the backwater model and the water surface elevation at this station was used as a surrogate for the operating level of Kootenay Lake. The downstream water surface slope as a function of stage and discharge is shown in Figure A-9 below for Porthill (RM 105.63) and Bonners Ferry (RM 152.79), Figure A-10.

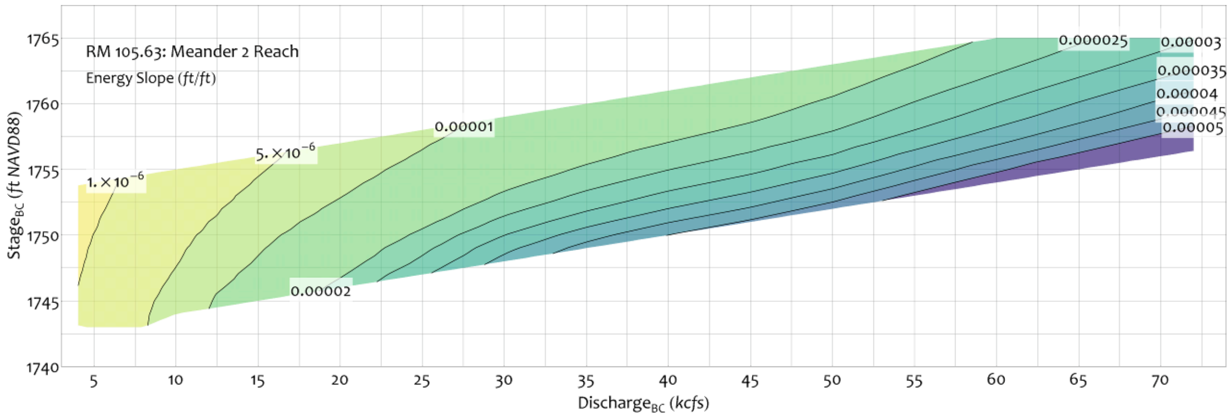

Figure A-9. Rating curves for energy slope for Kootenai River at Porthill (USGS Station #12322000).

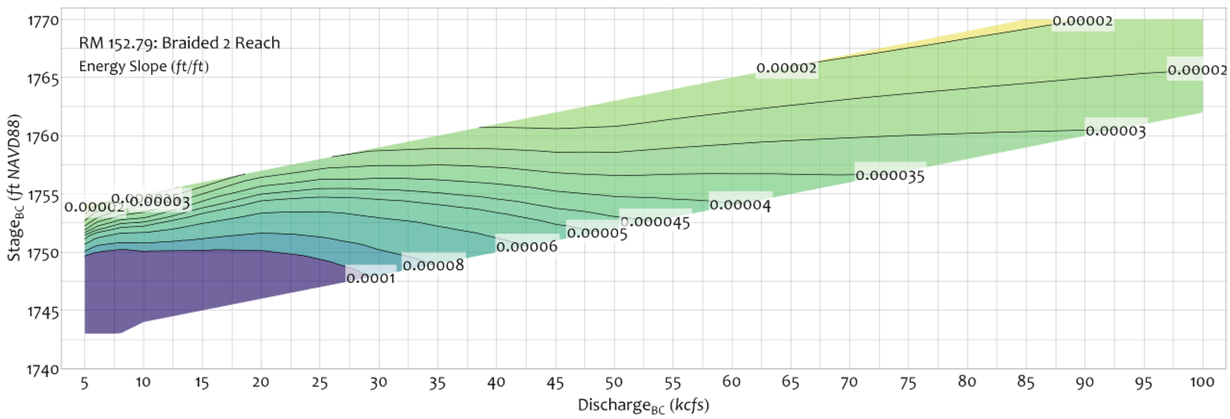

Figure A-10. Energy slope rating curves at RM 152.79 near Bonners Ferry.

In lieu of using looped rating curves, two parameter rating functions were developed for section-averaged hydraulic parameters of interest at each station in the backwater model utilizing standard two dimensional linear interpolation methods in order to accurately synthesize historical estimates of hydraulic response through the study reach. These rating functions can be visualized as a set of curves. Note that at cross sections which are upstream of the backwater influence, approximately upstream of RM 157, the curves essentially plot as vertical lines indicating that the hydraulic response can be directly related to discharge and thus the use of the backwater stage as a second predictor is not necessary (Figure A-11). Conversely, for cross sections within the backwater influence, the hydraulic response varies with both discharge and backwater (Figure A-12), and thus two parameter rating functions allow the backwater effect to be estimated for any time when both boundary conditions are known.

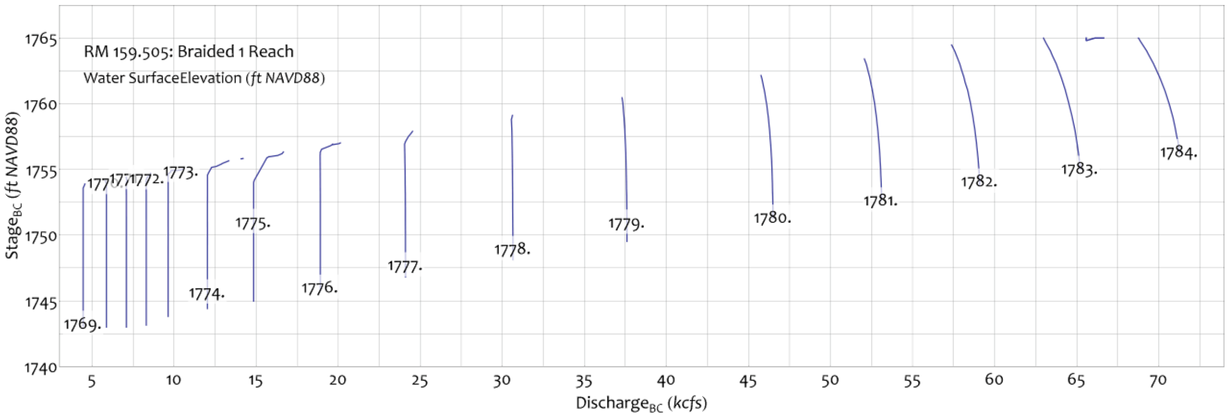

Figure A-11. Rating curves for water surface elevation at RM 159.505 above Bonners Ferry.

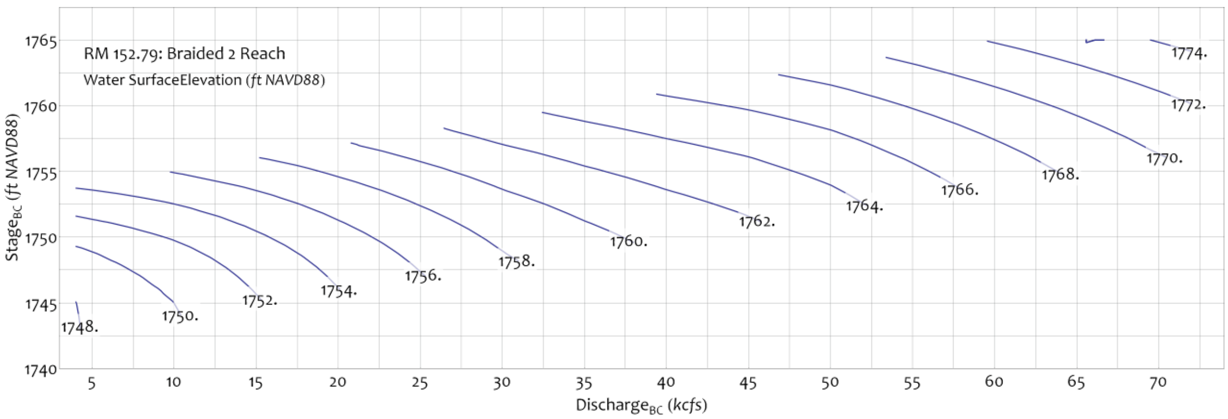

Figure A-12. Rating curves for water surface elevation at RM 152.79 near Bonners Ferry.

The spatial variability of backwater influence over a range of boundary conditions is illustrated through rating curve comparisons of velocity between reaches as shown in Figure A-13 below. Similar to water surface elevation, velocities at the top of the Braided Reach 1 are solely dependent upon discharge for flows <60kcfs. Further downstream in the Braided Reach 2, the backwater effect on velocity is not present for flows <15kcfs and Porthill stage < 1750 ft (Figure A-13, top graphic). However, the backwater effect on velocity increases with both discharge and lake level (Figure A-13, middle graphic). Downstream in the Meander Reach 2 near Shorty's Island, velocity is completely dependent upon both discharge and lake level over the entire range of boundary conditions (Figure A-13, bottom graphic).

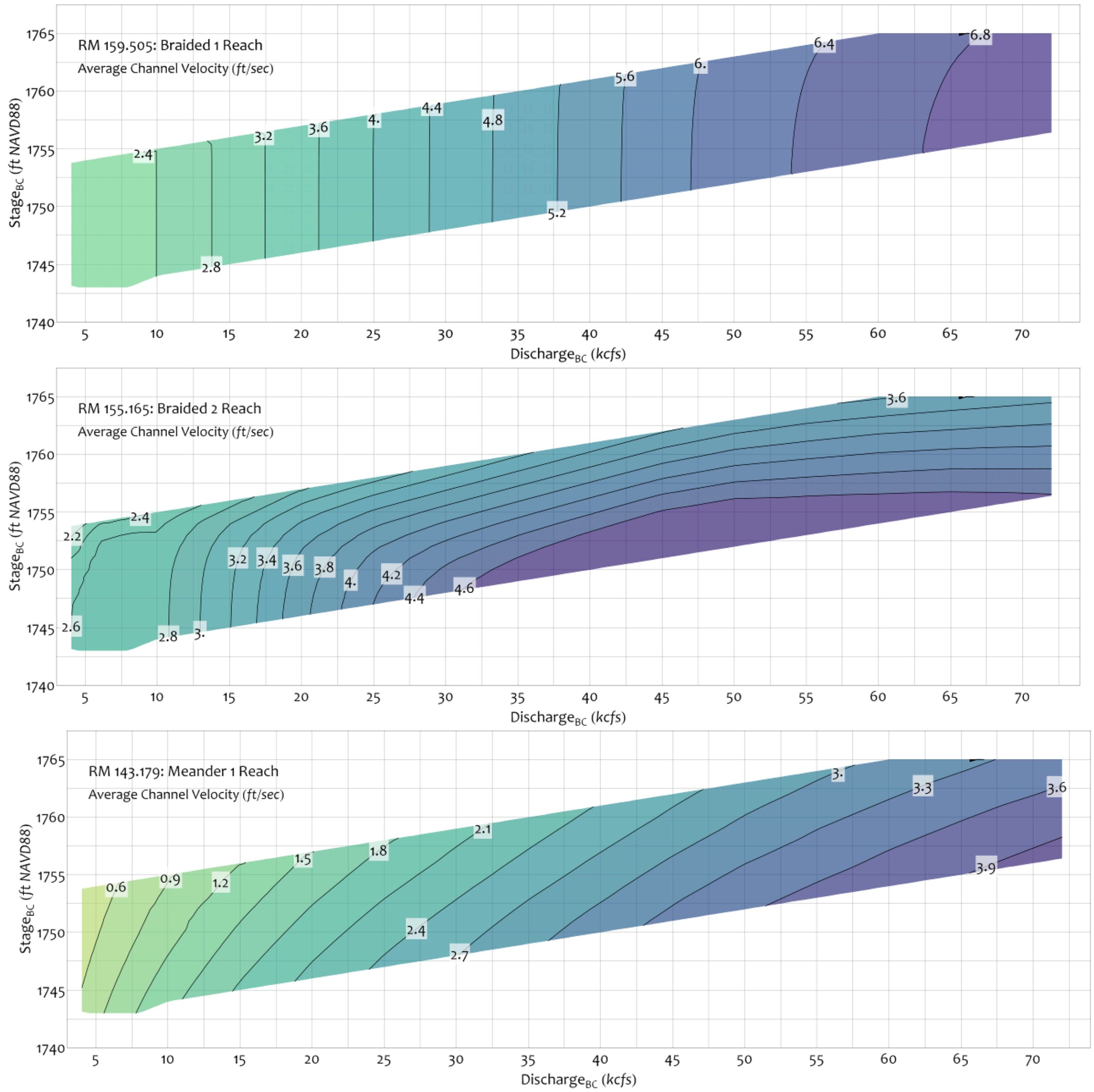

Figure A-13. Comparison of rating curves for velocity between select reaches including Braided Reach 1 (top), Braided Reach 2 (middle), and Meander Reach 1 (bottom). The graphics depict the varying influence of discharge and backwater on water velocities depending on location and discharge stage relationships.

Hydraulic Response

For the hydraulic response departure analysis, synthetic hydraulics were computed at each station in the model over the period of record and results were grouped by geomorphic reach and hydrologic regime. The hydraulic response corresponding to the departure in boundary conditions for the various reaches is shown by evaluating plots of stream power. Stream power represents the product of velocity and boundary shear and is commonly correlated with physical geomorphic processes in riverine systems.

Braided Reach 1

Figure A-14 presents the hydraulic response for average channel stream power in Braided Reach 1. At RM 156.604, the backwater influence on stream power is insignificant until flows exceed 35kcfs. Surrogate bankfull boundary conditions generate a response in stream power of approximately 2.1 lbf/ft sec under the pre-dam regime and approximately 1.4 lbf/ft sec under the post-BiOp bankfull regime, a 30% reduction.

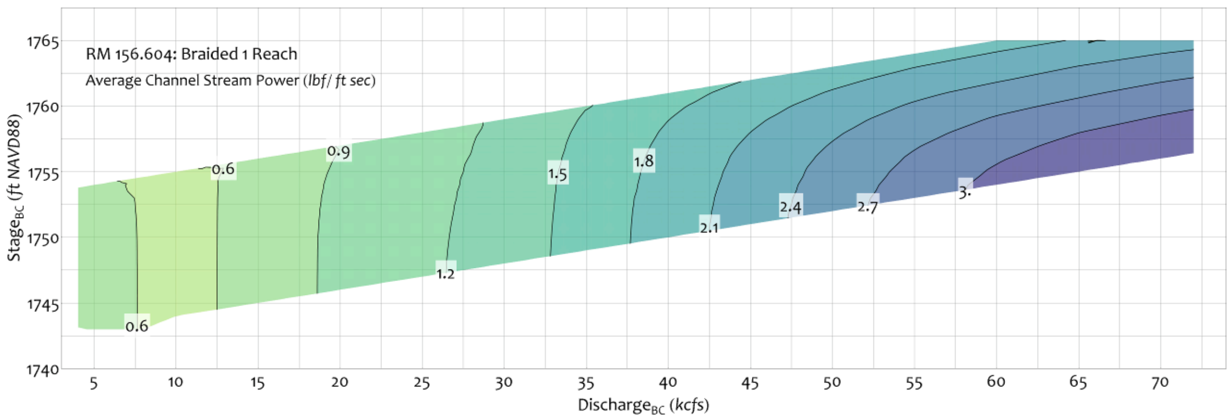

Figure A-14. Sampling rating curves for average channel stream power in Braided Reach 1.

In Braided Reach 1, pre-dam peaks for hydraulic response of stream power generally correlate with pre-dam discharge indicating a higher correlation of hydraulic response with discharge versus the Kootenay Lake backwater influence (Figure A-15). The low correlation of stream power with the backwater effect in Braided Reach 1 is due to the backwater not being present year-round in Braided Reach 1, as well as the backwater effect only influencing a portion of Braided Reach 1.

In the post-BiOp period, peak median channel stream power was reduced by over 50% to less than 1.5 lbf/ft sec, correlating with decreased spring discharge from Libby Dam and exhibiting only a slight increase above the annual mean near the spring peak (DWY 250). Also notable is a slight increase in stream power during the fall drafting period (DWY 1 ~ 175), with the lower 25th percentile of the post-BiOp briefly exceeding the upper 75th percentile of the pre-dam regime. In essence, in Braided Reach 1 the operation of Libby Dam has decreased stream power during the spring peak and increased stream power during the fall as the reservoir is drafted to increase capacity for the spring freshet.

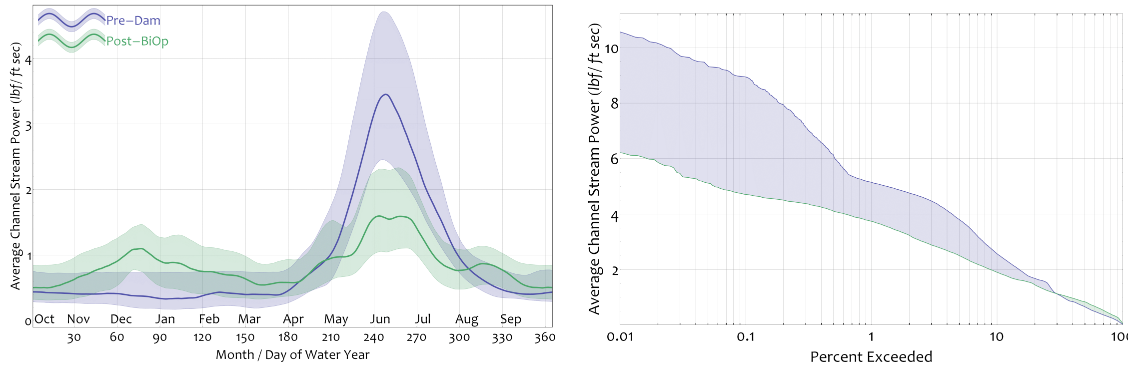

Figure A-15. Average stream power in Braided Reach 1: Median daily (left) and cumulative percent exceeded (right).

The cumulative degree to which peak hydraulic response has been shifted can be illustrated using plots of cumulative percent exceedance for various regime periods. Within the study reach, the general hydrologic pre-dam vs. post-dam regime departure has been a dampening of the annual peak hydraulic response accompanied by a slight increase in hydraulic response during the remainder of the year. Plots of cumulative percent exceedance allow the relative abundance of both extreme and common events to be compared between hydrologic regimes. Comparison of the cumulative percent exceedance in Braided Reach 1, implies that pre-dam stream power values greater than approximately 0.5 lbf/ft sec which occurred less than 30% of the time were significantly reduced in magnitude under the post-dam regime, while more common values of lower magnitude which occurred more than 30% of the time were only marginally increased under the post-BiOp regime indicating that larger less frequent events (i.e. < 1%) under the pre-dam regime may have had a greater influence on geomorphic response.

Braided Reach 2

The rating curves for average stream power response in Braided Reach 2 are presented in Figure A-16 below at RM 155.165. In general, the backwater influence on stream power is present above 15kcfs and becomes more pronounced as backwater stage at Porthill exceeds 1750 ft. Surrogate bankfull boundary conditions generate a response in stream power of approximately 0.7 lbf/ft sec under the pre-dam regime and approximately 1.2 lbf/ft sec under the post-BiOp bankfull regime, a 70% increase. The hydraulic response at many stations in Braided Reach 2 is dampened at larger flows as a result of the corresponding increase in backwater effect with increasing flows.

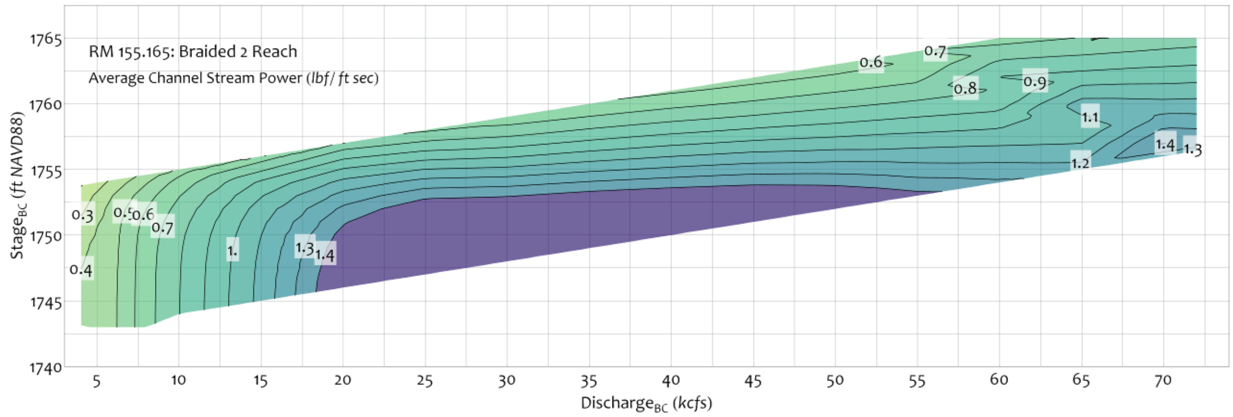

Figure A-16. Sample rating curves for average channel stream power in Braided Reach 2.

Following the general trend of decreasing energy with river mile, average stream power in Braided Reach 2 is roughly half that of Braided Reach 1 above, illustrative of the abrupt energy transition as the Kootenai River enters the Purcell Trench and the backwater influence from high Kootenay Lake levels dampens stream power, especially around the spring peak (~ DWY 250) for both pre-dam and post-BiOp hydrologic regimes (Figure A-17). Compared to Braided Reach 1, less separation between the pre-dam and post-BiOp median stream power in Braided Reach 2 is evident throughout the entire water year. The overall similarity of median stream power values in Braided Reach 2 for both the pre-dam and post-BiOp regimes (< 0.5 lbf/ft sec) indicates the hydraulic response is more strongly tied to the channel geometry and Kootenay Lake backwater than the Libby Dam discharge.

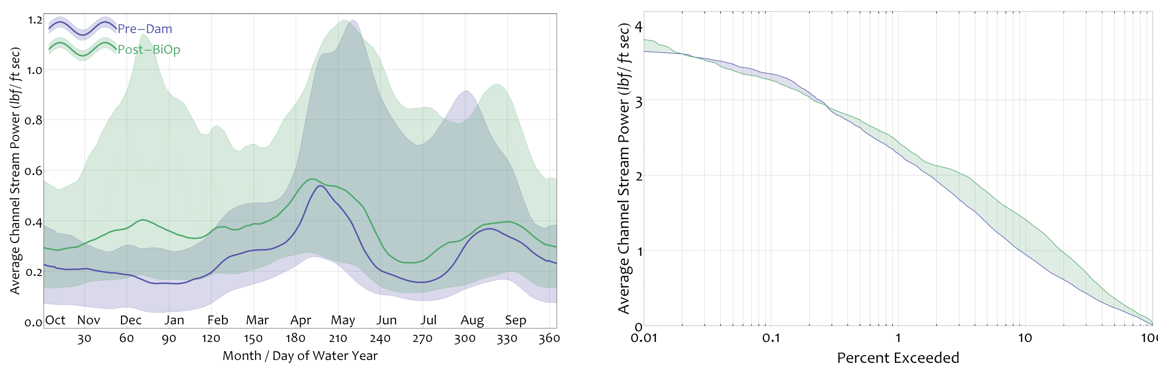

Figure A-17. Average channel stream power in Braided Reach 2: Median daily (left) and cumulative percent exceeded (right).

Also of interest in Braided Reach 2 is that, on the rising limb of the spring peak (~ DWY 200) a less frequent peak in hydraulic response occurred above median values during both pre-dam and post-dam regimes as indicated by the shape of the upper 75 percentile, where stream power as high as 1.0 lbf/ft sec were reached in the pre-dam era; this effect is generally on a declining trend by DWY 250, due to the combined effects of the over-widened braided channel geometry and backwater as Kootenay Lake levels approach a seasonal maximum. Also of note is the increased hydraulic response in Braided Reach 2 during the fall (DWY 1 ~ 175). Similar to Braided Reach 1, the hydraulic response in Braided Reach 2 is attributed to the increased influence of the backwater effect with decreasing river mile. Additionally, the fall dam regime operations governed by power generation also influence the hydraulic response. Comparison of the cumulative percent exceedance for stream power in Braided Reach 2 indicates that the magnitude of post-BiOp stream power is slightly above of the pre-dam regime for common events. In the context of net stream power, the results imply that the geomorphic response from more moderate and higher frequency events may exceed that of rare extreme events. This result is converse to the cumulative response in Braided Reach 1 upstream which is more greatly influenced by discharge.

Straight Reach

The Straight Reach marks the transition of the lower extent of the variable backwater effect, and hydraulic response downstream is dominated by Kootenay Lake elevations year round. The magnitude of average stream power varies over an order of magnitude and is less than one-half of the values above in Braided Reach 2, following the continuing trend of decreasing energy with decreasing river mile (Figure A-8). Surrogate bankfull boundary conditions generate a nearly equal response in stream power of approximately 0.25 lbf/ft sec under both pre-dam and post-BiOp regimes indicating the dominant influence of the backwater effect for larger flows (Figure A-18).

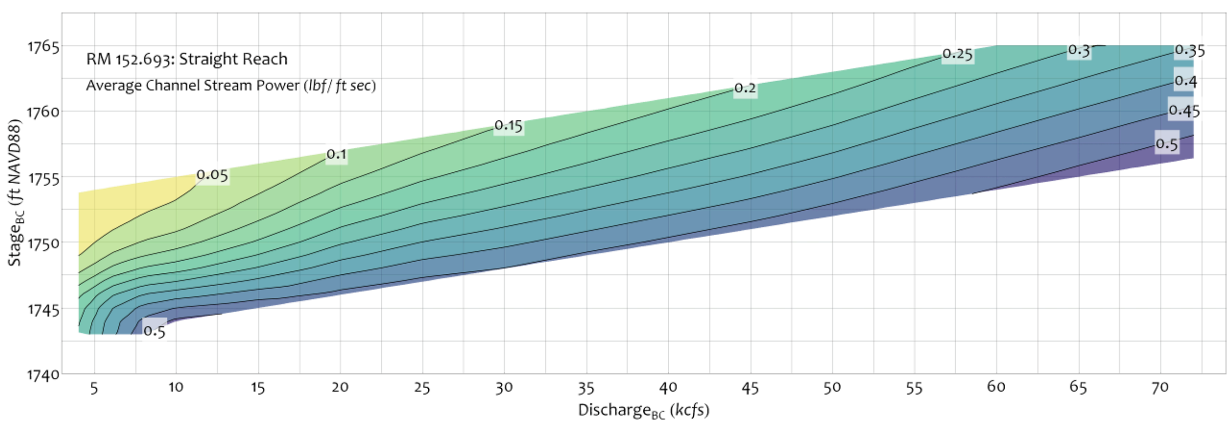

Figure A-18. Sample rating curves for average channel stream power in the Straight Reach below Bonners Ferry.

The median pre-dam stream power in the Straight Reach was characterized by a seasonal peak around DWY 250 correlating with the annual runoff peak (Figure A-19). This result indicates that the channel geometry within the Straight Reach can provide an increased hydraulic response given sufficient discharge and minimal backwater effect. In the post-dam period, this seasonal peak in stream power has been dampened by over one-half, indicating the inability of post-BiOp discharge to overcome the Kootenay Lake backwater effect in the Straight Reach.

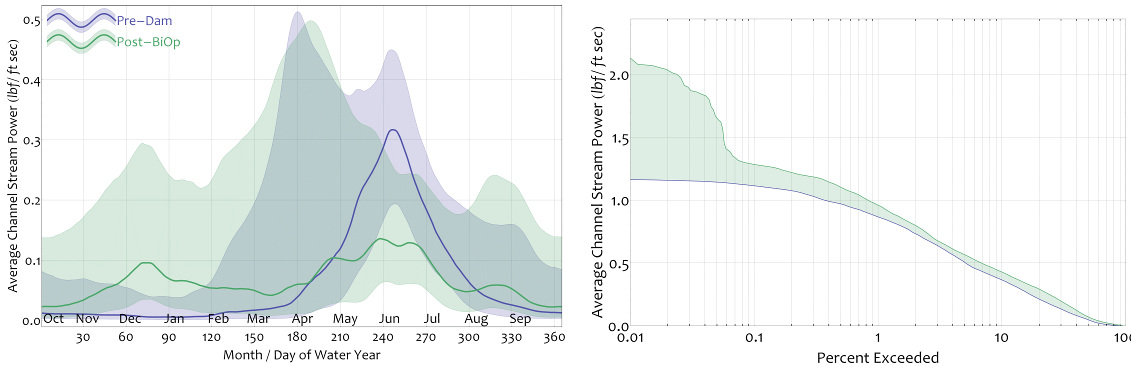

Figure A-19. Average channel stream power in the Straight Reach: Median daily (left) and cumulative percent exceeded (right).

Prior to the spring peak, an earlier less frequent peak in stream power occurs in the Straight Reach on the rising limb of the spring peak (< DWY 200) similar to Braided Reach 2 above, where the timing of the backwater effect varies. The initial spike in stream power is in response to increased discharge from Libby Dam and a spike in energy slope above 0.0002. This effect is short lived however and after DWY 200 the hydraulic response in the Straight Reach follows a notable decreasing trend as Kootenay Lake refills and the backwater extent migrates upstream. As the backwater extent migrates upstream, the median energy slope decreases to less than 0.00005. As in Braided Reach 1, the cumulative percent exceedance for stream power in the Straight Reach is higher in the post-BiOp regime. This seems to indicate that the cumulative effect of stream power generated during less frequent extreme discharge events is dampened by the increased backwater effect, and more stream power was generated overall for more moderate post-BiOp flows and corresponding lower lake levels.

Meander Reaches

By the top of Meander Reach 1, the backwater influence is present year round and follows the general trend of increased dampening with discharge. The stream power rating curve is flattened by the backwater effect in the Meander Reaches (Figure A-20 and A-21).

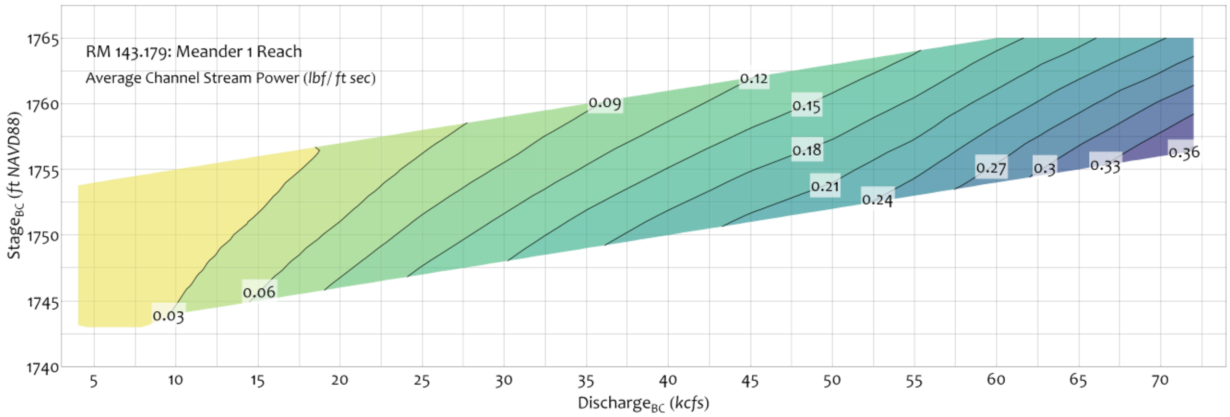

Figure A-20. Rating curves for average channel stream power in Meander Reach 1 near Shorty's Island.

In Meander Reach 1, average channel stream power varies over an order of magnitude and is reduced by another 40% relative to the response in the Straight Reach, following the continuing trend of decreasing energy with river mile (Figure A-8). Surrogate bankfull boundary conditions generate a response in stream power of 0.17 lbf/ft sec under the pre-dam regime and 0.09 lbf/ft sec under the post-BiOp bankfull regime, an approximately 50% decrease.

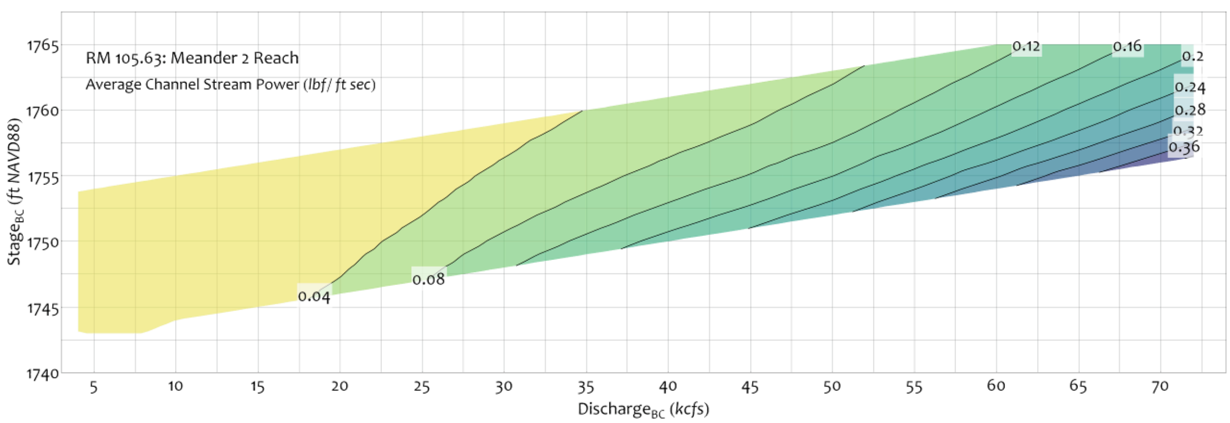

Figure A-21. Rating curves for average stream power in Meander Reach 2 at Porthill, ID.

Unlike the two immediate reaches upstream, the Meander reaches are not characterized by the short term peaks in hydraulic response coincident with the rising limb of the hydrograph (DWY 200-250). This result implies that for the Meander reaches during the post-BiOp period, any potential increases in hydraulic response on the rising limb of the hydrograph were sufficiently drowned out by the more sustained backwater effect of Kootenay Lake. Hydropeaking operations during the fall drafting period (DWY 1-175) resulted in increased stream power for the post-BiOp regime, similar to other upstream reaches. Figure A-22 displays the median daily and cumulative percent exceeded stream power in the Meander reaches.

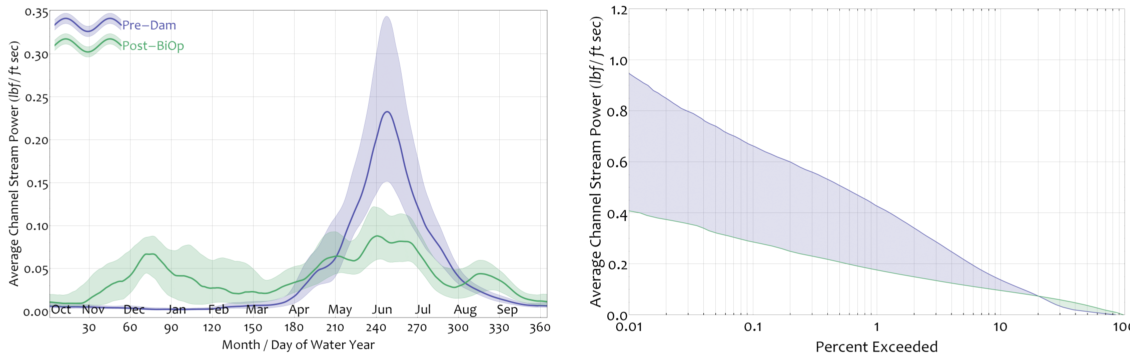

Figure A-22. Average channel stream power in the Meander reaches: Median daily (left) and cumulative percent exceeded (right).

Unlike the Straight Reach and Braided Reach 2, the trend for cumulative percent exceedance of stream power in the Meander reaches shifts back towards the pattern of the upper Braided Reach 1, where more common moderate events only exceed pre-dam magnitude for values occurring more often than 20% of the time, or ~4/5 of the record. Events that occur in the remaining ~1/5 of the record may indicate the increased geomorphic significance for these more extreme events on historical channel adjustment.

Summary

River hydraulics are strongly influenced by Kootenai River discharge and the Kootenay Lake backwater. The post-dam hydrograph is characterized by lower peak flows and higher base flows compared to the pre-dam condition. Additionally, a comparison of stage-discharge relationships illustrates a narrower range of results under the post-dam era relative to the pre-dam regime, suggesting the influence of river management on flow and backwater variability. Post-BiOp management has allowed a wider range of flow relative to the pre-BiOp period, although the variability is substantially less than the pre-dam period. In short, the Kootenai River currently has a more consistent range of flows with lower peaks and higher base flows.

Libby Dam and Corra Linn Dam operations have an overriding influence on water velocities and stream power. Modeling results indicate that pre-dam velocities and stream power were higher during the spring freshet and lower during the fall compared to post-dam conditions that are managed for flood control and other obligations. River hydraulics also vary according to location in the project area. In Braided Reach 1, the most upstream reach, hydraulics are almost entirely influenced by the river discharge, with little effect from the Kootenay Lake backwater. Moving downstream, the interplay between the river discharge and the backwater effect reverses as the backwater becomes more prominent. Within Meander Reach 2, the backwater effect wholly influences river hydraulics. River hydraulics are increasingly influenced by river discharge with increasing river mile. Conversely, hydraulics are increasingly tied to the backwater effect with decreasing river mile.