REPORT

Ministry of Transportation and Infrastructure

Fulton River Bridge No. 6646 Replacement
100% Hydrotechnical Design Report

DECEMBER 2023

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EXECUTIVE SUMMARY

Associated Engineering (B.C.) Ltd. completed a hydrotechnical engineering assessment to support the replacement of the Fulton River Hatchery Bridge No. 6646 on Highway 118. The bridge crosses Fulton River between Fulton Lake Dam (upstream) and Babine Lake (downstream). The dam regulates flow release to Fulton River, and Babine Lake water elevations have an influence on bridge hydraulics. Hydrological analysis was completed for Fulton River and Babine Lake. Hydraulic modelling and analysis was completed for the river channel and proposed bridge. A summary of the key hydrotechnical design recommendations are provided in the table below.

Parameter	Recommendation and Comment
Design Flow	• 302.3 m^3/s • 200-year peak instantaneous return period, with 10% upward scaling factor for climate change • Based on regional hydrological analysis
Design Water Surface Elevation at Bridge	• 713.36 m • Based on hydraulic model results • Model scenario number 1, with design flow and 200-year Babine Lake elevation (712.46 m)
Freeboard and Minimum Low Chord of Bridge	• Minimum Freeboard = 1.5 m • Minimum Low Chord of Bridge = 714.86 m • Proposed Design Low Chord for Bridge = 715.17 m • Proposed Design Freeboard = 1.81 m
Erosion and Scour Protection	Left Bank: • No riprap as per regulatory review and consultation process with DFO
	Right Bank: • Class 100 kg Riprap • Minimum Layer Thickness = 0.7 m • Riprap Thickness at Bridge Abutment = 2.0 m (for geotechnical stability) • Side Slope = 1.5H : 1V • Minimum Scour Depth = 1.7 m below channel bed elevation
	Right Bank Upstream of Bridge at Channel Bend: • Class 500 kg Riprap • Minimum Layer Thickness = 1.2 m • Side Slope = 2H : 1V • Minimum Scour Depth = 1.7 m below channel bed elevation • Scour Depth at Dolphin Piles = 2 m below channel bed elevation

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1 INTRODUCTION

The existing Fulton River Hatchery Bridge No. 6646 spans Fulton River and the Fisheries and Oceans Canada (DFO) spawning channels on Highway 118. The existing bridge site is located approximately 1.5 km upstream of Babine Lake, and 4.5 km below the Fulton Lake Dam (D620000-00) which is owned and operated by DFO. The bridge is nearing the end of its service life and the **Ministry of Transportation and Infrastructure** (MoTI) plans to replace the bridge structure. The project scope is to replace the bridge structure with a two-span bridge. The replacement bridge structure will include a pier in the berm that separates the spawning channel from Fulton River, and it will be located immediately downstream of the existing bridge. This report outlines the hydrotechnical engineering assessment and design recommendations completed by **Associated Engineering (B.C.) Ltd.** (AE).

A preliminary hydrotechnical assessment memorandum was completed on May 31, 2021. Following discussion with the MoTI regarding the limited survey that was provided, additional surveying was completed to obtain bathymetric and topographic data upstream and downstream of the bridge. The additional survey data was critical for the bridge considering the complicated nature of the site. This report is a stand-alone submission and supersedes the May 31, 2021 preliminary hydrotechnical assessment memorandum.

2 DESIGN FLOW CRITERION

Highway 118 is a provincial highway that connects the Yellowhead Highway to the Village of Granisle. Accordingly, the hydrological design criterion (design flow) for the site is the 200-year return period peak instantaneous flow (MoTI 2016, 2019).

A minimum freeboard of 1.5 m will be applied to the design flow to establish the minimum low chord elevation of the proposed bridge (MoTI 2016). The top of erosion protection shall be a minimum of 0.3 m above the design flow. The construction period design flow should be the 10-year return period based on the Water Sustainability Regulation.

Due to the complex nature of the site, water elevations of Babine Lake have also been evaluated. Babine Lake backwaters up the mouth of Fulton River to the vicinity of the bridge during freshet. The lake levels influence the hydraulic conditions.

3 SITE AND WATERSHED DESCRIPTIONS

3.1 Site and Fulton River

The Fulton River Hatchery Bridge spans Fulton River between the Fulton Lake Dam and Babine Lake. The site was modified by construction of the Fulton River Project in the late 1960's. The Fulton River Project includes Fulton Lake Dam, overflow spillway, low level outlet, intake and flow regulating system, valve house, tunnel, pipeline, and spawning channels. The Fulton River Hatchery spawning channel is approximately 1 km in length along the left bank of Fulton River at the bridge. An earth berm separates the river channel left bank from the spawning channel. The bridge spans the spawning channel and the natural channel. At the bridge, the river channel bottom width is approximately 30 m and the spawning channel bottom width is approximately 14 m. Refer to **Figure 3-1** for a project location map. Selected site photos are provided in **Appendix A**.

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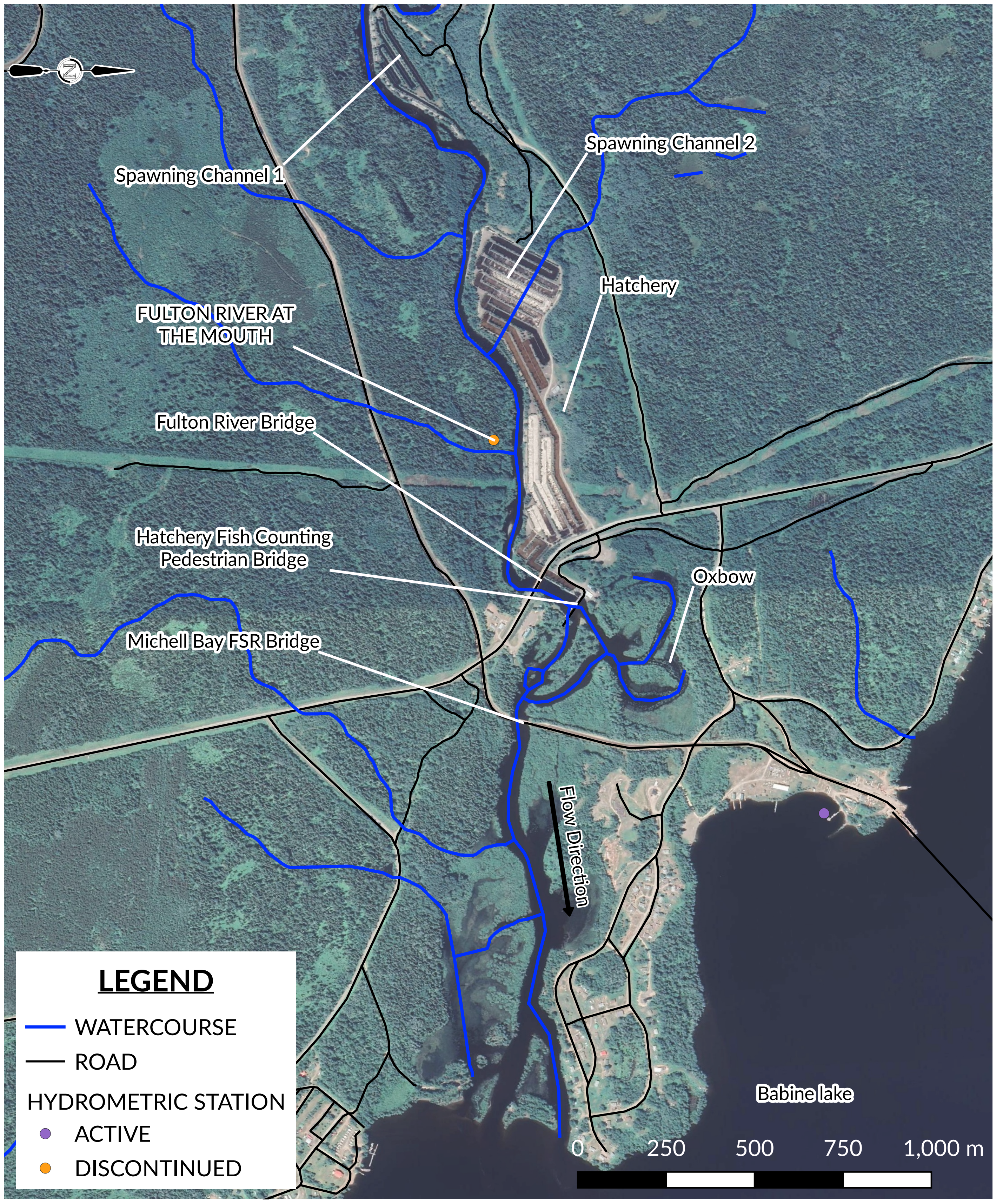

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FIGURE 3-1

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PROJECT LOCATION

Fulton River near the bridge is a low gradient (less than 1%), wandering channel. Downstream of the bridge there are two additional structures spanning Fulton River: the DFO fish counting fence bridge and the Michell Bay Forest Service Road (FSR) bridge. An oxbow and floodplain area is downstream of the DFO fish counting fence on the left bank of the river.

There is evidence of minor bank erosion on both banks at the existing bridge. The bank erosion is attributed to the sharp meander geometry. Approximately 35 m upstream of the bridge there is a vegetated bar on the inside left bank of the meander. Approximately 200 m upstream of the bridge there is a bar in the middle of the river channel, which is indicative of a change in longitudinal grade and a location of sediment deposition.

Fulton River drains into Babine Lake. Babine Lake is the longest natural lake in BC and drains northwest into the Babine River, which is a tributary to the Skeena River. There is a Water Survey of Canada (WSC) hydrometric station on the lake, *Babine Lake at Topley Landing* (Station 08EC003), which has a record period of 1955 – 2021. Although the bridge is 1.5 km upstream of Babine Lake, the lake influences hydraulic conditions at the site. The channel bottom elevation[1] at the bridge is approximately 708.1 m and the lowest recorded water surface elevation of Babine Lake is 710.2 m. So, the water surface of Babine Lake is backwaters up the mouth of the river to the bridge.

As per anecdotal information from DFO (Harborne 2021), during freshet Babine Lake backwaters to approximately 100 m upstream of the Fulton River Hatchery bridge on an annual basis. This information supports the sediment deposition observed in aerial imagery upstream of the bridge. During the elevated lake levels, the river has low velocity at the bridge site. This condition typically remains from May through July and sometimes into the middle of August. Further to this, Fulton River has not flooded over the natural channel into the spawning channel.

3.2 Watershed

The Fulton River watershed area is approximately 1,421 km^2. Numerous watercourses flow into Fulton River and ultimately into Fulton Lake. Fulton Lake is operated by DFO and outflows are regulated. The lake elevation was raised approximately 10 m through construction of the dam. After passing through Fulton Lake Dam, Fulton River flows into Babine Lake. Based on a desktop review of Google Earth imagery, the watershed is primarily forested and there are resources roads and forest operations. There is no notable land development in the watershed. The BC Historical Wildfire mapping indicates there have not been any fires within the watershed since the early 1900's.

The watershed is located within the Babine Lake watershed group. It is within the Nechako Plateau Hydrologic Zone (#8), with the Northern Coast Mountains (#1), Northern Central Uplands (#5), and Southern Hazelton Mountains (#9) near the watershed. The highest elevation of the watershed is approximately 2,396 m at the peak of Mount Cronin, and the lowest elevation of the watershed is the site at approximately 708 m.

3.3 Fulton Dam Operation

The Fulton River Project alters the natural distribution of stream flows in the Fulton River to provide optimum conditions for spawning and egg incubation, and some control over fry migration. Fulton River flows required for fish and fish habitat are listed in **Table 3-1** below (DFO 2010).

[1] Note that all elevations referenced in this report are to CGVD28.

Table 3-1: Fish Flows Required in the Fulton River

Fish Activity	Date	Flows Required in Fulton River
Upstream migration	Aug. 10 to Oct. 31	Optimum 3.4 m^3/s to 4.3 m^3/s
Adults spawn	Some Coho Salmon to Oct. 30	Max during rain flood: 28.32 m^3/s while it can be controlled
End spawning	After Oct. 31	As above
Incubation and hatching	Aug. 10 to June 1	Optimum 3.39 m^3/s to 5.09 m^3/s No max restriction
Downstream migration	After June 10	Maximum 85 m^3/s
End migration	After June 10	No max. restriction

For the periods where no maximum flow restriction is in place for Fulton River downstream of the dam, releases can be higher to accommodate reservoir conditions. Fulton Lake levels and dam release flows are higher during freshet period. The maximum historical recorded flow[2] in Fulton River is 220.5 m^3/s which occurred on May 15, 2018. The maximum spillway release is 566 m^3/s. A dam breach scenario[3] would produce a higher flow rate and there would be extensive damages in the flood zone, including the DFO fish hatchery infrastructure and the Fulton River bridge.

Fulton River flow up to 73.6 m^3/s is acceptable for operating the fish counting fence. It is also worthwhile noting that DFO (2010) indicates that flows more than about 170 m^3/s for several days could cause debris to float down the river, which would reduce water passage under the bridges and their counting fence.

4 CLIMATE CHANGE CONSIDERATIONS

4.1 Pacific Climate Impacts Consortium: Plan2Adapt

Climate change adaptation must be considered for the bridge. To help inform possible future change, the Bulkley-Nechako Regional District was reviewed for various time frames using the Pacific Climate Impacts Consortium (PCIC) Plan2Adapt tool. The PCIC projections are based on median values from 12 different Global Climate Models (GCMs) and the Representative Concentration Pathway (RCP) 8.5 greenhouse gas emission scenario. As per **Table 4-1**, the 2080's projection generally has the largest increases. For the 2080's period, a 5.3-degree annual temperature increase is projected. In addition, PCIC projects a 4.9% increase in summer rainfall and a 13% increase in winter rainfall. Lastly, PCIC projects annual snowfall will decrease, with the winter and spring decreasing by 27% and 67%, respectively. These future changes could lead to changes in the hydrologic regime, such as the timing and duration of runoff.

[2] From DFO records. Note that there is a higher recording in 1983, but there is uncertainty with the value because it is higher than the rating curve.
[3] It is noted that dam breach events are not considered as part of design criteria for MoTI infrastructure.

Table 4-1: PCIC Plan2Adapt Bulkley-Nechako Regional District Results

PCIC Plan2Adapt Cariboo Forestry Region: Projected Change from 1961-1990 Baseline							
Climate Variable	Season	2020's (2010 - 2039)		2050's (2040 - 2069)		2080's (2070 - 2099)	
		Ensemble Median	Range (10th to 90th percentile)	Ensemble Median	Range (10th to 90th percentile)	Ensemble Median	Range (10th to 90th percentile)
Temperature (°C)	Annual	+1.7 °C	+1.4 °C to +1.9 °C	+3.2 °C	+2.3 °C to +4.2 °C	+5.3 °C	+3.9 °C to +6.8 °C
Precipitation (%)	Annual	7.00%	+0.27% to +11%	9.70%	+3.7% to +18%	12%	+9.1% to +27%
	Summer	9.60%	-1.4% to +17%	10%	-12% to +21%	4.90%	-20% to +29%
	Winter	3.70%	-3.0% to +12%	6.60%	-0.16% to +12%	13%	+1.1% to +25%
Precipitation as Snow (%)	Annual	-18%	-24% to -12%	-29%	-35% to -23%	-41%	-51% to -37%
	Winter	-12%	-21% to -4.8%	-19%	-24% to -13%	-27%	-36% to -21%
	Spring	-30%	-35% to -21%	-48%	-57% to -42%	-67%	-78% to -58%

4.2 Pacific Climate Impacts Consortium: Station Hydrologic Model Output

Another method was completed to assess climate change impacts on hydrology. The PCIC Station Hydrologic Output considers simulated daily flow data from the Variable Infiltration Capacity (VIC) model for eight statistically downscaled GCMs. The most suitable Water Survey of Canada (WSC) hydrometric station in the PCIC Station Hydrologic Output is *Osilinka River near End Lake* (Station 07EC004). It is near the site and shares similar watershed characteristics and size as Fulton River. Data from this station was analyzed following methodology similar to the MoTI's Canadian Water Resources Associate (CWRA) workshop presentation (Sullivan 2019). The RCP 4.5 and RCP 8.5 emission scenarios were analyzed with 6 different GCMs. Five different time periods were sorted in 30-year increments and these were compared to a baseline data period (1945-2012). Statistical analysis was completed using HEC-SSP (US ACE 2019) with the Gumbel statistical distribution to estimate 200-year return period flows for each time period. The results of this analysis are listed in **Table 4-2**, which indicates a decrease in future peak flows.

Table 4-2: Station 07EC004 Flow Changes Compared to Baseline Period (1945 - 2012).

Emission Scenario	Percent Change in Peak Flow Compared to Baseline Period				
	2030-2059	2040-2069	2050-2079	2060-2089	2070-2099
RCP 4.5	-43%	-44%	-44%	-43%	-42%
RCP 8.5	-41%	-39%	-37%	-38%	-41%

4.3 Design Flow Increase due to Climate Change

Based on the climate change considerations discussed above, it is anticipated that Fulton River could be subject to a decrease in peak flow events in the future. In addition to this, Fulton River is a regulated system that is operated by DFO. Releases to the natural river are controlled by DFO. If the hydrologic regime changes in the future, it is anticipated that freshet duration could be longer but the peak could be lower. Therefore, to be consistent with EGBC (2018) for no observed increasing trend, AE applied a 10% increase to estimate the design flow for the site. The Design Criteria Sheet for Climate Change Resilience is included in **Appendix B**.

5 HYDROLOGICAL ANALYSIS

5.1 Fulton River

5.1.1 Hydrometric Data on Fulton River

Approximately 500 m upstream of the Fulton River Hatchery Bridge there is a discontinued WSC hydrometric station *Fulton River at the Mouth* (Station 08EC002) which recorded flows between 1964 and 1970. The Fulton Lake Dam was commissioned in 1969, so there are only two years of hydrometric data following dam operation that are available for review. A hydrograph of the recorded daily flows between 1964 and 1970 is shown in **Figure 5-1**. The maximum daily flows are listed in **Table** 5-1. The largest recorded daily flow was 194 m^3/s in 1968, which is prior to the dam commissioning. This data does not provide a long enough period of record for a reliable statistical analysis; however, it does provide some insight on the change of the hydrologic regime downstream of the dam.

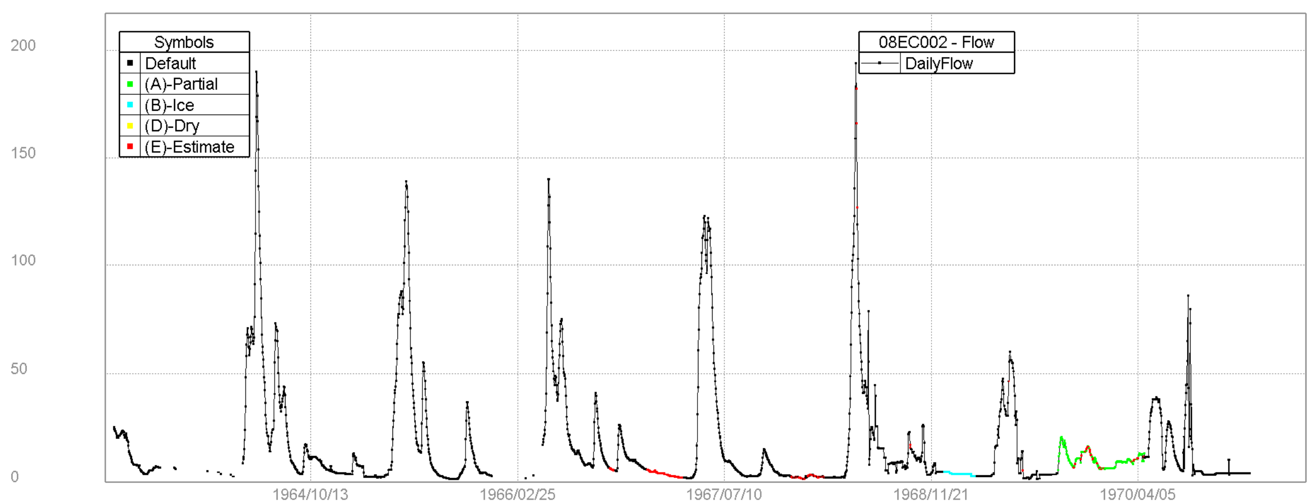

Figure 5-1: Station 08EC002 Fulton River at the Mouth Hydrograph between 1964 - 1970

Table 5-1: WSC 08EC002 Maximum Daily Flows

Year	Month, Day(s)	Maximum Daily Flow (m^3/s)	Pre or Post Dam Commissioning
1964	June 4	190	Pre-Dam Commissioning
1965	June 1	139	Pre-Dam Commissioning
1966	May 11	140	Pre-Dam Commissioning
1967	May 23	123	Pre-Dam Commissioning
1968	May 23	194	Pre-Dam Commissioning
1969	May 30	60	Post-Dam Commissioning
1970	August 4	86.1	Post-Dam Commissioning

5.1.2 Regional Analysis

In the absence of a long-term flow record for WSC Station 08EC002, AE completed a regional hydrological analysis to estimate naturalized flows at the site. WSC hydrometric stations within the Nechako Plateau hydrological zone were reviewed. Then nearby hydrometric stations in neighbouring hydrological zones with similar watershed characteristics to the site were reviewed. A long list of candidate stations was complied. The list was then narrowed down to 16 stations based on watershed area, period and years of record, quality of data, and watershed characteristic similarities to the site **(Table 5-2)**. Refer to **Figure 5-2** for the Regional Analysis map.

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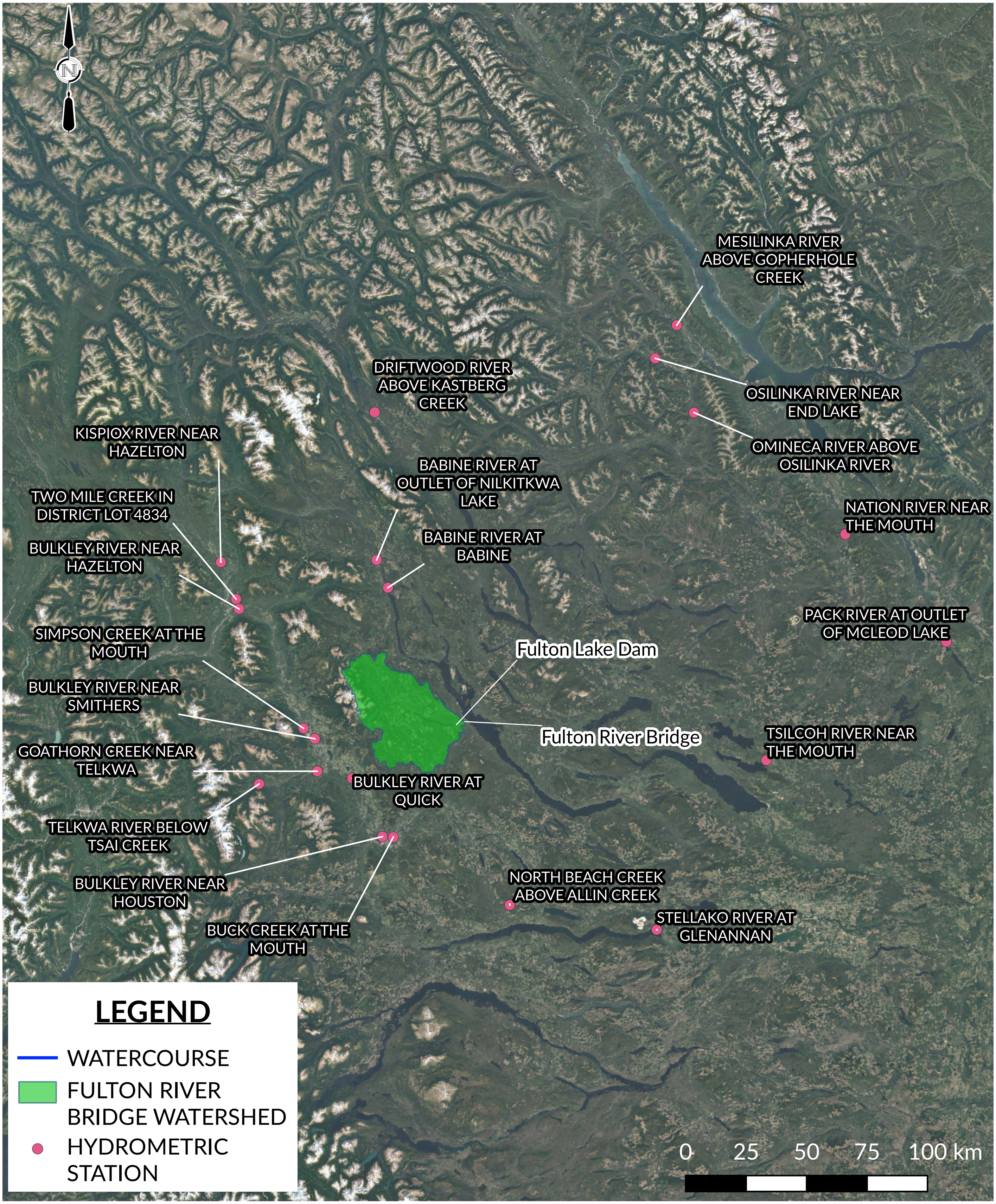

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FIGURE 5-2

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REGIONAL ANALYSIS

Table 5-2: List of WSC Hydrometric Stations Used in Hydrological Analysis

Station Number	Station Name	Drainage Area (km^2)	Hydrologic Zone	Period of Record
08JB013	North Beach Creek above Allin Creek	9.08	8	1998 - 2015
08EE012	Simpson Creek at the Mouth	13.2	8	1969 - 2017
08EE025	Two Mile Creek in District Lot 4834	21.2	8	1983 - 2018
08EE008	Goathorn Creek near Telkwa	125	8	1961 - 2017
08JD006	Driftwood River above Kastberg Creek	403	8	1980 - 2018
08JE004	Tsilcoh River near the Mouth	431	8	1976 - 2017
08EE013	Buck Creek at the Mouth	565	8	1973 - 2017
07EC004	Osilinka River near End Lake	1950	8	1981 - 2015
08EE003	Bulkley River near Houston	2370	8	1931 - 2019
07EC003	Mesilinka River above Gopherhole Creek	3060	3	1976 - 2016
07EE010	Pack River at Outlet of McLeod Creek	3710	8	1981 - 2018
07EC002	Omineca River above Osilinka River	5560	8	1976 - 2016
08EC013	Babine River at Outlet of Nilkitkwa Lake	6760	8	1972 - 2018
07ED003	Nation River near the Mouth	6790	8	1981 - 2017
08EE004	Bulkley River at Quick	7340	8	1931 - 2017
08EE005	Bulkley River near Smithers	8940	8	1947 - 2019

A statistical frequency analysis was completed with peak instantaneous flow data for each WSC hydrometric station listed in **Table 5-2**. For instances of missing peak instantaneous flow at a WSC hydrometric station for a given year, an average value was applied to that missing year by calculating the peak instantaneous flows divided by maximum daily flows for that WSC hydrometric station.

Statistical frequency analysis was completed using HEC-SSP (US ACE 2019). Five statistical distributions were analyzed: Log Normal, Log Pearson III, Generalized Extreme Value, Gamma, and Gumbel. The Cunnane plotting position was used for the analysis (Pilon and Harvey, 1993). Statistical results for most WSC hydrometric stations were similar for all five statistical distributions. In these instances, an average of the five statistical distributions was taken to estimate the 200-year peak instantaneous flow. For instances with an unreasonably low statistical distribution result, the low statistical distribution was ignored, and an average of the remaining statistical distributions was taken to estimate the 200-year peak instantaneous flow.

Results of the statistical frequency analysis for each WSC hydrometric station were placed into a regional chart. A regression curve was calculated with 95% confidence limits **(Figure 5-2)**. The coefficient of determination (R^2) for the regional regression curve is 0.94. Based on the regional regression curve and watershed area at the site (1421 km^2), the best fit 200-year return period flow estimate without climate change is 274.8 m^3/s.

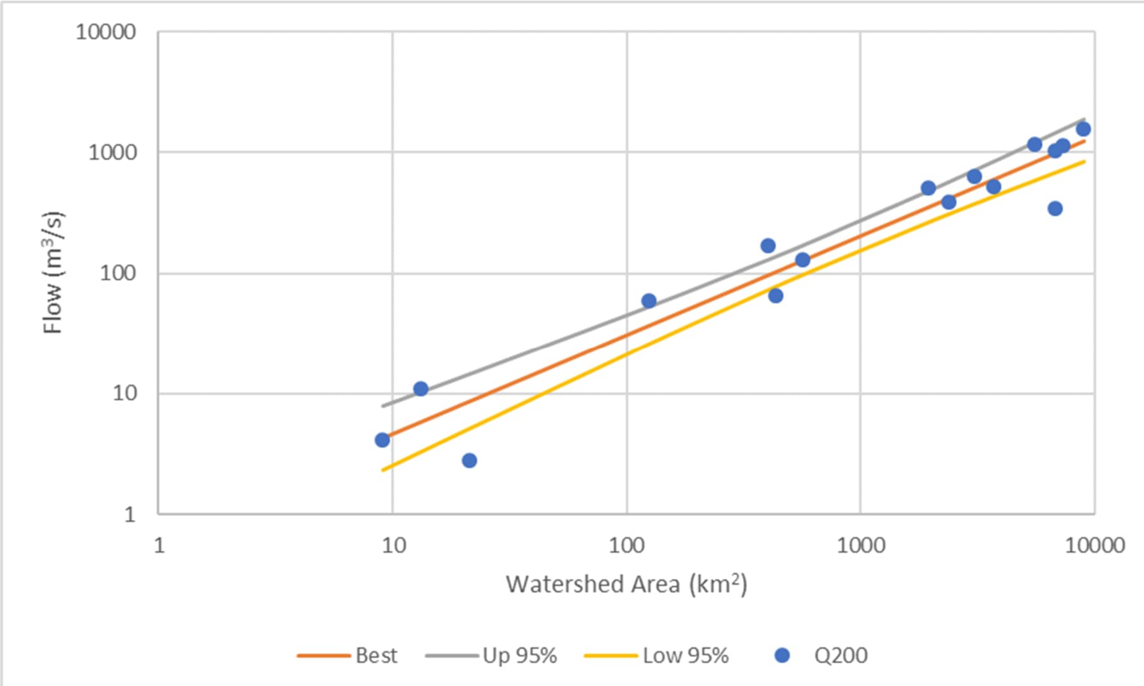

Figure 5-2: Fulton River Regional Regression Analysis

5.1.3 Hydrometric Data Provided by DFO

Following completion of the regional analysis and through communications with DFO (Harborne 2021), AE received scanned copies of a staff gauge measuring river levels that is approximately 200 m upstream of the bridge. The records are from 1974 to 2020. A rating curve for the river cross section at the staff gauge was also provided by DFO. It is unknown when the rating curve was developed, if it is changed over time, and how dynamic the cross-section geometry is. Although the manual readings are at a point in time, it was presumed that the measurements are representative of average daily flows. There is no peak instantaneous data available from the measurements provided.

AE reviewed the records and extracted the maximum annual staff gauge height. The rating curve was used to estimate flows, and the flows were used to perform a statistical frequency analysis on the flow data. Statistical frequency analysis was completed using HEC-SSP (US ACE 2019). Five statistical distributions were analyzed: Log Normal, Log Pearson III, Generalized Extreme Value, Gamma, and Gumbel. The Cunnane plotting position was used for the analysis (Pilon and Harvey 1993). An average of the five statistical distributions was taken to estimate the 200-year daily max flow of 282.9 m^3/s. See **Table 5-3** for frequency analysis results. These results exclude data from July 7, 1983, which had a staff gauge measurement (12.7 ft) exceeding the highest value of the rating curve (11.9 ft). All other measurements were within the rating curve limits. Outside of 1983, the largest recorded flow was 220.5 m^3/s on May 15, 2018. This was a result of a very high 2017/2018 winter snowpack (150% of normal range) (Harborne 2021).

Table 5-3: Fulton River Max Daily Flow Frequency Analysis

Return Period	% Chance Exceedance	GEV (m^3/s)	Gamma (m^3/s)	Gumbel (m^3/s)	LN (m^3/s)	LP3 (m^3/s)	Average (m^3/s)
200	0.5	327.0	249.5	259.9	266.3	312.0	**282.9**
100	1	277.8	229.0	235.5	238.6	269.7	**250.1**
50	2	234.3	207.9	211.1	211.6	231.1	**219.2**
20	5	184.3	178.5	178.4	176.7	184.8	**180.5**
10	10	151.1	154.7	153.1	150.6	152.8	**152.5**
5	20	120.9	128.8	126.8	124.0	122.7	**124.6**
2	50	82.5	87.4	87.1	85.6	83.2	**85.2**

5.1.4 Construction Period Flow Rates

Fulton River provides fish habitat and the least risk instream work window from July 15 – August 31. AE reviewed the DFO Fulton River discharge records from 1974 – 2021 and recorded the minimum and maximum gauge height for Fulton River within the least risk work window for each year. Note that 2009 – 2016 records are missing. An average gauge height was estimated, and the rating curve provided by DFO was used to estimate the flow. The construction period flow rate of 31.2 m^3/s was estimated based on an average of the same five statistical distributions.

5.1.5 Design Flow

Flow in Fulton River is regulated by upstream releases at Fulton Lake Dam. The WSC recorded a short period of record from 1964 to 1970. However, this period spans construction of the dam and is insufficient in length to complete a reliable statistical analysis. To estimate a design flow, a regional hydrological analysis was completed using WSC data and statistical analysis was completed using measurements provided by DFO. Lastly, and only for comparison purposes, the maximum outflow from Fulton lake Dam was assessed. **Table 5-4** summarizes the flow estimates. The recommended design flow for the bridge is 302.3 m^3/s. This is based on the regional hydrological analysis (274.8 m^3/s), with the 10% upward scaling factor for climate change adaptation.

Table 5-4: Fulton River Flow Summary

Scenario	Flow Condition	Flow (m^3/s)	Design Flow with Climate Change (m^3/s)
WSC Hydrometric Data on Fulton River	Maximum Recorded (1964-1970)	194	**302.3**
Regional Hydrological Analysis	**200-Year Peak Instantaneous**	**274.8**	
Measurements Provided by DFO	200-Year Maximum Daily	282.9	
Dam Spillway Release	Maximum Dam Spillway Capacity	566	
Construction Period Flow (July 15 – Aug 31)	10-Year Daily	31.2	

5.2 Babine Lake

5.2.1 Babine Lake Watershed

The Babine Lake watershed area is 6,552 km^2 and is considered a natural system. Babine Lake drains at its north end to the Babine River, which is a tributary to the Skeena River. Both Babine Lake and its watershed are considered large. The influence of climate change on the lake was not considered for this project. A watershed model is required to perform a detailed climate change assessment for Babine Lake. Watershed models require significant effort and hydro-meteorological data. Watershed models can be complex and carry uncertainty. AE has not completed watershed modelling for Babine Lake and this work is not recommended at this time. The cost of adding this scope of work could be substantial and may not be justified for the bridge replacement project. It is recommended that available data and engineering judgement is used to assess the influence of Babine Lake on the site. There are four active WSC hydrometric stations within the Babine Lake watershed, which are listed in **Table 5-5**.

Table 5-5: Active WSC Stations within the Babine Lake Watershed

Station Number	Station Name	Status	Record Period	Drainage Area (km^2)	Notes
08EC001	Babine River at Babine	Active-Realtime	1944 – present	6,350	Long flow record of Babine Lake outlet.
08EC003	Babine Lake at Topley Landing	Active-Realtime	1955 - present	6,552	Water elevation of Babine Lake near the Fulton River mouth.
08EC004	Pinkut Creek near Tintagel	Active-Realtime	1961 - present	808	Located between Taltapin Lake Dam (low consequence) and Babine Lake.
08EC014	Twain Creek Tributary near Babine Lake	Active-Realtime	1997 – present	10.4	Seasonal operation, located on an unnamed creek that is a tributary to Twain Creek.

There are nine discontinued WSC hydrometric stations within the watershed. However, all records are less than five years in duration and are from the 1970's. This data is not sufficient for statistical analysis or input to a watershed model. There is reliable lake outflow data (WSC station 08EC001), however only 34% of the total Babine Lake watershed area has inflows with long record data, including the DFO operated hydrometric station at the site. Refer to **Figure 5-3** for the Babine Lake Watershed and Hydrometric Stations.

Incorporating climate change adaptation to hydraulic conditions for any project is a requirement of the MoTI. AE has estimated the influence of climate change for river flows; however, the same analysis does not apply to the Babine Lake elevations and no climate change adjustment was made.

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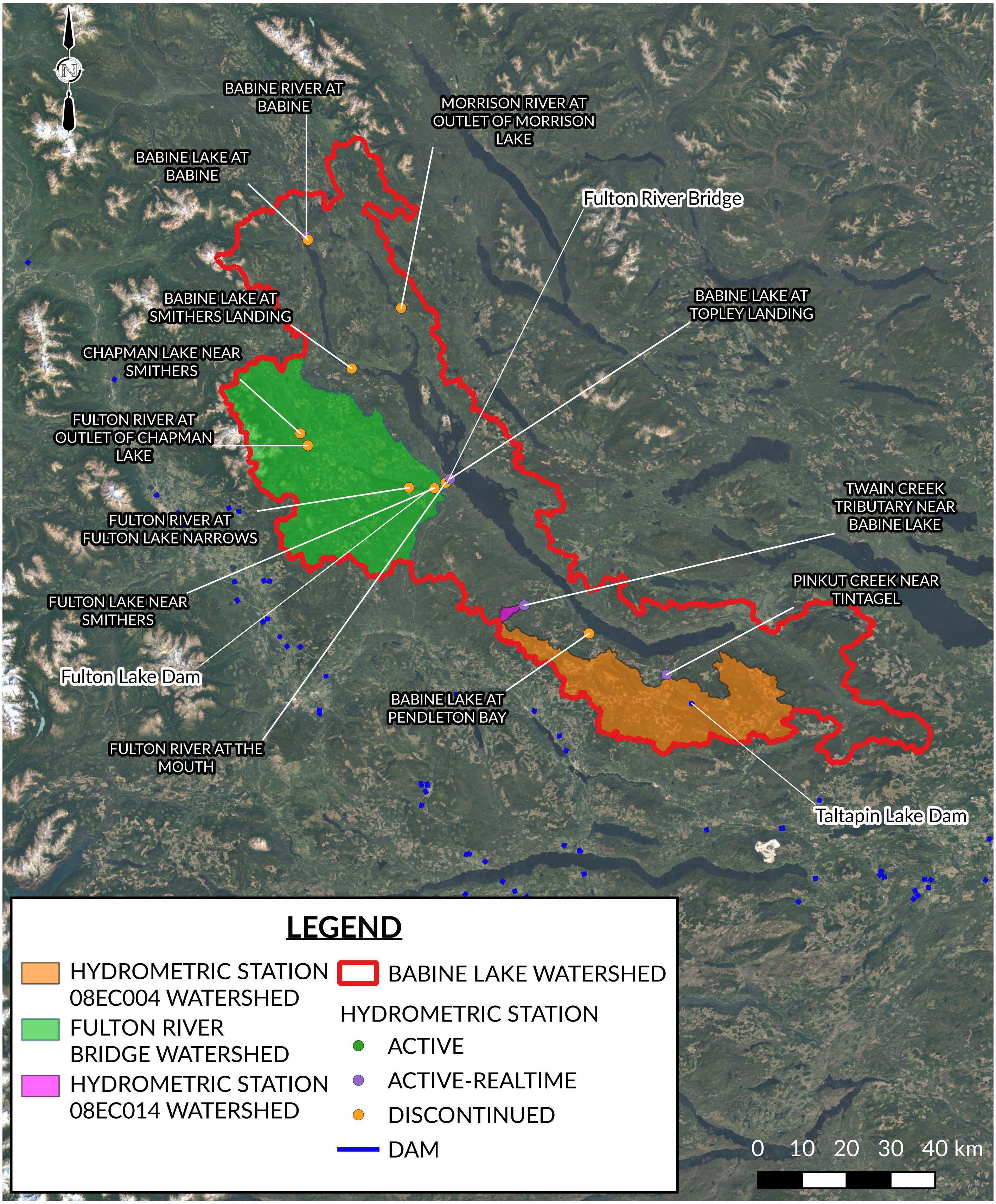

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AE PROJECT No.	2020-2034-00
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APPROVED	G. CAHILL
DATE	2021NOV17
REV	A
DESCRIPTION	ISSUED FOR REVIEW

FIGURE 5-3

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

BABINE LAKE WATERSHED

5.2.2 Historical Lake Elevations

As previously discussed, Babine Lake has a hydraulic influence at the bridge. WSC Station 08EC003 *Babine Lake at Topley Landing* has recorded lake elevations from 1956 to present. The minimum and maximum daily lake elevations were analysed and are summarized in **Table 5-6**. There was a low outlier year in 1967 that was removed from the dataset. The lowest recorded lake elevation is 710.23 m, which is approximately 2 m higher than the channel thalweg at the bridge site. This indicates that the lake elevation always has an influence on the site and that the lake elevation is the downstream boundary condition for the bridge hydraulics. It is noted that the average water elevation during the least risk instream work window is 711.15 m. All elevations in this report are in Canadian Geodetic Vertical Datum 1928 (CGVD28).

Table 5-6: Historical Babine Lake Elevations (1956 - 2017)

Statistic	Maximum Daily Lake Elevation (m)	Minimum Daily Lake Elevation (m)
Maximum	712.24	710.49
Average	711.50	710.33
Minimum	710.79	710.23

5.2.3 Statistical Frequency Analysis

Statistical frequency analysis was completed to estimate low probability lake elevations. The statistical frequency analysis was completed using HEC-SSP (US ACE 2019). Five statistical distributions were analyzed: Log Normal, Log Pearson III, Generalized Extreme Value, Gamma, and Gumbel. The Cunnane plotting position was used for the analysis (Pilon and Harvey, 1993). An average of the three best fit statistical distributions (LN, LP3, Gamma) was taken to estimate the 200-year return period water surface elevation of Babine Lake, which is 712.46 m. The results are in **Table 5-7** below. The result of this analysis is a 200-year lake elevation that is applied as the downstream lake boundary condition. A joint probability analysis of a 200-year streamflow and a 200-year lake elevation occurring at the same time was not completed and it is recognized that there is conservatism built into the analysis by assuming the two events are concurrent.

Table 5-7: Babine Lake Elevations Statistical Frequency Analysis

Return Period	% Chance Exceedance	LN (m)	LP3 (m)	Gamma (m)	Average (m)
200	0.5	712.42	712.55	712.42	712.46
100	1	712.33	712.43	712.33	712.36
50	2	712.23	712.30	712.23	712.25
20	5	712.08	712.12	712.08	712.10
10	10	711.95	711.97	711.95	711.96
5	20	711.80	711.79	711.80	711.79
2	50	711.50	711.47	711.50	711.49

6 HYDRAULIC ANALYSIS

6.1 Hydraulic Model

Modelling Software

Fulton River and the bridge were modelled using GeoHECRAS software. GeoHECRAS is a GIS-compatible version of the US Army Corps of Engineers Hydrologic Engineering Center River Analysis Software (HEC-RAS). The calculation engine from HEC-RAS version 5.0.7 was used for the model analysis.

Survey Data

The geometry used in the model is a combination of bathymetric surveys and LiDAR consisting of:

- Bathymetric survey, 3D Geomatics Land Surveying, November 7, 2020
- Bathymetric survey, McElhanney, July 23, 2021
- LiDAR provided by MoTI (date and flight provider unknown)

A surface was provided by the MoTI that combined both bathymetric surveys. The LiDAR surface data was merged with the combined bathymetric surface to create one model surface. This merged surface was used as the main geometry input to the model. The combined survey includes approximately 1.35 km of the channel length extending upstream and downstream of the Fulton River bridge. The upper extent of the survey is approximately at the upstream end of the spawning channels, and the downstream extent is approximately 140 m downstream of the Michell Bay FSR Bridge.

It is noted that the upstream LiDAR data was altered to ‘stamp in’ channel geometry over a 530 m reach at the upstream extent of the model river reach. This was done because the LiDAR showed the water surface, not the channel bed of Fulton River upstream of the bathymetric survey extents. This channel alteration provided a longer model extent to represent the gradient of the river. A plan view of the model schematic is shown in **Figure 6-1** below.

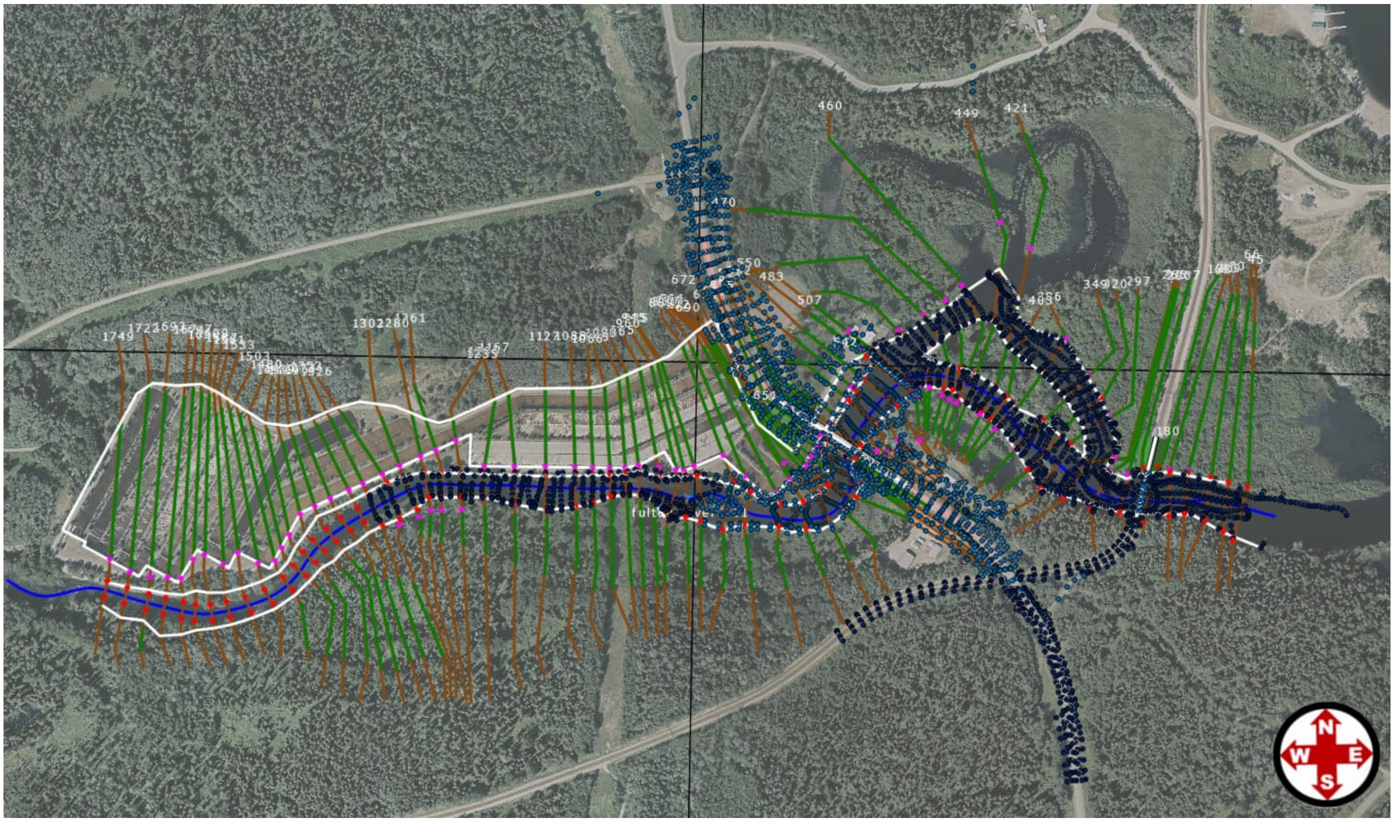

Figure 6-1: GeoHEC-RAS Model Geometry

Bridge Inputs

Three bridges are included in the hydraulic model. Various data sources were used to estimate the bridge geometry, including, but not limited to:

- Project survey, LiDAR and topographic, 2020 and 2021
- Michell Bay FSR Bridge Tender Drawings, Sandwell, 1969
- Fulton River Hatchery Bridge Inspection, Keery Consulting, DFO, 2021
- Fulton River Spawning Channel No. 2 Counting Fence, Department of Fisheries Canada, 1970

Expansion and contraction coefficients for the cross sections immediately upstream and downstream of each bridge are set to 0.3 and 0.5 respectively. The bridge geometry inputs for the hydraulic model are listed in **Table 6-1** below.

Table 6-1: Bridge Geometry Inputs for Hydraulic Model

Bridge	High Chord (m)	Low Chord (m)	Bridge Span (m)	Bridge Width (m)	# of Piers	Pile Diameter (mm)
Proposed Bridge	718.45	715.504	78.25	13.0	1	762
Fish Bridge	713.46	712.75	73.45	3.9	11	280
Michell Bay FSR Bridge	716.28	714.71	61.4	6.1	4 (2 sets)	254

Manning's n Values

To represent roughness of the channel and overbank areas, the Manning's n values in **Table 6-2** were applied in the hydraulic model.

Table 6-2: Manning's n Values

Description	Manning Roughness
Overbanks with heavy stand of timber	0.12
Oxbow wetland area	0.07
Overbanks with scattered brush and heavy weeds	0.05
Main Channel	0.04
Spawning channels with clean gravels	0.03
Gravel roads	0.02
Paved roads	0.011

Model Setup and Scenarios

The hydraulic model was built as a 1D steady state simulation and it was run using the mixed-flow regime, however all scenarios produced subcritical results. The upstream boundary was set to the normal depth (slope of energy grade line). The downstream boundary was set to a known water surface elevation due to the influence of Babine Lake at the site. The model scenarios are listed in **Table 6-3** below. Scenario 1 produces the highest water surface elevation and Scenario 2 produces the highest velocity at the bridge.

Table 6-3: Hydraulic Model Scenarios Summary

#	Flow Description	Flow (m^3/s)	Upstream Energy Grade (m/m)	Babine Lake Description	Downstream Lake (m)	Notes
1	Design Flow w/ High Lake	302.3	0.00149	200-Year Lake Elevation	712.46	Highest water surface at bridge
2	Design Flow w/ Low Lake	302.3	0.00149	Average May Lake Elevation	710.97	Highest velocity at bridge
3	Flow on May 18, 2018	220.5	0.00149	May 18, 2018 Lake Elevation	711.92	Calibration check
4	Flow on June 24, 2021	27.1	0.00149	June 24, 2021 Lake Elevation	711.50	Calibration check
5	Construction Period	16.1	0.00149	Average least risk window elevation	711.15	Jul 15 to Aug 31 average levels

Model Calibration

Based on anecdotal evidence by DFO, there is no known instance of Fulton River overtopping the berm into the spawning channels, but in 2018 the river was very close to overtopping. Scenario 3 is based on this condition. The model was checked, and the result showed water surface elevations that nearly overtop the berm. However, the flow does not overtop the berm. These results aligned with the anecdotal evidence.

On June 24, 2021, AE visited the site, took measurements at the Michell Bay FSR, and recorded site observations. The Fulton River streamflow on June 24, 2021 that was provided by DFO was used as the input. The Babine Lake elevation on June 24, 2021 was used as the downstream boundary condition. The water elevation at the Michell Bay FSR bridge produced by the hydraulic model were very close to the field measurement. A change in water surface characteristics and slope was noted between the upstream end of the Fulton River bridge and the sediment island. This inflection point is evident and representative in the model. Refer to **Figure 6-2**.

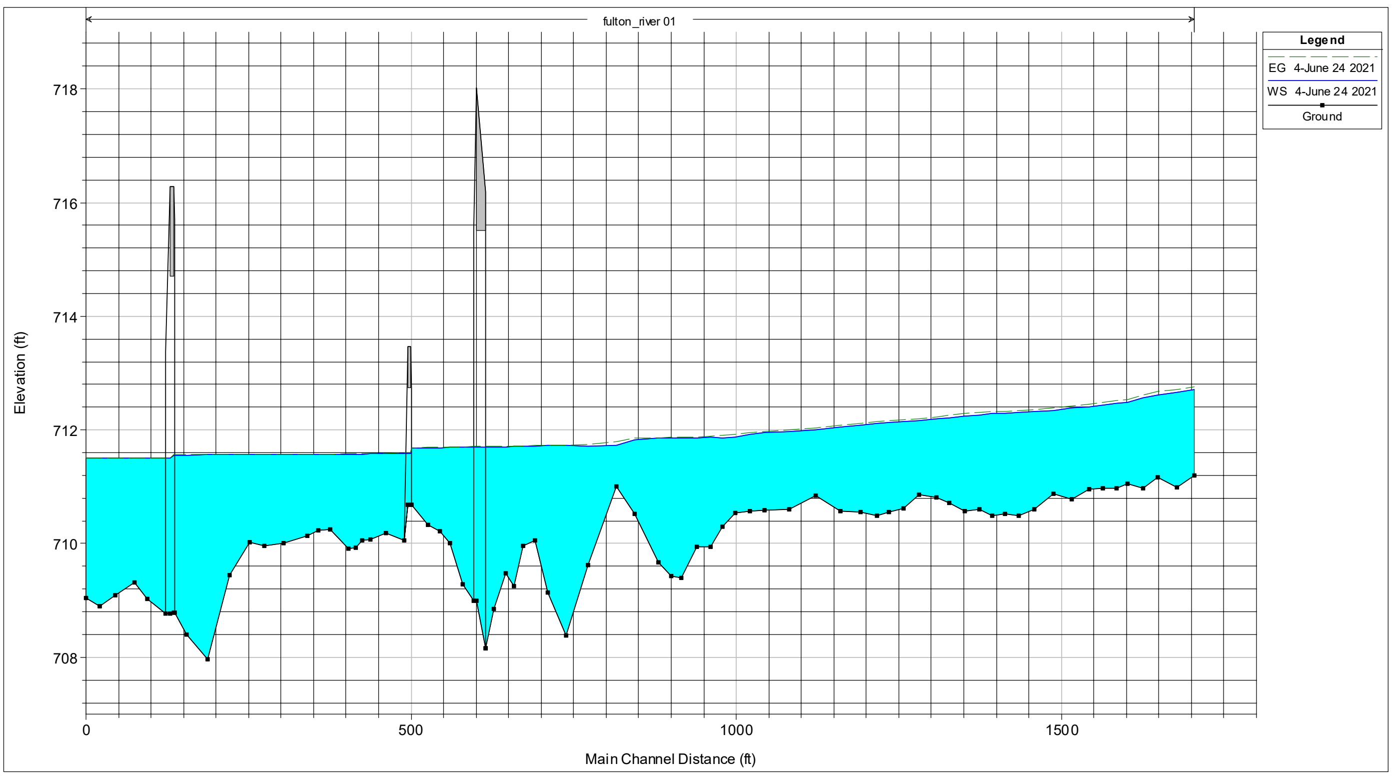

Figure 6-2: Water surface profile of June 24, 2021

6.2 Design Flow Model Results

General Channel Characteristics and Flood Profile

The design flow conditions produced in the hydraulic model are described herein. Along the upstream reach of the model the design flow is confined in the main channel with the berm separating the Fulton River and the spawning channels on the left bank, and a heavily forested area on the right bank. Approximately 600 m upstream of the bridge, the right bank overtops onto a floodplain and remains flooded all the way downstream to the bridge. Near the bridge the design flow overtops the left bank berm and enters the spawning channel. Due to the low gradient of the DFO spawning channel, the berm overtopping results in backwatering and inundation of more spawning channel area.

Immediately upstream of the bridge there is a sharp bend with a narrower channel width. This section has evidence of some erosion, indicating impinging flow and higher velocity. Downstream of the bridge the left bank berm does not overtop and flow is contained to the main channel. The DFO fish counting bridge is partially submerged during the design flow simulation.

Downstream of the DFO fish counting bridge, the main channel splits into two channels with similar bed elevations, and the left channel is connected to a large oxbow that provides storage. Immediately downstream of where the two channels converge is the Michell Bay FSR bridge. The Michell Bay FSR bridge has adequate clearance and the design flow is confined to the main channel through this bridge opening. Fulton River then drains into Babine Lake. Refer to **Figure 6-3** for the design flow water surface profile and Figure 6-4 for a flood map. The hydraulic grade line slope from Babine Lake to the bridge is considered flat, measuring approximately 0.14% (0.0014 m/m).

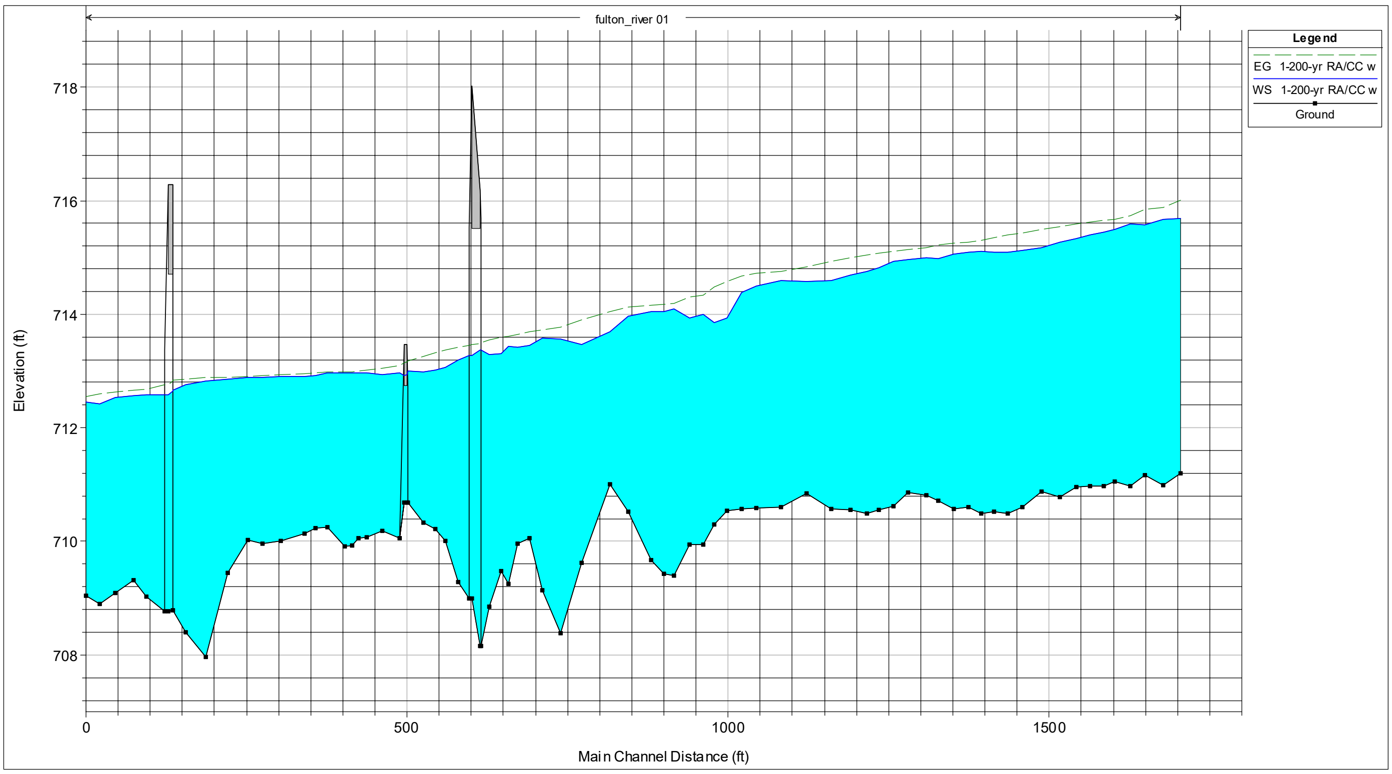

Figure 6-3: Fulton River Design Flow Profile

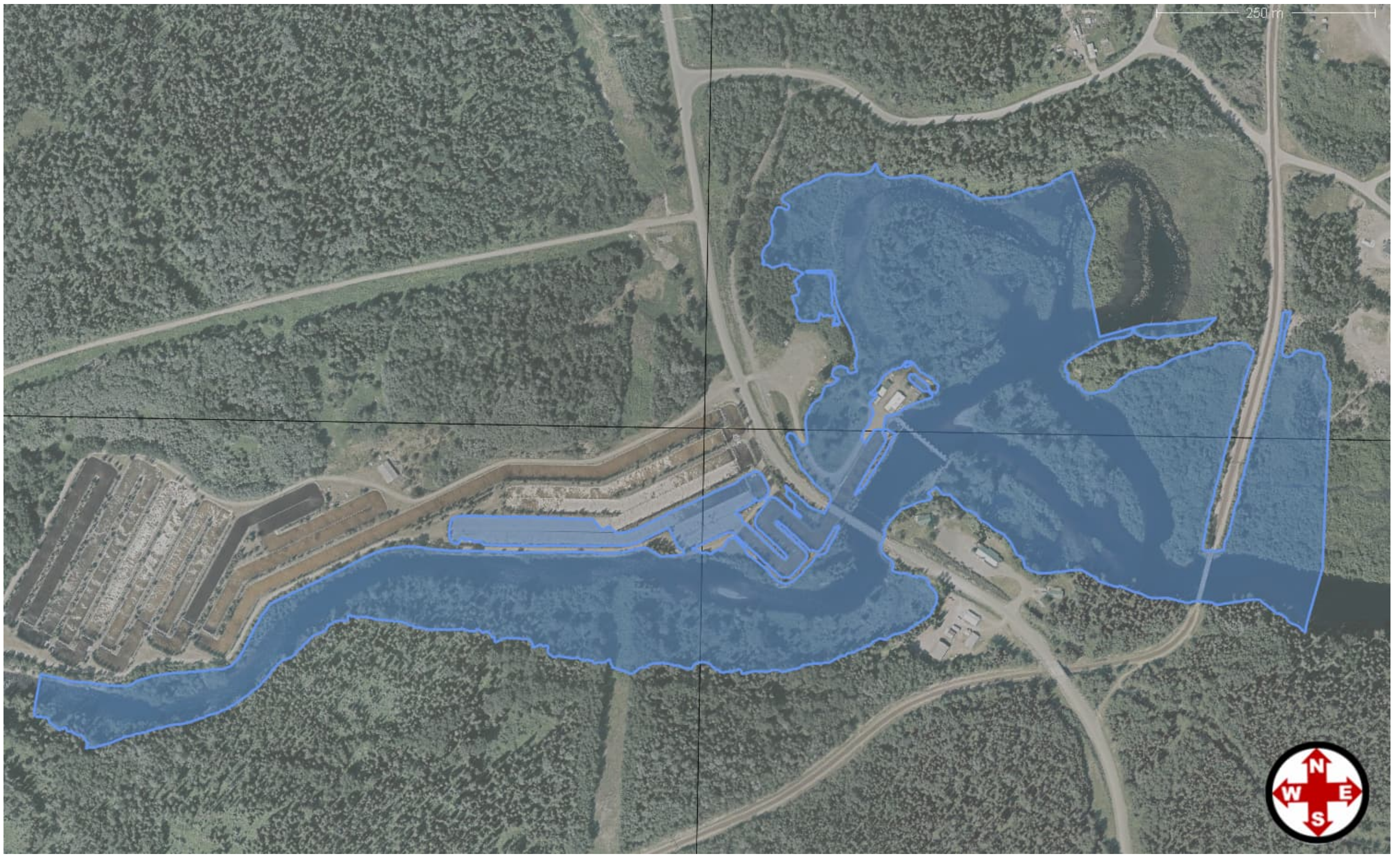

Figure 6-4: Fulton River Design Flow Flood Extents

Hydraulic Conditions at the Proposed Bridge

The hydraulic model outputs at the upstream bridge cross section for the design scenario are listed in **Table 6-4**. As per MoTI design standards, the minimum freeboard for this bridge is 1.5 m. The proposed bridge design soffit elevation achieves the design standard with an actual freeboard of 1.75 m above the design flow water surface elevation. Refer to **Figure 6-5** for the upstream cross section of the proposed bridge.

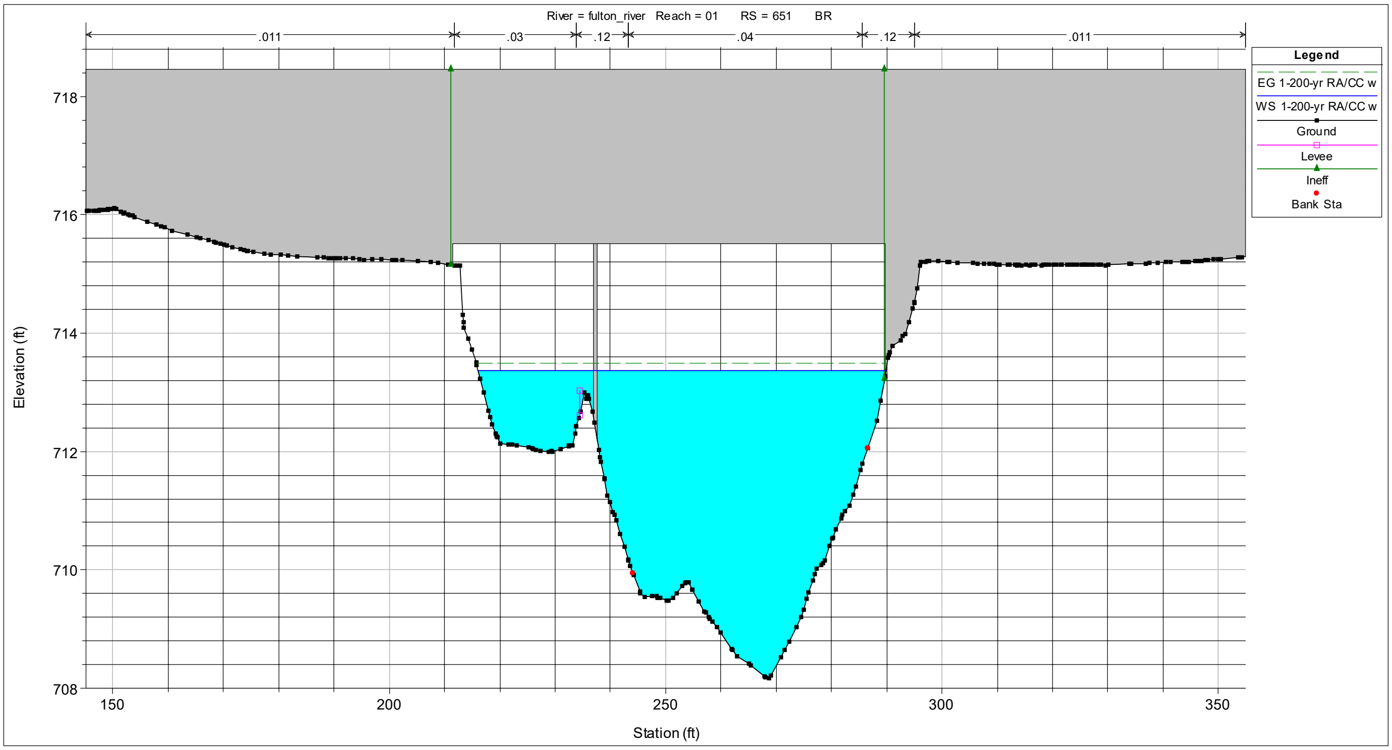

Figure 6-5: Proposed Bridge Cross Section with Design Flow Conditions

Table 6-4: Hydraulic Conditions at the Proposed Bridge

Design Flow (m^3/s) (with climate change)		Average Channel Velocity (m/s)	Water Surface Elevation (m)	Minimum Freeboard (m)	Minimum Bridge Low Chord Elevation (m)	Design Bridge Soffit Elevation (m)	Actual Freeboard (m)
200-year Instantaneous	302.3	1.65	713.36	1.5	714.86	715.11	1.75

7 HYDROTECHNICAL DESIGN

7.1 Scour Depth

The river bed profile near the bridge is variable and described as undulating **(Figure 6-3)**. The change in bed elevation at the bridge is about 1.7 m. This is likely due to scour and sediment deposition along the channel, and the presence of numerous piers at the existing bridge. The MoTI BMIS (2018) report indicates there has been significant degradation at the existing bridge, with no signs of aggradation. However, there is a sediment wedge upstream of the bridge and this is indicative of change in grade causing deposition of sediment.

Contraction, pier, and abutment scour were evaluated at the proposed bridge using the HEC-RAS bridge scour tool that applies HEC-18 methods. Model scenario number 2 (**Table 6-3**) was used for this analysis because it had the highest water velocity. There was no contraction or pier scour estimated. Abutment scour was calculated using

Froehlich's equation. The left bank abutment scour depth was 1.37 m and the right bank abutment scour depth was 1.26 m.

Natural scour was also calculated using the Neill (1973), Lacey (1930), and Blench (1969) (USBR 1984) formulas. This was calculated based on an assumed D_{50} of 20 mm, corresponding to a gravel bed material. The Neill (1973) formula produced an unreasonably large scour depth, so an average of the Lacey (1930) and Blench (1969) formulas were calculated and a safety factor of 20% was added. The estimated natural scour depth is 1.7 m below the existing river bed. Scour protection at least 1.7 m below the river bed elevation is recommended for the design.

7.2 Scour and Erosion Protection

General

Erosion and scour protection are required for the new bridge. Although the water velocities are estimated to be low, there is still a risk of erosion and scour occurring. The existing banks near the bridge do exhibit erosion and there could be large releases from the dam that affect the bridge, so these processes should be considered. Riprap is a common material used for erosion and scour protection, and it is recommended for the new bridge. There is existing riprap on site at the existing bridge that can be reused and worked into the new/imported riprap.

Riprap Sizing

Due to the complex nature of this site, the hydraulic design conditions must consider backwater effects from Babine Lake. Therefore, as noted above, model scenario number 2 (**Table 6-3**) was used for this analysis because it produced the highest water velocity.

The Maynord method (USACE 1994) was used to size riprap for the bridge erosion and scour protection design. It is based on site conditions and the hydraulic model results. This method determines the necessary riprap protection size based on various parameters including water velocity (shear stress), water depth, and channel morphology. The channel morphology and hydraulic characteristics affect the riprap size calculations.

Riprap Extents

Through the regulatory review and consultation process with DFO, there were concerns raised about the extent of instream works at the site. Therefore, a decision was made to exclude riprap protection on the left bank berm separating the river and hatchery channel. This results in an erosion risk that will have to be monitored by DFO.

There is a sharp bend on the right bank that could experience impinging flow conditions and this section requires larger riprap to withstand impinging flow. However, like above, DFO raised concerns raised about the extent of instream works and the upstream extents were reduced. Right bank riprap protection should extend approximately 20 m downstream and 50 m upstream of the proposed bridge (70 m total length).

Table 7-1 summarizes the recommended riprap for the bridge following MOTI Standard Specifications (Section 205), 2020. The riprap should be keyed in a minimum of 1.7 m below the channel bed to provide scour protection, and the top of riprap elevation should be at least 0.3 m above the design flow water surface elevation.

Geotechnical Stability

The geotechnical engineer provided an additional riprap recommendation for stability of the new bridge abutment and slope. Along the right bank bridge abutment, the riprap thickness should be increased to 2 m for geotechnical stability (not a requirement for erosion and scour protection). This has been included in the design.

Table 7-1: Riprap Design Summary

Location	Riprap Bank Slope	Design Riprap Class (kg)	Minimum Layer Thickness (mm)
Left Bank	No Riprap – As Per Discussion with DFO		
Right Bank (General)	1.5H:1V	100	700
Right Bank (Along Bridge Abutment)	1.5H:1V	100	2,000*
Right Bank (Upstream of Bridge at Channel Bend)	2H:1V	500	1,200
Riprap Scour Depth = minimum 1.7 m below channel bed Riprap Scour Depth at Steel Piles (Dolphins) = minimum 2 m below channel bed (refer to Section 7.3 below) Top of Riprap Elevation = minimum 0.3 m above design water surface = 713.66 m			

*Geotechnical Stability Requirement

7.3 Debris Boom and Access

There are steel dolphins immediately upstream of the existing bridge piers on the right side of the channel. They were installed in 2006 to intercept and minimize debris impacts to the existing bridge. The proposed bridge is a single span structure over Fulton River and does not require debris management for MoTI infrastructure. However, the DFO fish counting bridge that is downstream has low clearance, short spans between piers, and fish gates that can be damaged by debris. Therefore, in coordination with DFO, a debris boom (steel piles or dolphins) was added as a part of the project to protect the DFO infrastructure.

Five steel piles (dolphins) are proposed on the right bank side of the channel approximately 30 upstream of the proposed bridge. The selected location is at the downstream side of channel bend so that floating debris can be trapped and not impact the downstream DFO infrastructure. A maintenance access road is also proposed for DFO to mobilize equipment and remove trapped debris. The lower section of the maintenance access road requires erosion protection because it will be exposed to river forces during high water conditions.

Additional scour analysis was completed for the proposed steel piles (dolphins). These were modelled in GeoHECRAS as bridge piers/piles. The estimated scour depth at these piles is 2 m. The riprap scour protection should be to 2 m below the channel bed locally around the steel piles (dolphins) (i.e., ~4 m upstream and downstream of piles).

8 CONCLUSIONS AND RECOMMENDATIONS

AE completed a hydrotechnical assessment to support the replacement of the Fulton River Hatchery Bridge No. 6646 on Highway 118. The bridge crosses Fulton River between Fulton Lake Dam (upstream) and Babine Lake (downstream). The dam regulates flow release to Fulton River, and Babine Lake water elevations have an influence on hydraulics at the site. Hydrological analysis was completed for Fulton River and Babine Lake. Hydraulic modelling and analysis were completed for the river channel and proposed bridge. A summary of the key hydrotechnical recommendations is provided in **Table 8-1**.

Table 8-1: Summary of Hydrotechnical Design Recommendations

Parameter	Recommendation and Comment
Design Flow	• 302.3 m^3/s • 200-year peak instantaneous return period, with 10% upward scaling factor for climate change • Based on regional hydrological analysis
Design Water Surface Elevation at Bridge	• 713.36 m • Based on hydraulic model results • Model scenario number 1, with design flow and 200-year Babine Lake elevation (712.46 m)
Freeboard and Minimum Low Chord of Bridge	• Minimum Freeboard = 1.5 m • Minimum Low Chord of Bridge = 714.86 m • Proposed Design Low Chord for Bridge = 715.17 m • Proposed Design Freeboard = 1.81 m
Erosion and Scour Protection	Left Bank: • No riprap as per regulatory review and consultation process with DFO
	Right Bank: • Class 100 kg Riprap • Minimum Layer Thickness = 0.7 m • Riprap Thickness at Bridge Abutment = 2.0 m (for geotechnical stability) • Side Slope = 1.5H : 1V • Minimum Scour Depth = 1.7 m below channel bed elevation
	Right Bank Upstream of Bridge at Channel Bend: • Class 500 kg Riprap • Minimum Layer Thickness = 1.2 m • Side Slope = 2H : 1V • Minimum Scour Depth = 1.7 m below channel bed elevation • Scour Depth at Dolphin Piles = 2 m below channel bed elevation

CLOSURE

This report was prepared for the Ministry of Transportation and Infrastructure to summarize the hydrotechnical engineering completed for the Fulton Bridge No. 6646 replacement design. The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.
Engineers & Geoscientists of BC Permit Number 1000163

Prepared by:

Carly Davis, EIT
Hydrotechnical Engineer

Reviewed by:

PROFESSIONAL
PROVINCE OF
G. S. CAHILL
38248
BRITISH COLUMBIA
ENGINEER
2023-12-20

Geoffrey Cahill, P.Eng.
Senior Hydrotechnical Engineer

CD/GC

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APPENDIX A - PHOTOS

Photo 1: Fulton Bridge crossing Spawning Channel, looking downstream towards fish fence. Note concrete banks and gravel channel bottom (August 15, 2020).

Photo 2: Fulton Bridge crossing Fulton River, looking downstream from right bank. Note steel dolphins upstream of bridge

Photo 3: Spawning channel left bank, looking upstream. Note crack in concrete at piles (August 15, 2020).

Photo 4: Spawning channel right bank, looking upstream. Vertical wood wall prevents berm overtopping into Fulton River (August 15, 2020).

Photo 5: Fulton River crossing, left bank, looking upstream. The left bank is the outside corner after a sharp bend. Note the erosion, and low elevation of the bank relative to the wood wall for the spawning channel (August 15, 2020).

Photo 6: Fulton River crossing, left bank, looking upstream. Note the undermining of vegetation from erosion on the upstream bank (August 15, 2020).

Photo 7: Fulton River crossing, left bank, looking downstream. Note eroded outside corner with no riprap at bridge, and riprap berm downstream of bridge (August 15, 2020).

Photo 8: Fulton River crossing, right bank, looking downstream. Note parallel channel alignment to road upstream of bridge (August 15, 2020).

Photo 9: Fulton River, upstream of the bridge, looking upstream. Note the outside corner right bank, and the island with fallen trees. Upstream of the bridge there is a defined floodplain (August 15, 2020).

APPENDIX B - DESIGN CRITERIA SHEET FOR CLIMATE CHANGE RESILIENCE

Design Criteria Sheet for Climate Change Resilience

Highway Infrastructure Engineering Design and Climate Change Adaptation
BC Ministry of Transportation and Infrastructure
(Separate Criteria Sheet per Discipline)
(Submit all sheets to the Chief Engineers Office at:
BCMoTI-ChiefEngineersOffice@gov.bc.ca)

Project:	*Fulton River Hatchery Bridge No. 6646 Replacement*
Type of work:	*Hydrologic Analysis, Hydraulic Analysis and Design for Bridge Design and Erosion Protection*
Location:	*Fulton Bridge, near Fulton River Hatchery on Highway 118*
Discipline:	*Hydrotechnical*

Design Component	Design Life or Return Period	Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value from Future Climate	Design Value Including Climate Change	Adaptation Cost Estimate ($)	Comments / Notes / Deviations / Variances
Bridge Replacement, Hydrotechnical Analysis	200-Year Return Period	Flow (m3/s)	282.9	+10%	302.3	-	See report and notes below. Flow influences erosion and scour design.
Bridge Replacement, Hydrotechnical Analysis	200-Year Return Period	Babine Lake Elevation (m)	712.75	-	712.75	-	See report. Babine Lake elevation influences design water elevation at the bridge.

Explanatory Notes / Discussion:

Pacific Climate Impacts Consortium: Plan2Adapt

Climate change adaptation must be considered for the bridge. To help inform possible future change, the Bulkley-Nechako Regional District was reviewed for various time frames using the Pacific Climate Impacts Consortium (PCIC) Plan2Adapt tool. The PCIC projections are based on median values from 12 different Global Climate Models (GCMs) and the Representative Concentration Pathway (RCP) 8.5 greenhouse gas emission scenario. As per **Table 1**, the 2080's projection generally has the largest increases. For the 2080's period, a 5.3-degree annual temperature increase is projected. In addition, PCIC projects a 4.9% increase in summer rainfall and a 13% increase in winter rainfall. Lastly, PCIC projects annual snowfall will decrease, with the winter and spring decreasing by 27% and 67%, respectively. These future changes could lead to changes in the hydrologic regime, such as the timing and duration of runoff.

Table 1: PCIC Plan2Adapt Bulkley-Nechako Regional District Results

PCIC Plan2Adapt Cariboo Forestry Region: Projected Change from 1961-1990 Baseline							
		2020's (2010 - 2039)		2050's (2040 - 2069)		2080's (2070 - 2099)	
Climate Variable	**Season**	**Ensemble Median**	**Range (10th to 90th percentile)**	**Ensemble Median**	**Range (10th to 90th percentile)**	**Ensemble Median**	**Range (10th to 90th percentile)**
Temperature (°C)	Annual	+1.7 °C	+1.4 °C to +1.9 °C	+3.2 °C	+2.3 °C to +4.2 °C	+5.3 °C	+3.9 °C to +6.8 °C
Precipitation (%)	Annual	7.00%	+0.27% to +11%	9.70%	+3.7% to +18%	12%	+9.1% to +27%
	Summer	9.60%	-1.4% to +17%	10%	-12% to +21%	4.90%	-20% to +29%
	Winter	3.70%	-3.0% to +12%	6.60%	-0.16% to +12%	13%	+1.1% to +25%
Precipitation as Snow (%)	Annual	-18%	-24% to -12%	-29%	-35% to -23%	-41%	-51% to -37%
	Winter	-12%	-21% to -4.8%	-19%	-24% to -13%	-27%	-36% to -21%
	Spring	-30%	-35% to -21%	-48%	-57% to -42%	-67%	-78% to -58%

Pacific Climate Impacts Consortium: Station Hydrologic Model Output

Another method was completed to assess climate change impacts on hydrology. The PCIC Station Hydrologic Output considers simulated daily flow data from the Variable Infiltration Capacity (VIC) model for eight statistically downscaled GCMs. The most suitable Water Survey of Canada (WSC) hydrometric station in the PCIC Station Hydrologic Output is *Osilinka River near End Lake* (Station 07EC004). It is near the site and shares similar watershed characteristics and size as Fulton River. Data from this station was analyzed following methodology similar to MoTI's recent Canadian Water Resources Associate (CWRA) workshop presentation (Sullivan 2019). The RCP 4.5 and RCP 8.5 emission scenarios were analyzed with 6 different GCMs. Five different time periods were sorted in 30-year increments and these were compared to a baseline data period (1945-2012). Statistical analysis was completed using HEC-SSP (US ACE 2019) with the Gumbel statistical distribution to estimate 200-year return period flows for each time period. The results of this analysis are listed in **Table 2**. The analysis concludes that there would be a decrease in peak flows for all time periods.

Table 2: Station Hydrologic Model Output (Station 07EC004) flow changes for five different time periods compared to baseline period (1945-2012).

Emission Scenario	2030-2059	2040-2069	2050-2079	2060-2089	2070-2099
RCP 4.5	-43%	-44%	-44%	-43%	-42%
RCP 8.5	-41%	-39%	-37%	-38%	-41%

Design Flow Increase due to Climate Change

Based on the climate change considerations discussed above, it is anticipated that Fulton River could be subject to a decrease in annual peak flow events in the future. In addition to this, Fulton River is a regulated system that is operated by DFO. Releases to the natural river are controlled by DFO. If the hydrologic regime changes in the future, it is anticipated that freshet duration could be longer but the peak could be lower. Therefore, AE applied a 10% increase to estimate the design flow for the site. This increase is consistent with EGBC (2018) for no observed increasing trend.

Babine Lake

The Babine Lake watershed area is 6,552 km2 and is considered a natural system. Babine Lake drains at its north end to the Babine River, which is a tributary to the Skeena River. Both Babine Lake and its watershed are considered large. The influence of climate change on the lake was not considered for this project. A watershed model is required to perform a detailed climate change assessment for Babine Lake. Watershed models require significant hydro-meteorological data, which is lacking in the Babine Lake watershed. Watershed models can be complex and carry uncertainty. AE has not completed watershed modelling for Babine Lake and it is not recommended at this time. The cost of adding this scope of work could be substantial and may not be justified for the bridge replacement project. It is recommended that available data and engineering judgement is used to assess Babine Lake.

Incorporating climate change adaptation to hydraulic conditions for any project is a requirement of the MoTI. AE has estimated the influence of climate change for river flows; however, the same analysis does not apply to the Babine Lake elevations.

As previously discussed, Babine Lake has a hydraulic influence at the bridge. WSC Station 08EC003 Babine Lake at Topley Landing has recorded lake elevations from 1956 to 2017. The minimum and maximum daily lake elevations were analysed and are summarized in **Table 3**. All elevations are in CGVD1928. There was a low outlier year in 1967 that was removed from the dataset.

Table 3: Historical Babine Lake Elevations (1956 – 2017).

Statistic	Maximum Daily Lake Elevation (m)	Minimum Daily Lake Elevation (m)
Maximum	712.24	710.49
Average	711.50	710.33
Minimum	710.79	710.23

The lowest recorded lake elevation is 710.23 m, which is approximately two meters higher than the channel thalweg at the bridge site. This indicates that the lake elevation always has an influence on the site and that the lake elevation is the downstream boundary condition for the bridge hydraulics.

A statistical frequency analysis was completed to estimate low probability lake elevations. The statistical frequency analysis was completed using HEC-SSP (US ACE 2019). Five statistical distributions were analyzed: Log Normal, Log Pearson III, Generalized Extreme Value, Gamma, and Gumbel. The Cunnane plotting position was used for the analysis (Pilon and

Harvey, 1993). An average of the five statistical distributions was taken to estimate the 200-year return period water surface elevation of Babine Lake. The results are in **Table 4** below. All elevations are in CGVD1928.

The spread of statistical distribution estimates for the 200-year return period is 0.39 m (712.81 m minus 712.42 m). All five statistical distributions appeared to have reasonable fit. The standard deviation for these estimates is approximately 0.17 m. To account for uncertainty one standard deviation can be added to the average. The result of this analysis is a 200-year lake elevation of 712.75 m and this is recommended as the lake boundary condition.

Table 4: Babine Lake Elevations Frequency Analysis

Return Period	% Chance Exceedance	GEV (m)	Gamma (m)	Gumbel (m)	LN (m)	LP3 (m)	Average (m)
200	0.5	712.42	712.55	712.42	712.81	712.69	**712.57**
100	1	712.33	712.43	712.33	712.61	712.54	**712.45**
50	2	712.23	712.30	712.23	712.42	712.39	**712.31**
20	5	712.08	712.12	712.08	712.16	712.17	**712.12**
10	10	711.95	711.97	711.95	711.96	711.99	**711.96**
5	20	711.80	711.79	711.80	711.75	711.79	**711.78**
2	50	711.50	711.47	711.50	711.44	711.45	**711.47**

Recommended by: Engineer of Record: Geoffrey Cahill, P.Eng.
(Print Name / Provide Seal & Signature)

Date: December 20, 2023

Engineering Firm: Associated Engineering (B.C.) Ltd.

Accepted by BCMoTI Consultant Liaison: ______________________
(For External Design)

Deviations and Variances Approved by the Chief Engineer: ______________________
Program Contact: Chief Engineer BCMoTI