APPENDIX IR91-1 SPRINGBANK OFF-STREAM RESERVOIR (SR1) FISH PASSAGE DESIGN

Stantec

Appendix IR91-1 Springbank Off-stream Reservoir (SR1) Fish Passage Design
May 2019

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This report has been prepared to support the responses to AEP IRs 91, 93, 95, 103 and 344 and it also complements and summarizes information provided in the EIA, particularly information in Volume 4, Appendix M, Attachment 8A and described in the following internal memos:

Stantec (2016) - “SR1: Fish Passage Flows Analysis” (November 4, 2016), as Attachment IR91-1A

Stantec (2017) - “Fish Passage Mitigations at the SR1 Diversion Structure” (September 29, 2017), as Attachment IR91-1B

Stantec (2017) – “Springbank Off-stream Storage Project (SR1) – Hydraulic Modeling to Support Fish Passage Assessment” (September 13, 2017), as Attachment IR91-1C

The first two memos were accidently excluded in the March 2018 EIA Volume 4, Appendix M, Attachment 8A Fish Passage Analyses; and hereby presented here as Attachments. The third memo was presented in the March 2018 EIA and is reproduced here for convenience.

BACKGROUND

Analyses were undertaken to assess multiple factors that influence fish movement ability: including local geomorphology, flow frequency, river hydraulics, local fish species, biologically sensitive periods (BSPs) for identified fish species in the Elbow River, daily mean flow estimates, and associated water depths and velocities. The combined results of these analyses are used to quantify the necessary factors to maintain fish passage up and downstream of the service spillway and stilling basin of the Project. Engineered mitigation are designed using downstream reference reaches to emulate existing conditions as closely as possible in order to meet the fish passage conditions.

Fish passage criteria consider burst and sustained swimming speeds of several fish species at different sizes and life stages. Katapodis and Gervais (2016) reported the swimming capabilities of the species of interest for the Project, which are grouped under “pike – J-4b” to represent pike and non-trout species with lower swim performance in the Elbow River and “salmon & walleye – J-5b” as a surrogate for trout species in the Elbow River).

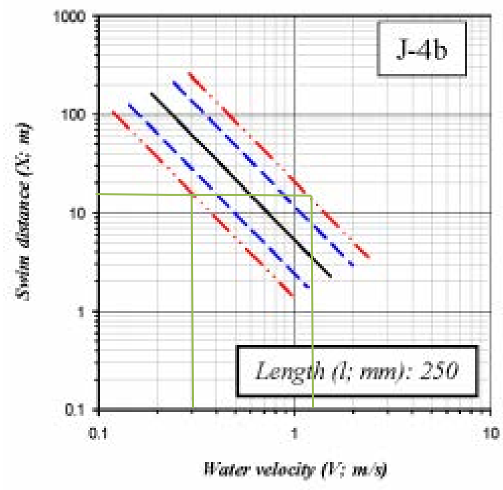

Figure 1 Calculated Swim Distance vs Water Velocity for Pike Group (Katapodis and Gervais 2016)

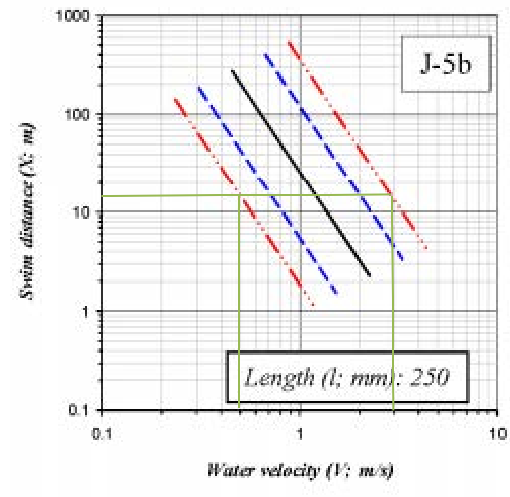

Figure 2 Calculated Swim Distance vs Water Velocity for Salmon & Walleye Group (Katapodis and Gervais 2016)

Figures 1 and 2 display five lines that represent a mean line and upper and lower 95% and 75% prediction interval lines. The mean line (indicated in black) reflects the swim distance that could be achieved by 50% of the fish for a given group and length. The lower 95% line (indicated in red) corresponds to the swim distance that 95% of the fish could achieve and the upper 95% line (indicated in red) reflects the swim distance for only 5% of fish. The lower and upper 75% lines (indicated in blue) correspond to swim distance that could be achieved by 75% and 25% (respectively) of fish in the given species and length group. This data is used to assess the ability of fish to pass through the instream structures: service spillway and stilling basin. The data is also used to determine downstream engineered mitigations. Given that the maximum length of hydraulic effect (increase in water velocity) due to any instream components is 15 m (Figure 5), the passable range of Elbow River water velocities is 0.3 m/s to 1.3 m/s for pike (and other fish) species and 0.4 m/s to 3 m/s for salmon and walleye species (including trout).

The minimum governing criteria for depth and flow calculated to maintain serviceability and fish passage through the instream works of the Project requires a depth of 18 cm over the service spillway and stilling basin at a calculated river low-flow of 0.8 m^3/s.

Further design considerations include simulation of existing natural river conditions; structure resilience up to the 100-year flood; and the ability to wash out at high magnitude events to avoid hydraulic issues at the service spillway (e.g., reduction in flow area, increased backwater, increased tractive force). The final design engineered mitigations were analyzed using a two-dimensional hydraulic model to verify their performance. A water surface elevation profile from this model is provided in Figure 5 for the identified low flow of 0.8 m^3/s through the service spillway and engineered fish passage mitigations.

ENGINEERED MITIGATIONS

The design mitigations consist of a series of three rock v-weirs downstream of the service spillway to stabilize the existing thalweg and limit step heights to a maximum of 20 cm (Figure 3 and Attachment IR91-1B). These weirs are an extension of Class 2 riprap vanes that are intended to affix an existing gravel bar in place and maintain the existing river geometry under normal flow conditions. The downstream side of the v-weirs are lined with a cobble apron as protection against erosion and undermining, and to form plunge pools that act as a refuge for migrating fish. This design is hydraulically similar to the existing geometry and profile of the river with the same velocity and depth characteristics as the river upstream and downstream of the diversion structure, as demonstrated in the attached model results figures (Attachment IR91-1B).

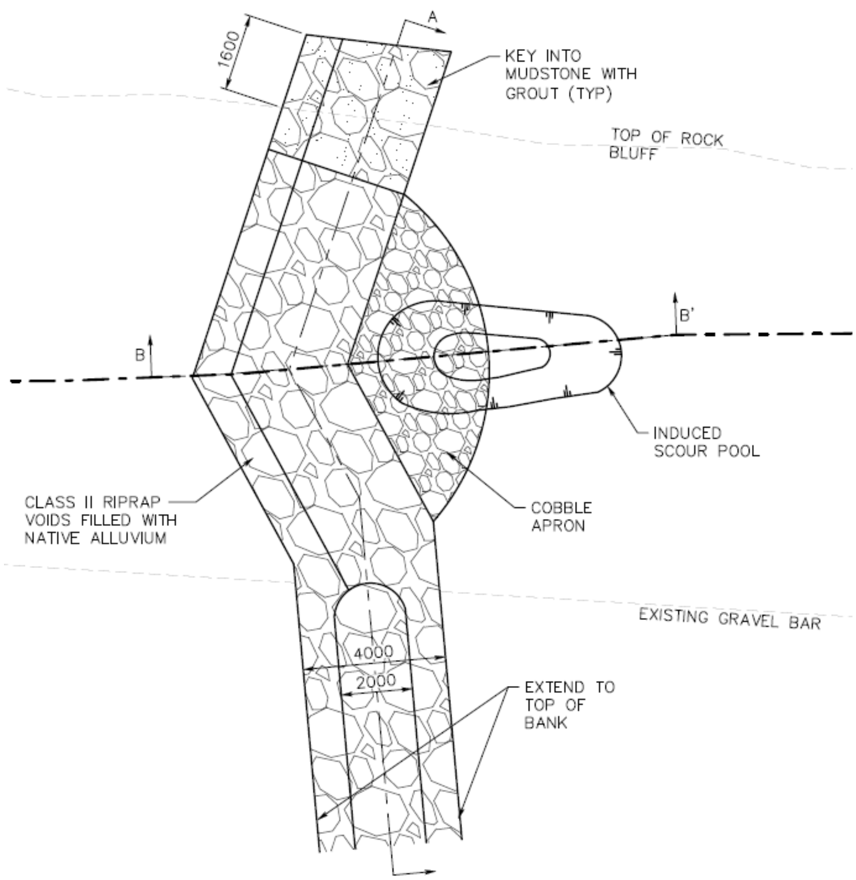

Figure 3 Rock V-Weir Detail

At the diversion structure, a backwater is maintained by a riprap vane at the end sill of the stilling basin that constricts flow through a gap in the left bay. Boulders placed in this gap will further constrict flow, maintaining flow depths of at least 18 cm in the lowest flow scenario (0.8 m^3/s) while also decreasing flow velocities. The arrangement of the rip rap and boulders in the stilling basin is illustrated in Figure 4.

These design features work in conjunction with gate operations: during times of low baseflow in the river, the right downstream gate will be raised in order to channel all river flow through the left bay of the service spillway and maintain sufficient flow depth for fish passage.

A summary of low flow conditions through the instream structures is demonstrated in Figure 5 and includes water surface elevations and velocities at 0.8 m^3/s:

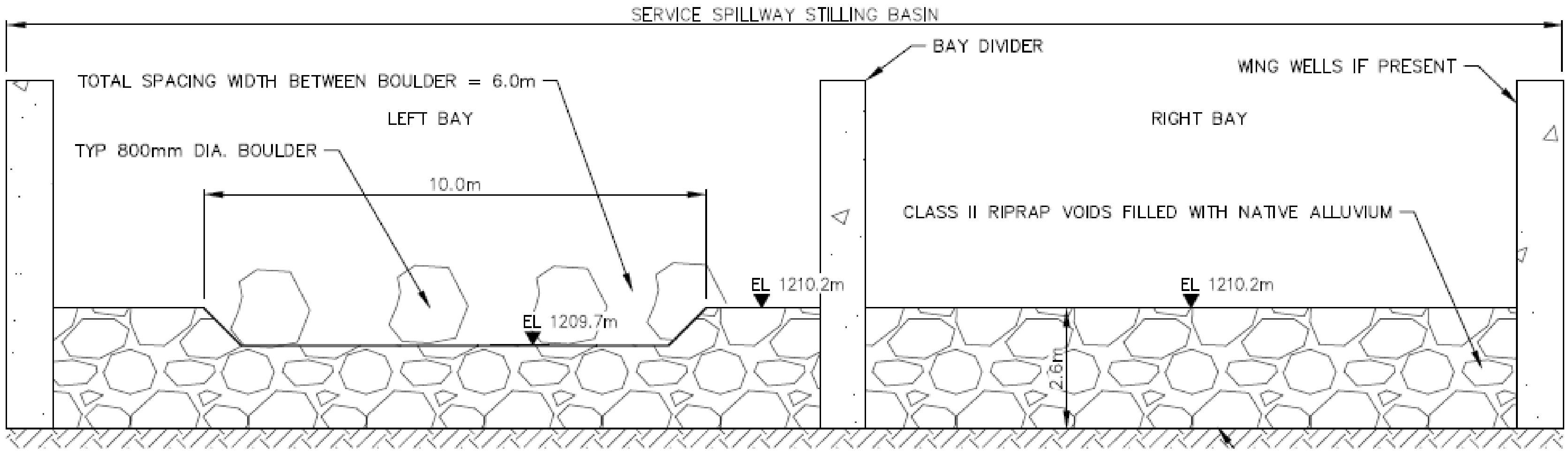

Figure 4 Stilling Basin Fish Passage Engineered Mitigations

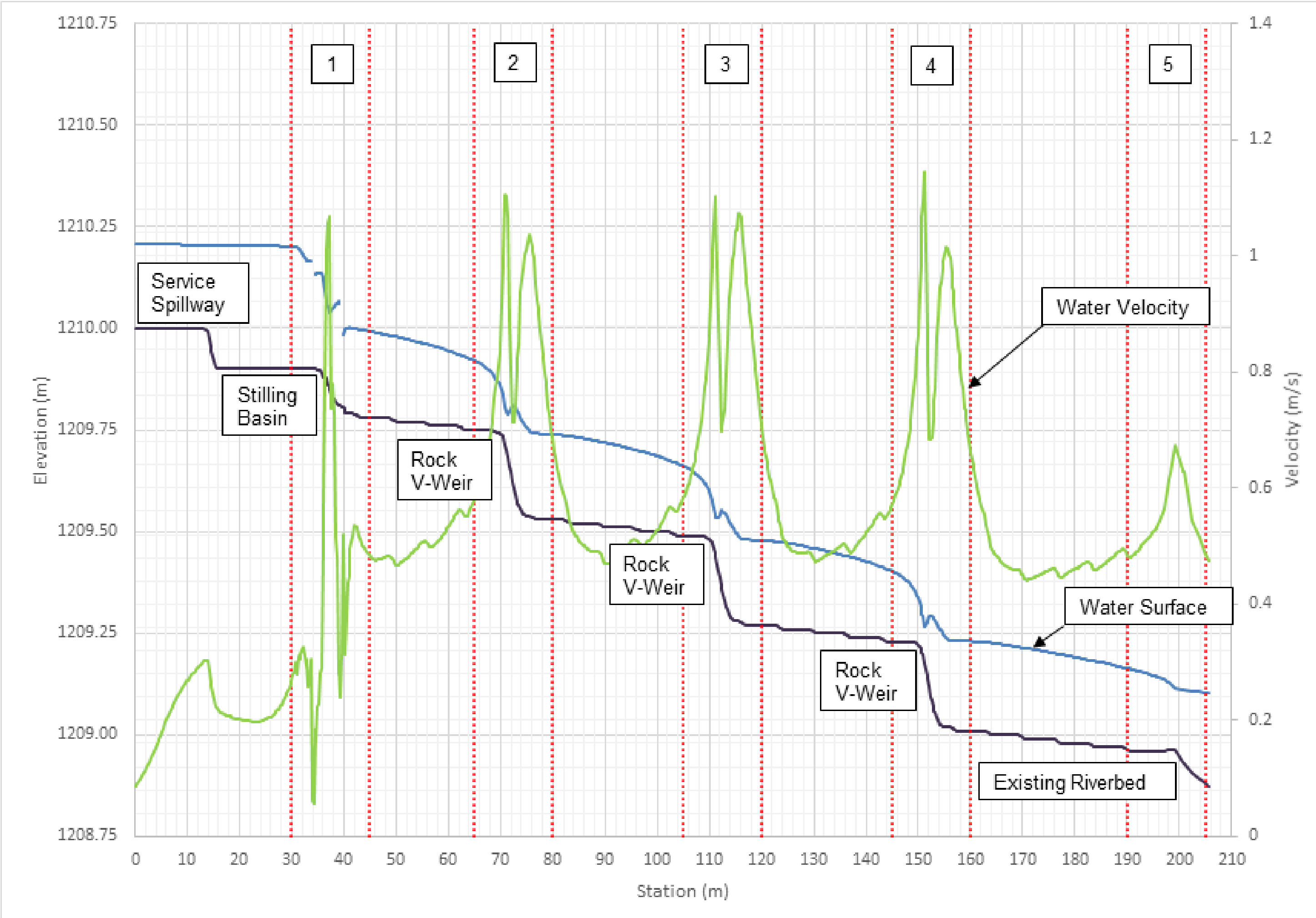

Figure 5 Elbow River Conditions through the Instream Structures for 0.8 m^3/s

The results of Figure 5 are summarized in Table 1.

Table 1 Hydraulic Assessment Results of Instream Components for Fish Passage During Low Flow (0.8m^3/s)

Section Number	Description	Max. Velocity (m/s)	Min. Water Depth (m)	Pike Species Pass?	Salmon and Walleye Species Pass?
1	Stilling Basin	1.07	0.19	Yes	Yes
2	Rock V-Weir 1	1.10	0.19	Yes	Yes
3	Rock V-Weir 2	1.10	0.19	Yes	Yes
4	Rock V-Weir 3	1.15	0.21	Yes	Yes
5	Natural Riverbed	0.63	0.18	Yes	Yes

REFERENCES

Katapodis and Gervais (2016). Fish Swimming Performance Database and Analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/002 vi + 550p.

Appendix IR91-1 Springbank Off-stream Reservoir (SR1) Fish Passage Design
May 2019

ATTACHMENT IR91-1A SR1: FISH PASSAGE FLOWS ANALYSIS

Attachment IR91-1A Fish Passage Internal Memos
May 2019

To:	Matt Wood Stantec, Calgary	From:	Seifu Guangul Stantec, Winnipeg
File:	110773396-302.600	Date:	November 4, 2016

Reference: SR1: Fish Passage Flows Analysis

This memo describes the data, approach and result of a fish passage flow analysis for Springbank Off-Stream Reservoir (SR1). The analysis includes estimate of both 3-day, 10-year maximum daily mean flow ($3Q10_{max}$) and the 3-day, 10-year minimum daily-mean flow (minimum flow) ($3Q10_{min}$) for the Biologically Sensitive time Periods as identified below:

> **BSP-1**: from 02 April to15 June (bull trout: incubation, fry, juvenile, adult, spawning; brown trout: fry, juvenile, adult; rainbow trout: incubation, fry, juvenile, adult, migration, spawning; mountain whitefish: fry, juvenile, adult)
>
> **BSP-2**: from 16 June to 25 September (bull trout: migration, spawning, incubation, juvenile, adult; brown trout: fry, juvenile, adult; rainbow trout: incubation, fry, juvenile, adult; mountain whitefish: fry, juvenile, adult)
>
> **BSP-3**: from 26 September to 01 December (bull trout: incubation, adult, spawning; brown trout: incubation, fry, juvenile, adult, migration, spawning; rainbow trout: fry, juvenile, adult; mountain whitefish: incubation, fry, juvenile, adult, spawning)
>
> **BSP-4**: from 02 December to 01 April (bull trout: incubation, fry, adult; brown trout: incubation, fry, juvenile, adult; rainbow trout: fry, juvenile, adult; mountain whitefish: incubation, fry, juvenile, adult)

The $3Q10_{max}$ separates the upper limit flow condition to which fish can pass a structure without a 3 day delay and annual exceedence probability of 0.1. Whereas, the $3Q10_{min}$ should provide low flow situations for specific BSPs at the same delay period and probability of exceedence.

DATA AND METHOD

The key gauging stations used for analysis were Elbow River below Glenmore Dam (05BJ001), Elbow River at Bragg Creek (05BJ004), Elbow River above Glenmore Dam (05BJ005), and Elbow River at Sarcee Bridge (05BJ010). The Bragg Creek Station is located upstream of the proposed SR1 diversion site, while the remaining stations are situated downstream of the diversion site near the Glenmore Reservoir. See Table1 for a summary of the relevant hydrometric stations.

Stations on the Elbow River below Glenmore Dam, above Glenmore Dam, and at Sarcee Bridge have drainage areas 1236, 1220, and 1189 km^2, respectively. With pro-ratio to account for the drainage areas between these stations, their data was combined and considered as one station for further analysis (hereafter referred to as the Combined Station). Therefore, the Combined Station consists of data from 1908 to 1932, 1934 to 1977, and 1979 to 2013. Only natural, unregulated flow is represented in the data series. Therefore, flow measurements up until the construction of the dam in 1934 were used at the station below Glenmore Dam. No flow data exists in 1933, 1978, and 1991 for any of the stations within the Combined Station grouping.

Table1: Relevant Hydrometric Station Summary

Station ID	Station Name	Drainage Area (km²)	Period of Record		Percent Missing Data	Years of Acceptable Flow Data	Type of Flow	Operation Schedule
			From	To				
05BJ001	Elbow River below Glenmore Dam	1235.7	1908	2011	2%	102	Unregulated (1908 – 1932)/ Regulated	Continuous
05BJ004	Elbow River at Bragg Creek	790.8	1934	2012	25%	59	Natural	Continuous
05BJ005	Elbow River above Glenmore Dam	1220	1933	1977	0%	45	Natural	Continuous
05BJ010	Elbow River at Sarcee Bridge	1189.3	1979	2012	37%	20	Natural	Continuous

The fish passage flow analyses were carried out using the Frequency Analysis Procedure for Storm water Design developed the City of Calgary (City of Calgary 2014). This method requires input data series from which it calculates basic, assessment, and statistical characteristics; as well as conducts a frequency analysis. The frequency analysis consists of determining the best fit theoretical probability distribution function for the sample and obtaining the prediction rule from the fitted distribution. The method requires another software package called Hydrologic Frequency Analysis Plus (HYFRAN+) for fitting a statistical distribution to the data series. HYFRAN+ is a numerical tool that can be used to compare multiple frequency distributions, parameter estimation methods, and provides some goodness-of-fit and data series characteristic tests to aid in the user's judgment. Accordingly, the following probability distributions were analyzed: Normal, Log Normal, Log Normal III, Exponential, Pearson III, Log Pearson III, Gumbel, GEV, Weibull, and Gamma.

Table 2 shows the statistical properties of each fish passage flow for each BSPs using different probability distributions.

Table2: Statistical Characteristics of Fish Passage Flows

Statistical Tests		Biologically Sensitive Period 1		Biologically Sensitive Period 2		Biologically Sensitive Period 3		Biologically Sensitive Period 4	
		$3Q10_{max}$	$3Q10_{min}$	$3Q10_{max}$	$3Q10_{min}$	$3Q10_{max}$	$3Q10_{min}$	$3Q10_{max}$	$3Q10_{min}$
Stationarity	**Spearman Rank Order Correlation Coefficient (Trend)**	no significant trend at a=0.05	no significant trend at a=0.05	no significant trend at a=0.05	no significant trend at a=0.05	no significant trend at a=0.05	trend detected at a=0.05	no significant trend at a=0.05	trend detected at a=0.05
	Mann-Whitney Test for Jump	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05
	Wald-Wofowitz Test (Jump)	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05	presence of jump possible at a=0.05
Homogeneity	**Mann-Whitney U Test**	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level
	Terry Test	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level	sample is not homogeneous at 0.05 significance level
Independence	**Spearman Rank Order Correlation Coefficient**	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05
	Wald-Wolfowitz Test for Independence	sample is independent at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05
	Anderson Test	sample is independent at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05	non-independence detected at a=0.05
Outliers	**Grubbs and Beck Test**	no high outlier; low outlier may be present	no high outliers; no low outliers	no high outliers; no low outliers	high outlier may be present; no low outlier	no high outliers; no low outliers	no high outliers; no low outliers	high outlier may be present; no low outliers	high outlier may be present; no low outliers

**Note: entries in red indicates the sample fails the test at 0.05 significance level.*

The frequency analysis method selects an appropriate probability distribution based on numerical and visual goodness-of-fit tests. These tests are:

- **Kolmogorov-Smirnov Test:** a numerical goodness-of-fit test. To apply this test, the maximum discrepancy (D-statistic) between the empirical probability and the probability distribution for the observed values is calculated and compared to a critical statistic for the data set. If the calculated D-statistic is greater than the critical statistic, the frequency distribution does not match the data set.

- **Anderson-Darling Test:** a numerical goodness-of-fit test. Similar to the Kolmogorov-Smirnov Test, a statistic A is compared to a critical statistic calculated from the sample size and significance level to determine if the data series fits with compared probability distribution.

- **Ranking Least Squares Method:** a visual goodness-of-fit test, which compares the fit of multiple distribution s to a single data sample. For this method, the sum of squares is calculated for the differences between calculated and observed discharges. A ranking of distributions by order of least standard error based on the sum of squares reveals the ranked goodness-of-fit of each distribution.

A summary of the results of the goodness-of-fit tests for the best fit probability distribution functions for the six datasets are presented in Table 3.

Table3: Goodness-of-Fit and Best Fit Probability Distribution Functions

Dataset		Numerical Goodness-of-Fit Tests			Best Fit Probability Distributions
		Anderson-Darling Test	Kologorov-Smirnov Test	Least Squares Ranking	
Biologically Sensitive Period1	**$3Q10_{max}$**	1	1	3	GEV
	$3Q10_{min}$	1	2	6	Log Normal
Biologically Sensitive Period 2	**$3Q10_{max}$**	1	2	2	Log Normal
	$3Q10_{min}$	1	1	3	GEV
Biologically Sensitive Period 3	**$3Q10_{max}$**	2	1	4	Log Normal Type III
	$3Q10_{min}$	1	3	4	Log Normal Type III
Biologically Sensitive Period 4	**$3Q10_{max}$**	1	1	3	GEV
	$3Q10_{min}$	1	1	2	Log Pearson Type III

Summary of results for each BSPs and fish passage flows using different probability distribution is shown below. Results based on the best-fit probability distribution and those which are considered for use in the fish passage analysis are highlighted in grey.

Table 4. Recommended Flows for Fish Passage Analysis

		Normal	Log Normal	Log Normal III	Exponential	Pearson Type III	Log Pearson Type III	Gumbel	GEV	Weibull	Gamma
Biologically Sensitive Period1	**$3Q10_{max}$**	82	78.3	76.5	91.3	81.8	78.2	71.2	75.7	81.2	77.2
	$3Q10_{min}$	2.2	2.8	2.5	1.71	2.45	2.7	2.5	2.5	2.1	2.4
Biologically Sensitive Period2	**$3Q10_{max}$**	69.7	69.5	71.5	76.3	71	69.9	65.8	70.1	70.8	68.6
	$3Q10_{min}$	N/A	3.04	3.3	2.43	2.89	4	3.13	3.47	1.11	2.4
Biologically Sensitive Period3	**$3Q10_{max}$**	15.2	14.5	15	16.2	15	14.7	13.8	15	15.4	14.7
	$3Q10_{min}$	2.17	2.39	2.38	1.56	2.36	2.37	2.38	2.39	2.12	2.36
Biologically Sensitive Period4	**$3Q10_{max}$**	11.9	9.93	10	11.8	11.5	10.2	9.47	9.81	11.7	10.4
	$3Q10_{min}$	0.17	0.74	0.8	0.66	0.78	0.8	1.04	0.82	0.42	0.63

***Biologically Sensitive Period1 (BSP-1)**: from 02 April to15; **Biologically Sensitive Period2 (BSP-2)**: from 16 June to 25 September; **Biologically Sensitive Period3 (BSP-3)**: from 26 September to 01 December; **Biologically Sensitive Period4 (BSP-4)**: from 02 December to 01 April*

The best-fit probability distributions for each of the fish passage flow are shown below. The distributions along with the raw data and the 95% confidence intervals were plotted on log scaled graphs. For some probability distribution functions and return periods, HYFRAN+ was unable to generate the 95% confidence intervals.

It is recommended that these hydrologic estimates be used for the analysis of fish passage at SR1

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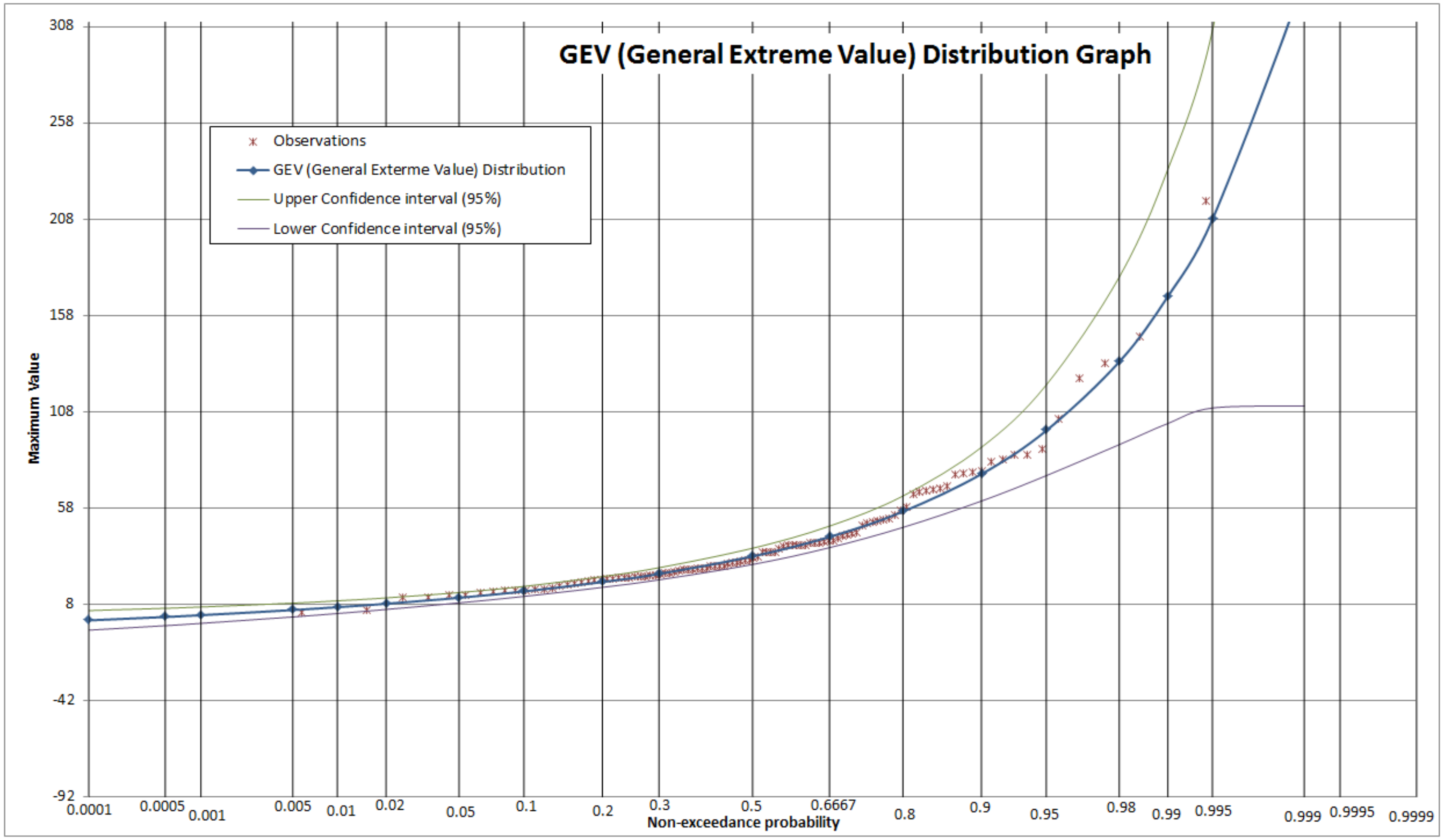


Figure 1. GEV: Best Fit Distribution for the BSP-1, $3Q10_{max}$ Flow

Reference: SR1: Fish Passage Flows Analysis

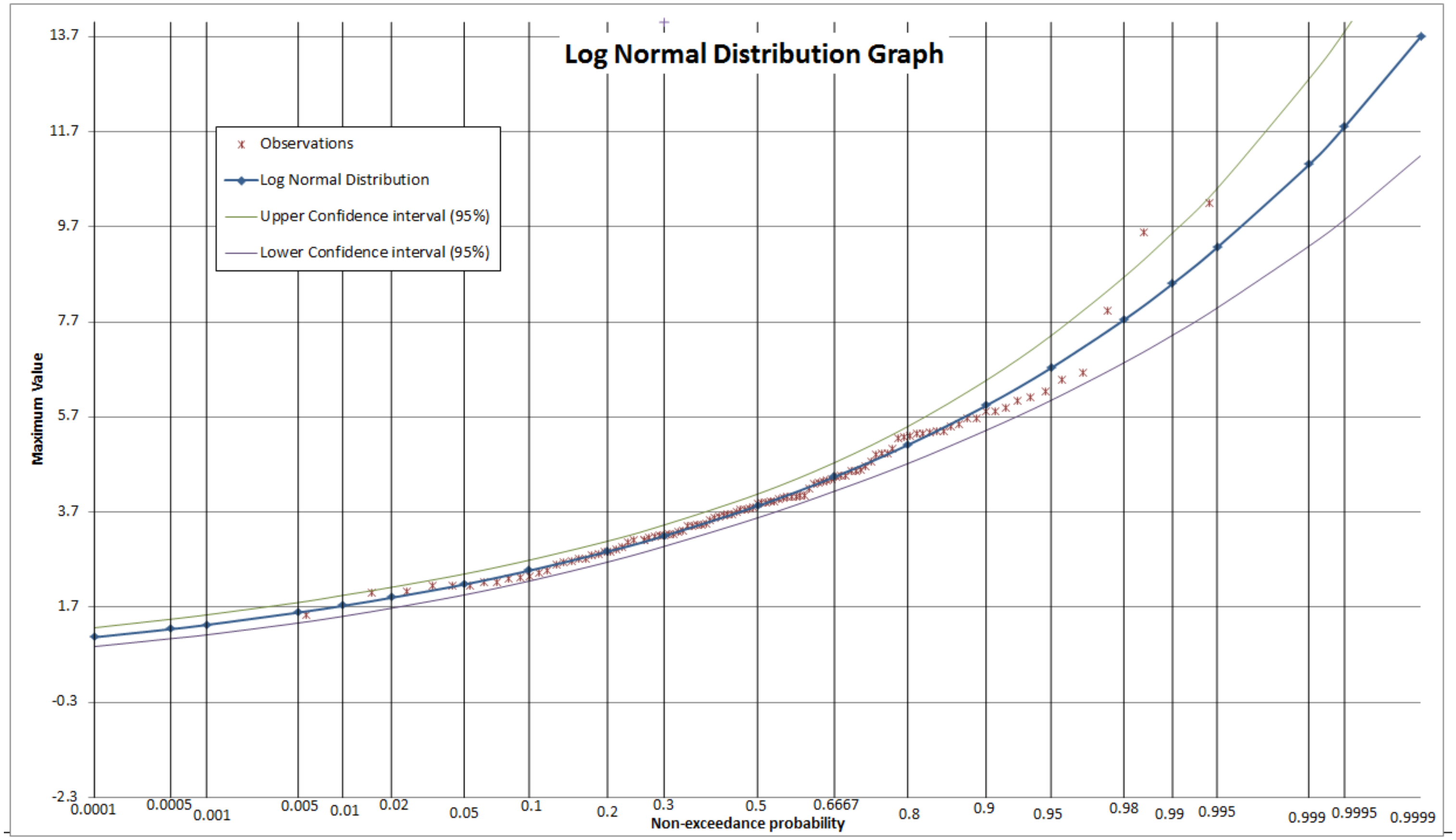


Figure 2. Log Normal: Best Fit Distribution for the BSP-1, 3Q10$_{min}$ Flow

Reference: SR1: Fish Passage Flows Analysis

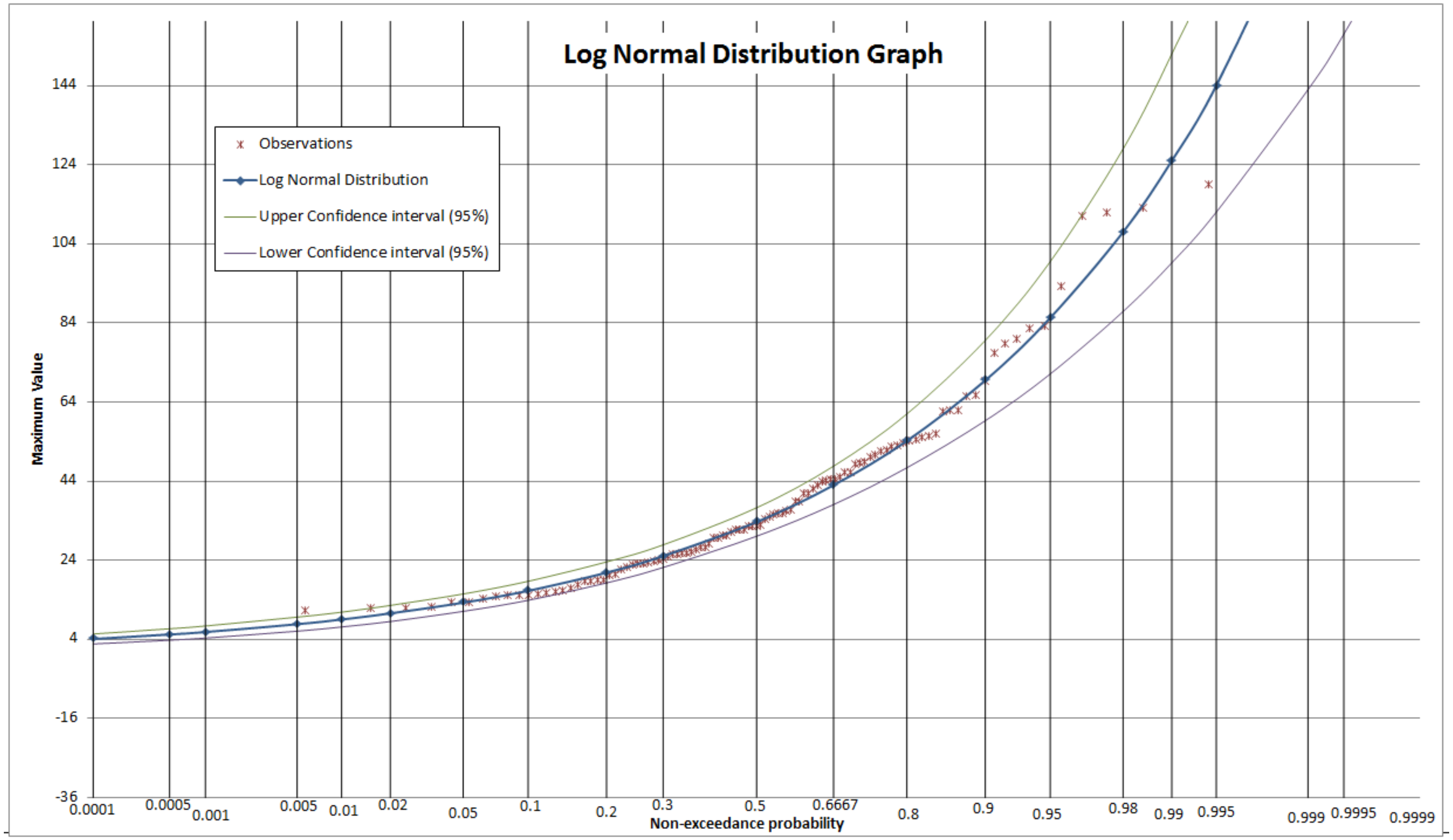


Figure 3. Log Normal: Best Fit Distribution for the BSP-2, 3Q10$_{max}$ Flow

Reference: SR1: Fish Passage Flows Analysis

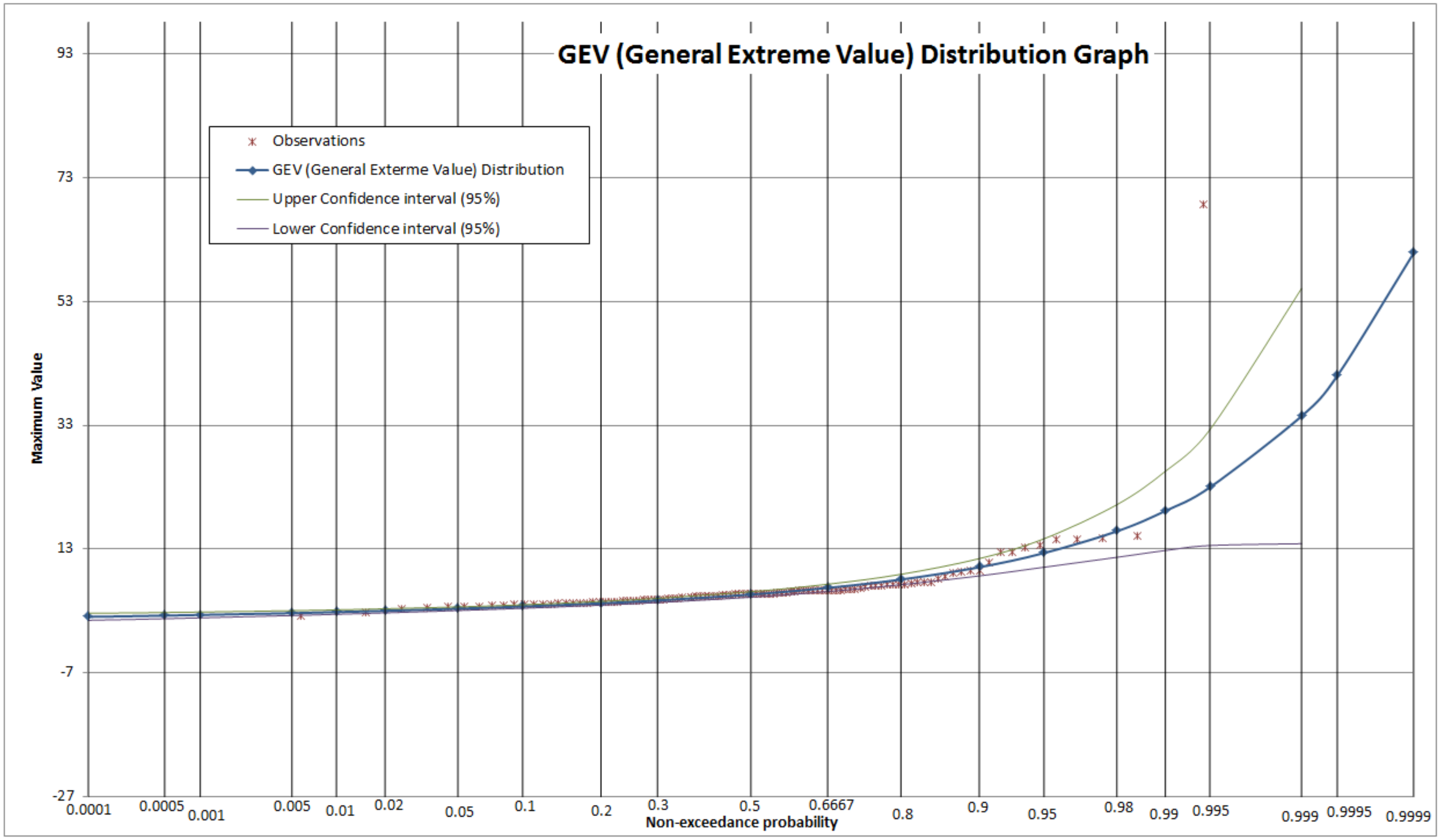


Figure 4. GEV: Best Fit Distribution for the BSP-2, $3Q10_{min}$ Flow

Reference: SR1: Fish Passage Flows Analysis

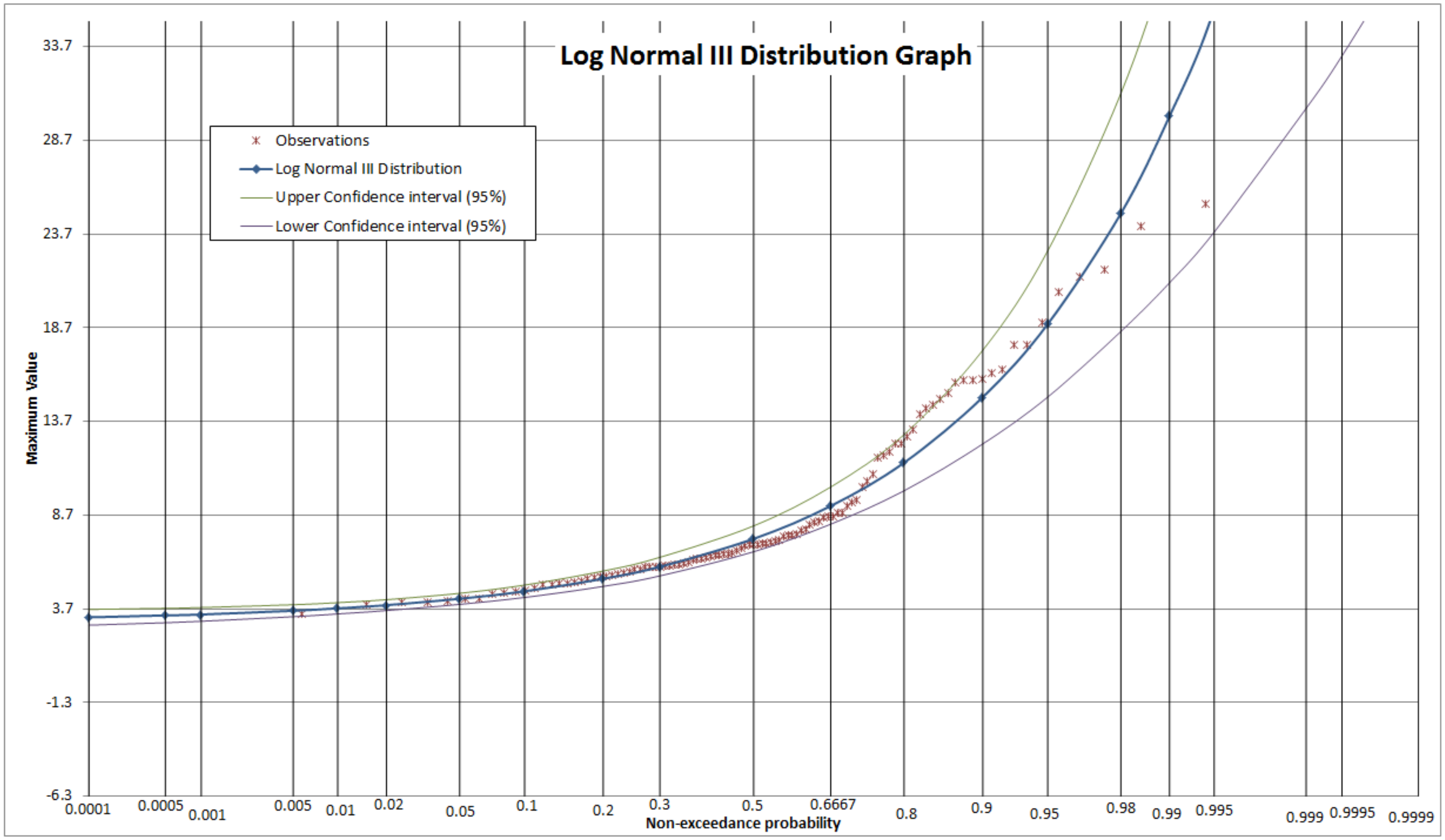


Figure 5. Log Normal III: Best Fit Distribution for the BSP-3, $3Q10_{max}$ Flow

Reference: SR1: Fish Passage Flows Analysis

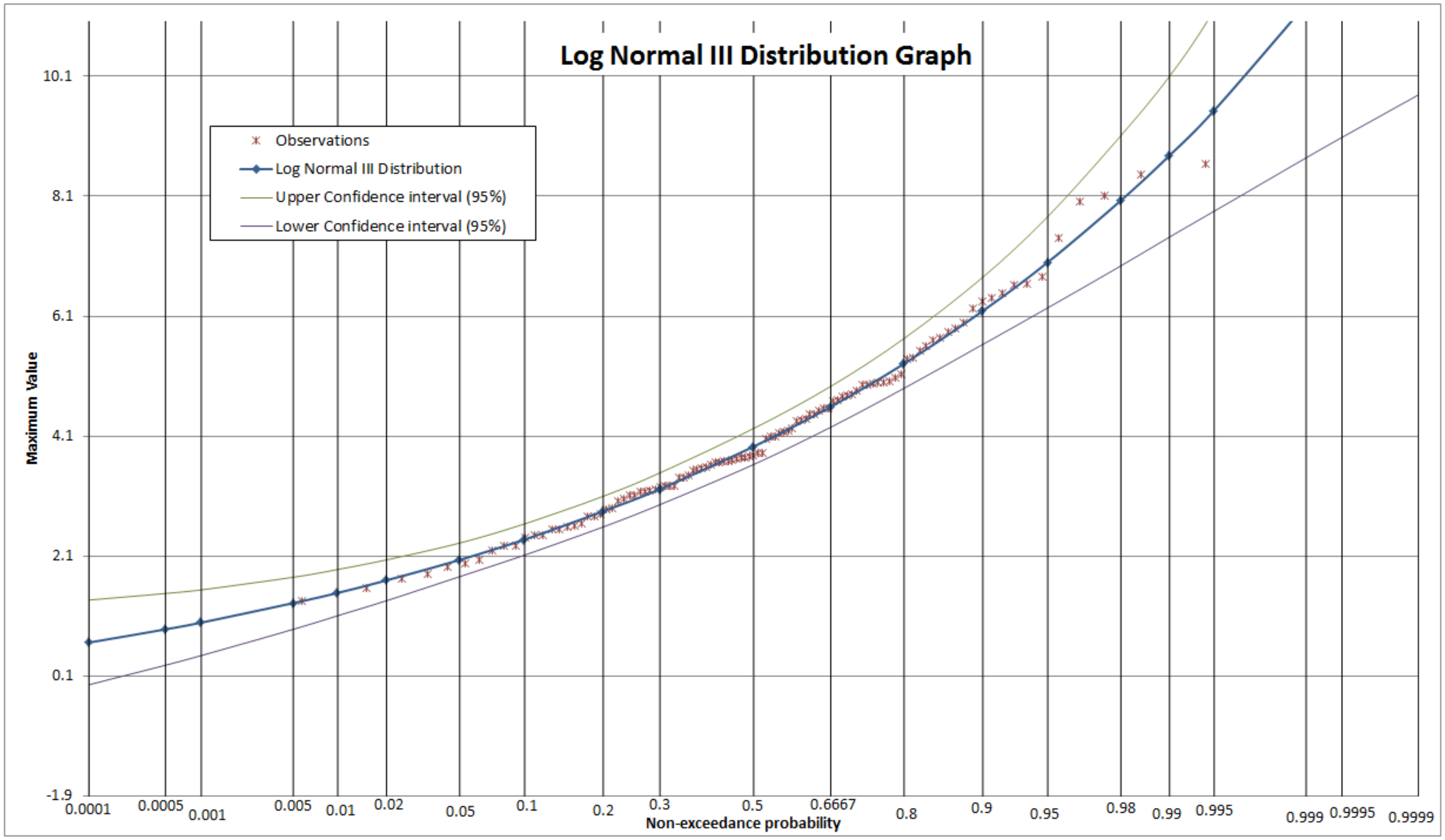


Figure 6. Log Normal III: Best Fit Distribution for the BSP-3, $3Q10_{min}$ Flow

Reference: SR1: Fish Passage Flows Analysis

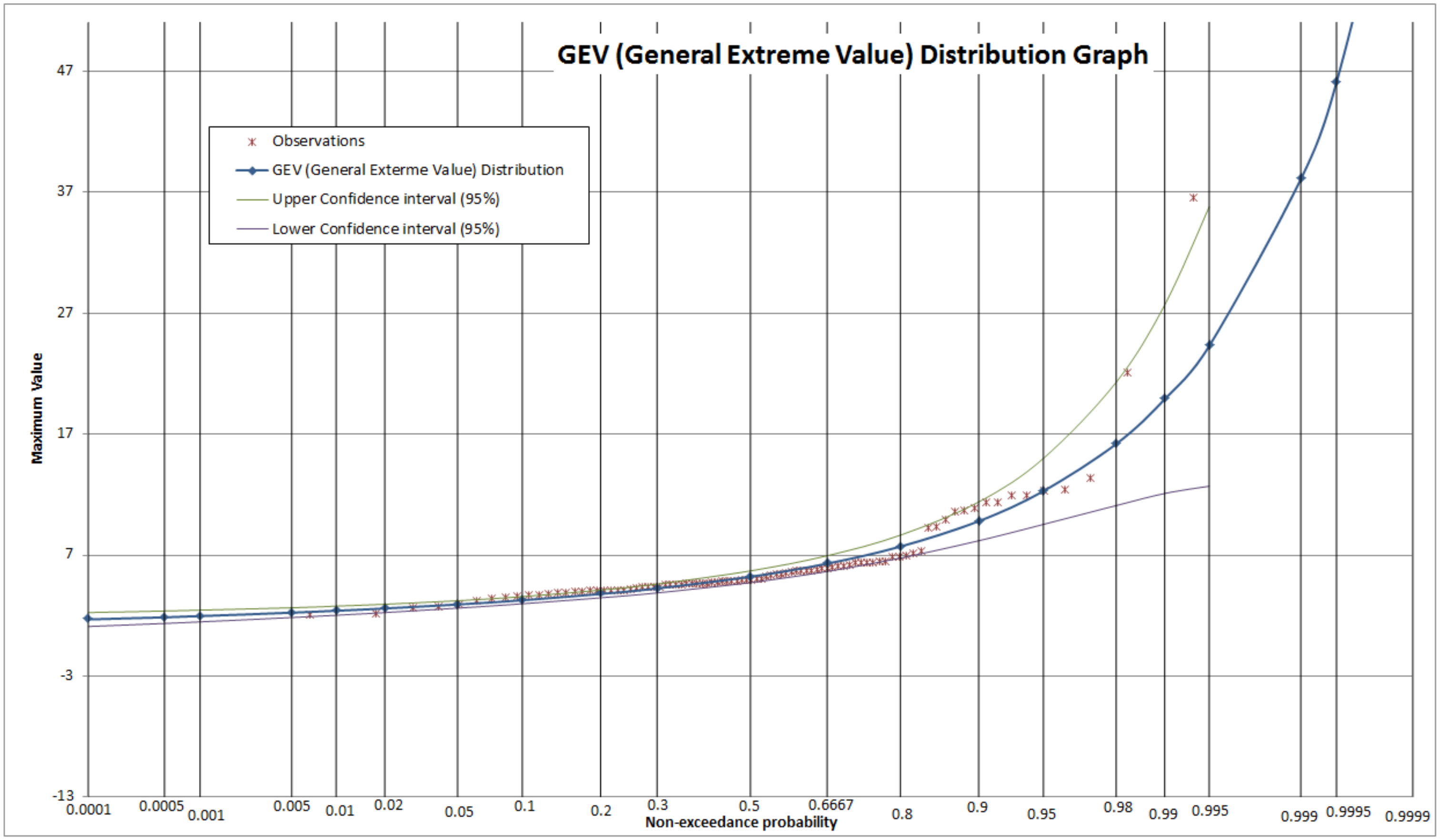


Figure 7. GEV: Best Fit Distribution for the BSP-4, $3Q10_{max}$ Flow

Reference: SR1: Fish Passage Flows Analysis

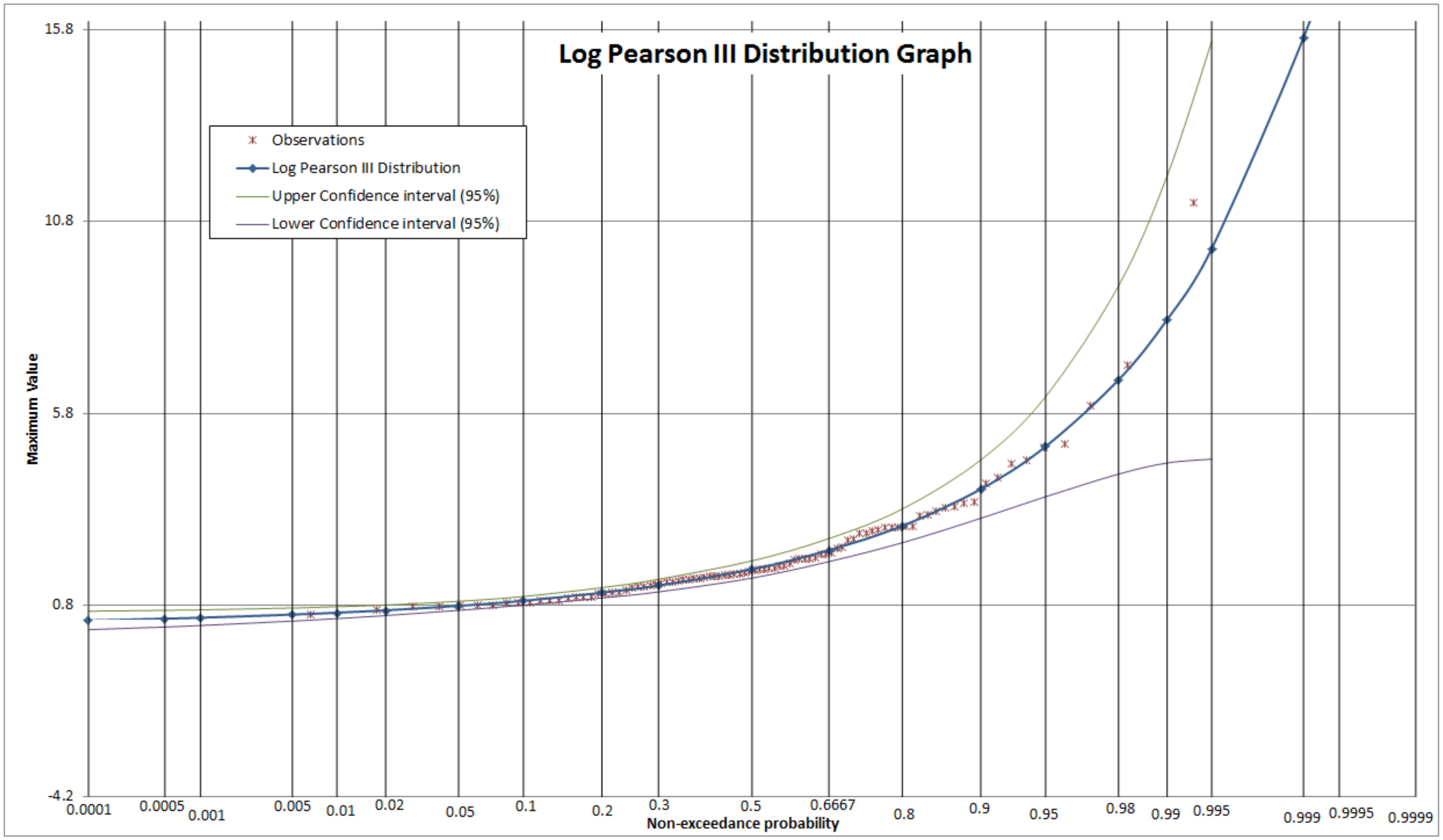


Figure 8. Log Pearson III: Best Fit Distribution for the BSP-4, $3Q10_{min}$ Flow

ATTACHMENT IR91-1B FISH PASSAGE MITIGATIONS AT THE SR1 DIVERSION STRUCTURE

Attachment IR91-1B Fish Passage Mitigations at the SR1 Diversion Structure
May 2019

Stantec

Memo

To:	Paul Harper	From:	Matt Wood, P.Eng., CPESC
	Lethbridge, Alberta		25th Street, Calgary, Alberta
File:	110773396	Date:	September 29, 2017

Reference: Fish Passage Mitigations at the SR1 Diversion Structure

The attached drawings provide the preliminary design for the fish passage mitigations at the service spillway of the SR1 diversion structure. The memo accompanies the attached drawings titled Fish Passage Arrangement Sheets 1-3.

Setting and Potential Passage Issues

Downstream of the diversion structure's service spillway, the thalweg of the Elbow River runs against the sandstone-mudstone outcrop that comprises the left (north) bank of the river. That thalweg is partially confined against that outcrop by a gravel point bar that had naturally formed along the right (south) side of the channel. That gravel bar is present in the historic air photo record prior to, and following the 2013 flood.

Though set at existing grade in the river bed, review of the preliminary design of the service spillway dated March 31, 2017 revealed the potential for a drop of up to 0.6 m form from the end-sill of the stilling basin to the thalweg of the Elbow River. This drop would only form should the presence of the structure, or its operation alter the existing bedform patterns in this location. Such a drop would pose a barrier to fish at low flow. This potential warrants measures to stabilize the thalweg and bedform so that they are more resilient to the presence of the service spillway, and its operation.

There was also some concern of the potential for low-flow to splay out across the full width of the gate bay resulting in insufficient depth for fish passage over the gates during low-flow conditions. This concern warrants mitigations to increase the depth over the gate at low-flows to at least 18 cm.

Design Basis for Mitigations

- The design must maintain a minimum depth of 18 cm over the gate bays.
- The design should best simulate natural existing conditions in the Elbow River and avoid synthetic fishways.
- The design should be resilient under operations up to the 100-year event (discharge over service spillway 160 m^3/s but should be able to wash-out at extreme events so as not to cause hydraulic issues at the service spillway.
- The design should be serviceable and provide hydraulic conditions that are conducive to passage for the design fish under the flow scenarios described in Stantec's memo titled "Fish Passage Flows" dated November 2nd, 2016.

Reference: Fish Passage Mitigations at the SR1 Diversion Structure

Proposed Mitigations

The preliminary design for the proposed mitigations for fish passage at the diversion structure are shown in the attached drawings titled "Fish Passage Arrangement" Sheets 1-3. Features of this design include following:

- The service spillway's obermeyer gates sit near flush with the river bed during non-operation.
- Operation of the obermeyer gates can have the left and right bays open or close independently so low-flow can be concentrated into either bay, if required for fish passage. The proposed design utilizes the left (north) bay for that purpose.
- The stilling basin of the service spillway is backfilled with native alluvium. This backfill could wash out in a major event but should backfill itself on the receding limb of a flood, and with infrequent operation of the service spillway.
- Class II riprap vanes are placed near-flush with the surface of the existing bar to fix it in its current condition. If operation is infrequent it is expected that these structures will cause the bar to grow towards the right service spillway bay as indicated in Sheet 1 of the drawings.
- Rock V-weirs form the extension of the vanes into the thalweg and are intended to stabilize the thalweg's grade and limit step heights to no more than 20 cm. The v-weirs concentrate low-flow in the thalweg to facilitate passage at the step.
- The v-weirs are keyed into the bedrock outcrop of the left (north) bank using grouted riprap. They are keyed into the right (south bank) for a distance of 4 m without grouting.
- Cobble aprons line the downstream side of the v-weirs and are set at a determined plunge pool depth. These aprons will increase the resiliency of the v-weirs to their self-undermining while allowing the formation of natural plunge pools that can be used as resting areas for fish.
- Backwater over the gates is created by a riprap vane on the end-sill that constricts low flow through a gap in the left (north) bay. The gap contains boulders to further confine flow and maintain a backwater of no less than 18 cm over the gates at the lowest fish passage flow of 0.8 m^3/s (3Q10 min for BSP4).
- Rip-rap mini-spurs consisting of 3 large boulders abut the bedrock outcrop on left bank to serve as additional resting places in between the thalweg's v-weirs.
- Loose boulders are placed in the thalweg between the v-weirs to serve as additional resting places.
- The use of Class II riprap has been chosen to meet the resiliency criteria of being stable to flows up to 160 m^3/s (100-year flood downstream release during operation); and could wash-out at extreme events so as to not create adverse hydraulics in the service spillway.
- All class II riprap presented in this design will be backfilled with native gravels and cobbles.

Reference: Fish Passage Mitigations at the SR1 Diversion Structure

- The design effectively freezes the current thalweg and bar position to a stable grade where fish passage can be achieved.
- The design closely simulates the current thalweg conditions on this reach of the Elbow River where it is confined by the gravel bars to a single, low-flow channel and grade in the thalweg is maintained by the bedrock outcrops that pass under the river channel in several locations. The effects that those outcrops have on the stability of the thalweg can be seen in publicly available aerial photography. That effect is mimicked by the v-weirs that line the thalweg at the proposed mitigations.

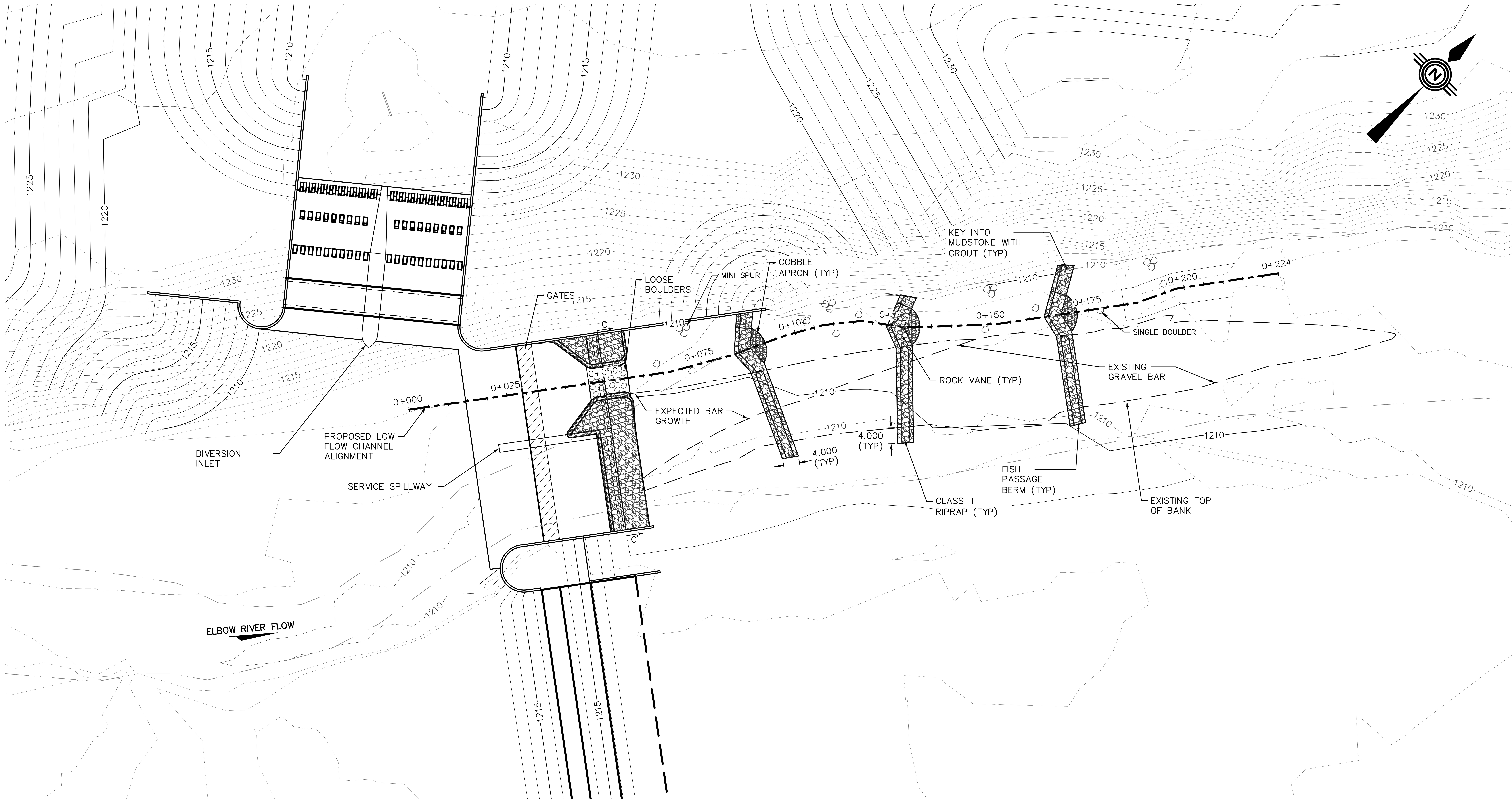
Performance of Proposed Mitigations

The proposed mitigations were modeled using Flow 2D and following the methods described in the Stantec memo titled "Hydraulic Modelling to Support Fish Passage Assessment" dated September 13, 2017. The results of that hydraulic modelling are included in that memo and can be used to inform the assessment of fish passage at the structure for the specified Biologically Significant Periods.

STANTEC CONSULTING LTD.

Matt Wood, P.Eng., CPESC
Senior Associate, Water
Phone: (403) 716-8032
matt.wood@stantec.com

Attachment: Memo: Fish Passage Flows – November 2, 2016
Memo: Hydraulic Modelling to Support Fish Passage Assessment - September 13, 2017



PLAN

1:500

0 20 40 Meters

NOTE:
GEOMORPHOLOGY SURVEY POINTS INCORPORATED INTO EXISTING GRADE SURFACE.

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DESIGNER
DATE

CHECKER
DATE

Alberta Transportation

SPRINGBANK OFF-STREAM STORAGE PROJECT
SR1

FISH PASSAGE ARRANGEMENT
PLAN

DEPARTMENT BAR CODE	DATE	ALBERTA ENVIRONMENT AND PARKS CAPITAL PROJECTS NUMBER	SITE	SHEET	CONSULTANT DRAWING	TRANSPORTATION DRAWING
	2017-03-31	-	-	1 OF 3		

PlotDate: 2017.09.29 5:27 PM Login: Tandara, Catalina
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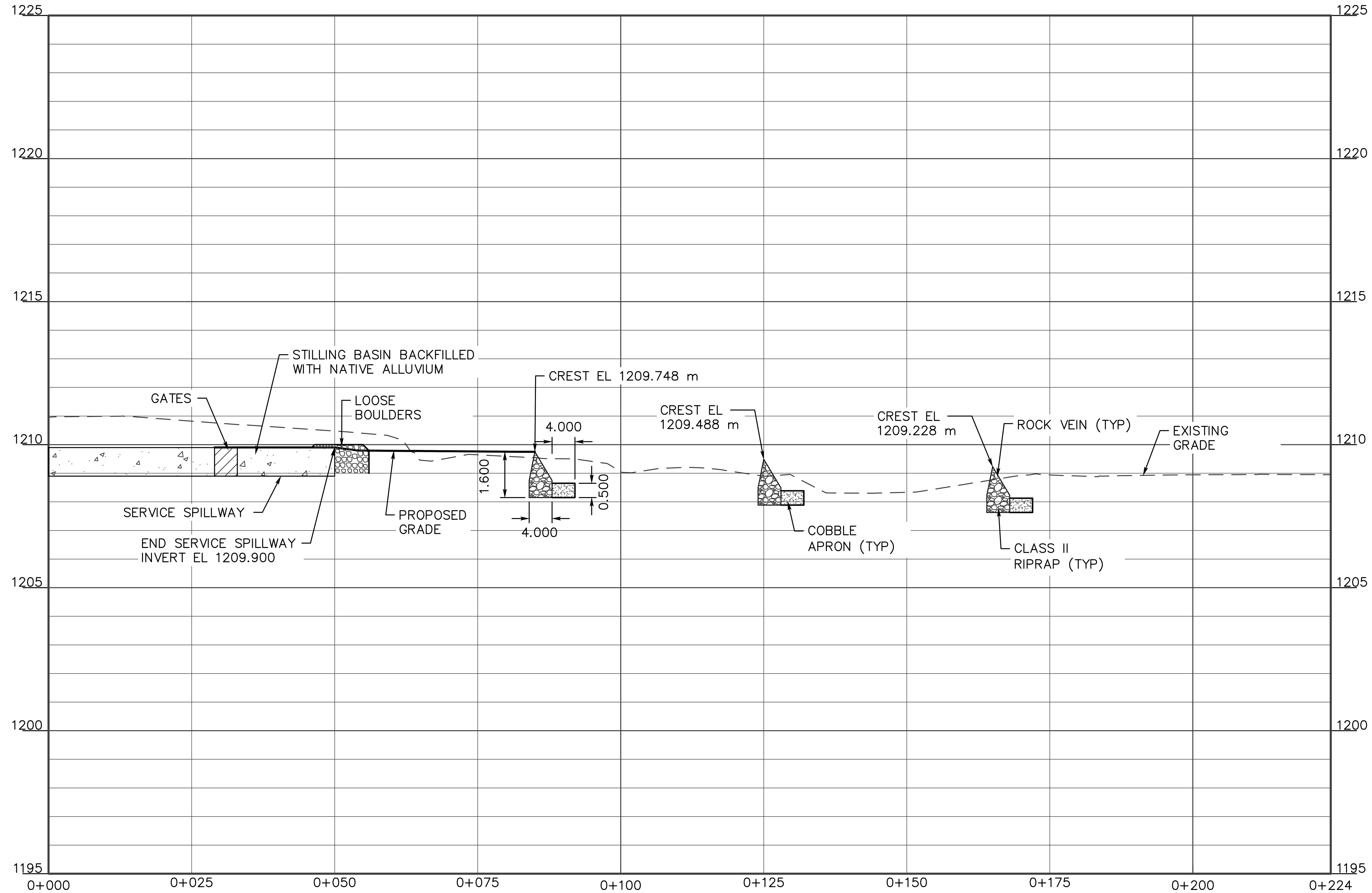

PROFILE
H 1:500, V 1:100

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CHECKER — DATE

Alberta Transportation

SPRINGBANK OFF-STREAM STORAGE PROJECT SR1

FISH PASSAGE ARRANGEMENT PROFILE

DATE	ALBERTA ENVIRONMENT AND PARKS CAPITAL PROJECTS NUMBER	SITE	SHEET	CONSULTANT DRAWING	TRANSPORTATION DRAWING
2017-03-31	-	-	2 OF 3		

PlotDate: 2017.09.29 3:29 PM Login: Tandara, Catalina
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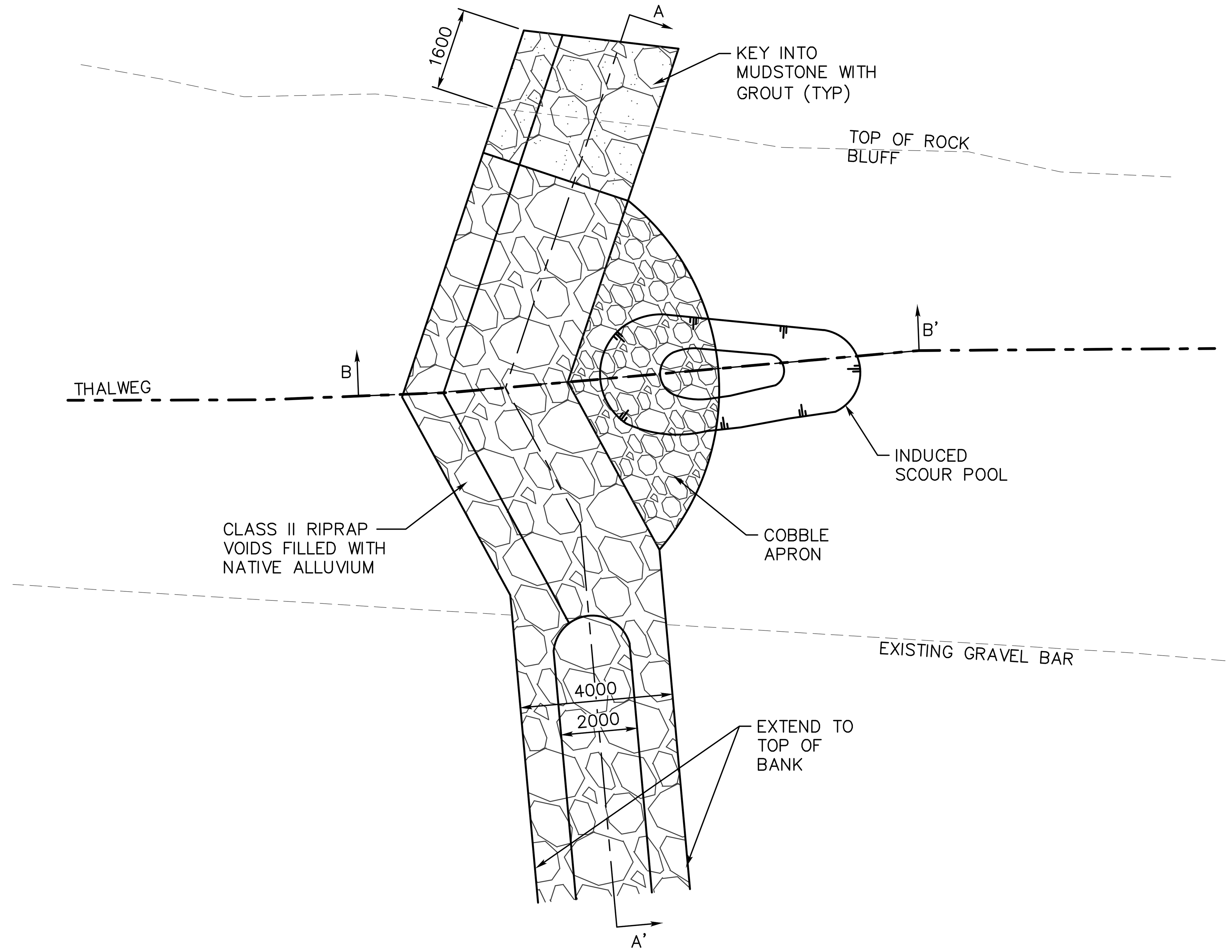
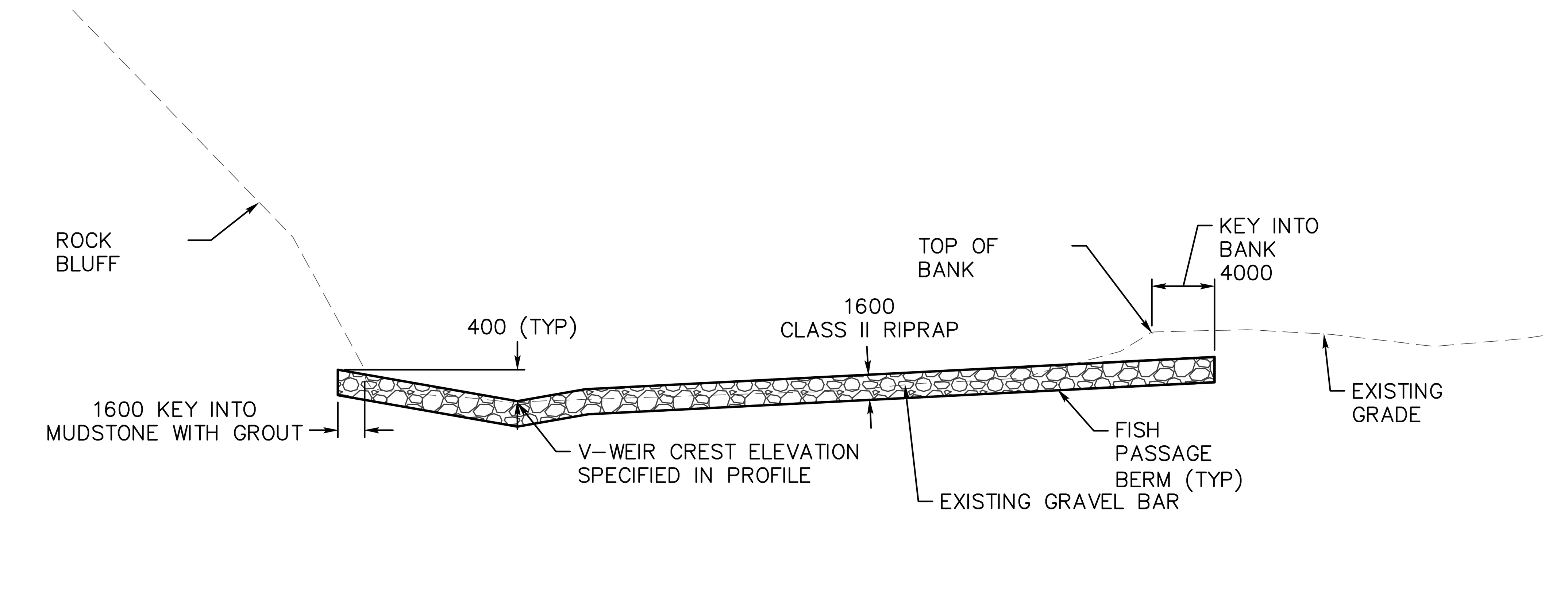


DETAIL – PLAN
1:100



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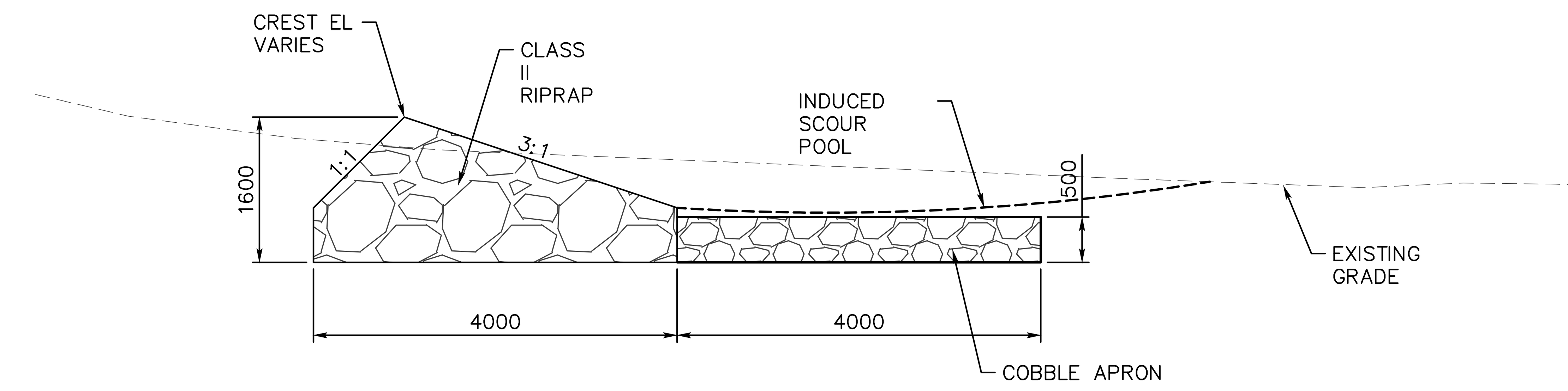

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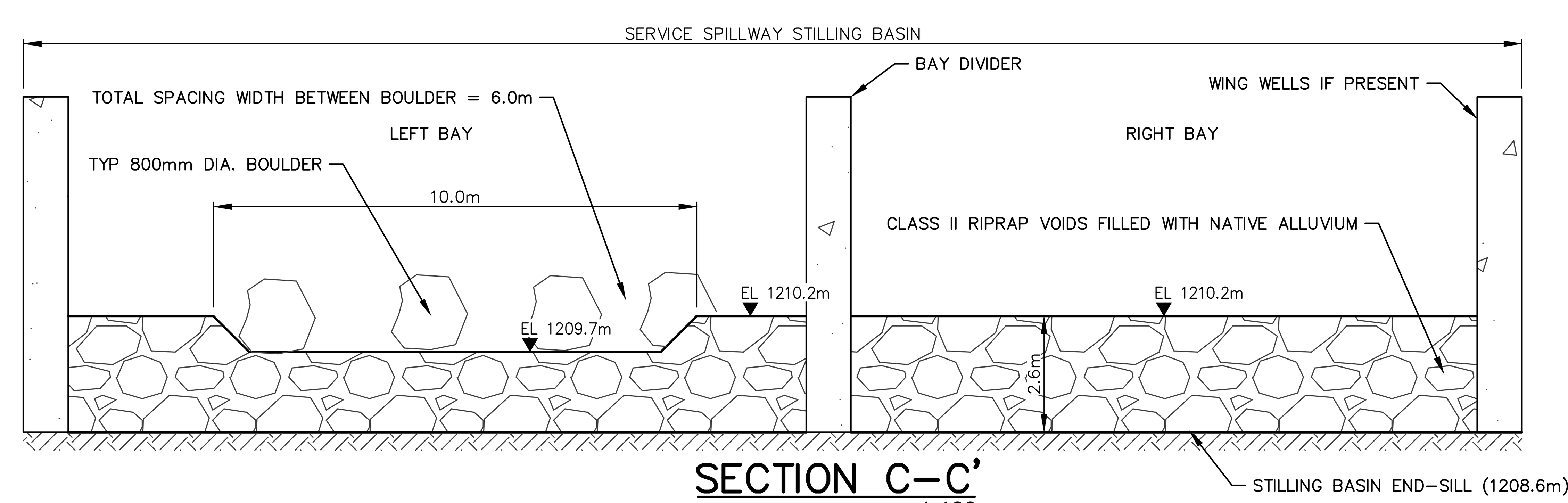

SECTION C–C'
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DATE
CHECKER
DATE

Alberta Transportation

SPRINGBANK OFF-STREAM STORAGE PROJECT
SR1

FISH PASSAGE ARRANGEMENT
SECTION AND DETAILS

DATE	ALBERTA ENVIRONMENT AND PARKS CAPITAL PROJECTS NUMBER	SITE	SHEET	CONSULTANT DRAWING	TRANSPORTATION DRAWING
2017-03-31	-	-	3 OF 3		

PlotDate: 2017.09.29 5:26 PM Login: Tandara, Catalina
AUTOCAD FILE No. P:\Catalina\SR1\fish_passage\Fish_Passage_Working_rev.dwg TENDER No. ?

ATTACHMENT IR91-1C SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) – HYDRAULIC MODELING TO SUPPORT FISH PASSAGE ASSESSMENT

Attachment IR91-1C Springbank Off-Stream Storage Project (SR1) – Hydraulic Modeling to Support Fish Passage Assessment
May 2019

Stantec

Memo

To:	Paul Harper Calgary	From:	John Menninger Dan Hoffman Cincinnati
File:	110773396	Date:	September 13, 2017 Revision A

Reference: Springbank Off-stream Storage Project (SR1) – Hydraulic Modeling to Support Fish Passage Assessment

Hydraulic modeling was completed to assess the existing conditions and the effects of the proposed project on the velocity and depth of water in the Elbow River at varying flow rates. Two-dimensional (2D) numerical modeling was developed using the RiverFlow2D Plus, version 5.1 two-dimensional finite volume river dynamics model software developed by Hydronia, LLC.

Two model geometries were developed for this assessment representing existing conditions and the proposed conditions with mitigation measures. The model domain is comprised of a triangular mesh with elevations assigned from a digital terrain model. Model mesh elements vary in size from less than 1 m to 7 m depending on the complexity of the terrain and detail of proposed project features.

Manning's roughness parameters in the model are spatially varied based on terrain data and aerial imagery. The roughness parameters were selected based on field reconnaissance photos and recommended literature values included in "Open-Channel Hydraulics" (Chow, 1959). Table 1 below summarizes the Manning's values used in the model.

Table 1. 2D Numerical Model Roughness Parameters

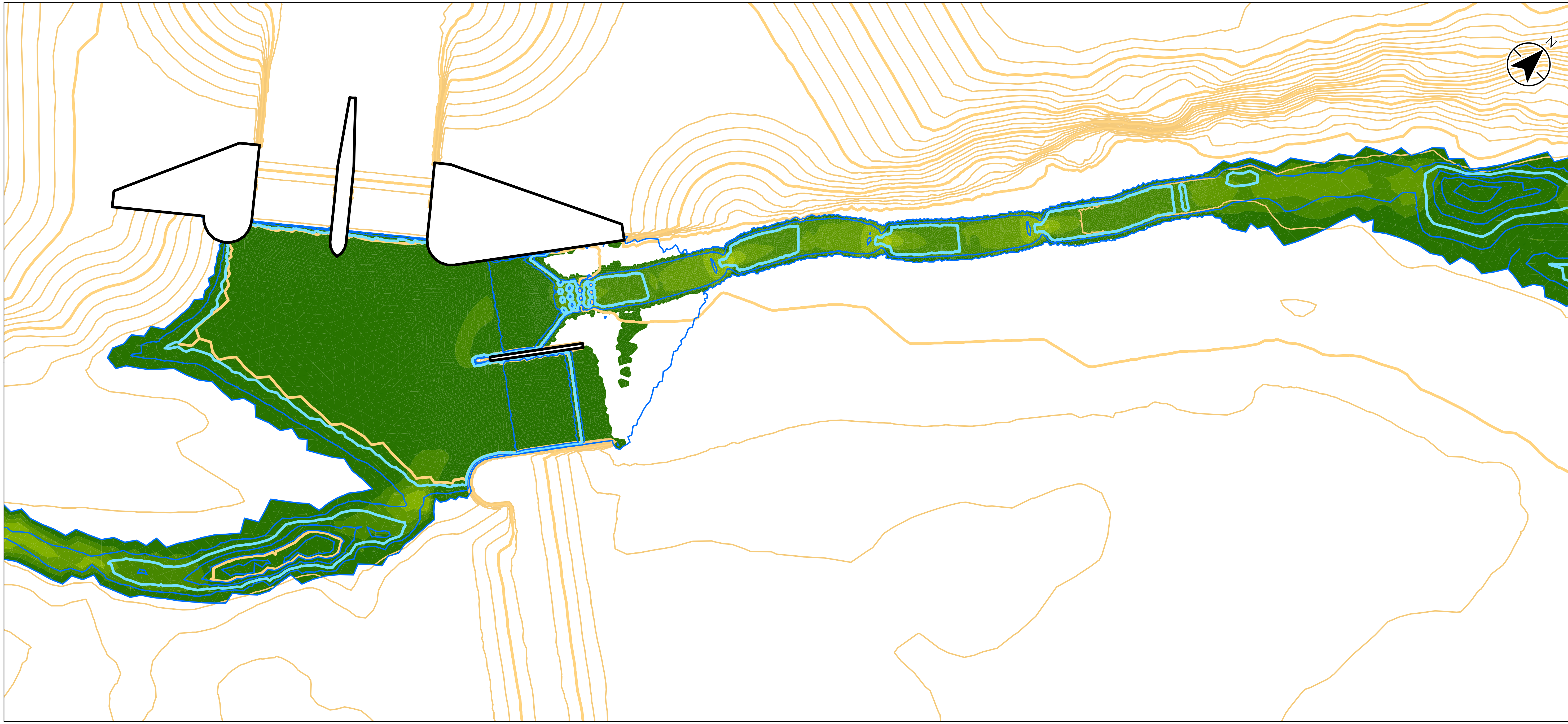
Surface / Land Use Type	Manning's "n"
Open Space / Grass	0.040
Wooded Area	0.100
Wooded Island	0.080
Main Channel / Riprap	0.038
Diversion Structure Concrete	0.013
Auxiliary Spillway RCC	0.020
Exposed Bedrock	0.025

Reference: Springbank Off-stream Storage Project (SR1) – Hydraulic Modeling to Support Fish Passage Assessment

The model domain includes approximately 3.5 km of the Elbow River extending from approximately 1.2 km downstream of the Diversion Structure (just above Highway 22) and 2.3 km upstream. The downstream boundary of the Elbow River at Highway 22 was set using a rating curve developed from the 1D regulatory model of the Elbow River. For each scenario, a fixed water surface elevation was set based on the selected river discharge. Due to their long distance downstream of the Diversion Structure, the selected downstream boundary conditions were observed to have a negligible effect on model results at the Diversion Structure.

The upstream boundary for each model scenario is a specified constant discharge rate. The simulation is then run until a steady-state condition is reached within the model. Model simulations were completed for the following discharge values: 0.8, 2.4, 2.8, 3.5, 9.8, 15, 70, 76 m^3/s.

Results of the analysis (depth averaged velocity and flow depth) are presented on the attached figures.



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75

3.25 - 3.5

3 - 3.25

2.75 - 3

2.5 - 2.75

2.25 - 2.5

2 - 2.25

1.75 - 2

1.5 - 1.75

1.25 - 1.5

1 - 1.25

0.75 - 1

0.5 - 0.75

0.25 - 0.5

0 - 0.25

0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

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Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.

1 of 2

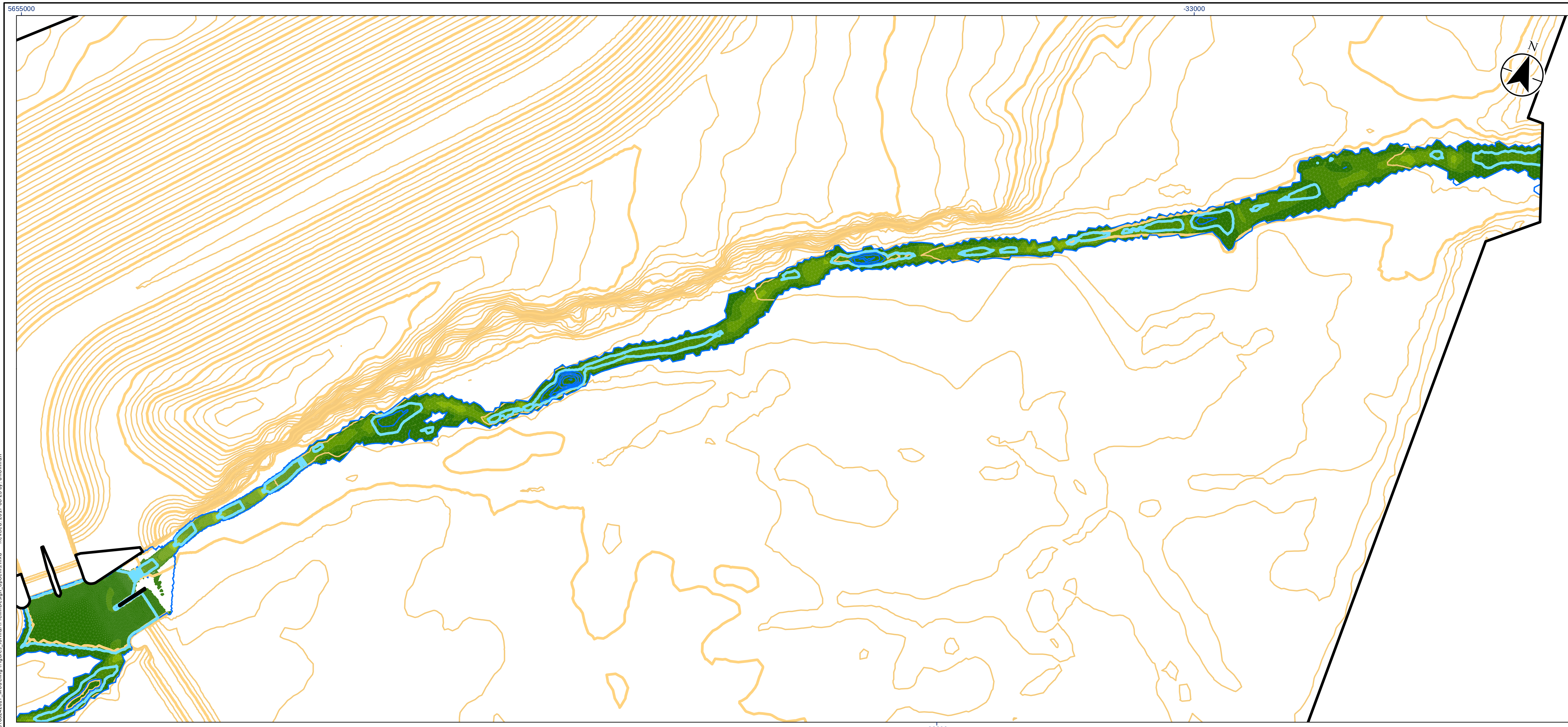
Title

Fish Passage Simulation
Preliminary Design, 0.8 cms

Notes

1. Coordinate System: NAD 1983 3TM 114

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_0p8cms_Zoom.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

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Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
2 of 2

Title
Fish Passage Simulation
Preliminary Design, 0.8 cms

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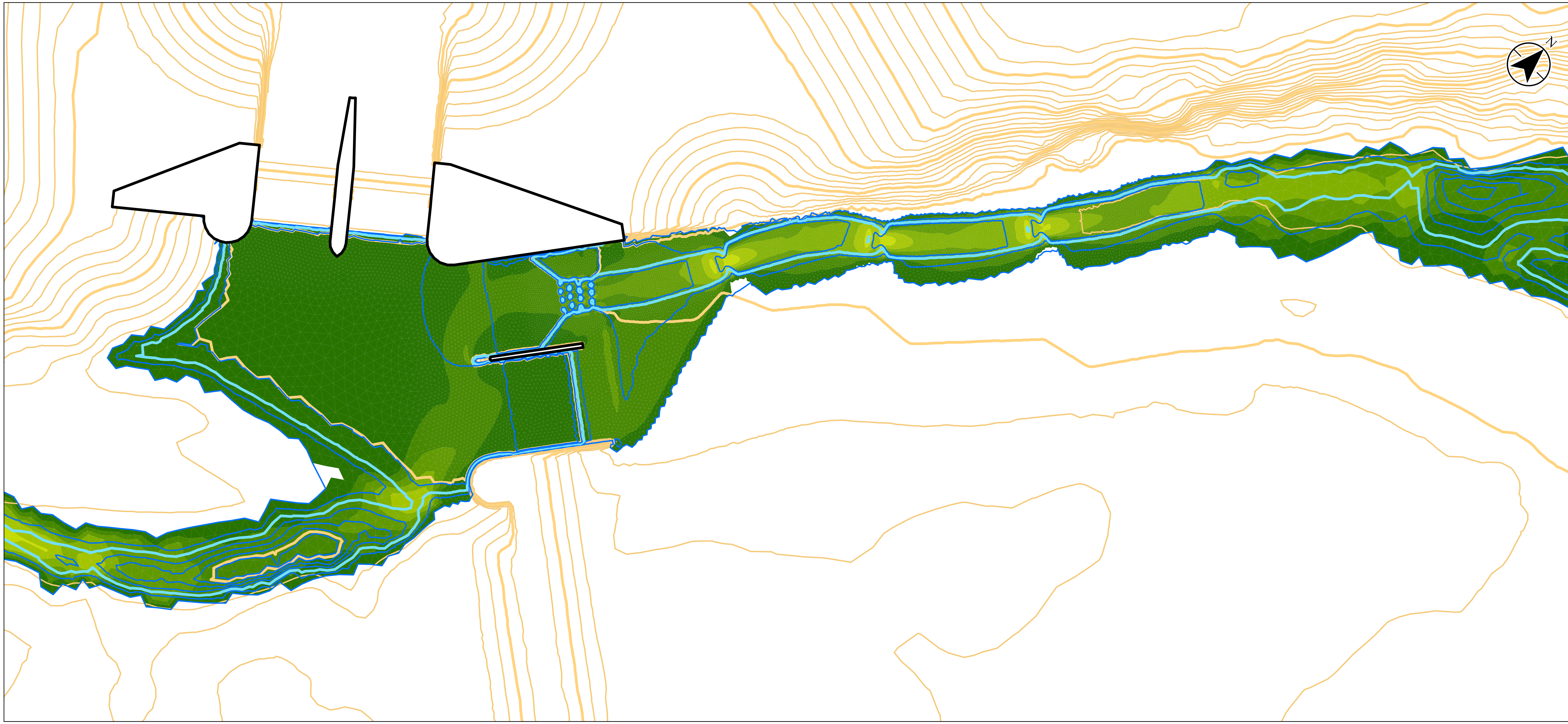

Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

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Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.

1 of 2

Title

Fish Passage Simulation
Preliminary Design, 2.38 cms

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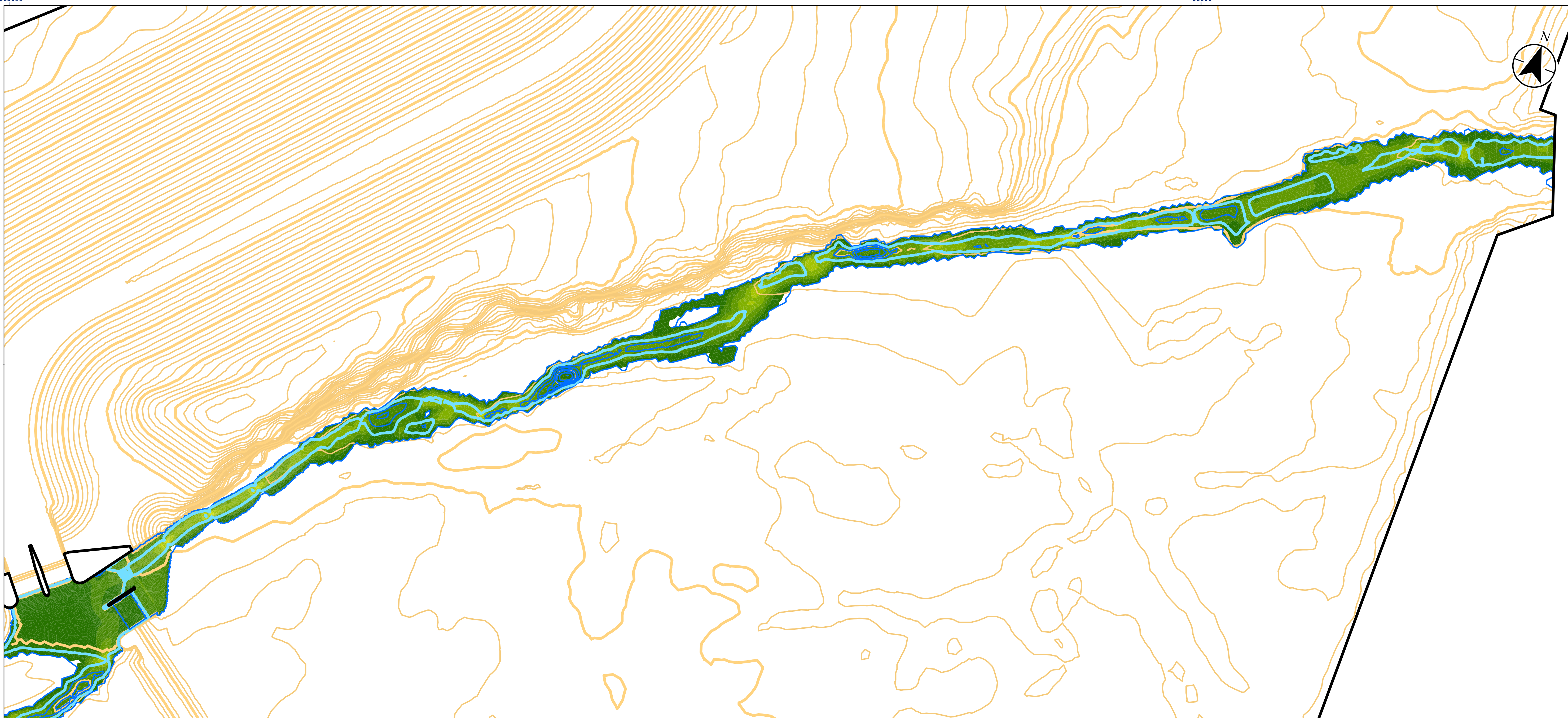

Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

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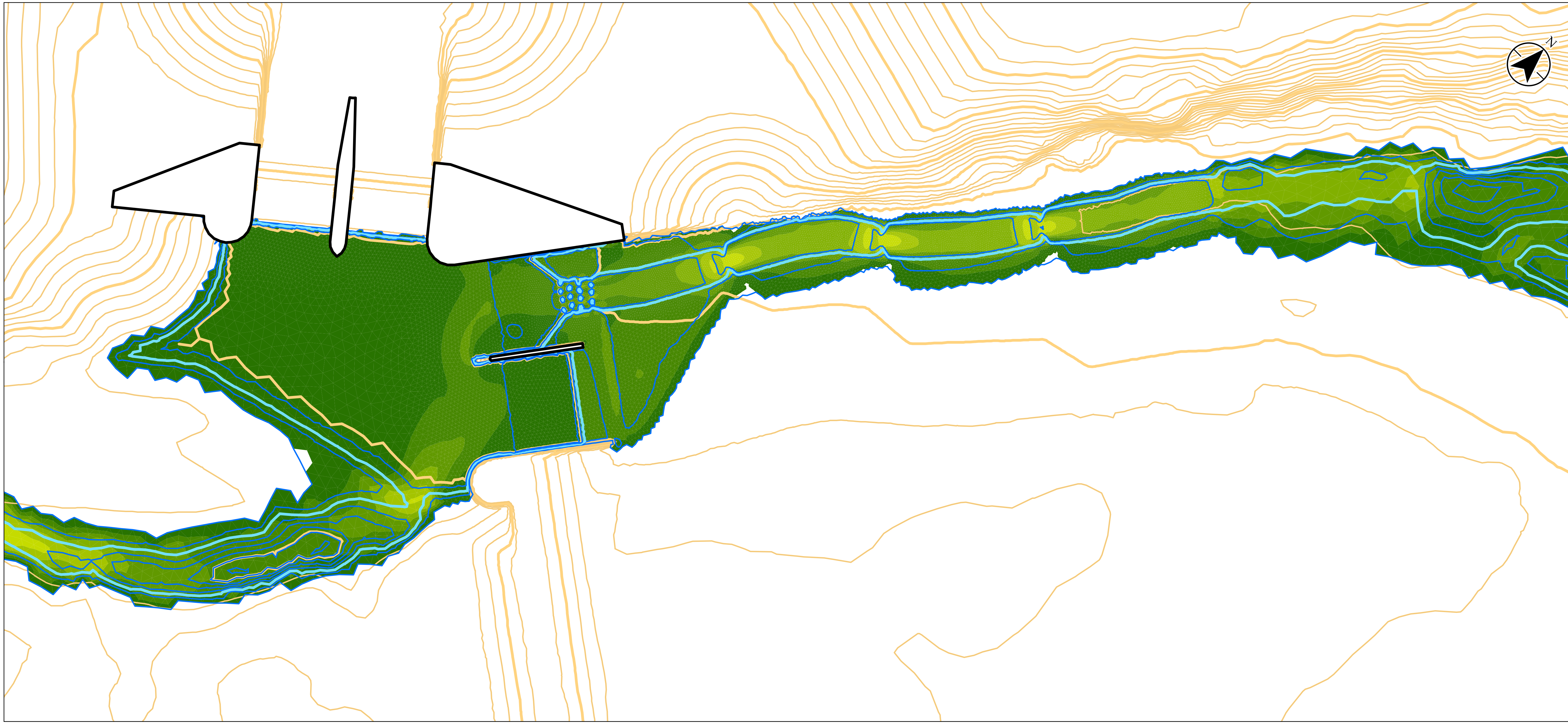
Client/Project
Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
2 of 2

Title
Fish Passage Simulation
Preliminary Design, 2.38 cms

Notes
1. Coordinate System: NAD 1983 3TM 114

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_format\PrelimDesign_2p38cms.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 20 40 Meters

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Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
1 of 2

Title
Fish Passage Simulation
Preliminary Design, 2.8 cms

Notes
1. Coordinate System: NAD 1983 3TM 114

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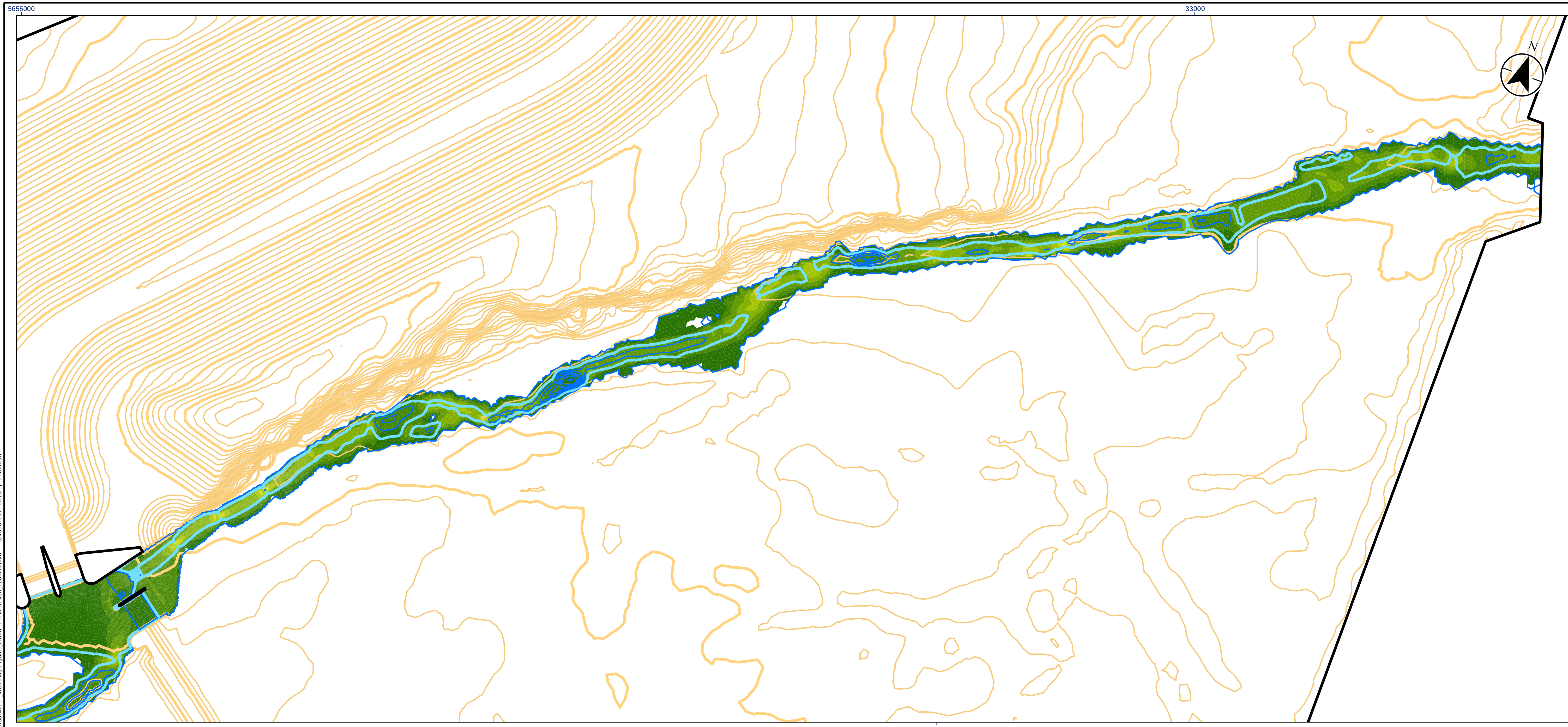

Legend

Model Domain Lines

Depth Contours (0.2 m interval)

- All depth contours
- 0.2 m depth contour

Bed Contours (1 m interval)

- Intermediate
- Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

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Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.

2 of 2

Title

Fish Passage Simulation
Preliminary Design, 2.8 cms

Notes

1. Coordinate System: NAD 1983 3TM 114

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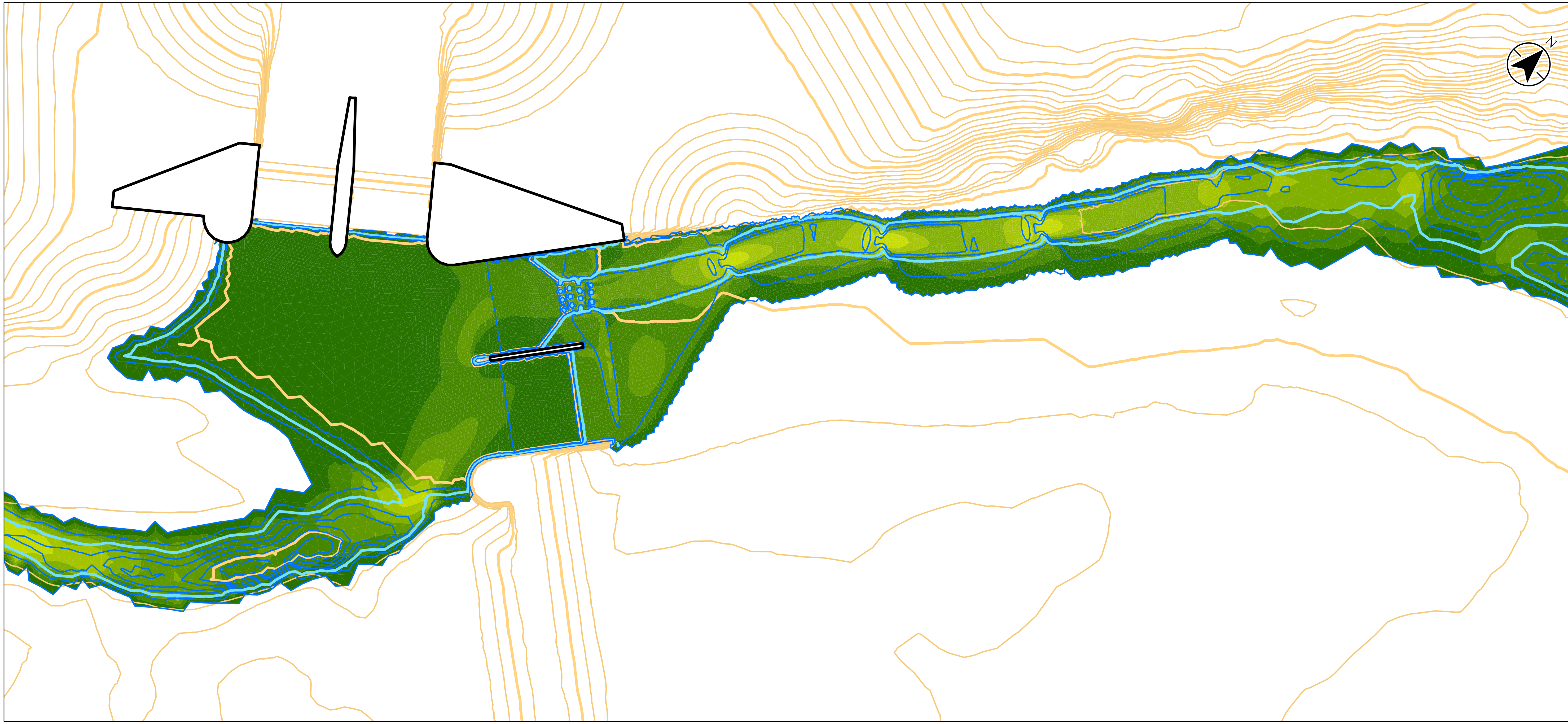

Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

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Springbank Off-Stream Reservoir (SR1)

Figure No.
1 of 2

Title
Fish Passage Simulation
Preliminary Design, 3.47 cms

Notes
1. Coordinate System: NAD 1983 3TM 114

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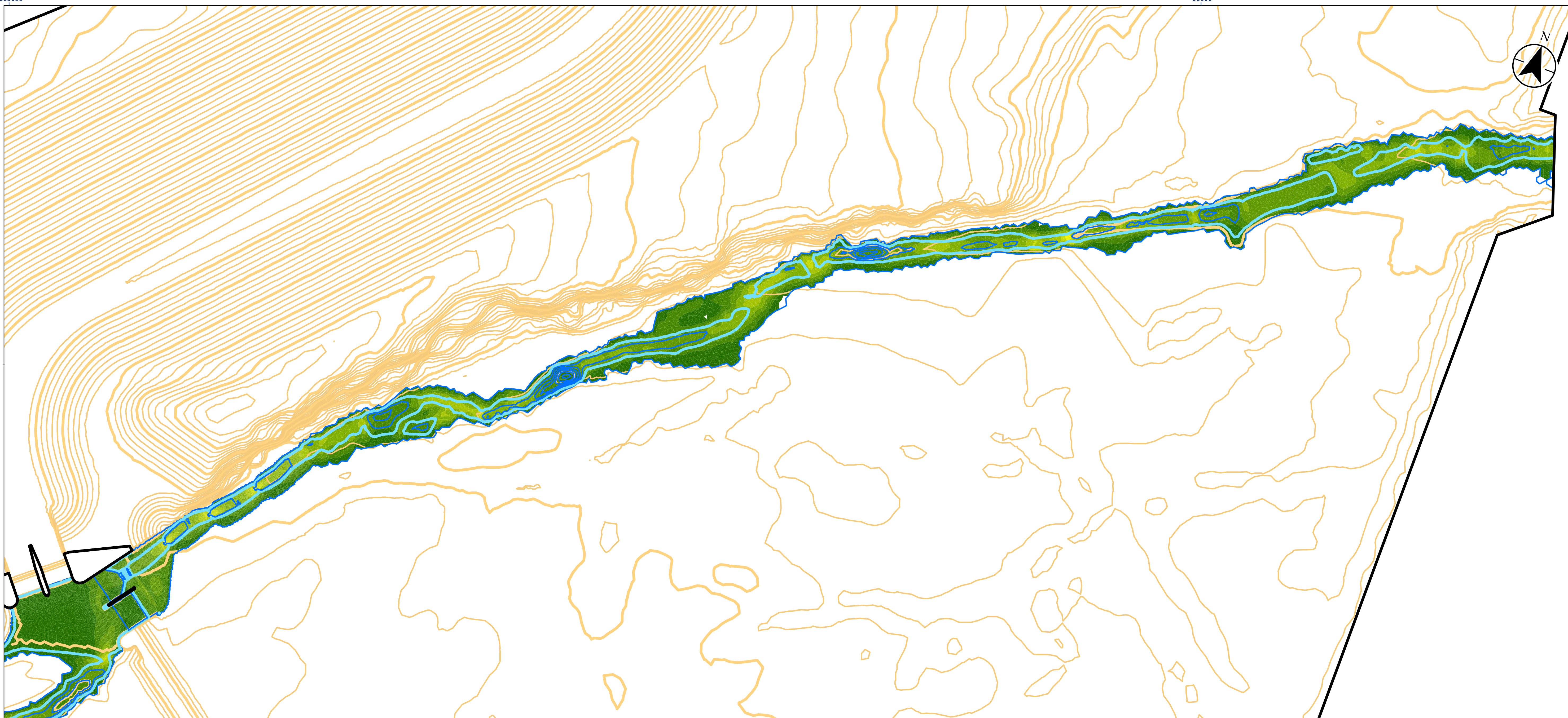

Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75

3.25 - 3.5

3 - 3.25

2.75 - 3

2.5 - 2.75

2.25 - 2.5

2 - 2.25

1.75 - 2

1.5 - 1.75

1.25 - 1.5

1 - 1.25

0.75 - 1

0.5 - 0.75

0.25 - 0.5

0 - 0.25

0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

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Independent Review by ABC on 2017-02-xx

Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.

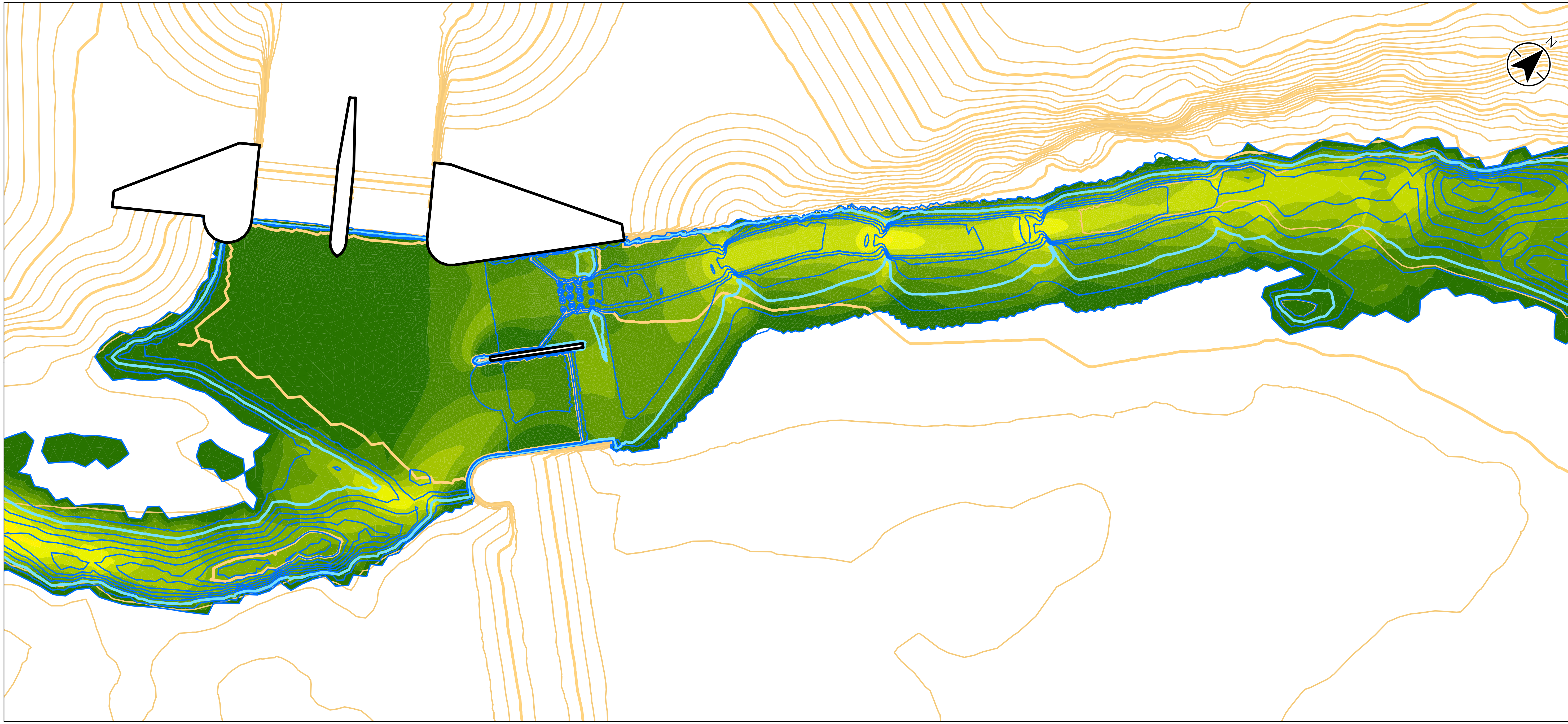
2 of 2

Title

Fish Passage Simulation
Preliminary Design, 3.47 cms

Notes

1. Coordinate System: NAD 1983 3TM 114



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75

3.25 - 3.5

3 - 3.25

2.75 - 3

2.5 - 2.75

2.25 - 2.5

2 - 2.25

1.75 - 2

1.5 - 1.75

1.25 - 1.5

1 - 1.25

0.75 - 1

0.5 - 0.75

0.25 - 0.5

0 - 0.25

0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

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Technical Review by ABC on 2017-02-xx
Independent Review by ABC on 2017-02-xx

Client/Project
Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
1 of 2

Title
Fish Passage Simulation
Preliminary Design, 9.81 cms

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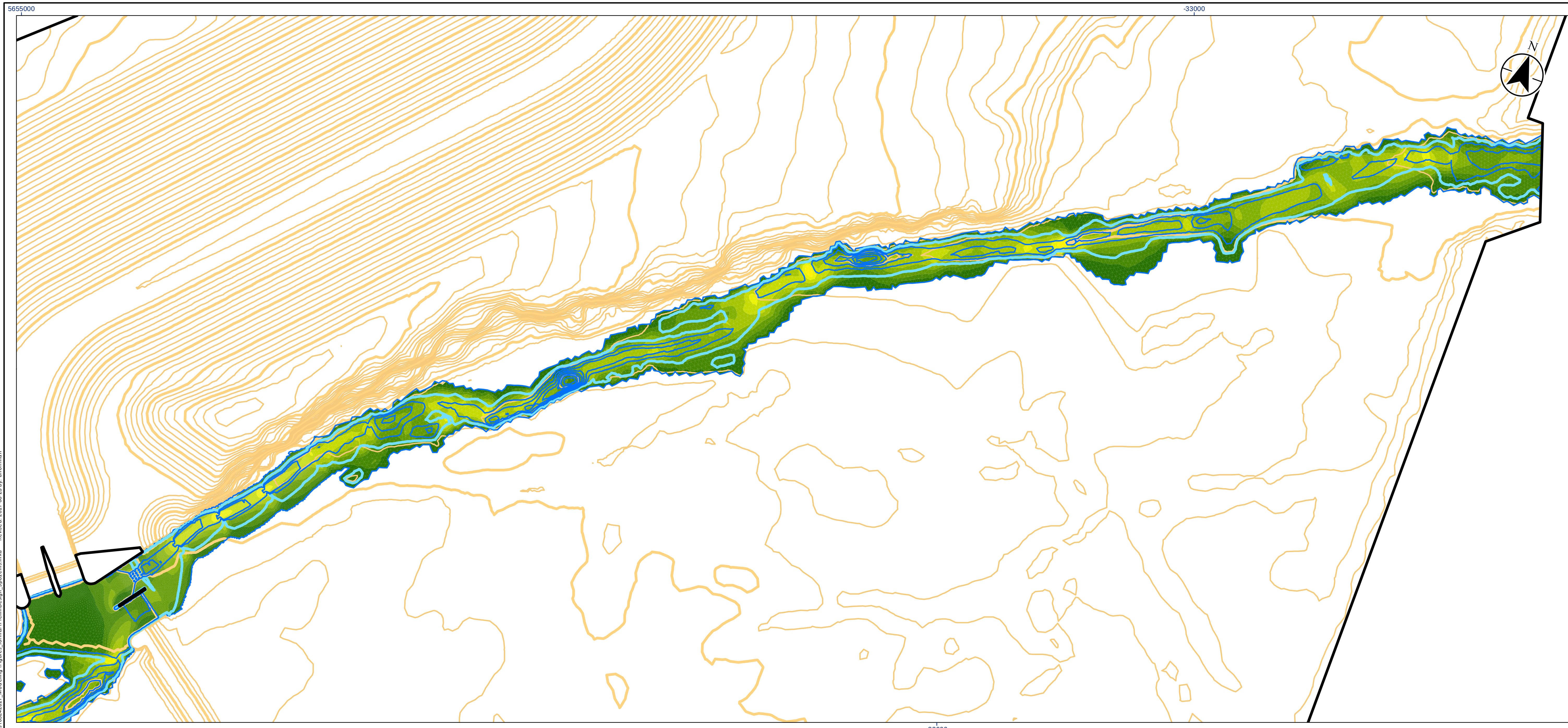

Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

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Alberta

Prepared by DEH on 2017-08-23
Technical Review by ABC on 2017-02-xx
Independent Review by ABC on 2017-02-xx

Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

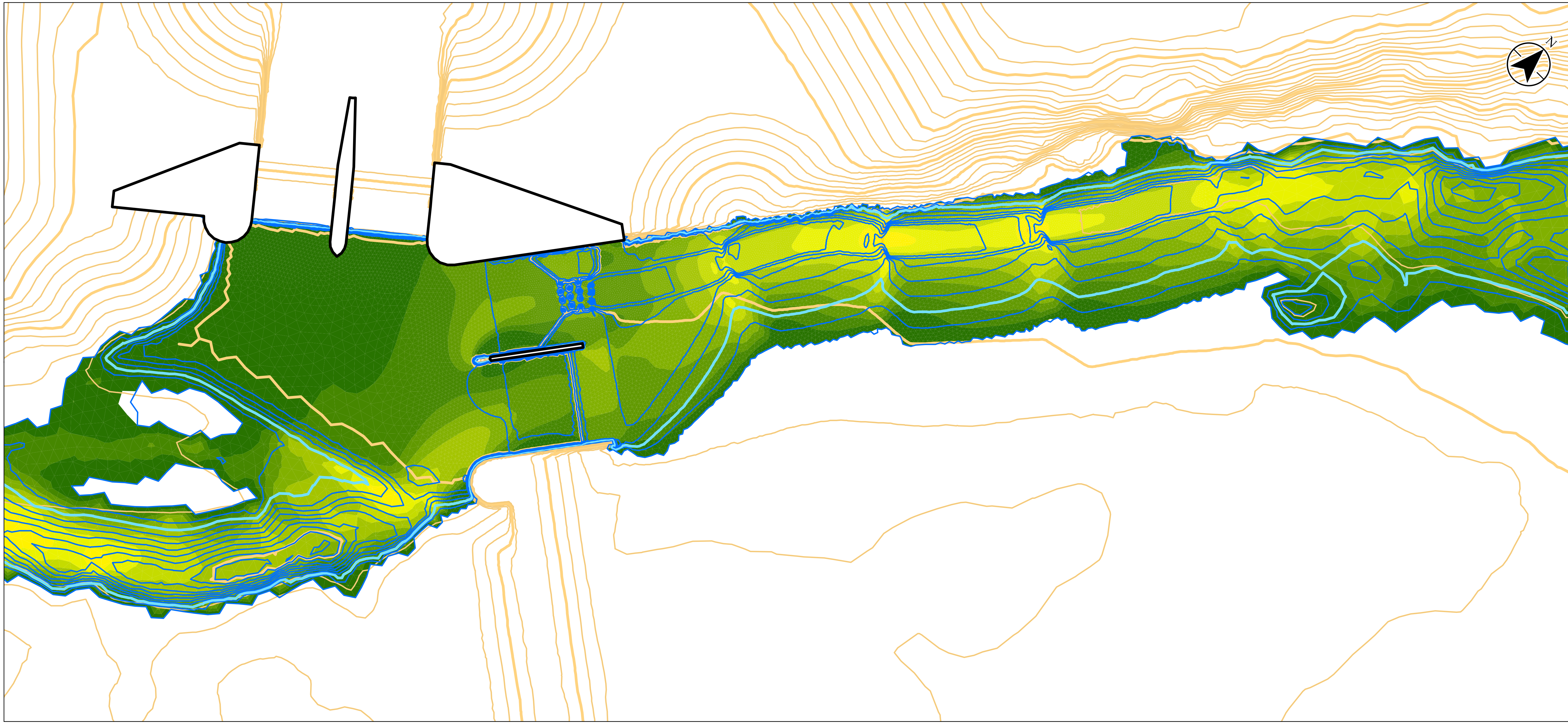
Figure No.

2 of 2

Title

Fish Passage Simulation
Preliminary Design, 9.81 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_9p81cms.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

Project Location 110773396

City of Calgary
Alberta

Prepared by DEH on 2017-08-23
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Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

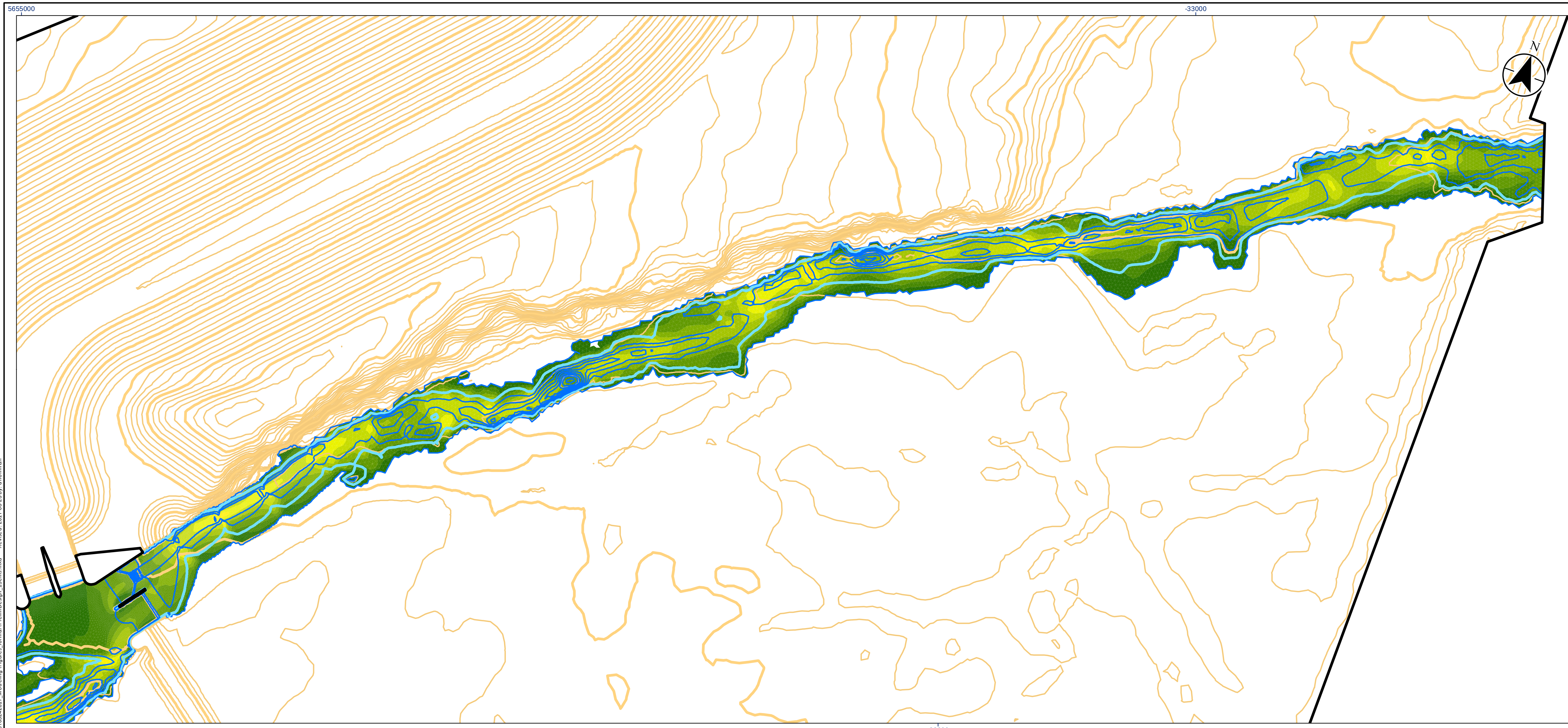
Figure No.

1 of 2

Title

Fish Passage Simulation
Preliminary Design, 15 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_15cms_Zoom.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

Notes

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Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

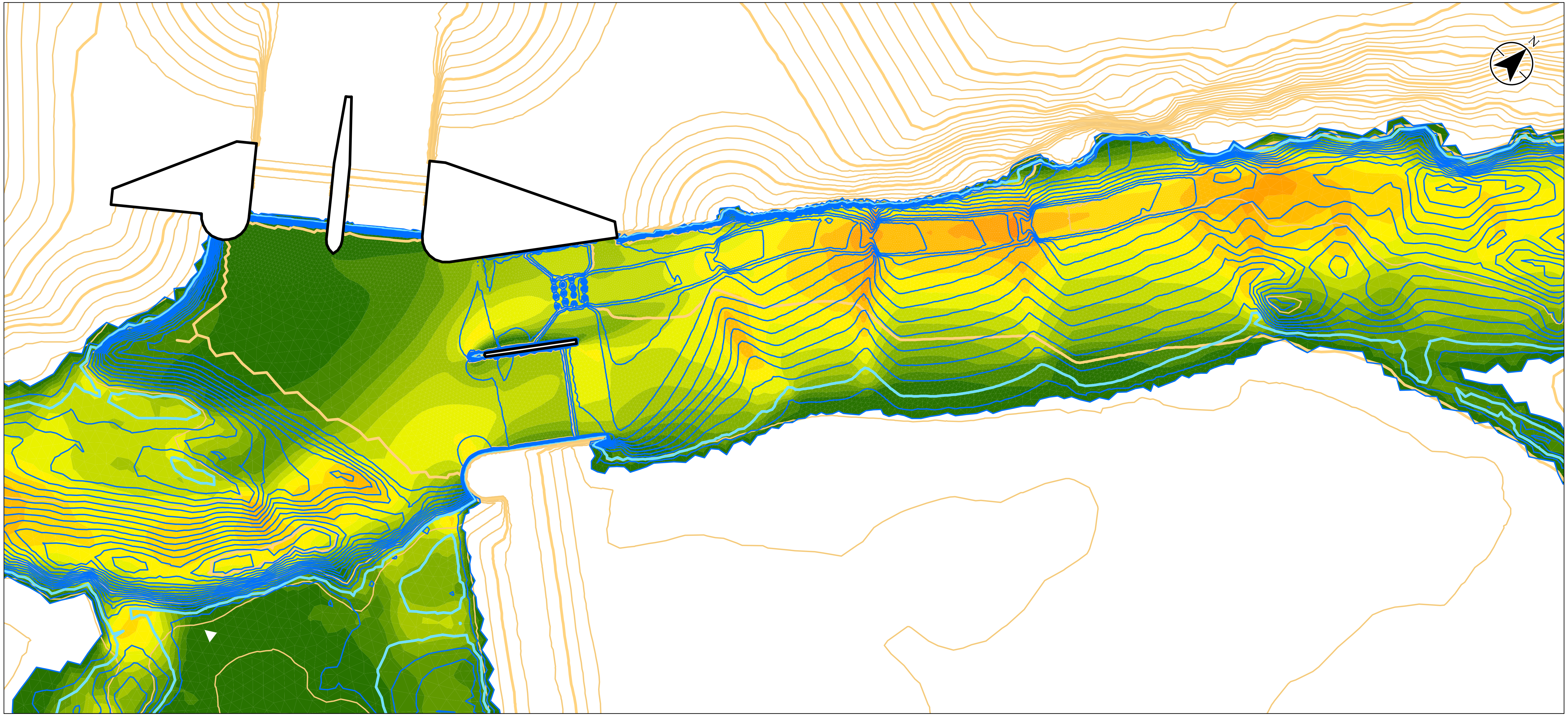
Figure No.

2 of 2

Title

Fish Passage Simulation
Preliminary Design, 15 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_15cms.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

- All depth contours
- 0.2 m depth contour

Bed Contours (1 m interval)

- Intermediate
- Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 20 40 Meters

1:1,000 (At original document size of 11x17)

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Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

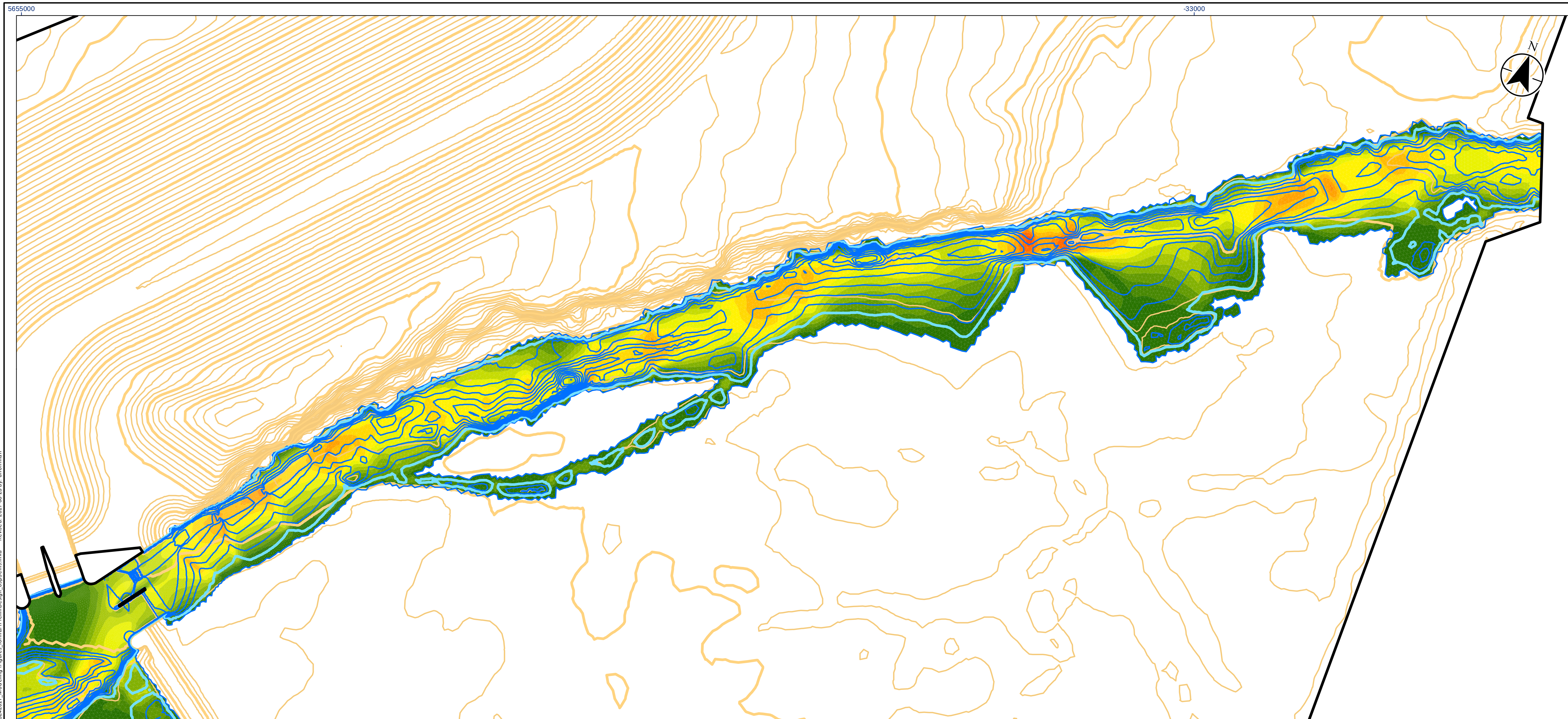
Figure No.

1 of 2

Title

Fish Passage Simulation
Preliminary Design, 69.5 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_69p5cms_Zoom.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.2 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

3.5 - 3.75
3.25 - 3.5
3 - 3.25
2.75 - 3
2.5 - 2.75
2.25 - 2.5
2 - 2.25
1.75 - 2
1.5 - 1.75
1.25 - 1.5
1 - 1.25
0.75 - 1
0.5 - 0.75
0.25 - 0.5
0 - 0.25
0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 3TM 114

Project Location
City of Calgary
Alberta

110773396
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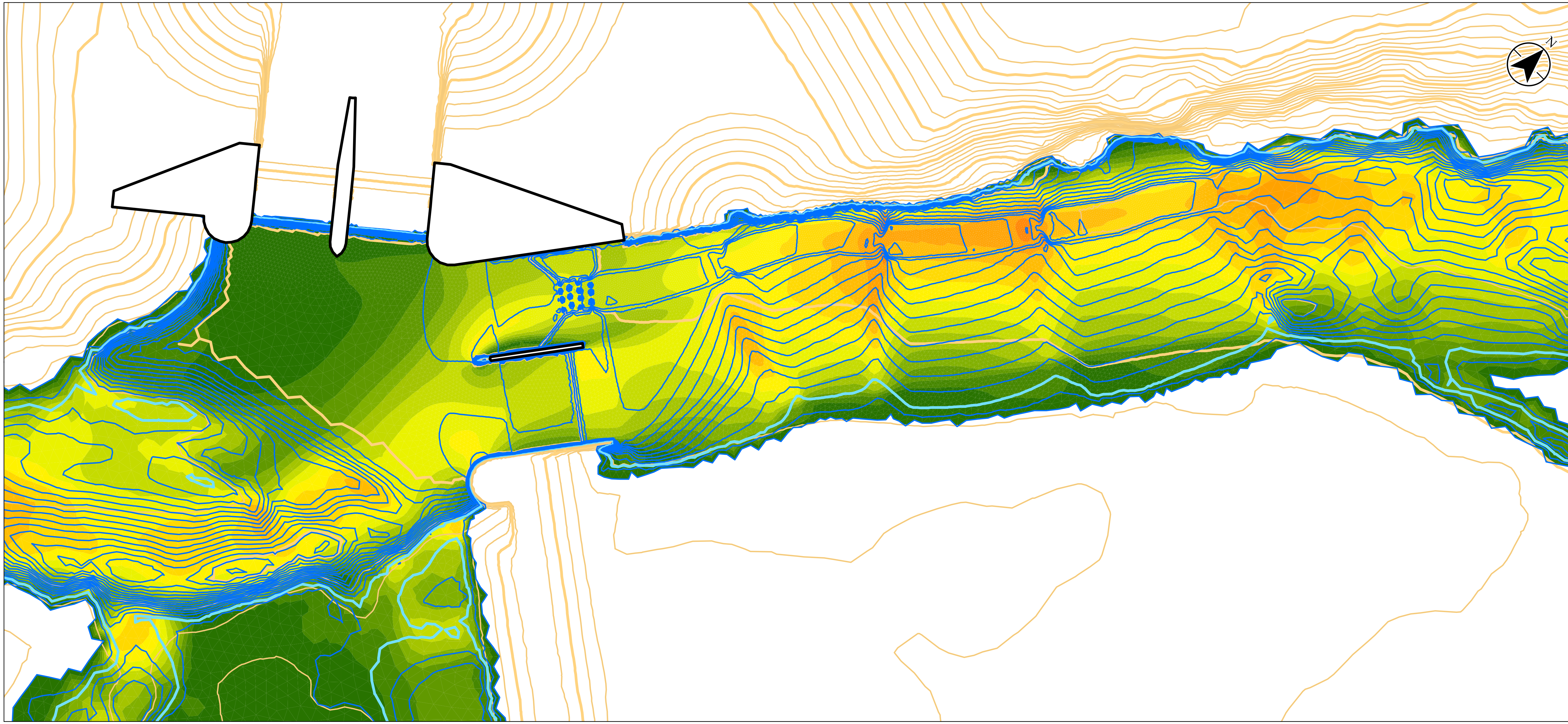
Client/Project
Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
2 of 2

Title
Fish Passage Simulation
Preliminary Design, 69.5 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_format\PrelimDesign_69p5cms.mxd Revised: 2017-08-23 By: dhoffman



Legend

Model Domain Lines

Depth Contours (0.1 m interval)

All depth contours

0.2 m depth contour

Bed Contours (1 m interval)

Intermediate

Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 20 40 Meters

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Client/Project

Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

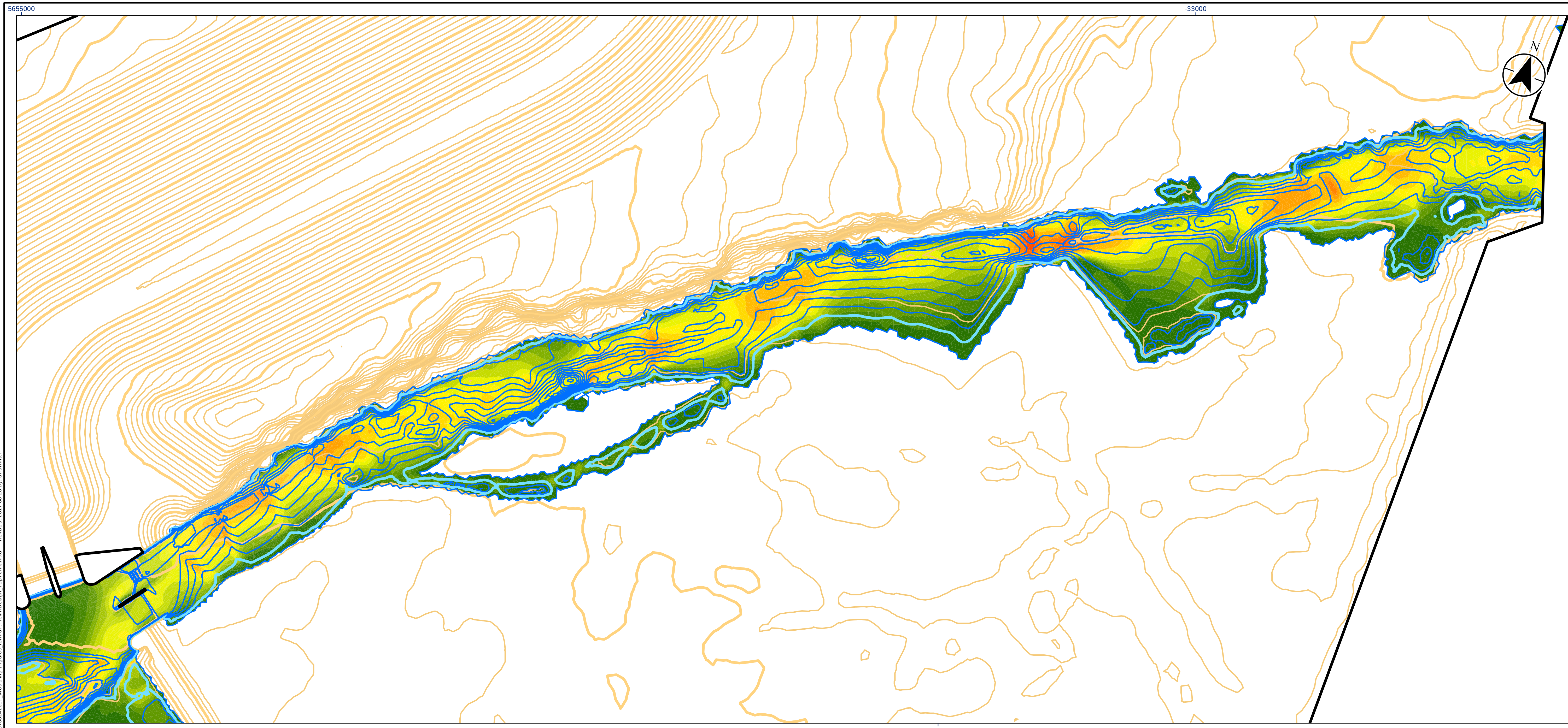
Figure No.

1 of 2

Title

Fish Passage Simulation
Preliminary Design, 75.7 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_75p7cms_Zoom.mxd Revised: 2017-08-23 By: dhoffman



Legend

- Model Domain Lines

Depth Contours (0.2 m interval)

- All depth contours
- 0.2 m depth contour

Bed Contours (1 m interval)

- Intermediate
- Index

Velocity (m/s)

- 3.5 - 3.75
- 3.25 - 3.5
- 3 - 3.25
- 2.75 - 3
- 2.5 - 2.75
- 2.25 - 2.5
- 2 - 2.25
- 1.75 - 2
- 1.5 - 1.75
- 1.25 - 1.5
- 1 - 1.25
- 0.75 - 1
- 0.5 - 0.75
- 0.25 - 0.5
- 0 - 0.25
- 0

0 60 120 Meters

1:3,000 (At original document size of 11x17)

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Client/Project
Alberta Transportation
Springbank Off-Stream Reservoir (SR1)

Figure No.
2 of 2

Title
Fish Passage Simulation
Preliminary Design, 75.7 cms

U:\110773396\component_work\dams_diversion\hydrotechnical\analysis\Local_Hydraulics_Analysis\05242017_Modeling\Figures_formal\PrelimDesign_75p7cms.mxd Revised: 2017-08-23 By: dhoffman