Analysis of Fisheries and Hydrologic Information of Apex River

Analysis to Support Request to DFO for Water Withdrawal to Exceed 10% Flow

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Executive Summary

The City of Iqaluit (the City) currently obtains its potable water from Lake Geraldine, located approximately 1 kilometer (km) north of the City center. In September 2019, the City received an amendment (Amendment #4) to its type A water license 3AM-IQA1625 to permit supplementation from the Apex River to Lake Geraldine on an annual basis to fill the reservoir prior to freeze-up.

The type A water license 3AM-IQA1625 permits taking of up to 10% of the instantaneous flows in Apex River during periods when flows are above 30% Mean Annual Discharge (MAD), for Lake Geraldine supplementation.

Multiple times over the past five years the City has found themselves in a public health emergency situation due shortages of potable water. These urgent situations have caused the City to amend their water licence on an emergency basis and apply for a temporary Fisheries Act Authorization (FAA) from DFO in the past.

In order to potentially avoid future shortages of potable water, the City wishes to increase the permitted taking from the Apex River. In order to do so, approval from DFO must be granted in the form of a Request for Review.

The objective of the following report is to evaluate the effects of increased water withdrawal on fish and fish habitat in the Apex River. Hydraulic modelling was used to examine the change in the amount of physical habitat based on selected parameters as a function of discharge within a representative sub-reach. Three variables and their relationship to flow were assessed: average depth, average velocity and wetted area. The results from the hydraulic modelling were then applied to fish and fish habitat by linking the results to HSI ratings.

At a 20% water withdrawal rate average depth, average velocity and average wetted area within the modelled sub-reach decreased by 10% or less. HSI ranking was found to not be particularly sensitive to a 10% water withdrawal. The proposed pumping protocol is to withdraw flow from the Apex River when flows are greater than 0.143 m^3/s (30% MAD), when flows are between 0.143 and 0.156 m^3/s pumping rates can be up to 10% of flow and when flows are great that 0.156 a 20% withdrawal rate is proposed. The proposed pumping protocol is based off the hydraulic analysis and is verified by the HSI ratings at three Arctic char life stages (spawning, rearing and foraging). It is unlikely that the proposed pumping protocol would result in negative impacts to fish and fish habitat in the Apex River.

The findings of this assessment will provide the basis for an application to the DFO for increased water withdrawal rates in future years of the annual Apex River supplementation program.

Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviations

2D .... Two-dimensional

DFO .... Fisheries and Oceans Canada

DGPS .... Differential Global Positioning System

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HADD .... Harmful Alteration, Disruption, or Destruction

HSM .... Habitat Simulation Modelling

HEC-RAS ....

HSI .... Habitat Suitability Index

km .... Kilometer

LiDAR .... Light Detection and Ranging

LPS .... Litres Per Second

MAD .... Mean Annual Discharge

R^2 .... Coefficient of Determination

RTK .... Real-Time Kinematic

TIF .... tagged image format

WSC .... Water Survey of Canada

UAV .... un-manned aerial vehicle

1 Introduction

The City of Iqaluit (the City) currently obtains its potable water from Lake Geraldine, located approximately 1 kilometer (km) north of the City center (Figure 1 1). In September 2019, the City received an amendment (Amendment #4) to its type A water license 3AM-IQA1625 to permit supplementation from the Apex River to Lake Geraldine on an annual basis to fill the reservoir prior to freeze-up.

The type A water license 3AM-IQA1625 permits the City to take up to 10% of the instantaneous flows in Apex River during periods where flows are above 30% Mean Annual Discharge (MAD). These criteria are consistent with Fisheries and Oceans Canada's (DFO) "Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada" (DFO 2013).

During the 2022 annual supplementation program, the City received emergency authorization from DFO under 22-HCAA-02043 to exceed the 10% of instantaneous flow withdrawal limit. The Emergency Authorization triggered a requirement to monitor fish and fish habitat before, during, and after the program to evaluate the effects of the increased water withdrawal rates on fish and fish habitat in the Apex River. DFO recommended that the City complete fish habitat and hydraulic assessments to evaluate the potential risks to fish and fish habitat from increased water withdrawals and to determine how much water could be withdrawn from the Apex River without causing harmful alteration, disruption, or destruction (HADD) of fish habitat.

During the 2022 pumping program, Nunami Stantec collected baseline fish habitat data to update data collected in 2016 (Nunami Stantec 2016) and manual flow measurements in the Apex River. Nunami Stantec also completed a topographic survey and substrate survey in a representative sub-reach of the Apex River immediately downstream of the pumping location where potential effects of increased water withdrawals on fish and fish habitat would most likely occur (Figure 1 1). These data, summarized in the 2022 Project Summary Report (Stantec 2023), provide the information used to evaluate the potential effects of increased water withdrawal rates on fish and fish habitat in the Apex River.

The objective of this report is to evaluate the potential effects of increasing water withdrawal above 10% of instantaneous flow on fish and fish habitat in the Apex River. A resident population of Arctic char (Salvelinus alpinus) is known to be present in the Apex River downstream of the proposed water withdrawal location (Nunami Stantec 2016). The findings of this assessment will provide the basis for an application to the Nunavut Water Board and DFO for increased water withdrawal rates in future years of the annual Apex River supplementation program provided that increased water withdrawals do not cause a HADD of fish habitat.

Stantec

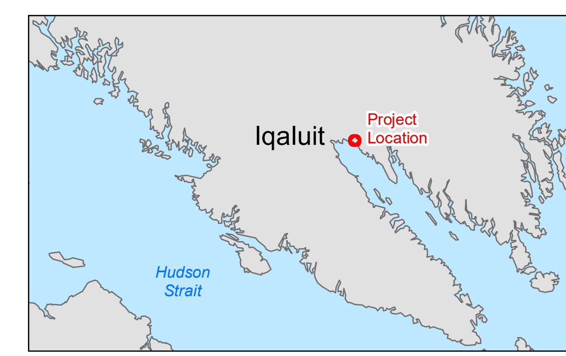
- WSC or SNP Station
- Point of Interest
- Discharge Point
- Pipeline
- Pumping Site

N

0 160 320 metres

(At original document size of 11x17)
1:8,500

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 19N
2. Background: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Project Location
Iqaluit
Nunavut

Client/Project 14490306

Iqaluit Water Supply

Figure No.
1-1

Title
Iqaluit 2022 Apex Pumping Project
Site Overview

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2 Methods

2.1 Representative Sub-Reach Hydraulics

2.1.1 Topographic Data

To facilitate the hydraulic analysis, Nunami Stantec completed a topographic survey of 200 m of mainstem channel within an approximately 750 m long sub-reach of the Apex River extending from downstream of the pumping location to upstream of the “Road to Nowhere” bridge in September 2022. The survey was completed using a Real-Time Kinematic (RTK) Differential GPS (DGPS). RTK DGPS units have a vertical precision of approximately +/- 0.03 m and are appropriate for surveys being used in hydraulic models. The survey focused on the area within the bankfull channel, as the vast majority (if not all) of flows during the pumping program were within the channel banks. Channel bed substrates were characterized using the Wolman (1954) pebble count method and photographs within quadrats.

Field data were supplemented with Light Detection and Ranging (LiDAR) data at a 30 cm resolution from Arctic UAV Inc. (August 2019).

2.1.2 Hydrology

Figure 1-1 shows the local Water Survey of Canada (WSC) gauge locations near the representative sub-reach in the Apex River. WSC ‘Apex River at Apex station 10UH002’ has an available period of record from 1973 to 2021 (38-year record, no data recorded from 1996 to 2005). WSC ‘Apex River 1 km Above Bridge to Nowhere 10UH015’ has an available period of record from 2021 to 2022.

The period of record for the available data set at 10UH015 is not sufficient to use for flow analysis. Therefore, a comparison of concurrent flow records from 2021 between WSC Station 10UH002 (Apex River at Apex) and WSC Station 10UH015 (Apex River 1 km Above Bridge to Nowhere) was conducted to obtain seasonal scaling factors to convert WSC Station 10UH002 flows to WSC Station 10UH015 flows. The seasonal scaling factors were 0.513 for August and September and 0.746 for the rest of the year.

After applying the seasonal scaling factors, a synthetic data set for Station 10UH015 was produced. This synthetic data set was used to calculate the 20% MAD, 30% MAD, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th percentile and maximum flows at WSC Station 10UH015. Calculated flows are provided in **Table 2-1**.

Table 2-1 Synthetic Flows used in Modelling Exercise

Flow (m^3/s)	Rationale
0.0864	20% MAD
0.130	30% MAD
0.145	20th Percentile flow
0.251	30th Percentile flow

Flow (m^3/s)	Rationale
0.362	40^{th} Percentile flow
0.493	50^{th} Percentile flow
0.652	60^{th} Percentile flow
0.898	70^{th} Percentile flow
1.352	80^{th} Percentile flow
2.544	90^{th} Percentile flow
11.638	Synthetic Maximum flow (June 8, 1974)

2.1.3 Hydraulic Modeling

2.1.3.1 Model Overview

A HEC-RAS 2D model (Version 6.3) of the Apex River main channel was developed for a 200 m long sub-reach located directly downstream of the pumping location. An unsteady flow simulation was run with Diffusion Wave equations to predict the average water velocity, average water depth, and average wetted area within the sub-reach at the different flow rates shown in Table 2 1.

A constant flow hydrograph was used for the upstream boundary condition, and fixed water surface elevation was used for the downstream boundary condition using data from the topographic survey. Local slopes of the energy grade lines at the upstream and downstream ends were estimated as the bed slope based on the topographic survey data.

The average depth, velocity, and wetted area throughout the entire wetted area were analyzed instead of individual cross sections to better model the entire habitat in which the fish may be living. The average velocity, depth and wetted areas were calculated by taking the parameter of interest measured within each cell within the wetted extents and averaging the value across the total number of cells within the wetted area.

2.1.3.2 Terrain Model

A terrain model was used to represent the ground surface in locations that affect the movement of water through the floodplain. The terrain model was created for the channel bed and the dry-land adjacent to the river bank by combining the RTK survey and LiDAR data to generate a Tagged Image Format (TIF) file (**Error! Reference source not found.**).

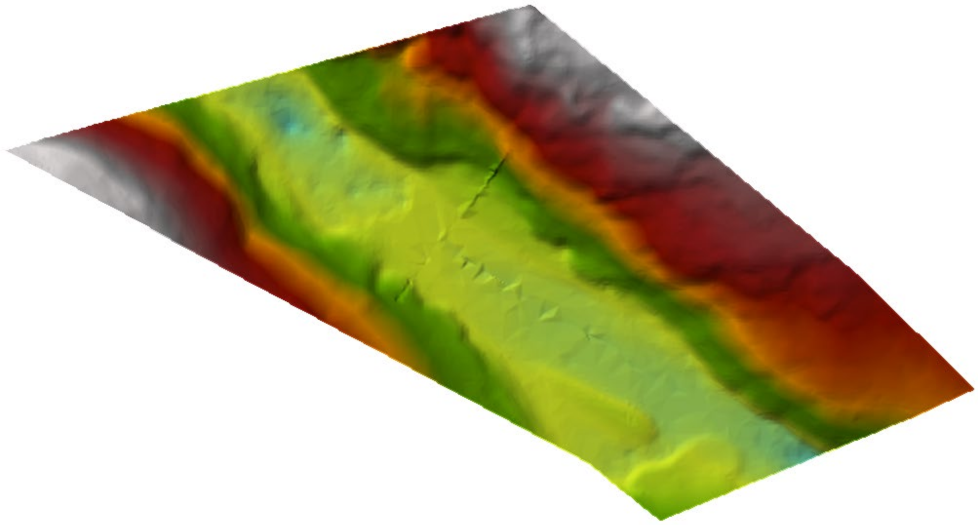

Figure 2-1 TIFF generated by combining survey and LiDAR

2.1.3.3 Model Domain and Computational Mesh

The model domain was delineated by the 2D flow area. The 2D flow area defined the boundary for which 2D computations occurred. A computational mesh was created to control the flow of water through the 2D flow area (Figure 2-2). Given, the relatively uniform and flat cross section of the sub-reach, a relatively large mesh size was used (2 m) in the model.

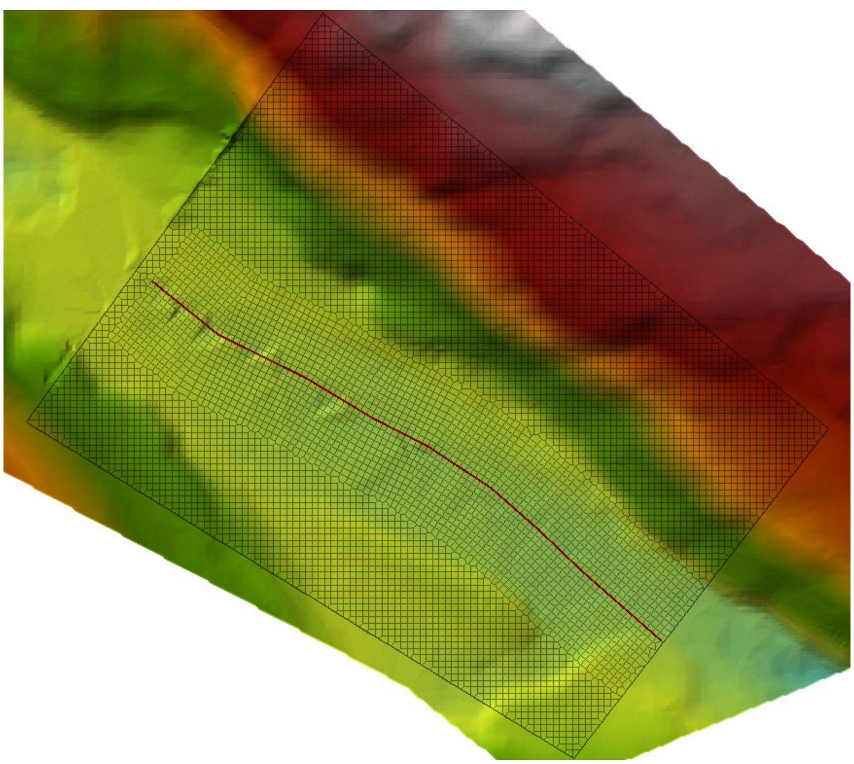

Figure 2-2 Mesh used in HEC-RAS Model

2.1.3.4 Upstream and Downstream Boundary Conditions

External boundary conditions were used to bring flow into a 2D flow area (upstream boundary condition) and to take flow out of a 2D flow area (downstream boundary condition). To model a range of flows within the synthetic hydrograph (Figure 2-3), a flow hydrograph was used as the upstream boundary condition. The duration of each flow shown in Figure 2-3 was set so that the model could reach steady state prior to the next flow step.

The flow hydrograph boundary condition required an input flow hydrograph and an energy slope. The energy slope was used to compute a normal depth from the given flow rate and the underlying terrain data along the boundary condition line for each computational time step. A flow distribution cross section was then computed and was used to distribute the flow to the cells along the boundary condition line that were wet.

For the downstream end of the model, a normal depth boundary condition was used. The normal depth boundary condition was composed of a friction slope that was based on the land slope in the vicinity of the 2D flow area boundary condition line. The friction slope was used within Manning's equation to compute a normal depth water surface elevation for each given flow, based on the terrain data underneath the 2D Boundary Condition Line.

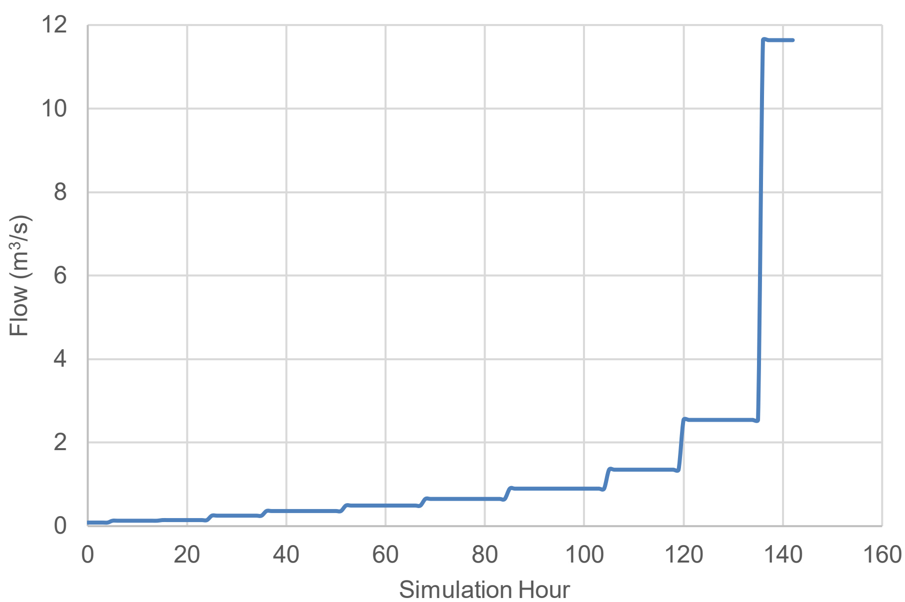

Figure 2-3 Modelled Flow Hydrograph for station WSC 10UH015

2.1.3.5 Model Calibration

Model calibration was completed by adjusting channel roughness until the model reproduced surveyed water surface elevations and edge of water lines within approximately a centimeter to what was observed in the field in September 2022. The discharge during the September 2022 field visit was estimated based on reported flow measurements from WSC station 10UH015 at the time survey was conducted.

A channel roughness coefficient of 0.04 within the bankfull channel was determined to yield the best representation of the water surface elevation observed during the September 2022 survey. A channel roughness coefficient of 0.04 fits within expected values found in literature for streams with similar gradient, substrate sizes and substate embeddedness and has been adopted for the model calibration. It was assumed there was negligible roughness variation with varying flow depth because the range of synthetic flows resulted in only an approximately 20 cm change in average water depth from the lowest modelled flow to the highest modelled flow.

2.1.3.6 Model Simulations

Water depth, water velocity, and wetted area within the representative sub-reach were predicted for each of the 11 discrete flows within the synthetic hydrograph for WSC station 10UH015 (Figure 2-3). These flows were selected because they represent the range of flows that may occur within the representative sub-reach. Flows higher than the range modelled were not anticipated based on the synthetic period of record. Flows lower than 20% MAD were not modelled because it was assumed that water withdrawals would not occur below 30% MAD.

2.2 Hydraulic Habitat Relationships

Relationships between modelled flow (Table **2-1**) and predicted average water velocity, average water depth and wetted areas, were determined to illustrate the sensitivity of these hydraulic parameters to changes in flow. A power trendline was fitted to the plotted values such that there was a high coefficient of determination (R^2) for each plotted trendline.

Equations for each trendline were used to determine the change in average water velocity, average water depth and wetted area depending on whether the flow fell within the high flow range (>1.352 m^3/s) or the low flow range (<1.352 m^3/s). These relationships were then applied to different water withdrawal scenarios to calculate the resulting average water velocity, average water depth, and wetted area in the representative sub-reach from the hydraulic model.

The predicted changes in hydraulic conditions in the Apex River were used to determine the proposed water withdrawal protocol. For this determination, it was assumed that < 10% change in hydraulic parameters (average water velocity and average water depth) would have a negligible effect on the resident Arctic char population in the Apex River. Therefore, the 10% threshold was selected as the criterion for determining the water withdrawal protocol in the Apex River at various flows.

Changes to hydraulic parameters (velocity, depth, and wetted area) were used for the basis of the proposed water withdrawal protocol (instead of potential effects of the changes in hydraulic habitat on the resident Arctic char population in the Apex River) because a habitat suitability model for resident Arctic char was not available. Arctic char in the Apex River downstream of the water withdrawal location represent a dwarf-resident population. Individuals in this population are smaller, and reach sexual maturity at smaller sizes, than anadromous Arctic char that have access to the ocean. The smaller size of resident fish made it unlikely that the water depths and water velocities preferred by larger anadromous fish would be the same as those preferred by the smaller resident Arctic char.

2.3 Effect of Water Withdrawals on Channel Hydraulics

Seven water withdrawal rate scenarios, as a proportion of observed flow, from the Apex River were analyzed: -10%, -15%, -20%, -25%, -30%, -35% and -40% of flow. For illustrative purposes, these seven water withdrawal scenarios were applied to a representative low flow of 0.493 m^3/s (Table 3-3) and a representative high flow of 2.544 m^3/s (Table 3-4). The low flow of 0.493 m^3/s was selected because it represented the 50th percentile flow, is less than 1.352 m^3/s and, therefore, requires use of the low flow power equations. A high flow rate of 2.544 m^3/s was selected because it represents the 90th percentile flow, is greater than 1.352 m^3/s, and, therefore, requires use of the high flow power equations.

2.4 Potential Effects on Fish and Fish Habitat

A Habitat Suitability Index (HSI) model was applied to the hydraulic conditions predicted by the HEC-RAS 2D model to verify that the proposed water withdrawal protocol determined from the hydraulic analysis will not substantially alter the suitability of the Apex River for the various Arctic char life stages (i.e., spawning/egg incubation, juvenile rearing, adult foraging).

The HSI model for Arctic char was adapted from an existing model for Dolly Varden Char (*S. malma*) and Bull Trout (*S. confluentus*) (Stantec 2023). A species specific HSI for Arctic char was not possible due to gaps within the available literature for resident Arctic char.

2.4.1 Habitat Suitability Index

HSIs are tools to objectively assess the range of environmental conditions that fully, marginally, or do not meet the life history requirements of a species (Wakeley 1988). The HSI provides a rank of habitat variables between 0 (does not meet species requirements) and 1 (fully meets the species requirements) for different life stages (e.g., spawning, rearing) of fish (de Kerckhove et al. 2008).

Table 2-2 Habitat Ranking

Assigned Rank	Habitat Suitability Rating	Description
1.00	Excellent	Available habitat is highly suitable. No limitations to suitability are identified within the life stage under consideration
0.75	Above Average	Available habitat has slight limitations for life stage under consideration.
0.50	Average	Available habitat can support the life stage under consideration, but may not be the most desirable habitat
0.25	Below Average	Moderate to severe limitations in habitat suitability are present for the life stage under consideration.
0.00	Unsuitable	Habitat suitability is negligible or nonexistent.

The HSI model included suitability curves for spawning/egg incubation, juvenile rearing, and adult foraging that depicted the change in habitat suitability for each of these life stages with changing water depth and water velocity. The HSI curves for spawning/egg incubation habitat, juvenile rearing habitat, **Error! Reference source not found.**and adult foraging are provided in Appendix A. Overwintering habitat suitability was not included in the analysis because water withdrawals from the Apex River would not occur during the winter months.

2.4.2 Application of Habitat Suitability Scores to Predicted Channel Hydraulics

The HSI curves for each life stage were applied to the water depths and water velocities predicted to occur in the Apex River by the HEC-RAS 2D model for flows resulting from withdrawal of different percentages of flow (i.e., 10% up to the maximum proposed water withdrawal as determined form the hydraulic analysis). This was done to illustrate how habitat suitability for Arctic char spawning/egg incubation, juvenile rearing, and adult foraging changed because of reduced flows from the proposed water withdrawal protocol within the modeled sub-reach.

To begin the analysis, a range in flows from 0.130 m^3/s (i.e., 30% MAD) to 5.08 m^3/s (i.e., >95th percentile flow) at 0.05 m^3/s increments were tabulated. Flow resulting from withdrawal of different percentages of flow (e.g., 10% up to the maximum proposed water withdrawal) were then calculated. Average water velocities and average water depths were then predicted for each of the calculated flows rates using the hydraulic habitat relationships developed in Section 2.2.

HSI scores were then calculated for each water velocity and water depth predicted for each calculated flow using the HSI curves provided in Appendix A. The HSI scores were plotted against flow to illustrate how predicted changes in average water depth and average water velocity resulting from flow changes affected the suitability of the Apex River for Arctic char. Plots were made showing HSI scores only at flows greater than 30% of MAD, the flow below which water withdrawals from the Apex River will be prohibited.

3 Results

3.1 Representative Sub-Reach Hydraulics

A summary of average depth, average velocity, and wetted area in the model sub-reach of the Apex River over the range of modelled flow is provided in **Error! Reference source not found.**. Example model output for depth and velocity at the 50th Percentile flow (0.493 m^3/s) are located within Appendix B.

As expected, average water velocity, average water depth, and average wetted area increased with increasing flow in the Apex River. The average water velocity in the representative sub-reach ranged from 0.10 m/s to 0.65 m/s over the range of modeled flows. Water velocities increased slowly with increasing flow due to the wide cross-sectional area of the sub-reach. Average water depth ranged from 0.06 m to 0.35 m over the range of modelled flows. All modelled flows remained within the bankfull channel, even during the highest flow event modelled.

Table 3-1 Representative Sub-reach Hydraulics Summary at Modelled Flow Rates

Modelled Flow (m^3/s)	Rationale	Average Velocity (m/s)	Average Depth (m)	Wetted Area (m^2)
0.086	20% MAD	0.10	0.06	3228
0.130	30% MAD	0.12	0.06	3665
0.145	20th Percentile	0.13	0.06	3743
0.251	30th Percentile	0.16	0.07	4278
0.362	40th Percentile	0.19	0.08	4690
0.493	50th Percentile	0.21	0.09	5028
0.652	60th Percentile	0.24	0.10	5382
0.898	70th Percentile	0.27	0.11	5834
1.352	80th Percentile	0.31	0.12	6524
2.544	90th Percentile	0.39	0.16	7535
11.638	Maximum Flow	0.65	0.35	9719

3.2 Hydraulic Habitat Relationships

Relationships between modelled flow and predicted average water velocity, average water depth, and wetted area in the Apex River are shown in Figure 3-1. To obtain high coefficients of determination (R^2) for each trendline, two power relationships were used for each relationship: one for low flows (i.e., Q<1.352 m^3/s) and one for high flows (i.e., Q>1.352 m^3/s).

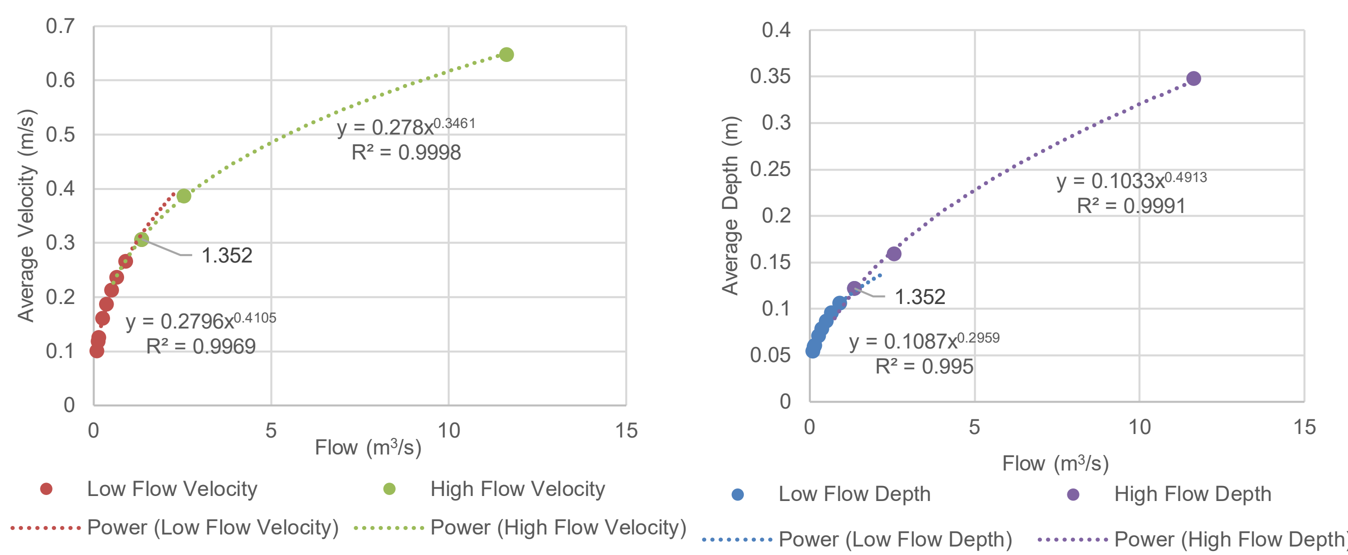

Figure 3-1 Relationships Between Flow and Average Velocity (Left) and Flow and Average Depth (Right) in the Apex River

Average water velocity had a higher exponent ($x^{0.4081}$) than average depth ($x^{0.2948}$) at low flows (Q<1.352 m^3/s), indicating that average water velocity was more sensitive to changes in flow during low flows than average water depth in the modeled sub-reach (Figure 3-1). When flows were greater than 1.352 m^3/s (i.e., 80th percentile flow), average water depth had a higher exponent ($x^{0.4913}$) than average water velocity ($x^{0.3461}$), indicating that average water depth was more sensitive to changes in flow during higher flows than average water velocity in the modeled sub-reach. As demonstrated by the lower exponent of the power relationship in Figure 3-2 (low flow = $x^{0.2507}$, high flow = $x^{0.1819}$), average wetted area was the least sensitive of the three hydraulic habitat variables to changes in flow.

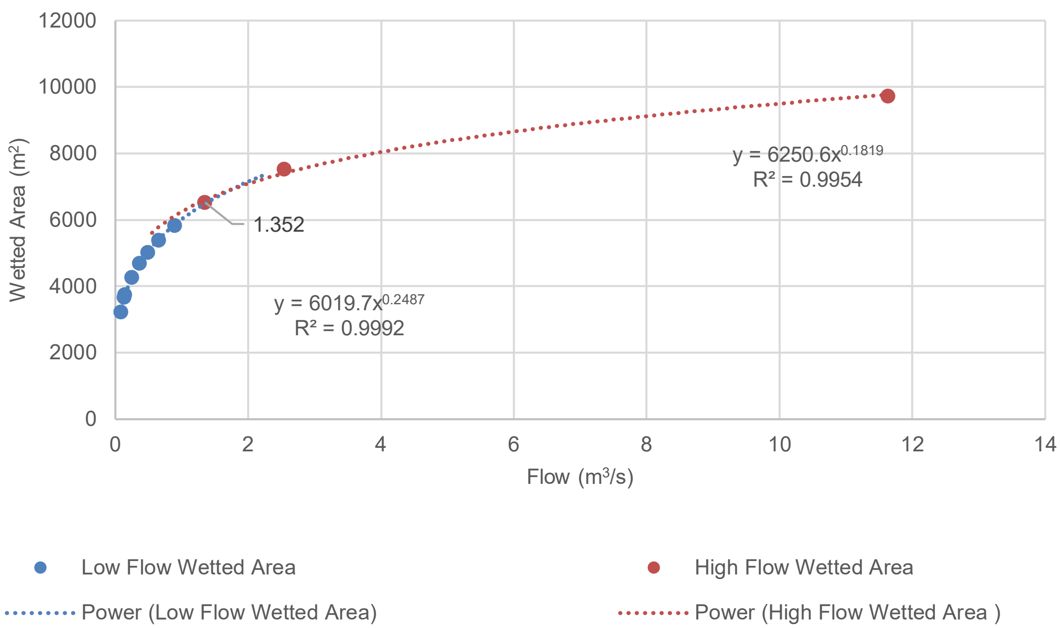

Figure 3-2 Relationship Between Flow and Average Wetted Area

Error! Not a valid bookmark self-reference. shows the equations for each trendline shown in Figure 3-1**Error! Reference source not found.** and Figure 3-2. These equations were used to determine the change in average water velocity, average water depth and average wetted area depending on whether the flow fell within the high flow range (>1.352 m^3/s) or the low flow range (<1.352 m^3/s). These relationships were then applied to different water withdrawal scenarios to calculate the resulting average water velocity, average water depth, and average wetted area in the representative sub-reach.

Table 3-2 Power Equations Derived from the Relationships Between Modelled Parameters and Flow

Equation	Low Flow (Q<1.352 m^3/s)	High Flow (Q>1.352 m^3/s)
Average Velocity	$= 0.2796Q^{0.4105}$	$= 0.278Q^{0.3461}$
Average Depth	$= 0.1087Q^{0.2959}$	$= 0.1033Q^{0.4913}$
Average Wetted Area	$= 6019.7Q^{0.2487}$	$= 6250.6Q^{0.1819}$

3.3 Effect of Water Withdrawals on Channel Hydraulics

Predicted average water velocities, average water depths, and wetted areas at low flows and high flows are presented in Table 3-3 and Table 3-4, respectively. For the low flow scenario, average water depth, average water velocity, and wetted area were predicted to change <10% compared to no water withdrawal at water withdrawal rates ≤20% Table 3-3). At water withdrawal rates between 20% and 40%, average water depths, average water velocity, and wetted area were predicted to change <20%.

For the high flow scenario, average water depth, average water velocity, and wetted area were predicted to change <10% compared to no water withdrawal at water withdrawal rates ≤20% (Table 3-4). At water withdrawal rates between 20% and 40%, average water velocity and wetted area were predicted to change <20% while average water depth was predicted to decrease by >20% only at the highest water withdrawal rate.

Table 3-3 Predicted Average Velocity, Average Depth and Average Wetted Area Under a Modelled Low Flow Condition (0.493 m^3/s)

Water Withdrawal Scenario	Flow (m^3/s)	Average Velocity (m/s)	Percent Difference (%)	Average Depth (m)	Percent Difference (%)	Average Wetted Area (m^2)	Percent Difference (%)
0%	0.493	0.209	-	0.088	-	5049	-
-10%	0.444	0.200	-4%	0.085	-3%	4918	-3%
-15%	0.419	0.196	-6%	0.084	-5%	4849	-4%
-20%	0.394	0.191	-9%	0.083	-6%	4776	-5%
-25%	0.370	0.186	-11%	0.081	-8%	4700	-7%
-30%	0.345	0.181	-14%	0.079	-10%	4620	-8%
-35%	0.320	0.175	-16%	0.078	-12%	4536	-10%
-40%	0.296	0.170	-19%	0.076	-14%	4446	-12%

Table 3-4 Predicted Average Velocity, Average Depth and Average Wetted Area Under a Modelled High Flow Condition (2.544 m^3/s)

Water Withdrawal Scenario	Flow (m^3/s)	Average Velocity (m/s)	Percent Difference (%)	Average Depth (m)	Percent Difference (%)	Average Wetted Area (m^2)	Percent Difference (%)
0%	2.544	0.384	-	0.163	-	7408	-
-10%	2.290	0.370	-4%	0.155	-5%	7267	-2%
-15%	2.162	0.363	-5%	0.151	-8%	7192	-3%
-20%	2.035	0.356	-7%	0.146	-10%	7113	-4%
-25%	1.908	0.348	-9%	0.142	-13%	7030	-5%
-30%	1.781	0.339	-12%	0.137	-16%	6942	-6%
-35%	1.654	0.331	-14%	0.132	-19%	6849	-8%
-40%	1.526	0.322	-16%	0.127	-22%	6750	-9%

3.4 Potential Effects on Fish and Fish Habitat

3.4.1 Spawning/Egg Incubation

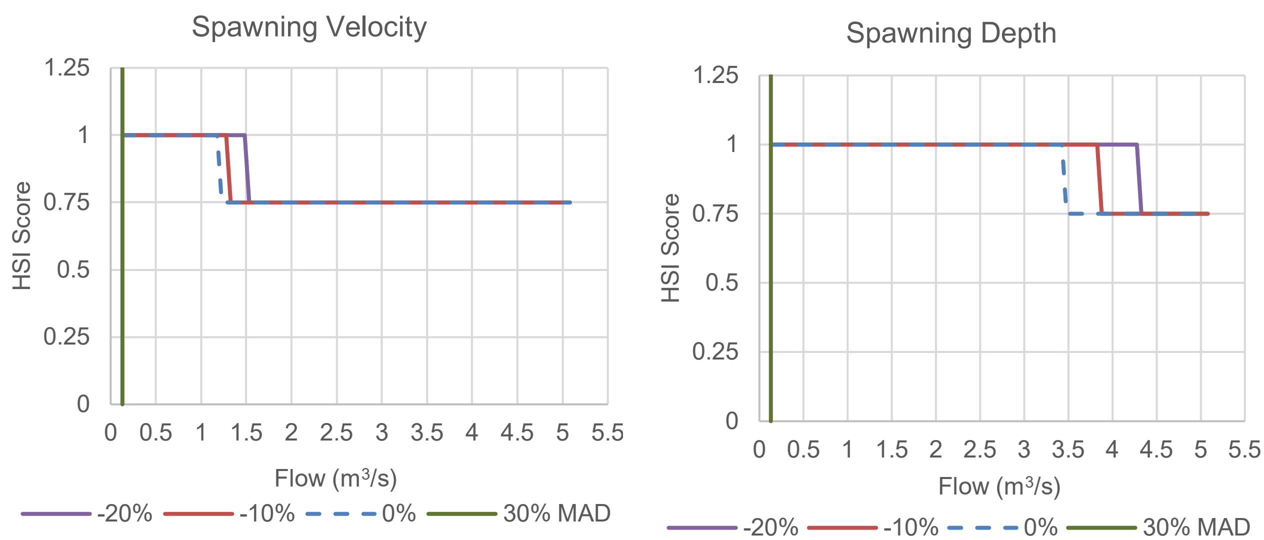

Figure 3-3 Relationships between Water Velocity HSI Score and Water Depth HSI Score for Arctic Char Spawning/Egg Incubation and Flow in the Apex River for Different Water Withdrawal Scenarios >30% of MAD

As shown in Figure 3-3, water velocities are predicted to be "excellent" (i.e., HSI=1) for Arctic char spawning/egg incubation in the Apex River at flows greater than 30% of MAD, the minimum flow at which water withdrawals will be allowed, for the 0%, 10%, and 20% water withdrawal scenarios. Water velocities are predicted to remain "excellent" for Arctic char spawning/egg incubation up to 1.2 m^3/s for all three water withdrawal scenarios.

Water velocities are predicted to decrease from "optimal" to "above average" (i.e., HSI=0.75) at 1.2 m^3/s with no water withdrawals and 1.3 m^3/s with water withdrawals of 20% of flow. These decreases in suitability at higher flows occur because of the shape of the spawning/egg incubation HSI curve (Appendix A, Figure A-1) which shows suitability decreasing with increasing water velocities above 0.25 m/s. Therefore, the lower flow in the Apex River resulting from a 20% water withdrawal scenario would maintain an optimal water velocity for Arctic char spawning at a higher discharge (1.3 m^3/s) than the 0% water withdrawal scenario (1.2 m^3/s). The suitability of water velocities for Arctic char spawning/egg incubation remains at "above average" at flows >1.3 m^3/s because water velocities in the Apex River do not substantially increase even at the highest flows due to the geometry and morphology of the Apex River, which is characterized by a shallow and wide channel with high channel roughness due to the abundant boulder and cobble substrates.

Like water velocity, water depths are predicted to be "excellent" for Arctic char spawning/egg incubation in the Apex River at flows above 30% of MAD until they decrease to "above average" suitability at flows >3.4 m^3/s under a 0% water withdrawal scenario and a flow of 4.4 m^3/s under a 20% water withdrawal scenario. These results are predicted to occur for the same reasons explained for Arctic char spawning/egg incubation suitability based on water velocity; water depth suitability for Arctic char spawning/egg incubation decreases when water depths are >0.05 m but water depths >0.05 m do not occur until very high flows because of the river's wide channel.

3.4.2 Juvenile Rearing

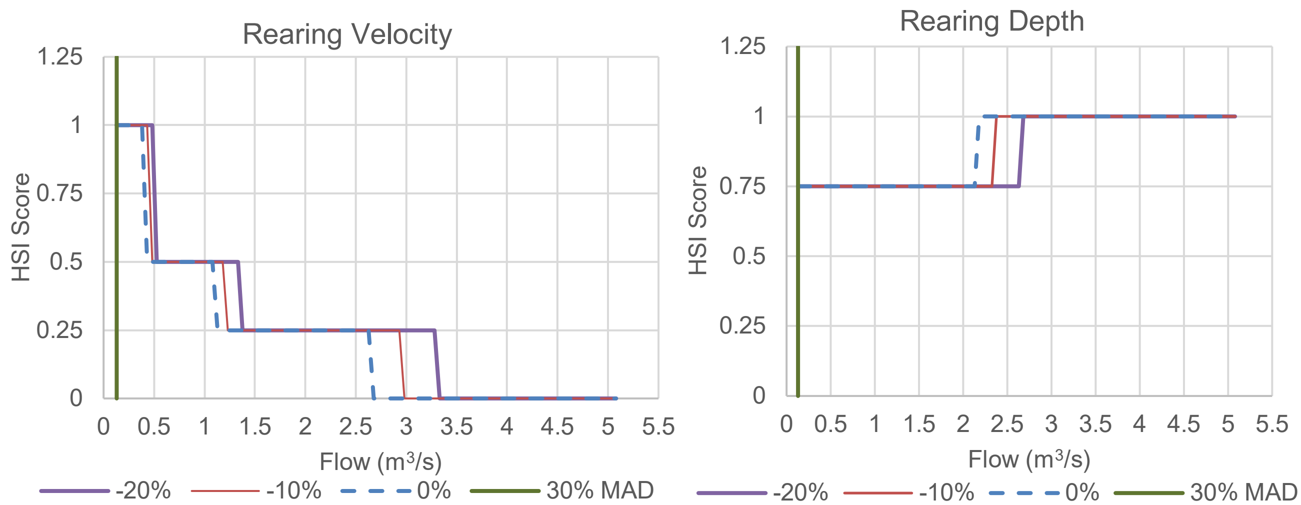

Figure 3-4 Relationships between Water Velocity HSI Score and Water Depth HSI Score for Arctic Char Juvenile Rearing and Flow in the Apex River for Different Water Withdrawal Scenarios >30% of MAD

As shown in Figure 3-4, the average water velocity in the Apex River was predicted to be "excellent" for the juvenile rearing stage of Arctic char at flows of 30% of MAD, the minimum flow at which water withdrawals would be allowed, for the 0%, 10%, and 20% water withdrawal scenarios. The HSI score for Arctic char juvenile rearing based on water velocity was predicted to decrease from "excellent" to "average" (i.e., HSI = 0.5) at flows near 0.5 m^3/s, to "below average" at flows >1.2 m^3/s, and to "unsuitable" (i.e., HSI score = 0) at flows >2.6 m^3/s under a 0% water withdrawal scenario. Water withdrawals of 10% and 20% of flow were predicted to decrease the suitability of water velocity for juvenile rearing at higher flows than a no water withdrawal scenario because removing water from the river at flows >0.5 m^3/s reduces water velocities in the river at the point when increasing water velocities are becoming less suitable for juvenile fish; the HSI curve shows habitat suitability decreasing from "excellent" to "unsuitable" as water velocities increase from 0.2 m/s to 0.4 m/s (Appendix A, Figure A-2).

The average water depth in the Apex River was predicted to be "above average" for juvenile Arctic char at flows of 30% of MAD, the minimum flow at which water withdrawals would be allowed, for the 0%, 10%, and 20% water withdrawal scenarios. The suitability of water depths in the Apex River were predicted to increase from "above average" to "excellent" at 2.1 m^3/s, 2.3 m^3/s, and 2.6 m^3/s for the 0%, 10% and 20% water withdrawal scenarios and remain "excellent" at flows up to at least 5 m^3/s. This is predicted to occur because the suitability of water depths for juvenile Arctic char increase from "above average" to "excellent" as depths increase from 0.1 m to 0.2 m (Appendix A, Figure A-2) and because increasing flow doesn't not have a substantial effect on water depths in the Apex River due to the river's wide, shallow channel.

3.4.3 Adult Foraging

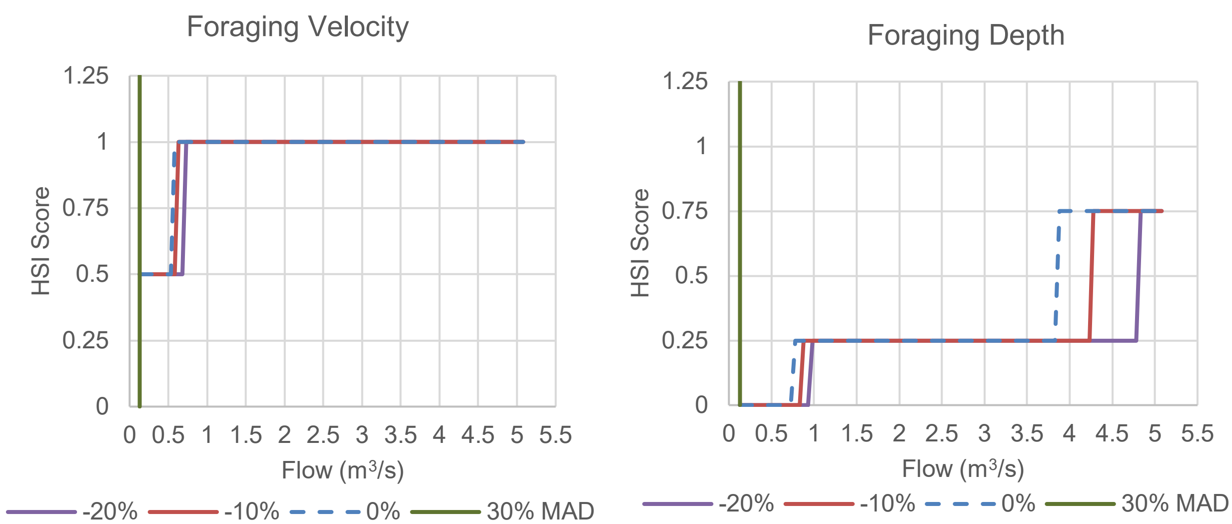

Figure 3-5 Relationships between Water Velocity HSI Score and Water Depth HSI Score for Arctic Char Foraging and Flow in the Apex River for Different Water Withdrawal Scenarios >30% of MAD

As shown in Figure 3-5, water velocities were predicted to be "average" (i.e., HSI=0.5) for Arctic char foraging in the Apex River at a flow of 30% of MAD, the minimum flow at which water withdrawals, for the 0%, 10%, and 20% water withdrawal scenarios. Water velocities are predicted to increase to "excellent" for Arctic char spawning/egg incubation at flows >0.5 m^3/s for the 0% water withdrawal scenario and at flows >0.6 m^3/s for the 20% water withdrawal scenario. This is predicted to occur because water velocity suitability for Arctic char foraging increases from "average" to "excellent" when water velocities increase above 0.2 m/s (Appendix A, Figure A-3). Water velocity suitability for Arctic char foraging in the Apex River was not predicted to decrease with increasing flows up to at least 5 m^3/s because of the wide channel and high roughness of the channel; water velocities in the Apex River were never predicted to exceed 0.55 m/s, the maximum velocity considered "excellent" for Arctic char foraging, at any of the modelled flows up to at least 5 m^3/s.

The average water depth in the Apex River was predicted to be "unsuitable" for Arctic char foraging at flows of 30% of MAD, the minimum flow at which water withdrawals would be allowed. This was true for existing conditions (i.e., 0% water withdrawal) and for the 10%, and 20% water withdrawal scenarios. This was predicted because water depths at this flow level were predicted to be <0.15 m, which, according to the HSI curve (Appendix A, Figure A-3), are too shallow for adult fish. The presence of Arctic char in Apex River highlights the limitations of using a HSI designed for bull trout/Dolly Varden and not specifically for the resident Arctic char population in the Apex River which are smaller fish and highlights the limitations of the hydraulic model which does not perform well when predicting low flow conditions in a shallow, rocky channel.

The HSI score for Arctic char foraging was predicted to increase from “unsuitable” to “below average” at flows between 0.5 m^3/s and 1 m^3/s for the 0%, 10%, and 20% water withdrawal scenarios, and to “above average” at flows between 3.8 m^3/s and 4.8 m^3/s for the 0%, 10%, and 20% water withdrawal scenarios. This was predicted to occur because water depth suitability for Arctic char foraging increases quickly at depths above 0.2 and doesn’t being to decrease until depths exceed 1 m.

4 Proposed Water Withdrawal Protocol

The following criteria must always be met for the proposed water withdrawal protocol in the Apex River:

- Water withdrawals at a rate of 20% of instantaneous discharge when flows are greater than 0.156 m^3/s, to ensure flows do not fall below 30% of MAD (i.e., 0.130 m^3/s)
- Water withdrawals at a rate of 10% of instantaneous discharge when flows are between 0.143 m^3/s and 0.156 m^3/s, to ensure that flows do not fall below 30% of MAD
- No water withdrawals when flows are lower than 30% of MAD (i.e., 0.130 m^3/s).

The 20% water withdrawal rate is higher than the 10% alteration of instantaneous flow threshold that DFO considers having “low probability of detectable impacts to ecosystems that support commercial, recreational, or Aboriginal fisheries in Canada” (DFO 2013). However, it is consistent with DFO’s recommendation to maintain a minimum of 30% of MAD to eliminate “a heighted risk of impacts to fisheries” (DFO 2013).

The 20% water withdrawal rate was considered not to pose a risk to fish in the Apex River for two reasons. First, the minimum flow threshold of 30% of MAD precludes creation of potentially adverse water depths and water velocities for Arctic char at low flows when flow reductions would have had the largest effect on channel hydraulics. Second, the wide, low gradient geometry and high roughness of the Apex River makes water depths and water velocities in the river relatively insensitive to changes in flow. Because of this, water depths and water velocities were predicted to change <10% compared to existing conditions at flows >30% of MAD. Such smaller changes in water depth and water velocity caused by water withdrawals up to 20% of instantaneous flow were considered insufficient to cause adverse effects on the resident Arctic char population in the Apex River.

In general, this assumption of no adverse effects was supported by the analysis of potential changes in habitat suitability for the different life stages of Arctic char in the Apex River. Of the three life stages considered, the suitability of adult foraging habitat was the most sensitive to changes in flow, with water velocities only exceeding “average” suitability and water depths only exceeding “unsuitable” at flows >0.5 m^3/s. However, this low suitability for adult Arctic char at flows near the 30% of MAD flow was predicted for existing conditions and the 10% or 20% water withdrawal scenarios had only small effects on habitat suitability for Arctic char by comparison.

5 Impact on the Current Water Withdrawal Program

The City has required emergency amendments to their water license from and emergency authorizations from DFO to pump water from the Apex River on numerous occasions over the last five years due to potable water shortages. In 2022, a potable water shortage occurred due to unforeseen water usage over the winter and spring and exceptionally dry conditions within the Apex River. During the water withdrawal program in 2022, 10% of flow was extracted from the Apex River when flows were above 30% MAD. During the FAA period (September 13, 2022 to September 19, 2022) approximately 30% of flow was pumped. As shown in Table 5-1, a total volume of 444,390 m^3 were pumped during the Specified Pumping Period (June 12 to September 12) and the FAA period (September 13 to September 19) combined in 2022.

Table 5-1 Hypothetical 2022 Withdrawal Rates at 10% vs Hypothetical 2022 Withdrawal Rates at 20% Protocol

Total Volume Pumped (Actual) 2022 (m^3)[1]	Hypothetical 2002 Volume based on Recorded Flow (m^3)	Hypothetical 2022 Volume based on Recorded Flow and Current Pumping Setup (m^3)[2]
444,390	1,017,806	875,790

1- This volume includes 367,501 m^3 pumped under the Supplementary Pumping Program and 76,889 m^3 pumped under the FAA
2- Currently the maximum pumping rate is 200 LPS

The proposed water withdrawal protocol allows a 10% withdrawal rate when flows are between 0.143 to 0.156 m^3/s and a 20% withdrawal rate at flow rates greater than 0.156 m^3/s. These ranges were selected to prevent flows in the river falling below 30% of MAD, the minimum flow threshold for avoiding heightened risks to Arctic char in the Apex River based on DFO guidance (DFO 2013). If the allowable water withdrawal rate had been increased per the proposed water withdrawal protocol prior to the 2022 pumping season, up to 1,017,806 m^3 of water could have been extracted from the Apex River (Table 5-1). The current water withdrawal infrastructure is limited by the current pump configuration which has a maximum pumping rate of 200 litres per second (LPS). Therefore, the actual amount that could have been extracted with the current infrastructure is closer to 875,790 m^3. Please note that the current permitted allowable annual volume is a maximum of 500,000 m^3 (Amendment No. 4 of the City's Type A Water License 3AM-IQA1626). Once the proposed rates are approved an application to amend the Amendment No. 4 to increase allowable annual volume of withdrawals.

6 Assumptions and Limitations

The above analysis was based on a 2-D hydraulic model for an approximately 200 m long section of Apex River. While this is a relatively short section of the river, the modeled section was selected after observing the entirety of the channel from the WSC gauging station downstream to the confluence with the unnamed lake watershed. This section was representative of hydraulic habitat present in most of the river. Nevertheless, the modeled section is unlikely to include all possible hydraulic habitats that may exist in the river downstream of the pumping station.

The model was used to predict average water depth, average water velocity, and wetted area at 11 different flow rates. Therefore, the model does not predict the full variability of water depths and water velocities that exist throughout the channel at different flows. As a result, it was necessary to assume that the average conditions predicted by the model represent the conditions experienced by individual fish. In reality, fish will actively select the hydraulic conditions that increase their ability to obtain food while limiting their energy expenditure and, depending on life stage, these locations are likely different within the river.

The HSI model used in this analysis was adapted from an existing model for Dolly Varden and Bull Trout. A species specific HSI model for Arctic char was not possible due to gaps within the available literature for resident Arctic char. The resident Arctic char represent a dwarf-resident population and individuals in this population are smaller, and reach sexual maturity at smaller sizes, than anadromous Arctic char that have access to the ocean. The smaller size of resident fish made it unlikely that the water depths and water velocities preferred by larger bull trout and Dolly Varden would be the same as those preferred by the smaller resident Arctic char.

Additional assumptions made in the analysis included:

- Flows measured at WSC station 10UH015 were representative of flows upstream of the pumping location and are thereby not influenced by pumping activities.
- The synthetic data set created from flow measured at WSC Station 10UH002 scaled with seasonal scaling factors are representative of flows upstream of the pumping location.
- The collected survey and available LiDAR data was sufficient to accurately represent the terrain within the modelled sub-reach.
- Model calibration to approximately 1 cm was sufficient when depth measured at the calibration point was <10 centimeters deep.
- The model was able to accurately represent the high channel roughness coefficient within the sub-reach.
- Roughness variation at varying flow depths within the model was negligible because the range of synthetic flows resulted in only an approximately 20 cm change in average water depth from the lowest modelled flow to the highest modelled flow.

- The hydraulic habitat relationships were representative of the relationship of flow and average velocity, depth and wetted area within the modelled sub-reach.
- The HSI curves were detailed enough to adequately categorize habitat suitability at the three life stages examined.
- < 10% change in hydraulic parameters (average water velocity and average water depth) would have a negligible effect on the resident Arctic char population in the Apex River

Despite these assumptions, the analysis was completed with the best available information. Therefore, it is Stantec's opinion that the analysis presented in this report provides reasonable conservative estimates of the water withdrawal rates from the Apex River if the protocol's criteria are met.

7 References

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Appendix A HSI Graphs

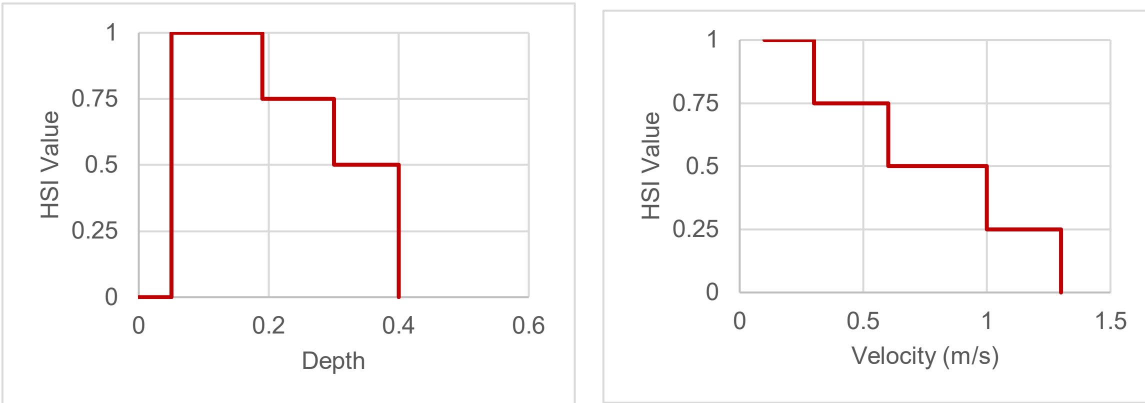

Figure A-1 Arctic char Spawning/Egg Incubation Habitat HSI for Depth (left) and Velocity (right)

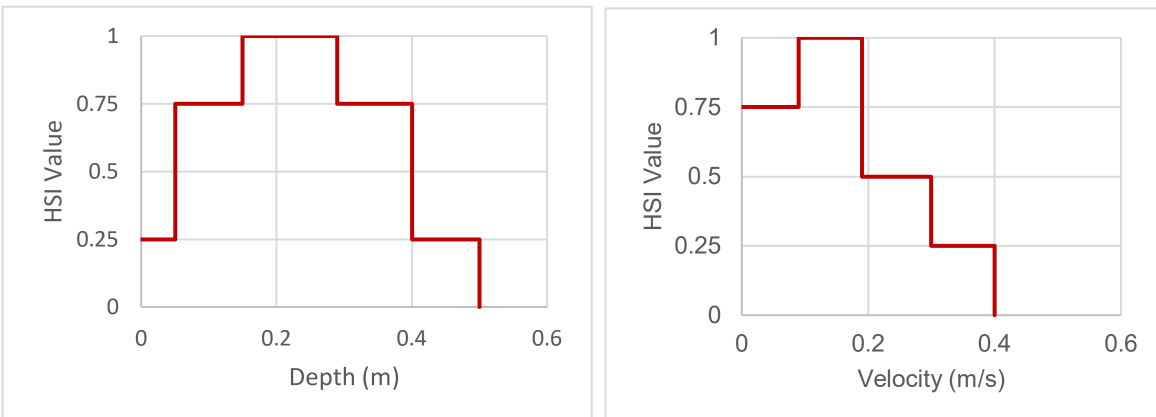

Figure A-2 Juvenile Arctic Char Rearing Habitat HSI for Depth (left) and Velocity (right)

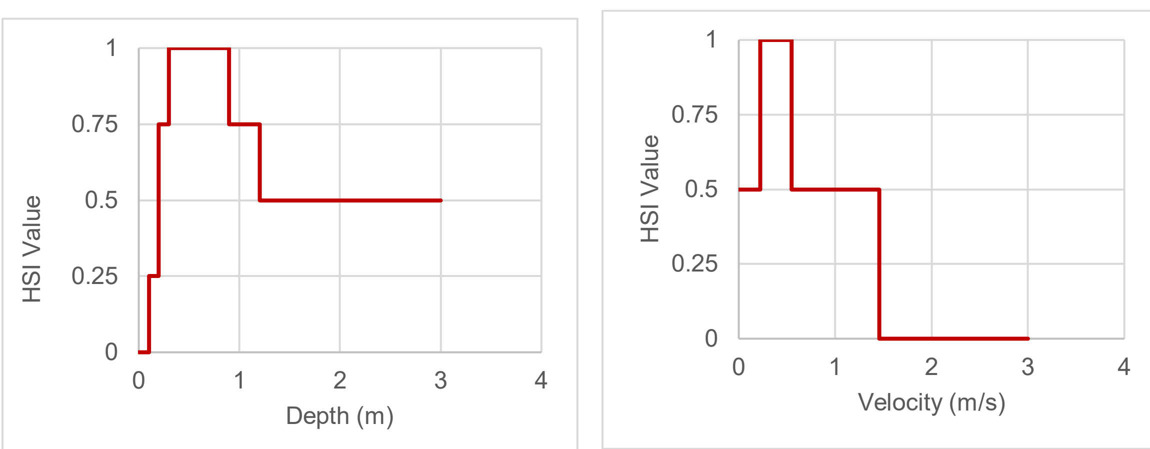

Figure A-3 Adult Arctic Char Foraging Habitat for Depth (left) and Velocity (right)

Appendix B Example Model Output

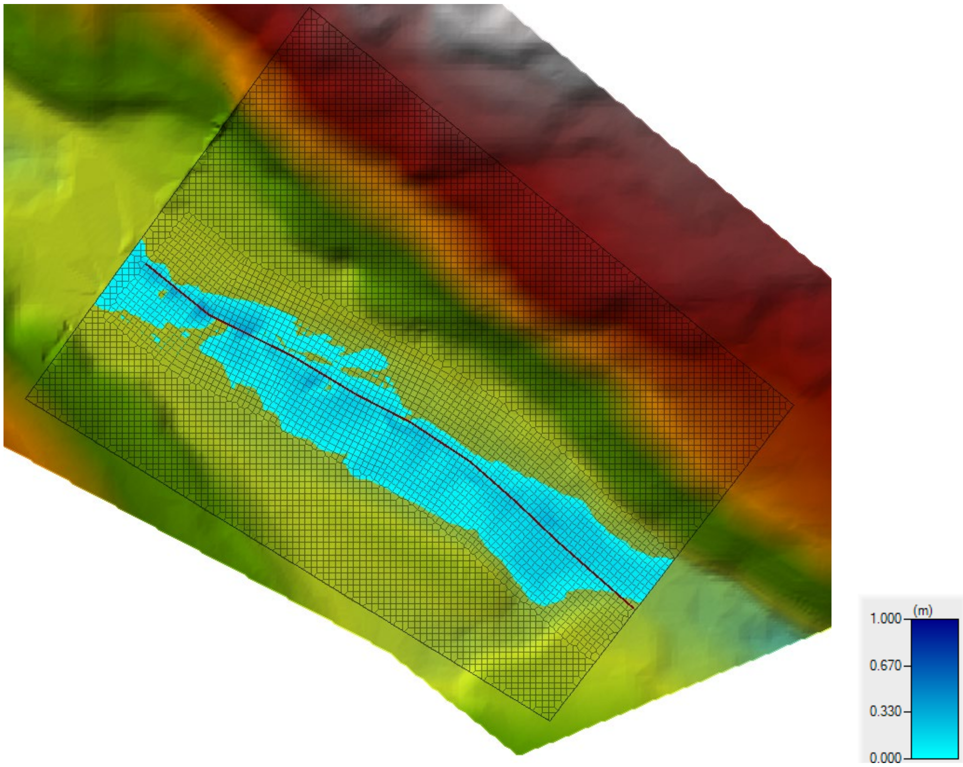

Figure B-1: Depth within the modelled Subreach at Q = 0.493 m^3/s

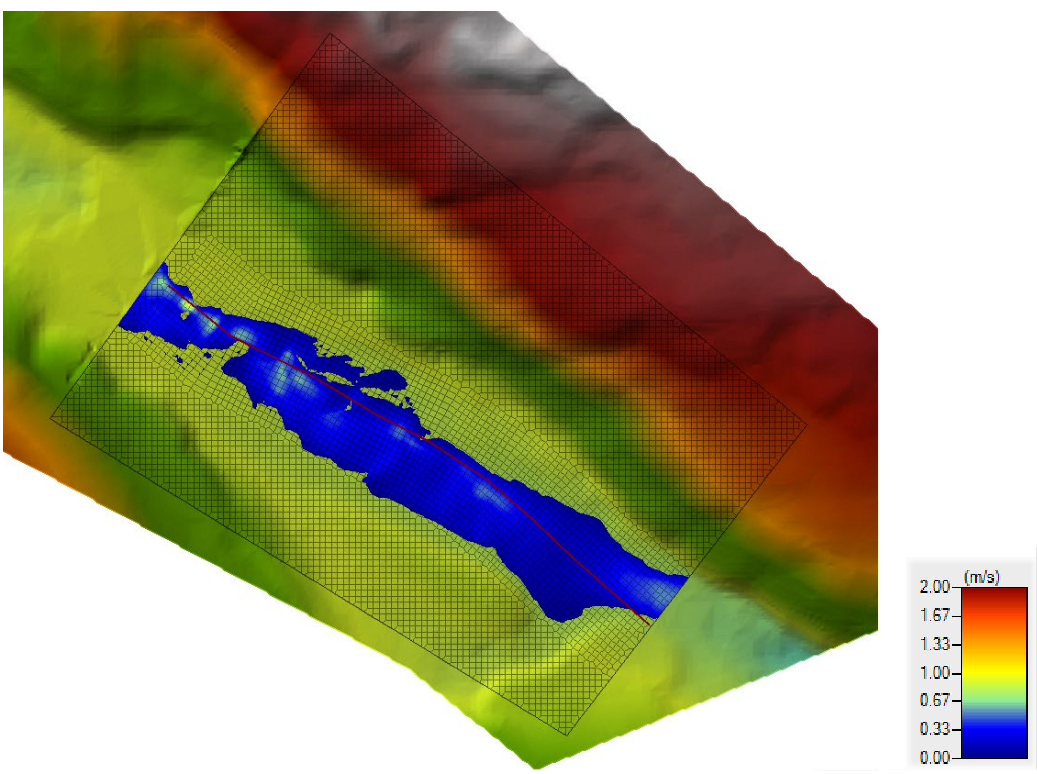

Figure B-2: Velocity within the modelled Subreach at Q = 0.493 m^3/s