Government of Northwest Territories | Gouvernement des Territoires du Nord-Ouest

Ms. Bonnie Bergsma
Regulatory Coordinator
Sahtu Land and Water Board
PO BOX 1
FORT GOOD HOPE NT X0E 0H0

March 24, 2023

Dear Bonnie Bergsma:

Application to Amend S20L8-002 for Water Sources

Please find enclosed, the Government of the Northwest Territories (GNWT) Department of Infrastructure (INF)'s application to amend Type "B" water licence S20L8-002 for the construction of the Prohibition Creek Access Road. The amendment is being sought to permit water withdrawal from five watercourses intersected by the PCAR. The proposed amendment will allow GNWT-INF and its contractor to obtain water for project construction from sources closer to the project, accessible by road, when sufficient flow is available.

The application documents include:

- Application for licence amendment
- Attachment A: Engagement Letter and Engagement Log
- Attachment B: Prohibition Creek Access Road: Desktop-based Assessment of Water Availability (K'alo-Stantec, 2022)

Please do not hesitate to contact the undersigned with questions about the application.

Sincerely,

Kelly Bourassa

Kelly Bourassa
Senior Environmental Analyst
Infrastructure

Land and Water Boards of the Mackenzie Valley

APPLICATION FOR LICENCE, AMENDMENT OF LICENCE, OR RENEWAL OF LICENCE IN NON-FEDERAL AREAS

Subsection 5(1) and Schedule C of the Waters Regulations

Use an “X” to indicate which Board the Application is being made to:	Mackenzie Valley Land and Water Board:		Sahtu Land and Water Board:	X
	Wek’èezhìi Land and Water Board:		Gwich’in Land and Water Board:	

To complete this form, please refer to the MVLWB *Guide to the Water Licensing Process* (Guide) and fill in the grey fields; attach additional pages, as necessary. Indicate N/A in the grey fields for Items or parts of Items that are not applicable. An application package checklist is provided in the Guide. Review the following MVLWB guidance for formatting your Application Package:

- *Document Submission Standards*
- *Standard Outline for Management Plans*

If applicable, provide the existing or current Water Licence number:	S20L8-002		
Use an “X” to indicate if this Application is accompanied by another Application for a Water Licence in a federal area and/or a Land Use Permit.		Water Licence:	n/a
		Land Use Permit:	n/a

1. NAME AND CONTACT INFORMATION – APPLICANT

Applicant’s Name:	Patricia Coyne		
Position:	Manager, Mackenzie Valley Highway Environmental Affairs		
Company Name:	Department of Infrastructure, Government of the Northwest Territories		
Mailing Address:	P.O. Box 1320		
Community:	Yellowknife	Telephone:	867-767-9082 ex 31033
Prov/Terr:	NWT	Email:	Patricia_coyne@gov.nt.ca

Postal Code:	X1A 2L9	Other:	

2. NAME AND CONTACT INFORMATION – APPLICANT'S HEAD OFFICE

Include a Certificate of Corporate Registration from the Government of the Northwest Territories to your Application Package.

Use an "X" to indicate this information is the same as Item 1 above:			X
Name:			
Position:			
Company Name:			
Mailing Address:			
Community:		Telephone:	
Prov/Terr:		Email:	
Postal Code:		Other:	

3. LOCATION OF PROJECT

Use the grey fields below to provide or reference the following information:

Traditional Place Name:	Location is commonly known as the Prohibition Creek Access Road

Maps and Geographic Information System (GIS) Data: Include a map in your Application Package, identifying local geographic features, watercourses and water sources, project structures, and location(s) of any proposed waste deposits. Provide geographic coordinates (latitude and longitude) of project features, and the maximum and minimum project boundary in degrees, minutes, seconds, or decimal degrees. Include GIS data in your Application Package, if applicable. Refer to the MVLWB *Geospatial Data Submission Standards* for providing geographic information.

Minimum latitude:	65° 9' 18.8" N	Maximum latitude:	65° 13' 25.5" N
Minimum longitude:	126° 18' 23.4" W	Maximum longitude:	126° 30' 53.4" W

NTS Map Sheet No.: Provide the map sheet number:	96 E/1

Land Types: Use an "X" to indicate the type(s) of land on which the activities are proposed:

Free Hold/ Private:		Commissioner's/ Territorial Lands:	**x**	Federal Land:		Municipal Land:	

4. DESCRIPTION OF PROJECT

Describe the proposed activities in the grey field provided below and contact Board staff to determine whether additional information will be required. For proposed amendments to authorized activities, specify: the nature of the amendment, the condition(s) to be amended, and the rationale for the amendment.

GNWT-INF is applying to amend condition: Part D, Item 1 to include additional water sources. The proposed amended condition is: "The Licensee shall only obtain Water for the Project from the Mackenzie River, Canyon Creek, Francis Creek, Helava Creek, Christina Creek and Prohibition Creek. The Licensee may

withdraw a total of up to 299m^3/day from all sources. For sources other than the Mackenzie River, no more than 10% of the instantaneous flow may be taken when flows are greater than 30% of the mean annual discharge, unless otherwise approved by Fisheries and Oceans Canada." The proposed amendment will allow GNWT-INF and its contractor to obtain water for project construction from sources closer to the project, accessible by road, when sufficient flow is available. A review of desktop information indicates that water will generally be available from May to October (K'alo-Stantec 2022; Attachment 'B') and will be confirmed through field measurements.

5. TYPE OF UNDERTAKING

Refer to Schedule B of the Waters Regulations. Use an "X" to indicate which one type of undertaking applies:

1	Industrial		
2	Mining and milling		
3	Municipal		
4	Power		
5	Agriculture		
6	Conservation		
7	Recreation		
8	Miscellaneous	**x**	(describe): Road construction

6. WATER LICENSING CRITERIA

Refer to Schedules D to H of the Waters Regulations. Use an "X" to indicate which criteria apply:

	Type B	Type A	
To obtain water	**x**		
To cross a watercourse			
To modify the bed or bank of a watercourse			
Flood control			
To divert water			
To alter the flow of, or store, water	**x**		
To deposit waste			
Other			(describe):

7. PROPOSED QUANTITY OF WATER INVOLVED

Describe the purpose of each proposed water use, name, and type (e.g., lake, river) of the water source, the location, and the quantity of water that would be used in the grey fields below. Add more rows as needed.

Purpose of Water Use	Name and Type of Water Source	Location	Geographic Coordinates		Proposed Water Use Volume/Rate, including units
			Latitude	Longitude	
Road construction	Canyon Creek	Canyon Creek	65°13'35.04" N	126°31'22.78"W	<10%IF when >30%MAD
Road construction	Francis Creek	Francis Creek	65°12'17.33" N	126°27'25.56"W	<10%IF when >30%MAD
Road construction	Helava Creek	Helava Creek	65°11'32.39" N	126°25'7.74"W	<10%IF when >30%MAD
Road construction	Christina Creek	Christina Creek	65°11'11.29" N	126°24'6.16"W	<10%IF when >30%MAD
Road construction	Prohibition Creek	Prohibition Creek	65° 9'12.19"N	126°18'3.37"W	<10%IF when >30%MAD

For each water source identified in the table above, provide a comparison of total proposed water use to the available capacity. Add more rows as needed.

Water Source	Capacity of Water Source, including units	Other Users of the Water Source	Comparison of Total Proposed Water Use to Available Capacity
Canyon Creek	See attached report Table 5.2	The source may be used for traditional and recreational purposes by local land users. There is an existing cabin near the mouth of Canyon Creek at the Mackenzie River (downstream).	Water take will not exceed 10% of instantaneous flow (IF) and only when flows are greater than 30% of mean annual discharge (MAD).
Francis Creek	See attached report Table 5.3	The source may be used for traditional and recreational purposes by local land users.	As above
Helava Creek	See attached report Table 5.4	The source may be used for traditional and recreational purposes by local land users.	As above
Christina Creek	See attached report Table 5.5	The source may be used for traditional and recreational purposes by local land users.	As above
Prohibition Creek	See attached report Table 5.6	The source may be used for traditional and recreational purposes by local land users. There are two existing cabins near the mouth of the creek at the Mackenzie River (downstream).	As above

8. PROPOSED WASTE MANAGEMENT METHODS

Use the grey field below to provide or reference the following information:

Waste Management Plan: Include a Waste Management Plan in your Application Package, if applicable, or for small-scale activities, describe proposed waste management activities in the grey field provided below. A template for the Plan is available in the MVLWB *Guidelines for Developing a Waste Management Plan*.

If waste is proposed to be disposed of off-site within the NWT, written confirmation (e.g., an email, letter, etc.) from the facility/facilities indicating they will accept the waste is required. Include it/these in your Application Package. Please note this information will be required by the Board prior to commencement of activities.

Municipalities: Complete the relevant Operations and Maintenance Plans using the available Templates and include them in your Application Package. Please refer to Sections 4-8 of Environment and Climate Change Canada's *Solid Waste Management for Northern and Remote Communities: Planning and Technical Guidance Document*.

EQC and AEMP: For activities that involve the deposit of waste into water, provide proposed effluent quality criteria (EQC) in accordance with the MVLWB *Water and Effluent Quality Management Policy* and MVLWB/GNWT *Guidelines for Effluent Mixing Zones*. Please refer to the MVLWB/GNWT *Guidelines for Effluent Mixing Zones* when mixing zones are being considered. Please refer to the MVLWB/GNWT *Guidelines for Aquatic Effects Monitoring Programs* for more information regarding the development of AEMP programs.

There are no proposed changes to the Waste Management Plan. There is no deposit of waste to water. EQC and AEMP are not applicable.

9. EXISTING WATER USERS AFFECTED BY THIS PROJECT

Describe pre-Application engagement efforts with any existing water users and associated possible claims for water compensation or compensation agreements. Include the names and locations of existing water users (e.g., persons or organizations) in the grey fields below. An additional table should be added for each water user.

Name:	See Attachment 'A' for Engagement Log
Community:	
Province/Territory:	
Describe Engagement Completed:	See Attachment 'A' for Engagement Letter sent to supplement previous engagement and traditional knowledge study completed on the original application.

10. POTENTIAL ENVIRONMENTAL IMPACTS OF THE PROJECT AND PROPOSED MITIGATIONS

If the proposed project, or parts of the proposed project, may be exempt from preliminary screening, describe the rationale for the exemption in the grey field below. Include the date of the most recent screening, and/or the environmental assessment or impact review number.

The proposed amendment - specifically water withdrawal from five watercourses along the PCAR, was not included within the original application as underwent preliminary screening by the SLWB leading to the issuance of S20L8-002.

Unless the project could be exempt from preliminary screening, using the Impact-Mitigation Table below, or the more detailed Table in Appendix F of the Guide, identify all potential impacts and possible mitigations that are relevant to the proposed project, and indicate whether any of the mitigation measures have been developed as a result of input from affected parties. Applicants for type A water licences must use the detailed Table in the Guide; other applicants may choose either the Table below or the Table in the Guide. Possible potential impacts are listed below; however, these lists are not exhaustive and may not apply to all projects. All information provided should reflect the size, scale, and nature of the proposed project. Cumulative impacts and climate change must be considered. Attach additional pages if needed.

Potential Impacts *Use an "X" to indicate which apply*	**X**	**Potential Project Impacts and Proposed Mitigations** *Describe the potential impact(s) and the proposed measure(s) to reduce each of these impacts.*
ABIOTIC COMPONENTS		
Land		
Soil contamination		no additional impacts
Soil compaction		no additional impacts
Destabilization/erosion	x	Vehicle use near water can lead to erosion. Existing Erosion and Sedimentation Control Plan will apply. Vehicles will remain on embankment as much as possible.
Change in soil structure		no additional impacts
Inability to support vegetation		no additional impacts
Other		
Water		
Groundwater		
Water table alteration		no additional impacts
Infiltration changes		no additional impacts
Changes in water quality		no additional impacts
Temperature changes		no additional impacts
Other		
Permafrost		
Loss or change in extent		no additional impacts
Changes in seasonal fluctuations		no additional impacts
Change in persistence		no additional impacts
Other		
Surface Water		
Water flow or level changes (permanent, temporary, seasonal)	x	There will be a temporary alteration of flow while the water truck is being filled (may be several hours). The rate of withdrawal will not exceed 10% of the IF of the creek.
Drainage pattern changes		no additional impacts
Temperature changes		no additional impacts
Changes in water quality		no additional impacts
Wetland impairment		no additional impacts
Changes to aquatic habitat (see Biotic section below)		no additional impacts
Other		
Air		

Potential Impacts *Use an "X" to indicate which apply*	X	Potential Project Impacts and Proposed Mitigations *Describe the potential impact(s) and the proposed measure(s) to reduce each of these impacts.*
Changes in air quality		no additional impacts
Harm to living things		no additional impacts
Increased greenhouse gases		no additional impacts
Other		
BIOTIC COMPONENTS		
Vegetation		
Direct loss of vegetation		no additional impacts
Loss of Species at Risk or may-be-at-risk plants		no additional impacts
Change in species composition		no additional impacts
Introduction of non-native (invasive) species		no additional impacts
Effects on plant health (dust, metals, toxins)		no additional impacts
Increased risk of fire		no additional impacts
Compaction of vegetation		no additional impacts
Other		
Terrestrial Wildlife Habitat		
Direct loss or removal of habitat, dens, or nests		no additional impacts
Loss or removal of keystone species and/or Species at Risk habitat		no additional impacts
Fragmentation of wildlife corridor		no additional impacts
Direct injury or mortality		no additional impacts
Disturbances to key lifecycle stages: breeding, feeding, nesting, staging		no additional impacts
Effects on population abundance		no additional impacts
Change in species diversity		no additional impacts
Effects on wildlife health (toxins, metals, etc.)		no additional impacts
Changes to migratory movement patterns		no additional impacts
Changes to predator-prey relationships		no additional impacts
Human-wildlife conflicts		no additional impacts
Other		
Aquatic Habitat		
Breeding disturbances	x	Potential for entrainment or entrapment of fish. -A fish screen will be installed on the intake in accordance with DFO Interim Code of Practice: End of Pipe Fish Screen Guidelines (2020) -Water withdrawal will not exceed 10%IF when flows are >30%MAD in accordance with DFO Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013). With mitigation no impacts to spawning are anticipated to occur.
Change in species diversity		no additional impacts

Potential Impacts *Use an "X" to indicate which apply*	**X**	**Potential Project Impacts and Proposed Mitigations** *Describe the potential impact(s) and the proposed measure(s) to reduce each of these impacts.*
Effects on health (toxins, metals, sediment, etc.)		no additional impacts
Changes to migratory movement patterns	x	Potential for entrainment or entrapment of fish. -A fish screen will be installed on the intake in accordance with DFO Interim Code of Practice: End of Pipe Fish Screen Guidelines (2020) -Water withdrawal will not exceed 10%IF when flows are >30%MAD in accordance with DFO Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013). With mitigation no impacts to changes in migratory patterns are anticipated to occur.
Changes to predator-prey relationships		no additional impacts
Effects on population abundance		no additional impacts
Change in species diversity		no additional impacts
Other		
CULTURAL COMPONENTS		
Wildlife Harvesting		
Loss or reduction in game species populations		no additional impacts
Effects on traditional land use, subsistence, and harvesting rights		no additional impacts; water truck movements will occur at the same time as other construction vehicle movements
Other		
Cultural Integrity and Heritage Resources		
Change to or loss of cultural integrity		no additional impacts
Change to or loss of traditional lifestyle		no additional impacts
Change to or loss of heritage resource		no additional impacts
Other		
Social and Economic Well-being		
Increased human health hazard and risk		no additional impacts
Economic opportunities or losses (employment, training)		no additional impacts
Change in ecological, cultural, social, or economic values identified for protection in approved Land Use Plans		no additional impacts
Impairment of the recreational or traditional uses of the land or water		No additional impacts anticipated; water take will be less than 10% of the flow when conditions allow.
Impairment of the aesthetic quality of the land or water		no additional impacts
Changes to the use of the area by other non-Indigenous people (e.g., trappers, outfitters, residents, hunters, forest harvesters, other authorized projects)		no additional impacts
Other		

Spill Contingency Plan: Include a Spill Contingency Plan in your Application Package, if applicable, or for small-scale activities, provide relevant details in the grey field provided below. An example of this Plan can be found in the INAC *Guidelines for Spill Contingency Planning*.

There are no proposed changes to the Spill Contingency Plan.

11. NAME AND CONTACT INFORMATION – CONTRACTORS AND SUB-CONTRACTORS

Include relevant names, responsibilities, and contact information in the grey fields below. An additional table should be added for each contractor and sub-contractor.

Name:	Chris Chivers		
Responsibilities:	Norman Wells Operations		
Company Name:	HRN Contracting		
Mailing Address:	65 Mackenzie Road		
Community:	Norman Wells	Telephone:	204 430 2503
Prov/Terr:	NWT	Email:	chrisc@hrncontracting.com
Postal Code:	X0E 0V0	Other:	

	Use an "X" to indicate that contractor and/or subcontractor information is not available at this time.

12. STUDIES UNDERTAKEN TO DATE

In the grey field below list any relevant studies that support the proposed activities and include them in your Application Package.

Please see attached report titled "Prohibition Creek Access Road: Desktop-Based Assessment of Water Availability" (K'alo-Stantec 2022) as Attachment 'A'.

13. PROPOSED PROJECT SCHEDULE AND TERM

Indicate the proposed project start and completion dates, and the time of year the project activities are planned to occur. Describe any anticipated temporary closure(s) or seasonal shutdowns. Indicate the term requested.

Start Date:		Completion Date:	
No change to licence term or schedule.			
Term of Licence Requested:			

14. ADDITIONAL SUPPORTING INFORMATION

Use the grey field below to provide or reference the following information:

Engagement*:* Conduct engagement, prepare an Engagement Record and Engagement Plan in accordance with the MVLWB *Engagement Guidelines for Applicants and Holders of Water Licences and Land Use Permits*, and include them in your Application Package. Templates are provided in the Guidelines. Please also refer to *Information for Proponents on MVLWB's Engagement Requirements*.

Eligibility*:* Contact Indigenous, federal, and territorial governments, and other parties to ensure all appropriate authorizations have been obtained or are in the process of being obtained. Obtain permission from the landowner(s), if necessary (e.g., obtain and reference licences of occupation, leases, access authorizations, etc.) and attach it/them to the Application.

Land Use Plans: Contact the applicable Land Use Planning Board or the Tłı̨chǫ Government to discuss conformity with the relevant Land Use Plan(s). Include a Land Use Plan Conformity Table in your Application Package, demonstrating how the project meets the requirements of the Land Use Plan, if applicable.

Traditional (Environmental) Knowledge (TEK/TK): Provision of TEK/TK is mandatory for Applications to the Sahtu Land and Water Board. Other applicants are strongly encouraged to include TEK/TK.

Facilities: Include the supporting information required under subsection 5(2) of the Waters Regulations if the project includes the following: dam(s); storage reservoir(s); watercourse crossing(s); camp(s) or lodge(s); use of water for industrial use or mining and milling; deposit of waste; or handling or storage of petroleum products or hazardous materials.

Closure and Reclamation: Include a Closure and Reclamation Plan in your Application Package, or for small-scale activities, describe the proposed closure and reclamation activities in the grey field provided below. Describe any temporary closure(s) and seasonal shutdowns. Please also refer to the MVLWB/AANDC *Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories* and Environment and Climate Change Canada's *Solid Waste Management for Northern and Remote Communities: Planning and Technical Guidance Document*.

Closure Cost Estimate: Prepare a Closure Cost Estimate and include it in your Application Package. Applicants are encouraged to contact Board staff, prior to applying, to determine which closure-cost-estimate template is most suited to the project activities being applied for. Guidance is provided in section 2.2 of the MVLWB/AANDC/GNWT *Guidelines for Closure and Reclamation Cost Estimates for Mines*. If your Application is submitted concurrently with a Land Use Permit Application, the estimate should include a breakdown of water- and land-related activities and liabilities.

Financial Capacity: Provide information relating to your financial capacity, as outlined in paragraph 26(5)(d) of the *Waters Act*. Please note this information will be required by the Board prior to issuance.

Please see attached engagement information letter and Engagement Log as Attachment 'A'.

There are no proposed changes to the Engagement Plan. A TK study was previously conducted and included with the original application.

Conformity with Land Use Plan: There are no updates to GNWT's original assessment of the Project's conformity with the Sahtu Land Use Plan. Additional information applicable to CR#5 is as follows:
The proposed water use will not substantially alter the quality, quantity, or rate of flow for waters that flow on, through, or are adjacent to Sahtu Lands, as the water take will be less than 10% of the flow of the creek, only when conditions are more than 30% of mean annual discharge (generally spring, summer and fall), unless otherwise approved. DFO considers this to be a low risk of detectable impacts to ecosystems that support fisheries.

15. FEES

Refer to the Guide for assistance with determining applicable fees.

Type of Fee	Amount ($)
Application fee (if applicable):	$30.00
Water use fee deposit:	$
Total Fees:	$

16. SIGNATURE

ANITA OGAA DEPARTMENT OF INFRASTRUCTURE, GNWT	ACTING MANAGER MACKENZIE VALLEY HIGHWAY ENVIRONMENTAL AFFAIRS
Applicant's Name (print) or Company Name	Position (print)

[signature]	03-23-2023
Signature	Date

Review the application package checklist provided in the Guide, and submit completed applications to the Regulatory Manager or Executive Director identified on the "Contact Us" pages of the respective Land and Water Board (www.mvlwb.com, www.wlwb.ca, www.slwb.com, www.glwb.com).

Attachment A:
Engagement Records

PER DISTRIBUTION LIST DELIVERED VIA EMAIL

(letters sent separately) JULY 14, 2022

Dear [ADDRESSEE]:

Notification of Intent to Amend Type B Water Licence S20L8-002 for the Prohibition Creek Access Road

The Government of the Northwest Territories Department of Infrastructure (GNWT-INF) is preparing for the construction of the Prohibition Creek Access Road (PCAR) between Canyon Creek and Christina Creek in the Sahtu Region of the Northwest Territories. The PCAR will replace the Mackenzie Valley Winter Road in this section with a wider all-season road. The segment of road between Christina Creek and Prohibition Creek will be constructed thereafter.

INTRODUCTION

The construction of the PCAR will require some new culverts to be installed at several creeks and drainages and will require repair and improvements of embankment and erosion protection around existing bridges. Construction of the PCAR will also require water for compaction of base material and dust control. GNWT-INF has received approvals from the Sahtu Land and Water Board (SLWB) to allow work in and around these creeks and drainages and to take water from the Mackenzie River; however, GNWT-INF has identified that additional approvals will be required to potentially take water from other sources. This letter describes the proposed activity that will require amendment of the Project's Type B water licence:

- Annual water withdrawal from potential creek sources

WATER REQUIREMENTS AND POTENTIAL SOURCES

During construction of the PCAR, water is used to compact layers of road base placed on top of embankment. GNWT-INF currently has approval to withdraw water from the Mackenzie River for this purpose. To eliminate long hauls, GNWT proposes to withdraw water from additional nearby sources between Canyon Creek and Jungle Ridge Creek which may be accessible and meet the flow requirements.

Water use may be up to 299 cubic metres per day, depending on the flow of each of the creek at the time. To protect fish and fish habitat, GNWT-INF proposes to only take 10 percent (one tenth) of the flow and only when water flows are more than 30 percent of the mean annual discharge of the creek, which is likely to be in spring, summer, and early fall.

…/2

No new access to the creeks is needed as the water truck will be parked on the road embankment. The water intake hose would have a fish screen to prevent entrapment of fish.

GNWT-INF looks forward to your ongoing interest in the PCAR project should you wish meet to discuss either of the above proposals, please contact Kelly Bourassa at kelly_bourassa@gov.nt.ca.

Sincerely,

Kelly Bourassa
Senior Environmental Analyst
Infrastructure

c. Ms. Patricia Coyne
Manager, Mackenzie Valley Highway Environmental Affairs
Strategic Infrastructure

WL S20L8-002 Engagement Log

Date	Affected Party	Name(s) of Representatives from Affected Party who Participated	Engagement Activity Type	Purpose	Issue Raised and Recommendations from Affected Party	Proponent Response to Issue (indicate if issue(s) was resolved or not)	Information Materials Provided to Affected Party (Y/N)	Type of Material Provided
14-Jul-22	Behdzi Ahda' First Nation	Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Sahtu Secretariat Incorporated	Chairperson Charles McNeely	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Délı̨nę Got'ınę Government	ʔekw’ahtı̨də́ Leeroy Andre	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Fort Good Hope Métis Nation Local #54 Land Corporation	President Aurora McNeely	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Tulita Land Corporation	President David Menacho	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Yamgo Land Corporation	President Edwin Erutse	Email	WL S20L8-002 Amendment Notification	Additional Water Sources Response: Good afternoon, Thank you for the information. Edwin	N/A	Y	Letter
14-Jul-22	Ayoni Keh Land Corporation	President David Codzi	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Tulita Dene Band	Chief Frank Andrew	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Sahtu Dene Council	Grand Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Norman Wells Land Corporation	President Sherry Hodgson	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Fort Good Hope (Kasho Got'ı̨nę) Dene Band	Chief Tommy Kakfwi	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Fort Norman Métis Community	President Lindsay Norwegian	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Tulita District Land Corporation	President Sherry Hodgson	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
14-Jul-22	Behdzi Ahda’ First Nation	Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Behdzi Ahda' First Nation	Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Sahtu Secretariat Incorporated	Chairperson Charles McNeely	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Délı̨nę Got'ınę Government	ʔekw’ahtı̨də́ Leeroy Andre	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Fort Good Hope Métis Nation Local #54 Land Corporation	President Aurora McNeely	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Tulita Land Corporation	President David Menacho	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Yamgo Land Corporation	President Edwin Erutse	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Ayoni Keh Land Corporation	President Joseph Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Tulita Dene Band	Chief Frank Andrew	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Sahtu Dene Council	Grand Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Norman Wells Land Corporation	President Sherry Hodgson	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Fort Good Hope (Kasho Got'ı̨nę) Dene Band	Chief Tommy Kakfwi	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Fort Norman Métis Community	President Lindsay Norwegian	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Tulita District Land Corporation	President Sherry Hodgson	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter
09-Mar-23	Behdzi Ahda’ First Nation	Chief Wilbert Kochon	Email	WL S20L8-002 Amendment Notification	Additional Water Sources No Reponse to Engagement Correspondence	N/A	Y	Letter

Attachment B: Desktop-based Assessment of Water Availability

Prohibition Creek Access Road: Desktop-Based Assessment of Water Availability

Prepared for:

Department of Infrastructure, Government of the Northwest Territories
Yellowknife, NT

Prepared by:

K'alo-Stantec Limited
P.O. Box 176
Tulita, NT

September 16, 2022

Project No.: 144903284

Executive Summary

Monthly average discharge, mean annual discharge, and water volumes available for withdrawal have been calculated for four ungauged—and one gauged—creeks along the proposed Prohibition Creek Access Road (PCAR) alignment (the Study Area), near Norman Wells, Northwest Territories. Selected results are summarized in the summary table below.

Summary Table: Selected Statistics and Observations for Predicted Discharge and Water Availability for Potential Water Sources Along the Proposed Prohibition Creek Access Road Alignment

Creek[a]	Watershed Area (km^2)	May Mean Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	30% of Mean Annual Discharge (m^3/s)[b]	Annual Volume Available (m^3)[c]	Flows Likely in Winter?	Winter Observation Data Source
Canyon	64	2.12	0.35	0.104	1,079,056	y	Water Survey of Canada gauge 10KA009
Francis	24	0.88	0.15	0.044	460,297	n	Limited qualitative observations
Helava	28	1.00	0.17	0.050	518,448	n	Limited qualitative observations
Christina	21	0.76	0.13	0.039	402,695	n	Limited qualitative observations
Prohibition	86	2.76	0.45	0.135	1,408,600	y	One manual discharge measurement in April 1973

NOTES:

[a] At bridge crossings.

[b] The criterion used to define periods of ‘low’ risk withdrawals (months with greater than 30% of mean annual discharge (MAD) vs. ‘high’ risk withdrawals (months with less than 30% of MAD

[c] *Annual Water Available’* is the monthly water volume available for withdrawal using DFO’s ‘desktop-based’ criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)

Criteria described above follow: Fisheries and Oceans Canada. 2013. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. Canadian Science Advisory Secretariat Science Advisory Report 2013/017

Water will be used for winter and summer construction related activities, compaction, and dust control. The amount and timing of water withdrawals are not yet known; however, the majority is anticipated to be needed in early winter (November-December) for winter road construction.

Flows were predicted with a regional analysis of data from Water Survey of Canada (WSC) stations. Predictions are statistically significant from May to November. Winter flows in regional creeks are conditioned by site specific groundwater inputs as well as watershed size. Therefore, WSC data and historic literature from the area were reviewed for information pertinent to winter flows. The two largest creeks, Canyon and Prohibition, flow in winter. Limited available data suggest that the smaller creeks (Francis, Helava, and Christina) do not flow in winter.

"Cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to ecosystems that support fisheries". Periods of heightened risk were assessed (1) locally, using the results of flow predictions calculated here, and (2) regionally, using WSC data. By this definition, periods of heightened risk consistently occur over winter (November through February) both locally and regionally. Regionally, the only exception is a creek that drains several upstream ponds.

Monthly and annual average water volumes potentially available for withdrawal were calculated using DFO's criteria and 'desktop-based' flow estimates produced here. Annual volumes range from about 403,000 m^3 from Christina Creek to about 1,409,000 m^3 from Prohibition Creek (Summary Table). About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February. Withdrawals during this overwinter period will likely require "*a more rigorous level of assessment… to evaluate potential impacts on ecosystem functions which support fisheries*" as required by DFO.

The region is sparsely gauged. Existing datasets are sometimes short and limited over winter. Stations with the shortest records are located close to the proposed PCAR alignment. Data from these stations were used in analyses because of their proximity to the Project. However, the variability of flows from these stations is similar to that of more distant stations with longer records, suggesting that the limited data available from these local sites adequately capture flow variability.

Table of Contents

List of Tables

List of Figures

Abbreviations

e.g.	example
DFO	Fisheries and Oceans Canada
EFN	Environmental Flow Needs
i.e.	that is to say
MAD	Mean Annual Discharge
masl	Metres Above Sea Level
PCAR	Prohibition Creek Access Road
QAQC	Quality Assurance/Quality Control
WSC	Water Survey of Canada

1 Introduction

This document provides monthly and annual flow estimates for candidate water withdrawal locations on streams crossing the proposed Prohibition Creek Access Road (PCAR) based on a desktop study of historic flows and literature in the region. The PCAR is proposed to be located about 16 to 30 km southeast of Norman Wells, Northwest Territories (NT), about 1.5 km from the north (right) bank of the Mackenzie River (Figure 1.1; Figure 1.2). The existing PCAR water licence authorizes water withdrawal from the Mackenzie River only (water license S20L8-002); this work investigates water availability in creeks along the PCAR alignment for potential future withdrawals.

The objectives and scope of the study are summarized below:

- Review potential water withdrawal sources along the proposed PCAR alignment. The five potential withdrawal sources are all moving waterbodies at existing bridges (Tetra Tech 2021; Tetra Tech 2022) (Table 1.1). An additional 39 proposed culvert crossings were identified that drain relatively small upstream catchments (<8.8 km^2) (Tetra Tech 2021; Tetra Tech 2022). Discharge is not predicted for these small creeks but can be calculated using equations presented here. No lakes or ponds were identified within 500 m of the PCAR alignment to be used as potential water withdrawal sources.
- Review existing available data to identify sources that are likely to support water withdrawal (based on watershed, flow data, hydrographs, etc.) during certain times of the year (Sections 4.1 and 5.2).
- Identify monthly discharge magnitudes and volumes potentially able to be withdrawn while meeting environmental flow needs (EFN; i.e. the volume and timing of water flow required for proper functioning of the aquatic ecosystem (FLNRORD 2022); Section 5.2). Criteria for low-risk withdrawals follow the '*Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*' (DFO 2013) and are described in Section 4.4.
- Identify additional studies required to verify the findings of this desktop study (Section 7) and to support licensing of water withdrawal.

Table 1.1 Potential Water Withdrawal Sources at Creek Crossings Along the Proposed Prohibition Creek Access Road Alignment

Crossing	UTM Easting (m)	UTM Northing (m)	Watershed Area (km^2)
Canyon Creek	615,829	7,235,942	64
Christina Creek	621,630	7,231,762	21
Francis Creek	618,988	7,233,671	24
Helava Creek	620,808	7,232,368	28
Prohibition Creek	626,507	7,228,256	86

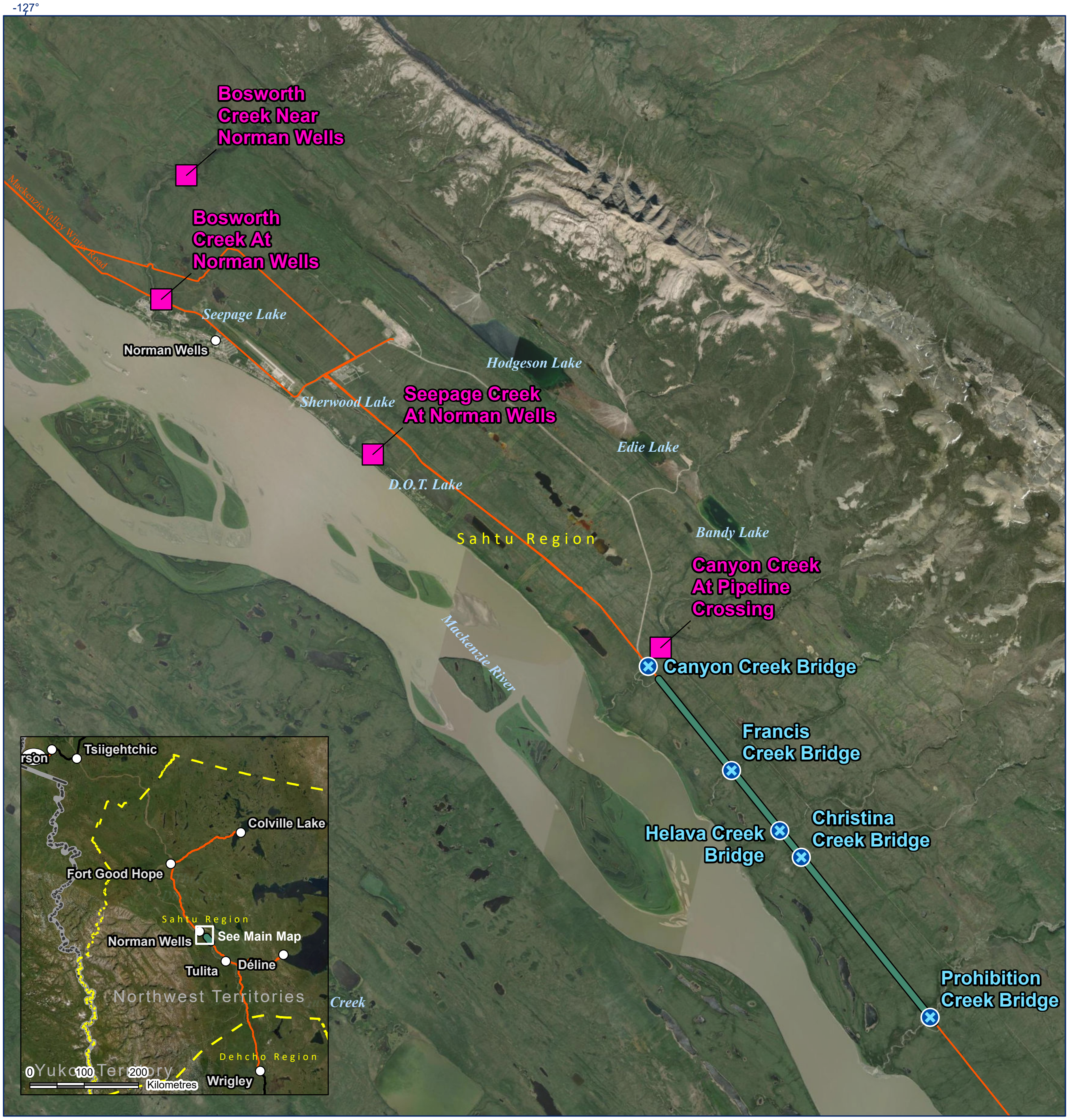
NOTE:

Coordinates are UTM Zone 9, WGS84 Datum. Watershed areas are from hydrotechnical assessments and design documents (Tetra Tech 2021; Tetra Tech 2022).

Fish habitat assessments have been conducted at each of the creeks near the crossings summarized in Table 1.1 (K'alo-Stantec Limited 2020). All creeks are classified as having the potential for fish habitat.

During construction and operation of the PCAR, water will be used for winter road construction, compaction and dust control. The amount and timing of water withdrawals are not yet known. This document aims to research potential water withdrawal sources that could support withdrawals throughout the year while meeting the DFO guidelines, and therefore could be supported by regulators for purpose of licensing. It is understood that the majority of water for winter road construction is needed in early winter (November-December) (Stevens 2022); whereas water is used for compaction and dust control from June to September.

This document provides average volumes available for withdrawal. Previous studies have provided discharges during floods and changes in flow due to climate change (Tetra Tech 2021; Tetra Tech 2022).



Water Survey of Canada Hydrometric Station
Existing Bridge
Prohibition Creek Access Road Proposed Alignment
Community
All-Season Road
Winter Road
Region Boundary

0 1.5 3 Kilometres
(At original document size of 8.5x11)
1:175,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/1/2022
TR by CES on 9/1/2022

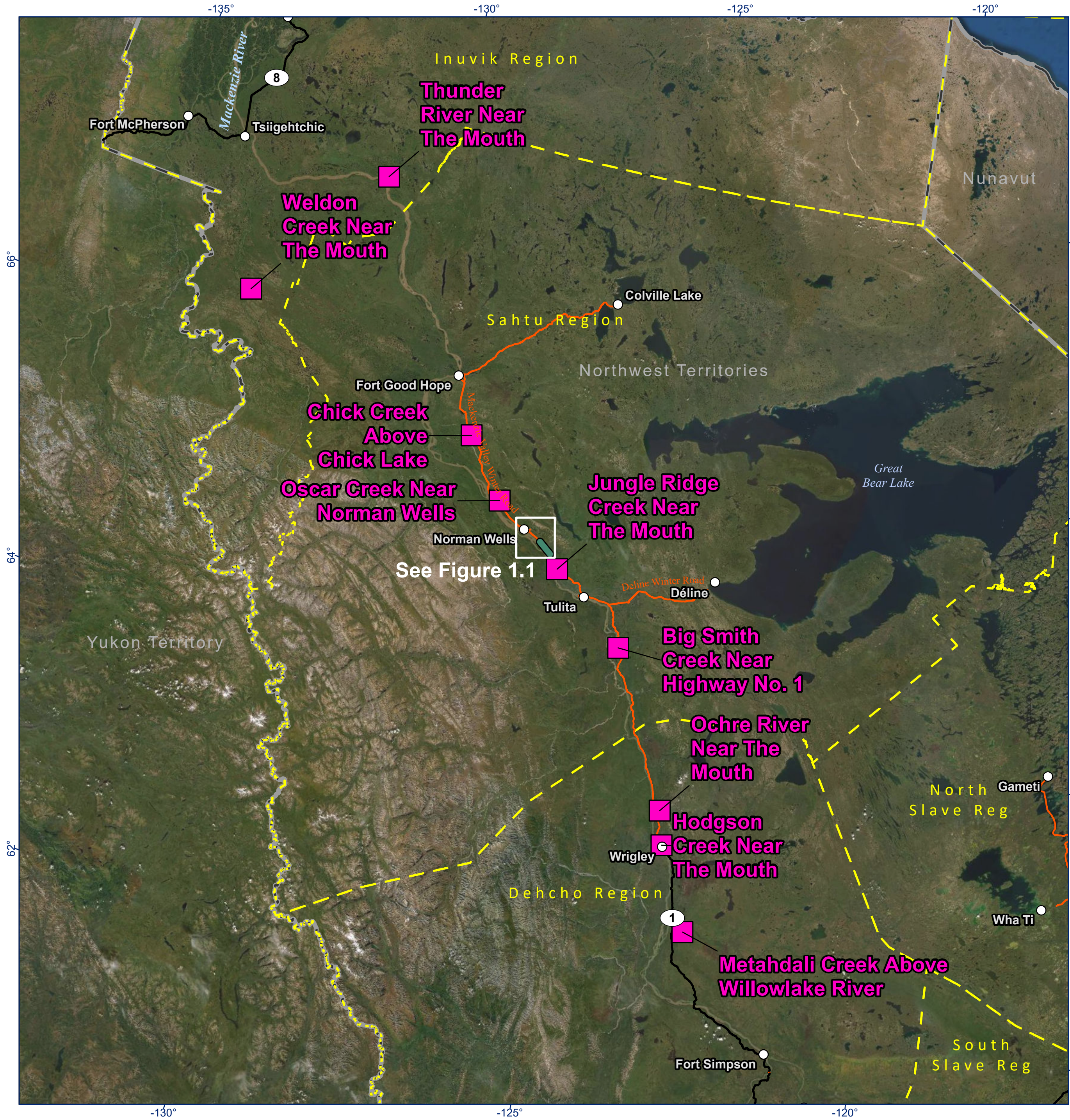
Client/Project
144903025-0156

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
Prohibition Creek Access Road Proposed Alignment, Potential Water Sources, and Analyzed Water Survey of Canada Stations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS



Water Survey of Canada Hydrometric Station

Prohibition Creek Access Road Proposed Alignment

Community

All-Season Road

Winter Road

Region Boundary

0 50 100 Kilometres

(At original document size of 8.5x11)
1:4,781,845

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/6/2022
TR by CES on 9/6/2022

Client/Project
144903025-0158

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.2

Title
Regional Water Survey of Canada Stations Selected for Analyses

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

2 Limitations

Flows and water volumes provided here are estimates for ungauged creeks in a sparsely monitored region (sparse both spatially and temporally). Results are approximations and are intended to focus efforts on creeks and time periods where the ecological impacts of withdrawals will be low. Limitations include:

- Flows and water volumes provided here are not prescriptive assessments of water availability in a given year. Flow predictions are reflective of average conditions in the years regional data were collected.
- Flows during floods and changes in flow due to climate change have been evaluated elsewhere (Tetra Tech 2021; Tetra Tech 2022).
- Results presented here should not be used for purposes other than those stated. For example, data presented here do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes.
- Analysis and recommendations are based on data available at the time of the report and rely on data provided by others which we assume to be correct but were not verified as part of this study.

Recommendations for refining estimates provided here are presented in Section 7.

3 Regional Hydroclimate

The proposed PCAR alignment is within the Mackenzie River Valley, about 30 km southeast of Norman Wells. A long-term climate station operates at Norman Wells (Station 'Norman Wells A', 73 masl). Average annual 30-year normal (1981-2010) air temperature is -5.1°C (ECCC 2022a). Average air temperatures dip below freezing in October and rise above freezing in May. Maximum monthly average air temperature occurs in July (17.1°C). The Mackenzie Valley itself has a somewhat milder climate than adjacent areas to the east and west (Kokelj 2001). Norman Wells receives 294 mm of precipitation annually, about 55% of which falls as snow. Daily rainfall amounts approaching 50 mm have historically occurred. Climate normal Hargreaves reference annual evapotranspiration is 389 mm (Wang et al. 2012); i.e., there is a potential annual moisture deficit in the region.

The proposed PCAR alignment is within the 'extensive discontinuous' (50-90%) permafrost zone (GNWT 2022). Norman Wells falls within the 'Taiga Plains, Norman Range LS Ecoregion'; vegetation is a "*complex of mixed-wood forests on westerly slopes and lacustrine deposits, mixed spruce stands on the interior plateau and slopes, and extensively burned areas*" (GNWT 2009).

The proposed PCAR alignment spans elevations from about 90 to 100 metres above sea level (masl). Creeks drain the Norman Range and Discovery Ridge to the east, with elevations up to about 1,500 masl.

The Sahtu Region has been classified into Arctic, East Mackenzie, Great Bear, and West Mackenzie hydrologic zones; the proposed PCAR alignment falls within the East Mackenzie zone (Golder Associates 2015). Regionally, a "*large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs*" (Kokelj 2001). Annual runoff for regional watersheds that drain into the Mackenzie River's east bank spans from about 60 mm (Seepage Creek at Norman Wells) to 327 mm (Jungle Ridge Creek near the Mouth)(Kokelj 2001). This is generally lower than runoff in the adjacent West Mackenzie zone.

Flows decline after freshet in May, with occasional increases in response to rainfall, then decline through winter. The ability of a watercourse to sustain flows over winter depends on "*watershed-specific factors including precipitation, channel slope, upland storage and particularly the presence of springs*" (Golder Associates 2006). Watercourses in the Sahtu Region have been described as:

> *"highly influenced by groundwater inflow… where streams with drainage areas larger than 50 km^2 likely maintain some flow over the winter because of groundwater contribution…Depending on local groundwater conditions, stream drainages smaller than 25 km^2 might also exhibit stream flow over the winter, whereas others with less groundwater inflow might freeze completely to the streambed."* (MGP 2004)

4 Methods

The main deliverables of this report are modelled predictions of mean monthly discharge, MAD, and ecologically 'low-risk' water withdrawal volumes at potential PCAR water sources. This was accomplished by conducting regression analyses of monthly mean flow for regional WSC stations and watershed area.

This section begins by describing available data, then describes the flow prediction methodology and criteria used for the assessment of low-risk water withdrawal volumes.

Data were collected, filtered, and analyzed in (R Core Team 2022). All regressions, statistics, and plotting were also conducted in R.

4.1 Data Sources

Daily flow data from WSC stations were compiled with the R library 'Tidyhydat' (Goetz, Albers and Pike 2018). Tidyhydat uses the WSC database 'Hydat' (ECCC 2022b). The Hydat version used here was published on 2022-04-18 and is the most recent database at the time of writing. The most recent finalized data for regional stations is from 2019 Provisional real-time data that have not yet undergone full quality assurance/quality control (QAQC) were not used here.

Hydrometric data were compiled for the WSC stations in the NT, then filtered to include only:

- Stations within 400 km of the Helava Creek crossing (a central point in the Study Area; Figure 1.2)
- Stations with watersheds that do not drain the Mackenzie Mountains, due to the different hydrologic regime there (Golder Associates 2015)(Section 3)
- Stations with relatively small to medium-sized watersheds, i.e., <~1000 km^2 [1]
- Stations whose discharge is unlikely to be affected by drainage of large upstream lakes, potentially causing delays between snowmelt and rainfall, and runoff[2]
- Months with greater than or equal to 92 daily observations (i.e., greater than about 3-years of data; Section 4.3; Section 6.2)

WSC stations included in the analysis after applying the filtering process are summarized in Table 4.1 and mapped in Figure 1.1 and Figure 1.2. Some stations in Table 4.1 have short periods of record, and/or have not recently operated. Several stations also have limited datasets over winter due to seasonal operation (Figure 4.1). Implications for use of relatively small sample sizes are explored in Section 6.2. Data from two stations[3] were frequently anomalous when flagged as backwatered. Backwatering causes river levels to rise independently from discharge, often in response to a downstream obstruction (e.g., ice, beaver dams), or a downstream waterbody or watercourse. These data were removed.

[1] 1,031 km^2. Set to include 10HC008, Oche River Near the Mouth.
[2] 10LB007 TIEDA RIVER NEAR THE MOUTH and 10LD002 JACKFISH CREEK NEAR FORT GOOD HOPE were excluded.
[3] 10KA005 SEEPAGE CREEK AT NORMAN WELLS and 10LA004, WELDON CREEK NEAR THE MOUTH.

4.2 Watershed Delineation

The WSC publish watershed areas for most stations in the NT (ECCC 2022b); however, watershed areas were missing for several stations that remained following the filtering process described above (station numbers 10KD009, 10HC007, 10HC008, and 10LB006; Table 4.1). The watershed areas for these stations were calculated using ArcGIS software. National Hydrographic Network basins (Natural Resources Canada 2022) were segmented along topographic ridgelines and flow patterns. Where watershed areas were available from the '*Prohibition Creek Access Road Hydrotechnical Assessments*' report, they were preferentially used here, since these watersheds were delineated using high-resolution LiDAR data (Tetra Tech 2021). The watershed area at the WSC station at Canyon Creek (10KA009) is about 3% smaller than 0.7 km downstream at the bridge crossing; for the purposes of these analyses, 64 km^2 (Tetra Tech 2021; Tetra Tech 2022) was used for both catchment areas.

Table 4.1 Regional Water Survey of Canada Stations Used for Flow Predictions along the Proposed Prohibition Creek Access Road Alignment

Station Number	Station Name	UTM			Drainage Area (km^2)	Location[a]		Monitoring Period		Data Points (n)[c]
		Easting (m)	Northing (m)	Zone		Dist. (km)	Bearing (deg)[b]	Begins	Ends	
10KA009	CANYON CREEK AT PIPELINE CROSSING	615,995	7,236,583	9	*64*	6	-46	2009	2018	2,199
10KA005	SEEPAGE CREEK AT NORMAN WELLS	606,333	7,239,786	9	31	16	-60	1974	1978	1,614
10KA006	JUNGLE RIDGE CREEK NEAR THE MOUTH	635,408	7,217,955	9	60	21	137	1980	2018	6,796
10KA003	BOSWORTH CREEK AT NORMAN WELLS	599,129	7,242,508	9	122	24	-63	1973	1979	1,375
10KA007	BOSWORTH CREEK NEAR NORMAN WELLS	598,863	7,246,213	9	125	26	-55	1980	2018	9,256
10KA008	OSCAR CREEK NEAR NORMAN WELLS	575,639	7,259,095	9	638	53	-57	2009	2018	2,264
10HC003	BIG SMITH CREEK NEAR HIGHWAY NO. 1	413,224	7,164,281	10	980	101	131	1973	1994	7,820
10KD009	CHICK CREEK ABOVE CHICK LAKE	539,521	7,304,005	9	**16**	108	-46	2008	2018	2,870
10HC008	OCHRE RIVER NEAR THE MOUTH	469,488	7,040,295	10	**1,031**	233	143	2006	2019	4,412
10HC007	HODGSON CREEK NEAR THE MOUTH	475,833	7,012,887	10	**303**	260	145	2006	2014	2,896
10LA004	WELDON CREEK NEAR THE MOUTH	602,944	7,367,726	8	852	318	-62	1978	1990	4,748
10LB006	THUNDER RIVER NEAR THE MOUTH	418,760	7,488,203	9	**441**	326	-36	2006	2017	3,867
10GB005	METAHDALI CREEK ABOVE WILLOWLAKE RIVER	504,798	6,946,566	10	344	332	147	1976	1987	4,201

NOTES:

Stations are sorted by distance from Helava Creek bridge, a central point along the PCAR proposed alignment.

[a] Relative to the Helava Creek bridge.

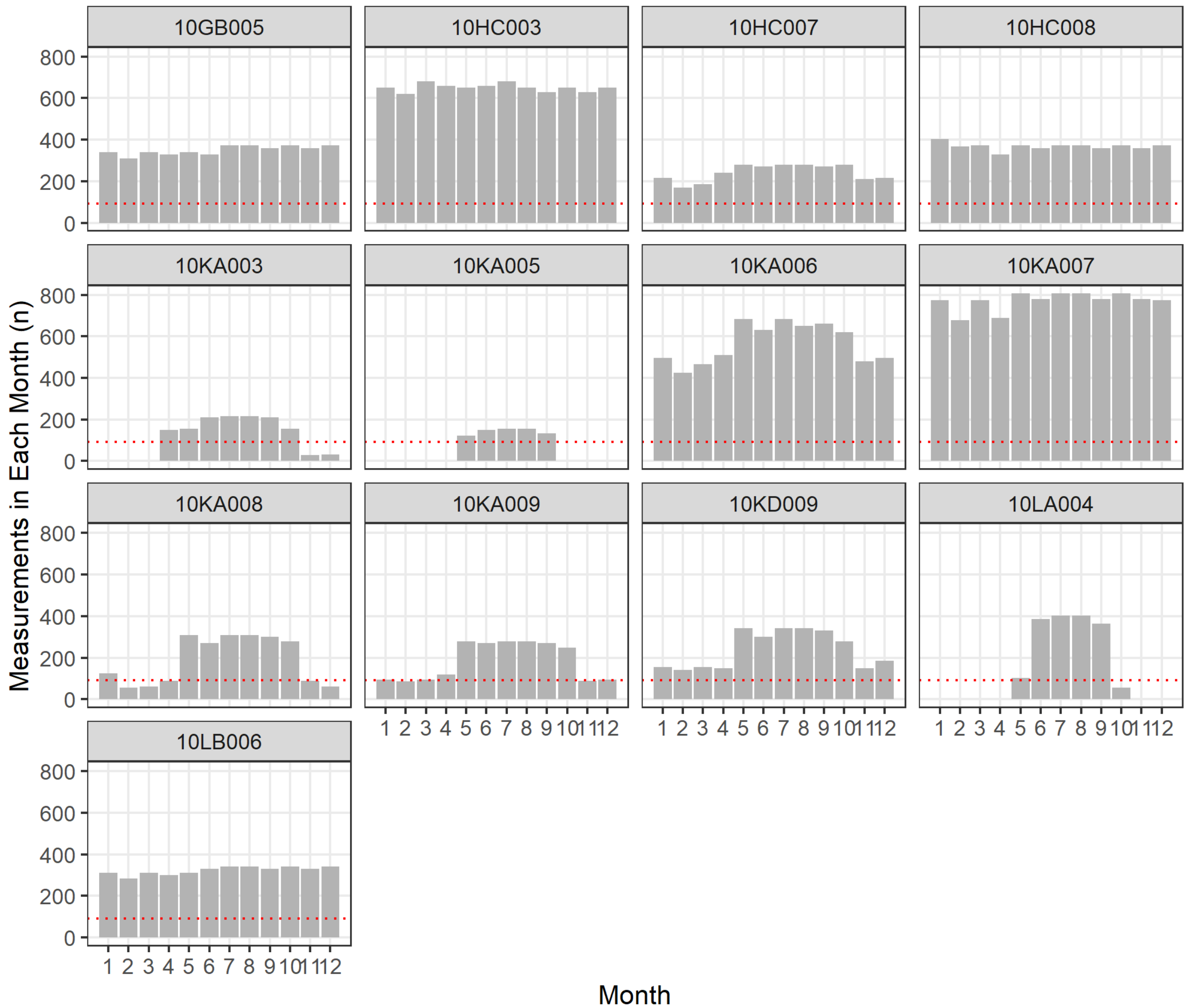
[b] Bearing is degrees clockwise (+) or counterclockwise (-) bearing from the Helava Creek bridge to the WSC station.

[c] Number of daily observations of flow.

*Bolded watershed areas were calculated by K'alo-Stantec (see text for methods). Watershed area for Canyon Creek was obtained from hydrotechnical assessment and design documents (Tetra Tech 2021; Tetra Tech 2022).

Coordinates use the WGS84 datum.

Figure 4.1 Histograms for Selected Water Survey of Canada Stations, Showing the Number of Observations in Each Month for the Period of Record



NOTES:

(1) the red horizontal line is at n=92. Months where n<92 at each station were excluded from regression modelling (Section 4.3).

(2) Month=1 represents January; Month=12 represents December

4.3 Flow Predictions

Monthly mean discharge was modelled for each of the five potential PCAR water withdrawal sources (Table 1.1). Modelling consisted of linear regressions between watershed area and mean monthly discharge for selected regional WSC stations (Table 4.1; Figure 1.2). Discharge and watershed area were log-transformed and regressions were conducted for each month. Watershed area is the predictor and mean monthly flow is the predictand.

Several WSC stations have operated very close to the Study Area (Table 4.1; Figure 1.1) and these stations have watershed areas that are relatively close to those of the potential water source creeks (Table 1.1). For example, ‘Canyon Creek at Pipeline Crossing’ (station 10KA009) was monitored by the WSC from 2009 to 2018 about 700 m upstream from the Canyon Creek bridge. ‘Seepage Creek at Norman Wells’ (station 10KA005) has a very small watershed area and is close to the Study Area; however, it only operated between 1974 and 1978. Given their watershed areas and proximity to the Study Area, data from these stations are valuable and were included in analyses whenever possible despite their relatively short period of operation.

It was therefore decided to include these local stations with short records in analyses while acknowledging that flow statistics from these stations may not characterize the full range of hydroclimatic variability. Flow data were grouped by station and month, and average flows were retained if at least 92 daily data points remained in each group (Figure 4.1; horizontal red lines). This would represent about three years of monitoring in each month if monitoring had been continuous. Implications for the use of relatively small sample sizes are discussed in Section 6.2.

An alternative to the methods described above would be to relax the filtering criteria, for example by increasing the maximum distance from PCAR where data should be collected. The disadvantage of relaxing filtering criteria is that distant or hydrologically different sites would be included in analyses. This is sometimes mitigated by incorporating additional predictors such as watershed elevation, air temperature and/or precipitation (Zhang, Balay and Liu 2020).

4.4 Criteria for Assessment of Environmental Flow Needs

For flowing waterbodies, DFO guidance (DFO 2013) is:

- “*cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a “natural flow regime” have a low probability of detectable negative impacts to ecosystems*”; and
- “*cumulative flow alterations that result in instantaneous flows less than 30% of MAD have a heightened risk of impacts to ecosystems that support fisheries*”. Periods below 30% MAD were identified as ‘highest risk’.

Mean monthly flows are predicted here in place of instantaneous flows as a desktop-based means of estimating monthly and annual low-risk withdrawals. MAD is calculated from mean monthly flows to identify the months with the ‘highest risk’. This approach allows for (a) an assessment of which months are likely candidates for low-risk water withdrawal, and (b) an estimation of water available for withdrawal.

5 Results

Regression model results are first presented below. Next, flow predictions for each water withdrawal candidate are described. Reports describing hydrologic conditions near withdrawal candidate sites were reviewed and are summarized in each section below.

5.1 Regression Model Results

Regressions between watershed area and mean monthly discharge are presented in Figure 5.1 and statistics are provided in Table 5.1.

Table 5.1 Regression Coefficients and Statistics

Month	Slope (m)	Intercept (b)	r^2	p-value	n
Jan	0.997	-3.861	0.11	0.461	7
Feb	2.480	-7.576	0.55	0.153	5
Mar	0.181	-1.188	0.58	0.238	4
Apr	0.444	-1.397	0.47	0.089	7
May	0.913	-1.326	0.86	<0.001	13
Jun	1.202	-2.538	0.95	<0.001	13
Jul	1.068	-2.502	0.83	<0.001	13
Aug	0.942	-2.231	0.78	<0.001	13
Sep	1.060	-2.472	0.77	<0.001	13
Oct	0.835	-2.068	0.86	<0.001	10
Nov	0.959	-3.045	0.61	0.022	8
Dec	0.583	-2.692	0.10	0.400	9

NOTE:
Regressions equations are solved using $\log_{10}$-transformed drainage area (see text below). r^2 is a measure of the regression's overall 'goodness of fit' and a p-value >0.05 (underlined) indicates that a regression is not statistically significant. n = sample size, i.e., the number of flow-area pairs in each regression.

Monthly average discharge (Q) is calculated as follows:

$$\log_{10}Q = m*\log_{10}A + b$$

where '$\log_{10}Q$' is $\log_{10}$ transformed monthly average discharge, 'm' and 'b' are regression coefficient slopes and intercepts (Table 5.1), and '$\log_{10}A$' is the $\log_{10}$ transformed watershed area for the location of interest.

Q in metres cubed per second (m^3/s) is calculated as:

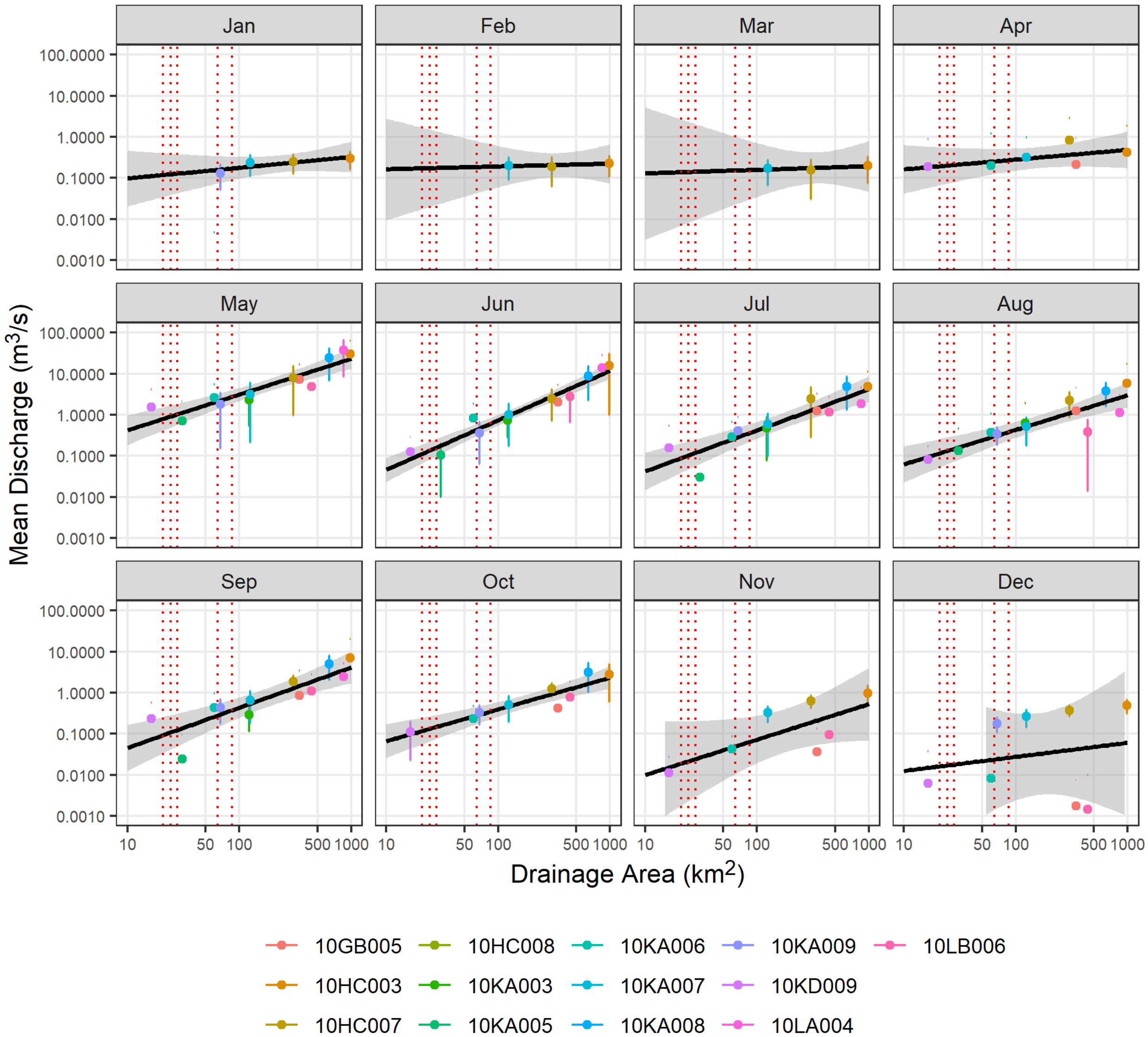
$$Q = 10^{\log_{10}Q}$$

In the 'thaw period' and early winter (May to November), monthly regressions are statistically significant (p-value less than or equal to 0.05) and correlation coefficients are generally high (Figure 5.1; Table 5.1). This is the period where snowmelt and rainfall produce the highest flows and most runoff of the year. Snowmelt and precipitation feed watercourses during these months, and the magnitude of discharge is proportional to watershed area.

In the 'frozen' period from December to April, regressions are generally not statistically significant (p-value >0.05; and/or low r^2; Figure 5.1; Table 5.1), meaning that discharge in these months is not strongly proportional to watershed area. Discharge is low in these months and is a small fraction of MAD. Discharge in winter is likely mainly fed by groundwater (Section 3). Seasonal operation of regional WSC stations also leads to small sample sizes for regressions in these winter months (Figure 4.1), making it difficult to establish regional relationships.

PCAR target watershed areas are relatively small (21 to 86 km^2; Table 1.1). However, regional WSC data exist from stations with watershed areas in the range of those of target watersheds (Table 4.1; vertical lines on Figure 5.1).

Figure 5.1 Relationships between Watershed Area and Mean Monthly Discharge at Selected Regional Water Survey of Canada Stations



NOTE:
Vertical red lines are the watershed areas of the five considered PCAR withdrawal sites. Vertical error bars on points are +/- one standard deviation. Grey shaded envelopes represent 95% confidence intervals. Where confidence intervals are missing, they are outside the y-axis limits. Regression statistics are provided in Table 5.1.

5.2 Flow Predictions and Historic Observations Pertinent to Flow for Potential PCAR Water Sources

Sections are presented below for each of the five PCAR crossings that were analyzed for potential water withdrawals. Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m). Results are tabulated in Table 5.2 through Table 5.6.

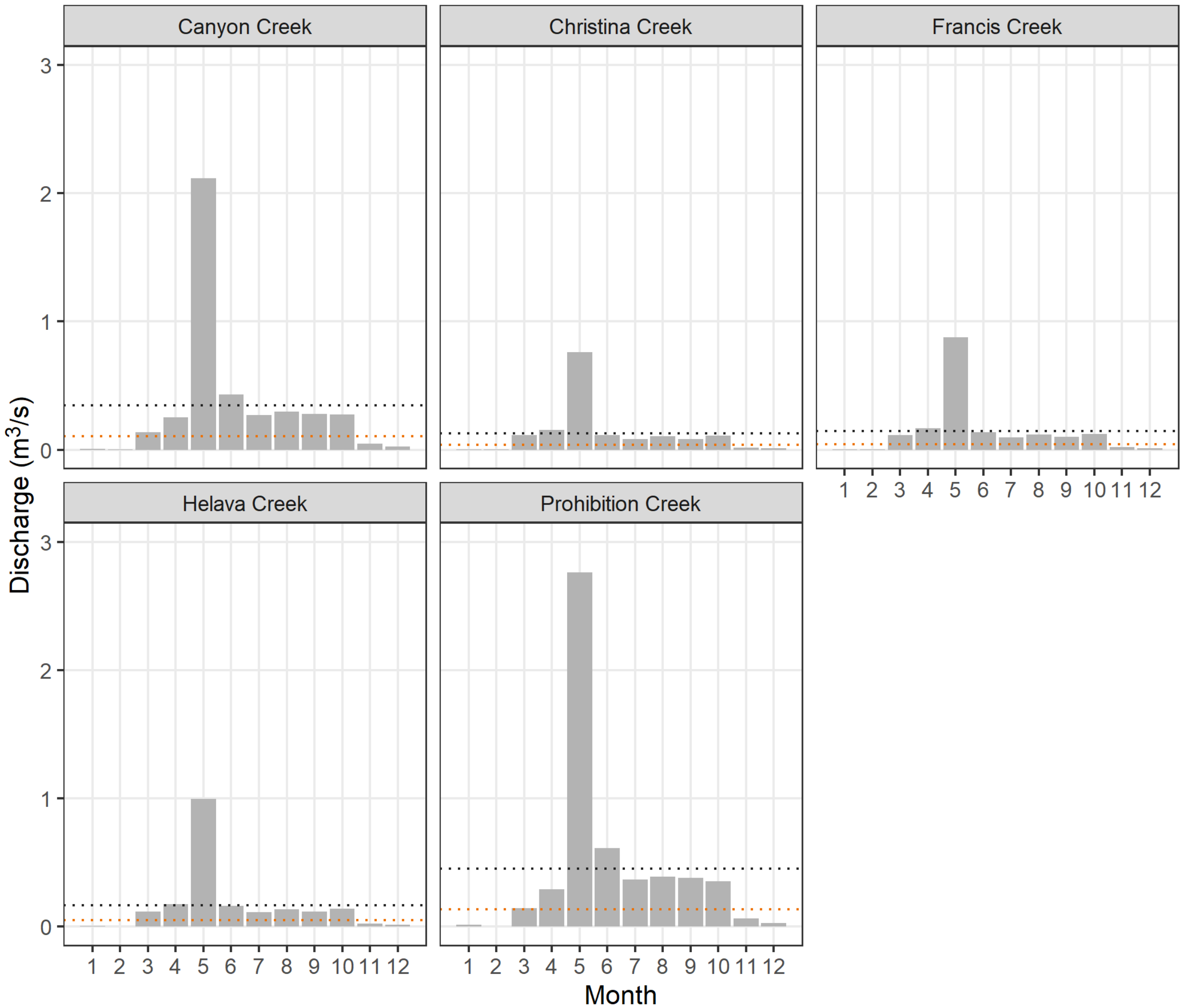
Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a “low probability of detectable impacts to ecosystems” (DFO 2013). Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Predicted monthly average flows for all candidate water sources are presented in Figure 5.2. Predicted flows follow the nival hydrologic regime of the region, i.e., typically a snowmelt dominated freshet in May, declining flows from June through to early fall, and a small increase in flows due to rainfall runoff in October (Section 3). Flows from December through April are presented in Figure 5.2 but were derived from regressions that are not statistically significant and are not likely to be representative of local flows in these months (see Section 6.2 for a discussion).

Historic reports and datasets pertinent to flow at these crossings were also reviewed and are summarized below. Historic observations of flow in winter were of particular interest given the difficulty of predicting winter flows in ungauged catchments in the region.

Cross sections of creeks at proposed water crossings along with summer and flood water levels have been compiled (Tetra Tech 2022). Depth to bed appears to be sufficiently shallow in all candidate creeks that they could freeze to bottom in the absence of winter groundwater discharge.

Figure 5.2 Predicted Monthly Average Discharge for Potential Water Withdrawal Locations Along the Proposed Prohibition Creek Access Road Alignment



NOTES:

(1) The upper dark horizontal lines are MAD for each creek. The lower orange lines are 30% of MAD;

(2) Month=1 represents January; Month=12 represents December.

Table 5.2 Canyon Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	756	76	23,436	2,356	0	0.00	2.20	0.11	0.461	7
Feb	0.00	0	0.000	70	7	1,960	196	0	0.00	2.10	0.55	0.153	5
Mar	0.14	40	0.014	11,879	1,188	368,249	36,828	36,828	0.10	0.40	0.58	0.238	4
Apr	0.25	74	0.025	21,930	2,193	657,900	65,790	65,790	0.10	0.70	0.47	0.089	7
May	2.12	614	0.212	182,924	18,292	5,670,644	567,052	567,052	1.40	3.20	0.86	0.000	13
Jun	0.43	125	0.043	37,348	3,735	1,120,440	112,050	112,050	0.30	0.60	0.95	0.000	13
Jul	0.27	78	0.027	23,208	2,321	719,448	71,951	71,951	0.20	0.50	0.83	0.000	13
Aug	0.30	86	0.030	25,572	2,557	792,732	79,267	79,267	0.20	0.50	0.78	0.000	13
Sep	0.28	81	0.028	24,026	2,403	720,780	72,090	72,090	0.10	0.50	0.77	0.000	13
Oct	0.28	80	0.028	23,878	2,388	740,218	74,028	74,028	0.20	0.50	0.86	0.000	10
Nov	0.05	14	0.005	4,223	422	126,690	12,660	0	0.00	0.20	0.61	0.022	8
Dec	0.02	7	0.002	1,988	199	61,628	6,169	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.35**	**n/a**	**0.035**	**29,817**	**2,982**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**11,004,125**	**1,100,437**	**1,079,056**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.104 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value >0.05).
[a] Calculated as monthly discharge divided by MAD x100.
[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)
(DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
n/a: not applicable.

Table 5.3 Francis Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	N[d]
Jan	0.00	2	0.000	289	29	8,959	899	0	0.00	11.90	0.11	0.461	7
Feb	0.00	0	0.000	6	1	168	28	0	0.00	6.20	0.55	0.153	5
Mar	0.12	78	0.012	9,979	998	309,349	30,938	30,938	0.00	0.50	0.58	0.238	4
Apr	0.17	112	0.017	14,292	1,429	428,760	42,870	42,870	0.00	0.60	0.47	0.089	7
May	0.88	596	0.088	75,744	7,574	2,348,064	234,794	234,794	0.50	1.60	0.86	0.000	13
Jun	0.14	92	0.014	11,703	1,170	351,090	35,100	35,100	0.10	0.20	0.95	0.000	13
Jul	0.10	65	0.010	8,277	828	256,587	25,668	25,668	0.00	0.20	0.83	0.000	13
Aug	0.12	81	0.012	10,302	1,030	319,362	31,930	31,930	0.10	0.30	0.78	0.000	13
Sep	0.10	68	0.010	8,638	864	259,140	25,920	25,920	0.00	0.30	0.77	0.000	13
Oct	0.12	84	0.012	10,667	1,067	330,677	33,077	33,077	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,673	167	50,190	5,010	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,133	113	35,123	3,503	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.15**	**n/a**	**0.015**	**12,725**	**1,273**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,697,469**	**469,737**	**460,297**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.044 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).
[a] Calculated as monthly discharge divided by MAD x100.
[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
n/a: not applicable

Table 5.4 Helava Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	332	33	10,292	1,023	0	0.00	9.20	0.11	0.461	7
Feb	0.00	0	0.000	9	1	252	28	0	0.00	5.20	0.55	0.153	5
Mar	0.12	71	0.012	10,231	1,023	317,161	31,713	31,713	0.00	0.50	0.58	0.238	4
Apr	0.18	106	0.018	15,196	1,520	455,880	45,600	45,600	0.00	0.60	0.47	0.089	7
May	1.00	600	0.100	85,944	8,594	2,664,264	266,414	266,414	0.60	1.80	0.86	0.000	13
Jun	0.16	96	0.016	13,820	1,382	414,600	41,460	41,460	0.10	0.30	0.95	0.000	13
Jul	0.11	67	0.011	9,595	960	297,445	29,760	29,760	0.10	0.20	0.83	0.000	13
Aug	0.14	82	0.014	11,736	1,174	363,816	36,394	36,394	0.10	0.30	0.78	0.000	13
Sep	0.12	70	0.012	10,002	1,000	300,060	30,000	30,000	0.00	0.30	0.77	0.000	13
Oct	0.14	84	0.014	11,973	1,197	371,163	37,107	37,107	0.10	0.30	0.86	0.000	10
Nov	0.02	13	0.002	1,910	191	57,300	5,730	0	0.00	0.10	0.61	0.022	8
Dec	0.01	8	0.001	1,228	123	38,068	3,813	0	0.00	0.50	0.10	0.400	9
Annual Mean	**0.17**	**n/a**	**0.017**	**14,331**	**1,433**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**5,290,301**	**529,042**	**518,448**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.050 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.5 Christina Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	247	25	7,657	775	0	0.00	16.10	0.11	0.461	7
Feb	0.00	0	0.000	4	0	112	0	0	0.00	7.70	0.55	0.153	5
Mar	0.11	87	0.011	9,700	970	300,700	30,070	30,070	0.00	0.50	0.58	0.238	4
Apr	0.15	120	0.015	13,329	1,333	399,870	39,990	39,990	0.00	0.60	0.47	0.089	7
May	0.76	589	0.076	65,612	6,561	2,033,972	203,391	203,391	0.40	1.40	0.86	0.000	13
Jun	0.11	87	0.011	9,687	969	290,610	29,070	29,070	0.10	0.20	0.95	0.000	13
Jul	0.08	63	0.008	6,998	700	216,938	21,700	21,700	0.00	0.20	0.83	0.000	13
Aug	0.10	80	0.010	8,884	888	275,404	27,528	27,528	0.00	0.20	0.78	0.000	13
Sep	0.09	66	0.009	7,313	731	219,390	21,930	21,930	0.00	0.20	0.77	0.000	13
Oct	0.11	84	0.011	9,355	936	290,005	29,016	29,016	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,438	144	43,140	4,320	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,033	103	32,023	3,193	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.13**	**n/a**	**0.013**	**11,133**	**1,113**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,109,821**	**410,983**	**402,695**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.039 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.6 Prohibition Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	1012	101	31,372	3,131	0	0.00	1.50	0.11	0.461	7
Feb	0.00	0	0.000	144	14	4,032	392	0	0.00	1.70	0.55	0.153	5
Mar	0.15	32	0.015	12,522	1,252	388,182	38,812	38,812	0.10	0.30	0.58	0.238	4
Apr	0.29	64	0.029	24,963	2,496	748,890	74,880	74,880	0.10	0.70	0.47	0.089	7
May	2.76	613	0.276	238,844	23,884	7,404,164	740,404	740,404	1.90	4.00	0.86	0.000	13
Jun	0.61	136	0.061	53,055	5,306	1,591,650	159,180	159,180	0.50	0.80	0.95	0.000	13
Jul	0.37	81	0.037	31,703	3,170	982,793	98,270	98,270	0.20	0.60	0.83	0.000	13
Aug	0.39	87	0.039	33,668	3,367	1,043,708	104,377	104,377	0.20	0.70	0.78	0.000	13
Sep	0.38	84	0.038	32,740	3,274	982,200	98,220	98,220	0.20	0.70	0.77	0.000	13
Oct	0.35	78	0.035	30,470	3,047	944,570	94,457	94,457	0.20	0.50	0.86	0.000	10
Nov	0.07	14	0.007	5,588	559	167,640	16,770	0	0.00	0.20	0.61	0.022	8
Dec	0.03	6	0.003	2,358	236	73,098	7,316	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.45**	**n/a**	**0.045**	**38,922**	**3,892**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**14,362,299**	**1,436,209**	**1,408,600**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.135 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

5.2.1 Canyon Creek

At 64 km^2, the watershed area upstream of the Canyon Creek bridge is the second largest of those assessed. Canyon Creek is unique in that a WSC station operated about 0.7 km upstream of the bridge crossing beginning in 2009, with data available until 2018 (Figure 1.1, Table 4.1).

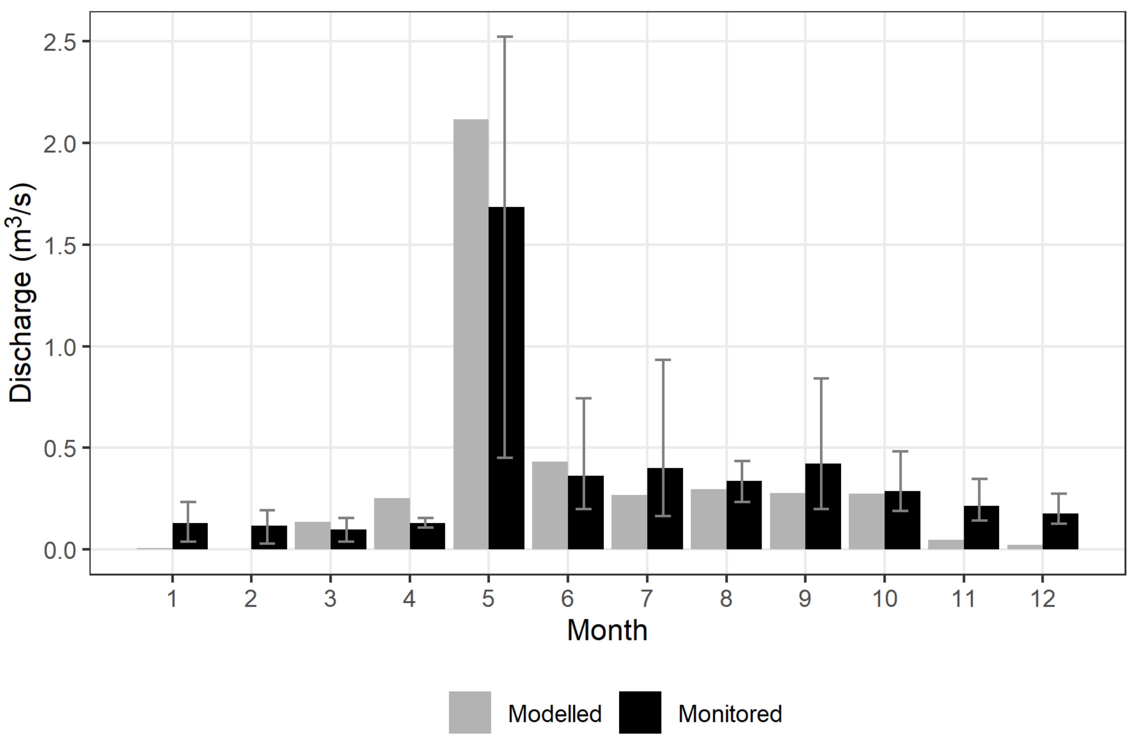
5.2.1.1 Flow Predictions

Flows and water availability predictions for Canyon Creek are presented in Table 5.2.

5.2.1.2 Historic Observations Pertinent to Flow

The Canyon Creek WSC data are highly valuable; therefore, these data are presented, described, and compared to modelled results (Figure 5.3). Flow predictions overlap with monitored flows in all months except in winter when regressions are not statistically significant (Section 5.1). Note that sample sizes for each month of monitored flows range from two in winter to eight to nine for June through to September, and therefore may not represent 'typical' hydrologic conditions, especially in winter.

Figure 5.3 Canyon Creek: Comparison of Monitored to Modelled Discharge (Monthly Averages)



NOTE:
Max/min error bars are presented rather than standard deviation due to low sample sizes in winter.

Predicted flows are lower than monitored flows in winter (Figure 5.3), reflecting the likely presence of groundwater discharge at Canyon Creek. This is supported by field studies on Canyon Creek, for example "*springs that flow year-round have been investigated here*" (Golder Associates 2006), and:

> *"Canyon Creek was noted as having "*open water in winter and a small aufeis area*". On 13-Apr-73, open water and a temperature of 0.5°C was noted, but discharge was not measured. It was noted that "there are several small springs located in the canyon about 3 miles upstream of the [pipeline corridor]."*

5.2.2 Francis Creek

At 24.5 km^2, the Francis Creek catchment has the second smallest of the assessed watersheds (Table 1.1).

5.2.2.1 Flow Predictions

Flows and water availability predictions for Francis Creek are presented in Table 5.3.

5.2.2.2 Historic Observations Pertinent to Flow

Limited historic observations suggest that there is no flow in winter at Francis Creek:

> *"Francis Creek had no winter observations and it was noted that "there are no winter data. It is frozen over in winter and is a doubtful overwintering area." There was no note of springs feeding the creek" (Golder Associates 2006)*

5.2.3 Helava Creek

At 28 km^2, the Helava Creek catchment is the median of those assessed (Table 1.1).

5.2.3.1 Flow Predictions

Flows and water availability predictions for Helava Creek are presented in

Table 5.4.

5.2.3.2 Historic Observations Pertinent to Flow

The same winter observations are available for Helava Creek ad Francis Creek (Golder Associates 2006); winter flow is unlikely.

5.2.4 Christina Creek

At 21 km^2, the Christina Creek catchment is the smallest of those assessed (Table 1.1).

5.2.4.1 Flow Predictions

Flows and water availability predictions for Christina Creek are presented in Table 5.5.

5.2.4.2 Historic Observations Pertinent to Flow

Available manual flow measurements for Christina Creek are summarized in Table 5.7.

Table 5.7 Summary of Historic Instantaneous Discharge Measurements on Christina Creek

Date (dd-mmm-yy)	Instantaneous Discharge (m^3/s)
04-Jun-02	0.04
17-Aug-02	0.1
28-Sep-02	0.07
12-Jul-03	0.01
10-Apr-04	Frozen to bottom

NOTE:
Data were published in Golder Associates (2006), originally from MGP 2004.

In April 2004, the creek was noted to be "*frozen to bottom at location 1.3 km upstream; likely frozen to bottom in winter*". Other assessments also suggest there is little or no flow in winter (Golder Associates 2006):

> "*March 2006, late winter assessments found no water under 0.55 m of ice. Similar, late winter field assessments by McCart and McCart (1982) and MGP (2004) in 1981 and 2002, respectively, also both found the stream frozen to the bed of the watercourse*"
>
> *"Christina Creek has none-to-low storage and a watershed area small enough that if it was solely fed by surface runoff, it would likely freeze to the bottom in winter. Winter observations in 1981, 2002 and 2006 noted the stream was frozen to bottom (McCart and McCart 1982; MGP 2004). There is some evidence of springs on adjacent creeks, but these are small and have not been noted as sufficient to sustain flows during the winter. Although this stream does not appear to provide overwintering fish habitat, because of low water levels it is an unlikely to be a candidate for winter water supply. If under-ice water is present during early winter months, its use for the construction and maintenance of the winter road would have negligible affects* [sic] *on fish habitat. The road crossing is only 0.4 km from the confluence with the Mackenzie River and no fish were recorded in the vicinity of the road crossing during winter months. Therefore, if under-ice water is present, its use for winter road construction and maintenance, should not adversely affect fish habitat at the site or in downstream environments."*

5.2.5 Prohibition Creek

At 86 km^2, the Prohibition Creek catchment is the largest of those assessed (Table 1.1).

5.2.5.1 Flow Predictions

Flows and water availability predictions for Prohibition Creek are presented in Table 5.6.

5.2.5.2 Historic Observations Pertinent to Flow

Limited observations suggest that there is flow in Prohibition Creek in winter:

> *Prohibition Creek was noted as "no overwintering likely". At the winter road, on 10-Apr-73 open water was noted "in patches" with an ice depth of 1.0 m. Approximately 6 km upstream of the winter road, open-water conditions were observed with a water temperature of 7.5°C and a measured discharge of 0.003 m^3/s."* (Golder Associates 2006)

6 Discussion

6.1 Will winter withdrawals be 'low-risk'?

Flow predictions for potential water sources in the PCAR region are statistically significant and relatively well constrained from May to November.

Flow predictions in winter are not statistically significant and winter flow appears to be controlled more by the occurrence of groundwater discharge than strictly by watershed area. Flow predictions for December through April should therefore not be considered accurate.

DFO identifies periods when flows are less than 30% of MAD as periods of 'highest risk' to river ecosystems (Section 4.4) (DFO 2013). Given that winter flow predictions presented here are uncertain and given the potential for water needs in winter for PCAR, a regional assessment of flows in winter was conducted.

Monthly average flows were calculated at regional WSC stations that operate year-round, and %MAD was calculated for each month. Results are presented in Table 6.1.

Regionally, monthly average flows at stations that operate year-round are consistently less than 30% MAD through winter (i.e., November through March-April) (Table 6.1). In addition, low flows at WSC stations that operate seasonally were summarized in Golder (2006) and found to be zero (at stations 10KA005, 10KA006, and 10LD002).

The notable exception is 10KA007, Bosworth Creek near Norman Wells, where monthly discharges are >30% MAD in all months except March (Table 6.1). Bosworth Creek is fed by a series of upstream lakes, including Hodgson (Jackfish) Lake, Edie Lake, and Bandy Lake (Figure 1.1). Winter flows may be fed by these lakes and/or groundwater discharge. The only other exception is 10HC007, Hodson Creek Near the Mouth in November.

Despite these exceptions, it can be said that regionally the winter period is typically a period of 'highest risk' following DFO guidelines. Guidelines state that "*for instances where the cumulative water use reduces the river flow below the level of 30% of the MAD, a rigorous level of assessment should be required to evaluate potential impacts on ecosystem functions that sustain fisheries, including identification of mitigation measures*" (DFO 2013). This rigorous level of assessment (e.g., fish habitat modelling) may be required if winter withdrawals are to be considered along the PCAR alignment (Section 7).

Table 6.1 Monthly Mean Discharge and Percent of Mean Annual Discharge at Regional Water Survey of Canada Stations That Routinely Operate Year Round

Month	Mean Discharge (m^3/s) 10GB005 (344 km^2)	10HC003 (980 km^2)	10HC007 (303 km^2)	10HC008 (1030 km^2)	10KA006 (60 km^2)	10KA007 (125 km^2)	10KD009 (64 km^2)	10LA004 (852 km^2)	10LB006 (441 km^2)	Percent of MAD 10GB005 (344 km^2)	10HC003 (980 km^2)	10HC007 (303 km^2)	10HC008 (1030 km^2)	10KA006 (60 km^2)	10KA007 (125 km^2)	10KD009 (64 km^2)	10LA004 (852 km^2)	10LB006 (441 km^2)
Jan	0.000	0.297	0.247	0.418	0.000	0.236	0.000	0.001	0.000	0	5	14	5	0	36	0	0	0
Feb	0.000	0.228	0.190	0.346	0.000	0.201	0.000	0.000	0.000	0	4	11	4	0	31	0	0	0
Mar	0.000	0.200	0.157	0.270	0.000	0.169	0.000	0.000	0.000	0	3	9	3	0	26	0	0	0
Apr	0.210	0.423	0.829	2.680	0.197	0.321	0.186	0.022	0.000	19	7	48	32	47	49	91	1	0
May	7.192	30.648	8.094	42.376	2.623	3.125	1.529	19.515	4.865	651	528	468	511	625	475	752	571	523
Jun	2.058	15.910	2.435	11.616	0.831	1.002	0.127	14.201	2.762	186	274	141	140	198	152	63	416	297
Jul	1.232	4.892	2.471	10.980	0.288	0.581	0.155	1.831	1.180	112	84	143	132	69	88	76	54	127
Aug	1.243	5.883	2.215	12.056	0.376	0.514	0.080	1.120	0.388	113	101	128	145	90	78	40	33	42
Sep	0.861	6.936	1.883	12.386	0.438	0.640	0.235	2.377	1.079	78	119	109	149	104	97	116	70	116
Oct	0.424	2.814	1.222	4.592	0.232	0.509	0.111	1.752	0.789	38	49	71	55	55	77	55	51	85
Nov	0.036	0.979	0.633	1.292	0.043	0.328	0.011	0.172	0.094	3	17	37	16	10	50	6	5	10
Dec	0.002	0.485	0.375	0.555	0.008	0.264	0.006	0.008	0.001	0	8	22	7	2	40	3	0	0
MAD	**1.105**	**5.808**	**1.729**	**8.297**	**0.420**	**0.658**	**0.203**	**3.417**	**0.930**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTE:
Cells are shaded grey where monthly discharge is less than 30% of MAD. Regional stations where winter flows were not routinely monitored year-round have been excluded (10KA003, 10KA005, 10KA008, 10KA009).

6.2 What volumes of water are available for withdrawal?

Table 5.2 through Table 5.6 present monthly and annual water volumes available for low-risk withdrawal, using criteria from DFO (2013); i.e., 10% of monthly average flow in months where discharge is greater than 30% of MAD. This is an estimate of the maximum monthly and annual volumes of water available for low-risk withdrawal. On average, annual water available for low-risk withdrawal ranges from a low of 402,695 m^3 at Christina Creek (Table 5.5) to 1,408,600 m^3 at Prohibition Creek (Table 5.6) during the months of May to October only. These volumes are useful as a basis for water license applications and will need to be verified by monitoring/measuring flows in the field (Section 7). Note that about half of the annual water volume available for low-risk withdrawal occurs in only one month: May. Monthly volumes available for low-risk withdrawal are presented in tables Table 5.2 through Table 5.6.

6.3 Is it justifiable to include Water Survey of Canada stations with relatively small datasets for flow predictions?

Several stations local to the PCAR proposed alignment have relatively small datasets due to limited periods of operation and/or seasonal operation (i.e., 10KA003, 10KA005, 10KA008, and 10KA009; Figure 4.1). It was decided to include months with greater than 92 measurements for each station given their proximity to the proposed alignment and the paucity of long-term regional flow data. Statistics derived from small populations might not be indicative of typical conditions, e.g., average flows calculated here might not be indicative of overall average conditions at these sites. For example, a minimum of 20 years of data are recommended for instream flow analyses (DFO 2013).

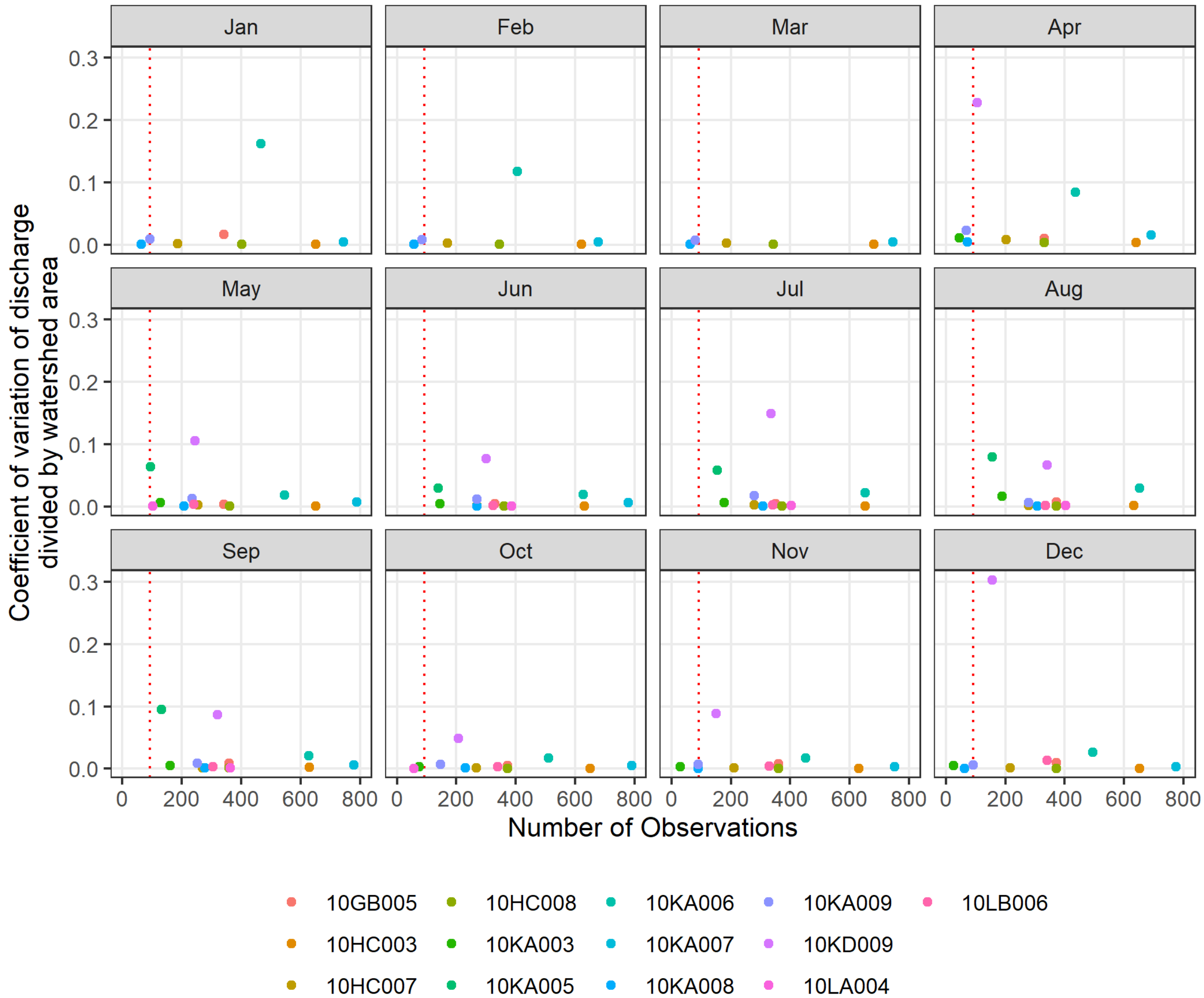
To assess whether stations with small numbers of observations in each month are statistically anomalous relative to stations with large numbers of observations, the monthly coefficient of variation of average flow was divided by basin area. The coefficient of variation is the standard deviation (68% of a normal distribution fall within +/- 1 standard deviation) divided by the mean and was chosen because it normalizes the effects of basin size on discharge. The statistic was further normalized by dividing by basin area.

Stations with small sample sizes might be expected to have smaller variability of flows than stations with larger sample sizes, but this does not consistently occur (Figure 5.1). This shows that the variability of flow in each month is typically not affected by relatively small sample sizes. Instead, Figure 5.1 shows that flow variability is more controlled at the station/site level (e.g., 10KD009 in most months, 10KA006 in January and February).

While the minimum number of observations in a month was set to 92, most months have many more observations than this. For example, the 25th percentile of sample size is a minimum of 120 in November and greater than or equal to 270 for 6 months of the year. Most data points on the left-hand sides of the vertical red lines in Figure 6.1 are in winter months. Any effects of small sample size would be greatest in winter when regressions are not statistically significant.

Given the value of data from stations proximal to PCAR, the methods described above are considered appropriate with the caveat that flow predictions provided here are representative of flows at the times where WSC monitoring occurred.

Figure 6.1 Effects of Sample Size on Flow Variability



NOTE:
Vertical dashed lines are at n=92, the minimum number of observations allowed in each month.

7 Conclusions and Recommendations

Measurements of instantaneous discharge should occur at the time of withdrawal. These flow measurements should be compared to mean annual discharge for each creek to ensure instantaneous flows are <10% of MAD.

Annual volumes of water predicted to be available for withdrawal within DFO's (2013) criteria range from about 403,000 m^3 for Christina Creek to about 1,409,000 m^3 for Prohibition Creek. About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February.

This assessment has shown that the three creeks along the proposed PCAR alignment with the smallest watersheds (Francis, Helava, and Christina) are unlikely to flow for at least part of the winter. Furthermore, creeks that do flow over winter (Canyon and Prohibition) are unlikely to be classified as 'low-risk' at these times, i.e. flows are likely to be less than 30% of mean annual discharge (DFO 2013).

The 'low' risk period varies regionally. Regression modelling suggests this period is approximately March to October along the PCAR alignment, but uncertainties are high in predicted flows over winter. Regionally, this "low-risk" period spans about April or May to October.

If water is required over winter, potential solutions include (a) withdrawal outside of these periods and storing water for winter, (b) supplying supplemental information/studies (see below), and/or (c) offsetting withdrawals.

Pertinent supplemental information for winter PCAR withdrawals would be defined by DFO but could take the form of the creation of a fish periodicity table, establishment of baseline hydrological data, preparation of a detailed fish habitat modelling, preparation of a reconnaissance-level fish and fish habitat impact assessment, issuance of withdrawal rate limits, issuance of limited licence terms, and/or requirement to monitor water use (FLNRORD 2022).

The rigor of additional studies required depends on the timing and volume of water required. If water is required in spring and to a lesser extent autumn, then additional site-specific flow measurements would be beneficial, given (a) flow predictions are not statistically significant in these months, (b) the months where discharge is greater than 30% varies regionally, and (c) monthly averages have been provided here, and flows will vary within each month and year.

If withdrawals over winter are required, additional flow measurements on Prohibition creek could help define the timing and magnitudes of flows over winter. Additional winter investigations at Francis, Helava, and Christina Creeks would help confirm previous assessments that these creeks freeze to bottom in winter.

8 Literature Cited

DFO (Fisheries and Oceans Canada). 2013. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. Canadian Science Advisory Secretariat Science Advisory Report 2013/017.

ECCC (Environment and Climate Change Canada). 2022a. Canadian Climate Normals. http://climate.weather.gc.ca/climate_normals/index_e.html.

ECCC (Environment and Climate Change Canada). 2022b. Environment Canada Data Explorer. HYDAT Database (April 2022 database).

FLNRORD (Ministry of Forests, Lands, Natural Resource Operations and Rural Development). 2022. Ministry of Environment and Climate Change Strategy. Environmental Flow Needs Policy.

GNWT (Government of the Northwest Territories). 2009. Ecological Regions of the Northwest Territories–Taiga Plains. *Ecosystem Classification Group. Government of Northwest Territories. Department of Environment and Natural Resources.*

GNWT (Government of Northwest Territories). 2022. NWT State of the Environment Report. https://www.enr.gov.nt.ca/en/services/nwt-state-environment-report/13-state-permafrost.

Goetz, Jon, Sam Albers and Robin Pike. 2018. Creating reproducible approaches for streamflow data analysis using the 'tidyhydat' and 'fasstr' R packages. In: *The 71st CWRA National Conference*. 71st Canadian Water Resources Association National Conference.

Golder Associates. 2006. Assessment of winter conditions at potentail water extraction sources along the Mackenzie Valley Winter Road. Sahtu Region, NWT. Submitted to Department of Transportation, GNWT.

Golder Associates. 2015. Central Mackenzie surface water and groundwater baseline assessment.

K'alo-Stantec Limited. 2020. Prohibition Creek Access Road. Fish and Fish Habitat Assessment Report. Prepared for Department of Infrastructure, Government of Northwest Territories.

Kokelj, S V. 2001. Hydrologic overview of the Gwich'in and Sahtu Settlement Areas. Water Resources Division Indian and Northern Affairs Canada. Yellowknife, Northwest Territories. Canada.

MGP (Mackenzie Gas Project). 2004. Environmental Impact Statement for the Mackenzie Gas Project. Volume 3: Biophysical Baseline. Section 7: Fish and Fish Habitat. Prepared by Mackenzie Project Environmental Group for Imperial Oil Resources Ventures Limited.

Natural Resources Canada. 2022. National Hydro Network - NHN - GeoBase Series. https://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977.

R Core Team. 2022. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Stevens. 2022. Stevens, Aileen. Personal communication. Teleconference meeting GNWT-INF and K'alo-Stantec January 21, 2022.

Tetra Tech. 2021. Mackenzie Valley Highway Prohibition Creek Access Road Hydrotechnical

Assessments.

Tetra Tech. 2022. Mackenzie Valley Highway Prohibition Creek Access Road Hydrotechnical Design GNWT Service Contract SC-5078.

Wang, Tongli, Andreas Hamann, David L Spittlehouse and Trevor Q Murdock. 2012. ClimateWNA—high-resolution spatial climate data for western North America. *Journal of Applied Meteorology and Climatology* 51, Nr. 1: 16–29.

Zhang, Zhenxing, John W Balay and Can Liu. 2020. Regional regression models for estimating monthly streamflows. *Science of the Total Environment* 706: 135729.

9 Closure

If you have any questions, please do not hesitate to contact the undersigned.

Respectfully Submitted,

K'ALO-STANTEC LIMITED

Prepared by:

Ted Lewis. Ph.D., P.Ag.
Senior Hydrologist
Mobile: 604-356-7596
Ted.Lewis@stantec.com

Reviewed by:

Ali Naghibi Ph.D., P.Eng.
Senior Water Resources Engineer
Direct: 778 328-1028
Mobile: 236 878-6147
Ali.Naghibi@stantec.com

Approved by:

Erica Bonhomme, M.Sc., P.Geo.
Principal, Environmental Services Northern Canada
Tel: 867-445-7388
Erica.bonhomme@stantec.com