CREE DEVELOPMENT CORPORATION

LA GRANDE ALLIANCE

PRE-FEASIBILITY STUDY – PHASES II & III – TRANSPORTATION INFRASTRUCTURE

TECHNICAL NOTE 14

CIVIL ENGINEERING STRUCTURES

FINAL VERSION

DATE: MARCH 25, 2024

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2024-03-27

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EXECUTIVE SUMMARY

This Technical Note 14 is intended to describe the proposed civil engineering structures required for the proposed roadway and railway alignments described in both Technical Note 11 - Roads and Technical Note 12 - Rails. The design of railway civil structures is mainly based on the AREMA regulations. The design of roadway civil structures is mainly based on the MTQ road and bridge design standards and CSA-S6 regulations and criteria. The civil structures were developed based on the same road and rail key factors:

- Respect, as much as possible, the natural site topography (mountains and plains);
- Consider the overall geology of the study area, including the locations of aggregate material deposits;
- Avoid, as much as possible, lakes and rivers; minimize the length of crossings and bridges where these are unavoidable.
- Avoid, as much as possible, existing, and projected Protected Areas; minimize encroachment and/or provide mitigation measures where these are unavoidable.
- Minimize crossing and impacts on caribou migration corridors.
- Avoid, as much as possible, areas of cultural significance such as areas currently used by Cree land users, archeological sites, etc.; minimize encroachment and/or provide mitigation measures where these are unavoidable.
- Propose, wherever applicable, alignment variants that could offer added value, such as:
  - Locations that minimize environmental footprint;
  - Locations that minimize construction cost;
  - Locations that minimize the impacts on existing camps and facilities;
- Remain, as much as possible, in close proximity to existing or proposed roads;
- Remain within 1 km corridor centered on existing or proposed roads when surrounded by recognized Protected Areas on both sides;
- Minimize the number of times the railway crosses existing or proposed roads.

The foreseen required civil engineering structures for La Grande Alliance proposed transportation infrastructures are presented in the table below:

Table Summary Table

INFRASTRUCTURE	TOTAL LENGTH	TOTAL BRIDGES NUMBER	MAJOR BRIDGES	TOTAL BRIDGES LENGHT	% OF ROAD OR RAIL ON A BRIDGE	NUMBER OF BRIDGE PER 10 KM
Route 167: 2 Upgrade segments	106 km 97 km	1*	-	n/a	n/a	n/a
Route 167: Extension to Trans-Taiga	172 km	23	2	0.5 km	0.5 %	1
Roadway: La Grande to Whapmagoostui/Kuujjuarapik	207 km	62	11	2 km	1 %	3
Railway: Rupert to La Grande	340 km	36	8	2.6 km	0,8 %	1
Railway: La Grande to Whapmagoostui/Kuujjuarapik	219 km	66	27	9.4 km	4 %	3

*Note *: Rehabilitation of one existing bridge by MTQ in the next 5 years*

BRIEF STATIONS EXPLANATION

A station indicates the relative position along the horizontal centerline of a linear structure. In our specific case, the linear structures are the roads. A starting station is set at a specific location and the linear distance along the centerline is added to that starting station. Stations are usually presented as follows:

KKK+MMM

Where:

— K: Kilometers

— M: Meters

For examples:

1. If the starting station was set at 000+000, station 000+001 would be located on the centerline 1 meter away from the starting station.
2. If the starting station was set at 000+000, station 000+020 would be located on the centerline 20 meters away from the starting station.
3. If the starting station was set at 000+000, station 000+300 would be located on the centerline 300 meters away from the starting station.
4. If the starting station was set at 000+000, station 004+000 would be located on the centerline 4 kilometers away from the starting station.
5. If the starting station was set at 000+000, station 050+000 would be located on the centerline 50 kilometers away from the starting station.
6. If the starting station was set at 000+000, station 600+000 would be located on the centerline 600 kilometers away from the starting station.
7. If the starting station was set at 000+000, station 324+678 would be located on the centerline 324 kilometers and 678 meters (324 678 m in total) away from the starting station.
8. If the starting station was set at 100+000, station 324+678 would be located on the centerline 224 kilometers and 678 meters (224 678 m in total) away from the starting station.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLES

FIGURES

TABLE OF CONTENTS

APPENDICES

1 INTRODUCTION

This Technical Note 14 is intended to describe the proposed civil engineering structures foreseen to be included in the La Grande Alliance Project infrastructures, namely:

PHASE I (1-5 YEARS)[1] (THE PHASE I IS STUDIED BY OTHERS)

- **Roadway: Upgrading and paving of the community access roads** for Waskaganish, Eastmain, Wemindji and Nemaska.
- **Railway: Matagami to Rupert**

  A proposed railway line following, as much as possible, that of the Billy-Diamond Highway (BDH) starting at the town of Matagami towards km 257 of the BDH (Rupert River Bridge).
- **Railway: Grevet to Chapais**

  A return to service for the railway line between Grevet (Lebel-sur-Quévillon) and Chapais (approximate distance of 147 km).

PHASE II (6-15 YEARS)

- **Railway: Rupert to La Grande**

  A proposed railway alignment following, as much as possible, that of the Billy-Diamond Highway (BDH) starting at km 257 (after the Rupert River Bridge, which is the junction point with the railway alignment developed by the Phase I Consultant) all the way to La Grande River. The Phase II railway alignment extends over an approximate distance of 340 km.
- **Route 167: Upgrade & extension to Trans-Taiga**

  Upgrade and paving the section from the Mistissini community access road to the Stornoway Renard Mine access road over an approximate distance of (±204 km);

  North extension to connect with the Trans-Taiga Road near km 408, over an approximate distance of 172 km.
- **Roadway: La Grande to Whapmagoostui/Kuujjuarapik**

  A proposed road corridor connecting Chisasibi community's access road and Whapmagoostui/Kuujjuarapik, over 207 km.

PHASE III (16-30 YEARS)

- **Railway: La Grande to Whapmagoostui/Kuujjuarapik**

  A proposed railway alignment extending from the Phase II railway alignment, and which follows, as much as possible, the proposed roadway alignment leading to Whapmagoostui/Kuujjuarapik developed during this study by WSP. The Phase III railway alignment extends over an approximate distance of 219 km.
- **Harbour at Whapmagoostui/Kuujjuarapik**

  A proposed seasonal Harbour for shallow draft vessels/boats (~6 m water depth) along the Whapmagoostui/Kuujjuarapik coastline between the mouth of Great Whale River and the entrance of the Manitounuk Strait.

This report is a complement of both Technical Notes 11 - Roads and 12 - Rails and describes the civil engineering infrastructures needs for the roadway and railway alignments described in these reports.

[1] All dates indicated herein are hypothetical and would begin as of the start of the construction period. This therefore does not include all pre-project phases, most notably the Environmental and Social Impact Assessment, that would be required if the infrastructures are pursued.

2 CIVIL STRUCTURES DESIGN CRITERIA

All the required civil engineering structures must comply with the applicable laws and regulations (refer to Technical Notes 11 - Roads and 12 - Rails). The design approach is also based on comparable projects (refer to Technical Note 1) and construction challenges that are related to the northern and isolated project specific nature.

In addition to parameters considered as standard when it comes to road design parameters, the specific approach of La Grande Alliance has strongly influenced design decisions. Indeed, the concept design work fully considers the significant socio-environmental datasets compiled from a wide variety of sources including knowledge from the Cree land users that had been engaged prior to the design stage to identify areas that would conflict with their own land use. The list below provides examples of how information was considered in this highly innovative approach:

- Respect, as much as possible, the natural site topography (mountains and plains);
- Consider the overall geology of the study area, including the locations of aggregate material deposits;
- Avoid, as much as possible, lakes and rivers; minimize the length of crossings and bridges where these are unavoidable.
- Avoid, as much as possible, existing and projected Protected Areas; minimize encroachment and/or provide mitigation measures where these are unavoidable.
- Minimize crossing and impacts on caribou migration corridors.
- Avoid, as much as possible, areas of cultural significance such as areas currently used by Cree land users, archeological sites, etc.; minimize encroachment and/or provide mitigation measures where these are unavoidable.
- Propose, wherever applicable, alignment variants that could offer added value, such as:
  - Locations that minimize environmental footprint;
  - Locations that minimize construction cost;
  - Locations that minimize the impacts on existing camps and facilities;
- Remain, as much as possible in close proximity to existing or proposed roads;
- Remain within 1 km corridor centered on existing or proposed roads when surrounded by recognized Protected Areas on both sides;
- Minimize the number of times the railway crosses existing or proposed roads.

2.1 RAILWAY CIVIL STRUCTURES

As shown on Table 2-1 below, the design of civil structures required for the railway alignment is based on the AREMA regulations (American Railway Engineering and Maintenance-of-Way Association). All railway structures must respect AREMA manuals for the design and the Transport Canada requirement for the railway.

The railway civil structures must respect the *Regulation respecting the sustainable development of forests in the domain of the State* (RADF) and special loading that can be planned in the design.

Table 2-1 Principal Railway Design Criteria – Civil Structures

DESIGN CRITERIA	VALUE
Design Speed	80 mph passenger, 60 mph freight
Load	Cooper E90
Maximum Gradient	1.5% (compensated), 2.0% (over maximum length of 500 m)
Rail	136 lb RE

Water crossing distance is measured between water bank and does not include the approach. All water crossings over 10 m in length are considered as bridges regardless the clearance under the bridge or the potential fill embankment and are therefore described as a Civil Engineering Structure in the next section below. In the determination of all water crossing, the presence of potential wetland was taken into account. All other structures less than 10 m in length are considered as railway culverts for estimation purposes. Also, the study considers one (1) culvert every 500 m of track for drainage regardless on the topography. Also, where the fill embankment above natural ground level was greater than 12 metres and the site cannot accommodate major fill, it was considered that a civil structure was required.

For these structures, steel spans or concrete prefabricated elements must be preferred to minimize the need for cast-in-place concrete which may be an issue in the north. Corrugated galvanised steel plate or prefabricated concrete culverts for shorter structures may also be used in some cases to ensure easier construction where environmental regulations can be met. Prefabricated bridge or bridge components and accelerated bridge construction (ABC) techniques should be used to minimize the time required to install.

The criteria for fish passage of Fisheries and Oceans Canada and of the RADF have not been integrated in the design. Care should be taken in the further phases of the project to gather the required information (necessity to ensure fish passage, stream slopes, railway profiles, etc.) and to adapt the design for fish passage, where applicable.

2.2 ROADWAY CIVIL STRUCTURES

As shown in Table 2-2 below, the design of civil structures required for the roadway alignment is based on the MTQ road and bridge design standards *Tome III – Ouvrages d’art* from MTQ’s *Normes sur la conception des ouvrages d’art (MTQ, 2021a),* and *CSA-S6:19 regulations and criteria*. As per discussions held with Hydro-Quebec in Spring 2022, there are no special load request to take into consideration for the proposed roads extensions (compare to the existing BHD based a 500 tons design load criteria).

The roadway civil structures must respect the *Regulation respecting the sustainable development of forests in the domain of the State* (RADF) and special loading that can be planned in the design.

Water crossing distance is measured between water banks and does not include the approach. All water crossings over 4.5 m in length are considered as bridge structures for the estimation purpose and are therefore described in the next section below. All other structures less than 4.5 m in length are considered as roadway culverts and are described within Technical Note 11. Note that those definitions of bridges and culverts are used to quantify the need for different types of structures within this study. More detailed hydraulic, environmental, and topographic studies will be required to confirm the type of structure at each location.

In determining the bridge spans that will be required for this road segment, the following elements have been considered in order to define the length of the crossings:

- Length required according to the interpretation of aerial photos to determine the width of the watercourses to be crossed;
- Required length according to the presence of presumed wetland;
- At this stage of the study, the worst-case scenario was considered for the determination of crossing lengths.

It should be noted that, during the Study, the proposed roadway of La Grande to Whapmagoostui/Kuujjuarapik was moved to the feasibility stage and thus led to preliminary additional hydrologic and hydraulic analysis. As such additional elements have been considered in order to define the length of those crossings:

- Preliminary determination of the full river flows according to the environment team;
- Length required according to preliminary hydraulic flows;
- The criteria for fish passage of Fisheries and Oceans Canada and of the RADF have not been integrated in the design. Care should be taken in the further phases of the project to gather the required information (necessity to ensure fish passage, stream slopes, roadway profiles, etc.) and to adapt the design for fish passage, where applicable.

For the watershed delineation, the Topographic Data of Canada (CanVec Series) was used. This data represents a recollection of vectorial data representing the following (Government of Canada, consulted in 2023):

- Constructions and Land Use in Canada - Manmade Features;
- Lakes, Rivers and Glaciers in Canada - Hydrographic Features;
- Administrative Boundaries in Canada - Administrative Features;
- Mines, Energy and Communication Networks in Canada - Resources Management Features;
- Wooded Areas, Saturated Soils and Landscape in Canada - Land Features;
- Transport Networks in Canada - Transport Features;
- Elevation in Canada - Elevation Features.

The CanVec also provides a numerical digital elevation model (DEM). This DEM was used to establish the watershed characteristics (area, average slope, land cover, runoff coefficient, etc.) for all stream crossing structures.

Additionally, a LiDAR band of approximately 1 km wide, following the proposed trace of the road was available and has been used for more specific hydraulic data requirements (stream slope, width, elevation of the water surface, etc.).

At this stage, it is considered that standard steel-wood bridges are preferred, when possible, for their ease of construction and prefabrication for this northern construction. However, a life cycle analysis shall be performed at a later stage of the study to confirm this approach. Corrugated galvanised steel plate or prefabricated concrete culverts may also be used in some cases to ensure easier construction where environmental regulations can be met.

Table 2-2 Principal Roadway Design Criteria – Civil Structures

DESIGN CRITERIA	VALUE
Design load	CL-625
Minimal driveable width	7.3 m (1 lane)
Specific to the proposed roadway of La Grande to Whapmagoostui/Kuujjuarapik	
Design Flow	The return period for the design flood for bridges is 50 years, and for culverts, 25 years for a “national” road (MTQ, 2022). At this stage of the project, the design return period was selected as 50 years for all stream crossing structures.
Climate change	Base data increment applied for climate change consideration: — For watershed with areas of less than 60 km², the increase should be of 18% for the region “Ailleurs au Québec”, which includes the region of the study. — For watershed areas between 60 and 400 km², the increase should be of 15%; and — For watershed areas above 400 km², the increase should be of 15% for the region “C-Région nord du Québec” which includes the region of the study.
Culverts Vertical clearance	The flow must be at free surface, hence the vertical clearance must be higher than zero cm for the selected design flood. This means that the water level elevation upstream and downstream of the culvert must be lower than the soffit elevation of the culvert at both the inlet and the outlet
Bridges Vertical clearance	Preliminary bridge opening has been determined to be of a minimum of 80% of the bankfull width, to which is added the width of the typical riprap protection (300-500 mm on a width of 800 mm).
Rip rap protection	This is essential to ensure the durability of the entire structure and to avoid deterioration such as scour, erosion, uplift and distortion faults generally observed at the entrance and at the exit of such structures. The sizing and thickness of the rockfill to be put in place at the ends of the structure.
RADF regulations	Articles 98, 102 and 103 could impact the sizing of the culverts
Type of culverts	Circular and rectangular culverts have been selected at this stage of the study. For circular culvert, the maximum culvert diameter that has been proposed is of 1200 mm. For culvert of less than 1200 mm, only a circular culvert has been proposed, whereas for culverts of a diameter of 1200 mm, a rectangular culvert has been proposed as well. Finally, when a circular culvert of 1200 mm of diameter was not enough to pass the design flow, a rectangular culvert has been proposed. At some location, more than one rectangular culvert will be required.

2.3 HYDROLOGY METHODOLOGY FOR ROADWAY

Hydrological calculations have been undertaken following three different methods. The selection of the method was based on the watershed's area:

— the rational method was used for watershed with areas lower than 25 km²;
— the SCS (Soil Conservation Service) method was used for watershed with areas between 25 km² and approximately 800 km²; and
— the frequency analysis mixed with a watershed transfer was used for the remaining watersheds.

It is to be noted that the upper limit of applicability of the SCS method (800 km²) is based on the lower limit of applicability of the frequency analysis and watershed transfer. The latter is determined by the catchment area of the nearby hydrometric stations that can be applicable for watershed transfer. Catchment area ratios between the hydrometric station and the study site should be between 0.5 and 2.0 (Anctil, 2005).

The results of the hydrological calculations are shown in appendix A.

2.3.1 RATIONAL METHOD

The design flows for crossings structure with watershed areas under 25 km² were calculated using the rational method, as described in the *Manuel de Conception des ponceaux* (MTQ, 2021a). This method has been used for 94 crossing structures out of 119.

Two meteorological stations were considered as potential candidates for the calculation of the Intensity-Duration-Frequency (IDF) to be used as part of the rational method. The two stations are located at each end of the proposed road.

Table 2-3 Specifications of the weather stations taken into consideration

ID	NAME	RECORDED YEARS AVAILABLE	LATITUDE	LONGITUDE	I[1] (mm/h)
7093716	La Grande Riviere A	1977-2015	53.63	-77.70	41.99
7103539	Kuujjuarapik	1969-2017	55.37	-77.57	35.81

1 This intensity is the 1:50 years return period for a precipitation event of 1 hour

The IDF curves that were retained as part of this study are the one associated with the station 7093716 of La Grande Riviere Airport as it produces intensity rates that are slightly higher and thus more conservative. It is to be noted that a sensitivity analysis was performed on the data recorded by the 7103539 stations of Kuujjuarapik and that the results of the rational method were slightly but not significantly lower.

2.3.2 SCS METHOD (SOIL CONSERVATION SERVICE)

Watersheds with catchment areas between 25 km² and approximately 800 km² fall out of the limit of applicability of the rational method. For basins with watershed areas of more than 25 km² and for which no surrounding hydrometric station allows a frequency analysis to be carried out, the SCS curve number method based on the USDA Soil Conservation Service (SCS) model was used. This method was used for 23 crossing structures out of 119.

The SCS curve number method is a simple model to estimate runoff flows associated with rain fall events. This model estimates runoff based on a rainfall intensity and on the Curve Number (CN), which is a proxy that includes antecedent humidity conditions, soil hydrological classification and land use. It is based on the concept that the total precipitation falling on a basin can be separated into three components: direct runoff, maximum potential water retention in the soil and initial losses.

2.3.3 FREQUENCY ANALYSIS AND WATERSHED TRANSFER

The frequency analysis is a method using statistical regressions to estimate the flood flows of a watercourse based on the recorded data. Once the flow values have been calculated for different return periods, the values can be adjusted to a specific site using a watershed transfer as shown in equation 1.

$$Q_2 = Q_1 \left[\frac{A_2}{A_1}\right]^a$$

Where :

- Q_1 = Design flow at site 1 (namely, the hydrometric station site);
- Q_2 = Design flow at site 2 (namely, the crossing structure site);
- A_1 = Watershed area at site 1 (namely, the hydrometric station site);
- A_2 = Watershed area at site 2 (namely, the crossing structure site);
- a = Regional exposant (equal to 1 unless there is available data)

The design flows of crossing structures PK159 (Roggan River) and PK337 (Great Whale River) were calculated using a frequency analysis of the maximum daily flows recorded respectively at hydrometric stations 093804, located on the Denys River, and 093801, located on the Great Whale River. For PK 159, the hydrometric station 093302 was also considered based on the similarities of the watershed (areas and hydrographic network) but was rejected based on the limited availability of recordings (13 years). For PK 337, the hydrometric station 093803 was also considered because it was located on the Great Whale River very close to the study site. It was rejected because it contained a limited number of recordings.

The HYFRAN software (INRS-ÉTÉ, 2002), developed by the National Institute of Scientific Reasearch, was used to perform the frequency analysis from the hydrological series of maximum daily averaged floods. The distribution laws most commonly used for the analysis of extreme flood event frequencies, according to the National Research Council of Canada (NRC, 1990), are: Pearson type III, Gumbel, Log-Normal and the general law of extreme values (GEV). In this case, the generalized extremum law (GEV) presents the best fit to the sample for the Denys station and the Log-Normal law presents the best fit to the sample for the Great Whale River. They were therefore retained to establish the characteristics of the floods. A watershed transposition was then performed to adjust the calculated flows to the sites under study.

Table 2-4 Characteristics of the hydrometric stations taken into consideration for the crossing structures PK159 et PK337

Nº OF THE STATION	NAME	RECORDED YEARS AVAILABLE	CATCHMENT AREA (km^2)	COORDINATES	
				Lat	Long
093804	Denys	1960 – 1993	4660	55° 1'	-77° 4'
093801	Great Whale River	1961 – en cours	32469	55° 14'	-76° 59'
093302	Anistuwach	1981 – 1993	4370	54° 25'	-78° 48'
093803	Great Whale River	1958 – 1970	43200	55° 17'	-77° 35'

2.4 HYDRAULIC METHODOLGY FOR ROADWAY

2.4.1 MODELLING APPROACH

The culverts were sized using HY-8 software. The HY-8 Culvert Hydraulic Analysis Program software is a software developed by the Federal Highway Administration of the U.S. Department of Transportation. It allows the simulation of the hydraulic behavior of culverts, particularly in terms of inlet and outlet speed, headlosses and vertical clearance at the inlet and at the outlet. It also calculates the flow regime and the backwater curve between the water levels upstream and downstream of the culvert. Finally, it allows for the determination of the inlet and outlet control depths and analyses the type of control under which the culverts is for different flow regimes.

At this stage of the study, and considering the limited data available, the following parameters have been selected to facilitate the hydraulic calculations:

- The bankfull width has been determined by photo-interpretation;
- The banks have a side slope of 2H: 1V;
- The Manning coefficient of the stream bed is 0.035;
- The culverts are either circular or rectangular, made out of concrete, are straight and have an inlet coefficient of 0.2 for circular culverts and 0.4 for rectangular culverts;
- The culverts are 24 m long;
- The slope downstream of the culvert has been determined to be equal to that of the watercourse downstream (based on the LiDAR survey);
- The culvert are installed at approximately the same slope as the watercourse;
- No burying of the culvert's sill has been considered for the culvert.

Results of the hydraulic calculations are shown in appendix B.

3 PROPOSED CIVIL ENGINEERING STRUCTURES

As mentioned in the previous sections, the identification of water crossing structure is based on the following methodology:

— Interpretation of aerial photos;
— Interpretation of topographic maps;
— Study of the proposed railway/roadway alignments in plan and in profile;
— Helicopter reconnaissance for the proposed road between La Grande and Whapmagoostui/Kuujjuarapik;
— Preliminary hydrological and hydraulic studies for the proposed road between La Grande and Whapmagoostui/Kuujjuarapik.

This approach will need to be refined and detailed in the next phases of the development of the proposed infrastructures based on additional further studies, namely for each civil engineering structures:

— Detailed hydrological and hydraulic studies;
— Geotechnical characteristics for foundations;
— Environmental studies;
— Optimized road and rail alignment in plan and in profile.

As this is a prefeasibility/feasibility study, the structure’s length is approximate and subject to considerable change. In the next step of the study, optimization, and some modification in the exact location of water crossing will have to be made to reduce the bridge overall length and to define bridge foundation required, number of spans in bridges location and each span length.

3.1 RAILWAY: RUPERT TO LA GRANDE

As per the established design criteria listed in Section 2, a total of 36 bridges are required for this proposed railway infrastructure. As mentioned in Technical Note 12, railway axis 2000+000 corresponds to the beginning point of this rail segment, close to Rupert River.

Table 3-1 Railway Rupert to La Grande – Bridge Structures

STATION (km) RAIL AXIS	OBSTACLE	APPROX. LENGTH (m)	MAXIMUM HEIGHT (m)	LATITUDE	LONGITUDE
2013+700	Unknown river	10	5	51.455009	-77.443261
2016+000	Unknown river	10	5	51.473607	-77.429780
2016+600	Ruisseau Waphyew	15	7	51.478377	-77.430539
2027+250	Unknown river	10	<5	51.562693	-77.4164010
2027+750	Unknown river	25	<5	51.567287	-77.417860
2036+000	Tetapishu River	40	5	51.635128	-77.391532
2044+750	Topography	10	10	51.711429	-77.408365
2047+800	Pontax River	150	10	51.733789	-77.427183
2051+400	Enistuwach river	60	10	51.761779	-77.453107

STATION (km) RAIL AXIS	OBSTACLE	APPROX. LENGTH (m)	MAXIMUM HEIGHT (m)	LATITUDE	LONGITUDE
2066+150	Jolicoeur River	25	7	51.883053	-77.429164
2075+000	Unidentified river	10	7	51.943453	-77.355255
2097+500	Unidentified river	20	<5	52.093418	-77.225132
2106+000	Unidentified river	25	<5	52.148119	-77.174148
2109+500	Unidentified river	25	<5	52.171513	-77.144408
2117+000	Unidentified river	10	<5	52.225372	-77.086093
2128+100	Eastmain	480	30	52.321791	-77.085571
2129+900	Important valley and watercourse	200	22	52.338324	-77.090515
2144+600	Opinaca	500	20	52.39354	-77.250483
2164+500	Unidentified river	10	<5	52.526137	-77.316144
2178+700	Important valley and watercourse	70	15	52.625743	-77.416558
2183+300	Pilpas river	10	10	52.663017	-77.415063
2186+000	Unidentified river	15	5	52.679432	-77.388458
2195+400	Du Vieux Comptoir River	600	40	52.755987	-77.345187
2201+500	Unidentified river	20	<5	52.795855	-77.318343
2207+500	Unidentified river	15	<5	52.842779	-77.286517
2216+500	Unidentified river	30	10	52.914301	-77.267417
2223+500	Unidentified river	30	<5	52.971443	-77.308136
2236+750	Unidentified river	15	<5	53.061933	-77.393146
2242+400	Awawachistikwach river	10	<5	53.100096	-77.439825
2255+800	Unidentified river (near lake Kaychikwapichu)	15	<5	53.192605	-77.463184
2260+300	Unidentified river	10	<5	53.218203	-77.418710
2270+800	Between lake Amisach Wat and lake Yasinski	15	11	53.300127	-77.445656
2281+650	Unidentified river (effluent of lake Ekomiak)	75	11	53.371233	-77.51392
2290+400	Castor river	10	10	53.432799	-77.585634
2299+000	Topography	15	<5	53.502654	-77.618401
2317+800	Unidentified river	15	<5	53.63651	-77.68703

In the table above, some water crossings and deep valleys are significant and would require major infrastructures. Extensive work, additional studies and design work shall be anticipated for those. We consider that a structure with a span of over 50 metres to be a major civil engineering structure.

Table 3-2 Railway Rupert to La Grande – Number of bridges

NUMBER OF BRIDGES	RAILWAY BRIDGES LENGTH		% IN QTY
28	Short	10 m to 50 m	78%
3	Major	51 m to 100 m	8%
4	Long	101 m to 500 m	11%
1	Extra Long	501 m and more	3%
36	**Total number of bridges**		

For the bridges longer than 50 m (major, long, and extra long bridges), extensive studies must be carried out in the subsequent phase of the study to minimize the cost. It could be achieved by balancing cut and fill, and by assembling geotechnical information to confirm that the backfill may be more than 10 metres in height for some areas, as considered for this preliminary study.

Another element that will need improvement and optimization in the subsequent phase is the vertical clearance between the railway alignment and the estimated water level under bridges. The prefeasibility alignment was designed without a defined criteria as a minimum clearance. Consequently, some bridges have a vertical clearance lower than 5 meters, which could be not viable considering the thickness of the bridge’s structure and the minimum clearance for spring flood, ice, debris, etc. As the bridges’ maximum height is presented in Table 3-1, the segments needing improvement for the low vertical clearance are those noted with “<5”.

The Eastmain River crossing at km 2128 is a major structure considering the width of the river at the proposed alignment. An arch bridge may be considered for this site. For other structures over a deep valley, multi-span bridges are being considered, avoiding foundations in wetlands as much as possible.

Figure 3-1 Current Roadway Bridge over Eastmain River

3.2 ROUTE 167: UPGRADE AND EXTENSION TO TRANS-TAIGA ROAD

As listed in the table below, the planned work for this infrastructure has been divided into four different sections as described in Technical Note 11.

Table 3-3 Route 167: Upgrade and extension to Trans-Taiga Road – Different sections

SECTION	STATION (START)	STATION (END)	LENGTH (KM)
Existing road			
Existing gravel road upgrade and paving	305+000	411+600	106.6
Existing unpaved MTQ road (no work)	411+600	553+000	141.4
Existing mine road upgrade	553+000	650+000	97.0
Extension to Trans-Taiga Road			
Proposed road extension	650+000	822+564	172.6
Total proposed infrastructure	305+000	822+564	517.6

Figure 3-2 on the following page shows Route 167 and the proposed extension.

3.2.1 EXISTING ROAD UPGRADE AND PAVING (305+000 TO 411+600)

The first section of the existing gravel road between 305+000 and 411+600 is under MTQ responsibility. Therefore, in this section of road, the bridges are under the responsibility of MTQ. The existing bridges on this section accommodate two lanes of traffic with legal weight truck, except for one bridge (P-0125A) at km 351.9. This concrete bridge has already been temporarily reinforced with the installation of a forestry capacity bridge to accommodate special forest wood transport.

In their 5-year program, the MTQ planned work on the bridge P-0125A located at station 351+922. Nonetheless, it was agreed with the MTQ that all the planned work in their five-year program would be excluded from the work proposed as part of the La Grande Alliance. Furthermore, since there is no paving planned by the MTQ in the short term for this road, discussions would be required with the MTQ to define how the cost associated with this work could be shared or entirely covered by the proposed La Grande Alliance proposed infrastructures.

3.2.2 EXISTING UNPAVED MTQ ROAD (411+600 TO 553+000)

The second existing roadway section is the MTQ road between 411+600 and 553+000. Since this existing 141.4 km section was built recently (8 years ago – opened in 2014) and the road and the bridges are in a good condition (as per our site visit in June 2022), there is no work identified for this section. The existing civil structures were adequate for the projected traffic on this road. This section has 23 bridges capable of carrying live loads of 50 tons. The bridge approaches are paved 60 m on each side.

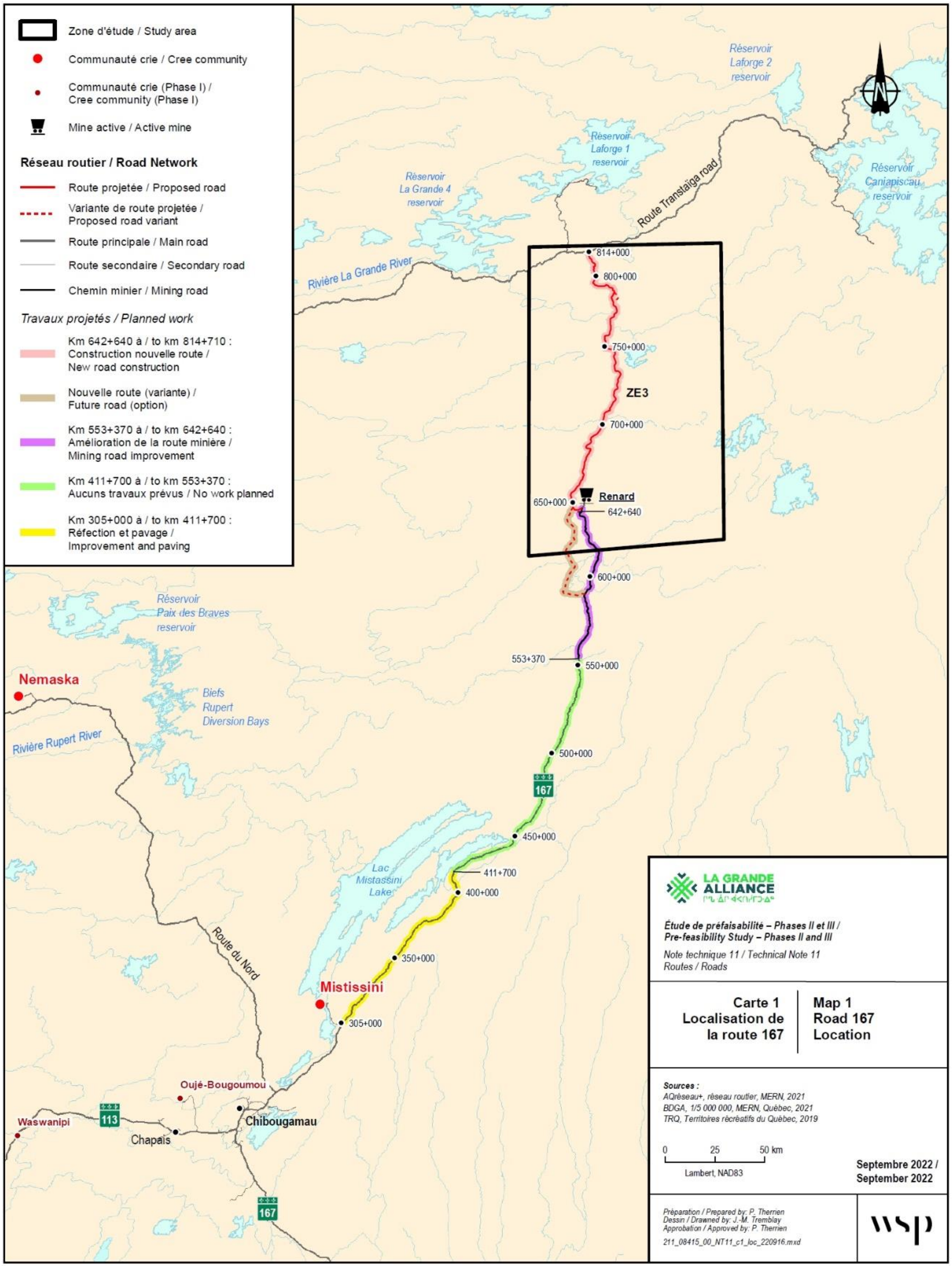

Figure 3-2 Route 167 – Proposed Alignment

3.2.3 EXISTING MINE ROAD UPGRADE (553+000 TO 650+000)

The third roadway section is the existing mine road between 553+000 to 650+000. As described in Technical Note 11, this existing 97 km section does not comply with MTQ standards. Some work needs to be done. The road is owned by the mining company and is used to supply the mine. However, with respect to the use of the road and its structures, a complete survey of the road structures will have to be carried out during future stages of the development of the proposed infrastructures, including an analysis of the structures' condition (culverts, bridges, etc.). Considering that a portion of the road is relatively new, we could assume that the structures are in good conditions. At this stage of the study, we consider that no repairs are required on these structures.

3.2.4 PROPOSED ROAD EXTENSION (650+000 TO 822+564)

As per the established design criteria listed in Section 2, a total of 23 bridges are planned on this proposed roadway between km 650+000 and km 822+564.

Table 3-4 Route 167 –Road Extension - Roadway Bridge Structures

STATION (km) ROAD AXIS	OBSTACLE	APPROX. LENGTH (m)	LATITUDE	LONGITUDE
644+200	Unidentified lake/river	20	52.748779	-72.247424
650+900	Unidentified river	7.5	52.783859	-72.291223
661+600	Topography	7.5	52.889803	-72.230637
667+600	Topography	15	52.908303	-72.222424
671+260	Unidentified river	20	52.939941	-72.224103
671+620	Unidentified river	15	52.942932	-72.222925
680+200	Unidentified river	7.5	53.016459	-72.185637
699+000	Unidentified river	35	53.135752	-72.098382
704+080	Sakami river	50	53.178596	-72.091758
716+040	Unidentified river	15	53.266015	-72.009526
757+600	Unidentified river	7.5	53.554895	-72.082304
761+160	La Grande River	150	53.585538	-72.072809
765+900	Topography	15	53.616562	-72.081742
769+900	Topography	10	53.650034	-72.050666
775+300	Unidentified river	15	53.689048	-72.060591
779+600	Unidentified river	7.5	53.721999	-72.078741
782+400	Unidentified lake/river	25	53.744675	-72.063396
785+500	Unidentified river	7.5	53.767886	-72.080345
788+100	Topography	7.5	53.777357	-72.110158
792+100	Topography	7.5	53.773466	-72.166467
794+700	Unidentified river	7.5	53.778638	-72.211981
805+300	Unidentified river	15	53.861929	-72.226595

In the table above, some water crossings are significant and would require major infrastructures. Extensive work, additional studies and design work shall be anticipated for those. We consider that a structure with a span over 50 meter long to be a major civil engineering structure. Two structures are considered major structures as listed below:

— Km 704+080 (river crossing) with a 50meter long bridge;
— Km 761+160 (La Grande River crossing) with a 150meter long bridge.

3.2.5 ALTERNATIVE OPTION (553+000 TO 650+000)

For comparison purposes, an alternative road parallel to a portion of the mine road was also considered as part of the study. While this approach optimizes compliance with design standards, this option does not provide significant added value as the benefits provided by the main option (as described above) are more significant. If this option is selected, it would involve ten (10) additional bridges between km 553+000 and km 650+000.

Table 3-5 Route 167 - Alternative Option to Mine Road – Roadway Bridge Structures

OBSTACLE	APPROX. LENGTH (m)	LATITUDE	LONGITUDE
ALTERNATIVE OPTION (553+000 TO 650+000)			
	7.5	52.360477	-72.210875
	7.5	52.362073	-72.284744
	15	52.369448	-72.330337
Major structure - Eastmain River	225	52.503917	-72.274401
	20	52.536193	-72.305215
	50	52.604235	-72.275098
	20	52.61291	-72.267878
	25	52.615575	-72.269025
Major structure	70	52.645027	-72.269836
	20	52.742062	-72.307082

In the table above, the following water crossings and deep valleys are more significant than for the main option and would therefore require longer infrastructures. Extensive work, additional studies and design work shall be anticipated for those. We consider that a structure with a span of over 50 metres to be a major civil engineering structure. Two structures are considered major structures as listed below:

— Unidentified River crossing with a 70-meter long bridge;
— Eastmain River crossing with a 225-meter-long bridge.

3.3 ROADWAY: LA GRANDE TO WHAPMAGOOSTUI/KUUJJUARAPIK

It should be noted that, during the Study, the proposed roadway of La Grande to Whapmagoostui/Kuujjuarapik was moved to the feasibility stage and thus led to a helicopter-based site reconnaissance carried out from July 15th to 20th, 2022, by a team composed of a hydraulic engineer (crossing structures sizing), a structural engineer (crossing structures design) and a civil engineer (road design). That site reconnaissance of the path envisioned for the proposed road includes the observation of the following:

- Watercourses: Watershed topography and land cover, stream networks, direction of flow, lakes, wetlands, etc.;
- Hydraulic features: Hydraulic controls, rapids, water levels, water velocities, etc.;
- Terrain in the vicinity of the structure: morphology, geological features, rock outcrops, etc.

Some pictures of the major crossing sites are presented in appendix C. It is to be noted that at this stage of the study, no optimization of the alignment has been performed. Some opportunities of optimization were identified during the site visit and will be available for the next stages of the project.

As per the established design criteria listed in Section 2, this analysis of civil structure for this proposed road infrastructures is including considerations from preliminary hydrology and hydraulic studies.

3.3.1 HYDROLOGY AND HYDRAULIC STUDIES

The site visit allowed to note several terrain features that have been used for this analysis, amongst others:

- Additional crossing structures point that were not identified by the desktop study have been identified;
- The topography of the sector is relatively flat;
- The road starts by crossing the La Grande River, downstream of the spillway of the LG-2 Dam;
- PK81 crossing structure crosses a branche of the Lake Pamigamachi (see photo 8, appendix C);
- PK 149 crosses an unidentified watercourse above a major serie of rapids (see photo 15, appendix C);
- PK 199 crosses an unidentified watercourse above a waterfall (see photo 18, appendix C);
- PK 214 crosses the Vauquelin River approximately 250 meters upstream of a major hydraulic control on the river (see photo 19, appendix C);
- PK 253 crosses Sucker creek between two lakes (see photo 20, appendix C);
- PK 337 crosses the Great Whale River above a major hydraulic control of the river (see photo 24, appendix C).

As per the established design criteria listed in Section 2, a total of 62 bridges are required for this new road segment. As mentioned in Technical Note 11, road axis 0+000 corresponds to the beginning point of this road segment, at La Grande River.

Table 3-6 Roadway - La Grande to Whapmagoostui/Kuujjuarapik – Bridge Structures

STATION (km) ROAD AXIS	OBSTACLE	APPROX. LENGTH (m)	LATITUDE	LONGITUDE
7+200	Unidentified river	7.5	53.856206	-77.419542
10+550	Unidentified river	25	53.881078	-77.443032
15+150	Unidentified river	35	53.910599	-77.409148
17+300	Unidentified river	30	53.929635	-77.40663

STATION (km) ROAD AXIS	OBSTACLE	APPROX. LENGTH (m)	LATITUDE	LONGITUDE
19+000	Unidentified river	7.5	53.944699	-77.40691
19+700	Unidentified river	10	53.950341	-77.411193
20+700	Unidentified river	7.5	53.958446	-77.416828
27+650	Unidentified river	10	54.018411	-77.410913
29+700	Piagochioui river	75	54.034261	-77.399022
31+600	Unidentified river	10	54.050194	-77.40838
33+200	Unidentified river	25	54.06326	-77.40663
40+750	Unidentified river	7.5	54.117787	-77.352936
41+600	Unidentified river	7.5	54.125204	-77.356425
45+650	Unidentified lake/river	50	54.156476	-77.381193
47+400	Lake Pamigamachi	40	54.169693	-77.388459
49+500	Unidentified lake/river	40	54.184914	-77.374087
51+900	Unidentified lake/river	90	54.204583	-77.363976
52+550	Unidentified river	7.5	54.210609	-77.36392
54+400	Roggan river	55	54.226353	-77.360054
58+200	Atawataweats river	25	54.254442	-77.336644
64+732	Unidentified river	7.5	54.309171	-77.352134
68+032	Unidentified river	10	54.340754	-77.355657
74+582	Unidentified river	45	54.383343	-77.310926
77+832	Unidentified river	35	54.400376	-77.341514
81+482	Unidentified river	35	54.421218	-77.384392
83+132	Unidentified river	7.5	54.435371	-77.390129
86+732	Unknown river (near Wiskichan lake)	75	54.46442	-77.397692
91+100	Unidentified	40	54.500624	-77.418621
92+532	Unidentified river	200	54.51031	-77.428758
98+607	Unidentified river	20	54.541821	-77.503747
105+607	Unidentified river	7.5	54.596858	-77.517474
108+207	Unidentified river	55	54.611326	-77.549828
115+921	Unidentified river	35	54.660064	-77.631119
119+900	Unknown river	10	54.695634	-77.633492
122+421	Unidentified river	15	54.715731	-77.623915
123+821	Vauquelin river	55	54.728937	-77.626527
126+471	Unidentified river	20	54.751268	-77.627424
135+271	Unidentified river	10	54.809279	-77.688456

STATION (km) ROAD AXIS	OBSTACLE	APPROX. LENGTH (m)	LATITUDE	LONGITUDE
139+671	Unidentified river	7.5	54.849496	-77.678472
141+000	Unidentified river	10	54.857778	-77.687143
146+546	Sucker river	20	54.899888	-77.706913
146+821	Unidentified river	20	54.902096	-77.705829
150+571	Unidentified river	35	54.934691	-77.692741
154+171	Unidentified river	15	54.966795	-77.699208
155+371	Unidentified river	7.5	54.977409	-77.69947
158+871	Unidentified river	20	55.007556	-77.694456
161+821	Major crossing (Unidentified river)	60	55.032188	-77.691883
163+021	Major crossing (Unidentified river)	50	55.042025	-77.691613
163+321	Unidentified river	20	55.044334	-77.689686
166+321	Unidentified river	15	55.067131	-77.668208
166+421	Unidentified river	15	55.06789	-77.667752
168+421	Unidentified river	10	55.085912	-77.661253
173+721	Unidentified river	20	55.131452	-77.671804
174+121	Unidentified river	15	55.135009	-77.672071
178+271	Sasapimakwananitikw river	20	55.1625053	-77.631505
181+171	Unidentified river	10	55.186994	-77.625379
185+271	Unidentified river	20	55.214065	-77.590487
185+621	Unidentified river	7.5	55.217231	-77.591022
187+321	Unidentified river	20	55.231353	-77.584639
188+521	Unidentified river	15	55.241921	-77.57961
193+971	Major crossing Great Whale River	100	55.286871	-77.588194
196+221	Major crossing (Unidentified river)	70	55.303005	-77.593866

At this stage of the study, as defined in Technical Note 11 - Road, the link between the shores of La Grande River is planned to be constructed over the HQ installations, LG-2 La Grande River spillway's deck.

In the table above, some water crossings and deep valleys are significant and would require major infrastructures. Extensive work, additional studies and design work shall be anticipated for those. We consider that a structure with a span over 50 meters long to be a major civil engineering structure. Eleven structures are then considered major structures.

Some opportunities have been identified for optimization of the road path, from the hydraulic perspective. The following points could be optimized:

— PK 018: The bankfull width at the right of the proposed crossing structures is 45 m. 200 m to the West, the bankfull width would be 12 m.

- PK 078: The bankfull width at the right of the proposed crossing structures is 46 m. 210 m to the West, the bankfull width would be 12 m.
- PK 089.1: The bankfull width at the right of the proposed crossing structures is 123 m. 350 m to the West, the bankfull width would be 70 m.

3.4 RAILWAY: LA GRANDE TO WHAPMAGOOSTUI/KUUJJUARAPIK

As per the established design criteria listed in Section 2, a total of 66 bridges are required for this proposed railroad. As mentioned in Technical Note 12, railway axis 3000+000 corresponds to the connection point to the end of phase II railroad, which extends between Rupert River and La Grande River. For this section of railroad, the hydraulic information available from the road study was taken into account where the water course crossing is adjacent to that of the road.

Table 3-7 Railway - La Grande to Whapmagoostui/Kuujjuarapik – Bridge Structures

STATION (km) RAIL AXIS	OBSTACLE	APPROX. LENGTH (m)	MAXIMUM HEIGHT (m)	LATITUDE	LONGITUDE
3001+014	Unidentified river	250	15	53.762342	-77.597726
3009+349	La Grande River (overpass + bridge)	1,100	75	53.7947	-77.52302
3019+300	Unidentified river	15	10	53.855899	-77.420484
3022+450	Unidentified river	25	<5	53.881243	-77.44472
3025+500	Unidentified river	50	5	53.906077	-77.436609
3026+950	Unidentified river	10	5	53.917789	-77.441233
3029+260	Unidentified river	20	11	53.931043	-77.414164
3031+088	Unidentified river	60	15	53.944502	-77.407963
3031+700	Unidentified river	10	<5	53.949958	-77.411718
3032+750	Unidentified river	10	<5	53.958212	-77.419562
3037+944	Unidentified river (2x)	200	15	54.003595	-77.418624
3039+700	Unidentified river	10	5	54.018253	-77.412444
3040+300	Piagochioui rRiver	75	<5	54.023195	-77.414289
3045+700	Unknown lake/river	40	10	54.063529	-77.427266
3053+525	Unidentified river	15	<5	54.117726	-77.353705
3054+395	Unidentified river	100	17	54.125204	-77.356425
3056+592	Unidentified river	40	15	54.138866	-77.375941
3058+500	Unidentified river	50	10	54.156476	-77.381193
3060+003	Important valley - Pamigamachi Lake	150	15	54.169693	-77.388459
3062+400	Unidentified lake	150	5	54.184914	-77.374087
3067+343	Roggan River	160	10	54.231038	-77.39281

STATION (km) RAIL AXIS	OBSTACLE	APPROX. LENGTH (m)	MAXIMUM HEIGHT (m)	LATITUDE	LONGITUDE
3069+600	Atawataweats river	150	<5	54.243184	-77.364265
3079+300	Unidentified lake/river	25	<5	54.312032	-77.336699
3082+800	Unidentified river	10	<5	54.340859	-77.354916
3083+600	Unidentified lake	150	<5	54.348819	-77.354395
3092+600	Unidentified lake	140	<5	54.402486	-77.336927
3096+300	Unidentified river	35	<5	54.420662	-77.385214
3097+950	Unidentified river	10	5	54.435191	-77.389209
3101+150	Wiskichan lake	50	5	54.463471	-77.397007
3106+000	Important valley	600	7	54.501443	-77.389364
3115+500	Unidentified river	20	11	54.541802	-77.502807
3119+351	Important valley	200	19	54.571201	-77.51807
3122+300	Unidentified river	10	8	54.595313	-77.509165
3125+300	Unidentified river	55	11	54.611914	-77.549651
3132+700	Unidentified lake/river	110	8	54.660314	-77.627054
3136+700	Unidentified river	10	10	54.695722	-77.632483
3139+100	Unidentified river	40	10	54.71562	-77.623271
3140+656	Vauquelin River	400	40	54.728838	-77.621775
3143+100	Unidentified river	50	10	54.750695	-77.622223
3143+700	Unidentified river	30	10	54.754051	-77.682896
3152+000	Unidentified river	30	10	54.808875	-77.685264
3156+300	Unidentified lake	130	10	54.847361	-77.675011
3157+900	Unidentified river	10	10	54.857935	-77.686979
3161+163	Valley/wetland	100	25	54.882452	-77.71386
3163+191	Sucker river	800	35	54.901827	-77.704075
3167+300	Unidentified river	60	10	54.934786	-77.691887
3170+900	Unidentified river	15	10	54.966602	-77.697728
3172+100	Unidentified river	15	5	54.977609	-77.698903
3175+600	Unidentified river	35	<5	55.007362	-77.682862
3178+450	Unidentified river	85	<5	55.032026	-77.692626
3179+600	Unidentified river	100	7	55.042308	-77.693313
3180+000	Unidentified river	30	<5	55.045191	-77.690398
3182+900	Unidentified river	15	9	55.067406	-77.668704
3183+000	Unidentified river	15	9	55.068401	-77.668254
3184+950	Unidentified river	10	<5	55.085702	-77.662075
3190+300	Unidentified river	25	9	55.131752	-77.674009

STATION (km) RAIL AXIS	OBSTACLE	APPROX. LENGTH (m)	MAXIMUM HEIGHT (m)	LATITUDE	LONGITUDE
3190+600	Unidentified river	25	9	55.134438	-77.673602
3194+600	Sasapimakwananistikw river	25	5	55.161789	-77.634334
3197+500	Unidentified river	70	7	55.186659	-77.627146
3201+300	Unidentified river	120	<5	55.214659	-77.595633
3201+700	Unidentified river	10	<5	55.217187	-77.593305
3203+400	Unidentified river	20	<5	55.231433	-77.586546
3204+600	Unidentified river	15	8	55.242052	-77.580345
3203+400	Topography	1,900	30	55.277929	-77.598373
3208+575	Great Whale River	1,100	65	55.287706	-77.586013
3210+202	Unidentified river	30	15	55.302847	-77.594987

Table 3-8 Railway - La Grande to Whapmagoostui/Kuujjuarapik – Number of bridges

NUMBER OFBRIDGES	RAILWAY BRIDGES LENGTH		% IN QTY
39	Short	10 m to 50 m	59%
9	Major	51 m to 100 m	14%
13	Long	101 m to 500 m	20%
5	Extra Long	501 m and more	8%
66	**Total number of bridges**		

We consider that a structure which length is over 50 meters to be a major civil engineering structure. Therefore, a total of 27 major structures are required. They are defined as follows: 9 major bridges, 13 long bridges and 5 extra long bridges.

Extensive work, additional studies, and design work shall be anticipated for those major infrastructures. The varying topography of the northern region of this proposed railroad has an impact on the need for structures. Moreover, the maximum slope significantly increases the need for structures when comparing with the proposed roadway in the same area.

For the major structures, extensive study must be carried out in the subsequent phase of the development of the proposed infrastructures to minimize the cost. It could be achieved by balancing cut and fill, and by assembling geotechnical information to confirm that the backfill may be more than 10 meters in height for some sectors, as considered for this preliminary study.

Moreover, as stated in chapter 3.1, the alignment will need improvement and optimization in the subsequent phase regarding the vertical clearance between the railway alignment and the estimated water level under bridges. The prefeasibility alignment was designed without a defined criteria as a minimum clearance. Consequently, some bridges have a vertical clearance lower than 5 meters, which could be not viable considering the thickness of the bridge's structure and the minimum clearance for spring flood, ice, debris, etc. As the bridges' maximum height is presented in Table 3-7, the segments needing improvement for the low vertical clearance are those noted with "<5".

One of the most critical challenges for phase III rail corridor is crossing La Grande River. While the road alignment can use the Robert Bourassa spillway to cross the river, the rail corridor will require its own structure due to the heavy axle load and vibration issues. This new structure may be designed to accommodate both rail and road traffic to avoid using the flood evacuator of LG-2 HQ installations.

The Great Whale River crossing also requires a major structure considering the width and the depth of the river at the projected crossing. An arch bridge must be considered for this site. For the other structures above a deep valley or crossing waterbodies, multi-span bridges are being considered, avoiding foundation in wetlands as much as possible.

4 CONCLUSIONS AND ADDITIONAL CONSIDERATIONS

The design of railway civil structures is mainly based on the AREMA regulations. The design of roadway civil structures is mainly based on the MTQ road and bridge design standards and CSA-S6 regulations and criteria. The civil structures were developed based on the same road and rail key factors:

- Respect, as much as possible, the natural site topography (mountains and plains);
- Consider the overall geology of the study area, including the locations of aggregate material deposits;
- Avoid, as much as possible, lakes and rivers; minimize the length of crossings and bridges where these are unavoidable;
- Avoid, as much as possible, existing and projected Protected Areas; minimize encroachment and/or provide mitigation measures where these are unavoidable;
- Minimize crossing and impacts on caribou migration corridors;
- Avoid, as much as possible, areas of cultural significance such as areas currently used by Cree land users, archeological sites, etc.; minimize encroachment and/or provide mitigation measures where these are unavoidable;
- Propose, wherever applicable, alignment variants that could offer added value, such as:
  - Locations that minimize environmental footprint;
  - Locations that minimize construction cost;
  - Locations that minimize the impacts on existing camps and facilities;
- Remain, as much as possible, in close proximity to existing or proposed roads;
- Remain within 1 km corridor centered on existing or proposed roads when surrounded by recognized Protected Areas on both sides;
- Minimize the number of times the railway crosses existing or proposed roads.

The foreseen required civil engineering structures for La Grande Alliance proposed transportation infrastructures are presented in the table below.

Table 4-1 Summary Table

INFRASTRUCTURE	TOTAL LENGTH	TOTAL BRIDGES NUMBER	MAJOR BRIDGES	TOTAL BRIDGES LENGHT	% OF ROAD OR RAIL ON A BRIDGE	NUMBER OF BRIDGE PER 10 KM
Route 167 2 Upgrade segments	106 km 97 km	1*	-	n/a	n/a	n/a
Route 167: Extension to Trans-Taiga	172 km	23	2	0.5 km	0.5 %	1
Roadway: La Grande to Whapmagoostui/Kuujjuarapik	207 km	62	11	2 km	1 %	3
Railway: Rupert to La Grande	340 km	36	8	2.6 km	0.8 %	1
Railway: La Grande to Whapmagoostui/Kuujjuarapik	219 km	66	27	9.4 km	4 %	3

*Note *: Rehabilitation of one existing bridge by MTQ in the next 5 years*

The alignment and profile, and the number and length of bridges for both the proposed roadways and railways will have to be optimized in the subsequent development phases of the proposed infrastructures, when the geotechnical constraints will be available, and the balance of the excavation quantities will be completed.

Finally, it is important to remember that the proposed alignments are conceptual and preliminary, and that the river and valley crossings have been defined in accordance with Technical Notes 11 – Roads and 12 - Rails. As the development of the proposed infrastructures evolves, additional studies and discussions will lead to adjustments and variations resulting in optimized alignments and probably fewer bridges. For example, validations with tallymen, flight observations, and integration of the railroad design will most likely lead to changes in the roadway alignments proposed in this study. Nevertheless, the current proposed alignments were developed and used to estimate the construction costs.

The estimated length and location of bridges reflect the information available to date. Subsequent and further investigations, studies, analyses, and design phases will most likely have an impact on the cost estimate of the structures. Finally, no formal recommendations were issued by the geotechnical team.

If the proposed infrastructures (all or separately) are deemed valuable by the communities, there are still a lot of work to be carried on before construction starts, this study is only the beginning of all the steps required to complete a project of this nature and scale. Detailed analysis, alignment optimization and further site data collection should be carried out in coordination with other preparatory studies that will feed the concept design and further detailed engineering and construction work. More specifically, the further development of civil structures will require to:

- Proceed with bathymetric and hydrometric surveys.
- Consider the use of watercourses by First Nations communities for navigation in the design of watercourse crossing structures. The application of Article 98 of the RADF yields a major change in soffit elevation of the structures, as it requires a vertical clearance of 1,5 m above the high-water level mark. In comparison, when the watercourse is not use for navigation, the vertical clearance can be of up to 1 m, but typically in the range between 0 cm (culverts) and 1 m for bridges.
- Evaluate the fish passage requirements: The fish passage requirement should be evaluated by biologists, and surveys should be planned along the watercourses to refine the sizing of the culverts associated with these watercourses.
- Proceed with a life cycle analysis to determine best suitable structural type at each location.

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APPENDIX

A

HYDROLOGY RESULTS

ID	Chainage	Watershed Area (km^2)	Hydrological method	Slope 85-10 (%)	2-year Flood - m^3/s	2-year Flood - CC - m^3/s	10-year Flood - m^3/s	10-year Flood - CC - m^3/s	25-year Flood - m^3/s -	25-year Flood - CC - m^3/s	50-year Flood - m^3/s	**50-year Flood - CC - m^3/s**	100-year Flood - m^3/s	100-year Flood - CC - m^3/s
PK009	6+150	0,89	Rational Method	0,8	0,2	0,3	0,4	0,5	0,5	0,6	0,5	**0,6**	0,6	0,7
PK010	6+700	2,18	Rational Method	0,5	0,7	0,9	1,2	1,4	1,5	1,7	1,7	**1,9**	1,8	2,2
PK013	7+200	13,77	Rational Method	0,5	2,4	2,8	3,8	4,5	4,5	5,3	5,1	**6,0**	5,6	6,6
PK017	9+900	2,28	Rational Method	0,5	0,5	0,6	0,9	1,0	1,1	1,3	1,2	**1,4**	1,3	1,6
PK018	10+550	56,45	SCS Method	0,5	3,2	3,8	11,5	13,5	17,4	20,5	22,2	**26,2**	27,5	32,4
PK026	15+150	4,06	Rational Method	0,8	0,8	1,0	1,4	1,6	1,6	1,9	1,8	**2,1**	2,0	2,4
PK028	16+550	0,47	Rational Method	1,0	0,1	0,1	0,1	0,2	0,2	0,2	0,2	**0,2**	0,2	0,2
PK030	17+300	184,04	SCS Method	0,5	8,4	9,7	30,9	35,5	47,2	54,3	60,9	**70,0**	75,6	87,0
PK031	18+050	2,45	Rational Method	0,5	0,7	0,8	1,1	1,3	1,4	1,6	1,5	**1,8**	1,7	2,0
PK032	19+000	0,52	Rational Method	1,9	0,5	0,6	0,9	1,0	1,1	1,3	1,2	**1,4**	1,4	1,6
PK034	19+700	6,97	Rational Method	0,9	1,4	1,6	2,3	2,7	2,7	3,2	3,0	**3,6**	3,4	4,0
PK035	20+700	5,16	Rational Method	1,0	1,8	2,1	3,0	3,5	3,6	4,2	4,0	**4,7**	4,4	5,2
PK036	21+100	1,87	Rational Method	0,8	0,5	0,5	0,8	0,9	0,9	1,1	1,1	**1,3**	1,2	1,4
PK037	21+400	1,39	Rational Method	0,9	0,4	0,5	0,7	0,8	0,8	0,9	0,9	**1,1**	1,0	1,2
PK039	23+000	1,2	Rational Method	1,1	0,3	0,4	0,6	0,7	0,7	0,8	0,8	**0,9**	0,9	1,0
PK041	24+200	0,94	Rational Method	2,1	0,2	0,2	0,3	0,4	0,4	0,5	0,5	**0,6**	0,5	0,6
PK044	25+800	1,93	Rational Method	1,6	0,3	0,4	0,6	0,6	0,7	0,8	0,8	**0,9**	0,8	1,0
PK046	26+600	0,56	Rational Method	1,3	0,1	0,1	0,2	0,3	0,3	0,3	0,3	**0,4**	0,3	0,4
PK047	27+650	7,76	Rational Method	0,6	0,6	0,8	1,0	1,2	1,2	1,5	1,4	**1,6**	1,5	1,8
PK050	29+050	0,47	Rational Method	1,8	0,2	0,2	0,3	0,3	0,4	0,4	0,4	**0,5**	0,4	0,5
PK051	29+700	316,60	SCS Method	0,5	28,6	32,9	72,1	82,9	100,8	115,9	123,8	**142,4**	148,1	170,3
PK052	30+500	0,36	Rational Method	3,3	0,4	0,5	0,8	0,9	1,0	1,1	1,1	**1,3**	1,2	1,5
PK053	30+900	0,48	Rational Method	1,5	0,4	0,4	0,6	0,7	0,8	0,9	0,9	**1,0**	1,0	1,2
PK054	31+600	2,54	Rational Method	1,4	0,8	0,9	1,3	1,6	1,6	1,9	1,8	**2,2**	2,0	2,4
PK057	33+200	90,55	SCS Method	0,1	8,1	9,3	25,1	28,9	36,8	42,3	46,2	**53,2**	56,3	64,8
PK064	37+500	12,48	Rational Method	0,3	1,6	1,8	2,5	2,9	2,9	3,4	3,3	**3,8**	3,6	4,2
PK067	39+200	0,30	Rational Method	1,2	0,1	0,1	0,2	0,2	0,2	0,2	0,2	**0,2**	0,2	0,3
PK068	39+700	0,43	Rational Method	1,7	0,2	0,2	0,3	0,3	0,4	0,4	0,4	**0,5**	0,4	0,5
PK070	40+750	1,48	Rational Method	0,6	0,3	0,4	0,6	0,7	0,7	0,8	0,8	**0,9**	0,9	1,0
PK071	41+600	43,98	SCS Method	0,1	2,8	3,3	12,2	14,4	19,1	22,5	24,8	**29,3**	31,0	36,5
PK075	43+100	0,67	Rational Method	2,1	0,2	0,2	0,3	0,3	0,3	0,4	0,4	**0,5**	0,4	0,5
PK078	45+650	15,17	Rational Method	0,2	0,8	1,0	1,3	1,5	1,5	1,8	1,7	**2,0**	1,9	2,2
PK081	47+400	199,34	SCS Method	0,5	18,3	21,0	52,7	60,6	75,8	87,2	94,5	**108,7**	114,4	131,5
PK085	49+500	108,01	SCS Method	0,5	12,6	14,5	37,6	43,2	54,2	62,3	67,6	**77,8**	81,8	94,1
PK089.1	51+900	3,45	Rational Method	0,5	0,9	1,1	1,5	1,8	1,8	2,2	2,1	**2,4**	2,3	2,7
PK089.2	52+100	3,69	Rational Method	0,5	0,8	1,0	1,4	1,6	1,6	1,9	1,8	**2,2**	2,0	2,4
PK090	52+550	1,85	Rational Method	0,5	0,5	0,6	0,9	1,0	1,0	1,2	1,2	**1,4**	1,3	1,5
PK094	54+400	158,84	SCS Method	0,5	19,8	22,8	47,0	54,0	64,3	74,0	78,1	**89,8**	92,5	106,4
PK095	55+500	1,07	Rational Method	1,0	0,3	0,4	0,6	0,7	0,7	0,8	0,8	**0,9**	0,9	1,1
PK098	57+000	0,57	Rational Method	0,4	0,1	0,1	0,2	0,2	0,2	0,2	0,2	**0,3**	0,3	0,3
PK100	58+200	152,40	SCS Method	0,1	13,4	15,4	38,6	44,4	55,6	63,9	69,3	**79,7**	83,9	96,5
PK104	60+700	3,09	Rational Method	0,2	0,5	0,6	0,8	1,0	1,0	1,2	1,1	**1,3**	1,2	1,5

ID	Chainage	Watershed Area (km²)	Hydrological method	Slope 85-10 (%)	2-year Flood - m³/s	2-year Flood - CC - m³/s	10-year Flood - m³/s	10-year Flood - CC - m³/s	25-year Flood - m³/s -	25-year Flood - CC - m³/s	50-year Flood - m³/s	**50-year Flood - CC - m³/s**	100-year Flood - m³/s	100-year Flood - CC - m³/s
PK108	62+500	0,22	Rational Method	2,6	0,1	0,2	0,2	0,3	0,3	0,3	0,3	**0,4**	0,4	0,4
PK110	64+000	1,64	Rational Method	1,2	0,9	1,1	1,6	1,9	1,9	2,3	2,2	**2,6**	2,4	2,9
PK111	64+700	11,92	Rational Method	0,5	2,0	2,3	3,2	3,7	3,7	4,4	4,2	**4,9**	4,6	5,5
PK117	68+000	16,11	Rational Method	0,5	2,7	3,1	4,3	5,0	5,1	6,0	5,7	**6,7**	6,3	7,4
PK121	70+400	1,37	Rational Method	0,5	0,4	0,5	0,7	0,9	0,9	1,1	1,0	**1,2**	1,1	1,3
PK124	72+000	20,92	Rational Method	0,5	3,1	3,7	4,9	5,8	5,8	6,9	6,5	**7,7**	7,1	8,4
PK127	74+000	8,31	Rational Method	0,5	1,8	2,1	2,9	3,5	3,5	4,1	3,9	**4,6**	4,3	5,1
PK128	74+600	7,86	Rational Method	0,5	2,0	2,3	3,2	3,7	3,8	4,5	4,2	**5,0**	4,7	5,5
PK133	77+800	354,30	SCS Method	0,1	48,5	55,8	97,1	111,6	127,2	146,3	150,6	**173,2**	174,9	201,2
PK138	81+000	3,82	Rational Method	0,2	0,7	0,9	1,2	1,4	1,4	1,6	1,5	**1,8**	1,7	2,0
PK140	81+300	19,56	Rational Method	0,1	2,5	2,9	3,7	4,4	4,4	5,2	4,9	**5,7**	5,3	6,3
PK141	81+400	0,28	Rational Method	1,7	0,1	0,1	0,2	0,3	0,3	0,3	0,3	**0,4**	0,3	0,4
PK142	83+100	1,94	Rational Method	0,6	0,4	0,5	0,7	0,8	0,8	1,0	0,9	**1,1**	1,0	1,2
PK144	83+900	2,41	Rational Method	0,4	0,5	0,6	0,8	0,9	1,0	1,1	1,1	**1,3**	1,2	1,4
PK149	86+700	0,02	Rational Method	3,1	0,0	0,0	0,1	0,1	0,1	0,1	0,1	**0,1**	0,1	0,1
PK153	88+100	2,05	Rational Method	0,8	0,8	0,9	1,3	1,5	1,5	1,8	1,7	**2,1**	1,9	2,3
PK156	89+100	638,53	SCS Method	0,5	79,2	91,1	148,4	170,6	191,4	220,2	224,8	**258,5**	259,5	298,4
PK159	92+500	3037,86	Frequency Analysis	0,5	202,2	202,2	261,2	261,2	279,4	279,4	289,3	**289,3**	297,6	297,6
PK167	97+100	4,61	Rational Method	0,5	1,0	1,2	1,7	2,0	2,0	2,4	2,3	**2,7**	2,5	3,0
PK169	98+600	114,20	SCS Method	0,5	14,2	16,4	38,8	44,6	54,9	63,1	67,7	**77,9**	81,3	93,4
PK182	105+600	4,80	Rational Method	0,7	1,2	1,5	2,1	2,4	2,5	2,9	2,8	**3,3**	3,1	3,6
PK186	108+200	38,95	SCS Method	0,5	4,6	5,4	19,7	23,3	30,4	35,8	39,2	**46,3**	48,7	57,4
PK199	115+900	332,72	SCS Method	0,5	35,7	41,0	80,2	92,3	108,8	125,2	131,5	**151,2**	155,2	178,5
PK202	117+400	1,39	Rational Method	2,5	1,1	1,3	2,0	2,4	2,5	2,9	2,8	**3,3**	3,1	3,7
PK204	118+700	2,46	Rational Method	1,8	3,0	3,6	5,4	6,4	6,6	7,8	7,5	**8,9**	8,4	9,9
PK206	119+600	0,42	Rational Method	1,7	1,0	1,1	1,8	2,1	2,2	2,6	2,5	**2,9**	2,8	3,3
PK207	120+000	35,85	SCS Method	0,5	11,0	12,9	34,2	40,4	48,9	57,7	60,6	**71,6**	72,8	85,9
PK211	122+400	3,98	Rational Method	0,8	2,9	3,4	4,9	5,7	5,9	6,9	6,6	**7,8**	7,3	8,7
PK214	123+800	812,60	SCS Method	0,5	71,6	82,4	158,3	182,0	214,7	246,9	259,6	**298,5**	306,8	352,8
PK216	125+000	0,77	Rational Method	2,0	0,7	0,8	1,2	1,4	1,4	1,7	1,6	**1,9**	1,8	2,2
PK218	126+400	167,33	SCS Method	0,5	26,9	31,0	65,9	75,8	90,4	103,9	109,7	**126,2**	129,9	149,4
PK224	130+200	0,20	Rational Method	2,3	0,1	0,1	0,2	0,2	0,2	0,2	0,2	**0,3**	0,3	0,3
PK230	133+500	0,08	Rational Method	2,3	0,0	0,1	0,1	0,1	0,1	0,1	0,1	**0,1**	0,1	0,1
PK233	135+200	8,08	Rational Method	0,5	1,5	1,8	2,4	2,9	2,9	3,4	3,3	**3,9**	3,6	4,3
PK234	135+900	0,01	Rational Method	3,4	0,0	0,0	0,0	0,0	0,0	0,1	0,0	**0,1**	0,1	0,1
PK235	136+300	0,63	Rational Method	0,9	0,4	0,4	0,6	0,8	0,8	0,9	0,9	**1,0**	1,0	1,2
PK236	137+000	0,31	Rational Method	3,0	0,3	0,3	0,5	0,6	0,7	0,8	0,7	**0,9**	0,8	1,0
PK241	139+700	2,87	Rational Method	0,8	0,9	1,1	1,5	1,8	1,8	2,1	2,0	**2,4**	2,3	2,7
PK243	140+500	1,11	Rational Method	1,1	0,5	0,6	0,9	1,0	1,1	1,3	1,2	**1,4**	1,3	1,6
PK244	141+100	2,53	Rational Method	1,1	0,8	0,9	1,3	1,5	1,5	1,8	1,7	**2,1**	1,9	2,3
PK246	142+400	0,60	Rational Method	1,6	0,3	0,3	0,5	0,6	0,6	0,7	0,7	**0,8**	0,8	0,9
PK249	144+500	0,64	Rational Method	2,2	0,4	0,5	0,7	0,8	0,9	1,0	1,0	**1,2**	1,1	1,3
PK253	146+500	124,67	SCS Method	0,5	16,8	19,3	52,4	60,3	76,0	87,5	95,2	**109,5**	115,3	132,6
PK254	146+800	10,60	Rational Method	0,5	3,0	3,5	4,8	5,7	5,8	6,8	6,4	**7,6**	7,1	8,4
PK258	149+500	0,11	Rational Method	1,5	0,1	0,2	0,3	0,3	0,3	0,4	0,4	**0,4**	0,4	0,5

ID	Chainage	Watershed Area (km²)	Hydrological method	Slope 85-10 (%)	2-year Flood - m³/s	2-year Flood - CC - m³/s	10-year Flood - m³/s	10-year Flood - CC - m³/s	25-year Flood - m³/s -	25-year Flood - CC - m³/s	50-year Flood - m³/s	**50-year Flood - CC - m³/s**	100-year Flood - m³/s	100-year Flood - CC - m³/s
PK260	150+570	119,39	SCS Method	0,5	26,6	30,6	70,0	80,4	97,0	111,5	118,3	**136,1**	140,5	161,6
PK262	151+600	0,42	Rational Method	3,7	1,1	1,3	2,1	2,5	2,6	3,0	2,9	**3,5**	3,3	3,9
PK264	153+000	1,43	Rational Method	0,3	1,1	1,2	1,8	2,2	2,2	2,6	2,5	**3,0**	2,8	3,3
PK266	154+200	3,33	Rational Method	0,9	2,5	2,9	4,3	5,0	5,1	6,1	5,8	**6,8**	6,4	7,6
PK268	155+400	1,37	Rational Method	0,7	0,8	0,9	1,3	1,6	1,6	1,9	1,8	**2,2**	2,0	2,4
PK270	156+400	1,41	Rational Method	0,3	1,3	1,5	2,2	2,6	2,7	3,2	3,0	**3,6**	3,4	4,0
PK274	158+400	22,52	Rational Method	0,5	10,7	12,6	17,3	20,4	20,7	24,4	23,1	**27,3**	25,6	30,2
PK275	158+900	2,88	Rational Method	0,5	2,1	2,4	3,5	4,2	4,3	5,0	4,8	**5,7**	5,3	6,3
PK280	161+800	26,60	SCS Method	0,5	7,6	8,9	22,3	26,3	31,6	37,3	39,0	**46,0**	46,6	55,0
PK282	163+000	35,00	SCS Method	0,5	7,4	8,8	19,5	23,0	26,9	31,8	32,9	**38,8**	39,0	46,1
PK283	163+300	1,66	Rational Method	1,1	0,3	0,4	0,5	0,6	0,6	0,7	0,7	**0,8**	0,8	0,9
PK288	166+300	102,91	SCS Method	0,5	25,4	29,2	60,3	69,3	81,5	93,7	98,0	**112,7**	115,1	132,4
PK291	168+400	3,16	Rational Method	0,7	1,4	1,6	2,4	2,8	2,8	3,4	3,2	**3,8**	3,6	4,2
PK293	169+300	0,75	Rational Method	1,1	0,4	0,5	0,8	0,9	0,9	1,1	1,0	**1,2**	1,1	1,4
PK294	169+900	0,82	Rational Method	2,4	0,7	0,8	1,2	1,4	1,5	1,7	1,7	**2,0**	1,9	2,2
PK297	171+400	0,19	Rational Method	1,2	0,2	0,2	0,3	0,4	0,4	0,5	0,5	**0,6**	0,5	0,6
PK301	173+700	1,94	Rational Method	0,5	1,0	1,1	1,6	1,9	1,9	2,3	2,2	**2,6**	2,4	2,9
PK302	174+100	2,95	Rational Method	0,5	0,7	0,8	1,1	1,3	1,3	1,6	1,5	**1,8**	1,7	2,0
PK309	178+300	62,92	SCS Method	0,5	13,0	14,9	33,6	38,6	46,4	53,4	56,6	**65,1**	67,1	77,2
PK310	178+900	0,46	Rational Method	3,8	0,5	0,6	0,9	1,1	1,1	1,4	1,3	**1,5**	1,5	1,7
PK311	179+700	0,53	Rational Method	2,1	0,9	1,1	1,6	1,9	2,0	2,4	2,3	**2,7**	2,6	3,0
PK314	181+200	12,82	Rational Method	0,5	2,8	3,3	4,5	5,3	5,3	6,3	6,0	**7,1**	6,6	7,8
PK317	183+000	0,53	Rational Method	2,4	0,3	0,4	0,6	0,7	0,7	0,8	0,8	**0,9**	0,9	1,0
PK321	185+300	1,91	Rational Method	0,1	0,2	0,3	0,4	0,4	0,4	0,5	0,5	**0,6**	0,5	0,6
PK322	185+600	0,18	Rational Method	1,8	0,0	0,0	0,1	0,1	0,1	0,1	0,1	**0,1**	0,1	0,1
PK324	186+500	0,03	Rational Method	5,7	0,1	0,1	0,2	0,2	0,2	0,3	0,2	**0,3**	0,3	0,3
PK325	187+300	7,05	Rational Method	0,5	2,3	2,7	3,8	4,5	4,5	5,4	5,1	**6,0**	5,7	6,7
PK327	188+500	0,29	Rational Method	1,7	0,2	0,3	0,4	0,5	0,5	0,6	0,5	**0,6**	0,6	0,7
PK331	190+800	0,55	Rational Method	1,6	0,6	0,7	1,0	1,2	1,2	1,4	1,4	**1,6**	1,5	1,8
PK333	191+700	0,95	Rational Method	3,6	1,9	2,3	3,5	4,2	4,4	5,1	5,0	**5,9**	5,6	6,6
PK337	194+000	42196,66	Frequency Analysis	0,5	1932,2	1932,2	2611,4	2611,4	2913,3	2913,3	3124,7	**3124,7**	3320,9	3320,9
PK341	196+200	7,53	Rational Method	1,0	5,2	6,2	8,8	10,4	10,7	12,6	12,0	**14,2**	13,3	15,7

APPENDIX

B HYDRAULIC RESULTS

ID	Chainage	Design Flow (m³/s)	Watercourse downstream slope %	Crossing structure slope (%)	Bankfull Width (m)	Culvert Shape	Dimensions (WxH) / minimal diameter (mm)	Vertical Clearance (m)	Outlet Velocity (m/s)	Rip-Rap protection (mm)
PK009	6+150	0,65	3,2	3,2	5	Circulaire	900	0,24	3,68	300-500
PK010	6+700	1,95	0,5	0,5	2	Circulaire	1200	0,07	2,64	200-300
						Rectangulaire	1800 x 900	0,14	1,90	100-200
PK013	7+200	5,97	0,8	0,8	32	Rectangulaire	2400 x 1500	0,18	3,6	300-500
PK017	9+900	1,41	0,4	0,4	10	Circulaire	1050	0,02	2,40	200-300
PK018	10+550	26,23	0,2	0,2	45	A bridge with an hydraulic opening of approximately 38,4m, corresponding to 80% of the bankfull width (36,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK026	15+150	2,15	0,0	0,02	35	Rectangulaire	1800 x 1200	0,30	2,27	100-200
PK028	16+550	0,21	1,7	1,68	1	Circulaire	525	0,09	2,36	200-300
PK030	17+300	70,01	0,5	0,45	28	A bridge with an hydraulic opening of approximately 24 m, corresponding to 80% of the bankfull width (22,4 m) plus twice the width of the riprap protection of 300-500 mm				300-500
PK031	18+050	1,81	0,4	0,4	1	Circulaire	1200	0,09	2,48	200-300
						Rectangulaire	1800 x 900	0,09	1,38	100-200
PK032	19+000	1,45	0,3	0,29	82	Circulaire	1200	0,22	2,28	100-200
						Rectangulaire	1800 x 900	0,22	1,99	100-200
PK034	19+700	3,59	1,2	0,78	10	Rectangulaire	2400 X 1200	0,26	3,07	300-400
PK035	20+700	4,72	0,1	0,1	8	Rectangulaire	2000 X 1500	0,07	2,85	300-400
PK036	21+100	1,26	1,2	1,2	1	Circulaire	1050	0,13	3,11	300-400
PK037	21+400	1,06	1,0	1,00	1	Circulaire	1050	0,22	2,83	300-400
PK039	23+000	0,93	2,3	1,81	1	Circulaire	900	0,07	3,31	300-500
PK041	24+200	0,56	2,0	2	9	Circulaire	750	0,08	3,08	300-400
PK044	25+800	0,89	1,2	1,2	< 1	Circulaire	900	0,09	2,90	300-400
PK046	26+600	0,35	1,2	1,17	1	Circulaire	600	0,03	2,35	200-300
PK047	27+650	1,64	3,1	3,13	1	Circulaire	1200	0,20	4,31	300-500
						Rectangulaire	1800 x 900	0,24	3,87	300-500
PK050	29+050	0,47	2,9	1,67	1	Circulaire	750	0,15	2,80	200-300
PK051	29+700	142,37	0,1	0,14	25	A bridge with an hydraulic opening of approximately 21,6m, corresponding to 80% of the bankfull width (20 m) plus twice the width of the riprap protection of 300-500 mm				300-500
PK052	30+500	1,30	1,2	1,2	1	Circulaire	1050	0,11	3,23	300-500
PK053	30+900	1,03	1,5	1,5	2	Circulaire	900	0,01	3,29	300-500
PK054	31+600	2,16	0,3	0,3	8,5	Rectangulaire	1800 x 900	0,09	2,69	200-300
PK057	33+200	53,17	1,0	1,04	8	Rectangulaire	3 culverts 3000 x 2400	0,03	4,87	300-500
PK064	37+500	3,84	1,6	1,6	5	Rectangulaire	2000 x 1500	0,39	3,98	300-500
PK067	39+200	0,25	0,9	0,9	2	Circulaire	525	0,03	2,09	100-200
PK068	39+700	0,48	0,6	0,6	2	Circulaire	750	0,13	2,12	100-200
PK070	40+750	0,94	0,1	0,1	4	Circulaire	1050	0,22	2,06	100-200
PK071	41+600	29,25	0,61	0,61	5	Rectangulaire	2 ponceaux 3000 x 2100	0,01	3,12	300-400
PK075	43+100	0,46	2,35	2,3	2	Circulaire	750	0,12	3,2	300-400
PK078	45+650	1,99	0,10	0,1	12	Rectangulaire	1800 x 900	0,05	2,21	100-200
PK081	47+400	108,70	0,10	0,10	20	A bridge with an hydraulic opening of approximately 17,6m, corresponding to 80% of the bankfull width (16 m) plus twice the width of the riprap protection of 300-500 mm				300-500
PK085	49+500	77,75	0,10	0,10	45	A bridge with an hydraulic opening of approximately 38,4m, corresponding to 80% of the bankfull width (36,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK089.1	51+900	2,42	0,10	0,10	123	A bridge with an hydraulic opening of approximately 100m, corresponding to 80% of the bankfull width (98.4 m) plus twice the width of the riprap protection of 300-500 mm				300-500
PK089.2	52+100	2,16	0,94	0,94	2	Rectangulaire	1800 x 900	0,39	3,01	300-400
PK090	52+550	1,36	0,16	0,16	4	Circulaire	1050	0,04	2,36	200-300
PK094	54+400	89,80	8979,82	0,10	140	A bridge with an hydraulic opening of approximately 113.6m, corresponding to 80% of the bankfull width (112,0 m) plus the width of the riprap protection of 300-500 mm				
PK095	55+500	0,94	1,47	1,5	2	Circulaire	900	0,06	3,24	300-500
PK098	57+000	0,28	4,4	4,4	5	Circulaire	600	0,12	3,60	300-500
PK100	58+200	79,71	0,1	0,1	10	Rectangulaire	8000 x 4000	0,43	3,4	300-500
PK104	60+700	1,33	1	1,0	2	Circulaire	1050	0,10	2,99	300-400
PK108	62+500	0,39	1	1,0	1	Circulaire	750	0,21	2,26	100-200
PK110	64+000	2,58	1	1,0	1	Rectangulaire	1800 x 1200	0,29	3,16	300-400
PK111	64+700	4,94	1	1,0	55	Rectangulaire	2000 x 1500	0,18	3,69	300-500

ID	Chainage	Design Flow (m^3/s)	Watercourse downstream slope %	Crossing structure slope (%)	Bankfull Width (m)	Culvert Shape	Dimensions (WxH) / minimal diameter (mm)	Vertical Clearance (m)	Outlet Velocity (m/s)	Rip-Rap protection (mm)
PK117	68+000	6,71	1	1,0	8	Rectangulaire	2400 x 1500	0,06	3,86	300-500
PK121	70+400	1,19	1	1,0	1	circulaire	1050	0,16	2,91	300-400
PK124	72+000	7,65	1	1,0	10	Rectangulaire	2400 x 1800	0,24	4,00	400-600
PK127	74+000	4,62	1	1,0	1	Rectangulaire	2000 x 1500	0,24	3,62	300-500
PK128	74+600	5,00	1	1,0	1	Rectangulaire	2000 x 1500	0,17	3,7	300-500
PK133	77+800	173,21	1	1,0	18	A bridge with an hydraulic opening of approximately 14.4m, corresponding to 80% of the bankfull width (14.4) plus the width of the riprap protection of 300-500 mm				300-500
PK138	81+000	1,82	1	1,0	1,5	Rectangulaire	1800 x 900	0,18	2,87	300-400
PK140	81+500	5,73	1	1,0	13	Rectangulaire	2400 x 1500	0,22	3,7	300-500
PK141	81+300	0,36	1	1,0	1	Circulaire	750	0,23	2,21	100-200
PK142	83+100	1,11	1	1,0	20	Circulaire	1050	0,19	2,86	300-400
PK144	83+900	1,26	1	1,0	8	Circulaire	1050	0,13	2,95	300-400
PK149	86+600	0,12	1	1,0	24	Circulaire	600	0,10	1,72	100-200
PK153	88+100	2,06	1	1,0	1	Rectangulaire	1800 x 900	0,11	3,06	300-400
PK156	89+100	258,54	1	1,0	40	A bridge with an hydraulic opening of approximately 33.6m, corresponding to 80% of the bankfull width (32,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK159	92+500	3037,86	1	1,0	200	A bridge with an hydraulic opening of approximately 161.6m, corresponding to 80% of the bankfull width (160,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK167	97+100	2,69	1	1,0	3	Rectangulaire	1800 x 1200	0,26	3,19	300-400
PK169	98+600	77,89	1	1,0	18	A bridge with an hydraulic opening of approximately 16m, corresponding to 80% of the bankfull width (14.4 m) plus the width of the riprap protection of 300-500 mm				300-500
PK182	105+600	3,28	1	1,0	3	Rectangulaire	1800 x 1200	0,13	3,37	300-500
PK186	108+200	46,28	1	1,0	15	A bridge with an hydraulic opening of approximately 13,6m, corresponding to 80% of the bankfull width (12m) plus the width of the riprap protection of 300-500 mm				300-500
PK199	115+900	151,18	0,1	0,1	35	A bridge with an hydraulic opening of approximately 29.6m, corresponding to 80% of the bankfull width (28,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK202	117+400	3,29	0,63	0,63	30	A bridge with an hydraulic opening of approximately 25.6m, corresponding to 80% of the bankfull width (24,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK204	118+700	8,88	1,11	1,11	30	A bridge with an hydraulic opening of approximately 25.6m, corresponding to 80% of the bankfull width (24,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK206	119+600	2,91	3,33	3,33	2	Rectangulaire	1800 x 1200	0,22	4,55	300-500
PK207	120+000	71,56	2,5	0,5	5	Rectangulaire	6100 x 4000	0,32	5,42	300-500
PK211	122+400	7,80	1	1,0	5	Rectangulaire	2400 x 1800	0,22	4,02	300-500
PK214	123+800	298,50	0,01	0,01	42	A bridge with an hydraulic opening of approximately 35.2m, corresponding to 80% of the bankfull width (33.6 m) plus the width of the riprap protection of 300-500 mm				
PK216	125+000	1,92	1,75	1,75	2	Circulaire	1200	0,09	3,75	300-500
						Rectangulaire	1,62	0,15	3,39	300-500
PK218	126+500	126,20	1	0,5	15	A bridge with an hydraulic opening of approximately 13,6m, corresponding to 80% of the bankfull width (12m) plus the width of the riprap protection of 300-500 mm				300-500
PK224	130+200	0,28	1	1,00	1	Circulaire	600	0,10	2,11	100-200
PK230	133+500	0,13	2,7	1	1	Circulaire	600	0,09	1,75	100-200
PK233	135+300	3,85	1	1	4	Rectangulaire	2000 x 1500	0,39	3,45	300-500
PK234	135+900	0,06	1,0	1	1	Circulaire	450	0,22	1,42	100-200
PK235	136+300	1,05	0,75	0,75	2	Circulaire	1050	0,22	2,59	200-300
PK236	137+000	0,87	2,5	2,5	1	Circulaire	900	0,11	3,61	300-500
PK241	139+700	2,42	2	2	2	Rectangulaire	1800 x 1200	0,33	3,74	300-500
PK243	140+500	1,43	2	1	1	Circulaire	1050	0,05	3,04	300-400
PK244	141+100	2,06	1	1	6	Circulaire	1200	0,04	3,28	300-500
						Rectangulaire	1800 x 900	0,11	2,96	300-400
PK246	142+400	0,81	1	1	2	Circulaire	900	0,13	2,68	200-300
PK249	144+500	1,15	2	1	1	Circulaire	1050	0,17	2,88	300-400
PK253	146+500	109,46	0,15	0,15	15	A bridge with an hydraulic opening of approximately 13,6m, corresponding to 80% of the bankfull width (12m) plus the width of the riprap protection of 300-500 mm				300-500
PK254	146+800	7,61	0,1	0,1	5	Rectangulaire	2400 x 1800	0,08	2,57	200-300

ID	Chainage	Design Flow (m^3/s)	Watercourse downstream slope %	Crossing structure slope (%)	Bankfull Width (m)	Culvert Shape	Dimensions (WxH) / minimal diameter (mm)	Vertical Clearance (m)	Outlet Velocity (m/s)	Rip-Rap protection (mm)
PK258	149+500	0,43	8	8	1	Circulaire	750	0,20	4,69	300-500
PK260	150+600	136,09	0,83	0,01	35	A bridge with an hydraulic opening of approximately 29.6m, corresponding to 80% of the bankfull width (28,0 m) plus the width of the riprap protection of 300-500 mm				300-500
PK262	151+600	3,45	0,5	0,5	3	Rectangulaire	1800 x 1200	0,08	2,86	300-400
PK264	153+000	2,99	1,2	0,1	6	Rectangulaire	1800 x 1200	0,09	2,54	200-300
PK266	154+200	6,84	0,1	0,1	6	Rectangulaire	2400 x 1800	0,21	2,66	200-300
PK268	155+400	2,16	0,1	0,1	5	Rectangulaire	1800 x 1200	0,3	1,95	100-200
PK270	156+400	3,59	0,2	0,2	3	Rectangulaire	2000 x 1500	0,33	2,11	100-200
PK274	158+400	27,30	2,5	2,5	8	Rectangulaire	8000 x 2200	0,33	4,3	400-600
PK275	158+900	5,67	0,5	0,5	2	Rectangulaire	2000 x 1500	0,05	3,24	300-500
PK280	161+800	45,97	0,1	0,1	3	Rectangulaire	5000 x 4000	0,06	2,68	200-300
PK282	163+000	38,81	0,07	0,07	7	Rectangulaire	5000 x 3500	0,16	2,8	200-300
PK283	163+300	0,83	0,90	0,90	4	Rectangulaire	1200 x 900	0,34	2,4	200-300
						Circulaire	900	0,12	2,61	200-300
PK288	166+300	112,74	2	2	28	A bridge with an hydraulic opening of approximately 24m, corresponding to 80% of the bankfull width (22.4 m) plus the width of the riprap protection of 300-500 mm				
PK291	168+400	3,78	0,1	0,1	7	Rectangulaire	2000 x 1500	0,29	2,65	200-300
PK293	169+300	1,22	0,8	0,8	2	Circulaire	1050	0,14	2,74	200-300
PK294	169+900	1,96	0,75	0,75	1	Circulaire	1200	0,07	3,00	300-400
						Rectangulaire	1800 x 900	0,14	1,67	100-200
PK297	171+400	0,56	0,1	0,1	2	Circulaire	900	0,22	1,76	100-200
PK301	173+700	2,58	0,1	0,1	5	Rectangulaire	1800 x 1200	0,17	2,11	100-200
PK302	174+100	1,79	0,2	0,1	4	Rectangulaire	1800 x 900	0,1	1,96	100-200
						Circulaire	1200	0,07	2,47	200-300
PK309	178+300	65,06	0,01	0,01	15	Rectangulaire	2 culverts 6000 x3100	0,33	2,25	100-200
PK310	178+900	1,54	3	3	2	Rectangulaire	1200 x 900	0,06	3,82	300-500
PK311	179+700	2,70	2,5	2,5	1	Rectangulaire	1800 x 1200	0,27	4,10	300-500
PK314	181+200	7,06	1	1	9	Rectangulaire	2400 x 1800	0,33	3,91	300-500
PK317	183+000	0,90	1	1	2	Circulaire	900	0,24	2,59	200-300
PK321	185+300	0,58	6,0	3,5	5	Rectangulaire	1200 x 900	0,42	3,38	300-500
						Circulaire	750,00	0,07	3,75	300-500
PK322	185+600	0,11	0,1	0,1	3	Circulaire	450	0,08	1,34	100-200
PK324	186+500	0,29	0,4	0,4	1	Circulaire	600	0,07	1,69	100-200
PK325	187+300	6,02	0,1	0,1	3	Rectangulaire	2400 x 1800	0,22	1,89	100-200
PK327	188+500	0,64	1,5	1,5	1	Circulaire	900	0,23	2,85	300-400
PK331	190+800	1,64	4	4	2	Rectangulaire	1800 x 900	0,24	4,30	600-800
PK333	191+700	1,60	4	4	2	Rectangulaire	1800 x 900	0,25	4,30	600-800
PK337	194+000	42196,66	1,5	1	70	A bridge with an hydraulic opening of approximately 70 m				
PK341	196+200	14,18	1,3	1,25	4	Rectangulaire	3000 x 2400	0,38	4,69	600-800

APPENDIX

C PHOTOS

LA GRANDE ALLIANCE

Hydrologic and hydraulic assessment of crossing sites along the proposed road between Radisson and Kuujjuarapik

Photo 1	Crossing point PK013 viewed from above

Photo 2	Crossing point PK018 viewed from above

Photo 3	Crossing point PK026 viewed from above

Photo 4	Crossing point PK030 viewed from above

Photo 5	Crossing point PK032 viewed from above

Photo 6	Crossing point PK051 viewed from above

Photo 7	Crossing point PK078 viewed from above

Photo 8	Crossing point PK081 viewed from above, Lake Pamigamichi

Photo 9	Crossing point PK085 viewed from above

Photo 10	Crossing point PK089.1 viewed from above

Photo 11	Crossing point PK094 viewed from above

Photo 12	Crossing point PK111 viewed from above

Photo 13	Crossing point PK133 viewed from above

Photo 14	Crossing point PK140 viewed from above

Photo 15	Crossing point PK149 viewed from above

Photo 16	Crossing point PK156 viewed from above

Photo 17	Crossing point PK159 viewed from above

Photo 18	Crossing point PK199 viewed from above

Photo 19	Crossing point PK214 viewed from above

Photo 20	Crossing point PK253 viewed from above

Photo 21	Crossing point PK260 viewed from above

Photo 22	Crossing point PK288 viewed from above

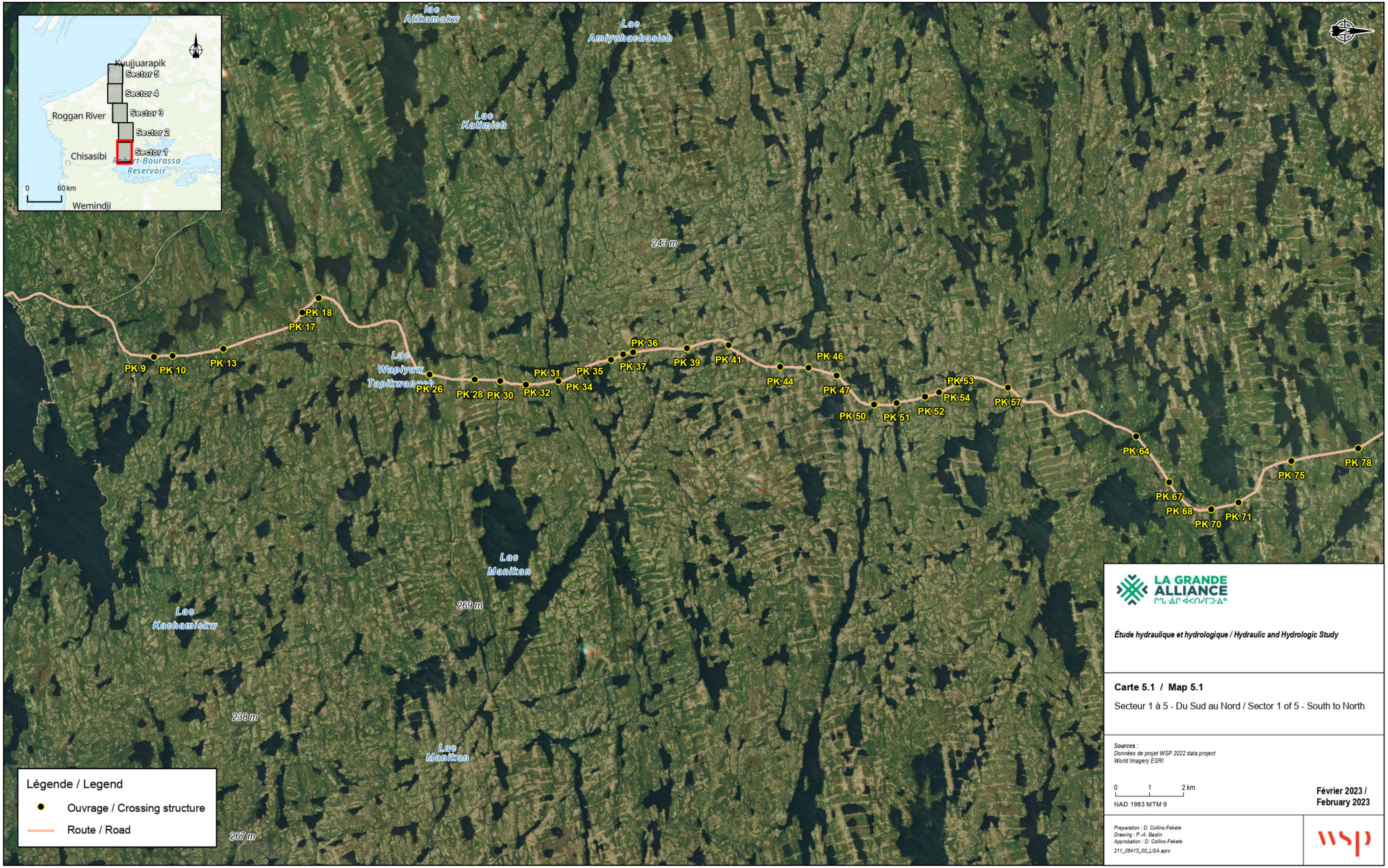
Photo 23	Crossing point PK337 viewed from above

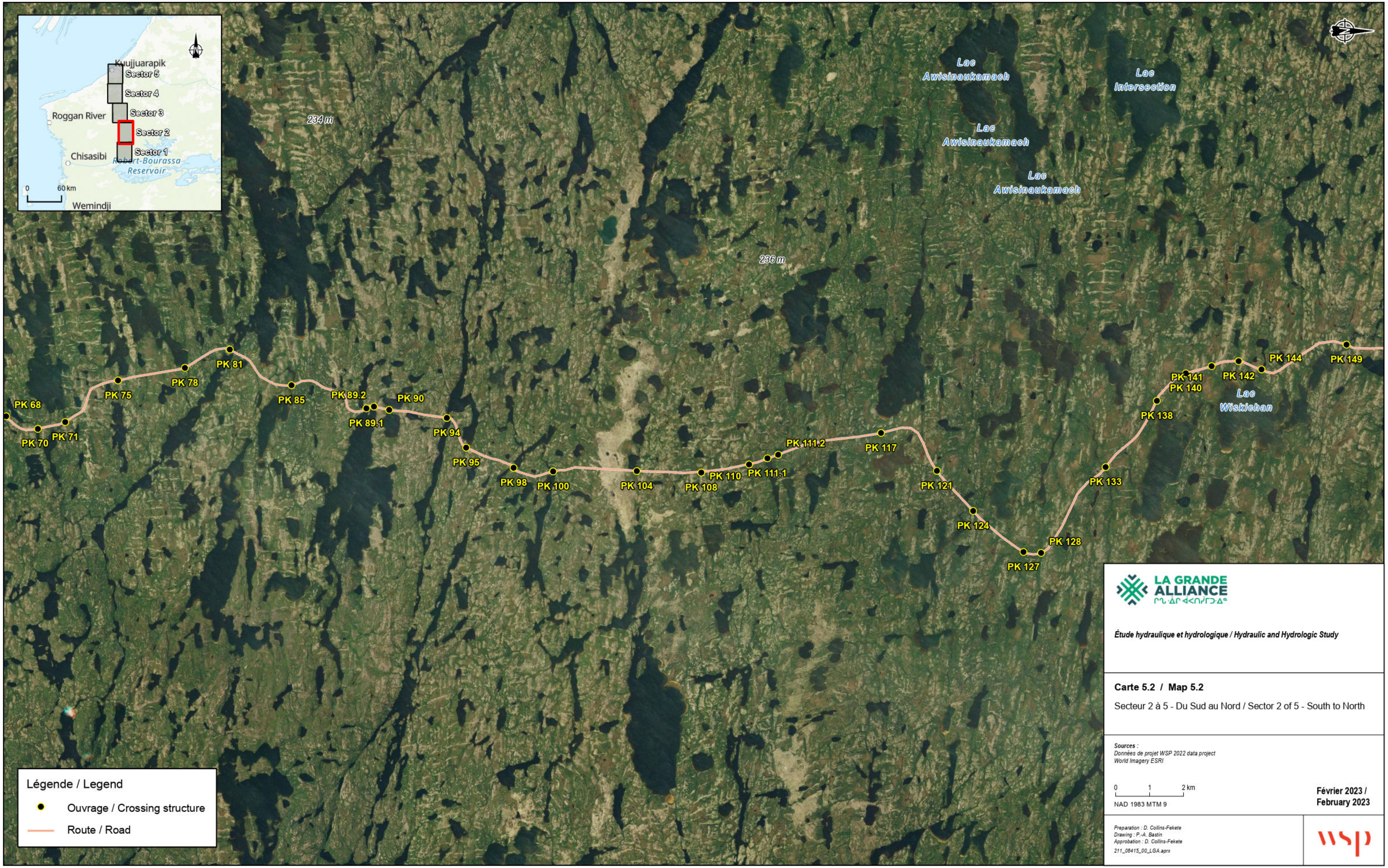
Photo 24	Crossing point PK337 viewed from above

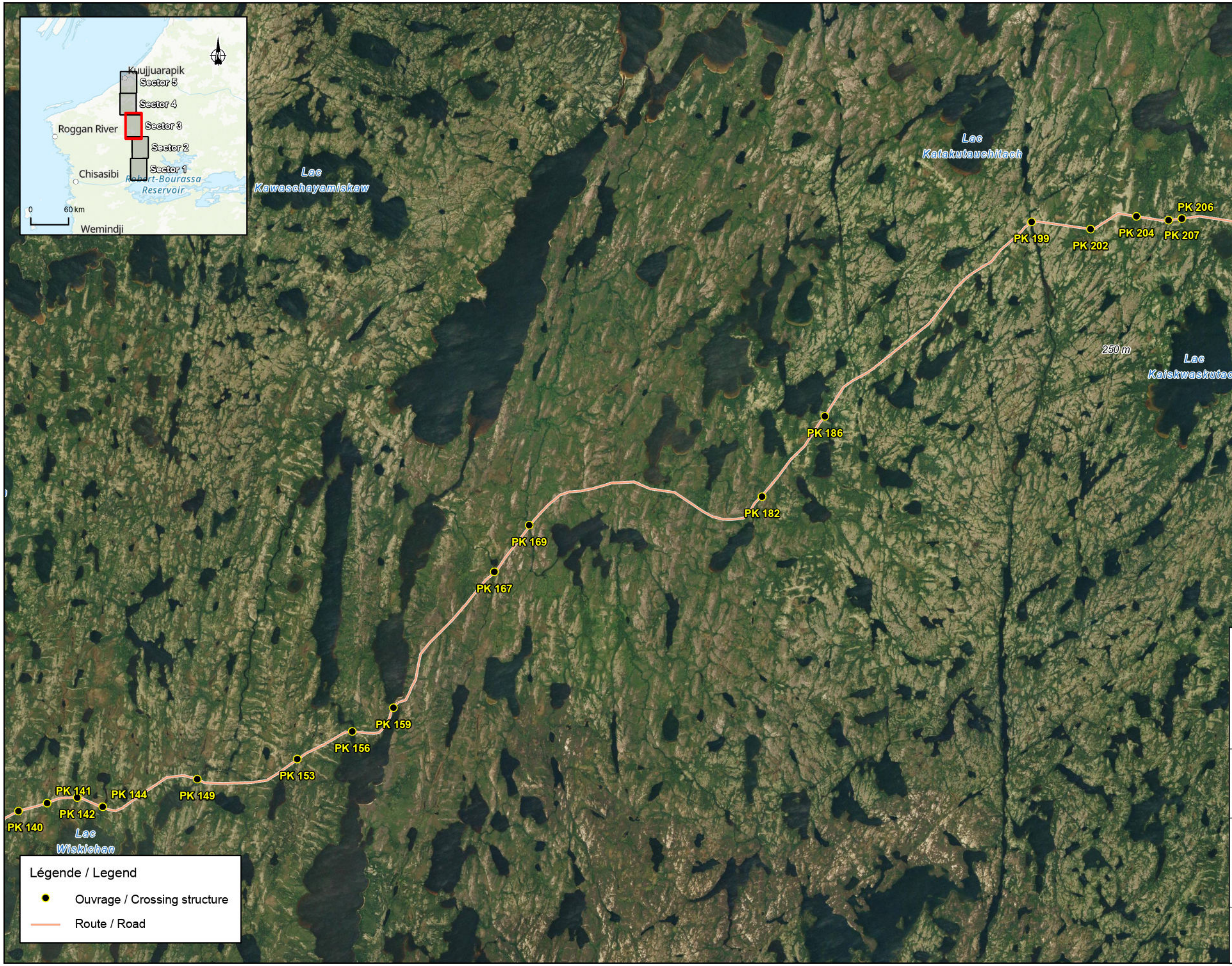
APPENDIX

D

MAPS


Kuujjuarapik
Sector 5
Sector 4
Sector 3
Sector 2
Sector 1
Roggan River
Chisasibi
Robert-Bourassa Reservoir
0 60 km
Wemindji
lac Atikamakw
Lac Amiyuhachasich
Lac Katimich
243 m
PK 9
PK 10
PK 13
PK 17
PK 18
Lac Wapiyaw Tapikwanuch
PK 26
PK 28
PK 30
PK 31
PK 32
PK 34
PK 35
PK 36
PK 37
PK 39
PK 41
PK 44
PK 46
PK 47
PK 50
PK 51
PK 52
PK 53
PK 54
PK 57
PK 64
PK 67
PK 68
PK 70
PK 71
PK 75
PK 78
Lac Manikan
269 m
Lac Kachamiskw
238 m
Lac Manikan
267 m
Légende / Legend
Ouvrage / Crossing structure
Route / Road
LA GRANDE ALLIANCE
Étude hydraulique et hydrologique / Hydraulic and Hydrologic Study
Carte 5.1 / Map 5.1
Secteur 1 à 5 - Du Sud au Nord / Sector 1 of 5 - South to North
Sources :
Données de projet WSP 2022 data project
World Imagery ESRI
0 1 2 km
NAD 1983 MTM 9
Février 2023 / February 2023
Preparation : D. Collins-Fekete
Drawing : P.-A. Bastin
Approbation : D. Collins-Fekete
211_08415_00_LGA.aprx


Kuujjuarapik
Sector 5
Sector 4
Roggan River
Sector 3
Sector 2
Chisasibi
Sector 1
Robert-Bourassa Reservoir
0 60 km
Wemindji
234 m
236 m
Lac Awisinaukamach
Lac Awisinaukamach
Lac Awisinaukamach
Lac Intersection
Lac Wiskichan
PK 68
PK 70
PK 71
PK 75
PK 78
PK 81
PK 85
PK 89.2
PK 89.1
PK 90
PK 94
PK 95
PK 98
PK 100
PK 104
PK 108
PK 110
PK 111.1
PK 111.2
PK 117
PK 121
PK 124
PK 127
PK 128
PK 133
PK 138
PK 140
PK 141
PK 142
PK 144
PK 149
Légende / Legend
Ouvrage / Crossing structure
Route / Road
LA GRANDE ALLIANCE
Étude hydraulique et hydrologique / Hydraulic and Hydrologic Study
Carte 5.2 / Map 5.2
Secteur 2 à 5 - Du Sud au Nord / Sector 2 of 5 - South to North
Sources :
Données de projet WSP 2022 data project
World Imagery ESRI
0 1 2 km
NAD 1983 MTM 9
Février 2023 / February 2023
Preparation : D. Collins-Fekete
Drawing : P.-A. Bastin
Approbation : D. Collins-Fekete
211_08415_00_LGA.aprx



LA GRANDE ALLIANCE

Étude hydraulique et hydrologique / Hydraulic and Hydrologic Study

Carte 5.3 / Map 5.3

Secteur 3 à 5 - Du Sud au Nord / Sector 3 of 5 - South to North

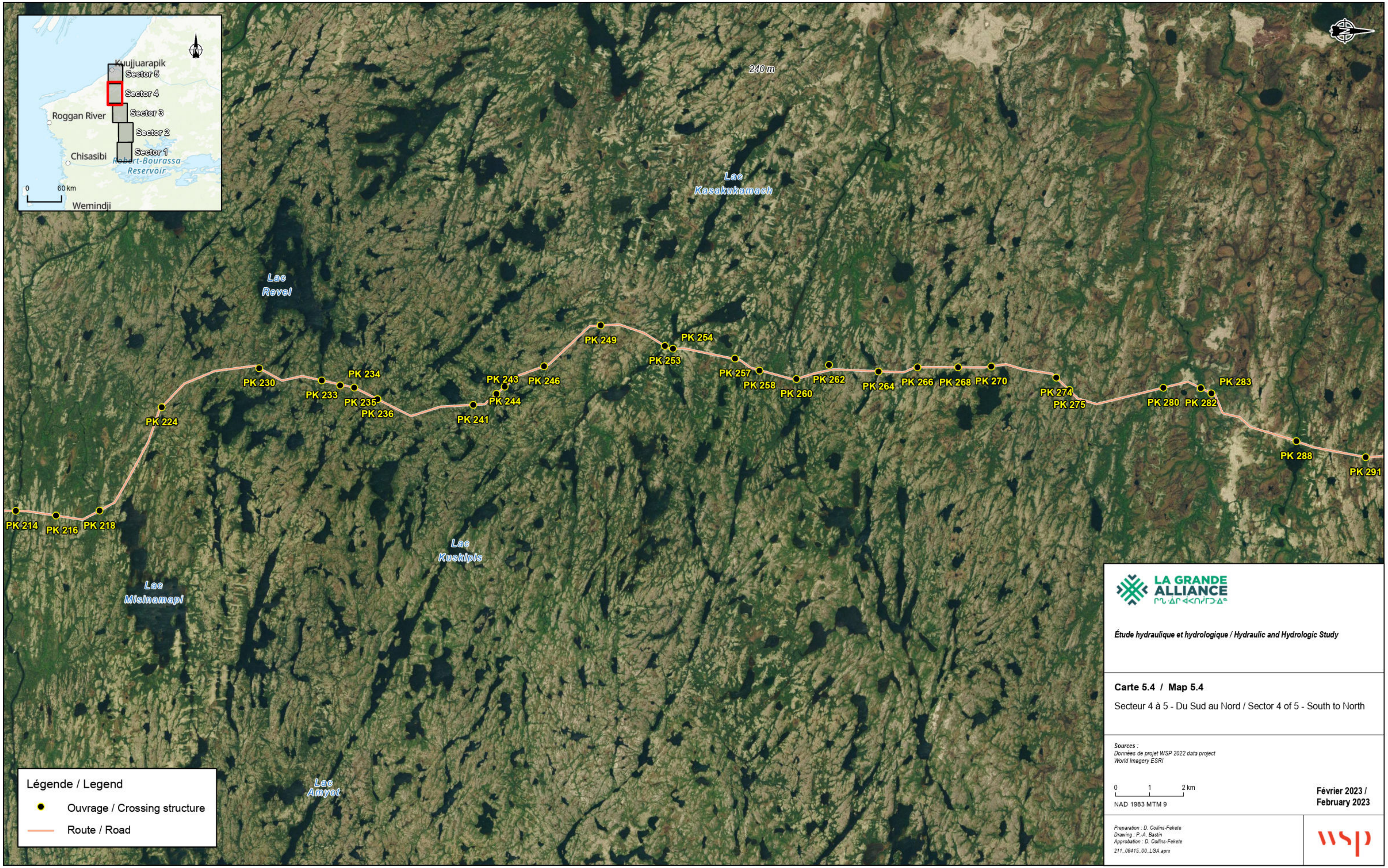
Sources :
Données de projet WSP 2022 data project
World Imagery ESRI

0 1 2 km
NAD 1983 MTM 9

Février 2023 / February 2023

Preparation : D. Collins-Fekete
Drawing : P.-A. Bastin
Approbation : D. Collins-Fekete
211_08415_00_LGA.aprx

wsp



LA GRANDE ALLIANCE

Étude hydraulique et hydrologique / Hydraulic and Hydrologic Study

Carte 5.4 / Map 5.4

Secteur 4 à 5 - Du Sud au Nord / Sector 4 of 5 - South to North

Sources :
Données de projet WSP 2022 data project
World Imagery ESRI

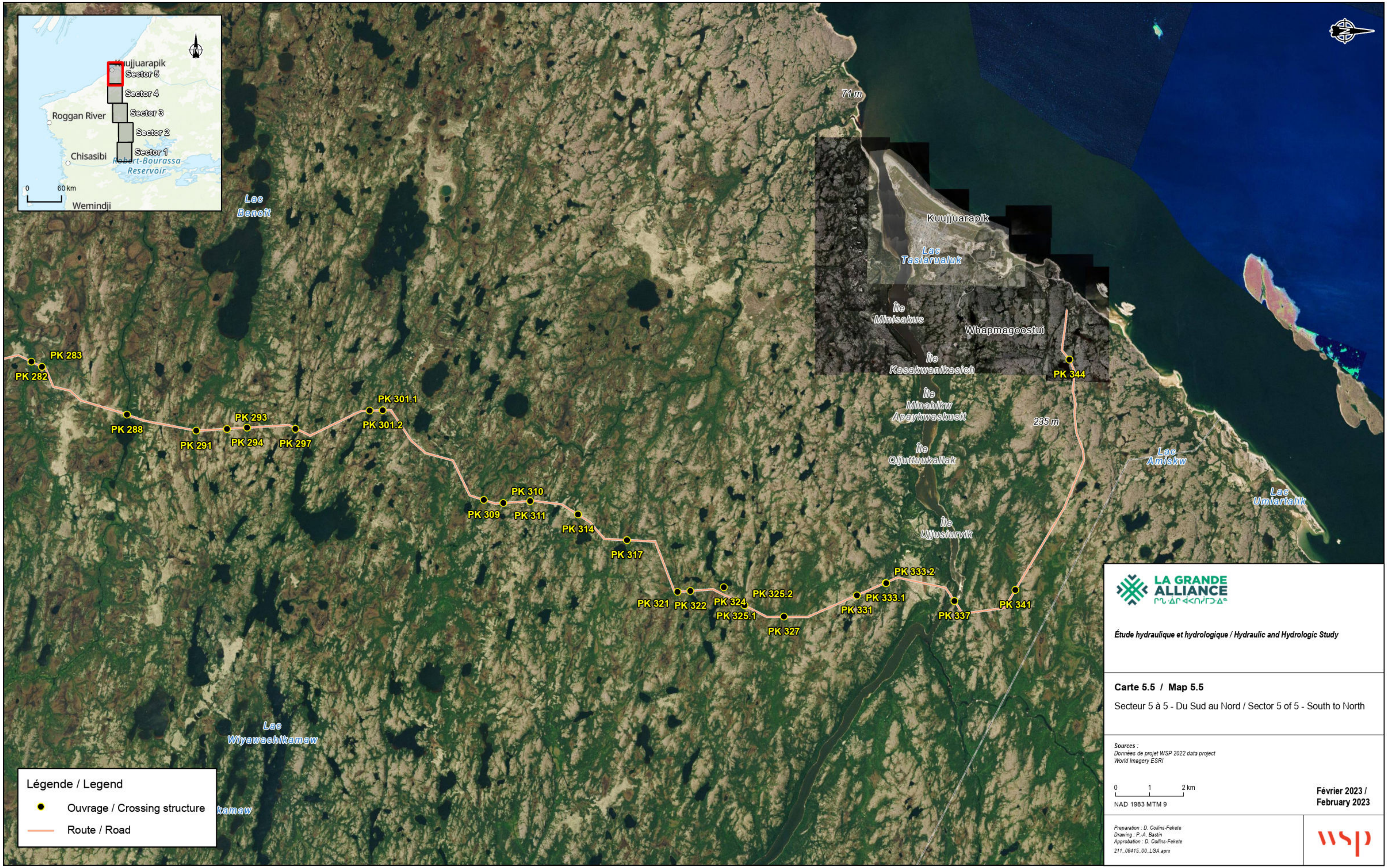
0 1 2 km

NAD 1983 MTM 9

Février 2023 / February 2023

Preparation : D. Collins-Fekete
Drawing : P.-A. Bastin
Approbation : D. Collins-Fekete
211_08415_00_LGA.aprx

wsp


Kuujjuarapik
Sector 5
Sector 4
Sector 3
Sector 2
Sector 1
Roggan River
Chisasibi
Robert-Bourassa Reservoir
0 60 km
Wemindji
Lac Benoit
71 m
Kuujjuarapik
Lac Tasiarualuk
Île Minisakus
Whapmagoostui
Île Kasakwankasich
Île Minahikw Apaykwaskusit
Île Qijuttuukallak
Île Ujjusiurvik
235 m
Lac Amiskw
Lac Umiartalik
Lac Wiyawachikamaw
PK 282
PK 283
PK 288
PK 291
PK 293
PK 294
PK 297
PK 301.1
PK 301.2
PK 309
PK 310
PK 311
PK 314
PK 317
PK 321
PK 322
PK 324
PK 325.1
PK 325.2
PK 327
PK 331
PK 333.1
PK 333.2
PK 337
PK 341
PK 344
Légende / Legend
Ouvrage / Crossing structure
Route / Road
LA GRANDE ALLIANCE
Étude hydraulique et hydrologique / Hydraulic and Hydrologic Study
Carte 5.5 / Map 5.5
Secteur 5 à 5 - Du Sud au Nord / Sector 5 of 5 - South to North
Sources :
Données de projet WSP 2022 data project
World Imagery ESRI
0 1 2 km
NAD 1983 MTM 9
Février 2023 / February 2023
Preparation : D. Collins-Fekete
Drawing : P.-A. Bastin
Approbation : D. Collins-Fekete
211_08415_00_LGA.aprx
wsp