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GeoVirtual 2020 September 14-16
Resilience and Innovation

Webequie First Nation Supply Road: Terrain Analysis and Routing for the First Indigenous-Led Environmental Assessment in Ontario

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ABSTRACT

Webequie First Nation, located approximately 500 km north of Thunder Bay, Ontario, is developing an all-season road between the community of Webequie and a proposed Ring of Fire mining development around Esker Camp near the Mukutei River, approximately 110 km to the east. The Webequie First Nation Supply Road (WSR) project is the first Indigenous-led environmental assessment in Ontario. Once completed, the WSR will offer year-round movement between the community and the future mine site and will facilitate economic opportunities for the community. This paper presents a description of the terrain analysis and mapping within the proposed route corridor, along with potential aggregate sources and stream crossings, that will guide the identification of an optimal route based on terrain and engineering considerations.

RÉSUMÉ

La Première Nation de Webequie, située à environ 500 km au nord de Thunder Bay, en Ontario, développe une route toutes saisons entre la communauté de Webequie et un projet de développement minier Ring of Fire autour d'Esker Camp près de la rivière Mukutei, à environ 110 km à l'est. Le projet Webequie First Nation Supply Road (WSR) est la première évaluation environnementale dirigée par des Autochtones en Ontario. Une fois terminé, le WSR offrira un mouvement à toute-l'année entre la communauté et le futur site minier et facilitera les opportunités économiques pour la communauté. Cet article présente une description de l'analyse et de la cartographie du terrain dans le corridor d'itinéraire proposé, ainsi que des sources d'agrégats potentiels et des traversées de cours d'eau, qui guideront l'identification d'un itinéraire optimal en fonction du terrain et des considérations d'ingénierie.

1 INTRODUCTION

Webequie First Nation, located approximately 500 km north of Thunder Bay, Ontario, is developing an all-season road between the community of Webequie and a proposed Ring of Fire mining development around Esker Camp near the Mukutei River, approximately 110 km to the east (Figure 1). The Webequie First Nation Supply Road (WSR) project is the first Indigenous-led environmental assessment in Ontario. Once completed, the WSR will offer year-round movement between the community and the future mine site and will facilitate economic opportunities for the community.

Preliminary corridor alternatives were identified, and a preferred corridor was selected, by the community based on engagement with youth representatives, elders, and the Webequie land use planning committee. The preferred corridor, selected by the community, is approximately 107 km in length (extending about 51 km toward the south-southeast from Webequie before turning east for about 56 km toward Esker Camp), and 2 km in width. It is within this preferred corridor that the road route is to be selected.

As part of the Environmental Assessment and Preliminary Engineering Services for Webequie First Nation's Supply Road Project, J.D. Mollard and Associates (2010) Limited conducted terrain mapping within the proposed community corridor to facilitate identification of potential aggregate sources, characterize stream crossings, map several competing route alternatives, and identify an optimal route based on terrain and engineering considerations.

2 DATA SOURCES

Terrain analysis was conducted using aerial and satellite imagery, digital elevation data, and existing surficial geology and land cover maps. The primary source of desktop information for terrain mapping was high-resolution orthoimagery (20 cm resolution) and LiDAR elevation data (1 m resolution) acquired within the 2-km wide corridor for the project. Satellite imagery available through ESRI World Imagery Basemap and Google Earth offered supplemental imagery at high-resolution. Air photo interpretation was also conducted at select locations using 1954 black & white photos at 1:60,000 scale, which, when viewed stereoscopically, provide 3-D perspectives to evaluate terrain and topographic conditions. These multiple sources of imagery assist with the terrain unit classification, particularly with resolving wetlands and permafrost-affected terrain.

Elevation data covering the 2-km wide route corridor were provided by LiDAR (light detection and ranging) and processed at a spatial resolution of 1 m. Using the LiDAR data, shaded-relief and slope rasters were generated to assist with the interpretation of terrain units.

Additional information on the surficial geology, hydrology, and land cover was obtained from published datasets by the Ontario Geological Survey (Quaternary and Surficial Geology), Ontario Hydrology Network (waterbodies and stream), and the Ontario Ministry of Natural Resources (Provincial Land Cover 2000 Database).

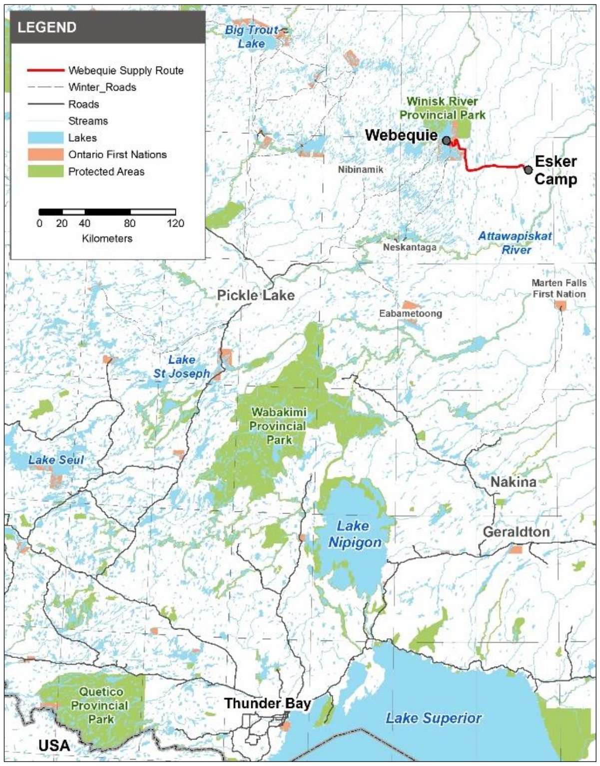

Figure 1. Location of the Webequie First Nation Supply Road Project.

3 METHODOLOGY

3.1 Terrain Mapping

Terrain mapping within the proposed route corridor involved the interpretation of remotely sensed imagery (air photos and satellite images) and digital elevation data, supplemented with surficial geology, hydrology, and land cover data, to characterize the landforms, surficial materials, topography, and hydrology. Geospatial data available for this study were compiled in a geographic information system (GIS) and terrain units were manually digitized over base layers of imagery (air photos and satellite) and elevation data (elevation, shaded-relief, and slope rasters).

Terrain units were classified and mapped according to a legend developed for this area based on a compilation of previous reports and existing mapping (J.D. Mollard and Associates (2010) Ltd., 2010). The route corridor crosses extensive organic terrains of various bogs and fens along the east-west section of the corridor west of Esker Camp and glacial terrains with mineral soils on the roughly north-south section leading to the community of Webequie. Mineral terrains include till with a discontinuous lacustrine clay veneer, glaciofluvial ice-contact, esker ridges, and alluvial floodplains. Organic terrains include bogs and fens with tremendous diversity and extent.

3.1.1 MINERAL TERRAINS

Mineral terrains were classified into four units (TL, ER, GF, and AF). TL (Till and glacial lake clay): silty till (T) on a north-south oriented fluted plain with a mostly thin, discontinuous cover of soft, sticky plastic lacustrine silty clay (L). Extensive cover of TL terrain over the N-S section of the route corridor with some areas of thin bog or fen cover.

ER (Esker ridge): the esker near Esker Camp consists of thick sand, reaching a total depth of more than 20 m, with a discontinuous cover of glacial-lake clay on the side-slopes. The esker system is segmented, with mostly short gaps and three notable local expansions called “bulges” (esker fans and deltas), resulting in very large volumes of nearby granular material.

GF (Glaciofluvial): Ice-contact glaciofluvial deposits (kames and eskers) consisting of sorted granular material.

AF (Alluvial floodplain): Varying mineral-soil textures along small creek channels whose floodplains are discontinuous and around the periodically flooded perimeters of water bodies. Relatively thin peat over alluvium, stream-eroded till, and intermittently flooded mineral soil. Mostly narrow and subject to flooding. Some creek channels are linear, following abandoned flute depressions or ice-keel scour depressions.

3.1.2 ORGANIC TERRAINS

Bog Terrains

DB (Domed bog): Oval, lenticular, teardrop and irregular-outlined domed shapes; common occurrence; usually greater than 500 m in longest dimension; notably convex surface with crest up to several metres higher than bog edges and the surrounding terrain. Multiple drainage lines (e.g., watertracks) commonly radiate outward from the bog summit. Clusters of bog pools on DB are less common than they are on PB, also with smaller pools and smaller and less well-defined clusters. Peat depth may exceed 3m near the DB central area. Stratified Sphagnum-sedge-woody shrub peats with large Sphagnum lawn and black spruce areas at ground surface.

PB (Northern plateau bog): Generally large, slightly raised (0.5 to 1 m) bog above the surrounding terrain with steep edges - plateau-like in appearance with a commonly irregular outline edge in plan. Numerous larger bog pools usually occur in larger clusters than observed on DB. Distinct pool clusters are also more common on PB than on DB, forming net bog (NB) with reticulate patterns of narrow peaty ridges between large pools, occasionally transitioning downslope to string bogs (SB) and then downslope to string (ribbed) fens. Includes flat bog, not raised above the surrounding surface with peat depth generally uniform and with less common NB. Light grey air photo tones result from extensive Sphagnum moss lawns with sparse black spruce trees and shrubs. Common stratified peat depths are 2 to 4 m, consisting of moderately decomposed Sphagnum peat over Sphagnum and sedge peats.

NB (Net bogs): component of northern plateau bogs (PB), located at one or more locations on flat-topped bog summits, includes minor string bog and string fen. The pattern consists of a network of reticulate narrow (2 to 3 m wide) peaty ridges about 1m high, separating numerous small to large bog pools having irregular and linear shapes (NB). Pools are occasionally aligned in parallel strings at right angles to surface-water runoff and to groundwater flow (SB). In this study, NB included SB in the terrain mapping. Pools vary from shallow to very deep.

TB (Treed bog): Areas of extensive tree cover developed on relatively thin organic material over mineral soils. Typically occur along the margins of streams and watercourses.

TK (Thermokarst bog, also called collapse scar bog, often associated with treed bog): Slightly raised perennially frozen peatland (permafrost-affected) with small, uniform-sized, roundish ground-ice-thawed collapse holes containing water or wet fen vegetation, called “collapse scars”. The resulting spotty speckled or mottled air photo pattern of whitish collapse holes is caused by subsidence upon melting of ground ice and possibly melting of palsas in a few places. This unit tends to occur along the sloping margins of small and large creek drainages, and is also found as small isolated randomly distributed patches in neighbouring upland areas.

Fen Terrains

SF (String fen): on sloping terrain; narrow subparallel stringy peat ridges enclosing slit-like depressions with open water or wet fen vegetation (mostly sedge with shrubs and tamarack trees). Strings are aligned at right angles to the slope and in the direction of surface-water runoff and groundwater flow. SF areas are larger than ladder fens. String width becomes narrower and more closely spaced as slope gradient increases downslope. Peat depth is commonly over 2 m.

LF (Ladder fen): subtype of string fen, thus similar to string fens in appearance but smaller with narrower pools, often along the margin of domed and plateau bogs. Peat thickness is commonly 1 to 2 m.

CF (Channel fen): fens occupying generally well-defined longer and wider channels, including abandoned glacial meltwater channels, with and without small streams. Peat depth may exceed 2 m in some CF fens.

WF (Watertrack fen): A flowing pattern of narrow slightly concave surface runoff courses and groundwater seepage on slopes, radiating from the summits of domed and plateau bogs. WF may also originate from springs and seeps. Common peat depths of 1 to 2 m.

HF (Horizontal fen): broad, featureless gentle slopes. Commonly uniformly forested with trees, shrubs, coarse grasses and sedges. Commonly transitional to swamps (swamp-fens). Common peat thickness of 2 to 3 m.

Figure 2. String fen and domed bogs.

Figure 3. Stream crossing and treed bogs.

3.2 Peat Thickness (GPR and Probes)

Peat depths for some terrain units are reported in the Canadian Wetland Classification System (University of Waterloo, Wetlands Research Centre, 1997). Ground penetrating radar (GPR) and peat probing was conducting at representative peatlands within the routing corridor to help characterize the depth and variability of the peat layer over bedrock or glacial sediment.

GPR survey sites were identified from air photo interpretation and mapping work. At each survey site, two or more transects were identified that crossed multiple organic terrain units. A total of five (5) peatland areas were surveyed following a total of sixteen (16) survey transects, capturing approximately 22 km of GPR profile data. The field surveys were conducted used a Sensors & Software Noggin™ 100MHz GPR system mounted on custom skies and towed by snowmobile. A

TopCon DGPS unit provided submeter geographic positioning for the GPR reflectance data as it was collected along each survey transect. The radar reflectance data for each survey transect was processed using Sensors & Software Ekko_Project v5.3 GPR software suite. The processed GPR profiles assume a return radar wave velocity of 0.040 m/ns, a typical value cited in the literature for peatlands in northern Ontario.

Peat depths were also measured in the summer using a peat probe (Figure 4). The probe was manually pushed through the peat until reaching refusal. At most sites, the probe returned a smear of grey clay or brown till, indicating the base of organic soils and the top of mineral sediments. Since most survey transects cross several peatland types (as interpreted by the air photo mapping), statistics on the minimum, maximum and average peat depths for each terrain type were also compiled, for individual transects and for the study sites as a whole.

Figure 4. Peat probe on the margin of a fen.

3.3 Identification of Alternative Routes

The selection of a final road route between Webequie First Nation and Esker Camp will rely on various social, cultural, environmental, and engineering considerations. An initial road route provided by the community was used to establish a 2-km-wide corridor within which LiDAR data and orthoimagery were collected. In this study, the identification of several route alternatives, and the selection of an optimal route within the proposed route corridor from a terrain perspective follows the interpretation of terrain conditions and consideration of related engineering factors. Terrain mapping characterized the landforms, surficial materials, topography, hydrology and groundwater conditions within the proposed corridor, which provided the basis for evaluating the favourability for route location and construction. Detailed engineering design will take into consideration these terrain conditions.

The following considerations served to guide the evaluation of all-weather road route alternatives in this study:

- Route length
- Surficial material (mineral vs organic soils)
- Topographic relief and slopes
- Ice-rich peat bogs and fens
- Extensive thermokarst-affected terrain
- Characteristics of river and stream crossings
- Proximity to potential aggregate sources

Several route alternatives were identified with consideration to minimize the total route length, to follow routes that maximize terrain units of favourable constructability (e.g., mineral soils), minimize units of poor constructability (e.g., fens), minimize the number and widths of stream crossings, and minimize aggregate haul distances. While a shorter route is typically preferred, *ceteris paribus*, there can be environmental, engineering, social and economic advantages of an overall longer route that follows favourable terrain units and minimizes stream crossings. Terrain units with mineral soils are considered favourable for route construction, while those units with organic soils are considered unfavourable (Table 1). Bogs are preferred over fens because bogs typically have a lower water table and fewer open water areas. Treed bogs are considered more favourable than other bogs because the extensive tree cover hints at thinner organic cover with better drainage and roots anchored in mineral soils.

3.4 Water Crossings

Surficial hydrology within the route corridor includes numerous streams, fens and bogs that will require various engineered water crossings. Overall, drainage of the area trends south to north, following the orientation of the fabric of glaciated landforms and ultimately draining into Hudson Bay. Stream crossings include both open water and flat alluvial floodplains. Many of the alluvial floodplains appear to feature extensive aquatic vegetation floating as a mat along the margins of the main open water channels. At these locations, the width of the water crossings should consider the area mapped as alluvial plain. Fens, particularly channel and ladder fens, having water tables at or near the surface and flowing groundwater gradients may also need to be treated as “water crossings” when considering engineering design options.

Stream crossings were characterized using the orthoimagery and LiDAR elevation data to describe the open water width, alluvial floodplain width, maximum slope, bank height, and terrain unit.

3.5 Potential Aggregate Sources

The road route corridor crosses an area of extensive wetlands and organic soils that limit prospects for potential aggregate sources. Aggregate prospects were identified while terrain mapping the route corridor. Air photo and satellite imagery, along with existing surficial geology maps, were used to identify granular landforms as potential sources of aggregate. Landforms created by meltwater processes during deglaciation are typically composed of sorted granular material. It is this relationship between landforms and materials that allows for granular prospects to be mapped by terrain analysis. Bedrock outcrops, with or without minimal overburden were identified and mapped as potential quarry sites.

The characteristics of the glaciofluvial granular deposits (overburden thickness, stratigraphy, gradation, *etc*.) were evaluated from shallow test holes dug with either a mini-excavator or manually with a shovel. Where access allowed, the mini-excavator was brought in by helicopter to dig test pits to a depth of about 2 m. At other locations, where logistical challenges restricted slinging in the mini-excavator, test holes were dug manually to a depth of 30-90 cm. Sieve tests were run on samples collected from the test holes.

Bedrock outcrops identified and mapped on the imagery as potential quarry sites were visited in the field to describe the lithology and structural elements (fractures, bedding, foliation, etc.) visible at surface to make an initial assessment of bedrock suitability for aggregate production.

At the planning stage, the availability, distance, and distribution of construction material along a proposed route provides an important input to construction and maintenance cost estimates.

4 RESULTS

4.1 Terrain Mapping

Terrain mapping was completed within the 2-km-wide corridor between the community of Webequie and the Mukutei River near Esker Camp (Figure 5). The total area mapped is 255.48 km^2, of which mineral terrains cover 87.12 km^2, organic terrains cover 133.33 km^2, and water (lakes and rivers) covers 35.03 km^2 (Table 1).

Table 1. Terrain units and area within the 2-km-wide corridor of the WSR.

Terrain Units	Area (km^2)
Mineral Terrains	
TL	78.06
ER	0.95
GF	0.98
AF	7.13
Total Mineral Terrains	87.12
Organic Terrains	
<u>Bogs</u>	
DB	12.87
PB	51.32
TB	31.93
NB	0.22
TK	11.66
Total Bog Terrains	108.00
<u>Fens</u>	
SF	3.89
LF	1.72
CF	5.67
WF	12.84
HF	1.21
Total Fen Terrains	25.33
Total Organic Terrain	133.33
Water	
Total Water Terrains	35.03
Total	
Total	255.48

4.2 Peat Thickness

Peat thickness measured by GPR varied for each of the terrain units, with depths ranging from 0.5 m to 5.0 m. Soil probe measurements returned peat thicknesses typically from 1 to 4 m, which is consistent with reported values from the wetlands classification system. At most of the sampling sites, the peat probe penetrated the organic material and was stopped in underlying clay or clayey till.

Overall, these observations suggest that peat thickness is similar in bogs and fens, typically 1-3 m with a maximum thickness of up to 5 m. Peat thickness in treed bogs is generally less than 1 m. The range of values observed for each of the terrain units at all of the testing locations is summarized in Table 2. Previous peat probing by JDMA at sites approximately 5 km south of the Webequie route corridor, but within similar terrain units, measured peat thickness between 1.0 and 4.7 m, which is consistent with the range of thicknesses observed with the GPR data and peat probe at sites within the corridor.

Table 2. Summary of peat depths from GPR Surveys.

Terrain Type	Min Depth (m)	Max Depth (m)
Domed Bog (DB)	0.7 m	3.7 m
Plateau Bog (PB)	0.5 m	5.0 m
Treed Bog (TB)	0.5 m	1.0 m
String Fen (SF)	1.7 m	3.7 m
Ladder Fen (LF)	1.0 m	4.7 m
Channel Fen (CF)	1.0 m	3.3 m

4.3 Routing

A total of six alternative routes were mapped within the proposed corridor, each of which share various common segments and differ along other segments that offer advantages and disadvantages. An optimal route from a terrain perspective was identified by picking segments from the competing alternative routes that meet the major criteria of route length, terrain conditions, stream crossings, and proximity to aggregate sources. The optimal route minimizes total length in two main locations. The first is in the area southwest of Prime Lake, where the corridor transitions from north-south to east-west at nearly a right angle. By crossing outside of the original corridor to the north, the optimal route cuts the overall length without adding additional water crossings. The second key location is around Bender Lake, where the optimal route crosses the shorter path northward around the lake.

The optimal route minimizes length crossing terrain units that have a poor constructability ranking (see Tables 3 and 4), in particular the various types of fens that feature organic soils and a water table at surface.

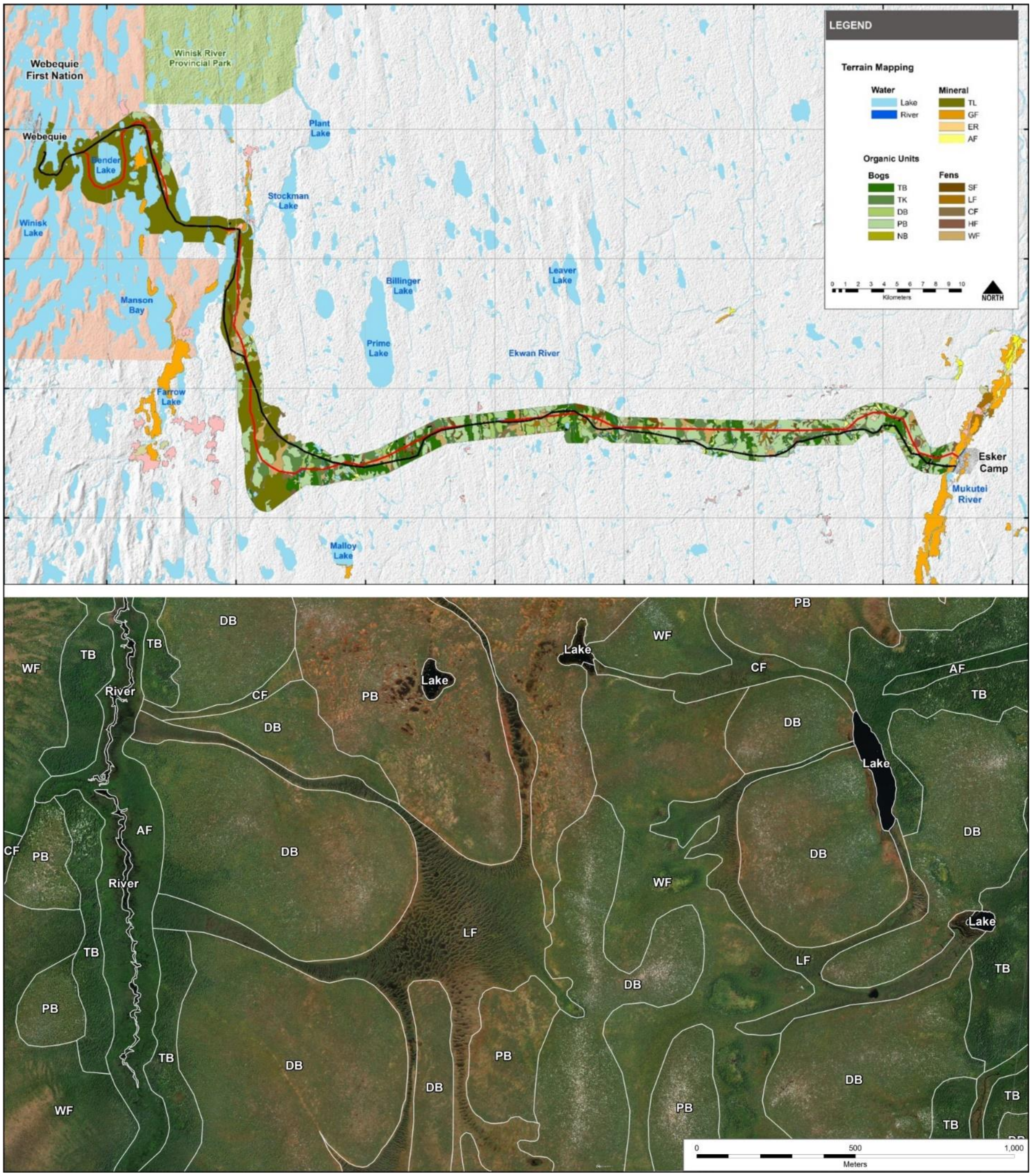

Figure 5. Overview (top) and detailed example (bottom) of terrain mapping in the WSR corridor.

Table 3. Route length over terrain units.

Terrain Type	Optimal Route (km)	Community (km)
Mineral Terrains		
TL	39.33	41.13
ER	0.56	0.56
GF	0.61	0.69
AF	2.11	2.20
Organic Terrains		
Bogs		
DB	6.44	7.43
PB	13.89	22.94
TB	21.95	13.30
TK	4.94	4.95
Fens		
SF	0.77	1.20
LF	0.06	0.78
CF	1.76	2.49
WF	5.37	6.74
HF	0.71	0.54
Water Crossings		
Water	0.53	0.92
Total		
Total	99.04	105.88

Table 4. Length of constructability rankings.

Terrain Type	Optimal Route (km)	Community Route (km)
Good	40.50	42.39
Fair	26.89	18.26
Poor	20.83	31.18
Very Poor	10.29	13.13
Water Crossing	0.53	0.92
Total	99.04	105.88

4.4 Water Crossings

Water crossings were characterized by open water width, alluvial floodplain width, maximum slope, bank height, and adjacent terrain types. Figure 6 provides an example of a large-scale image, slope raster, and cross-sections at a water crossing along the community route. Drainage across the east-west portion of the corridor flows typically toward the north-northeast, draining northward into larger lakes like Prime Lake or Billinger Lake or into one of the larger river systems like the Ekwan River and the Mukutei River. Along the western portion of the corridor, which trends north-south and is covered largely by glacial terrains, the surficial drainage features fewer stream crossings than the east-west section of the corridor.

Most stream crossings exhibit relief of less than a few metres and cross flat alluvial floodplains that feature floating aquatic vegetation, have water tables near the surface, and are subject to flooding. The widest crossing, spanning approximately 250 m, is from Eastwood Island to the mainland. Two of the most deeply incised stream crossings appear to cut into glacial deposits (including glaciofluvial material) over bedrock. The Mukutei River crossing encounters the greatest bank heights of up to 20 m and slopes of up to 30 degrees on the west bank formed within a large ice-contact glaciofluvial landform. The river crossing entering Stockman Lake spans a channel between two lakes and exhibits bank heights of up to 7.5 m and slopes of up to 23 degrees. The channel is cut through glacial sediment, with till on the south bank and glaciofluvial deposits on the north bank.

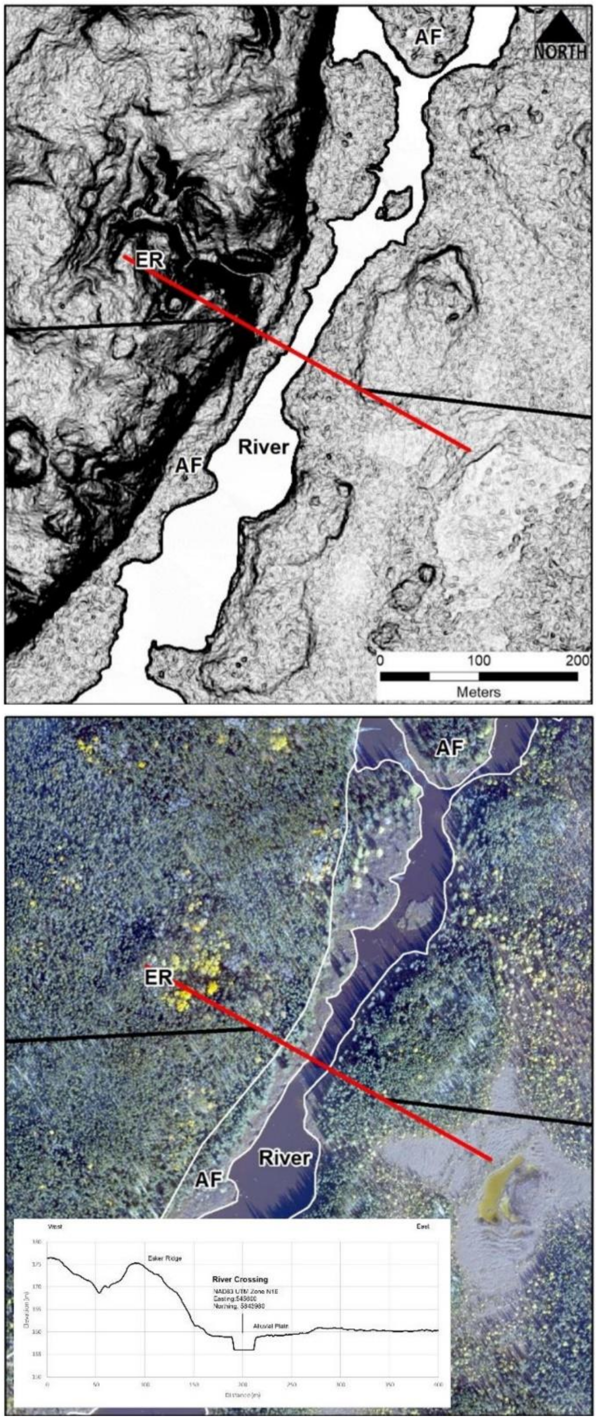

Figure 6. Mukutei River crossing. Lidar slope raster (top) and orthoimagery (bottom). Cross-section (inset) from lidar data.

4.5 Potential Aggregate Sources

The Webequie Supply Road corridor crosses mostly glacial till along the north-south trending western section and extensive peatlands and organic soils along the east-west trending eastern section, which make identifying potential aggregate prospects a challenge. Surficial mapping using digital air photos and lidar identified several potential aggregate sources that include ice-contact glaciofluvial landforms and bedrock outcrops. Extensive, roughly north-south trending, ice-contact glaciofluvial systems are known to exist near the east and west ends of the proposed corridor and provide a source of surficial granular material (Figure 7).

Near Esker Camp, on the west side of the Mukutei River, there is a large esker that trends north-northeast and is among the largest granular prospects in the region.

Along the western section of the route, there is an ice-contact glaciofluvial deposit that is most extensive to the west and north of Farrow Lake and that extends discontinuously northward along the eastern side of Manson Bay on Winisk Lake. In addition to these two large prospects, a smaller ice-contact glaciofluvial landform occurs within the corridor and extends northward west of Stockman Lake. These landforms are primarily composed of clean medium to coarse sand and occur at locations close to the proposed road route, which would limit the haul distances for construction.

Near the half-way point of the route, one small ice-contact glaciofluvial landform was tested that returned coarse sand to medium gravel but offers a limited volume of aggregate.

Figure 7. Mini-excavator digging a test pit into an ice-contact glaciofluvial landform.

Bedrock outcrops scattered across the length of the corridor and in proximity to route alternatives offer potential quarry rock sources. The lithology of rock in the area is mapped as metamorphic and igneous. Bedrock observed at four sites was felsic plutonic (granite), massive and homogenous. The largest outcrops occur south and east of Farrow Lake located west of the corridor. Several small bedrock outcrops were identified near the half-way point of the route, both inside and outside the proposed corridor, and offer potential for a rock quarry, especially given their locations that would drastically reduce the haul distances.

Figure 8. Crystalline bedrock outcrop along the route corridor.

5 SUMMARY

This study was undertaken as part of the Environmental Assessment and Preliminary Engineering Services for Webequie First Nation's Supply Road Project – the first Indigenous-led environmental assessment in Ontario. Terrain analysis and mapping within the proposed corridor facilitated the identification of potential aggregate sources, characterization of stream crossings, and mapping of competing route alternatives. Six alternative routes were identified largely within a 2 km wide road route corridor that is centred on a community-selected preferred route. From these an optimal route was selected that reduced the overall length of the route by approximately 5 km and improved the constructability ranking of the overall route. Peat thicknesses were determined to be mostly 1-3 m ranging upwards to 5m based on ground penetrating radar and probe surveys. A number of prospective aggregate sources were identified in glaciofluvial deposits and as potential quarries in outcrops of Precambrian crystalline bedrock.

6 REFERENCES

J.D. Mollard and Associates (2010) Ltd., 2010. Report on mineral and organic terrain mapping in a 10 km radius around Esker Camp. *McFaulds Lake Project*. 40 p.