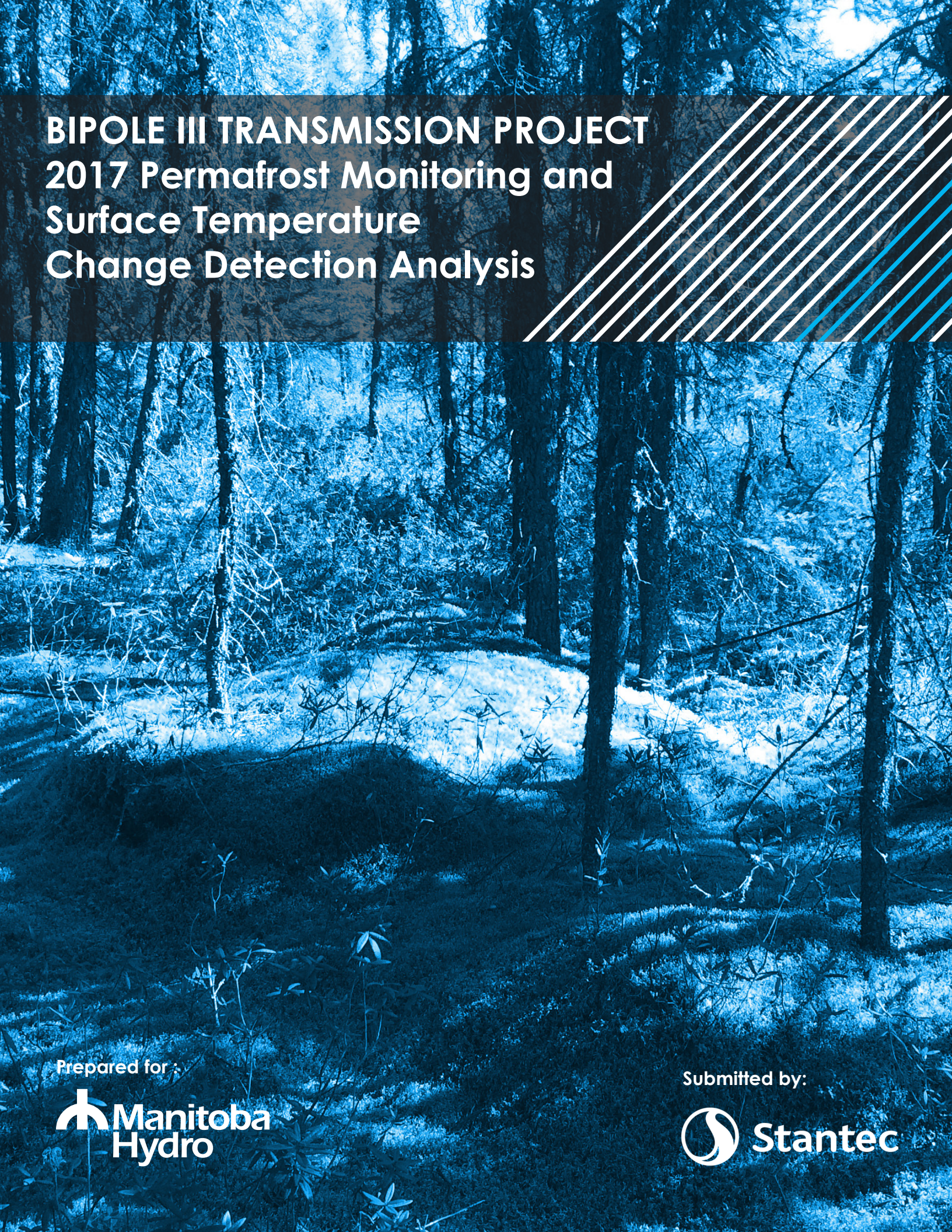


BIPOLE III TRANSMISSION PROJECT
2017 Permafrost Monitoring and Surface Temperature Change Detection Analysis

Prepared for :

Manitoba Hydro

Submitted by:

Stantec

Bipole III Transmission Project 2017 Permafrost Monitoring and Surface Temperature Change Detection Analysis

Final Annual Report

Prepared for:

Manitoba Hydro
820 Taylor Avenue
Winnipeg, MB R3M 3T1

Prepared by:
Stantec Consulting
500-311 Portage Avenue
Winnipeg, Manitoba
MB R3B 2B9

November 30, 2017

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Glossary

Active layer	The layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost.
Collapse scar bog	Collapse scar bogs are circular or oval-shaped wet depressions in perennially frozen peatland. They originated as perennially frozen peatland and subsequently the permafrost thawed which caused the surface to subside.
Discontinuous permafrost	Permafrost occurring in some areas beneath the exposed land surface throughout a geographic region where other areas are free of permafrost.
Peat mound bog	Peat mound bogs usually are small (up to 3 m in diameter and 0.5 to 1 m in height), discrete mounds of peat occurring in permafrost regions. Peat mound bogs are often situated in or surrounded by fen.
Peat plateau	Peat plateau bogs are composed of perennially frozen peat which extents are sharply defined. The surface sits about 1 m higher than unfrozen fen that surrounds it. The surface is relatively flat, even and often covers large areas. Collapse scar bogs are commonly found with peat plateau bogs. These bogs are common in areas of discontinuous permafrost.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years.
Permafrost degradation	A naturally or artificially caused decrease in the thickness and/or areal extent of permafrost. Permafrost degradation may be caused by climatic warming or by changes in terrain conditions, such as disturbance or removal of an insulating vegetation layer by fire, or by flooding caused by a landslide-blocked stream, or by anthropogenic activity. It may be expressed as a thickening of the active layer, a lowering of the permafrost table, a raising of the permafrost base, or a reduction in the areal extent or the complete disappearance of permafrost.
Riparian bog	Riparian bogs form on edges of ponds, lakeshores or banks of slow-flowing streams and rivers.

Sources include:

- National Snow and Ice Data Center (NSIDC). Permafrost and Related Ground Ice Terms.
- National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Ottawa: Sustainable Development Branch, Environment Canada and Montreal, Quebec: Polyscience Publications Inc.

1.0 INTRODUCTION

As a result of Bipole III Transmission Project's (the "Project") licence conditions imposed by Provincial regulatory authorities, Manitoba Hydro has requested that Stantec develop a permafrost and soil productivity monitoring program under its existing environmental monitoring framework agreement (Purchase Order No. 4500305162).

The following sections summarize the work conducted as part of the second year (year 2017) of the permafrost monitoring program developed along the northern sections of the Project, that is, Sections N1, N2, N3, the AC Collector Line and the Construction Power Line (Map 1-1).

1.1 BACKGROUND

Part of Manitoba Hydro's commitment to environmental protection included the development of a comprehensive Environmental Protection Program (EPP). This program included the development of a Project-Level Environmental Protection Plan (EnvPP) and Construction (CEnvPPs) specific to each major Project component.

A number of Environmentally Sensitive Sites (ESS) have been identified around the various transmission components. ESS are locations, features, areas, activities or facilities that were identified in the Bipole III Transmission Project Environmental Impact Statement (EIS) to be ecologically, socially, economically or culturally important or sensitive to disturbance and require protection during construction of the project. The occurrence of permafrost in wetlands is an example of an ESS, as disturbance from anthropogenic activities has the potential to affect the stability of the permafrost.

Clearing Methods

Manitoba Hydro has implemented several clearing prescriptions for the construction of the transmission line rights-of-way. Various clearing methods have been used depending on specific site conditions initially identified in the CEnvPP (e.g., vegetation types, topography, distance from a wetland or from a riparian zone, permafrost occurrence, etc.). According to the Bipole III Transmission Project Annual Harvest Plan, clearing methods include:

- Blading – using bull dozer equipment to pile biomass for disposal.
- Selective harvest – using low impact harvest techniques such as feller buncher, and hand clearing using brush and chainsaws as prescribed on ESS map sheets within the CEnvPP.

Disposal methods include:

- Salvage – disposal of merchantable timber to local milling operations or communities for firewood.

MAP 1-1 - Project Study Area

- Burning – disposal of biomass by pile and burning between November 15 and March 31.

Table 1-1 summarizes the various clearing types and methods used along the northern sections of the Project.

Table 1-1 Vegetation Clearing Methods

Clearing type	Method(s) used
General	• Shear blade (i.e., a bull dozer equipment to remove and pile biomass for disposal) • Feller-buncher (i.e., a motorized vehicle used to grab, cut and gather trees).
Low Disturbance	• Shearblade ("Light-touch") • Mulcher (i.e., a single motorized vehicle to cut and grind vegetation)
Selective	• Hand clear • Feller-buncher

1.2 SCOPE OF WORK

1.2.1 Field Monitoring Program

Although it is recognized that permafrost degradation has the potential to affect the integrity of various infrastructure types (e.g., roads, tower structures, buildings, etc.); the focus of the current monitoring program is not to assess potential impacts to the Project's infrastructure. The main objective of the permafrost monitoring program is to assess potential impacts of the various clearing methods and disposal methods (i.e., Burn piles-the disposal of biomass by fire during the November to March period) on the local permafrost.

Both natural and anthropogenic disturbances have the potential to alter the local permafrost conditions over relatively short time scales. The degradation of some of the permafrost found along the Bipole III Right-of-Way (RoW), either related to natural processes or anthropogenic activities, both of which could affect local ecosystem components (e.g., wetlands, lake, rivers). A key project activity having the potential to affect permafrost present along the Bipole III Project is the disturbance, or removal, of the vegetation along the RoW. The vegetation cover interacts with the permafrost by limiting the heat transfer between the ground and the ambient air (e.g., by insulating the ground and impeding seasonal soil thawing). Disturbing or removing the vegetation could initiate a thickening of the active layer and/or a reduction in the overall thickness and extent of the permafrost at a given location. These modifications have the potential to affect local ecosystem components, which could translate in changes to the local topography (e.g. ground subsidence), hydrology (e.g., increased flooding potential) and vegetation communities (e.g., transition of black spruce bogs to open fens).

A key project activity having the potential to affect permafrost present along the Bipole III Project is the disturbance, or removal, of the vegetation along the RoW. The vegetation cover interacts with the permafrost by limiting the heat transfer between the ground and the ambient air (e.g., by insulating the ground and impeding seasonal soil thawing). Disturbing or removing the vegetation could initiate a thickening of the active layer and/or a reduction in the overall thickness and extent of the permafrost at a given location. These modifications have the potential to affect local ecosystem components, which could translate in changes to the local topography (e.g. ground subsidence), hydrology (e.g., increased flooding potential) and vegetation communities (e.g., transition of black spruce bogs to open fens).

The methodology designed for the monitoring program consists of the following activities:

1. Preliminary site selection (desktop exercise)
2. Initial field visit, site description and field instrumentation
3. Annual field monitoring activities (ground temperature and active layer monitoring)

Information on the methodology is presented in Section 2.0.

1.2.2 Surface Temperature Change Detection Analysis

Due to the shear length of the Bipole III transmission line, collecting permafrost data for the entire RoW would be too time consuming and costly. Stantec used Landsat-8 Thermal Infrared Sensor (TIRS) imagery to track surface temperature of the entire length of N1 to N3 and the construction power and collector lines. TIRS records the exposed surface temperature of objects within its instantaneous view of the Earth; it does not measure the ambient air temperature but rather the top of vegetation and top of soil surface temperature. TIRS cannot penetrate vegetation or ground surfaces and therefore cannot record sub-surface temperatures. Surface temperatures from Landsat-8 imagery in this investigation act as a surrogate measure for the temperature of sub-surface permafrost. Identifying surface temperature changes from clearing provides an understanding of areas that are at risk or are more likely to experience permafrost melting and ground subsidence.

Complete RoW coverage by Landsat-8 TIRS enabled all clearing practice types to be monitored for their effectiveness of retaining surface temperatures. TIRS data was collected for the entire northern RoW study area throughout the growing season. Landsat-8 has been continuously collecting thermal imagery since 2014 allowing for preconstruction thermal information of the entire RoW to be collected and analyzed for the effectiveness of each clearing practice type since 2014.

1.3 REGIONAL SETTING

1.3.1 Climate

The climatic zones in which the northern sections of the Project are located have been defined in various ways by different authors. Generally, most attributes display similar characteristics in the area; i.e., having long cold winters and short, generally cool summers.

The following paragraphs summarize the climate regimes found within the various Ecozones crossed by the northern sections of Bipole III. This information was gathered from Environment Canada and Agriculture and Agri-Food Canada data and uses climate averages obtained on data series information covering the 1971 to 2000 period. This climate information was previously presented as part of the Project Environmental Impact Statement. The northern sections of Bipole III cross three main Ecozones: the Hudson plain, The Boreal Shield and the Boreal Plain (note that the Taiga Shield Ecozone is not included).

Hudson Plain. In the north, the Hudson Plain Ecozone is strongly influenced by cold and moisture-laden Hudson Bay and Polar High air masses, resulting in short, cool summers with long, very cold winters. Mean annual temperatures can reach –7°C (Churchill Airport station). Precipitation varies from about 400 to 800 mm annually.

Boreal Shield. The Boreal Shield Ecozone has a continental climate characterized by long, cold winters, with summers that are generally short and cool. The mean annual temperature is near -4°C and the area receives approximately 400 mm of precipitation annually. The average number of growing degree days over 5°C ranges from 1038 to 1079. The frost-free period ranges from 59 to 115 days. Climate stations within this Ecozone include Gillam, Thompson and Flin Flon Airports.

Boreal Plain. The Boreal Plain Ecozone has a continental climate that consists of cold winters and moderately warm summers. The mean annual temperature ranges from –2°C to 2.5°C with approximately 500 mm of precipitation annually. The average number of growing degree days over 5°C is 1395. The frost-free period is approximately 114 days. The climate station at The Pas Airport is the only station within this Ecozone.

Table 1-2 summarizes climate normals compiled from the three main communities located along the northern sections of Bipole III. From northeast to the southwest, these climate stations are located in Gillam, Thompson and The Pas. The data was recorded from Environment Canada climate stations and covers the 1981 to 2010 period (Environment Canada 2010).

Table 1-2 1981 to 2010 Climate Normals at Gillam, Thompson and The Pas

Climate Station	Latitude/Longitude	Mean Annual Air temperature (°C)	Precipitation (mm)		Degree Days		Average Length of Frost-free Period (in days)
			Rainfall	Snowfall	Above 0°C	Below 0°C	
Gillam	56.358° -94.711°	-3.7	315	221	1772	3079	92
Thompson	55.805° -97.863°	-2.9	340	187	1889	2904	72
The Pas	53.967° -101.100°	0.5	337	146	2358	2151	114

1.3.2 Surficial Geology

Surficial geology varies along the various Project sections. Based on regional surficial geology mapping available for Manitoba (Matile and Keller 2006a and 2006b), the dominant surficial geology consists of glaciomarine and glaciolacustrine sediments. Till, glaciofluvial, alluvial, colluvial and eolian sediments are found locally but in much lesser quantities. Bedrock outcrops are rare; however shallow bedrock is present at various locations. Organic deposits (i.e., fens and bogs) are not accounted for in this regional mapping, although they should be considered as a dominant surficial material. Main surficial geology type (s) found within each Project sections are summarized in Table 1-3.

Table 1-3 Dominant Surficial Geology along the Northern Sections of Bipole III

Section	Dominant Surficial Geology[1]
AC Collector and Construction Power Lines	• **Offshore glaciomarine sediments**: clay, silt, minor sand; 1-20 m thick; low relief, massive and laminated deposit. • **Alluvial sediments**: sand and gravel to sand, silt, clay, organic detritus; 1-20 m thick; found along fluvial channels and as overbank sediments. • **Organic deposits**: peat, muck;1-5 m thick; low relief wetland deposits; commonly found in low-lying areas; accumulates in fen, bogs and swamps; commonly found as peat plateaus in permafrost areas.
N1 and N2	• **Offshore glaciolacustrine sediments**: clay, silt, minor sand; 1-20 m thick; low relief, massive and laminated deposit. • **Proximal and distal glaciofluvial sediments**: fine sand with minor gravel to sand and gravel; generally 1-20 m thick; complex deposits, generally low-relief along the RoW. • **Organic deposits**: peat, muck;1-5 m thick; low relief wetland deposits; commonly found in low-lying areas; accumulates in fen, bogs and swamps; commonly found as peat plateaus in permafrost areas.
N3	• **Offshore glaciolacustrine sediments**: clay, silt, minor sand; 1-20 m thick; low relief, massive and laminated deposit. • **Eolian**: sand and minor silt; generally found as blowout and undulating plains; generally sits over deltaic sediments, coarse lacustrine sediment, or glaciofluvial deposits.

Table 1-3 Dominant Surficial Geology along the Northern Sections of Bipole III

Section	Dominant Surficial Geology[1]
	• **Organic deposits**: peat, muck; 1-5 m thick; low relief wetland deposits; commonly found in low-lying areas; accumulates in fen, bogs and swamps; commonly found as peat plateaus in permafrost areas.

1.3.3 Permafrost

Permafrost is defined as ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (Permafrost Subcommittee, 1988). In northern Manitoba, permafrost is an important component of the landscape. Based on regional permafrost mapping by Heginbottom et al. (1995), the Project area encompasses the southern limit of the extensive discontinuous permafrost zone as well as the sporadic discontinuous permafrost zone (Figure 1-2). Volumetric ground ice contents within these two zones have been described as varying between 5 and 15%; however can largely vary, depending on location.

Permafrost distribution is related to several interconnected factors including: local climate, physiography and local topography, material types and textures, vegetation coverage, moisture and drainage conditions. Peat bogs and fine grained deposits (e.g., silty to clayey glaciolacustrine and/or glaciomarine sediments) are the terrain units most likely to contain permafrost along the northern sections of Bipole III. Bedrock outcrops and well- to rapidly drained, medium to coarse-grained deposits such as till and glaciofluvial deposits are generally free of permafrost.

Permafrost-related features such as peat plateaus are especially present in northeastern Manitoba towards the Hudson Bay Lowlands, an area described as one of the largest regions of peatland soils in Canada (Dredge and Nixon 1992; Glooschenko et al. 1994). These features have been supported through terrain mapping conducted along the northern sections of Bipole III. This desktop mapping exercise was presented to Manitoba Hydro as part of the development of the CEnvPPs for the Bipole III Transmission Project (Manitoba Hydro 2014).

Sections N1, N2, the AC Collector and the Construction Power Lines were found to be the most likely to contain areas of permafrost, especially in low-lying terrain characterized by black spruce bogs and peat plateaus. Fine-grained soils and organic deposits found in areas of discontinuous permafrost will contain various amount of ground ice, mostly as pore ice and ice lenses. This has been confirmed by geotechnical investigations conducted in support of the design and construction of the structure foundations (Amec and Manitoba Hydro 2014, 2016).

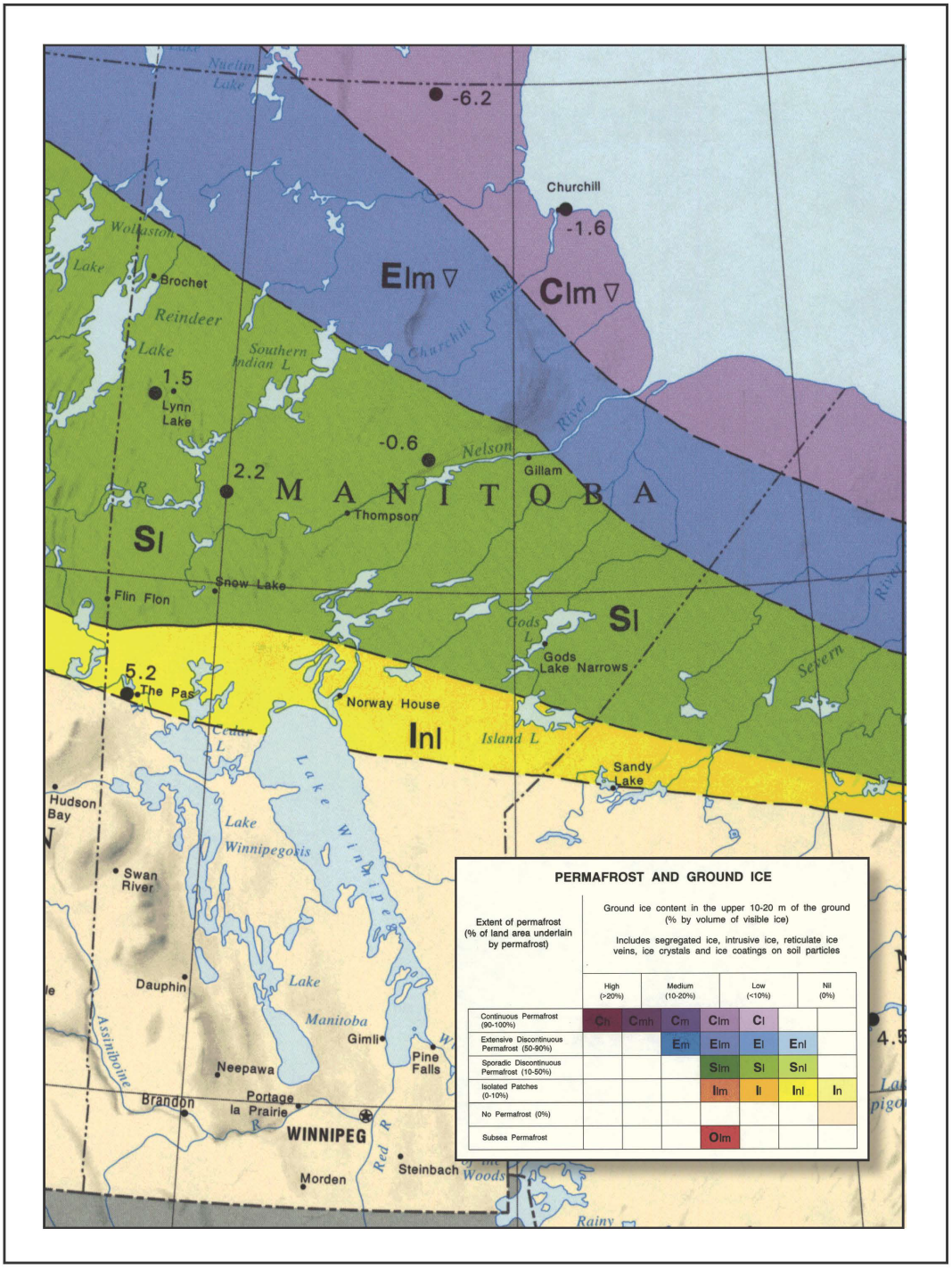


Figure 1-1 Regional Permafrost Distribution Map (Heginbottom et al. 1995)

2.0 FIELD MONITORING PROGRAM

2.1 PREVIOUS WORK AND SITE SELECTION

Preliminary terrain mapping conducted in 2013 along the northern sections of Bipole III suggested the presence of permafrost along the transmission corridor. This initial terrain analysis consisted in defining the main terrain attributes present within a 1,300-m-wide corridor centered on the proposed rights of way (RoW). The nature of the surficial deposits (e.g., organic soils), specific topographic features (e.g., plains and plateaus, pitted terrain, etc.) as well as the occurrence of specific geoprocesses (e.g., thermokarst) were used as indices for assigning a probability of permafrost occurrence at a given location.

One of the first steps conducted in preparation of the field program consisted in selecting candidate permafrost sites assumed to be representative of the various terrain units containing permafrost throughout the northern sections of the Project. Candidate permafrost monitoring sites were initially selected by reviewing the permafrost ESS polygons from the Construction Environmental Protection Plan (CEnvPP), existing satellite imagery, terrain mapping, access and recent geotechnical investigation data provided by Manitoba Hydro. The candidate sites were then submitted for review. Feedback relevant to specific clearing methods used at these candidate sites were received from Manitoba Hydro, resulting in some of the sites being removed from the list. Note that other candidate sites were considered while in the field and in those cases, decisions to select one of these sites, were based on the occurrence of permafrost and on site access. An updated list of permafrost monitoring sites is presented in Table 2-1.

Table 2-1 Permafrost Monitoring Sites

Site Number	Section / Segment location	Structure Span	POINT_X	POINT_Y
Site 1	N2 – S10	1159-1160	583205	6149560
Site 2	N2 – S24	1376-1377	530500	6075852
Site 3	N1 – S10	506-507	623052	6215792
Site 4	N1 – S16	298-299	326843	6252086
Site 5	Construction Power Line (Kelsey G.S to Radisson)	N.A.	430713	6265996
Site 6	AC Collector Lines (Long Spruce G.S. to Keewatinoow)	N.A.	429067	6258147
Site 7	AC Collector/Construction Power Line	N.A.	414962	6251845
Site 8	N1 – S5	N.A.	424393	6287500
Site 9	N1 – S5	N.A.	418122	6287121
Site 10	N1 – S5	N.A.	411669	6283327
Site 11	N1 – S3	N.A.	443356	6281859

2.2 FIELD METHODOLOGY

2.2.1 Site Visits

The initial site visit was conducted between September 15 and September 22, 2016. The field crew consisted of a geomorphologist and a soil scientist. A second site visit was conducted between October 2 and October 10, 2017. This visit was conducted by a geomorphologist and a remote sensing scientist. Sites 1 to 6 (Appendix A, Maps 2-1 to 2-7) were accessed using existing roads, trails and cut lines. Only sites located within less than 1 km from accessible driving roads were considered. A helicopter flight was conduct on October 4, 2017. The flight allowed for a reconnaissance visit at five additional sites (sites 7 to 11; Appendix A, Maps 2-8 to 2-12).

General site descriptions were documented through visual observations; with a focus on describing the local topography, surficial deposits, vegetation communities and presence/absence of features indicative of the presence of permafrost. At sites 1 to 6, both an "on-RoW" and an "off-RoW" monitoring stations were selected. Special attention was given so that the on-RoW and off-RoW stations presented similar overall terrain conditions; therefore allowing comparisons to be made during later phases of the monitoring program. At sites 7 to 11, no thermistor equipment was installed and only active layer depths were measured.

2.2.2 Active Layer Monitoring

The active layer is defined as the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost (Permafrost Subcommittee 1988). Generally, active layer thickness varies in response to air temperature, snow cover, summer rainfall, soil characteristics and vegetation (Nelson et al. 1998). The active layer is also influenced by differential thermal conductivity, ground moisture content and meteorological events (Romanovsky and Osterkamp 1995). Changes in active layer thickness, accompanied by melt of ground ice and thaw settlement can have profound impacts on local environments. The monitoring and early detection of an increase in active layer depth will allow for a better evaluation of potential impacts on the permafrost.

Active layer depths were measured as part of the 2016 and 2017 field programs by inserting a metal rod vertically into the ground until refusal on the inferred permafrost. At sites 1 to 6, measurements were taken at nine locations within a 30 m^2 plot located both at the on-RoW and off-RoW sites. At sites 7 to 11, active layer measurements were taken along transects crossing the RoW. The locations of the 2017 active layer measurements are displayed on Maps 2-1 to Map 2-12 (Appendix A).

2.2.3 Shallow Borehole Drilling

A shallow borehole was drilled at each monitoring station. The boreholes were drilled using a modified two-man auger equipped with a 4-inch-wide core sampler. This type of portable drill

system has proven to be especially efficient for shallow permafrost investigations at remote locations (Calmels et al. 2005). The average drilling depth reached 2 m below ground surface. Recovering cores of undisturbed soil allowed the description of various types of ground ice found within the permafrost (i.e., interstitial ice, ice veins and ice lenses).

2.2.4 Ground Temperature Monitoring

The removal of the vegetation along the Project RoW has the potential to affect the thermal stability of the permafrost by allowing the ground temperature to increase. This increase in temperature could translate in a deepening of the active layer and the melting of near surface permafrost. An efficient way to assess potential changes in the permafrost thermal regime is to monitor the local near surface ground temperature (in this case, the first two metres below ground surface).

Twelve 2-m-long thermistor rods (SensorRod) equipped with a total of seven temperature sensors were acquired from Alpha Mac. Their ground temperature monitoring equipment use the iButtons® technology, a low cost but reliable temperature sensor used by other scientific investigations for permafrost ground temperature monitoring (e.g., Smith and Ednie 2014). The temperature sensors contained within the rod were installed at fixed intervals (i.e., 0 cm, 25 cm, 50 cm, 75 cm, 100 cm, 150 cm and 200 cm). The equipment was set-up to record temperature every four hours. Sensors recording ambient air temperatures were also installed at each monitoring stations (iBCods temperature sensors from Alpha mac). General specifications of the monitoring equipment are presented in Table 2-2.

Table 2-2 Specifications of Ground Temperature Equipment Installed at the Sites

General Equipment Specifications		
Equipment	SensorRod (Type L)	iBCod (Type L)
Range	-40 to 85°C	-40 to 85°C
Precision	+/- 0.5°C	+/- 0.5°C
Resolution	0.0625°C	0.0625°C
Memory (Nbr. of values)	4096	4096
Record interval	1 second to 273 hours	1 second to 273 hours
Monitoring Program Specifications		
Equipment	SensorRod (Type L)	iBCod (Type L)
Recording parameter	Subsurface temperatures	Ambient temperature
Recording depths (cm)	0, 25, 50, 75, 100, 150, 200	150 above ground
Recording interval	4 hours	4 hours

2.3 Results

2.3.1 Field Monitoring Data

As initially prescribed in the permafrost monitoring workplan, a total of six sites, each including an on-RoW and an off-RoW monitoring station were selected (i.e. sites 1 to 6). The sites were selected on one or more of the following criteria:

- Presence of permafrost confirmed.
- Presence of distinct permafrost-related features (e.g. frozen peat mound or peat plateau).
- The sites offer good overall representation of the permafrost throughout the Project area.
- Presence of features indicative of ground disturbance and/or permafrost degradation.

In October 2017, five additional sites were accessed via helicopter along Section N1, the AC Collector and the Construction Power Lines.

Tables 2-3 to 2-8 summarize field observations at sites 1 to 6. An overview map is located in Appendix A (Map 2-1). Maps displaying the location of the on-RoW and off-RoW monitoring stations as well as the active layer measurements are also included Map 2-2 to Map 2-12. Site photographs showing a general overview of the terrain conditions at each sites are presented in Appendix C.

Table 2-3 Summary of Observations at Site 1

<table>
<tr><td colspan="2">BPIII section nbr.</td><td colspan="2">Section N2, between towers 1159 and 1160</td></tr>
<tr><td colspan="2">Distance from nearest tower</td><td colspan="2">200 m west from tower 1159</td></tr>
<tr><td colspan="2">Coordinates (UTM 14)</td><td>On-RoW: N6149561 / E583260</td><td>Off-RoW: N6149503 / E583218</td></tr>
<tr><td colspan="2">RoW width</td><td colspan="2">Variable. Approximately 50 m at the on-RoW monitoring station.</td></tr>
<tr><td colspan="4">General site description</td></tr>
<tr><td colspan="4">• Site 1 is located 30 km south from Thompson, approximately 3 km north from the eastern reach of Wintering Lake. The site is accessible via a forest road.
• The area consists of undulating terrain with slope gradients averaging 5 to 15 %. The monitoring stations are located in a topographic low marking the transition between upland glaciolacustrine terrain and a flooded/beaver-impacted wetland. Both on-RoW and off-RoW monitoring stations are located within a 30 m wide riparian buffer zone.
• Field observations indicate that permafrost is limited to the riparian zone (i.e., absent from the flooded wetland and absent from the upland glaciolacustrine deposit), with only small discontinuous islands of permafrost encountered within the cleared portion of the RoW (none within the active layer plot).
• Some ponding water was observed within localized depressions (e.g., under 2 m^2 in size and 0.5 m in depth) and could be related to recent permafrost melt-out.</td></tr>
<tr><td colspan="4">Vegetation type and clearing method</td></tr>
<tr><td colspan="4">• Black spruce, jack pine and lesser amounts of paper birch are the dominant tree species. Forest understory species include feather moss, rock cranberry, blueberry, Labrador tea and mosses.
• Selective clearing within 30 m from the edge of the wetland (i.e., at the site), with general clearing in the upland terrain east and west of the wetland.</td></tr>
<tr><td colspan="4">Soil description, active layer and air temperature</td></tr>
<tr><td rowspan="2">On-RoW</td><td>2016</td><td colspan="2">• 0.35 m of peat over silty clay.
• Active layer was encountered at none of the 9 probing locations.
• Active layer of 55 cm was measured in small isolated peat mound located 10 m east from main probing locations. Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer of 49 and 51 cm measured west of probing stations in undisturbed Labrador tea cover.
• Thermistor string recorded no permafrost.
• Average air temperature of 0.6°C.</td></tr>
<tr><td rowspan="2">Off-Row</td><td>2016</td><td colspan="2">• 0.75 m of peat over silty clay, active layer 48 cm.
• Active layer was encountered at all 9 probing locations, ranged from 48 cm to 66 cm and averaged 54 cm. Active layer at the thermistor rod was 48 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered in 7 of the 9 probing locations, ranged from 42 cm to 107 cm and averaged 65 cm. Active layer at the thermistor rod was 65 cm.
• Thermistor rod recorded permafrost at 100 cm.
• Average air temperature of 0.4°C.</td></tr>
<tr><td colspan="4">Summary of available geotechnical data</td></tr>
<tr><td colspan="4">Borehole at tower no. 1160:
• Located 270 m west from Site 1.
• 1.5 m of peat overlying over 10 m of soft to firm silty clay.
• Permafrost noted in the clays but no visible ice observed, permafrost thickness unknown.</td></tr>
</table>

Figure 2-1 Average Ground Temperatures at Site 1

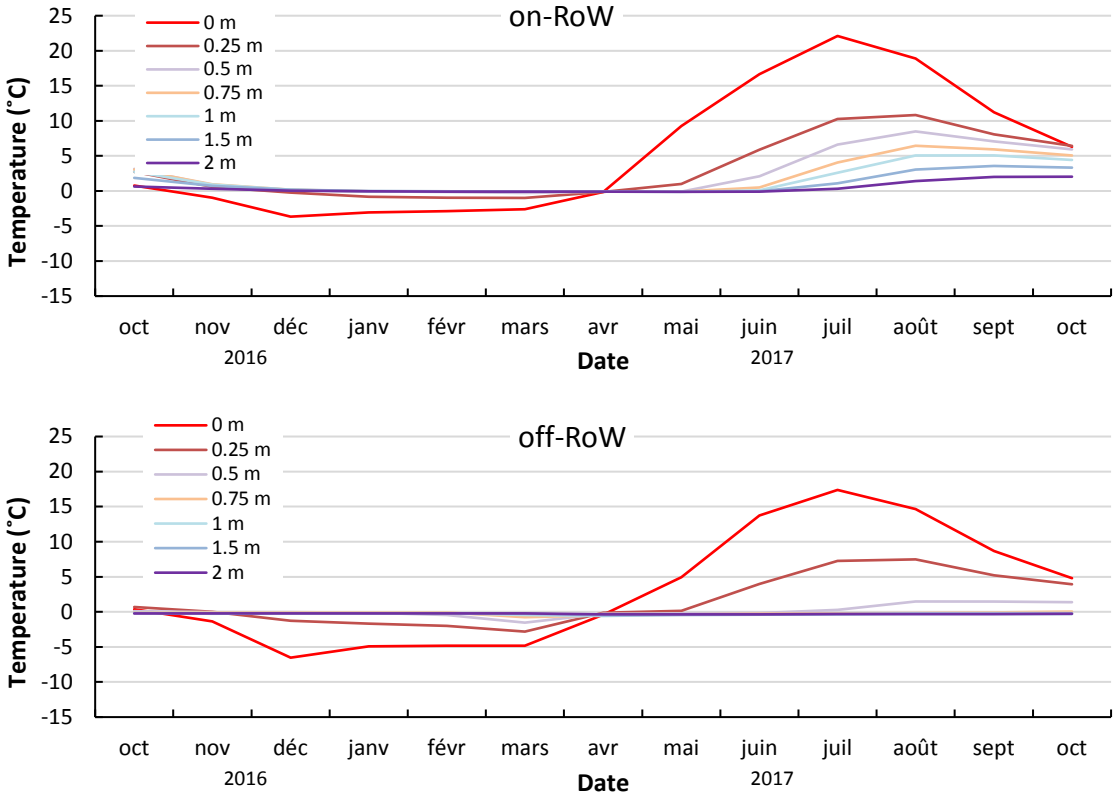


Figure 2-2 Annual Ground Temperature Envelopes at Site 1

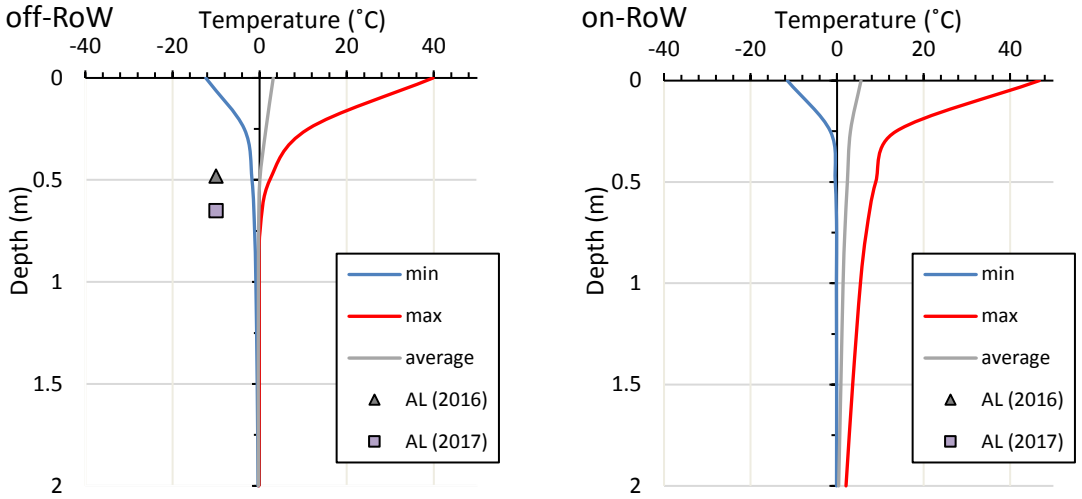


Table 2-4 Summary of Observations at Site 2

<table>
<tr><td colspan="2">BPIII section nbr.</td><td colspan="2">Section N2, between towers 1376 and 1377</td></tr>
<tr><td colspan="2">Distance from nearest tower</td><td colspan="2">160 m west from tower 1376</td></tr>
<tr><td colspan="2">Coordinates (UTM 14)</td><td>On-RoW: N6075857 / E530502</td><td>Off-RoW: N6075789 / E530509</td></tr>
<tr><td colspan="2">RoW width</td><td colspan="2">24 m</td></tr>
<tr><td colspan="4">General site description</td></tr>
<tr><td colspan="4">• Site 2 is located 11 km southeast from Wabowden, approximately 200 m north from Highway 373.
• The area is characterized by flat to gently undulating terrain located along the western boundary of the Hayes River Upland. Upland terrain consists of silty to clayey glaciolacustrine and sandy to gravelly glacial outwash deposits, while topographic lows are poorly-drained areas are characterized by large fens, and black spruce bogs.
• The monitoring stations are located in a black spruce bog. Portions of the bog are characterized by undulating to hummocky microtopography related to the presence of frozen peat mounds.
• Indicators of naturally-occurring permafrost degradation observed at the site. They include several tilted-trees and some collapsed scar located alongside the peat mounds.</td></tr>
<tr><td colspan="4">Vegetation type and Clearing Method</td></tr>
<tr><td colspan="4">• The vegetation is dominated by stands of black spruces, with an understory of dwarf birch, tamarack, Labrador tea, mosses and lichens.
• General clearing on most of the RoW, with minor areas of selective clearing immediately at the site.</td></tr>
<tr><td colspan="4">Soil description, active layer and air temperature</td></tr>
<tr><td rowspan="2">On-RoW</td><td>2016</td><td colspan="2">• Over 2 m of peat.
• Active layer was encountered at 8 of the 9 probing locations, ranged from 63 cm to 156 cm and averaged 105 cm. Active layer at the thermistor rod was 63 cm.
• Permafrost at 127 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at 8 of the 9 probing locations, ranged from 72 cm to 132 cm and averaged 100 cm. Active layer at the thermistor rod was 136 cm.
• Thermistor rod recorded permafrost at 150 cm.
• Average air temperatures 1.3°C.</td></tr>
<tr><td rowspan="2">Off-Row</td><td>2016</td><td colspan="2">• Over 2 m of peat.
• Active layer was encountered at 5 of the 9 probing locations, ranged from 127 cm to 160 cm and averaged 148 cm. Active layer at the thermistor rod was 127 cm.
• Permafrost at 109 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at 5 of the 9 probing locations, ranged from 137 cm to 177 cm and averaged 152 cm. Active layer at the thermistor rod was 137 cm.
• Thermistor string recorded permafrost at 200 cm.
• Average air temperatures of 1.1 C.</td></tr>
<tr><td colspan="4">Summary of available geotechnical data</td></tr>
<tr><td colspan="4">No geotechnical data available for the site.</td></tr>
</table>

Figure 2-3 Average Ground Temperatures at Site 2

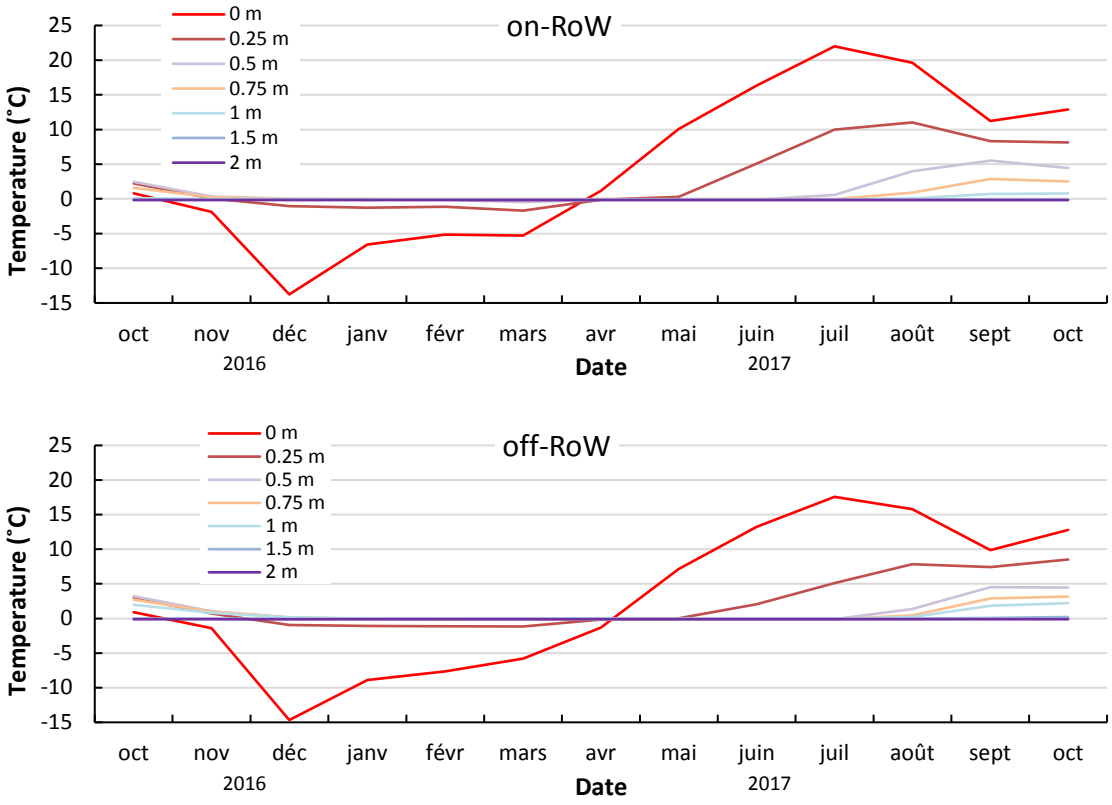


Figure 2-4 Annual Ground Temperature Envelopes at Site 2

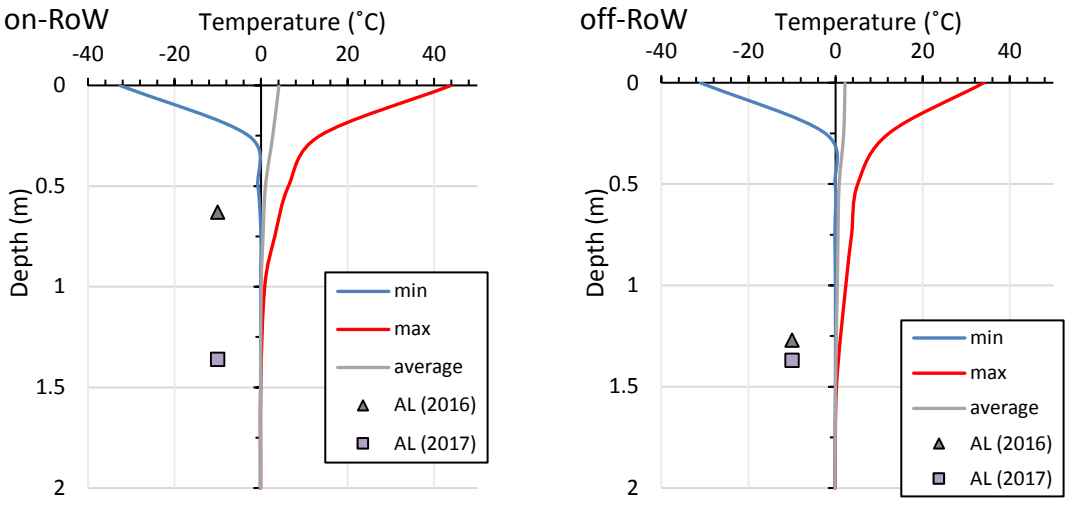


Table 2-5 Summary of Observations at Site 3

BPIII section nbr.	Section N1, between tower 507 and 508		
Distance from nearest tower	110 m east from tower 507		
Coordinates (UTM 14)	On-RoW: N6215784 / E623072	Off-RoW: N6215732 / E623080	
RoW width	Variable (40 to 60 m)		
General site description			
• Site 3 is located 65 km east from Thompson, approximately 100 m southwest from where the Bipole III alignment crosses Highway 280. • The area is characterized by gently undulating terrain where glaciolacustrine clays and peaty organic soils are dominant. Glaciofluvial (i.e., sand and gravel) deposits overlying shallow bedrock terrain is present in the area. The monitoring stations are located within a black spruce bog which ground surface is flat to gently undulating. • Discontinuous permafrost at both the on-RoW and off-RoW monitoring stations.			
Vegetation type and Clearing Method			
• Black spruce bog with vegetation comprised of stands of (generally low) black spruce with an understory of Labrador tea, blueberry, bog rosemary and sphagnum mosses. • General clearing on most of the RoW, with minor areas of selective clearing immediately at the site. • Peaty ground surface is intact, with black spruces trees cut approximately 0.3 m above the ground.			
Soil description, active layer and air temperature			
On-RoW	2016	• 105 cm of peat over clay. • Active layer was encountered at 7 of the 9 probing locations, ranged from 49 cm to 59 cm and averaged 53 cm. Active layer at the thermistor rod was 50 cm. • Permafrost between 50 cm and 62 cm only.	
	2017	• Active layer was encountered at 7 of the 9 probing locations, ranged from 63 cm to 140 cm and averaged 101 cm. Active layer at the thermistor rod was at 109 cm. • Thermistor rod recorded no permafrost. • Average air temperatures -0.1 C.	
Off-Row	2016	• 104 cm of peat over clay. • Permafrost between 54 cm and 67 cm only. • Active layer was encountered at 6 of the 9 probing locations, ranged from 45 cm to 63 cm and averaged 54 cm. Active layer at the thermistor rod was 55 cm.	
	2017	• Active layer was encountered at 7 of the 9 probing locations, ranged from 48 cm to 100 cm and averaged 71 cm. Active layer was not encountered at the thermistor rod. • Thermistor rod recorded no permafrost. • Average air temperatures 0.0 °C.	
Summary of available geotechnical data			
Test pit at tower no. 506: • Located 330 m west from Site 3. • 0.4 m of black organic material overlying clay. Permafrost noted in the clay at depth ranging between 0.4 m and 2 m. Visible ice crystals. Test pit at tower no. 507: • 0.4 m of black organic material overlying clay. • No permafrost noted in test pit log.			

Figure 2-5 Average Ground Temperatures at Site 3

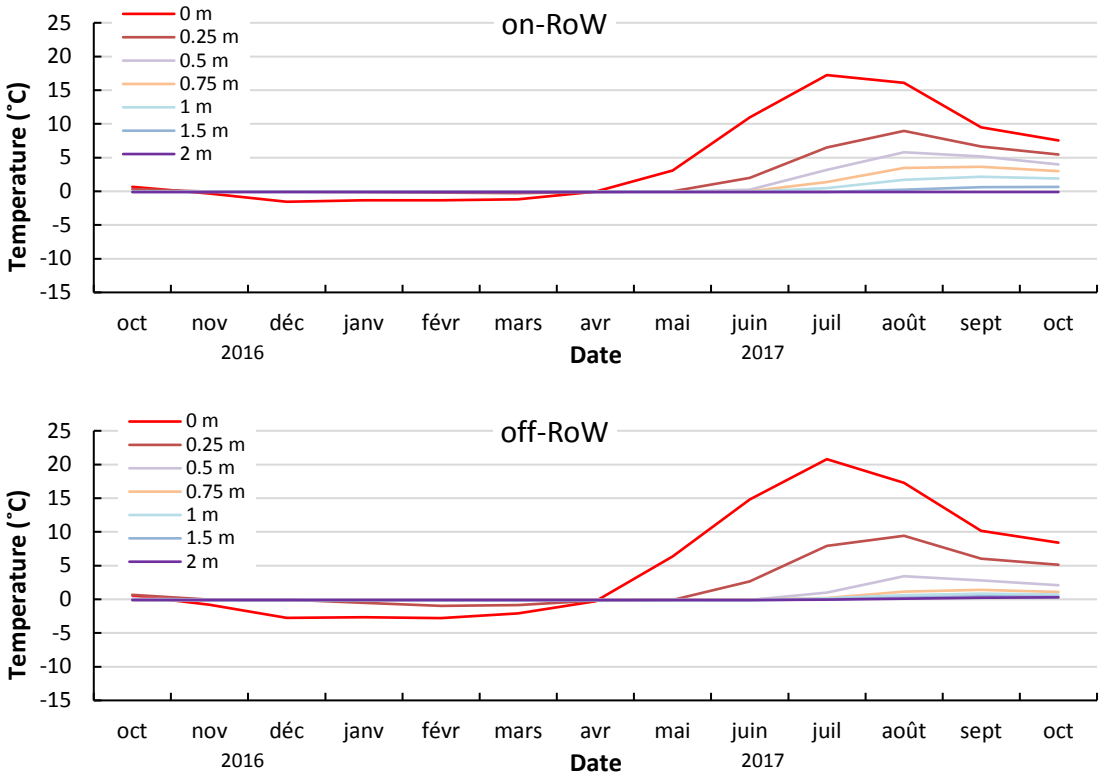


Figure 2-6 Annual Ground Temperature Envelopes at Site 3

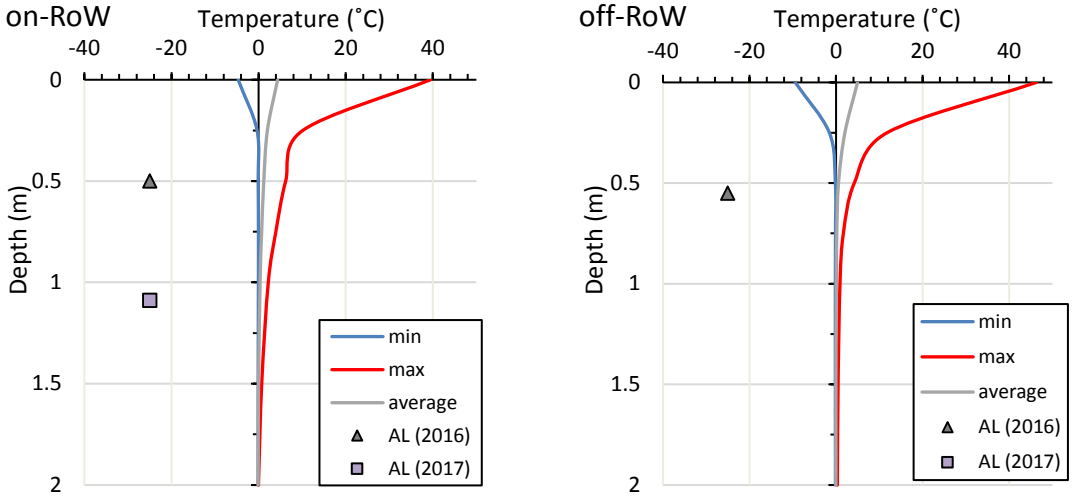


Table 2-6 Summary of Observations at Site 4

<table>
<tr><td>BPIII section nbr.</td><td colspan="2">Section N1</td></tr>
<tr><td>Distance from nearest tower</td><td colspan="2">150 m east from tower 299</td></tr>
<tr><td>Coordinates (UTM 15)</td><td>On-RoW: N6252102 / E326818</td><td>Off-RoW: N6252118 / E326918</td></tr>
<tr><td>RoW width</td><td colspan="2">65 m</td></tr>
<tr><td colspan="3">General site description</td></tr>
<tr><td colspan="3">• Site 4 is located 25 km northeast from Spilt Lake, approximately 300 m south from Highway 280.
• The site is located in an area characterized by gently undulating terrain characterized by extensive fens and peat bogs.
• The monitoring stations are located on a peat plateau, which surface rises approximately 2.5 m above the surrounding topography.
• Field observations indicate that permafrost is absent in the fens surrounding the peat plateaus.</td></tr>
<tr><td colspan="3">Vegetation type and clearing method</td></tr>
<tr><td colspan="3">• Local vegetation is dominated by a generally dense cover of black spruces, with an understory consisting mainly of Labrador tea, mosses and lichens.
• Evidences of a previous forest fire(s) were observed at the site. This fire is assumed to have occurred sometime during the 1945-1969 period.
• General clearing on most of the RoW. Likely some selective clearing along the steep slopes marking the edge of the peat plateau. Thick layer of mulch observed on the RoW. Portions of the top layer of peat is absent at the on-RoW station (either been shear-bladed or mulched).</td></tr>
<tr><td colspan="3">Soil description, active layer and air temperature</td></tr>
<tr><td rowspan="2">On-RoW</td><td>2016</td><td>• Over 2 m of peat.
• Active layer was encountered at all probing locations, ranged from 55 cm to 78 cm and averaged 66 cm. Active layer at borehole was 60 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td>• Active layer was encountered at all probing locations, ranged from 50 cm to 76 cm and averaged 65 cm. Active layer at the thermistor rod was 57 cm.
• Thermistor rod recorded permafrost at 100 cm.
• Average air temperatures -0,6 C.</td></tr>
<tr><td rowspan="2">Off-Row</td><td>2016</td><td>• Over 2 m of peat.
• Active layer was encountered at all probing locations, ranged from 33 cm to 70 cm and averaged 55 cm. Active layer at the thermistor rod was 55 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td>• Active layer was encountered at all probing locations, ranged from 54 cm to 82 cm and averaged 69 cm. Active layer at the thermistor rod was 54 cm.
• Thermistor rod recorded permafrost at 75 cm.
• Average air temperatures -0.3 C.</td></tr>
<tr><td colspan="3">Summary of available geotechnical data</td></tr>
<tr><td colspan="3">Test pit at tower no. 299:
• Located 150 m west from Site 4.
• 0.4 m of peat overlying clay.
• Permafrost noted in the clay down to 2.2 m; test pit was terminated due to refusal on permafrost.
• Visible ice lenses reaching up to 50 mm thick.</td></tr>
</table>

Figure 2-7 Average Ground Temperatures at Site 4

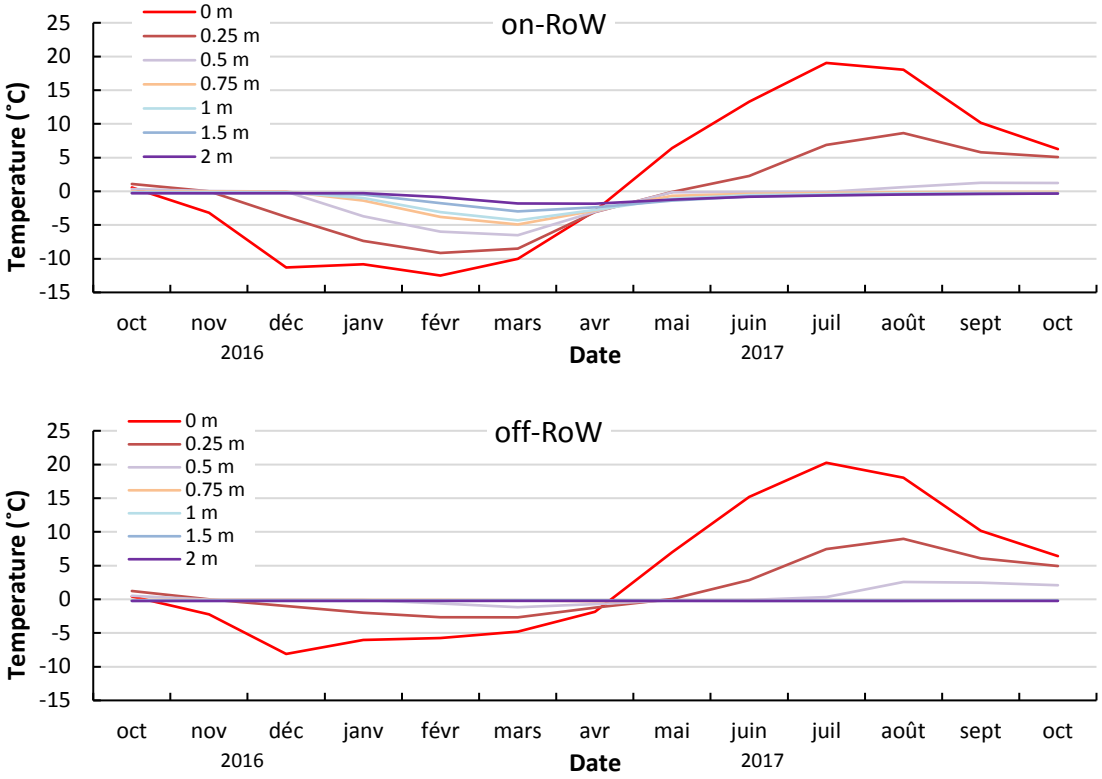


Figure 2-8 Annual Ground Temperature Envelopes at Site 4

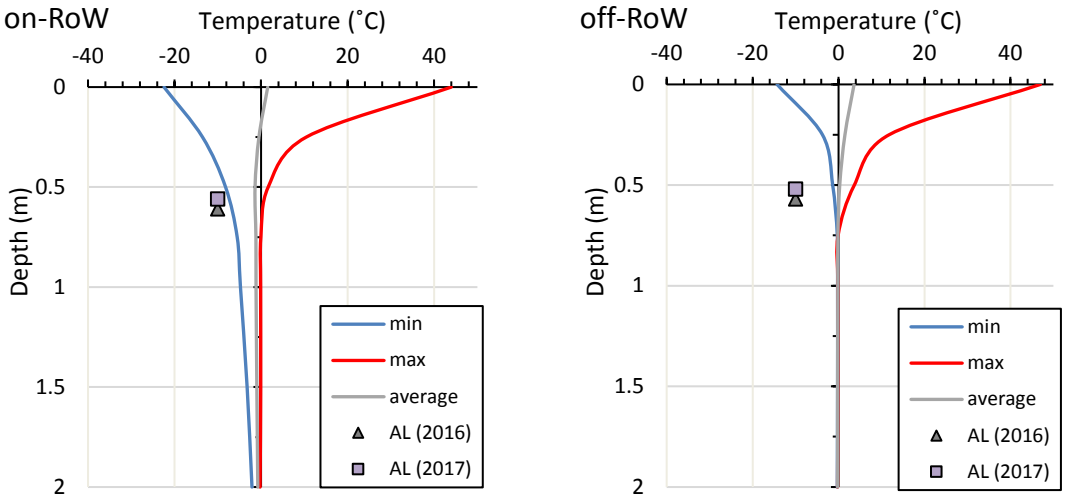


Table 2-7 Summary of Observations at Site 5

<table>
<tr><td>BPIII section nbr.</td><td colspan="3">Construction Power Line (Kelsey g.s. to Radisson)</td></tr>
<tr><td>Distance from nearest tower</td><td colspan="3">170 m west from tower 16</td></tr>
<tr><td>Coordinates (UTM 15)</td><td colspan="2">On-RoW: N6268026 / E430793</td><td>Off-RoW: N6265959 / E430781</td></tr>
<tr><td>RoW width</td><td colspan="3">Variable (varies from 90 m to 600 m)</td></tr>
<tr><td colspan="4">General site description</td></tr>
<tr><td colspan="4">• Site 5 is located north of the Nelson River, 3 km north from the Limestone Generating Station. The monitoring site is found approximately 600 m north of Highway 290.
• The monitoring stations are located within a vast black spruce bog, which area covers several hundred hectares in size. A small creek is located 50 m east from the monitoring site.
• Undulating to hummocky terrain, mounds and hollows (+/-1 m microtopography).
• Discontinuous permafrost at the off-RoW monitoring station.</td></tr>
<tr><td colspan="4">Vegetation type and clearing method</td></tr>
<tr><td colspan="4">• Black spruces up to 8 m, Labrador tea, mosses and lichen.
• Width of RoW varies in relation with the presence of a creek and associated riparian zone.
• Most of the RoW was mulched (aside from riparian buffer zone).
• Most of the vegetation within the riparian buffer zone was left untouched, with the exception of the taller trees which were hand-cut.
• The peat surface was observed to be disturbed at a few locations within the RoW, especially along the access trail where it was observed that portions of the top layer of peat were either disturbed or removed.</td></tr>
<tr><td colspan="4">Soil description, active layer and air temperature</td></tr>
<tr><td rowspan="2">On-RoW</td><td>2016</td><td colspan="2">• 150 cm of peat over clay silt, some sand, trace gravel.
• Active layer was encountered at all probing locations, ranged from 39 cm to 59 cm and averaged 48 cm. Active layer at the thermistor rod was 47 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at all probing locations, ranged from 44 cm to 68 cm and averaged 56 cm. Active layer at borehole was 54 cm.
• Thermistor rod recorded permafrost at 100 cm.
• Average air temperatures of -1.0 C.</td></tr>
<tr><td rowspan="2">Off-Row</td><td>2016</td><td colspan="2">• 175 cm of peat over silt, some sand, some gravel.
• Active layer was encountered at eight of the nine probing locations, ranged from 47 cm to 71 cm and averaged 58 cm. Active layer at the thermistor rod was 44 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at all probing locations, ranged from 41 cm to 69 cm and averaged 52 cm. Active layer at the thermistor rod was 59 cm.
• Thermistor rod recorded permafrost at 75 cm.
• Average air temperatures -0.6°C.</td></tr>
<tr><td colspan="4">Summary of available geotechnical data</td></tr>
<tr><td colspan="4">No geotechnical data available for the site.</td></tr>
</table>

Figure 2-9 Average Ground Temperatures at Site 5

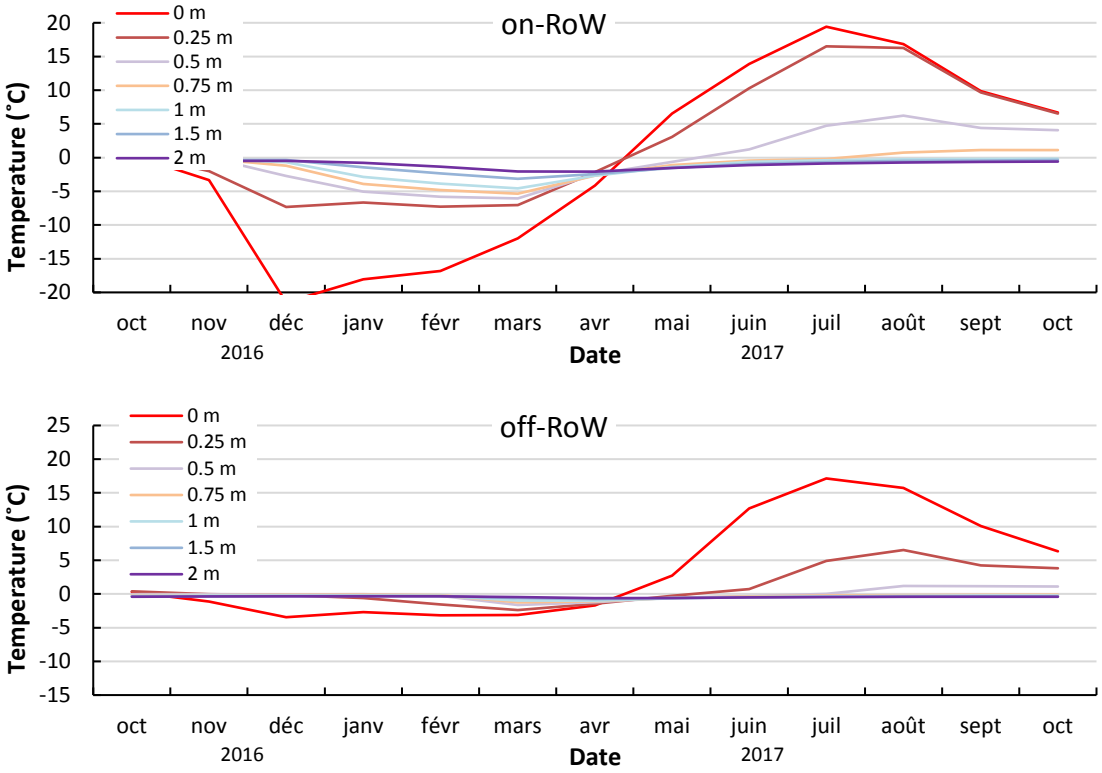


Figure 2-10 Annual Ground Temperature Envelopes at Site 5

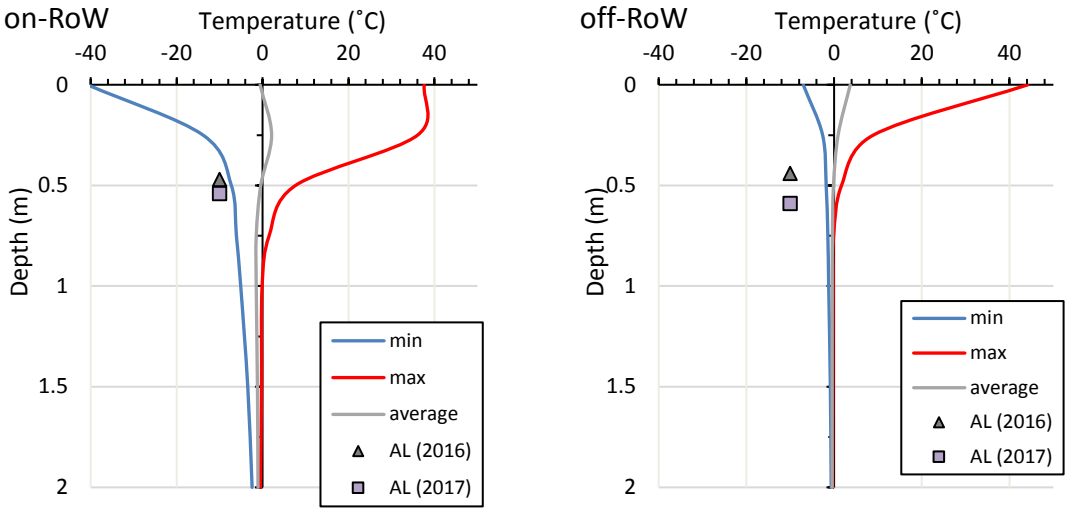


Table 2-8 Summary of Observations at Site 6

<table>
<tr><td>BPIII section nbr.</td><td colspan="3">AC Collector Lines (Long Spruce g.s. to Keewatinoow)</td></tr>
<tr><td>Distance from nearest tower</td><td colspan="3">200 m west from tower 1159</td></tr>
<tr><td>Coordinates (UTM 15)</td><td colspan="2">On-RoW: N6258140 / E429081</td><td>Off-RoW: N6258259 / E429106</td></tr>
<tr><td>RoW width</td><td colspan="3">50 m, with a 5- to 10 m-wide band of trees left between parallel (pre-existing) transmission lines.</td></tr>
<tr><td colspan="4">General site description</td></tr>
<tr><td colspan="4">• Site 6 is located north of the Nelson River, a few hundred metres north from where the AC Collector Lines cross the Nelson River. The monitoring stations are found approximately 150 m south of Highway 290.
• The terrain consists of undulating fluvial and glacial deposit overlying bedrock. Peaty organic (bogs and fens) soils occupy low-lying, poorly-drained terrain throughout the area.
• The area is characterized by discontinuous islands of permafrost, often raised by 0.5 m to 1.0 m above the surrounding ground surface (peat bog mounds).
• Discontinuous permafrost at the on-RoW and off-RoW monitoring stations.</td></tr>
<tr><td colspan="4">Vegetation type and clearing method</td></tr>
<tr><td colspan="4">• Mature black spruces stand with some areas of low black spruce and an understory of dwarf birch, Labrador tea, lichen and moss.
• The peat surface was observed to be disturbed at a few rare locations within the RoW, especially along the access trail where it was observed that portions of the top layer of peat were either disturbed or removed.</td></tr>
<tr><td colspan="4">Soil description, active layer and air temperature</td></tr>
<tr><td rowspan="2">On-RoW</td><td>2016</td><td colspan="2">• 125 cm of peat over silt, some sand, trace gravel.
• Active layer was encountered at eight of the nine probing locations, ranged from 48 cm to 85 cm and averaged 57 cm. Active layer at the thermistor rod was 54 cm.
• Thickness of permafrost unknown.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at all probing locations, ranged from 44 cm to 117 cm and averaged 64 cm. Active layer at the thermistor rod was 65 cm.
• Thermistor rod recorded permafrost at 75 cm.
• Average air temperatures -0.4 C.</td></tr>
<tr><td rowspan="2">Off-Row</td><td>2016</td><td colspan="2">• Over 2 m of peat over silt, some sand, trace gravel.
• Active layer was encountered at five of the nine probing locations, ranged from 44 cm to 67 cm and averaged 52 cm. Active layer at the thermistor rod was 45 cm.
• Base of the permafrost at 165 cm.</td></tr>
<tr><td>2017</td><td colspan="2">• Active layer was encountered at five of the nine probing locations, ranged from 39 cm to 144 cm and averaged 67 cm. Active layer at the thermistor rod was 48 cm.
• The thermistor rod recorded permafrost between 75 cm and 100 cm. No permafrost below 150 cm.
• Average air temperatures -0.7 C.</td></tr>
<tr><td colspan="4">Summary of available geotechnical data</td></tr>
<tr><td colspan="4">No geotechnical data available for the site.</td></tr>
</table>

Figure 2-11 Average Ground Temperatures at Site 6

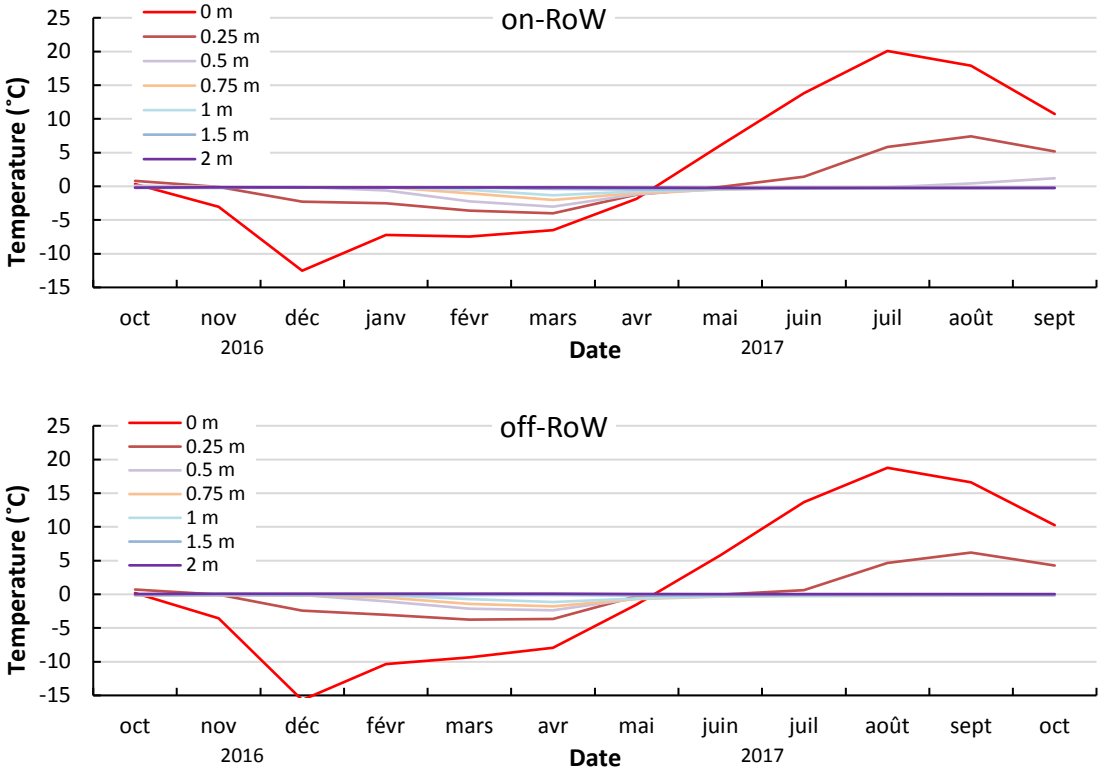


Figure 2-12 Annual Ground Temperature Envelopes at Site 6

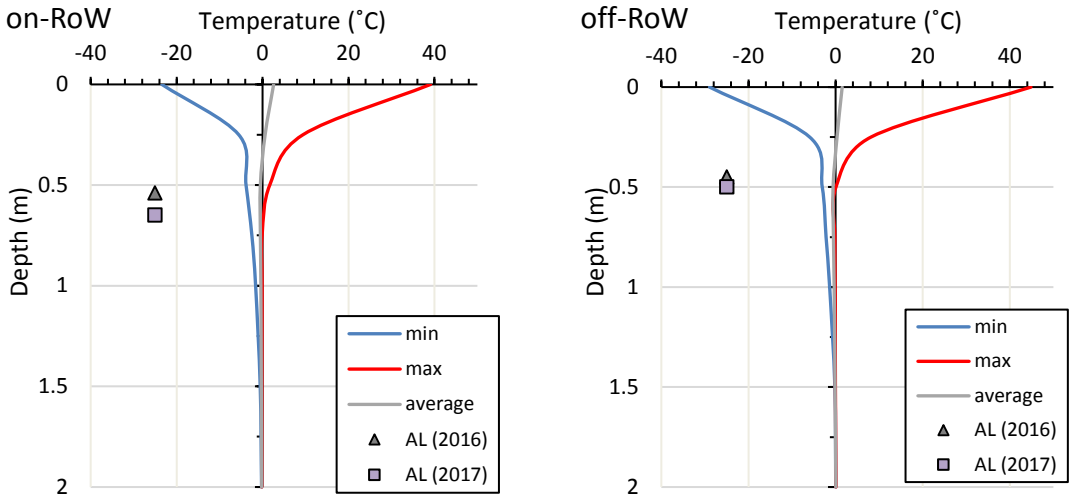
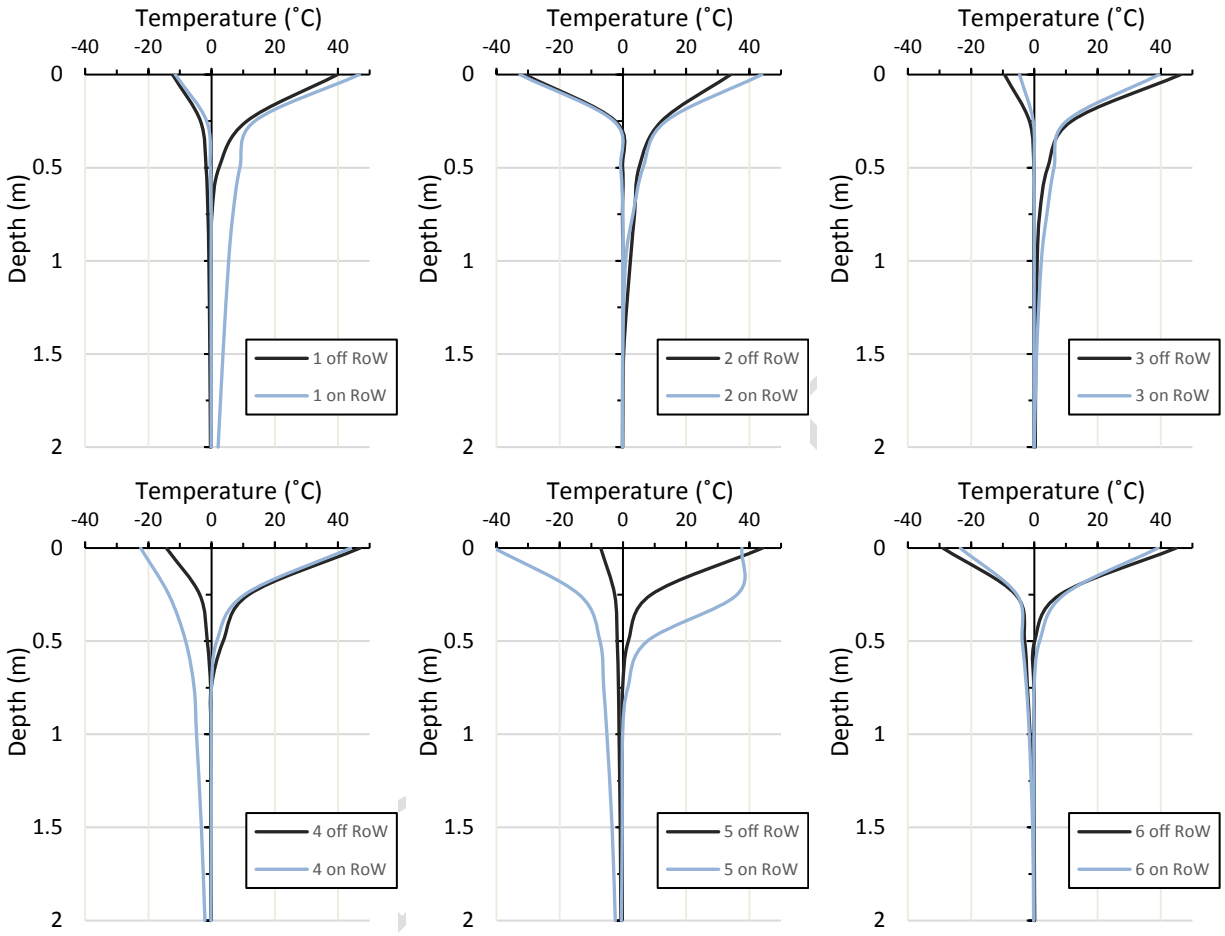


Figure 2-13 Annual Ground Temperature Envelope for all Sites



2.3.2 Active Layer Transects

Additional active layer data was gathered in October 2017 at sites 7 to 11. A summary table is presented below.

Table 2-9 Active Layer at Sites 7 to 11

	Average Active Layer (cm) On-RoW	Average Active Layer (cm) Off-RoW
Site 7	61	44
Site 8	57	42
Site 9	53	52
Site 10	52	55
Site 11	53	40

3.0 SURFACE TEMPERATURE CHANGE DETECTION ANALYSIS

3.1 IMAGE ACQUISITION

Landsat-8 Thermal Infrared Sensor (TIRS) records surface temperature using two thermal channels, 10.8 µm and 12 µm, at 30-m resolution. The TIRS sensor is affected by atmospheric interference such as clouds, fog, rain or smoke and requires cloud free conditions to collect surface temperature information. The Landsat-8 satellite has a repeat coverage cycle of 16 days and has a 30% overlap swath width at mid-latitudes. Satellite image acquisition for the Bipole III RoW required multiple orbital paths due to the sheer size of the extent. Due to cloud cover, a long repeat coverage period and a high level of orbital overlap, each Landsat-8 image mosaic is unique in timing, orbital paths and number of images required to cover the RoW. Landsat-8 imagery was collected twice for 2017 where cloud free data was available (Table 3-1).

Table 3-1 Landsat-8 TIRS Image Acquisition for Six Time Periods and Dates

Summer 2017	Fall 2017
Jun 13, 2017	Sept 7, 2017
Jul 26, 2017	Sept 14, 2017
	Sep 21, 2017

3.2 ATMOSPHERIC CORRECTION

PCI Geomatica's ATCOR program was used to generate top of atmosphere (TOA) reflectance values used to convert pixel values to physical temperature measurements using the radiometric calibration coefficients for the TIRS thermal channels. Haze removal was performed as part of the atmospheric correction allowing for precise thermal measurements. ATCOR successfully normalized solar illumination conditions at different time periods allowing for accurate change detection analysis over multiple years. All imagery was converted to Celsius degree data resulting in six continuous coverages of Bipole III sections N1, N2, N3 and the AC construction power and collector lines.

3.3 METHODOLOGY

The Bipole III final preferred route is 66 m in width and represents the area that will be affected by the Bipole III RoW. The 66-m-wide RoW was then buffered again by 66 m on both sides, resulting in three 66-m-width corridors – one 'On- Row' and two 'Off - RoW' (Figure 3-1). The same procedure was used for the AC collector lines but 132-m buffers were used.

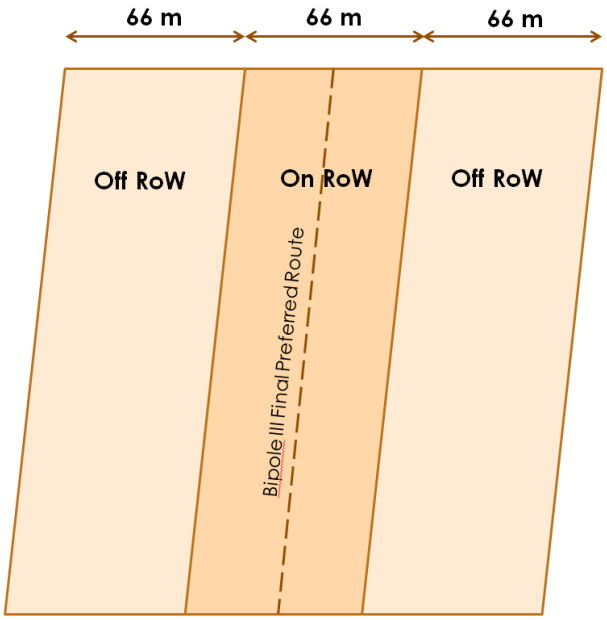


Figure 3-1 Bipole III Final Preferred Route Buffered Creating Three Corridors – One On-RoW and Two Off-RoW

The three corridors were then clipped by areas identified as environmentally sensitive permafrost sites in the Manitoba Hydro Construction Environmental Protection Plan (CEnvPP) (MB Hydro, 2013) to isolate permafrost areas (Figure 3-2).

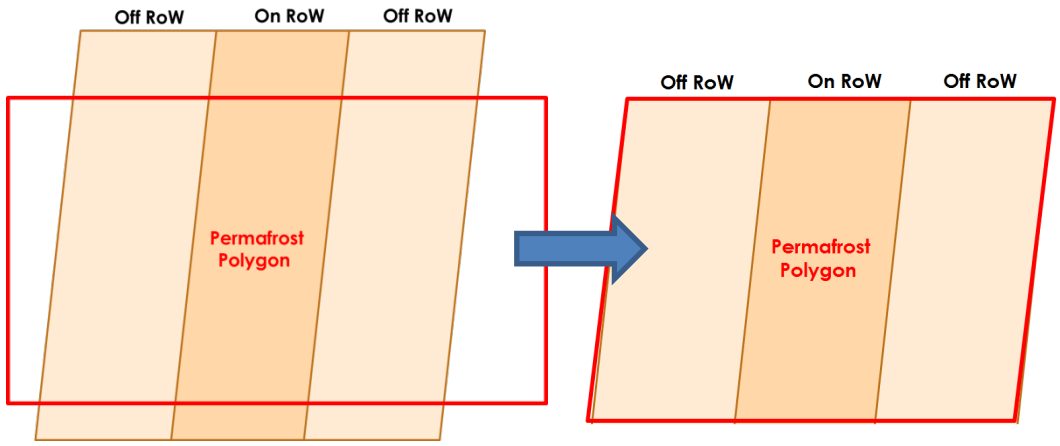


Figure 3-2 The Three Bipole III RoW Corridors Clipped by Permafrost Polygons to Isolate Permafrost Areas

3.4 CLEARING PRESCRIPTION COMPARISON

Permafrost polygons were then overlaid with the 2014-2016 surface temperature Landsat-8 TIRS coverages generating an average celsius value calculated for each polygon and for each time period. Permafrost areas were sub-sampled further to compare the effect of Manitoba Hydro's clearing perscription practices and to what extent the clearing method had an impact on derived surface temperature values (Figure 3-3).

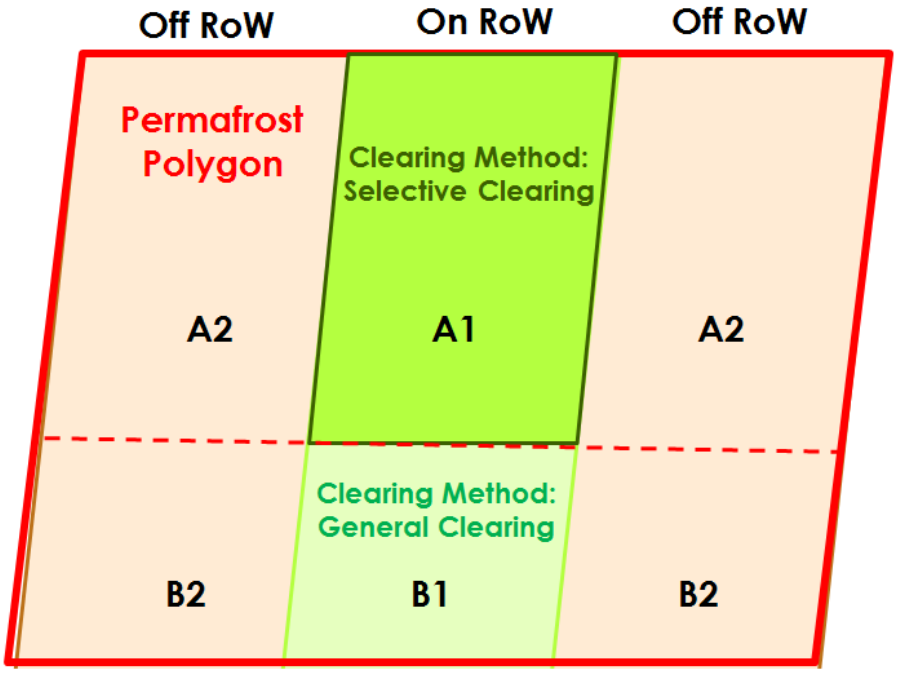


Figure 3-3 Permafrost Areas (red) were Subdivided by Clearing Methods to Compare On-RoW and Off-RoW Surface Temperatures

In the sample, Area A1 is compared against A2 areas to detiermine the surface temperature difference based on the Clearing Method – Selection Clearing (dark green). Area B1 is compared against B2 areas to determine the surface temperature difference based on the Clearing Method – General Clearing (light green).

Temperature readings of On-RoW versus Off-RoW polygons were compared to determine if there is a relative surface temperature difference between cleared and non-cleared areas. Surface temperature differences were also compared for each clearing method type (Table 3-2).

Table 3-2 Clearing Prescription Methods used for Surface Temperature Analysis of Permafrost Polygons

Clearing Type	Method(s) Used	Disturbance
General Clearing	Shearblade/Mulcher/Feller-buncher	Moderate-High
Low Disturbance Clearing	Shearblade (Light)/Mulcher	Low
Selective Clearing	Hand clear/Feller-buncher (saw mounted Pro Mac)	Low

3.5 SATELLITE/SURFACE PROBE COMPARISON

A comparison of Landsat-8 TIR temperature readings and surface probe readings was conducted to determine how well satellite temperature correlated to on the ground temperature. Satellite thermal data is collected at roughly 5:30 pm local for each BPIII N1-N3 and AC Collector line orbit. Field probes collect temperature reading six times daily every four hours beginning at midnight. A prorated temperature value for 5:30 pm was created using the following formula assuming temp declines linearly from 4:00 p.m. to 8:00 p.m. (Equation 3-1).

Equation 3-1*. An interpolated surface probe temperature reading for time of satellite data collection derived from surface probe temperatures taken at 4:00 p.m. and 8:00 p.m.*

(4:00 p.m. Temp x 5) + (8:00 p.m. Temp x 3) / 8 = 5:30 pm Temp

3.6 RESULTS

3.6.1 On- versus Off-Row Satellite Surface Temperature Change

There were a total of 325 and 330 permafrost polygons examined for the 2017 summer and fall satellite surface temperature analysis. On-RoW permafrost polygon temperatures were compared against corresponding Off-RoW permafrost polygons 80.3% of all summer permafrost polygons showed an increase in surface temperature with 80.3% of all fall permafrost polygons also showed an increase in surface temperature (Table 3-3).

Table 3-3 On-RoW versus Off-RoW Satellite Surface Temperature Comparison

On- versus Off-RoW Change	Summer 2017		On- versus Off-RoW Change
Total number of Permafrost Sites (PS)	**325**		**Total number of Permafrost Sites (PS)**
PS with On-RoW Temperature Increase	261	64	PS with On-RoW Temperature Decrease
PS with > +2 °C change	4	0	PS with > -2 °C change
PS with > +1 °C change	25	0	PS with > -1 °C change
PS with > +0.5 °C change	99	6	PS with > -0.5 °C change
PS with > +0.25 °C change	164	22	PS with > -0.25 °C change

On- versus Off-RoW Change	Fall 2017		On- versus Off-RoW Change
Total number of Permafrost Sites (PS)	**330**		**Total number of Permafrost Sites (PS)**
PS with On-RoW Temperature Increase	265	65	PS with On-RoW Temperature Decrease
PS with > +2 °C change	1	0	PS with > -2 °C change
PS with > +1 °C change	38	0	PS with > -1 °C change
PS with > +0.5 °C change	78	2	PS with > -0.5 °C change
PS with > +0.25 °C change	138	14	PS with > -0.25 °C change

Twenty-five summer and 38 fall On-RoW permafrost polygons had a significant increase in surface temperature of greater than +1°C versus corresponding Off-RoW permafrost polygons. No permafrost polygons showed a significant decrease in surface temperature of greater than -1°C compared to Off-RoW permafrost polygons. 46.1% of all permafrost polygons showed an increase in surface temperature greater than +0.25°C while 5.5% of all permafrost sites had a decrease in temperature greater than -0.25°C.

3.6.2 Clearing Prescription Comparison

Clearing prescription methods were examined on 275 Summer and 274 Fall 2017 permafrost polygons for On- versus Off-RoW satellite surface temperature change. General, Low Disturbance and Selective Clearing practices were studied (Table 3-4).

Table 3-4 Clearing Prescription Methods Comparing On-RoW Satellite Surface Temperature versus Off-RoW Surface Temperature

Clearing Prescription	Summer 2017		Fall 2017	
	Count	Temp. Change	Count	Temp. Change °C
General Clearing	34	+0.46°C	34	+0.55°C
Low Disturbance Clearing	72	+0.21°C	73	+0.16°C
Selective Clearing	169	+0.22°C	171	+0.11°C

For summer 2017, the permafrost polygon surface temperature increase was over double for General compared to corresponding Low Disturbance and Selective Clearing. For Fall 2017 permafrost polygon surface temperature increase was over four times greater for General Clearing compared to corresponding Low Disturbance clearing and five time greater for Selective Clearing.

3.6.3 Satellite Imagery and Surface Probe Comparison

A comparison for each Landsat-8 TIRS thermal image in summer and fall for all 12 probes (6 On-RoW, 6 Off-RoW) was conducted using Equation 3-1 to test the validity of satellite image as a surrogate measure of surface temperature for all BPIII RoW permafrost locations (Table 3-5).

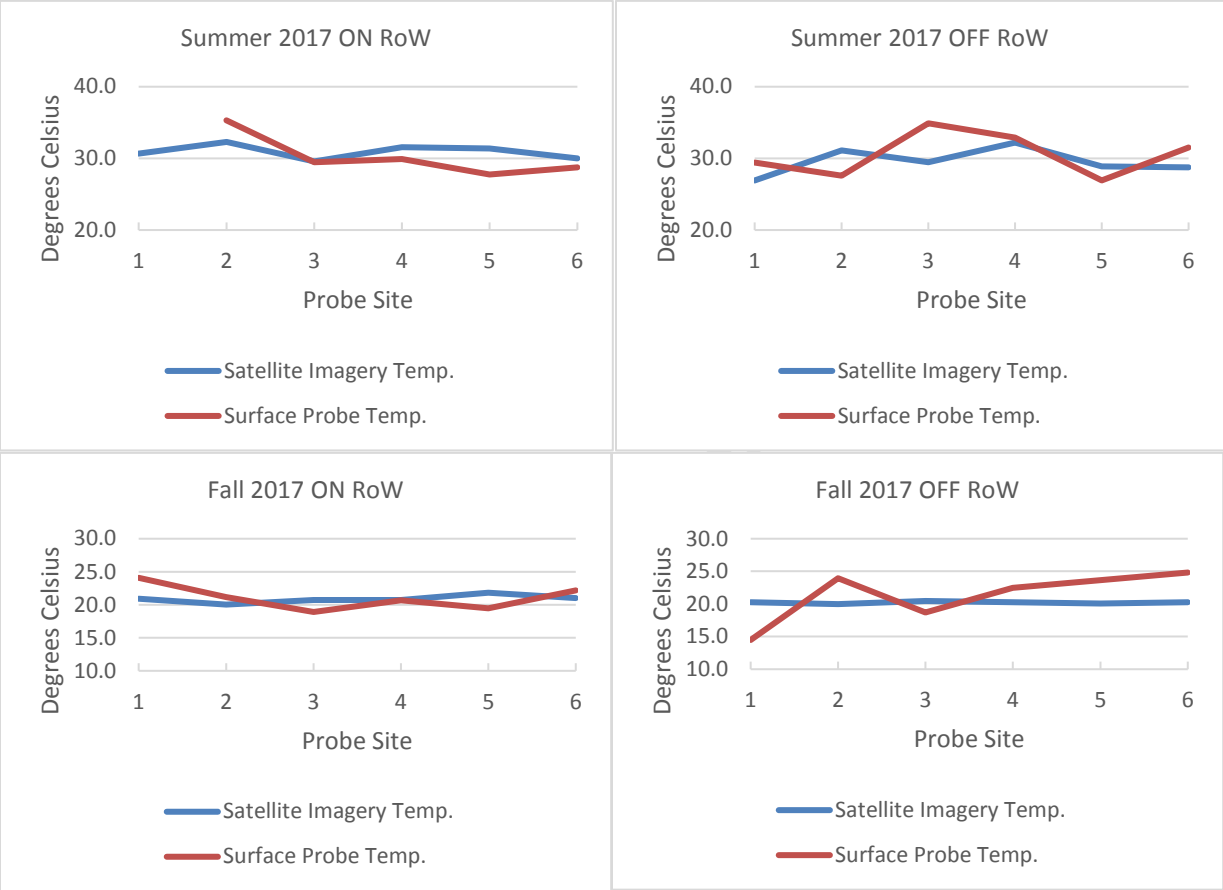
Table 3-5 A Comparison of Satellite and Surface Probe Temperature Readings for Summer and Fall 2017

Site	Date	Satellite Imagery		In Situ Probe Temp.		5:30 PM Temperature	Satellite Probe Temp. Difference
		Time	Temperature	4:00 PM	8:00 PM		
1 ON	Jul. 26, 2017	5:39 PM	30.68	N/A	N/A	N/A	N/A
1 OFF	Jul. 26, 2017	5:39 PM	26.92	31.99	25.08	29.40	-2.48
2 ON	Jul. 26, 2017	5:39 PM	32.29	36.75	32.90	35.31	-3.02
2 OFF	Jul. 26, 2017	5:39 PM	31.10	28.96	25.32	27.60	3.50
3 ON	Jul. 26, 2017	5:26 PM	29.58	33.43	22.88	29.48	0.10
3 OFF	Jul. 26, 2017	5:26 PM	29.47	41.06	24.61	34.89	-5.42
4 ON	Jul. 26, 2017	5:26 PM	31.57	34.01	23.01	29.89	1.68
4 OFF	Jul. 26, 2017	5:26 PM	32.20	37.89	24.61	32.91	-0.71
5 ON	Jun. 19, 2017	5:20 PM	31.37	28.41	26.65	27.75	3.62
5 OFF	Jun. 19, 2017	5:20 PM	28.88	29.67	22.36	26.93	1.95
6 ON	Jun. 19, 2017	5:20 PM	29.98	29.91	26.83	28.76	1.22
6 OFF	Jun. 19, 2017	5:20 PM	28.73	34.79	26.10	31.53	-2.80

Site	Date	Satellite Imagery		In Situ Probe Temp.		PR 5:30 PM Temperature	Satellite Probe Temp. Difference
		Time	Temperature	4:00 PM	8:00 PM		
1 ON	Sept. 30, 2017	5:26 PM	20.90	33.43	8.50	24.08	-3.18
1 OFF	Sept. 30, 2017	5:26 PM	20.29	17.17	10.01	14.48	5.81
2 ON	Sept. 21, 2017	5:33 PM	20.03	26.18	12.83	21.17	-1.14
2 OFF	Sept. 21, 2017	5:33 PM	19.98	29.48	14.66	23.92	-3.94
3 ON	Sept. 30, 2017	5:26 PM	20.73	25.08	8.63	18.91	1.82
3 OFF	Sept. 30, 2017	5:26 PM	20.46	24.92	8.32	18.70	1.77
4 ON	Sept. 30, 2017	5:26 PM	20.71	27.31	9.64	20.68	0.03
4 OFF	Sept. 30, 2017	5:26 PM	20.28	30.04	9.83	22.46	-2.18
5 ON	Sept. 7, 2017	5:20 PM	21.83	25.27	9.82	19.48	2.35
5 OFF	Sept. 7, 2017	5:20 PM	20.09	33.47	7.25	23.64	-3.55
6 ON	Sept. 7, 2017	5:20 PM	21.03	28.91	10.90	22.16	-1.13
6 OFF	Sept. 7, 2017	5:20 PM	20.29	33.92	9.66	24.82	-4.53

Satellite and surface probe temperature were correlated within +/- 2.51°C for all 23 Summer and Fall On and Off- RoW surface probe locations. All On-RoW locations had a +/- 1.76°C deviation and all Off-RoW locations had a +/- 3.21°C deviation from satellite imagery temperatures. All Summer On-Row had a difference of +/- 1.93°C while all Fall On-RoW had a difference +/- 1.61°C. All Summer Off-RoW had a difference of +/- 2.81°C while all Fall Off-RoW had a difference +/- 3.63°C (Figure 3-4).

Figure 3-4 Satellite Data Temperature and Surface Probe Temperature Correlation Summarized by Summer On-RoW, Off-RoW and Fall On-RoW, and Fall Off-RoW



4.0 DISCUSSION

4.1.1 Local Permafrost Conditions

The site visits conducted in support of the permafrost monitoring program have confirmed the presence of permafrost at several locations along the northern sections of the Bipole III project. The permafrost is discontinuous to sporadic and most generally limited to wetlands, riparian areas and/or areas with thick organic soils. Subsurface materials consist generally of fine-grained soils (i.e., glaciolacustrine and glaciomarine deposits), with some occurrence of permafrost in peat deposits overlying sandy to gravelly fluvial deposits.

By far the most dominant vegetation type associated to the presence of permafrost consists of stands of low black spruce forest that have developed on thick organic soils. These are generally found within, or along the immediate perimeter of wetlands. The dominant wetland classes where permafrost was encountered consist of bogs, peat mound bogs and peat plateaus. Bogs are described as peatland receiving water exclusively from precipitation and not influenced by mineral-rich groundwater, while fens are described as peatland where the mineral-rich water table is at, or slightly above, the ground surface (National Wetlands Working Group 1988). Large wetland complexes encountered along the Bipole III RoW often contain both fens and bogs; however, the permafrost is generally limited to the bogs.

4.1.2 Field monitoring Results

One year of ground temperature data have been recorded at monitoring sites 1 to 6. This data covers a relatively short monitoring period (October 2016 to September 2017) and for this reason doesn't yet allow for in depth assessment of potential impacts of the vegetation clearing prescriptions on permafrost ground temperatures over time.

Comparing ground temperatures at on- versus off-RoW sites currently suggests limited relationships between warmer ground temperatures and the absence of vegetation cover. For most sites, the differences between on- and off-RoW temperatures appear primarily related to the variations in the local terrain conditions rather than on the recent impact of vegetation clearing. Warmer summer temperatures observed at site 5 on-RoW appear related to the clearing of the vegetation (i.e., vegetation removal allowed for increased heat penetration in the summer). Similarly, the colder winter temperatures recorded at the on-RoW sites at site 4 and site 5 appear related to vegetation clearing, where the removal of the vegetation and the disturbance of the ground surface would have translated in reduced insulation and increased frost penetration. Additional ground temperature data is required to better assess differences and/or relationships between on- and off-RoW sites.

A better correlation between warmer soil profiles and cleared vegetation cover is observed in active layer data obtained from sites 7 to 11. At those sites, the permafrost is present within large

peat plateaus found to extend on either side of the cleared RoW. Active layer depths measured along transects intersecting the RoW suggest that the active layer is generally shallower in undisturbed terrain than along the cleared portion of the RoW (anywhere from 1 to 15 cm).

4.1.3 Clearing Practice Results

Although no direct relationships were identified between clearing practices and currently available ground temperature data, the change detection analysis allowed for the identification of clearing trends with reference to on-RoW and off-RoW areas. For 2017, the Landsat-8 TIR satellite imagery captured a warming trend of On-RoW permafrost areas compared to corresponding Off-RoW areas in both summer and fall seasons. Over 80% of all permafrost sites were warmer on the RoW compared to off (Appendix B, Map Series 4-100 and Map Series 4-200). This suggests construction of the BPIII RoW is having a warming effect on permafrost locations.

The clearing practice trends identified would suggest permafrost thawing will occur more rapidly in areas that were cleared using the General Clearing methods than areas cleared by Low Disturbance or Selective Clearing methods (Appendix B, Maps 4-1 to 4-3). The Low Disturbance and Selective Clearing mitigation methods implemented by MB Hydro initially appear to have slowed surface temperature increases relative to General Clearing practices.

However, in 2017 it appears the relative On and Off-RoW temperature differences of the General Clearing practice has subsided compared to Low Disturbance and Selective Clearing practices (Table 4-1).

Table 4-1 2014 to 2017 Relative On- and Off-RoW Temperature Difference of the General, Low Disturbance and Selective Clearing Practices

Clearing Practice	Summer 2014	Fall 2014	Spring 2015	Summer 2015	Spring 2016	Summer 2016	Summer 2017	Fall 2017
General Clearing	3.4	2.9	1.3	2.2	3.2	3.9	**0.5**	**0.6**
Low Disturbance Clearing	0.6	0.8	0.7	1.2	0.9	1.5	**0.2**	**0.2**
Selective Clearing	1.1	1.7	0.4	0.9	1.2	2.2	**0.2**	**0.1**

4.1.4 Satellite and Probe Results

Results suggest satellite imagery temperatures are more accurate at On-RoW sites than Off-RoW sites. The satellite temperature is based on a reading covering 900 m^2 compared to the surface probe reading covering 25 cm^2. The satellite temperature data is better suited for homogeneous areas given the large footprint. Since the On-RoW locations have been cleared of trees they are less complex than heterogeneous Off-RoW locations that still have standing trees. Given the season range of temperature from summer to fall at 5:30 pm of roughly 30°C the +/-1.76°C

deviation of On-RoW site suggest Landsat-8 TIR thermal temperature readings are an accurate and reliable data source.

5.0 CONCLUSION AND RECOMMENDATIONS

Aside from changes triggered by climate warming, it is recognized that anthropogenic disturbance in wetland-dominated basins located within the zone of discontinuous permafrost have resulted in significant permafrost thaw in recent years (Quinton and Hayashi 2005; Mohammed 2013). This is especially the case for disturbed peat plateaus, where permafrost degradation can have a significant impact on local drainage conditions by releasing important quantities of water into the ecosystem.

Naturally occurring permafrost degradation is known to occur in peatlands of northern Manitoba (Thie 1974; Zoltai 1972; Vitt et al. 1994; Dyke and Sladen 2010). Numerous signs of thaw degradation were observed while in the field, both at the on-RoW And at the off-RoW sites. They include (but are not limited to): occurrence of thermokarst terrain, changes to hydrology and soil drainage conditions, impacted vegetation. The goal of the permafrost monitoring program was not to confirm if permafrost degradation is indeed occurring along the Bipole III Project, but rather to assess if the disturbance associated to the vegetation clearing activities have accelerated and/or accentuated the degradation process. In essence, is there a correlation between the type of clearing method used by Manitoba Hydro and permafrost degradation.

5.1 FIELD MONITORING PROGRAM

The analysis of ground temperature data obtained at 6 monitoring sites suggest limited to no acceleration of the permafrost degradation progress along the cleared RoW. This interpretation is severely limited by the fact that only a single year of data is currently available for review, but also by the fact that the terrain conditions were observed to be slightly different between some of the on- versus off-RoW sites. Based on the 2016/2017 data alone, it is too early to conclude if the clearing activities have accelerated and/or accentuated the degradation of permafrost along the RoW.

The active layer data; however, indicated a stronger relationship between deeper thaw penetration and the absence/presence of vegetation cover. This data is line with the baseline assumption that the vegetation cover (just like snow cover) act as an insulation layer, limiting heat transfers between the ground and the ambient air.

5.2 SURFACE TEMPERATURE CHANGE DETECTION ANALYSIS

It is evident thermal satellite imagery is detecting a surface warming trend of permafrost sites through On-RoW and Off-RoW comparisons. In 2017, over 80% of On-RoW sites recorded higher temperatures and 46% of those permafrost sites had a warmer surface temperature of +0.25°C. This will have a negative effect on permafrost thaw but how long and to what degree remain largely unknown. Only continued monitoring of the Bipole III RoW permafrost locations will provide a reliable understanding.

We also found General Clearing practice areas continue to show warmer surface temperatures than areas cleared by Selective and Low Disturbance practices paralleling 2014-2016 results. However, this difference between clearing practices was substantially reduced in 2017. Whether clearing practices had a long-term effect is currently unknown. Only continued monitoring of the Bipole III RoW clearing practices will provide a scientific answer.

With finally having in situ temperature probe data available to compare to satellite thermal data, we can now say with a high degree of confidence the satellite temperature readings are accurate and reliable. Landsat-8 TIR imagery can continue to be used to study the long-term effects of Bipole III construction and operation on all permafrost sites in a cost effective, time efficient and scientifically sound and repeatable manner.

6.0 REFERENCES

Agriculture and Agri-Food Canada (AAFC). 1998. Terrestrial Ecozones, Ecoregions, and Ecodistricts of Manitoba, Saskatchewan and Alberta.

Amec Foster Wheeler Environment and Infrastructure. 2016. Bipole III N1 Borehole Logs.

Amec Foster Wheeler Environment and Infrastructure. 2014. Bipole III N2 and N2A Drill Logs.

Calmel et al. 2005. A portable earth-drill system for permafrost studies. Permafrost and Periglacial Processes. Volume 16, Issue 3, pages 311–315, July/September 2005.

Dyke, L.D. and W.E. Sladen. 2010. Permafrost and Peatland Evolution in the Northern Hudson Bay Lowland, Manitoba. Arctic. Vol. 63, No. 4. December 2010. P. 429-441.

Dredge, L.A. and Nixon, F.M., 1992. Glacial and Environmental Geology of Northeastern Manitoba. Geological Survey of Canada, Ottawa, Memoir 432, 80 p.

Environment Canada. Canadian Climate Data and Information Archive. "Canadian Climate Normals 1971-2000". Government of Canada. Originally accessed in March 2010.

Glooschenko, W., Roulet, N. T., Barrie, L. A., Schiff, H. I., and McAdie, H. G.: The Northern Wetlands Study (NOWES): An overview, J. Geophys. Res., 99(D1), 1423–1428, 1994.

Johnston, G.H., Brown, R.J.E., and Pickkersgill, D.N., 1963. Permafrost Investigations at Thompson, Manitoba: Terrain Studies.

Heginbottom, J.A., Dubeuil, M.A., and Harker, P.T. 1995. Canada, Permafrost. The National Atlas of Canada, 5th ed. Ottawa: Natural Resources Canada.

Manitoba Hydro. 2014. Bipole III Transmission Project Construction Environmental Protection Plan-Section N1

Manitoba Hydro. 2014. Bipole III Transmission Project Construction Environmental Protection Plan-Section N2

Manitoba Hydro. 2014. Bipole III Transmission Project Construction Environmental Protection Plan-Section N3

Manitoba Hydro. 2014. Bipole III Transmission Project Construction Environmental Protection Plan-AC Collector Lines, Construction Powerline and Station

Manitoba Hydro. 2014. Bipole III N3 Specialty Foundation Recommendations

Matile, G.L.D. and Keller, G.R. 2006a. Surficial Geology east-central Manitoba; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Surficial geology Compilation Map Series, SG-WCMB, scale 1:500,000.

Matile, G.L.D. and Keller, G.R. 2006b. Surficial Geology west-central Manitoba; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Surficial geology Compilation Map Series, SG-WCMB, scale 1:500,000.

Mohammed, Aaron A., 2013. Mitigating permafrost degradation due to linear disturbances in sub-arctic peatlands. Electronic Thesis and Dissertation Repository. Paper 1758.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Ottawa: Sustainable Development Branch, Environment Canada and Montreal, Quebec: Polyscience Publications Inc.

Nelson FE, Hinkel KM, Shiklomanov NI, Muller GR, Miller LL, Walker DA. 1998. Active layer thickness in north-central Alaska: systematic sampling, scale and spatial autocorrelation. Journal of Geophysical Research 103: 28963-28973.

Permafrost Subcommittee, 1988. Glossary of Permafrost and Related Ground-ice Terms, National Research Council of Canada, Technical Memorandum No. 142, p. 156.

Quinton, W.L., Hayashi, M. 2005. The flow and storage of water in the wetland dominated central Mackenzie River Basin: Recent advances and future directions, in Prediction in Ungauged Basins:

Approaches for Canada's Cold Regions, edited by C. Spence, J. W. Pomeroy, and A. Pietroniro, pp. 45– 66, Can. Water Resour. Assoc., Ottawa, Ontario.

Romanovsky, V.E., and Osterkamp, T.E. 1995. Interannual variations of the thermal regime of the active layer and near-surface permafrost in northern Alaska. Permafrost and Periglacial Processes, 6: 313–315.

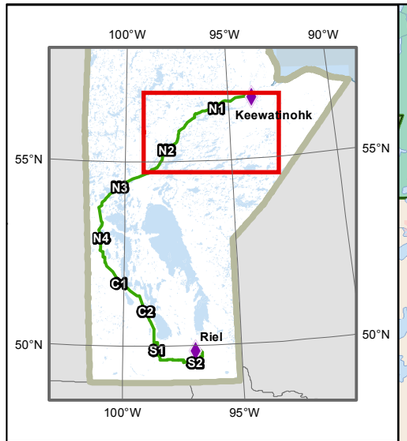
Smith S.L. and M. Ednie. Ground thermal data collection along the Alaska Highway easement (KP 1559-1895) Yukon, summer 2014. Geological Survey of Canada, Open File 7762.

Thie J. 1974. Distribution and thawing of permafrost in the southern part of the discontinuous permafrost zone in Manitoba. Arctic 27:189–200

Vitt, D.H., Halsey, L.A., and Zoltai, S.C. 1994. The bog landforms of continental western Canada in relation to climate and permafrost patterns. Arctic and Alpine Research 26:1–13.

Zoltai, S.C. 1972. Palsas and Peat Plateaus in Central Manitoba and Saskatchewan. Canadian Journal of Forest research, 2, 291-302.

Appendix A PERMAFROST MONITORING FIELD MAPS



Bipole III Transmission Project

AMISK PARK RESERVE
Baldock Lake
Waskaiowaka Lake
N1
SITE 10
SITE 8
SITE 11
SITE 9
NELSON
Potential Conawapa G.S.
Proposed Keewatinohk C.S.
RC60
SITE 5
Bird
Limestone G.S.
FOX LAKE FIRST NATION
Henday C.S.
SITE 6
KN36
290
Kettle G.S.
Long Spruce G.S.
SITE 7
Gillam
Radisson C.S.
Stephens Lake
Proposed Keeyask G.S.
SITE 4
NELSON RIVER
280
TATASKWEYAK FIRST NATION
Split Lake
KS37
Wivenhoe
Split Lake
YORK FACTORY FIRST NATION
York Landing
KN36
R26K
Ilford
WAR LAKE FIRST NATION
Kelsey G.S.
SITE 3
Nelson River
Munk
KT1
KT2
K24B
Moak Lake
Pit Siding
WL43
391
Nelson House
NISICHAWAYASIHK CREE NATION
THOMPSON
Partridge Crop Lake
Pikwitonei
RIVER
KH38
Wuskwatim Lake
Wuskwatim G.S.
W76B
Paint Lake
PAINT LAKE PROVINCIAL PARK
SITE1
6
N2
Thicket Portage
Landing Lake
NELSON
DC1
W74H
PR19W
Utik Lake
Bear Lake
Knee Lake
Sipiwesk Lake
Waboden
SITE 2
373
BUNIBONIBEE CREE NATION
Oxford House
MANTO SIPI CREE NATION
God's River
Oxford Lake
Gods Lake
Gods Lake
Edmund Lake
HG61
Walker Lake
Hayes River

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 12.5 25 Kilometres
0 5 10 Miles

N

1:1,000,000

Legend

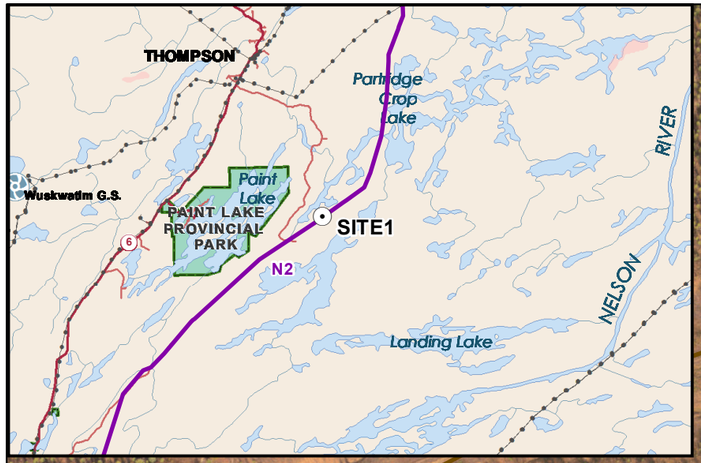
- Permafrost Monitoring Sites
- BPIII Final Preferred Route
  - Section N1
  - Section N2
- Existing G.S.
- Proposed G.S.
- Proposed Converter Station
- Existing Converter Station
- Transmission Line
- AC Collector Line
- Construction Power Line
- Provincial Highways
- Provincial Roads
- First Nation
- Provincial Park
- Wildlife Management Area

Bipole III Transmission Project
Permafrost Monitoring Field Program

Location of 2017 Permafrost Monitoring Sites

Map 2-1

File Location: G:_GIS_Project_Folder\00_Hydro\111420045\ArcMap\Permafrost\2017BPIII_Permafrost_Actual_SampleLocns_ALL_2017.mxd



156
1159
N2-S10
Thermistor 1B
211
212
213
205
209
206
Thermistor 1A
208
1160

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

0 100 200 Feet
0 25 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

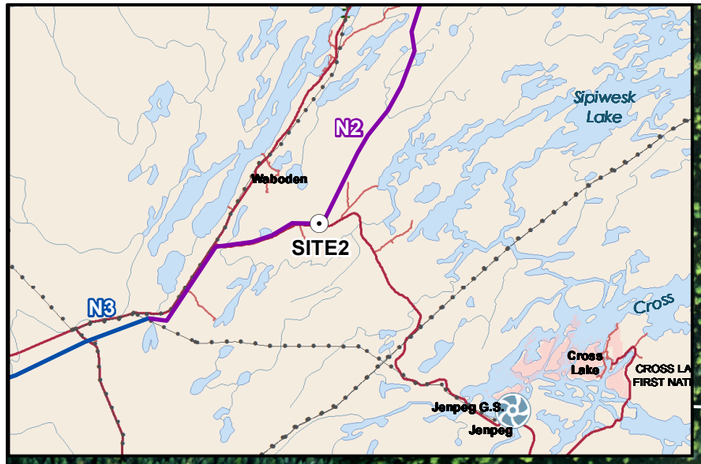
Permafrost Monitoring
Active Layer Depth (cm)
- 65 Off ROW
- 55 On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 1 - 2017
(N2-S10)

File Location: G:_GIS_Project_Folder\00_Hydro\1114200454\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site1_2017.mxd

Map 2-2



75 79 97
72 136 119
90 132
Thermistor 2B
N2-S24
140 137 157
177 150
Thermistor 2A
373

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 100 200 Feet
0 25 50 100 Meters

N
1:1,500

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

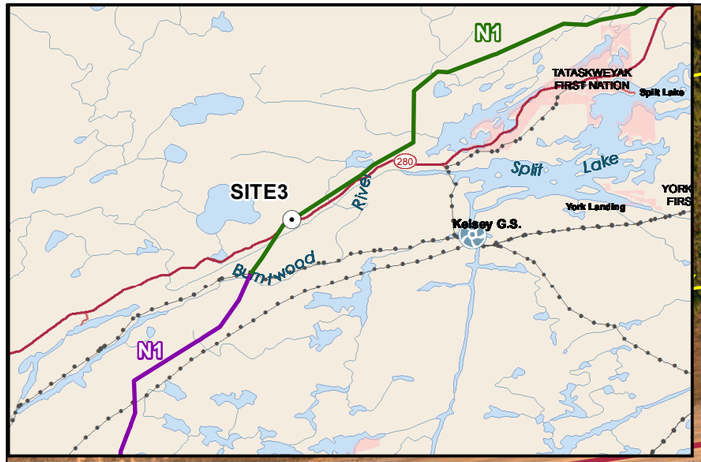
Permafrost Monitoring
Active Layer Depth (cm)
- 65 Off ROW
- 65 On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 2 - 2017
(N2-S24)

File Location: G:_GIS_Project_Folder\00_Hydro\11142004\5\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site2_2017.mxd

Map 2-3



12
12RT
280
95
140
63
109
106
68
124
Thermistor 3B
100
74
68
48
61
54
89
Thermistor 3A
507
N1-S30

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

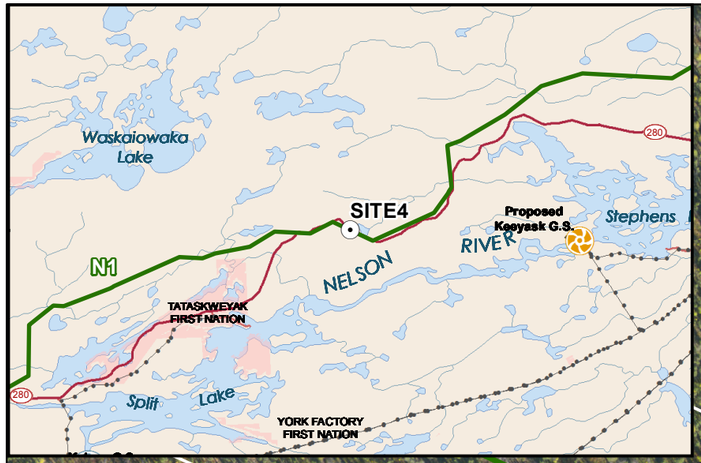
Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 3 - 2017
(N1-S30)

Map 2-4

File Location: G:_GIS_Project_Folder\00_Hydro\111420045\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site3_2017.mxd



07A

07AR/T

299

298

Thermistor 4A

Thermistor 4B

60 79 77 82 54 54 79 66 71

69 63 67 72 64 76 54 68 50

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

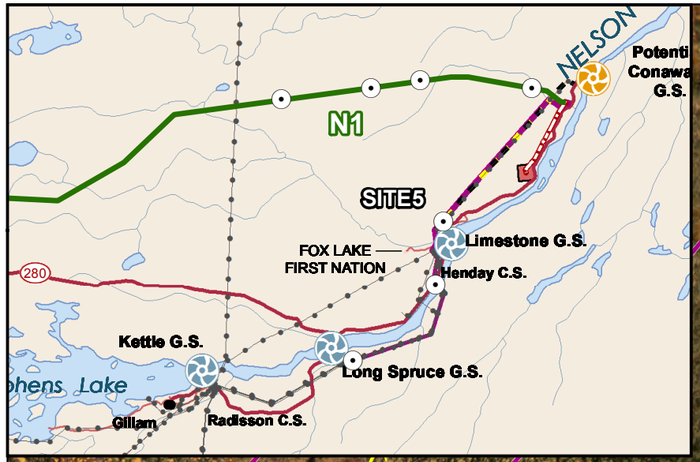
Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 4 - 2017
(N1-S16)

Map 2-5

File Location: G:_GIS_Project_Folder\00_Hydro\1142004\5\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site4_2017.mxd



53
47
44
61
54
68
Thermistor 5B
54
65
61
Unnamed Tributary
69
46
55
41
53
50
45
54
Thermistor 5A
51

File Location: G:_GIS_Project_Folder\00_Hydro\1114200451\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site5_2017-.mxd

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

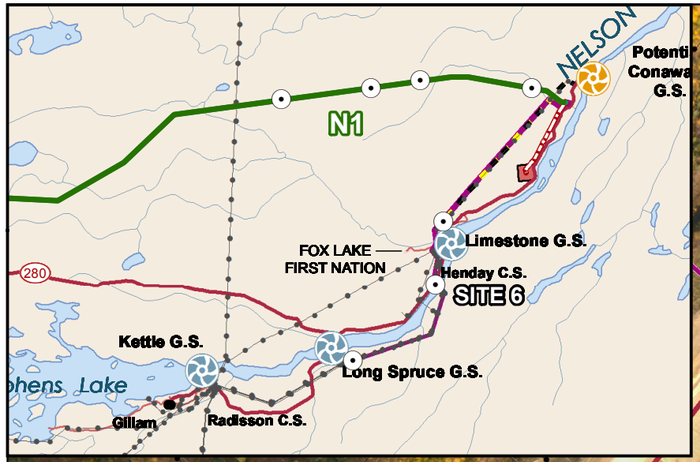
Project Infrastructure
- BPIII Final Preferred Route (Section N1)
- Proposed AC Collector Line
- Proposed Construction Power Line

Permafrost Monitoring
- Active Layer Depth (cm)
- 69 Off ROW
- 69 On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 5 - 2017
AC Collector/Construction Power)

Map 2-6



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

N

0 100 200 Feet
0 50 100 Meters
1:1,500

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
- BPIII Final Preferred Route (Section N1)
- Proposed AC Collector Line
- Proposed Construction Power Line

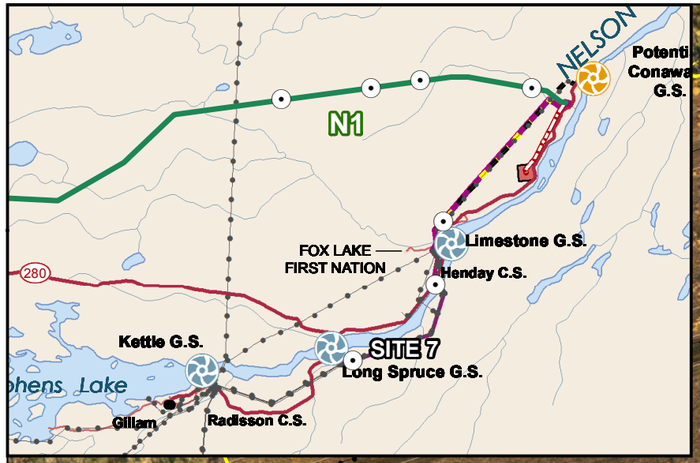
Permafrost Monitoring
- Active Layer Depth (cm)
- 53 Off ROW
- 53 On ROW
- Thermistor Locations
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 6 - 2017
AC Collector/Construction Power)

File Location: G:_GIS_Project_Folder\00_Hydro\111420045\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site6_2017.mxd

Map 2-7



67
44
64
68
64
54
67
43
52
48
47
72

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
- BPIII Final Preferred Route (Section N1)
- Proposed AC Collector Line
- Proposed Construction Power Line

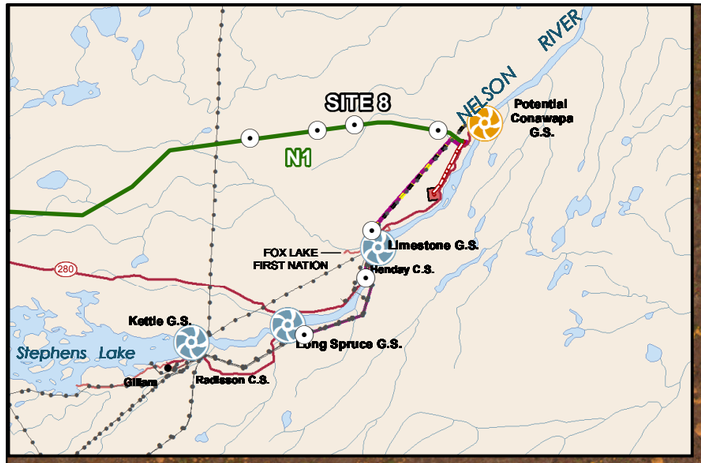
Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 7 - 2017
AC Collector/Construction Power)

File Location: G:_GIS_Project_Folder\00_Hydro\1114200045\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site7_2017.mxd

Map 2-8



SITE 8 - T1

35 62 42 55 56 52 65 60 69 58 66 57 52 85 92

SITE 8 - T2

59 84 51 55 43 45 45 42 51 63 54 138

N1-S5

42 41

TEXT

File Location: G:_GIS_Project_Folder\00_Hydro\111420045\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site8_2017.mxd

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

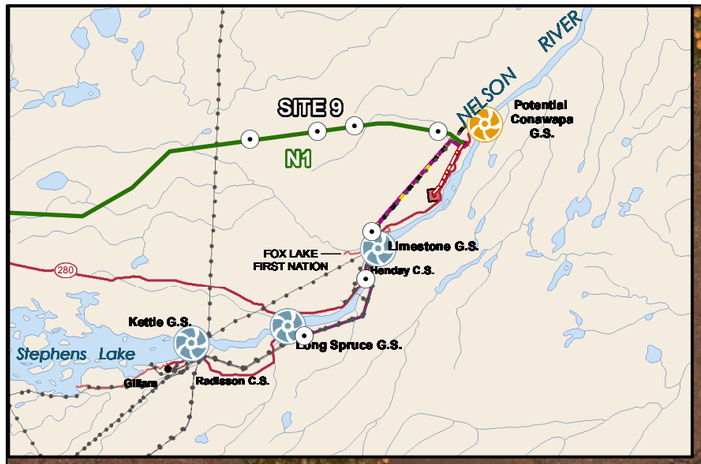
Points of Access
- Proposed Access Point
- Access Route

Permafrost Monitoring
Active Layer Depth (cm)
- 59 Off ROW
- 65 On ROW
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 8 - 2017
(N1-S5)

Map 2-9



67
47
65
66
56
53
44
59
51
55
54
51
50
52
56
66
55
54

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

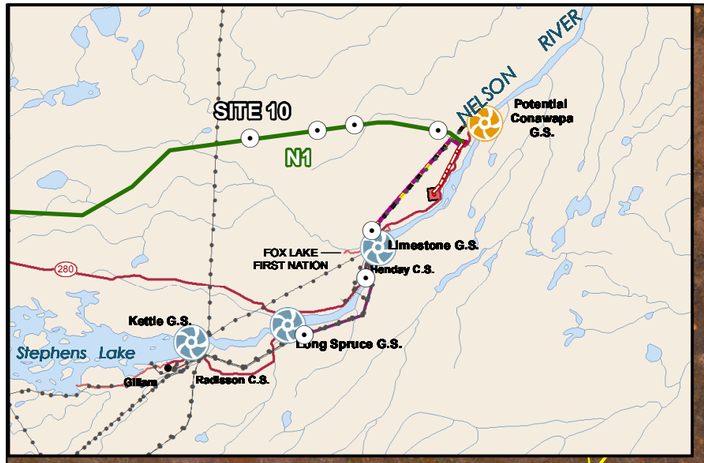
Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 9 - 2017
(N1-S5)

File Location: G:_GIS_Project_Folder\00_Hydro\1114200451\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site9_2017.mxd

Map 2-10



73
64
47
51
54
53
52
47
50
51
59
53
55
62
54
46
46
58

N1-S5
79
80

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 24, 2017

0 100 200 Feet
0 50 100 Meters
1:1,500

N

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

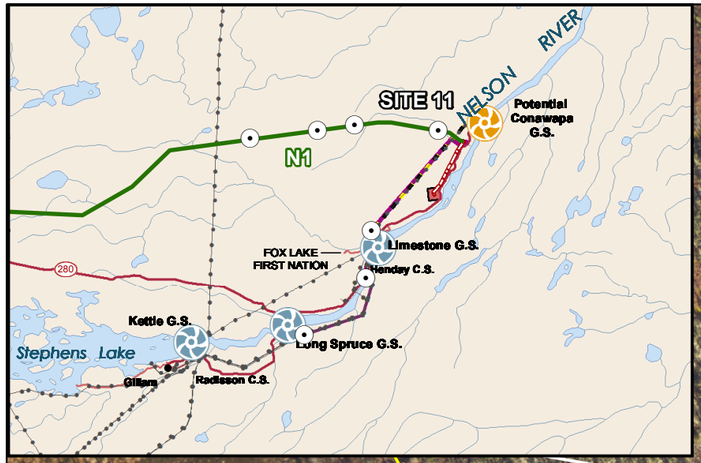
Points of Access
- Proposed Access Point
- Access Route

Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Permafrost

Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 10 - 2017
(N1-S5)

Map 2-11



49
54
49
58
54
54
52
47
51
N1-S3
44
50
63
44
46

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 23, 2017

0 100 200 Feet
0 50 100 Meters
N
1:1,500

Land Base
- Transmission Line
- Provincial Highway
- Major Road
- Local Road
- Railway (Operational)

Project Infrastructure
BPIII Final Preferred Route
- Section N1
- Section N2
- Towers (Preliminary)
- 66 m Right of Way
- Angle Tower Locations (Preliminary)

Points of Access
- Proposed Access Point
- Access Route

Permafrost Monitoring
Active Layer Depth (cm)
- Off ROW
- On ROW
- Permafrost

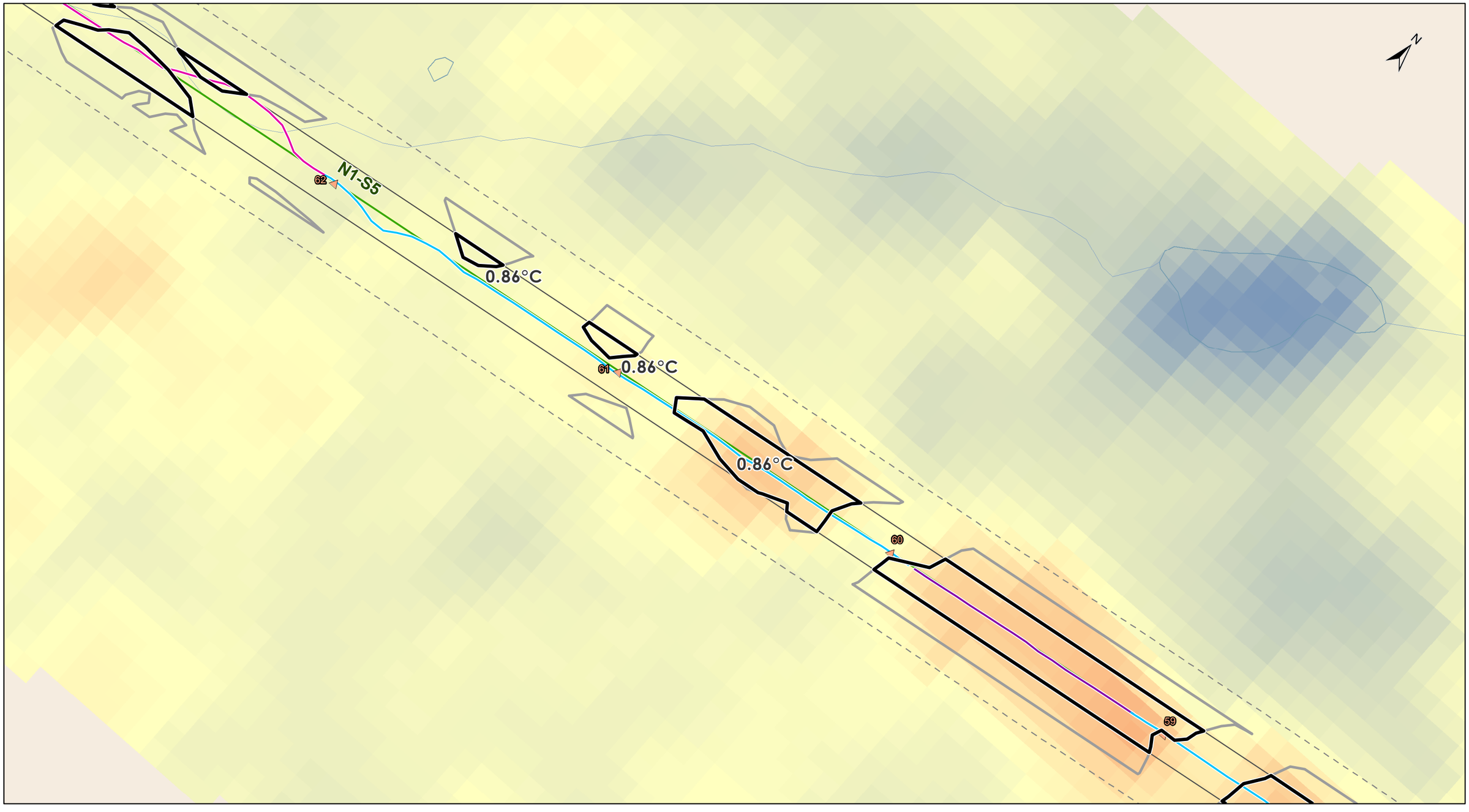
Bipole III Transmission Project
Permafrost Monitoring Field Program

Site 11 - 2017
(N1-S3)

Map 2-12

File Location: G:_GIS_Project_Folder\00_Hydro\111420045\ArcMap\Permafrost\2017\BPIII_Permafrost_Actual_SampleLocn_Site11_2017.mxd

Appendix B THERMAL CHANGE DETECTION MAPS



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 62.5 125 250
Metres

1:5,000

TIR Summer 2017 (°C)

Value
High : 46
Low : 0

TIR Change Detection Analysis

On ROW Polygons Used in Thermal Change Detection Analysis

Off ROW Polygons Used in Thermal Change Detection Analysis

ROW Clearing Methods

General Clearing

Low Disturbance Clearing

Selective Clearing

°C Temperature Change in °C Between On and Off ROW Polygons

Project Infrastructure

BPIII Final Preferred Route

66m ROW

66m Buffer of ROW

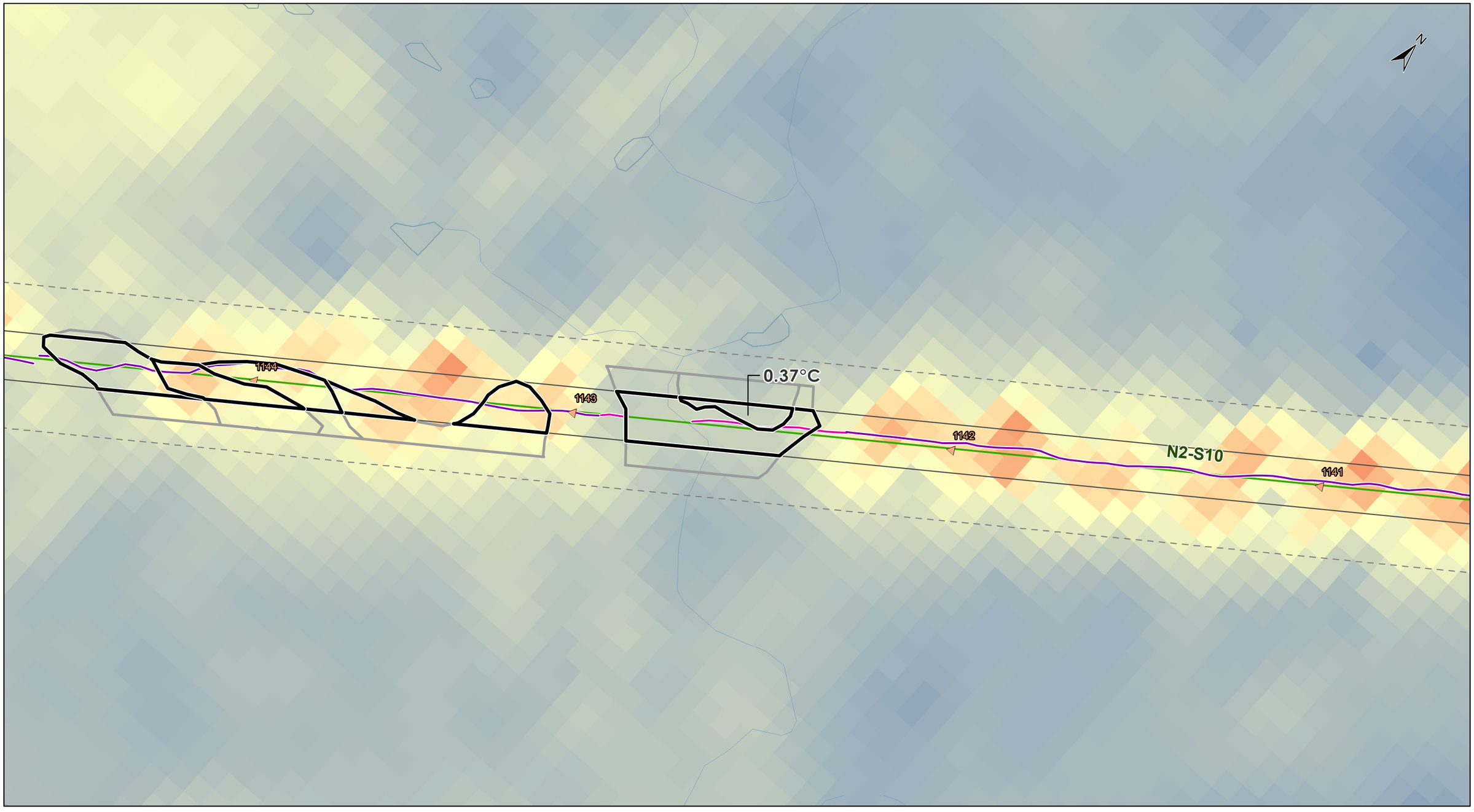
Towers (Preliminary)

Bipole III Transmission Project
Permafrost Monitoring

Thermal Change Detection Analysis
N1-S5, Low Disturbance Clearing Method
Summer 2017

Map 4-1

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_CHANGEDETECTION_2017_N1S5_20171129.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 62.5 125 250
Metres

1:5,000

TIR Summer 2017 (°C)

Value

High : 46

Low : 0

TIR Change Detection Analysis

On ROW Polygons Used in Thermal Change Detection Analysis

Off ROW Polygons Used in Thermal Change Detection Analysis

ROW Clearing Methods

General Clearing

Selective Clearing

°C Temperature Change in °C Between On and Off ROW Polygons

Project Infrastructure

BPIII Final Preferred Route

66m ROW

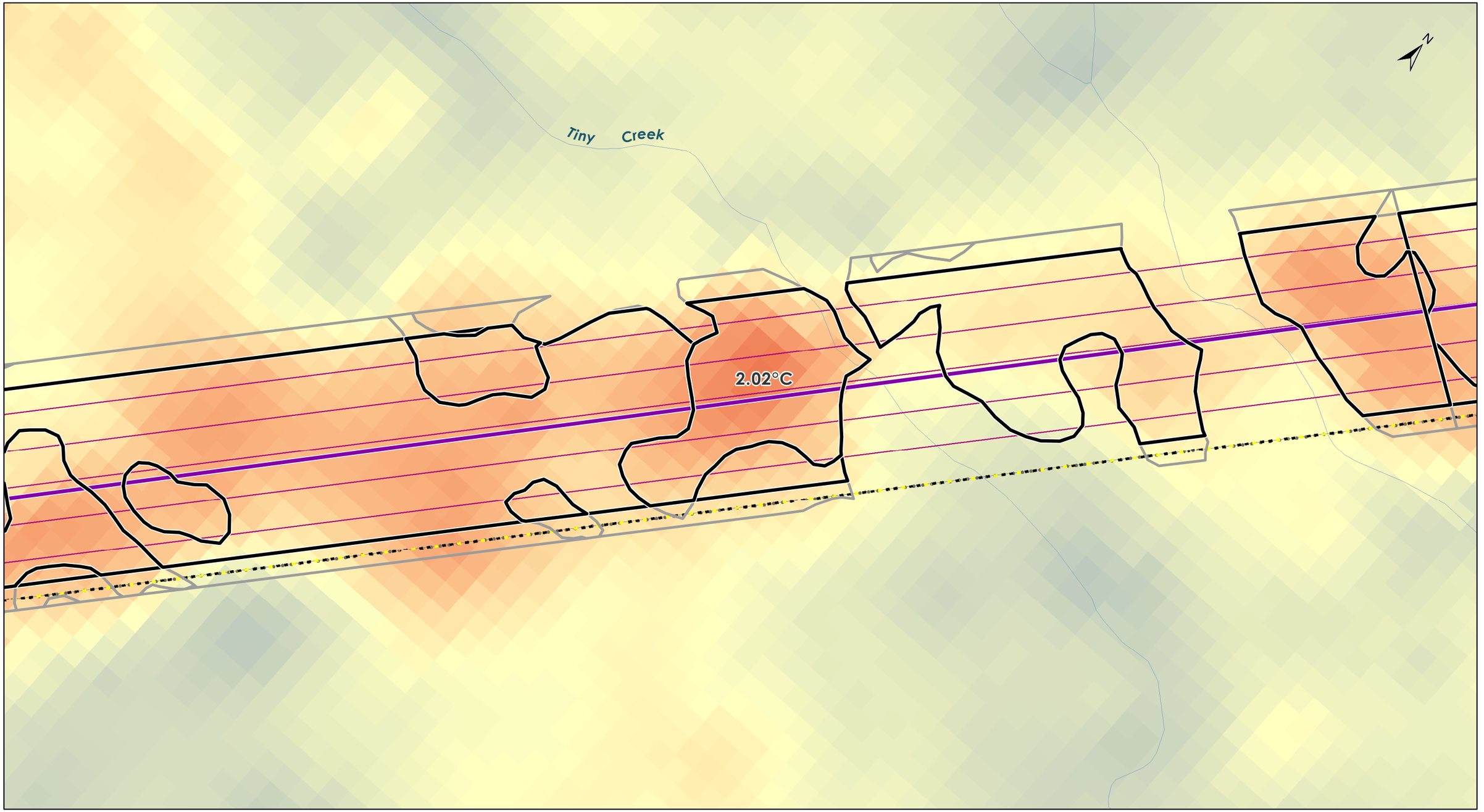
66m Buffer of ROW

Towers (Preliminary)

Bipole III Transmission Project
Permafrost Monitoring

Thermal Change Detection Analysis
N2-S10, Selective Clearing Method
Summer 2017

Map 4-2



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_CHANGEDETECTION_2017_ACCOLL_20171129.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 62.5 125 250
Metres

1:5,000

TIR Summer 2017 (°C)

High : 46

Low : 0

TIR Change Detection

On ROW Polygons Used in Thermal Change Detection Analysis

Off ROW Polygons Used in Thermal Change Detection Analysis

ROW Clearing Methods

General Clearing

Low Disturbance Clearing

Selective Clearing

°C Temperature Change in °C Between On and Off ROW Polygons

Project Infrastructure

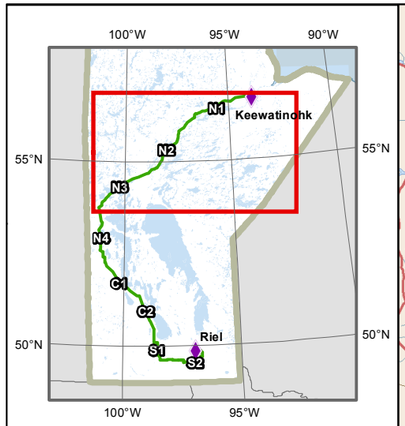
Construction Power (KN36)

AC Collector Line

Bipole III Transmission Project
Permafrost Monitoring

Thermal Change Detection Analysis
AC Collector Line, General Vegetation Clearing Method
Summer 2017

Map 4-3



Bipole III Transmission Project

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, Stantec, ProvMB, NRCAN
Date Created: November 29, 2017

0 12.5 25 Kilometres
0 5 10 Miles

N

1:1,500,000

Legend

BPIII Final Preferred Route
- Section N1
- Section N2
- Section N3

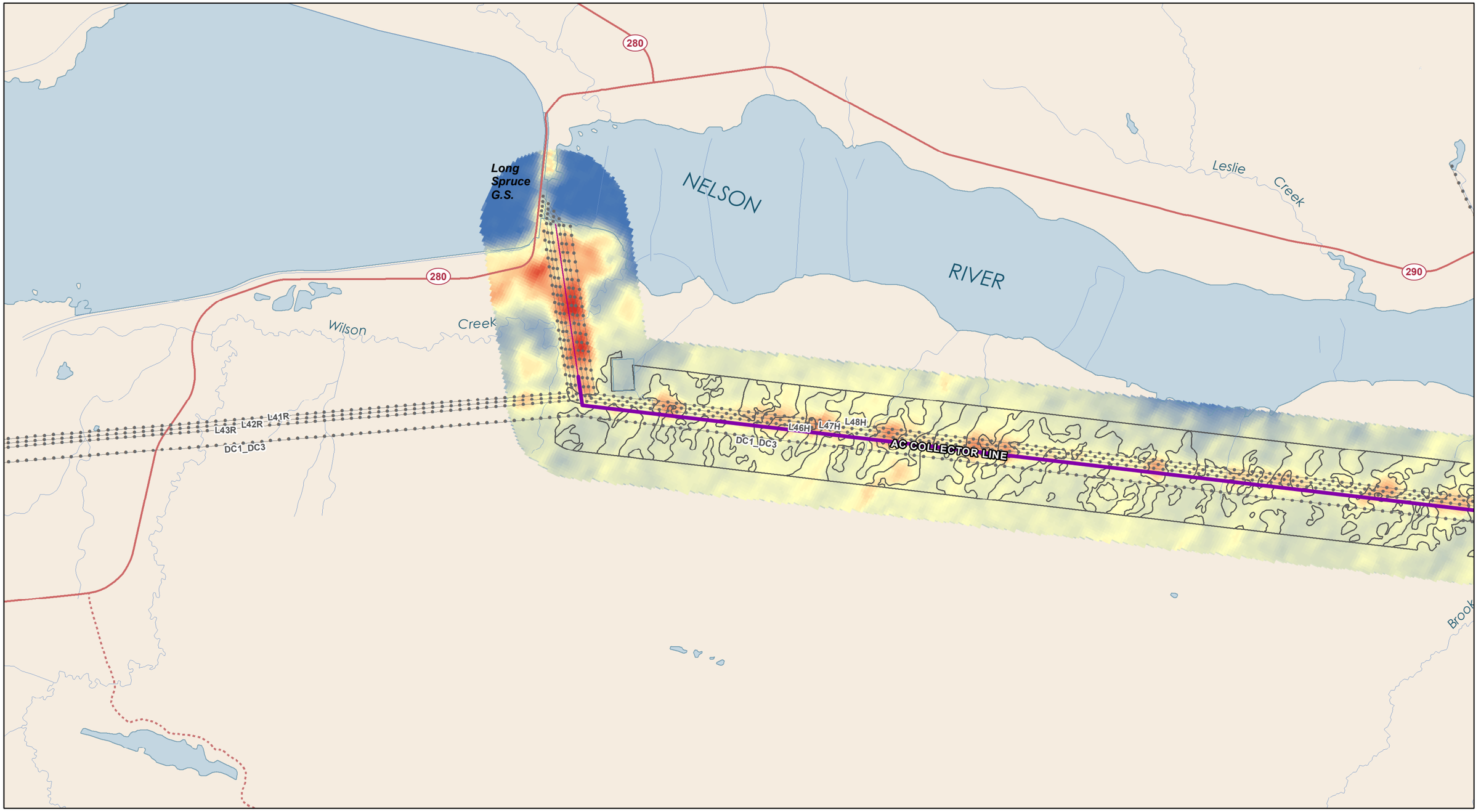
- Existing G.S.
- Proposed G.S.
- Proposed Converter Station
- Existing Converter Station
- Transmission Line
- Provincial Highways
- Provincial Roads
- First Nation
- Provincial Park
- Wildlife Management Area

Bipole III Transmission Project
Permafrost Monitoring Field Program

Landsat-8 Thermal Data
Map Index

Map 4-100

File Location: G:_GIS_Project_Folder\00_Hydro\111412004\5\ArcMap\Permafrost\2017\BPIII_PMF_IndexMap_2017.mxd



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

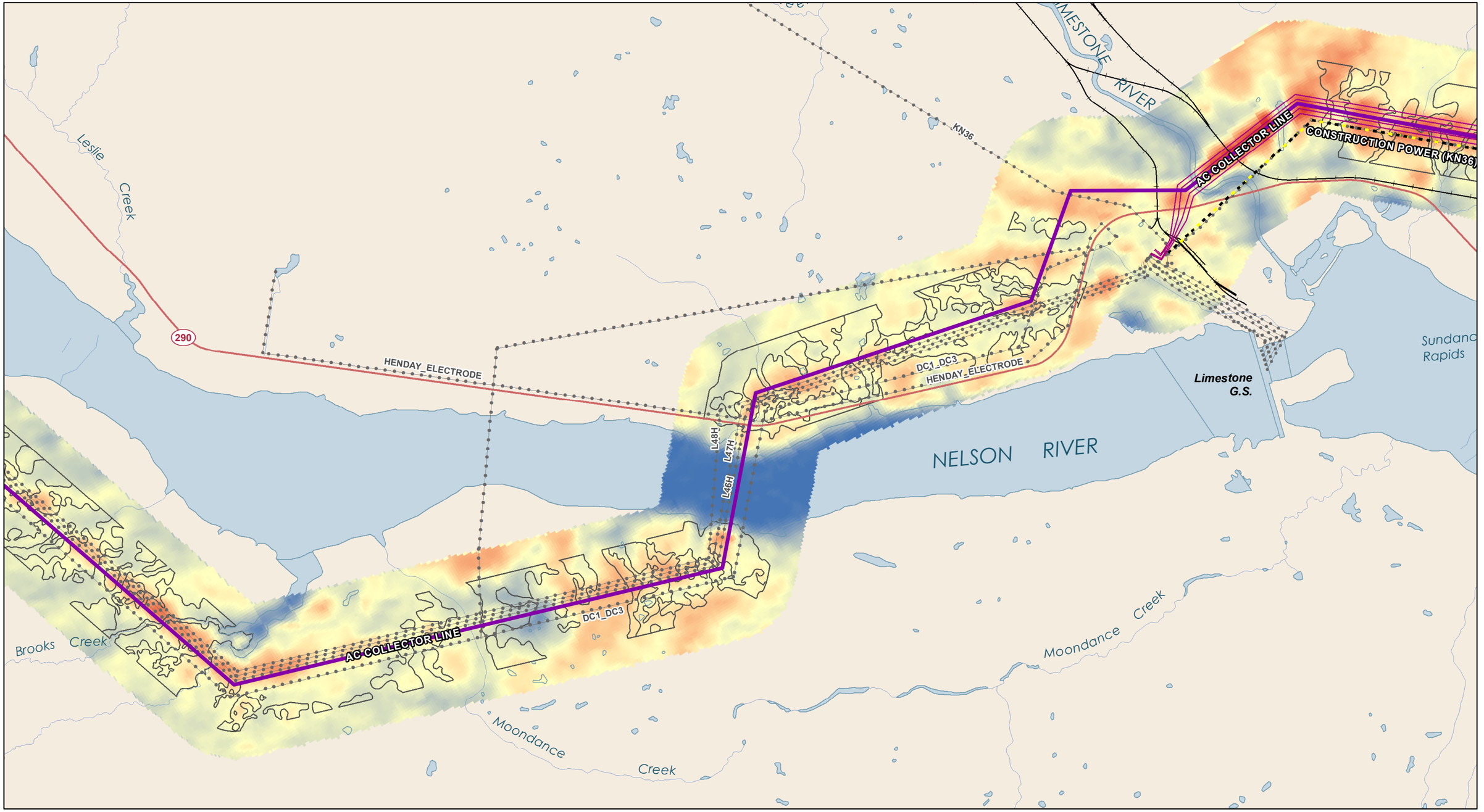
Project Infrastructure
- AC Collector Line

Landbase
- Provincial Road
- Winter Road
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-1



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- Construction Power (KN36)
- AC Collector Line

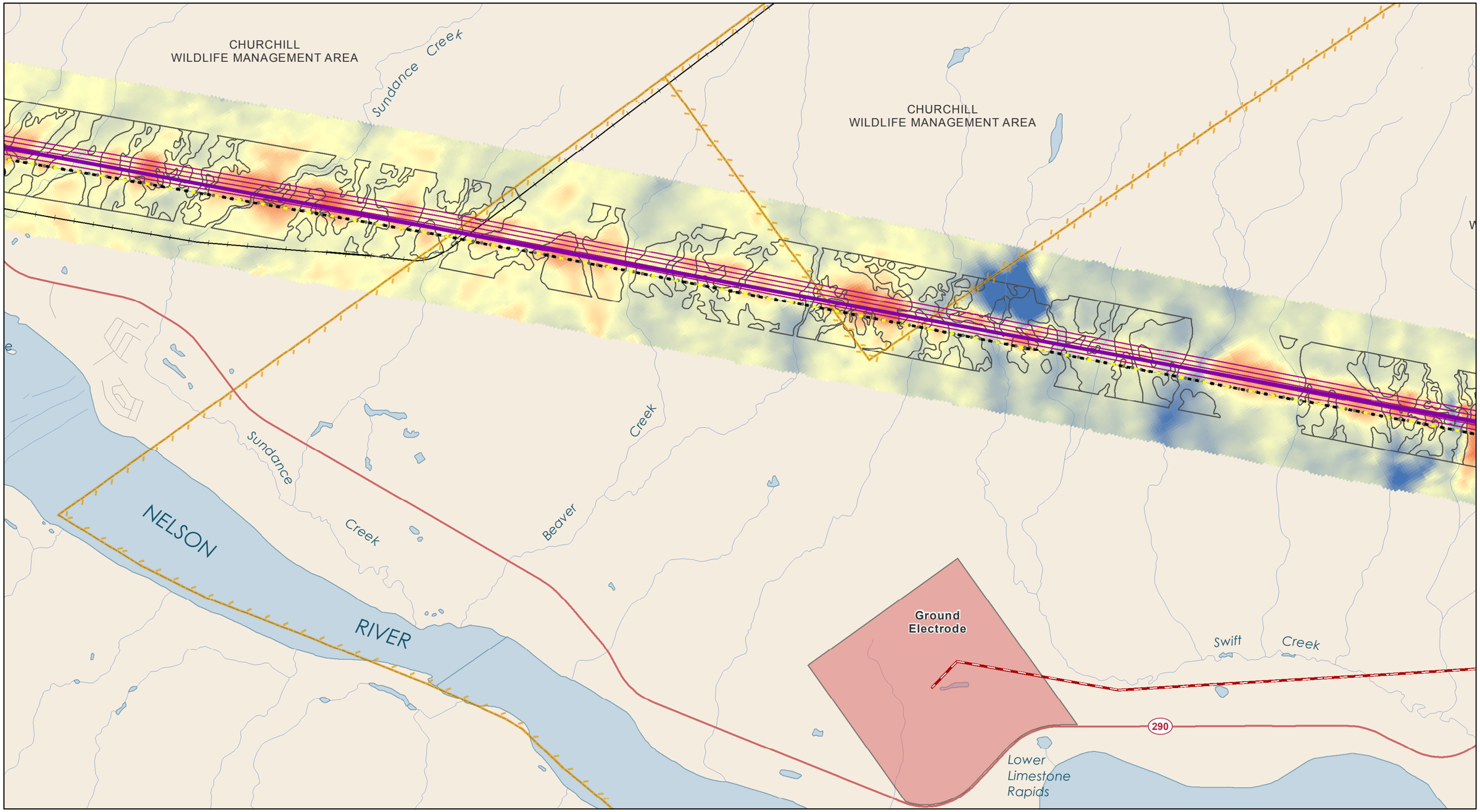
Landbase
- Provincial Road
- Railway (Operational)
- Transmission Line
- First Nation
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-2

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- Construction Power (KN36)
- Ground Electrode Line
- AC Collector Line
- Ground Electrode

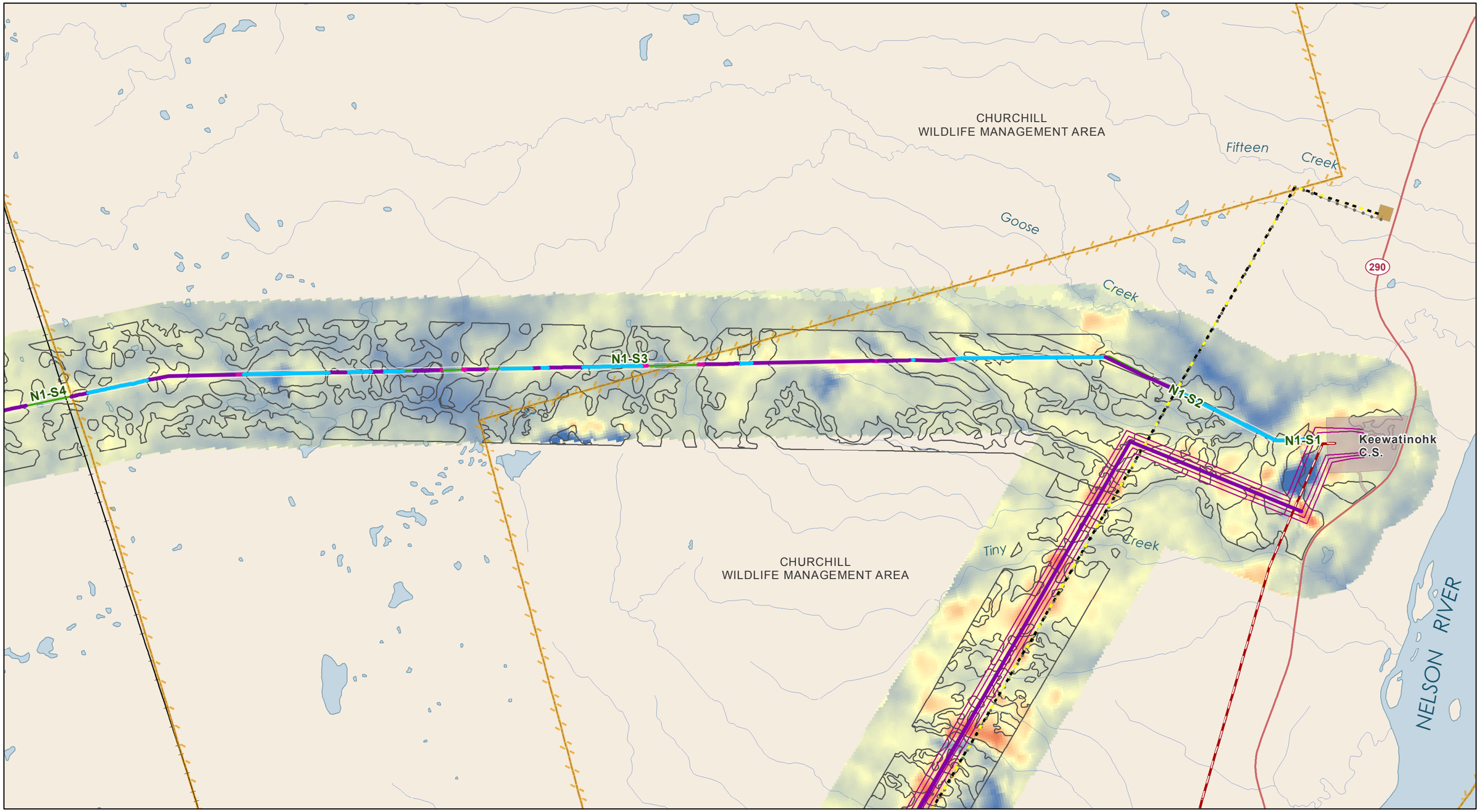
Landbase
- Provincial Road
- Local Road
- Railway (Operational)
- Transmission Line
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-3

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

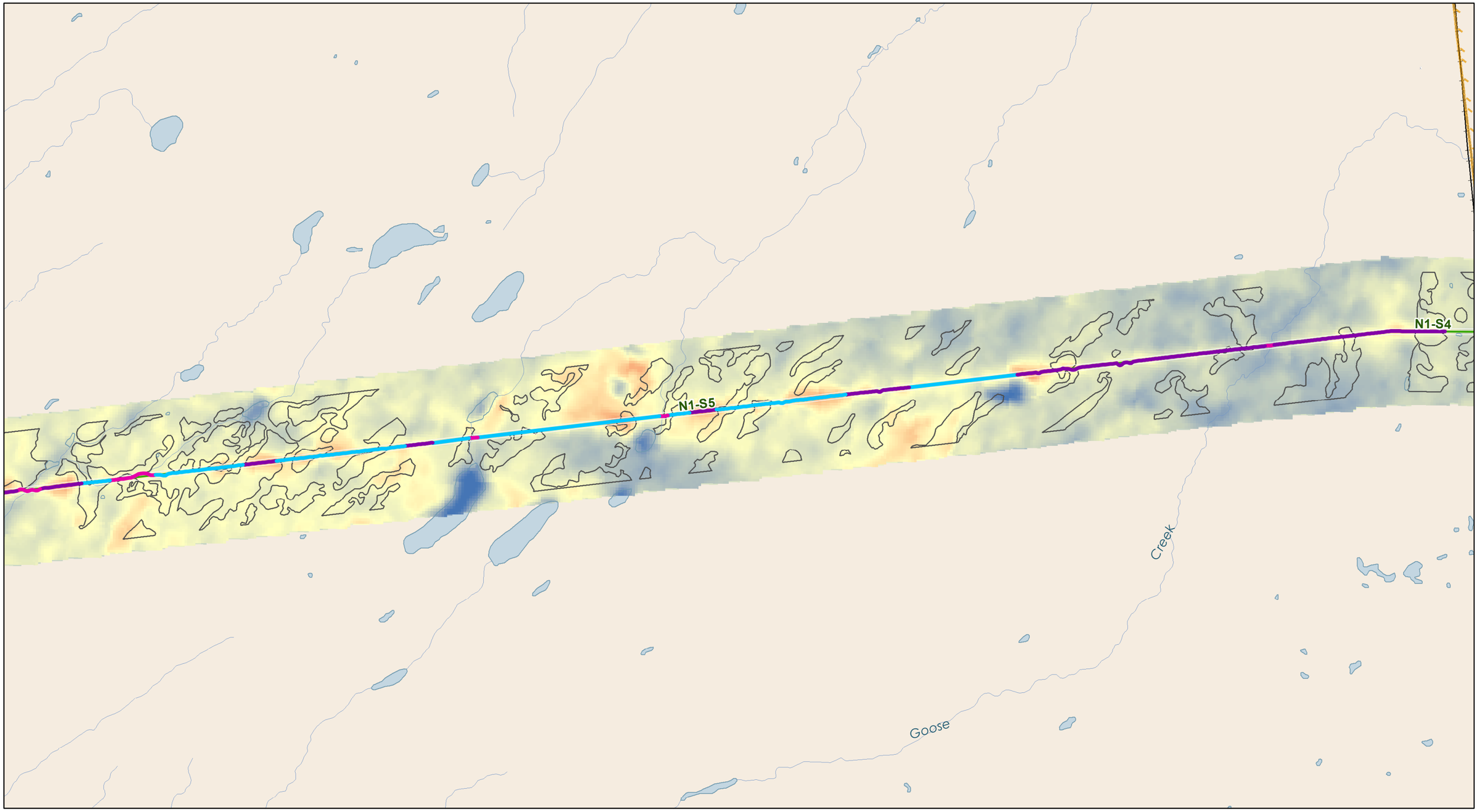
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- Construction Power (KN36)
- Ground Electrode Line
- AC Collector Line
- Keewatinoow Converter Station
- Construction Power Station

Landbase
- Provincial Road
- Railway (Operational)
- Transmission Line
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-4



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

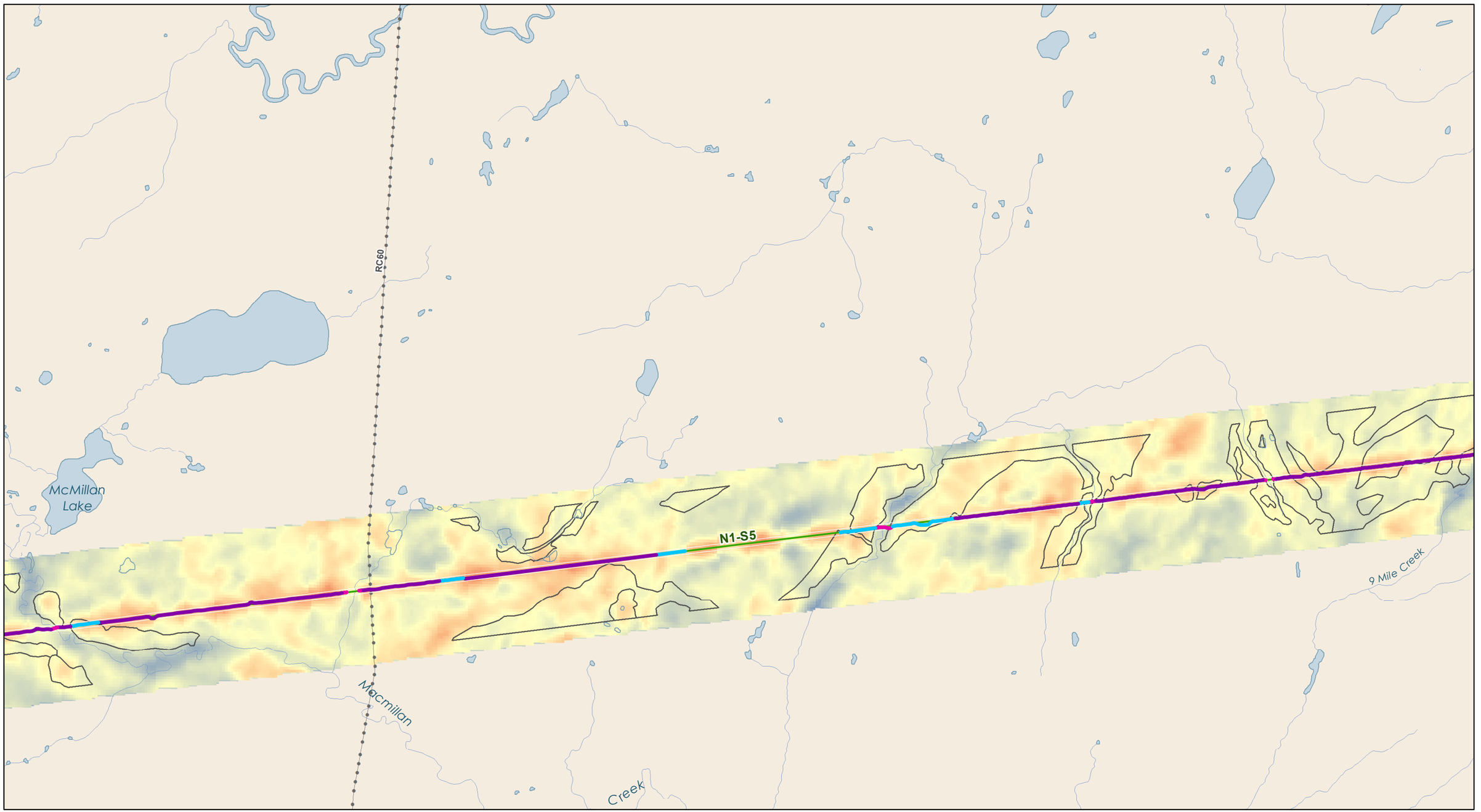
Landbase
- Railway (Operational)
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-5

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

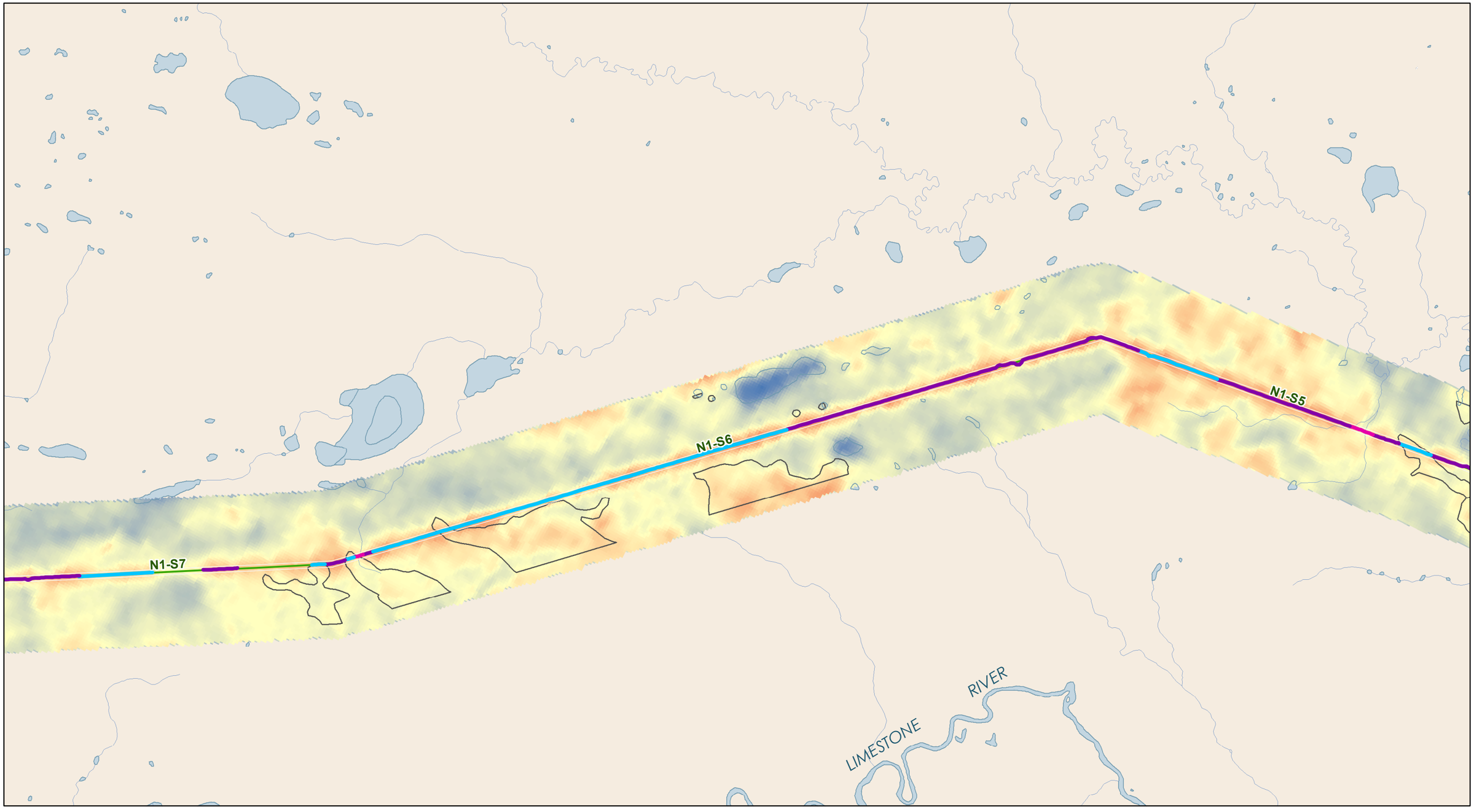
Landbase
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-6

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

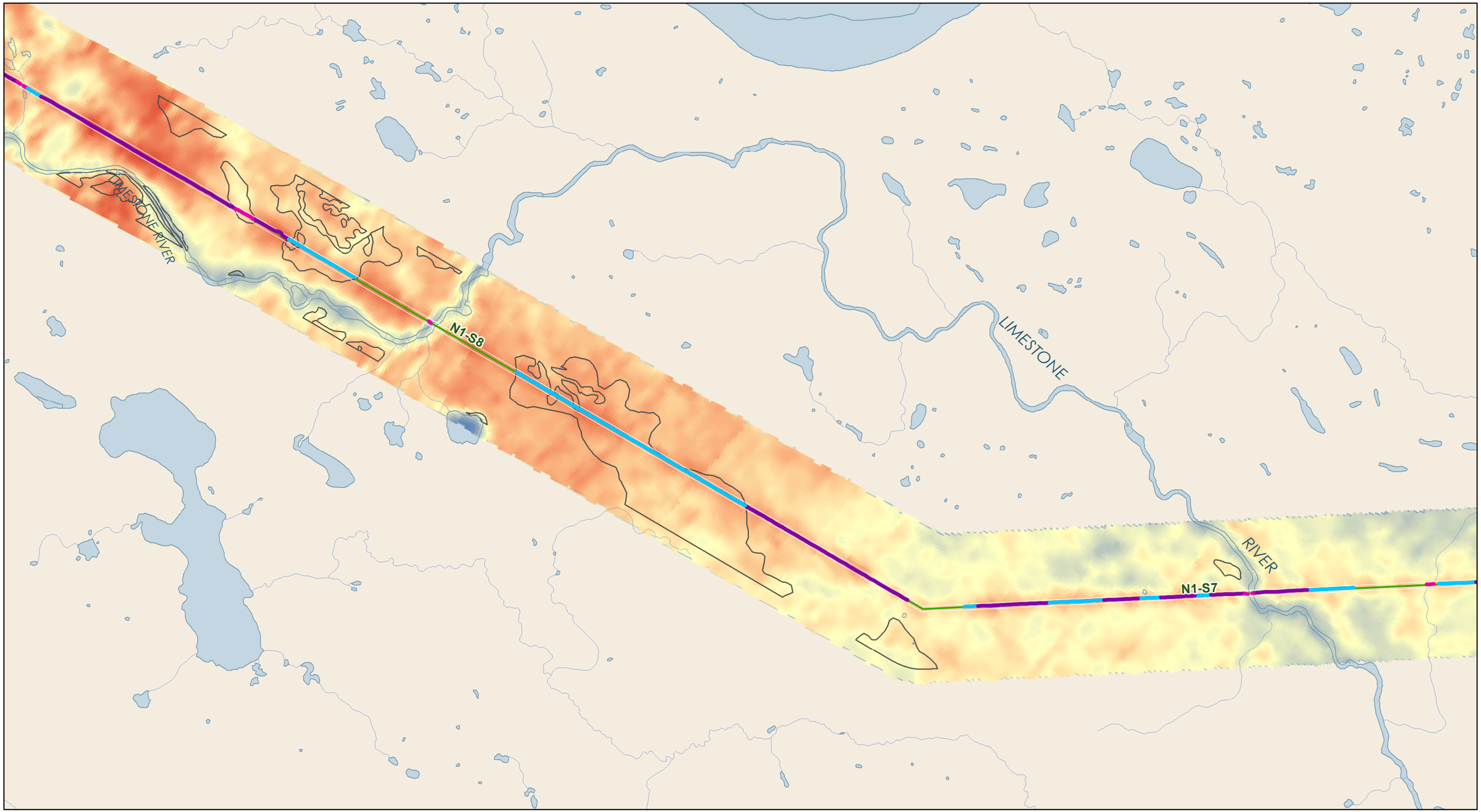
Landbase
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-7

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

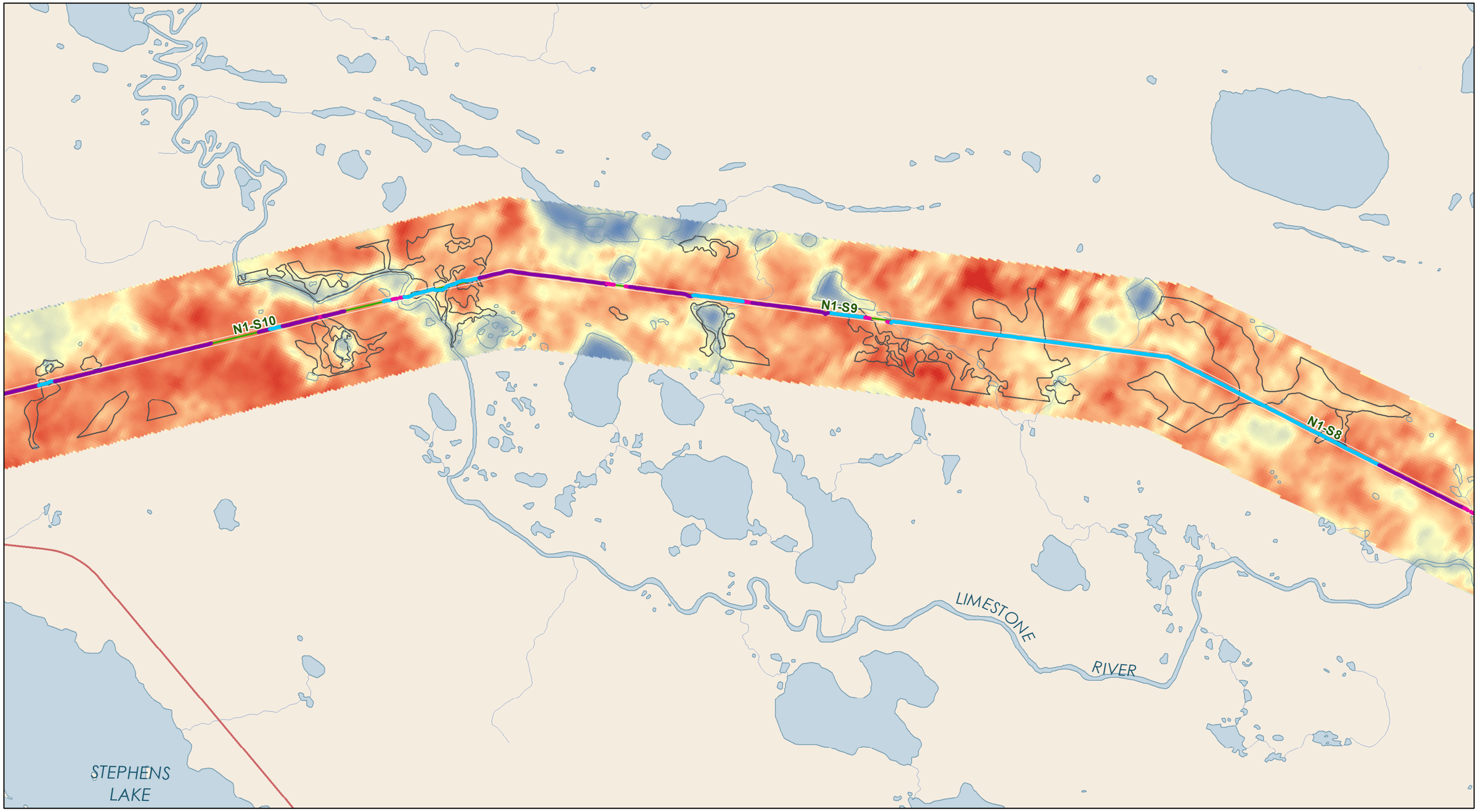
Landbase
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-8

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\1114200045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

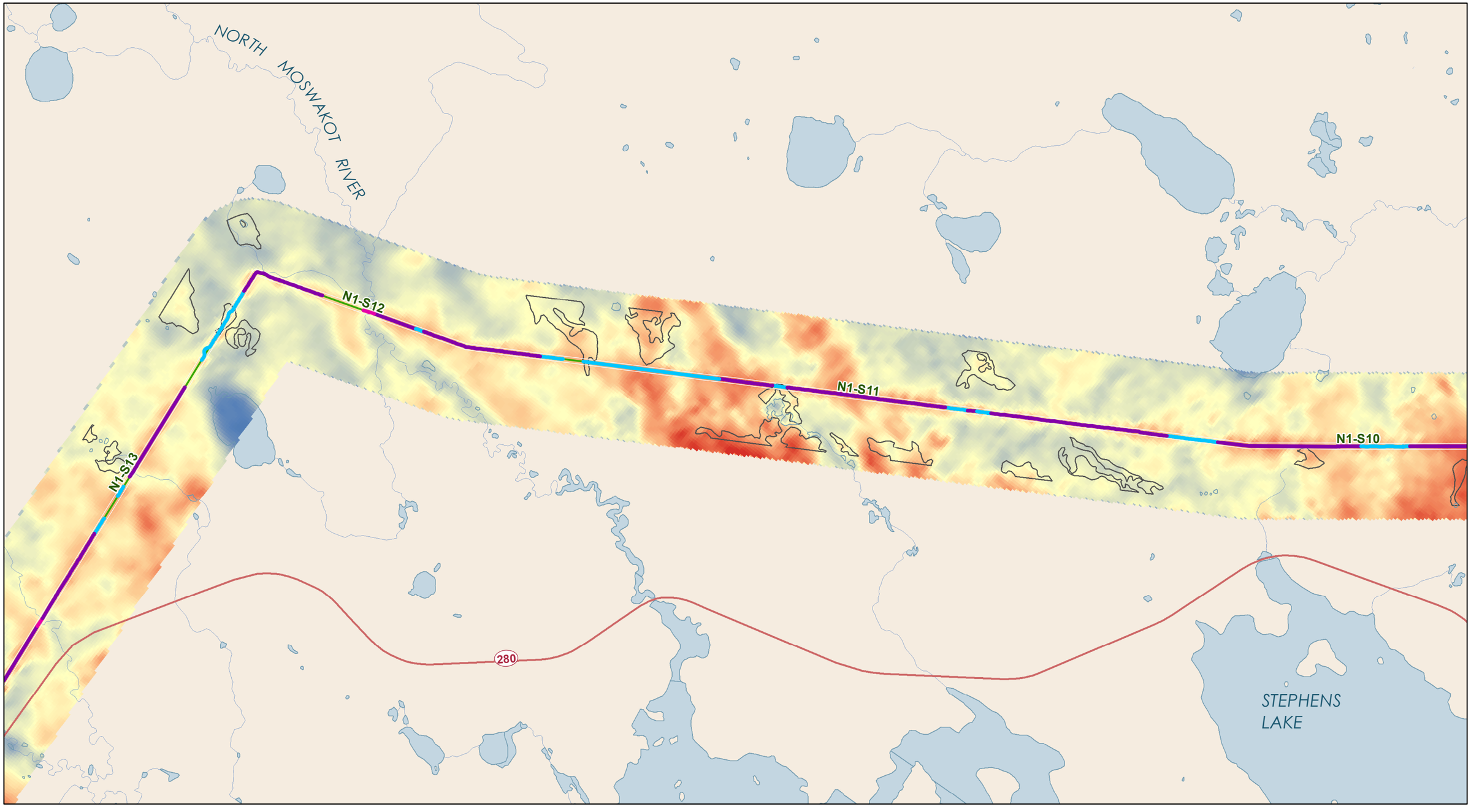
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-9



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

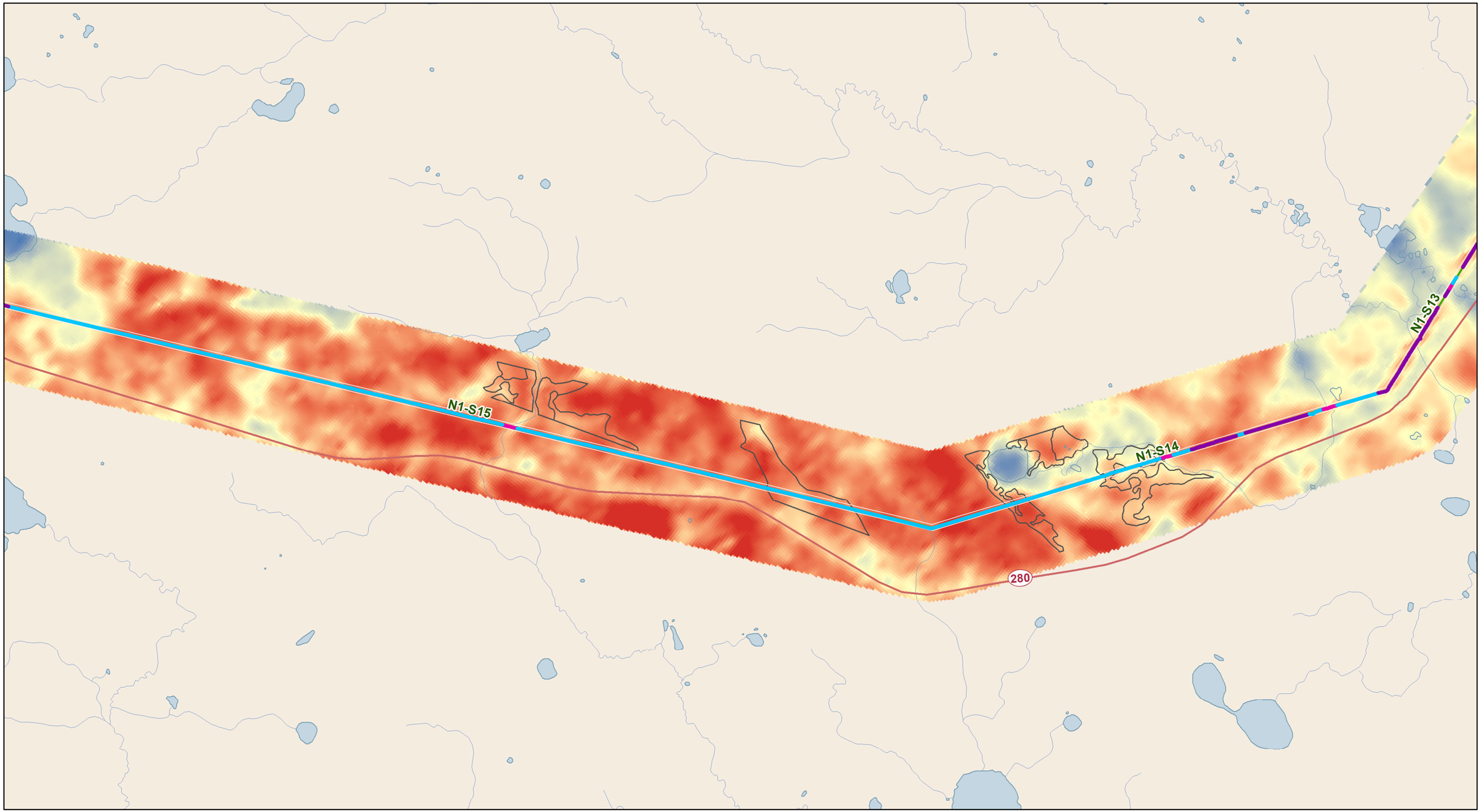
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-10

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

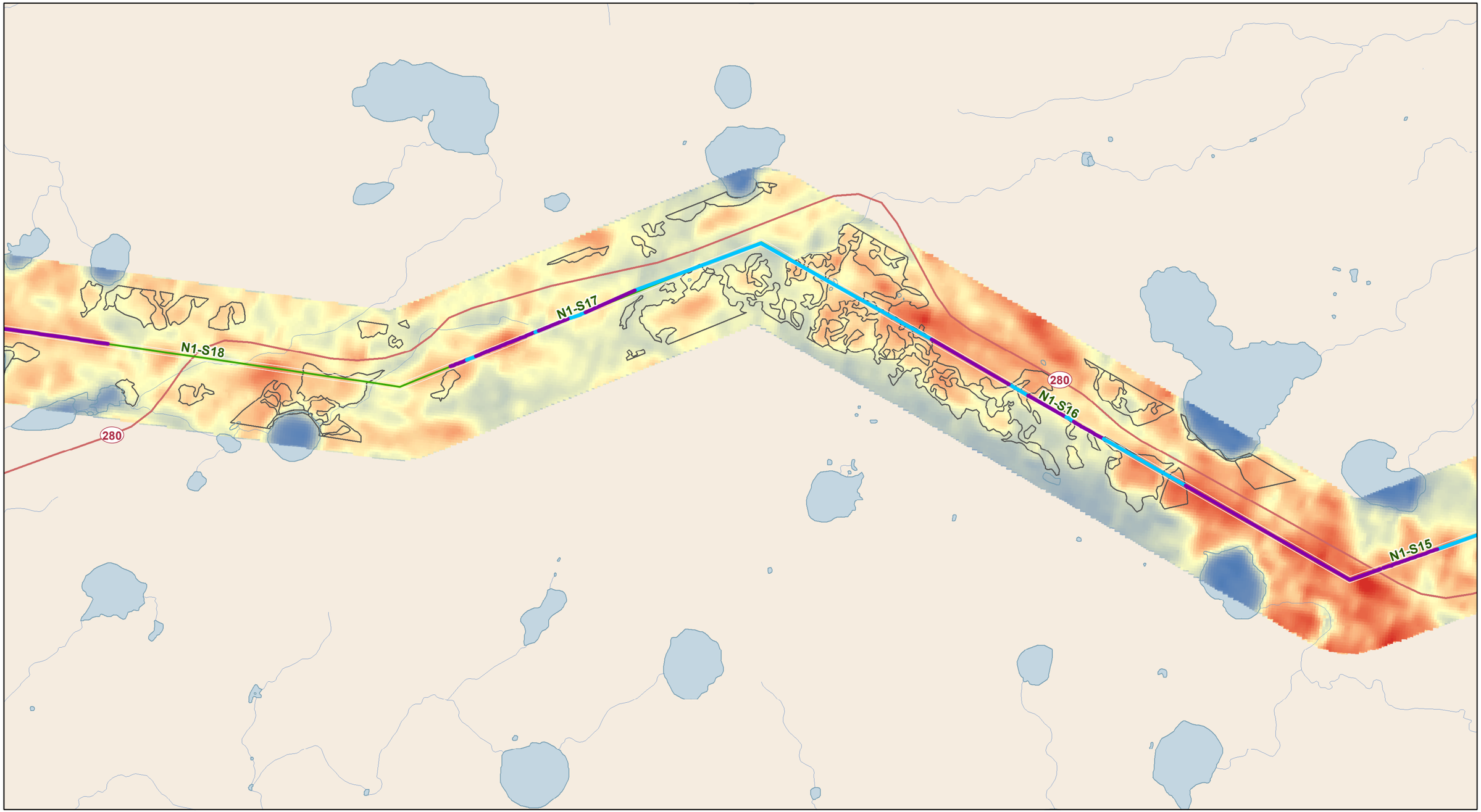
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-11

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

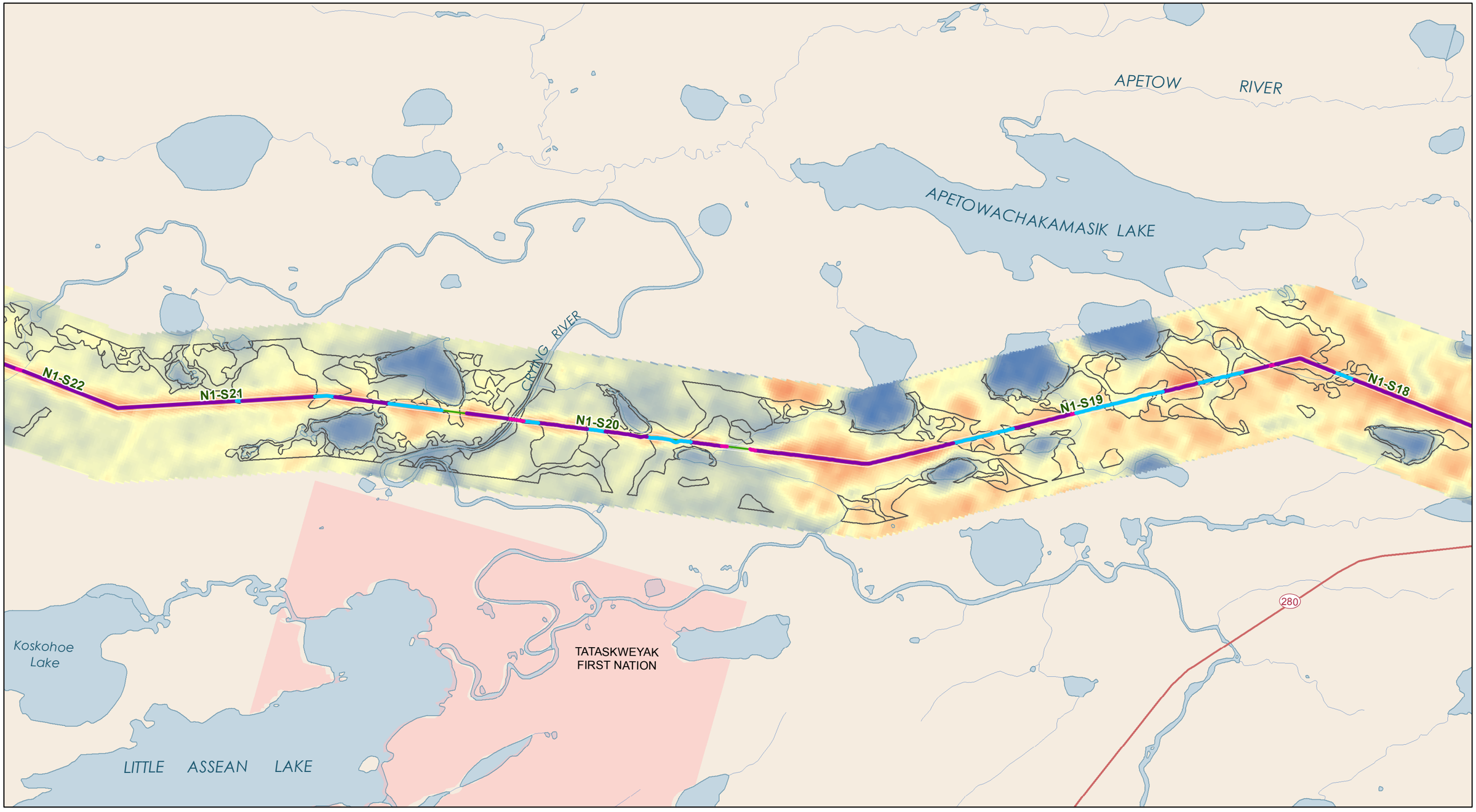
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-12

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

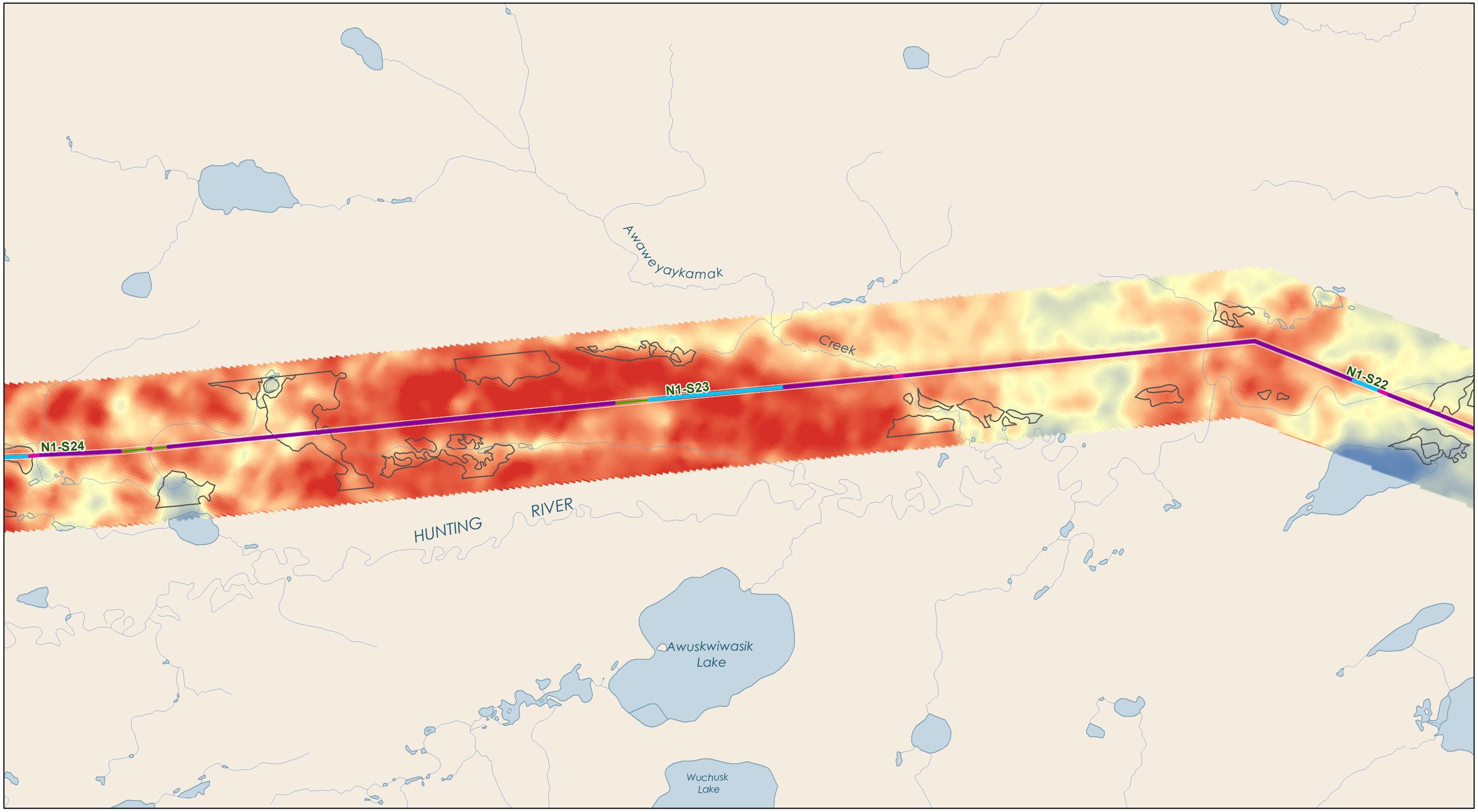
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- First Nation
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-13



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

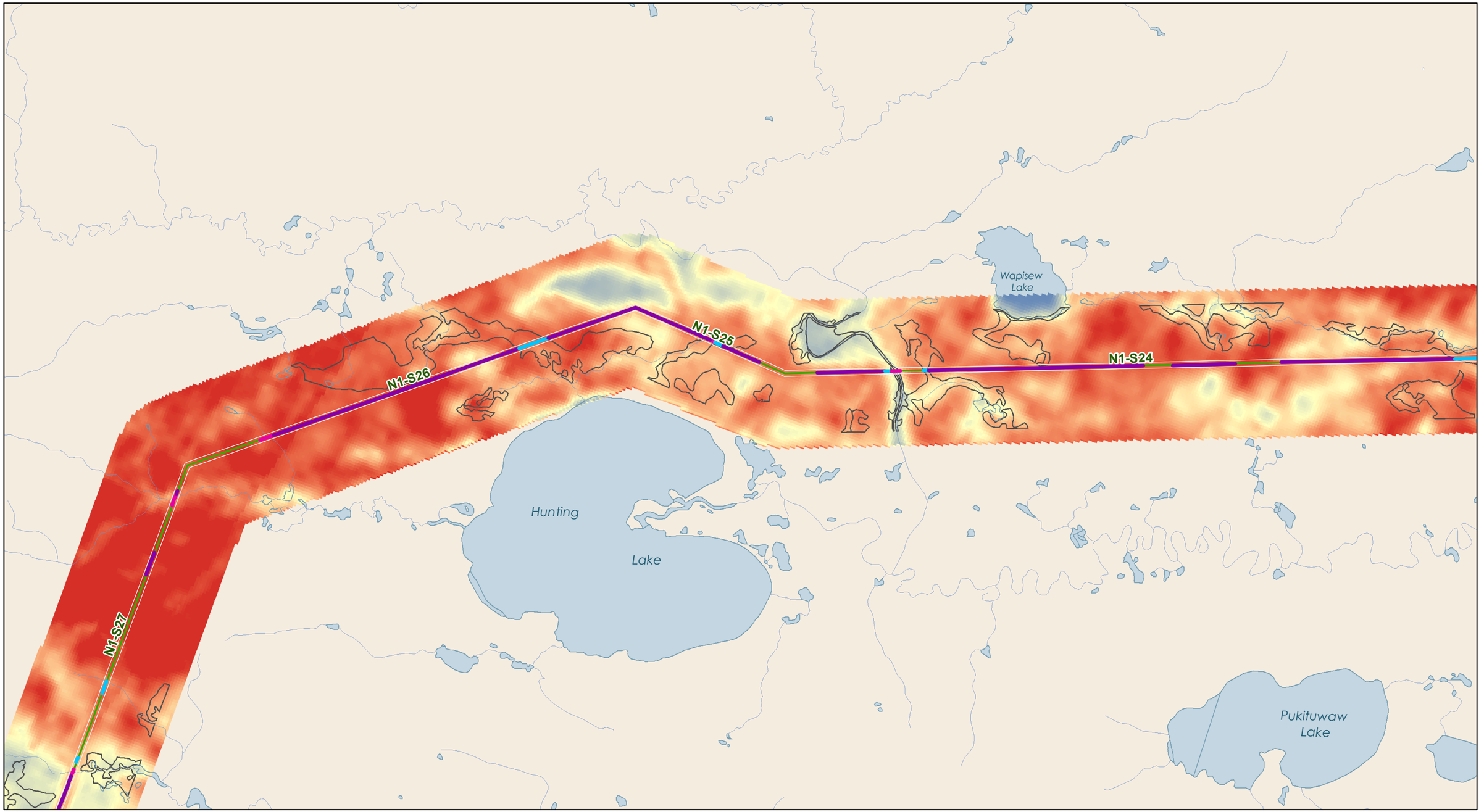
Landbase
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-14

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

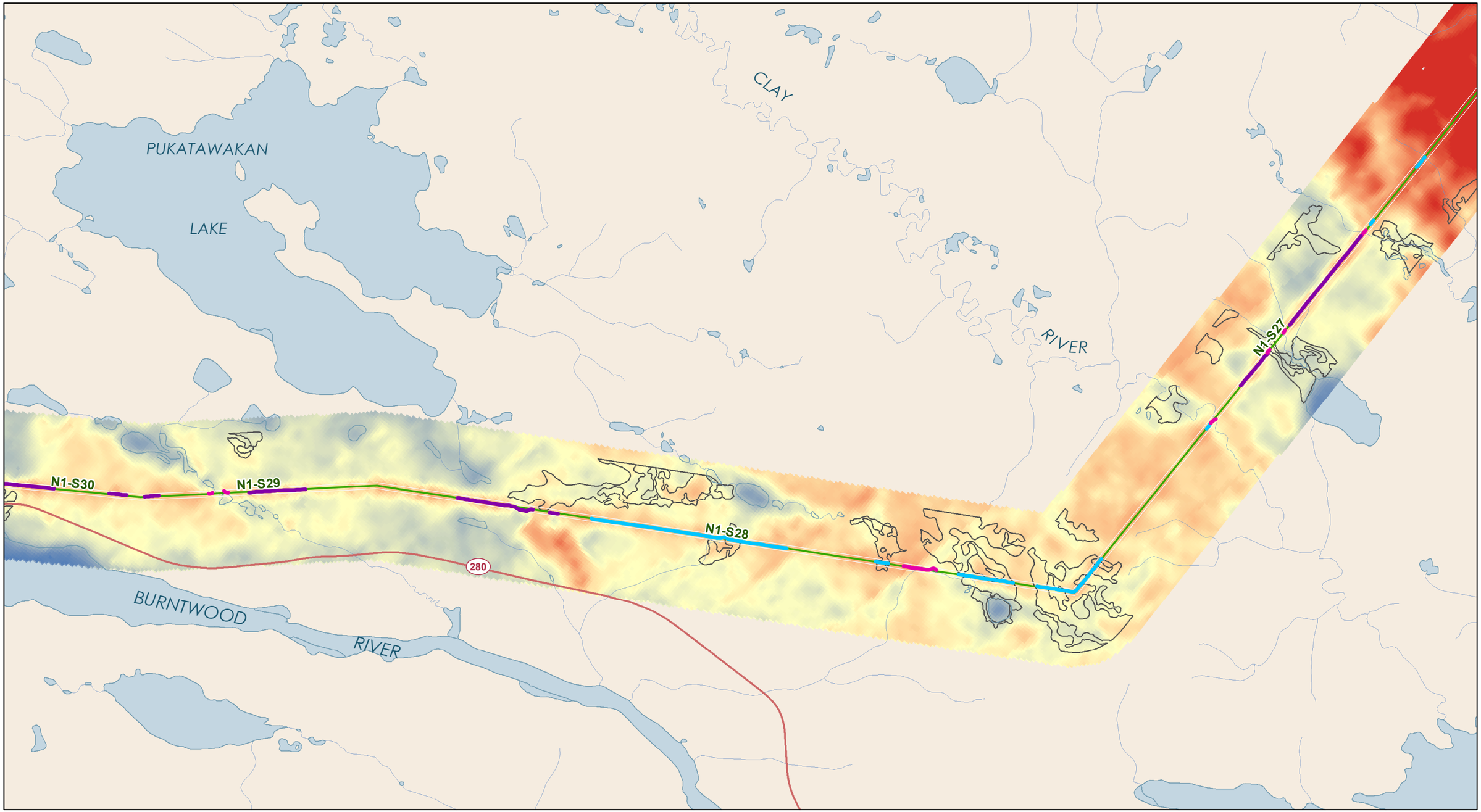
Landbase
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-15

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

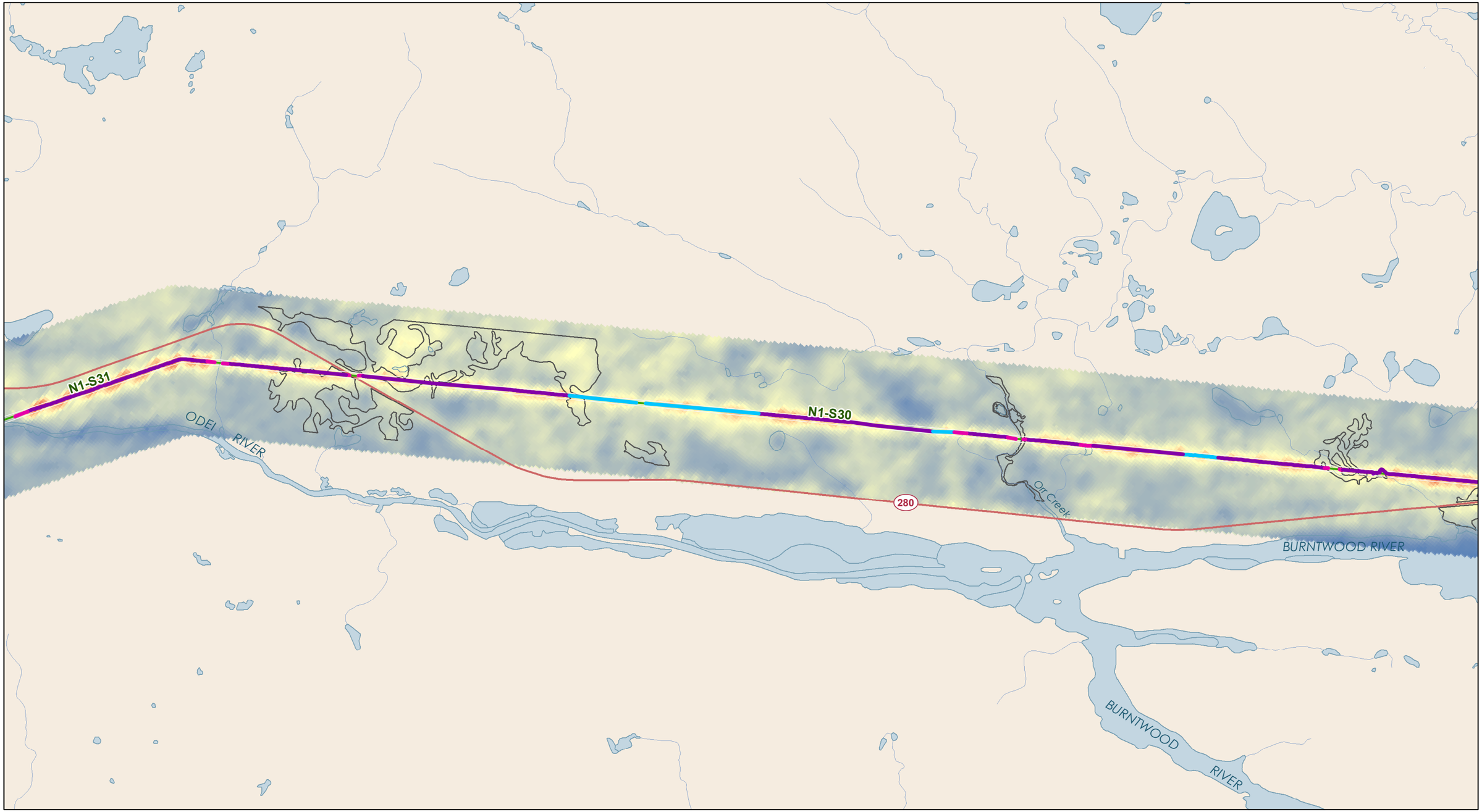
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-16

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
High : 46
Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

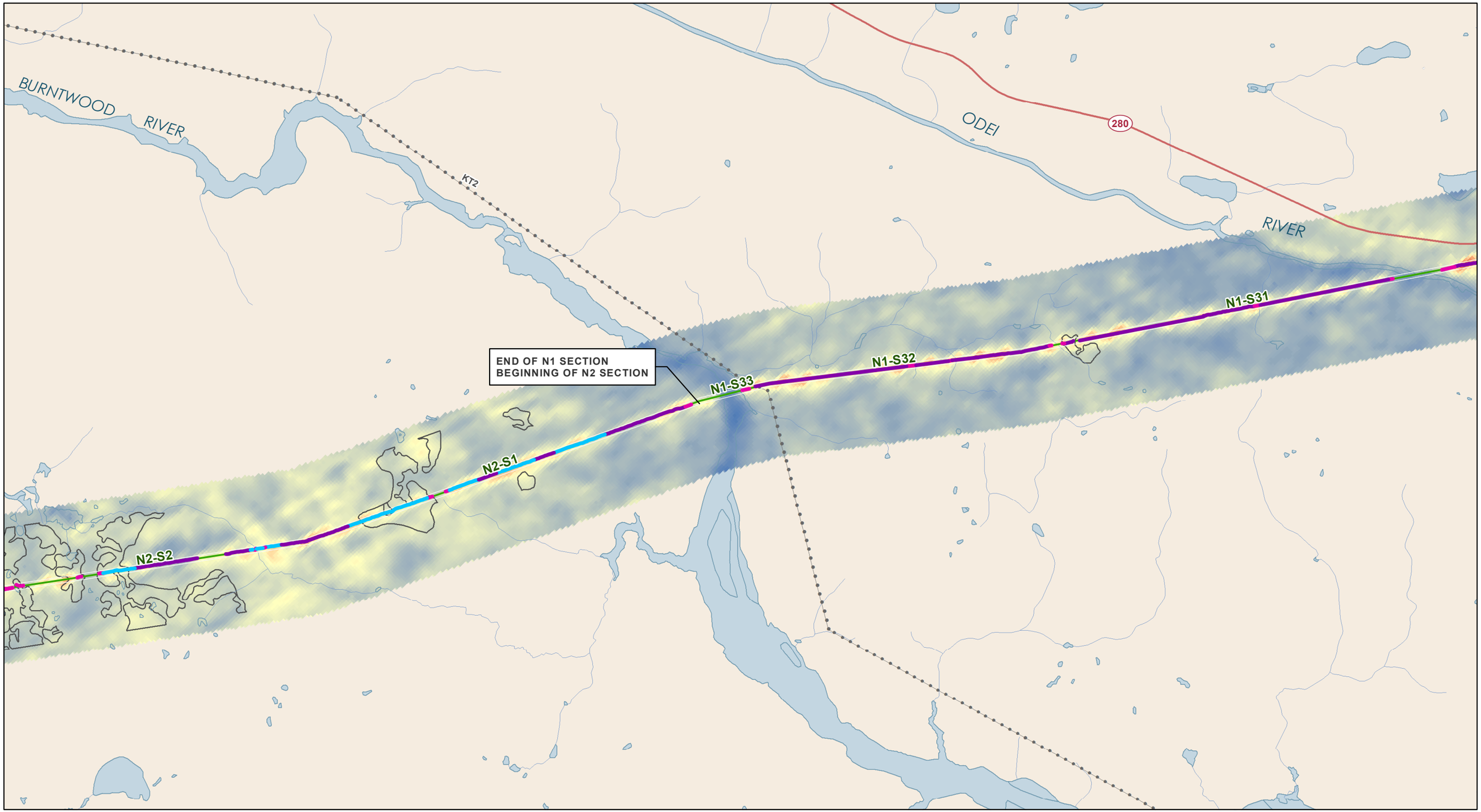
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-17

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
High : 46
Low : 0

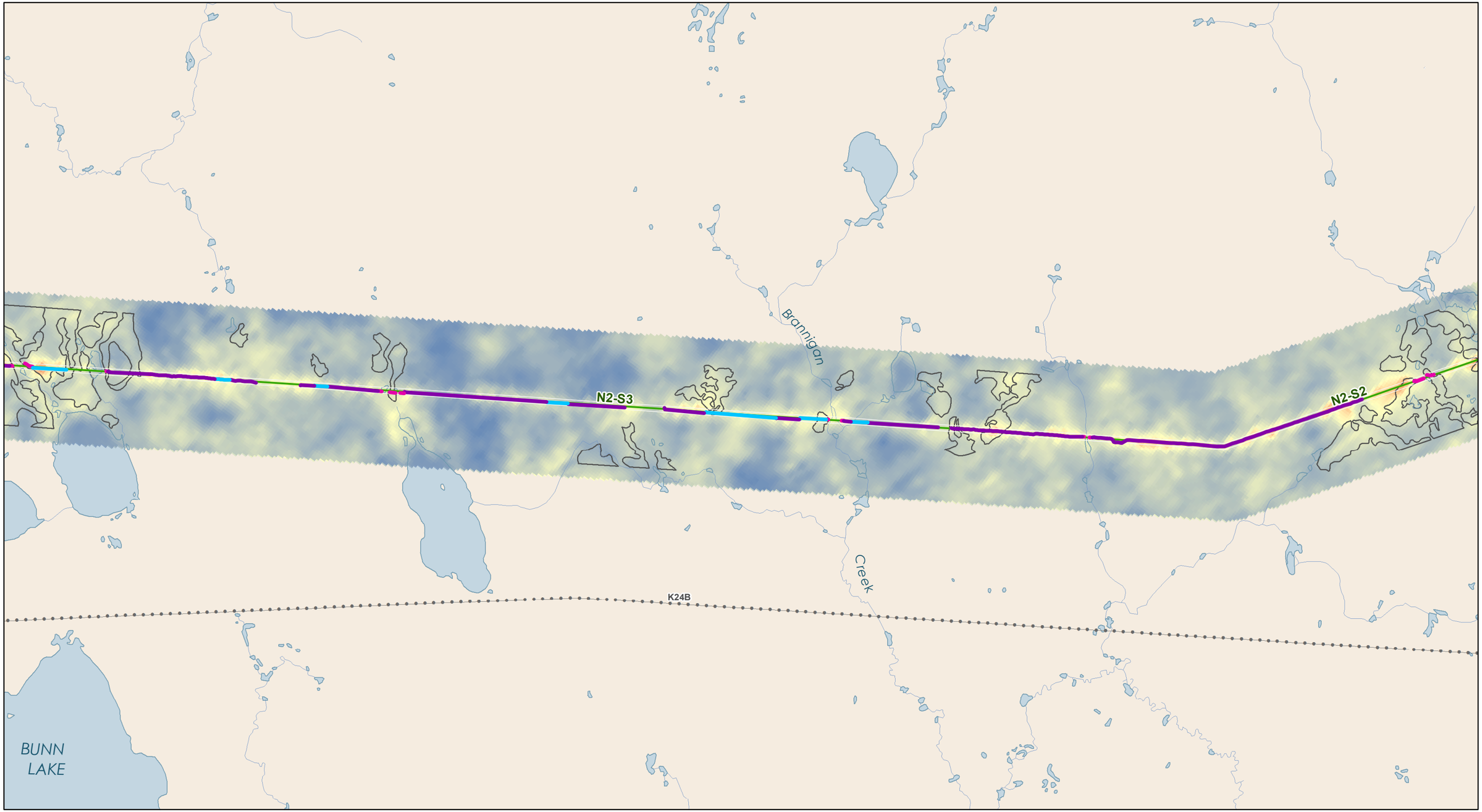
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-18



Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

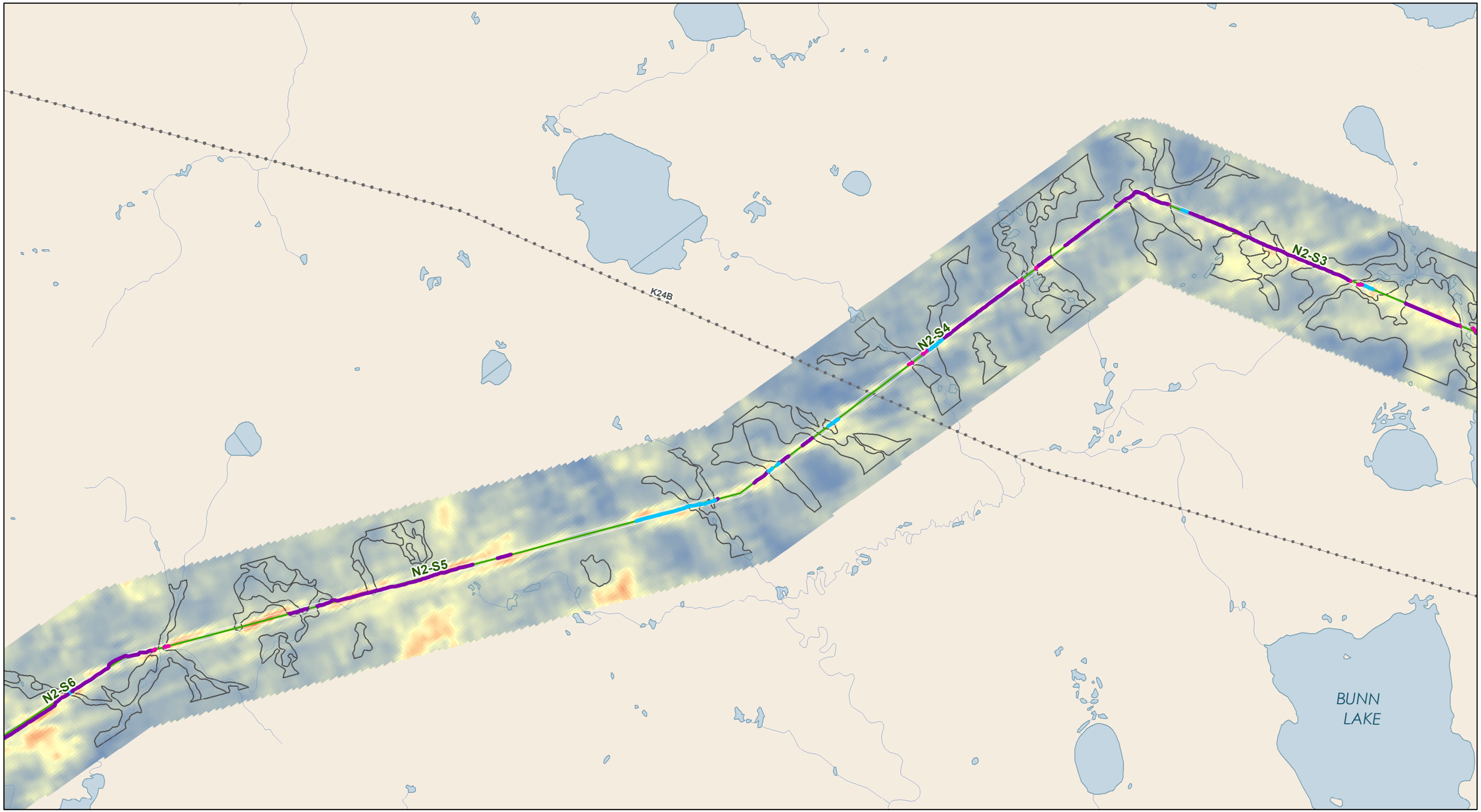
Landbase
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-19

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

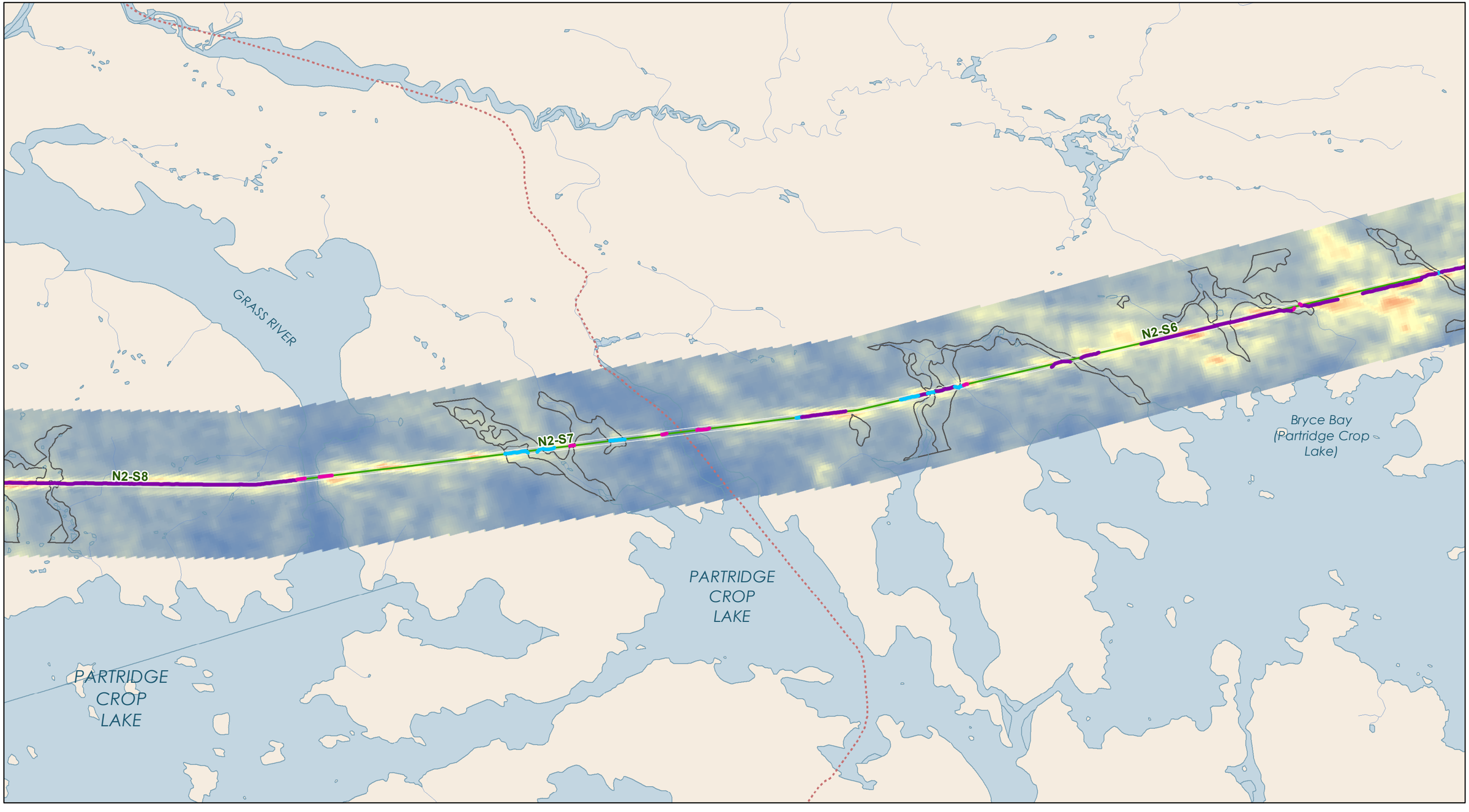
Landbase
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-20

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

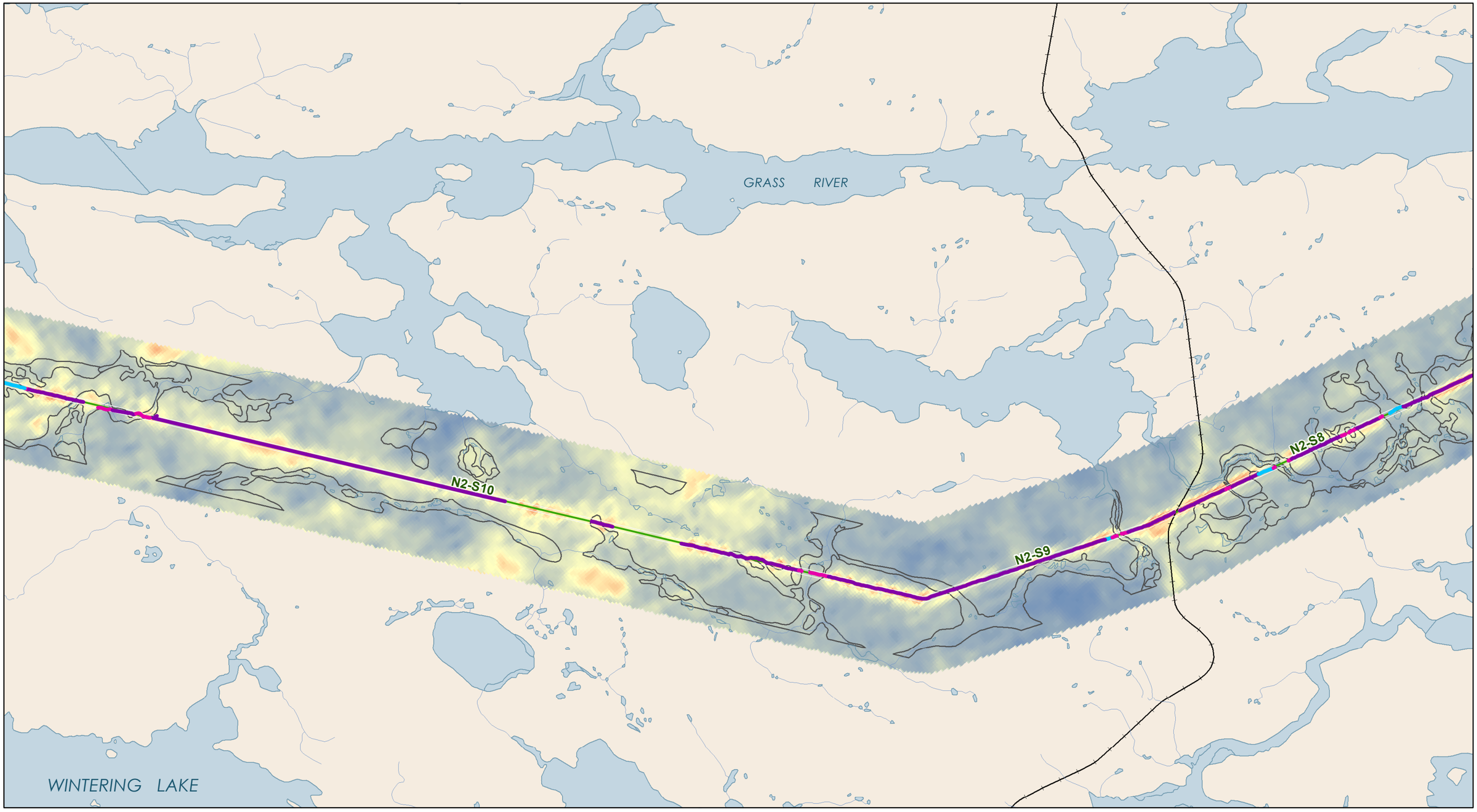
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Winter Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-21



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-22

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

PAINT LAKE
PROVINCIAL PARK

Teardrop
Lake

N2-S12

N2-S11

WINTERING
LAKE

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

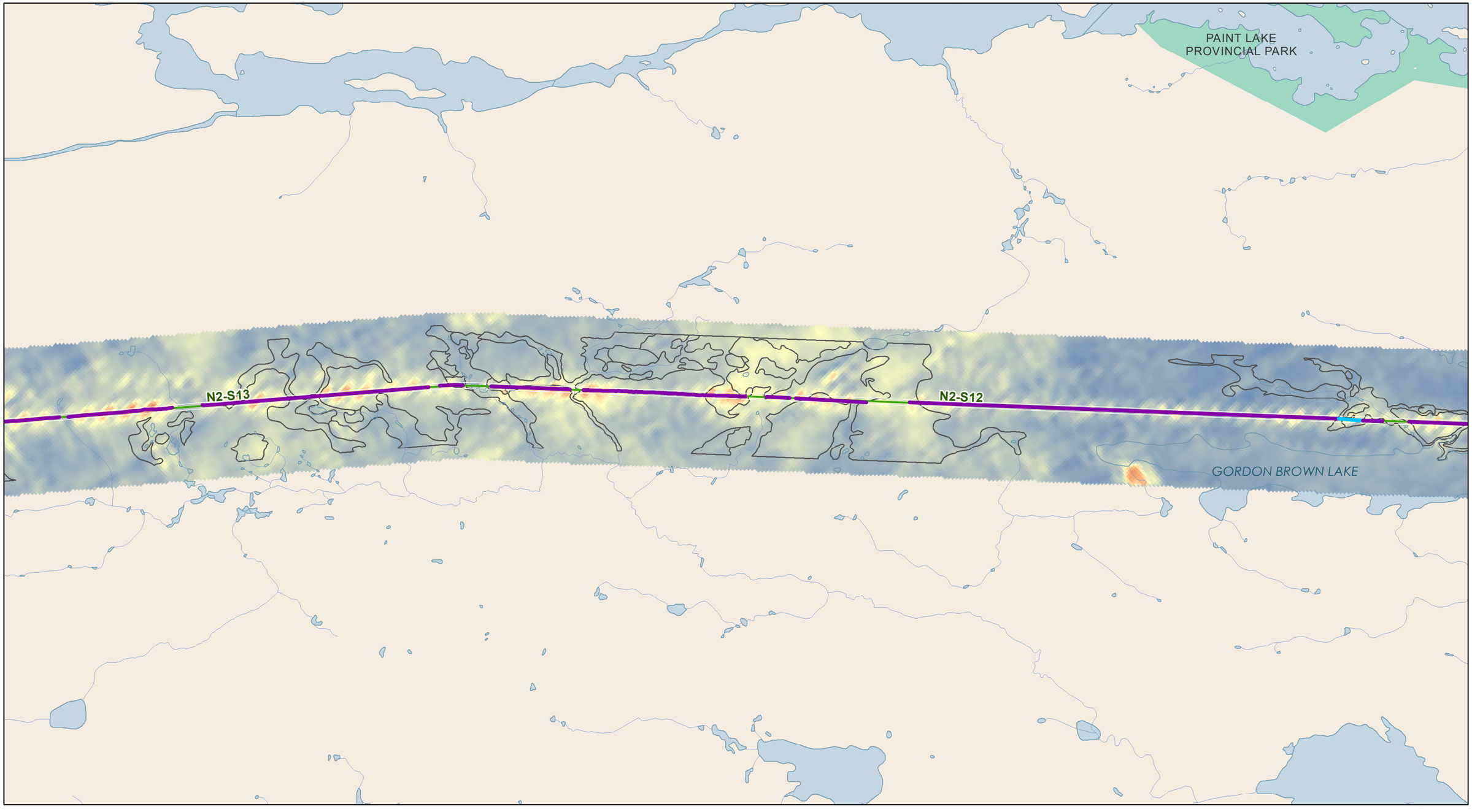
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Winter Road
- Provincial Park
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-23



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

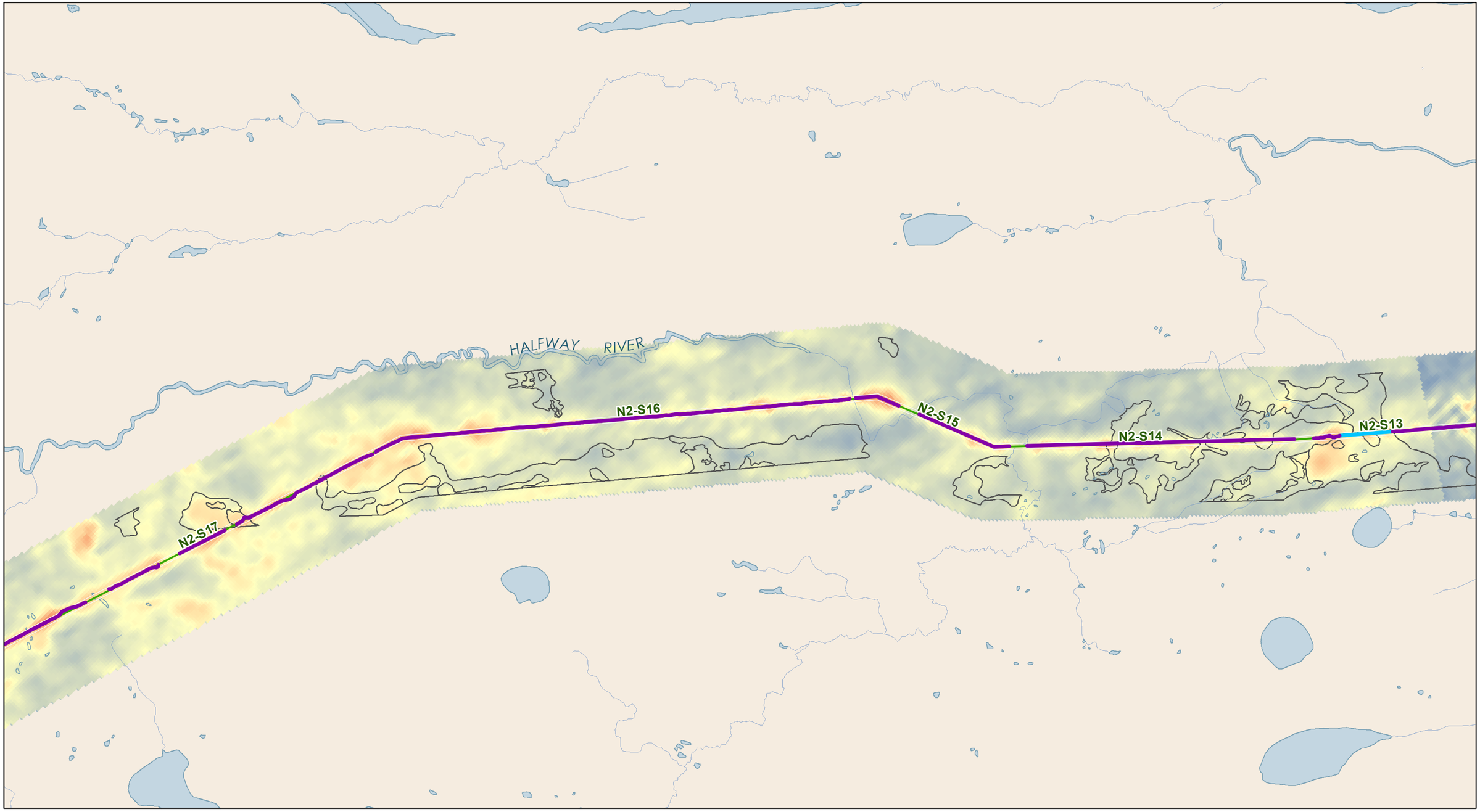
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Park
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-24



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

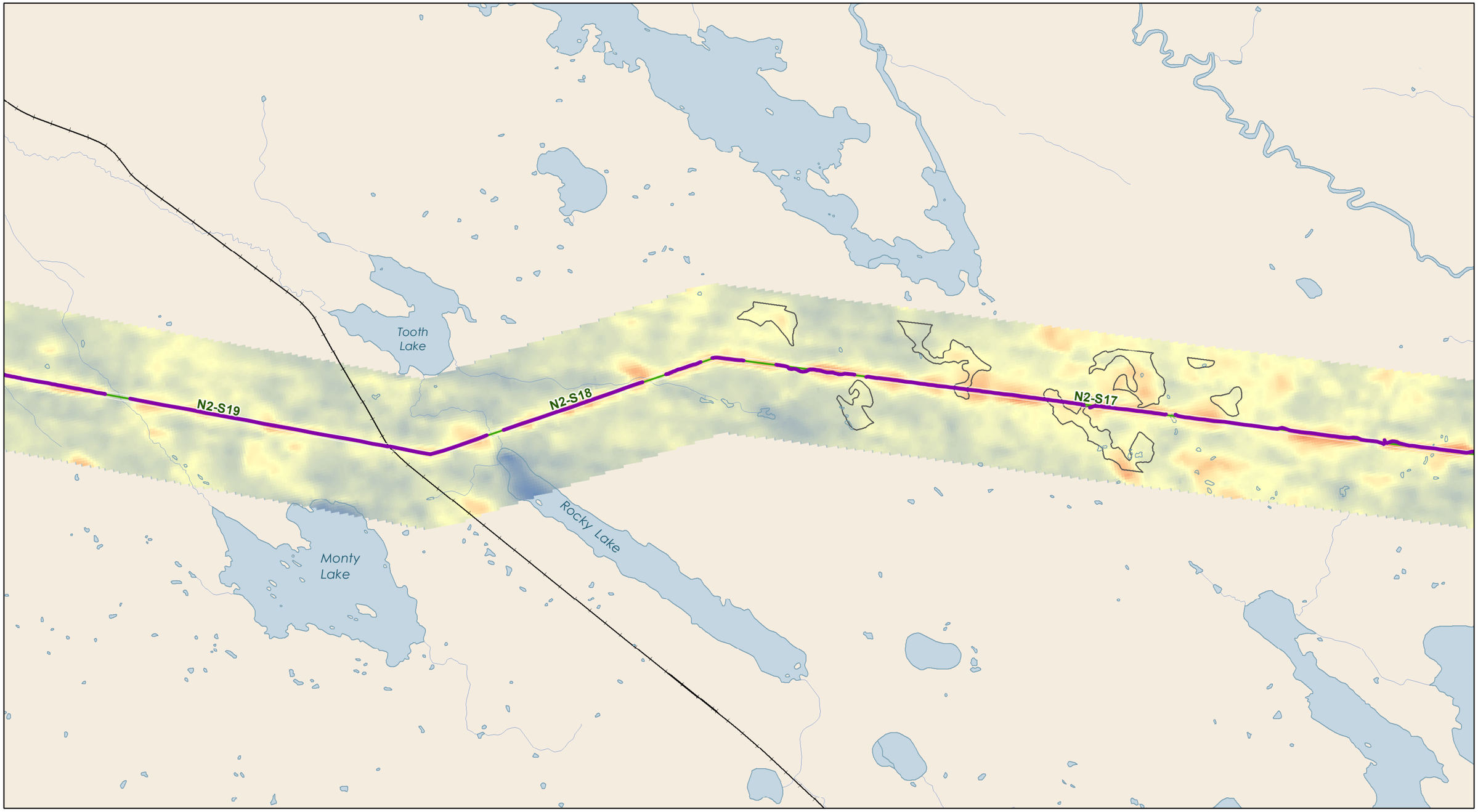
Landbase
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-25

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

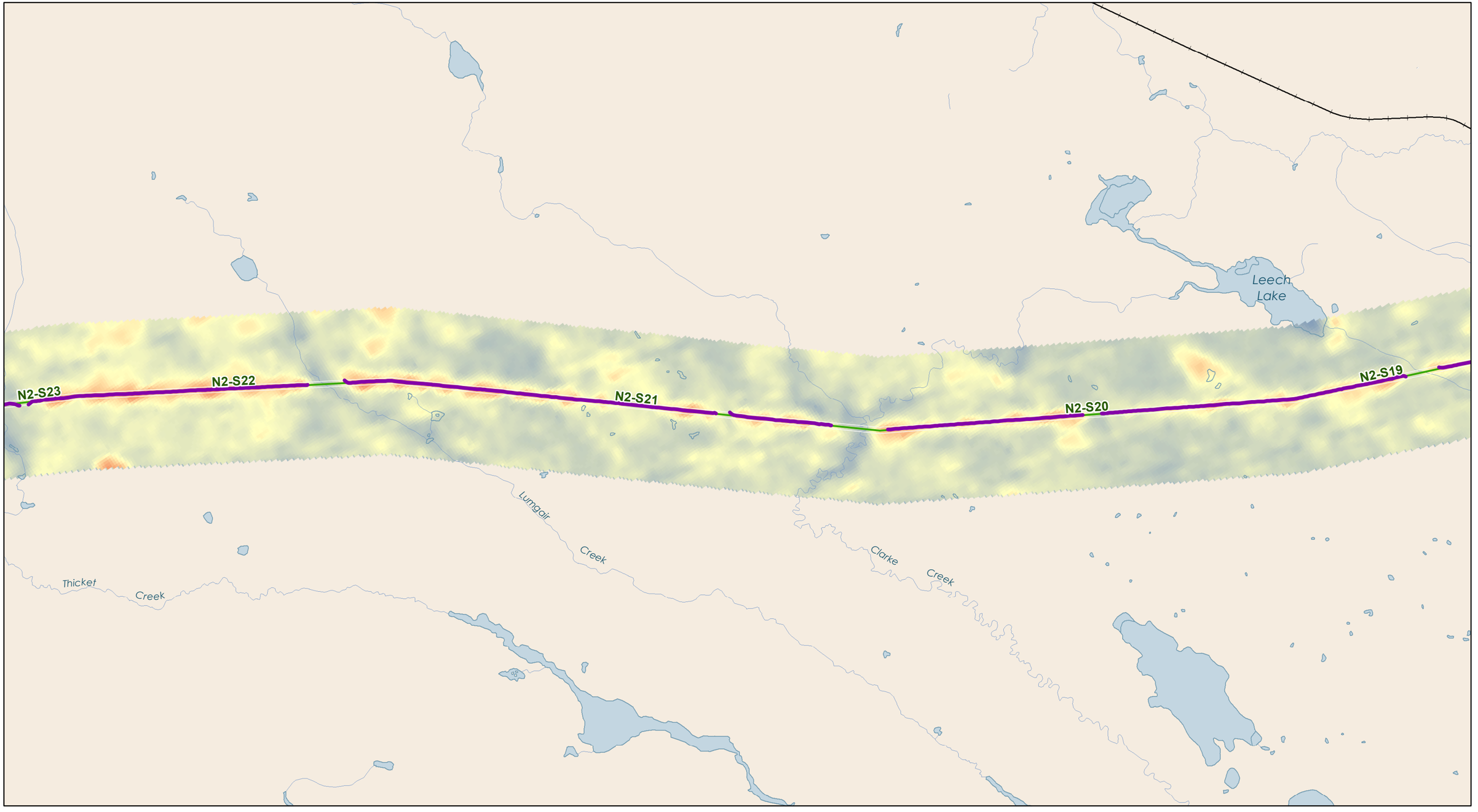
Landbase
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-26

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

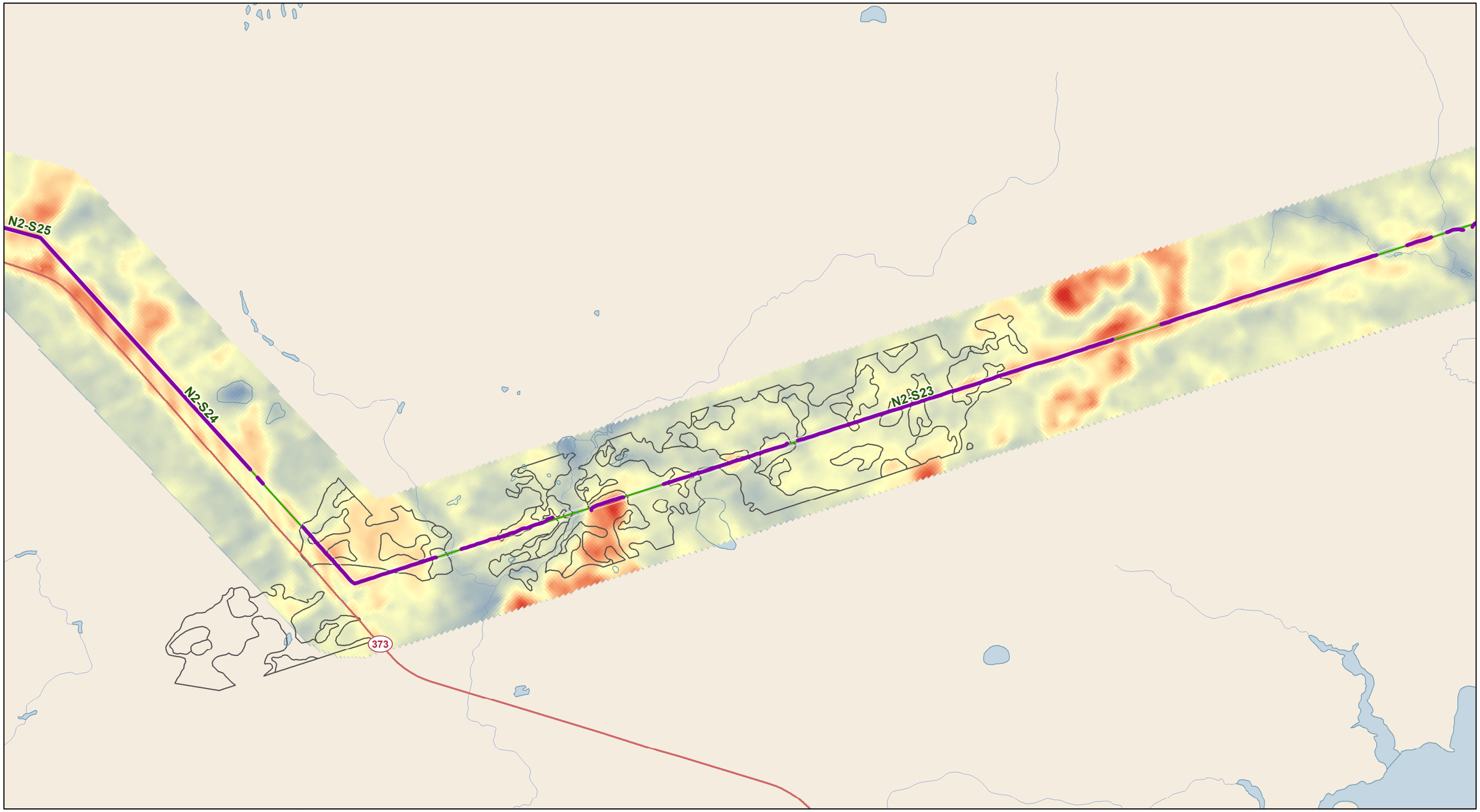
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-27



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

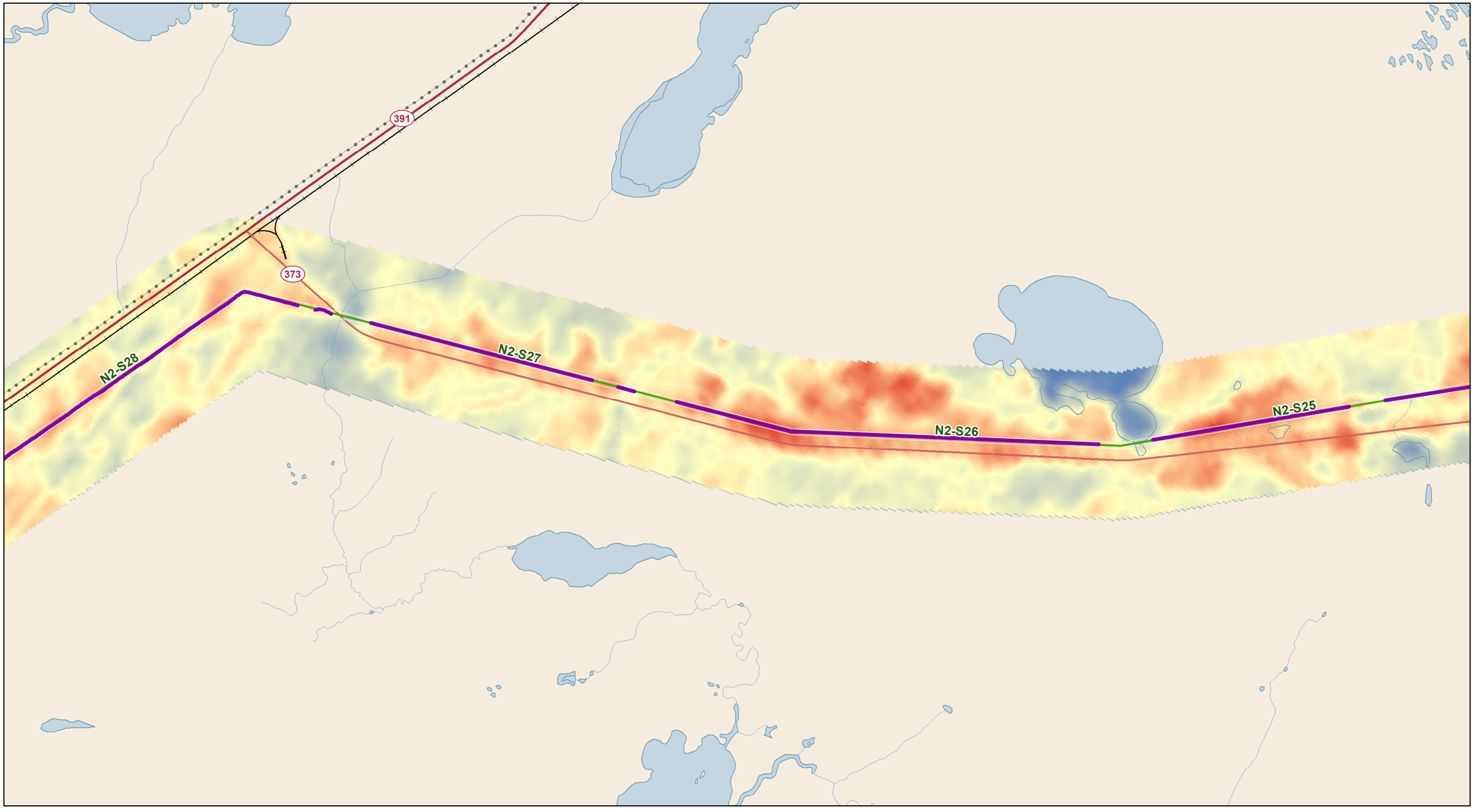
Landbase
- Provincial Road
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-28

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

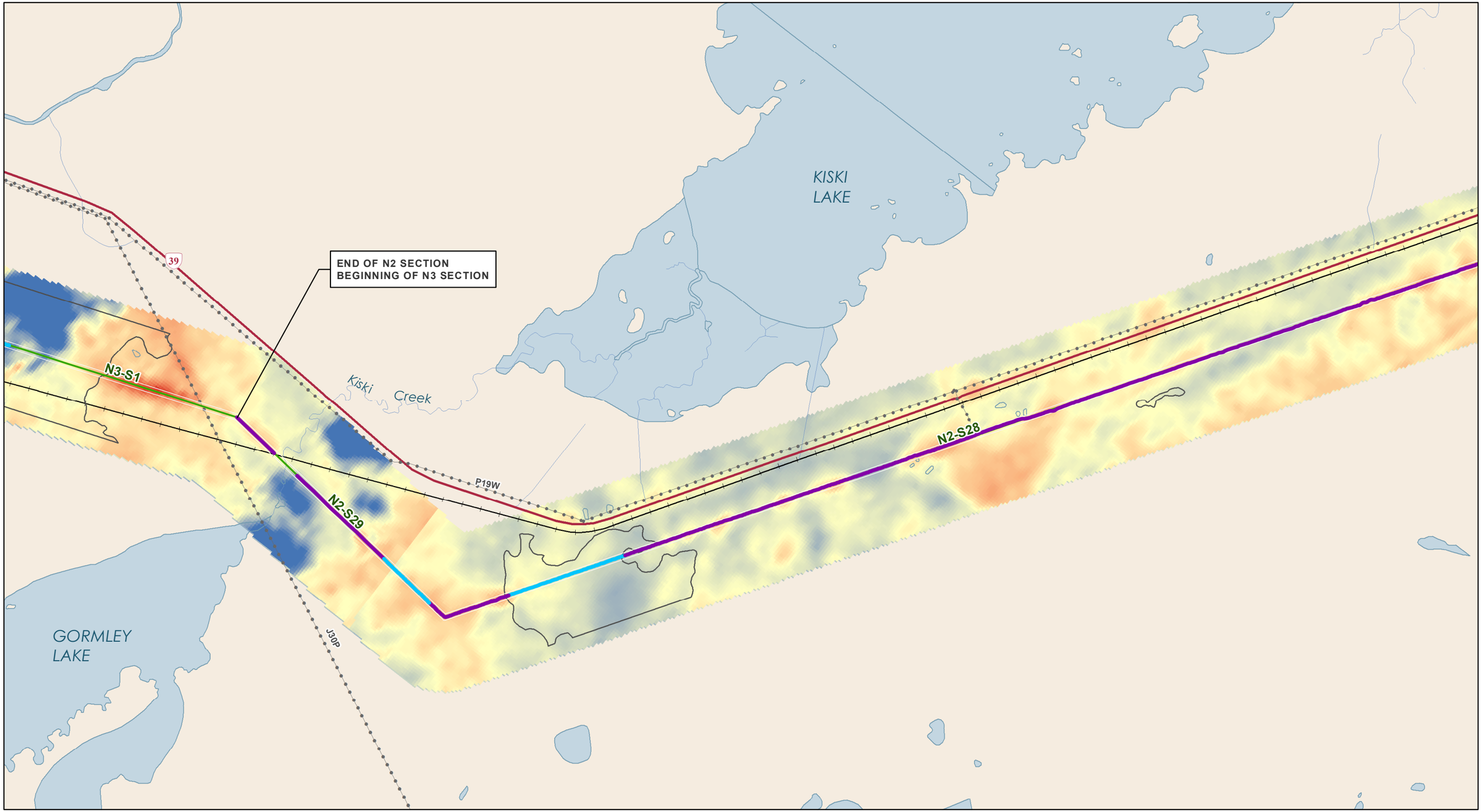
Landbase
- Provincial Highway
- Provincial Road
- Railway (Operational)
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-29

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

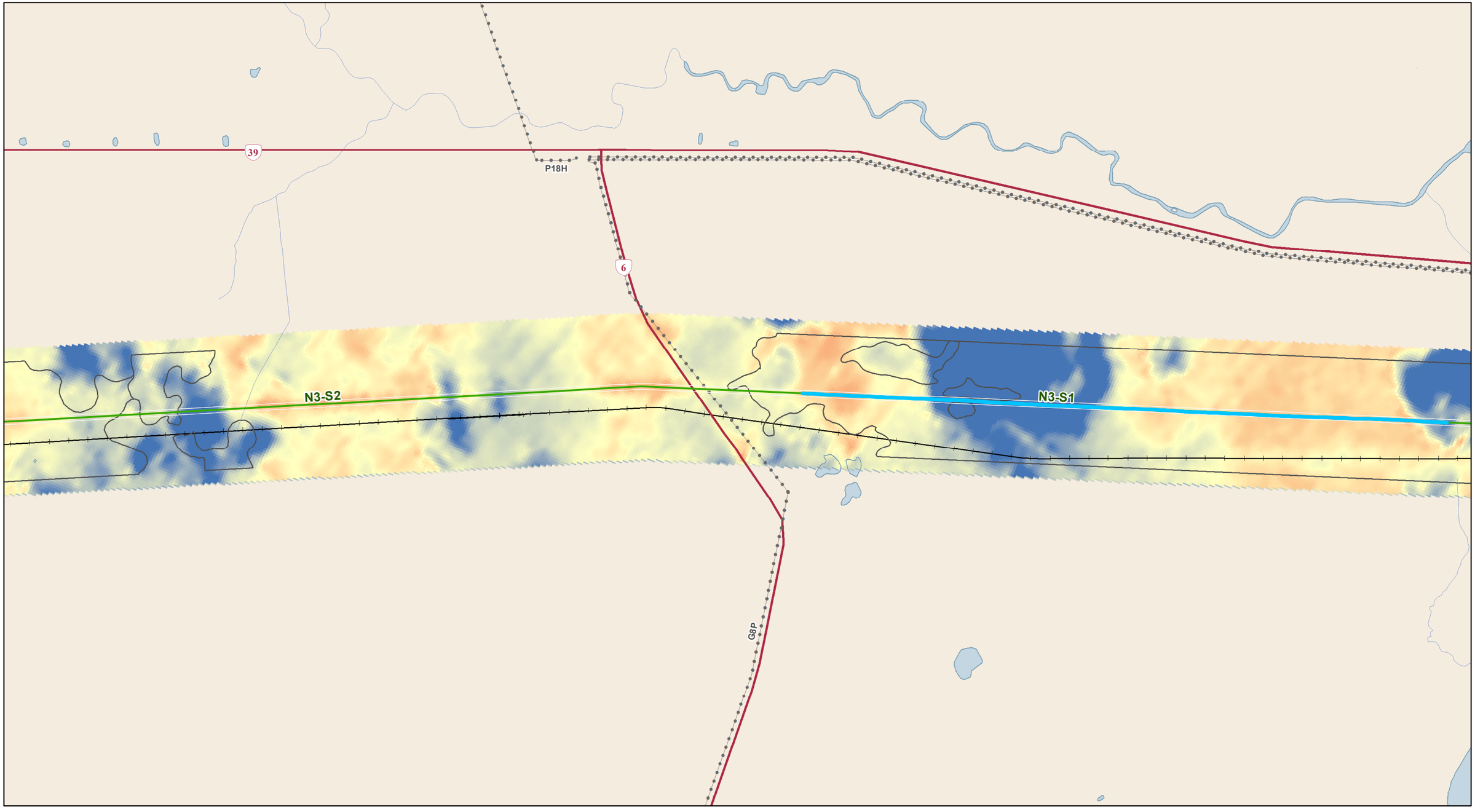
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Highway
- Railway (Operational)
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-30



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

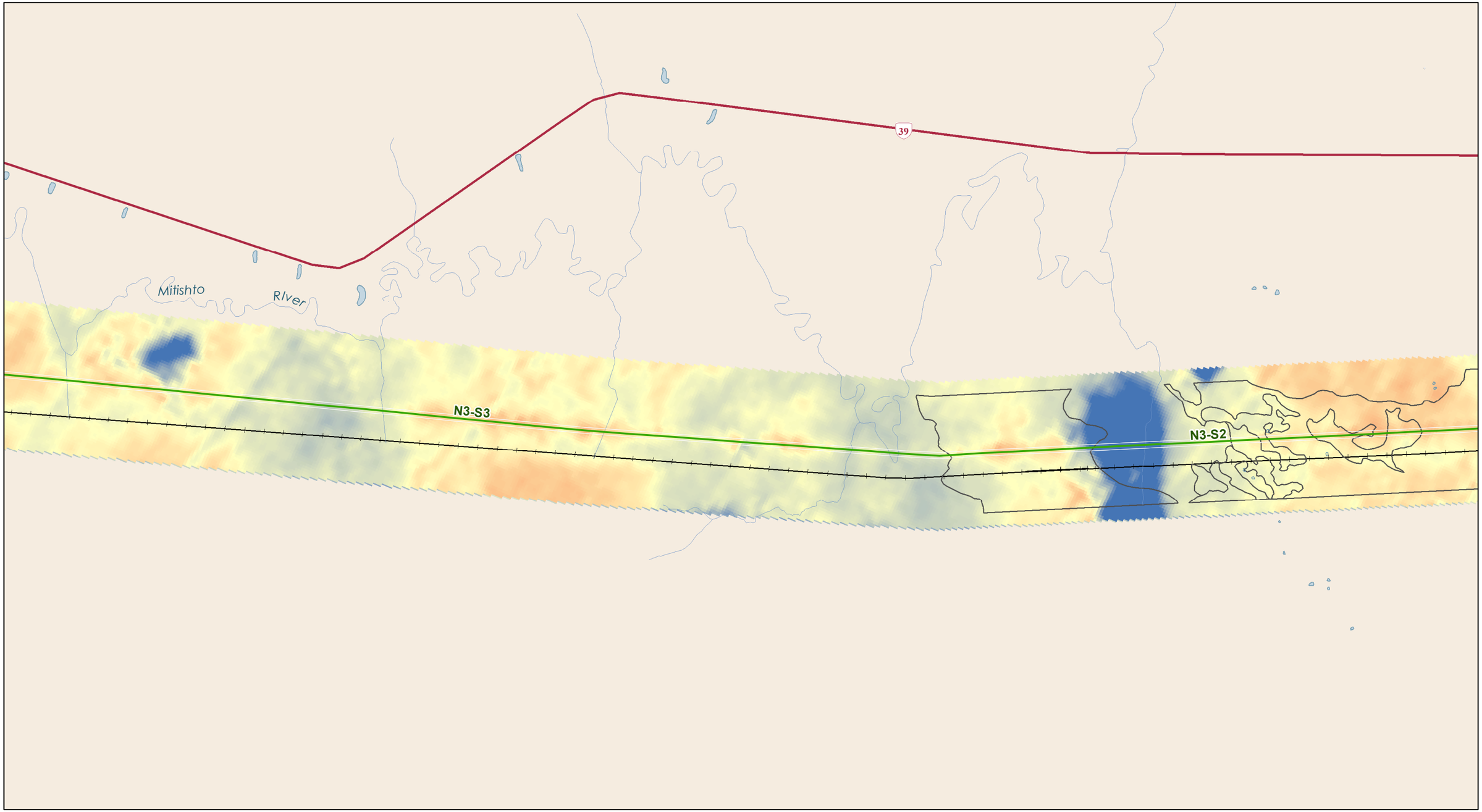
Landbase
- Provincial Highway
- Railway (Operational)
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-31

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

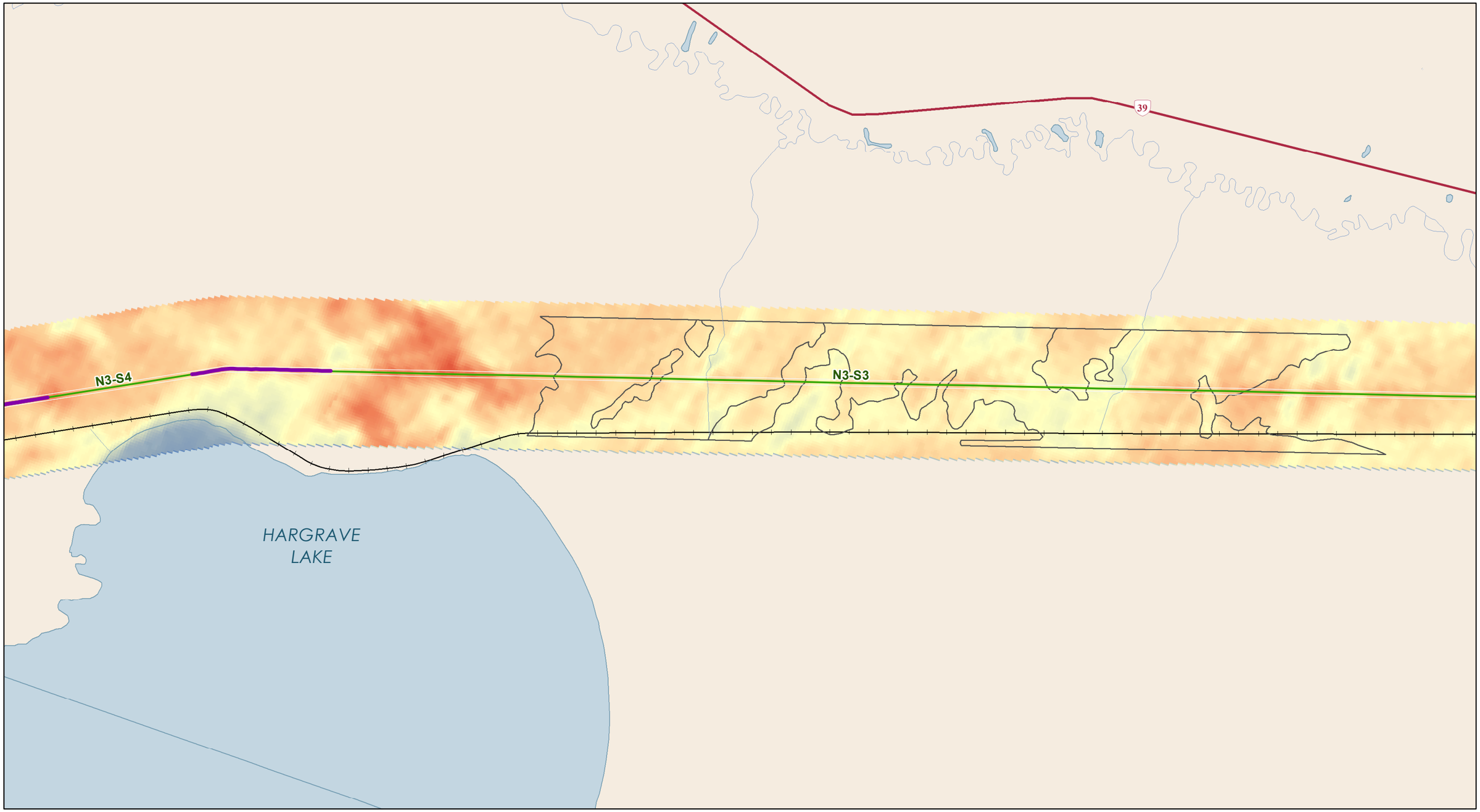
Landbase
- Provincial Highway
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-32

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

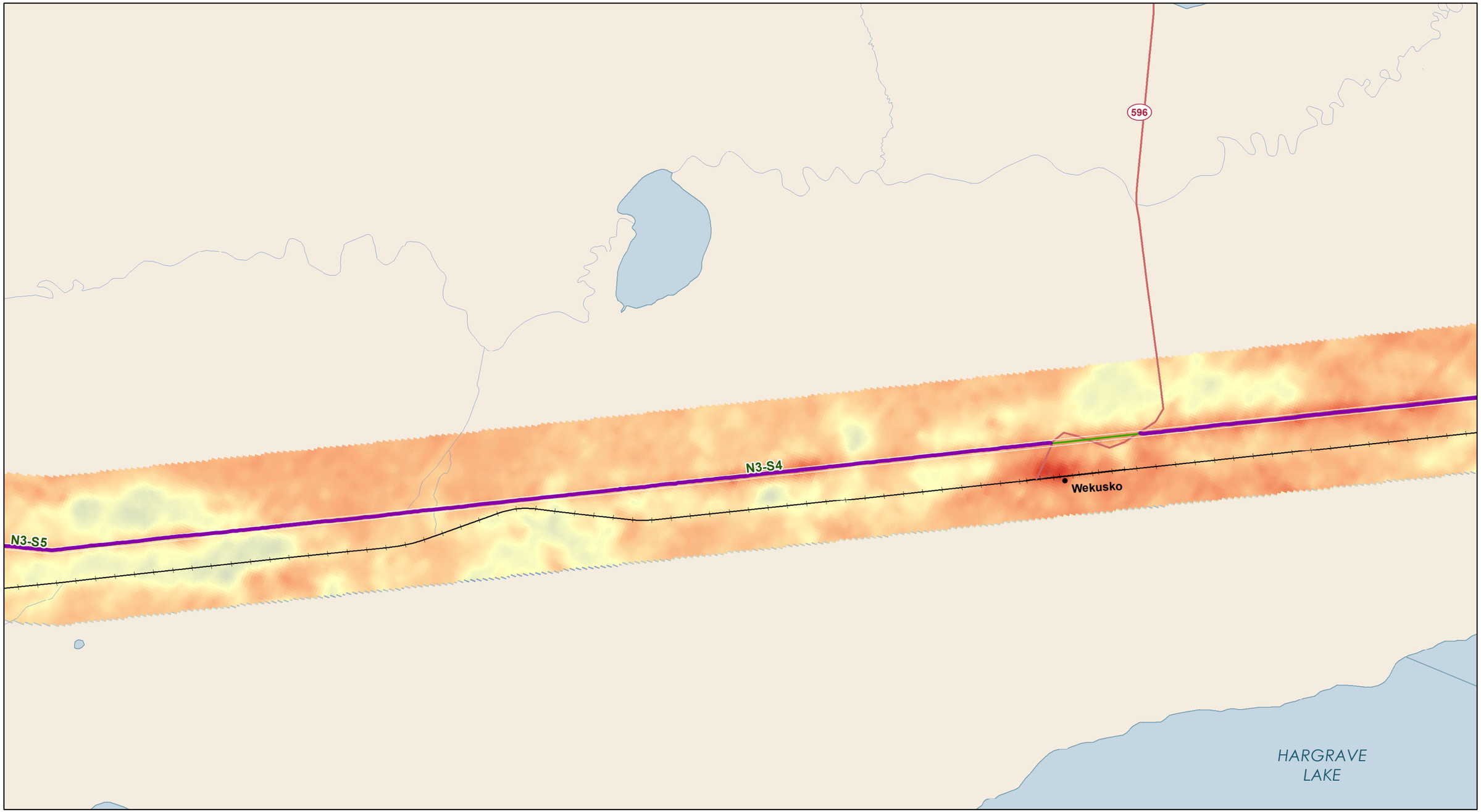
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Highway
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-33



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

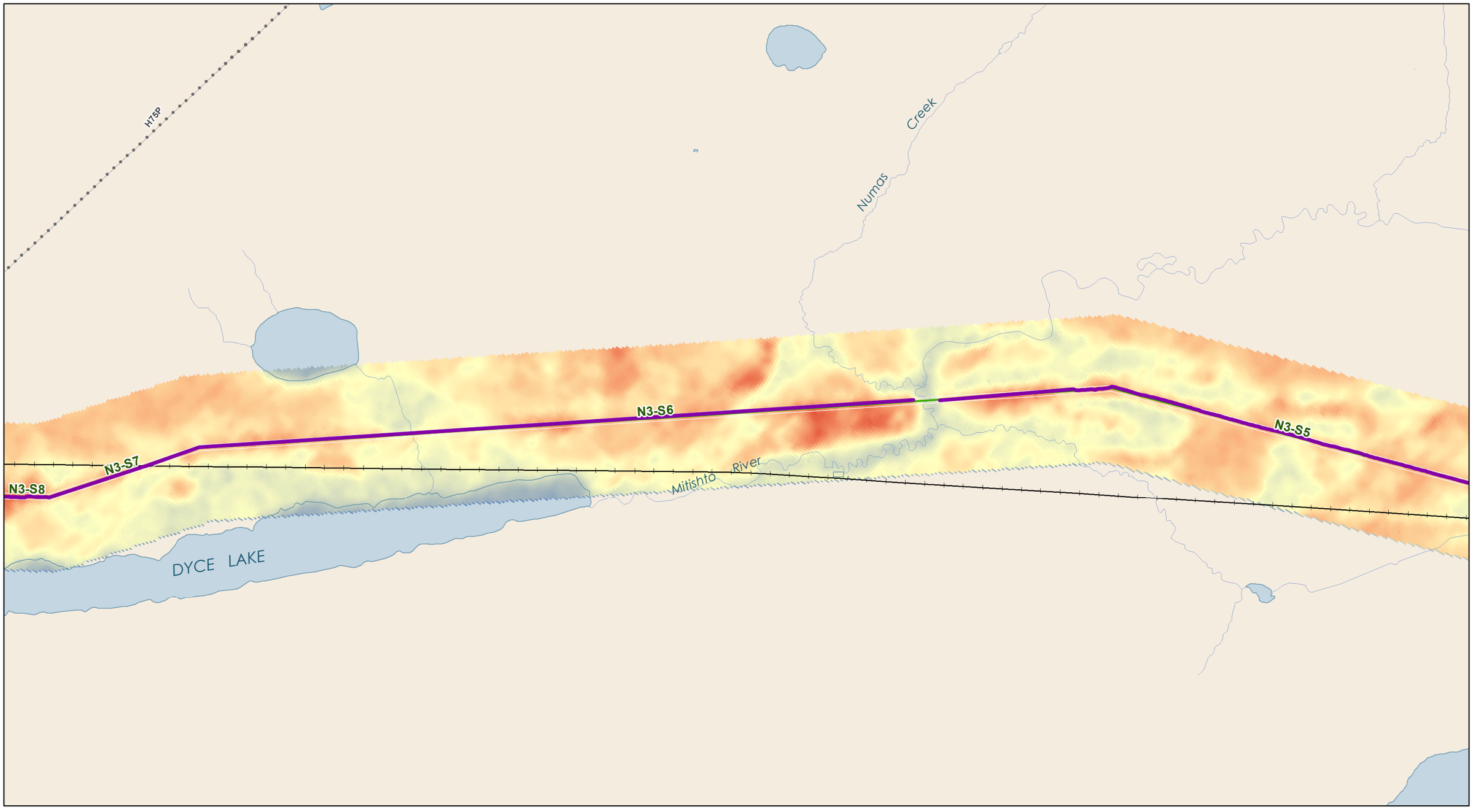
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Local Road
- Railway (Operational)
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-34



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

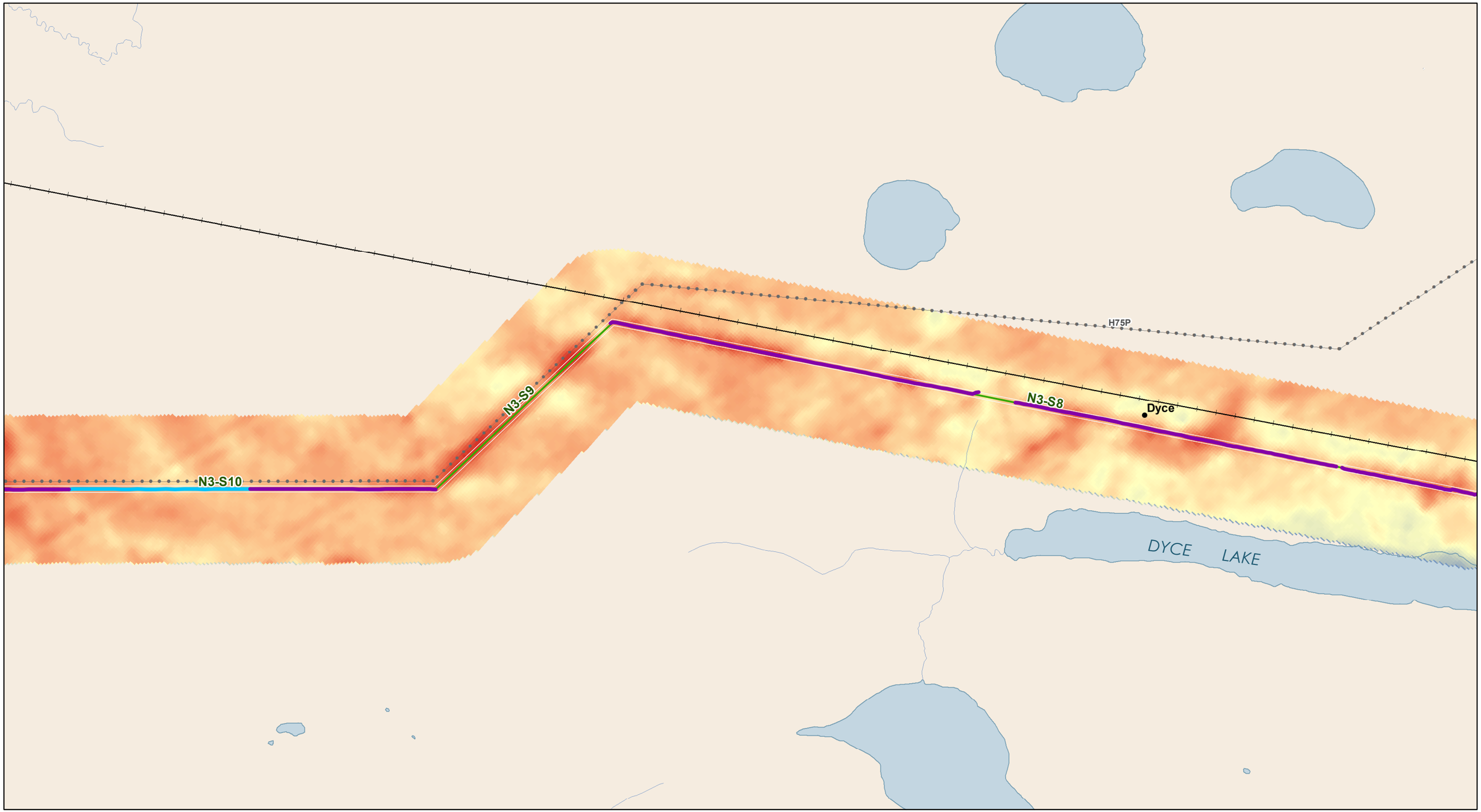
Landbase
- Railway (Operational)
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-35

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

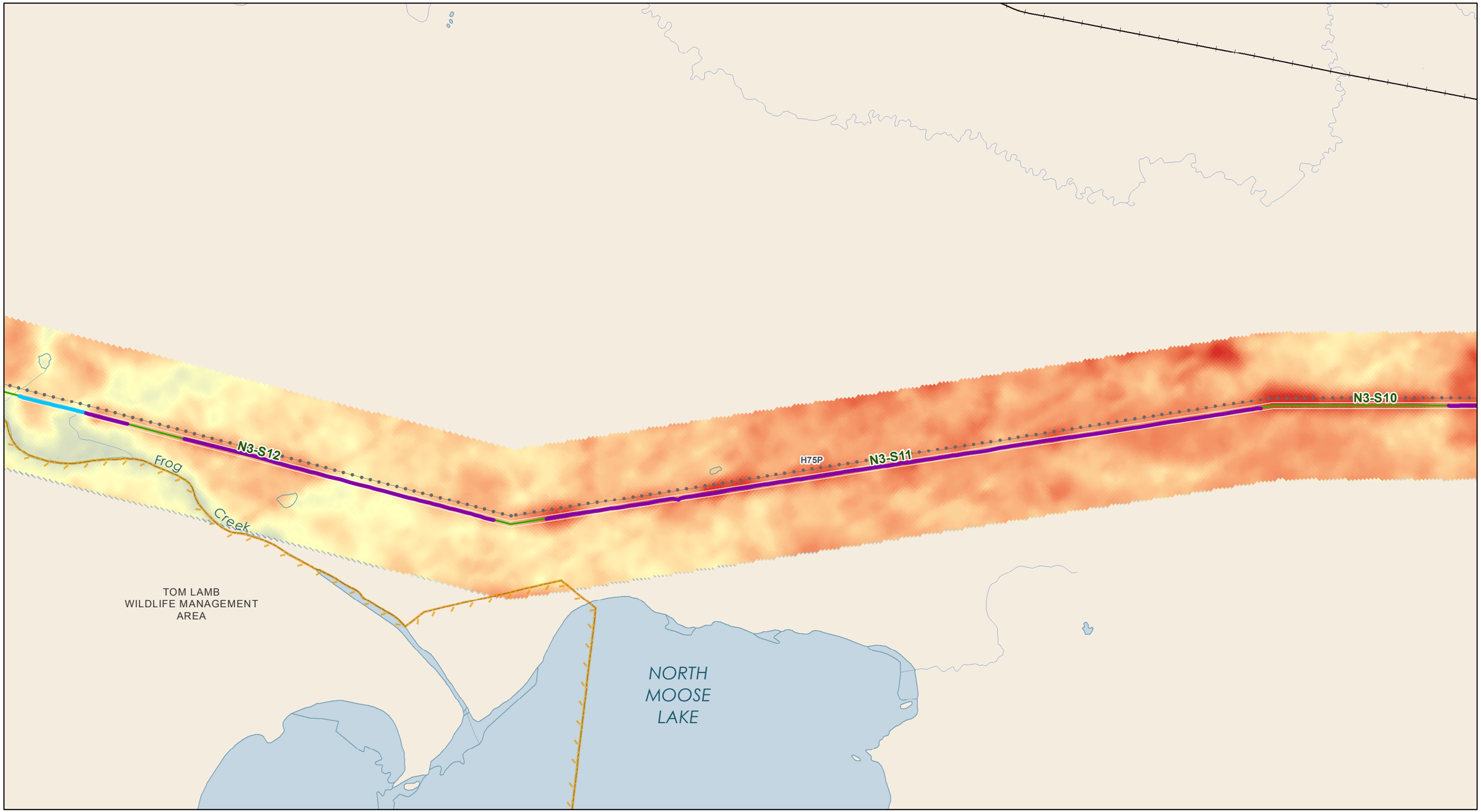
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Railway (Operational)
- Transmission Line
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-36



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

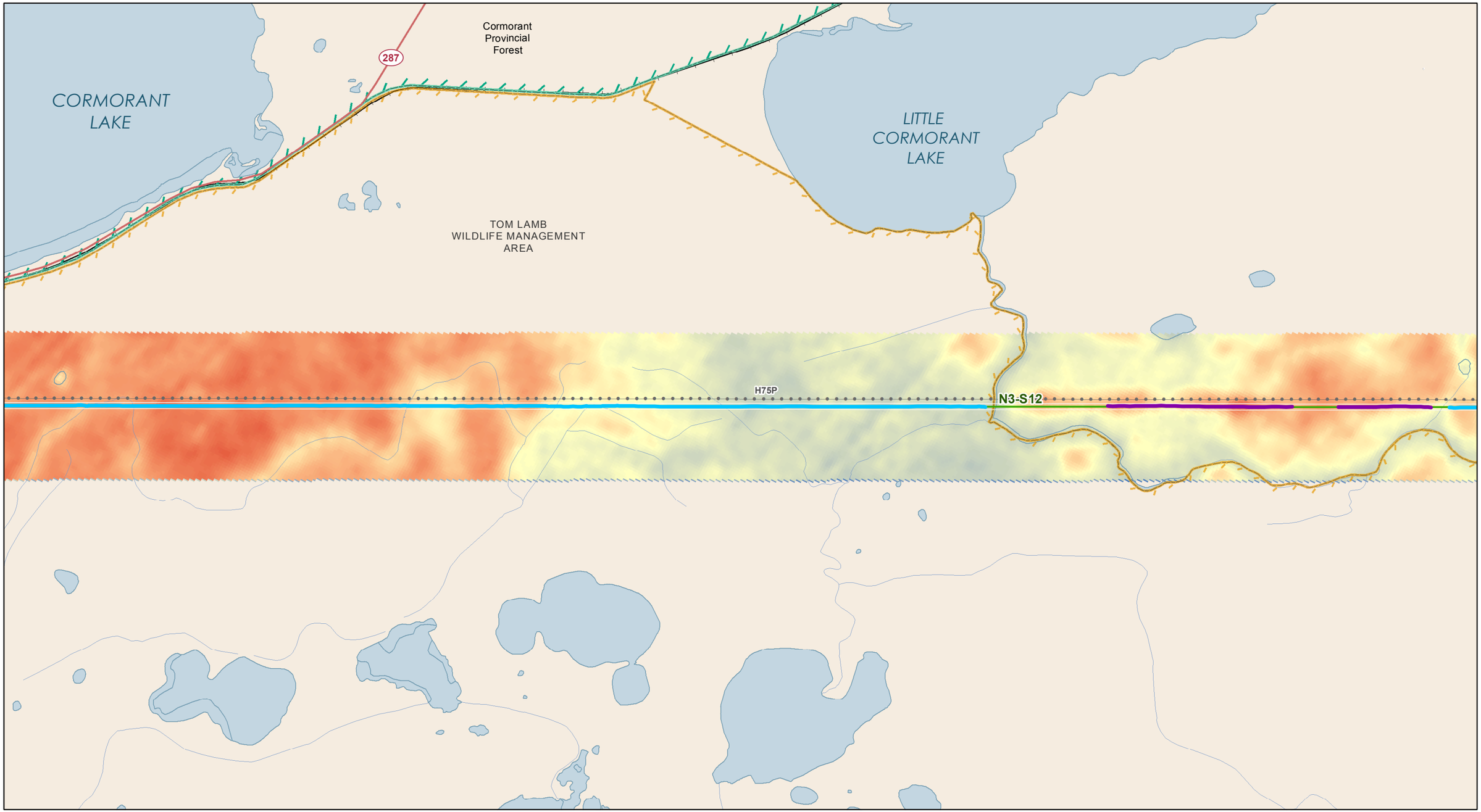
Landbase
- Railway (Operational)
- Transmission Line
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-37

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

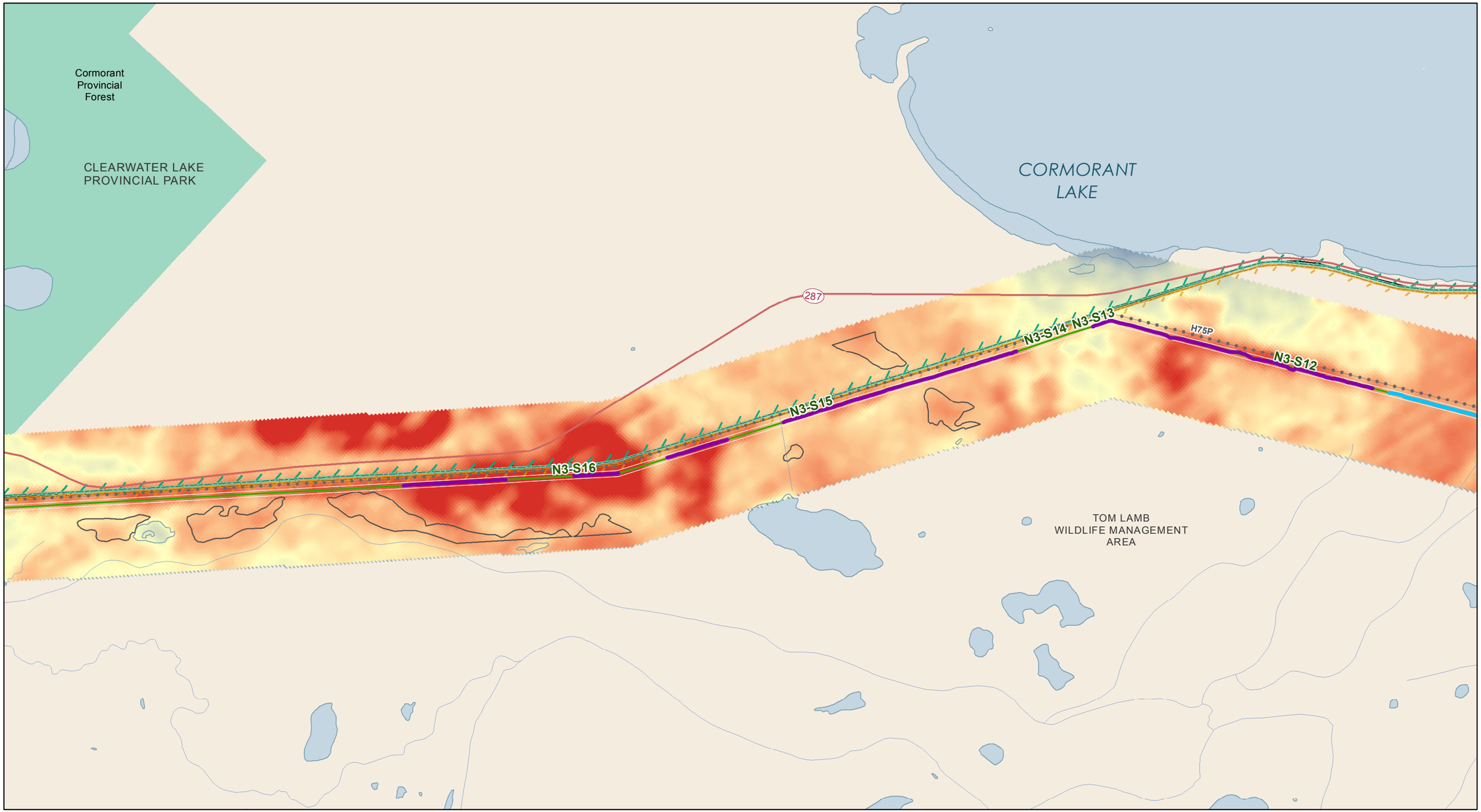
Landbase
- Provincial Road
- Railway (Operational)
- Transmission Line
- Provincial Forest
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-38

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

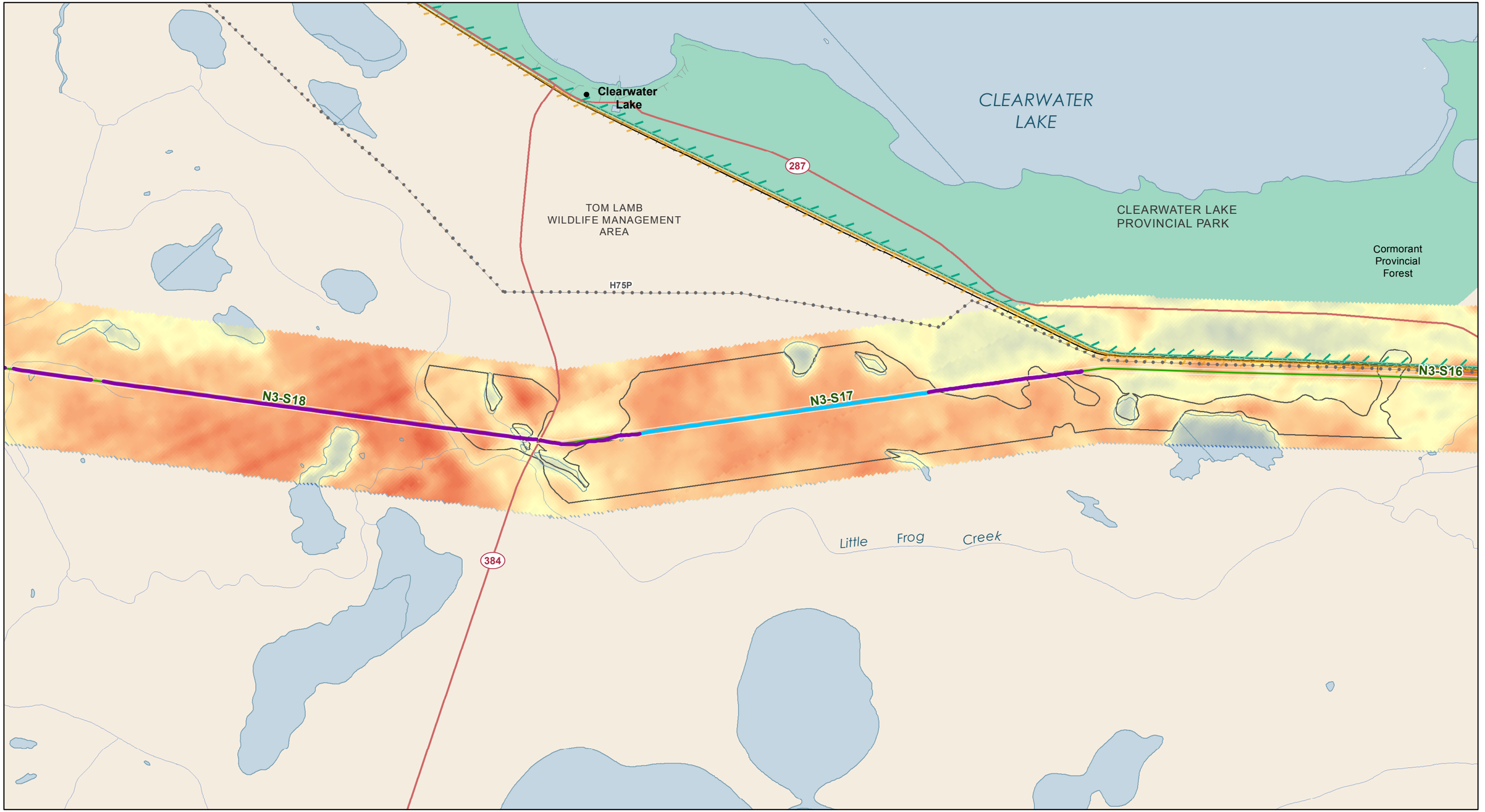
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Railway (Operational)
- Transmission Line
- Provincial Park
- Provincial Forest
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-39



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

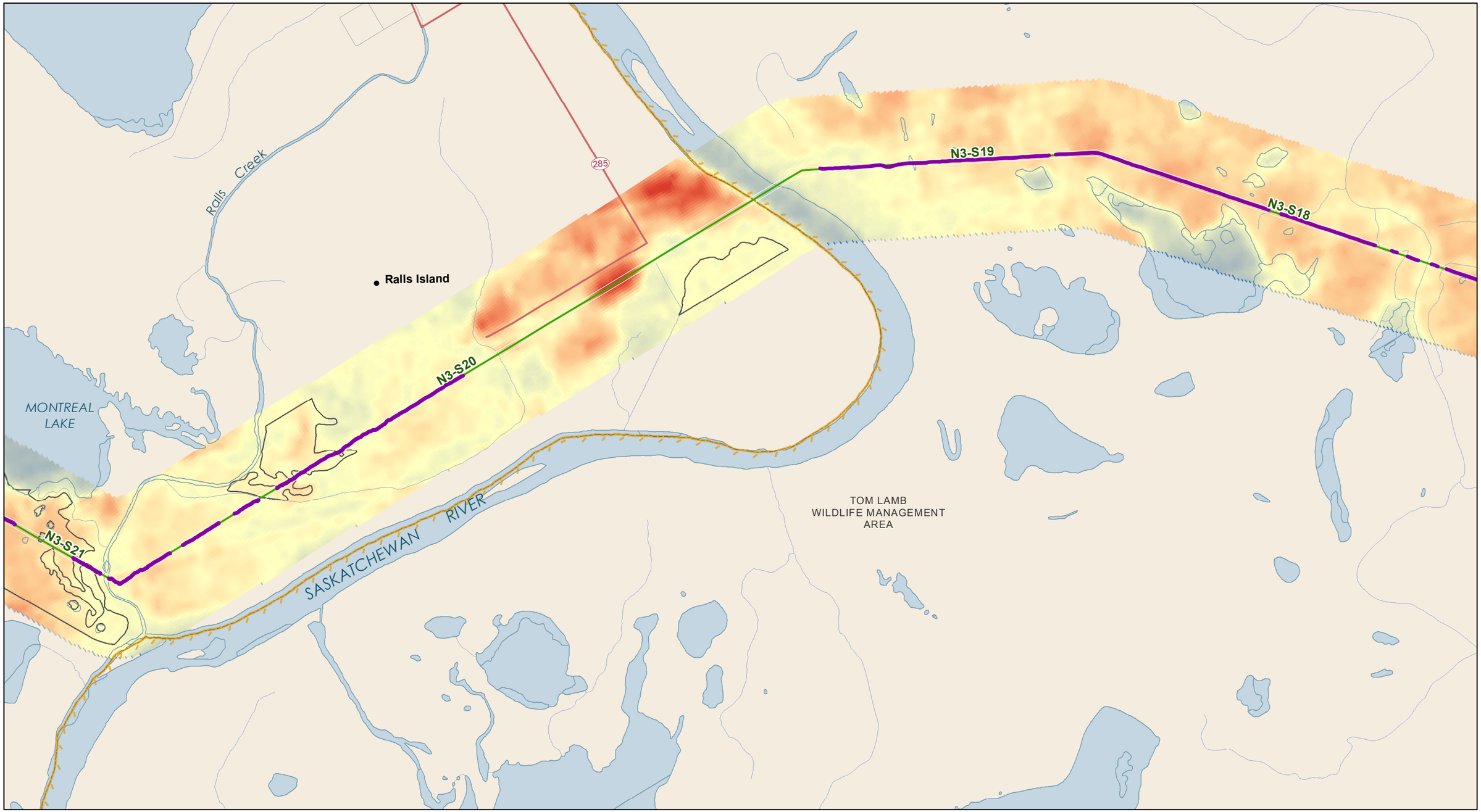
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Local Road
- Railway (Operational)
- Transmission Line
- Provincial Park
- Provincial Forest
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-40



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

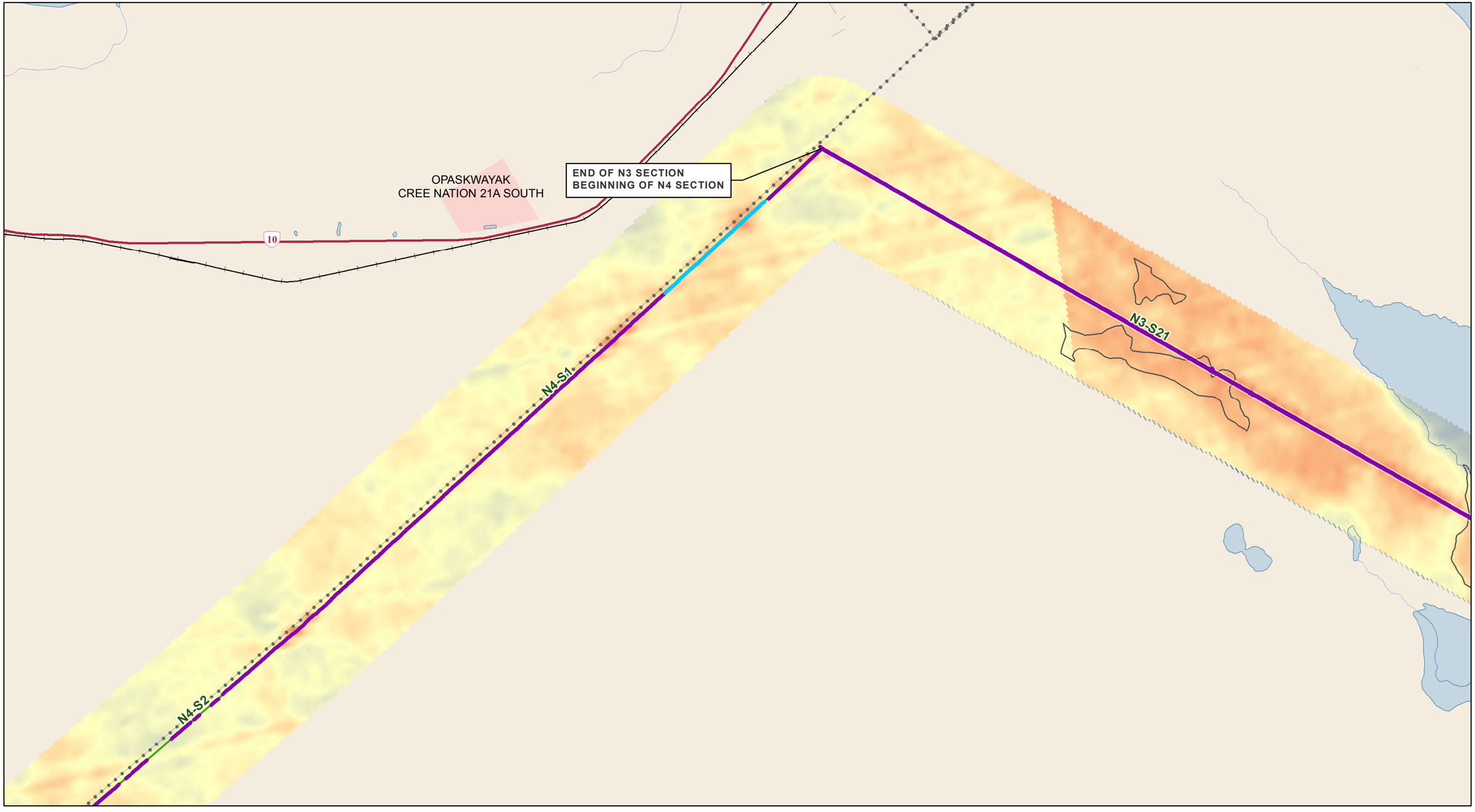
Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Road
- Local Road
- Wildlife Management Area
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-41



DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\111420045\ARCMAP\PERMAFROST\2017\BPIII_TIR_2017SUMMER_20171124.MXD

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN
Date Created: November 29, 2017

0 500 1,000 2,000
Metres

1:40,000

Base Data
- Permafrost

ROW Clearing Methods
- General Clearing
- Low Disturbance Clearing
- Selective Clearing

TIR Summer 2017 (°C)
- High : 46
- Low : 0

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW

Landbase
- Provincial Highway
- Local Road
- Railway (Operational)
- Transmission Line
- First Nation
- Watercourse
- Waterbody

Bipole III Transmission Project
Permafrost Monitoring

Landsat-8 Thermal Data
Summer 2017

Map 4-100-42

Appendix C SITE PHOTOGRAPHS

Photo C-1 Site 1 on-RoW

Photo C-2 Site 2 off-RoW

Photo C-3 Site 2 on-RoW

Photo C-4 Site 2 off-RoW

Photo C-5 Site 3 on-RoW

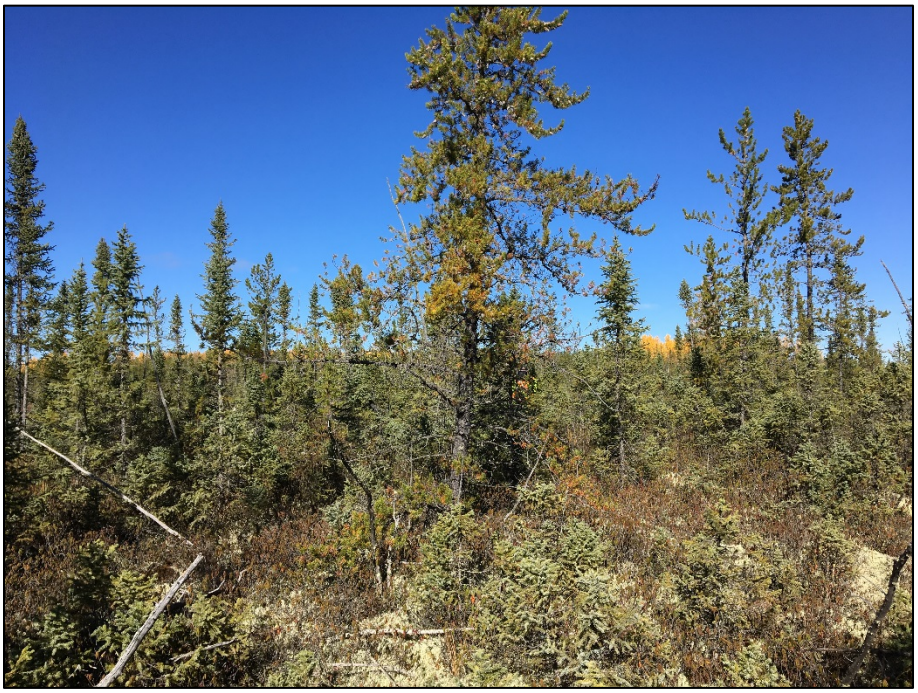


Photo C-6 Site 3 off-RoW

Photo C-7 Site 4 on-RoW

Photo C-8 Site 4 off-RoW

Photo C-9 Site 5 on-RoW

Photo C-10 Site 5 off-RoW

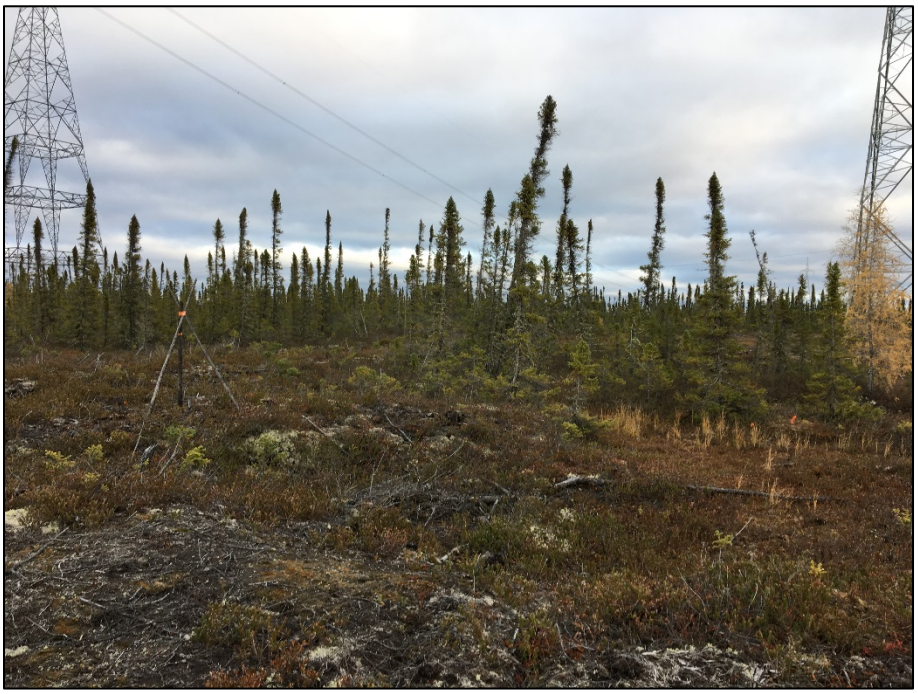


Photo C-11 Site 6 on-RoW

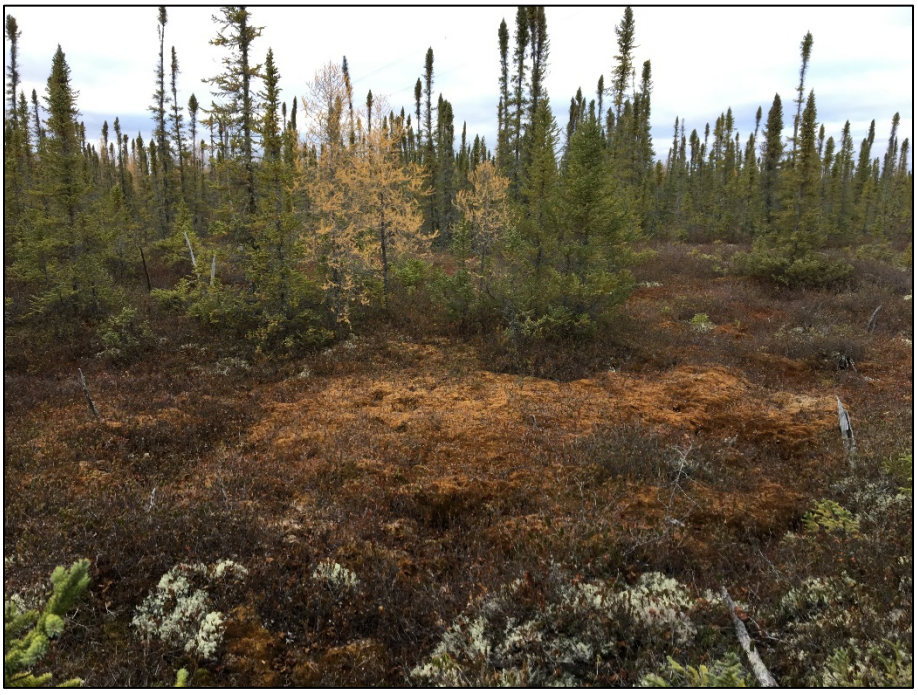


Photo C-12 Site 6 off-RoW

Photo C-13 Site 7 on-RoW

Photo C-14 Site 7 on-RoW

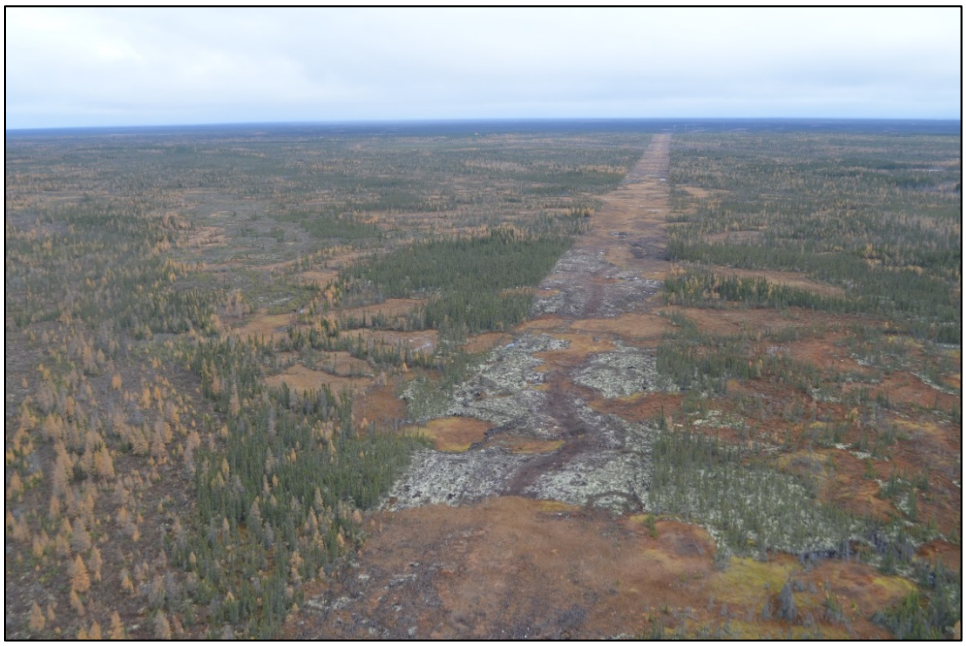


Photo C-15 Site 8 on-RoW

Photo C-16 Site 8 on-RoW

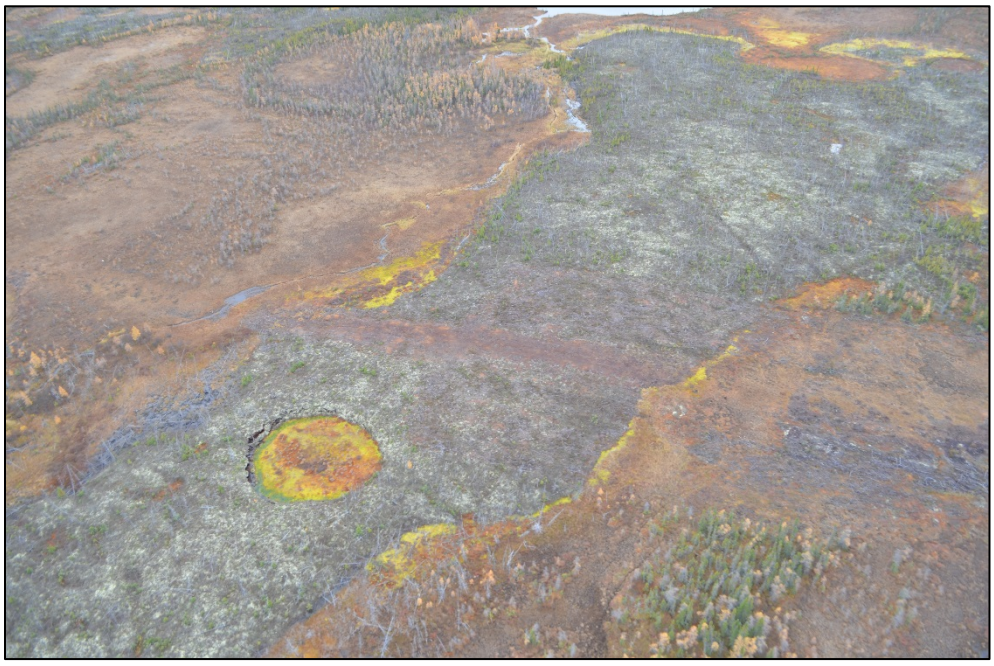


Photo C-17 Site 9 on-RoW

Photo C-18 Site 9 off-RoW

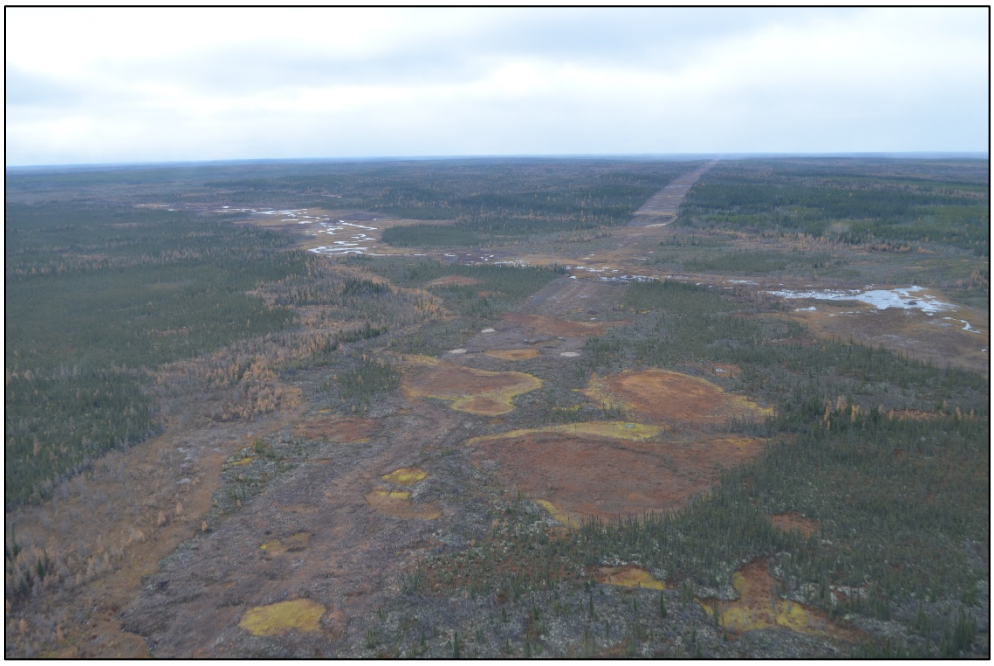


Photo C-19 Site 10 on-RoW

Photo C-20 Site 10 on-RoW

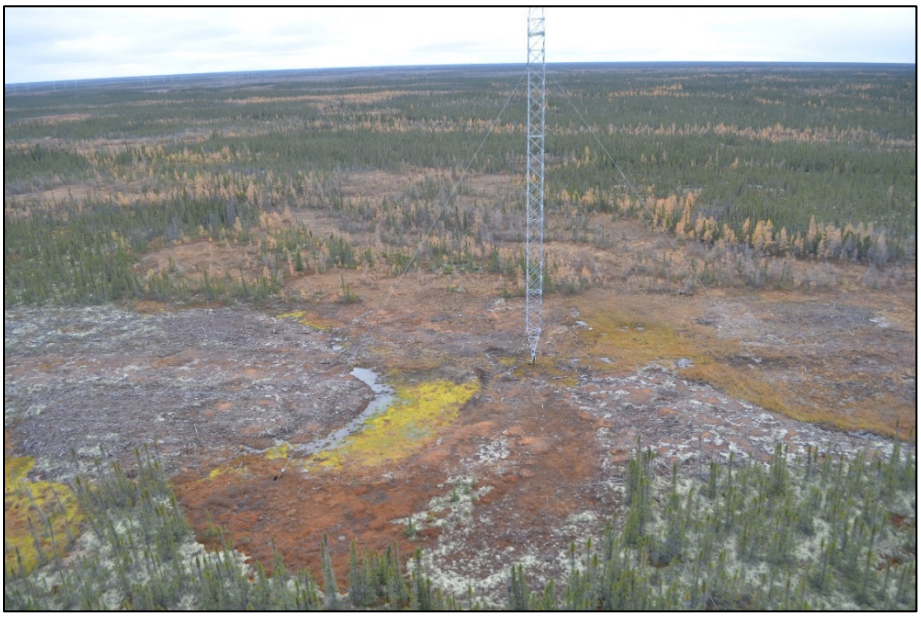


Photo C-21 Site 11 on-RoW

Photo C-22 Site 11 on-RoW

Available in accessible formats upon request