SECTION 10

TERRAIN

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Section 10 Abbreviations

Abbreviation	Definition
AWS	automatic weather station
AZ	azimuth
BSA	baseline study area
CNSN	Canadian National Seismograph Network
CSA	Canadian Standards Association
DAR	Developer's Assessment Report
Dominion Diamond	Dominion Diamond Ekati Corporation
e.g.	for example
EBA	EBA Engineering Consultants Ltd.
Ekati Mine	Ekati Diamond Mine
ESA	effects study area
et al.	and more than one additional author
i.e.	that is
INCL	angle of inclination
n/a	not applicable
NAD	North American Datum
NWT	Northwest Territories
PAG	potentially acid generating
PGA	peak ground accelerations
PMP	probable maximum precipitation
Project	Jay Project
SON	Subject of Note
TDS	total dissolved solids
TOR	Terms of Reference
UTM	Universal Transverse Mercator
VC	valued component
WLWB	Wek'èezhìi Land and Water Board
WROMP	Waste Rock and Ore Storage Management Plan
WRSA	waste rock storage area

Section 10 Units of Measure

Unit	Definition
%	percent
°	degrees
°C	degrees Celsius
°C/m	degrees Celsius per metre
cm	centimetre
ha	hectare
hr / hrs	hour(s)
km	kilometre
km^2	square kilometre
kPa	kiloPascals
m	metre
m/day	metres per day
m/m	metres per minute
m/s	metres per second
m^3	cubic metres
m^3/d	cubic metres per day
m^3/s	cubic metres per second
masl	metres above sea level
mbgs	metres below ground surface
mg/L	milligrams per litre
mm	millimetre
No.	number
ppt	parts per trillion
t	time

10 TERRAIN

10.1 Introduction

10.1.1 Background

The existing Dominion Diamond Ekati Corporation (Dominion Diamond) Ekati Diamond Mine (Ekati Mine) and its surrounding claim block are located approximately 300 kilometres (km) northeast of Yellowknife in the Northwest Territories (NWT) (Map 10.1-1). Dominion Diamond proposes to develop the Jay Project (Project), which includes associated mining and transportation infrastructure, to add 10 or more years of additional mine life to the Ekati Mine. The majority of the facilities required to support the Project and process the kimberlite already exist at the Ekati Mine, including:

- Misery Pit mining infrastructure (e.g., fuel facility, explosives magazines);
- primary roads and transportation infrastructure (e.g., Ekati airstrip, Misery Haul Road);
- Ekati main camp and supporting infrastructure;
- Ekati processing plant; and,
- fine processed kimberlite management facilities.

The Jay kimberlite pipe (Jay pipe) is located beneath Lac du Sauvage in the southeastern portion of the Ekati claim block about approximately 25 km from the main facilities and approximately 7 km northeast of the Misery Pit. A horseshoe-shaped dike will be constructed to isolate the portion of Lac du Sauvage overlying the Jay pipe. The isolated portion of Lac du Sauvage will be dewatered to allow open-pit mining of the kimberlite pipe. The Project will also require access roads, pipelines, and a power line to the Jay Pit from the Misery Pit.

10.1.2 Purpose and Scope

The purpose of this section of the Developer's Assessment Report (DAR) for the Project is to meet the Terms of Reference (TOR) issued by the Mackenzie Valley Review Board (Appendix 1A) and address the Subject of Note (SON): Impacts to Terrain from Project Components. The TOR is included in Appendix 1A and the Table of Concordance for the DAR is provided in Appendix 1D of Section 1. Specifically, the TOR requires that the DAR provides the following information with respect to terrain.

Describe the existing geotechnical stability of the area proposed for mine rock management, including:

- physical and chemical characteristics of mine rock and tailings;
- soil and hydrological conditions;
- permafrost, ground thermal conditions, and ground ice conditions; and,
- topography and slope stability.

LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- ALL-SEASON ROAD
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- TREELINE
- WATERCOURSE
- WATERBODY

150 0 150

SCALE 1:6,000,000 KILOMETRES

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
PROJECTION: CANADA LAMBERT CONFORMAL CONIC

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF THE JAY PROJECT

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Terr_001_GIS	
DESIGN	LD	02/09/14	SCALE AS SHOWN	REV. 0
GIS	LMR	06/10/14	MAP 10.1-1	
CHECK	JF	06/10/14		
REVIEW	JV	06/10/14		

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The geotechnical stability of all engineered structures, including site access roads, is assessed against a range of climate, seismic, and precipitation scenarios. The scope also includes plans to mitigate and monitor against impacts to terrain, including:

- erosion control measures;
- prevention of permafrost degradation or growth encouragement; and,
- monitoring of the geotechnical stability of the mine rock management area and the system of dikes and dams.

10.1.3 Valued Components, Assessment Endpoints, and Measurement Indicators

The TOR identified that impacts on terrain from Project components should be included in the DAR. Therefore, terrain is considered the valued component (VC) for this SON. All VCs have measurement indictors, but not every VC has an assessment endpoint (Section 6.2). Terrain is a VC with measurement indicators but no explicit assessment endpoint (Table 10.1-1). Measurement indicators are quantitative and/or qualitative expressions of changes to assessment endpoints. Assessment endpoints are qualitative expressions used to assess the significance of effects on a VC. Assessment endpoints represent the key properties of the VC that should be protected for future human generations (i.e., incorporate sustainability).

Although terrain does not have an assessment endpoint, Project-specific changes in the measurement indicators for terrain are presented in this section. The analysis of measurement indicators for terrain is also included in other sections of the DAR, where these measurement indicators are applied to VCs with assessment endpoints and are evaluated for significance of Project-specific and cumulative effects as described in Section 6.2. Although soil quantity and distribution and surface hydrology are included as measurement indicators for terrain, the changes to these indicators are analyzed in detail in Section 8 and Section 11, Appendix 11A. Where applicable, results from those sections are summarized in this SON.

Table 10.1-1 Summary of the Terrain Measurement Indicators

Valued Component	Assessment Endpoints	Measurement Indicators
Terrain	• no assessment endpoint[a]	• soil quantity and distribution • surface hydrology • permafrost distribution • quantity and distribution of terrain units • topography and slope stability

a) Terrain measurement indicators and pathways are applied to other valued components with assessment endpoints.

10.1.4 Spatial Boundaries

10.1.4.1 Baseline Study Areas

The data on measurement indicators for terrain were collected from a number of baseline study areas (BSAs), and are briefly described in the following subsections. The BSAs were designed to measure and characterize existing environmental conditions on a continuum of scales from the anticipated Project footprint to broader regional levels.

10.1.4.1.1 Soil and Permafrost Baseline Study Areas

The soils and permafrost BSA is approximately 236 square kilometres (km^2) (23,578 hectares [ha]), and includes the existing Ekati Mine operations and the Project footprint, plus and a 500 metre (m) buffer (Annex IV, Section 1.3 and Annex V, Section 1.4.2).

10.1.4.1.2 Terrain Baseline Study Area

The terrain BSA is approximately 338 km^2 (33,761 ha) and includes the existing Ekati Mine operations and the proposed Project footprint at the time of the baseline studies, plus an approximate 500 m buffer (Golder 2014a). The terrain BSA includes Duchess Lake and other waterbodies to the north of Lac du Sauvage.

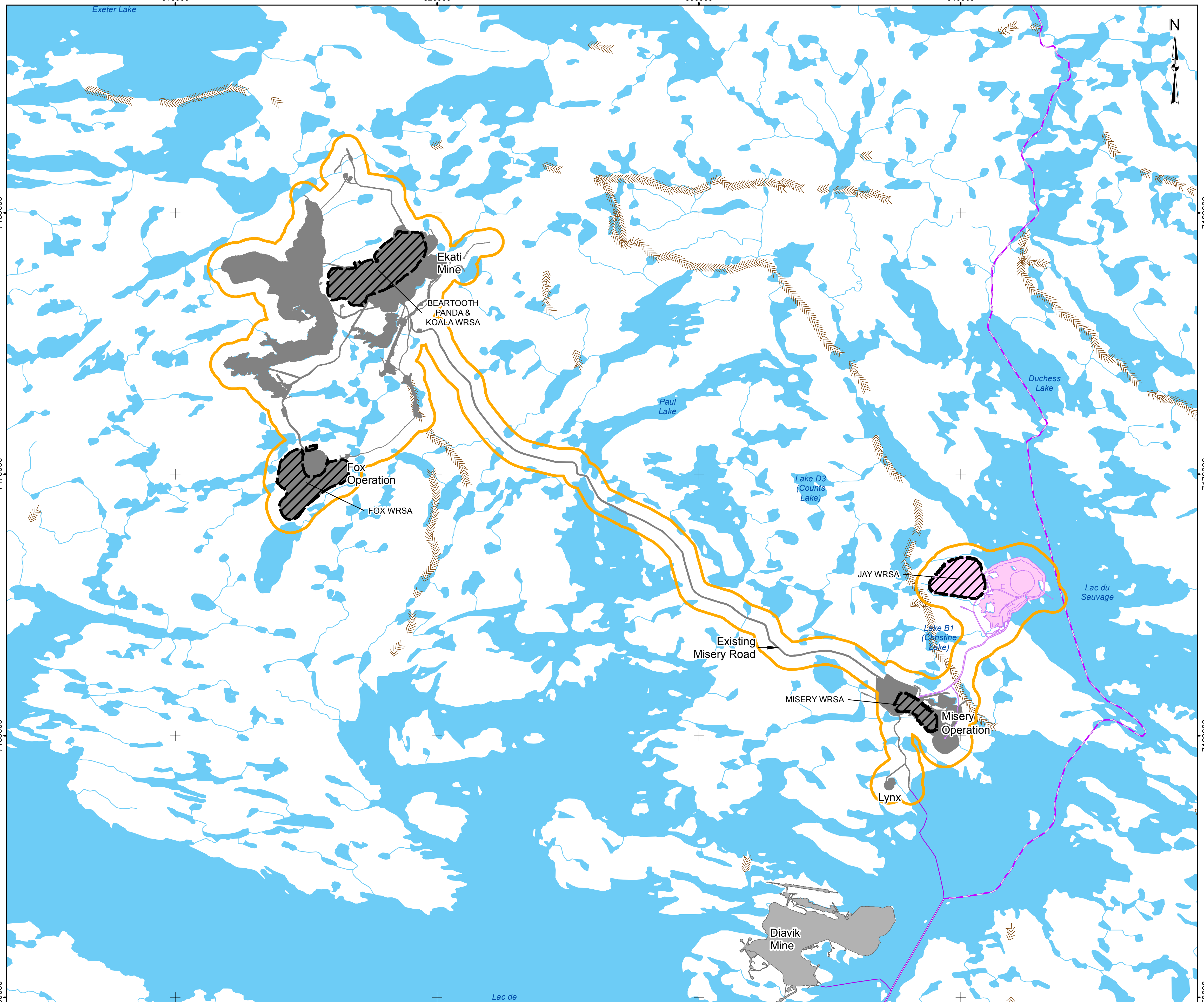
10.1.4.1.3 Hydrology Baseline Study Area

The hydrology BSA encompasses the entire Lac de Gras basin, including the Lac du Sauvage basin and all tributary land areas, and the mainstem of the Coppermine River from the Lac de Gras outlet to the mouth of the Coppermine River (Annex X, Section 1.3).

10.1.4.2 Effects Study Area

The terrain effects study area (ESA) is within the terrain BSA, and is approximately 142 km^2 (14,170 ha). The terrain ESA includes the Ekati Mine and the Project footprint, plus a 500 m buffer (Map 10.1-2). The TOR requires that an ESA be large enough to provide a confident assessment of the effects on terrain from the Project and potential cumulative effects from the Project and previous, existing and reasonably foreseeable developments (if applicable) (Appendix 1A). An ESA must also be large enough to determine the effects of natural environmental factors on engineered structures required for the Project. The terrain ESA was designed to include the extent of permafrost effects and the influence of terrain stability on the Project.

Esker and kame terrain features are common in the region, and were formed by glaciofluvial processes associated with the transport and deposition of coarse material by glacial meltwater. These landforms are composed of well-sorted sand and gravel. Areas of rolling terrain with ridges and hills that compose much of the region are associated with glacial till/morainal deposition. Glacial till deposits are typically shallow, and consist of heterogeneous, sandy-textured material that has been deposited directly by the glacier by mechanical processes or melt-out. Lacustrine plains are gently sloping areas associated with lakes and compose a small portion of the region. Lacustrine terrain features are composed of silty and gravelly sands.



LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ESKER
- WATERCOURSE
- WATERBODY
- EFFECTS STUDY AREA
- WASTE ROCK STORAGE AREA (WRSA)

REFERENCE

NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

3 0 3
SCALE 1:150,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF THE TERRAIN EFFECTS STUDY AREA

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Terr_002_GIS
DESIGN	LD	02/09/14	SCALE AS SHOWN REV 0
GIS	LMR	06/10/14	
CHECK	JF	06/10/14	MAP 10.1-2
REVIEW	JV	06/10/14	

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The ESA occurs entirely within the Tundra Shield Low Arctic (south) Level III Ecoregion (ECG 2012), and is characterized by long, cold winters and very short, cold summers (mean annual temperature of approximately -9 degrees Celsius [°C]). Characteristic landscape features in the region include extensive till and outwash deposits, as well as granitic and sedimentary rocklands bisected by numerous eskers. Ice-wedge polygons, frost-shattered bedrock, high-centre polygons, and non-sorted circles are evidence of continuous permafrost present in this ecoregion. The ESA is located in a transitional area between the boundaries of the Level IV Point Upland Ecoregion and the Contwoyto Upland Ecoregion (ECG 2012).

The western portion of the ESA occurs within the Point Upland Ecoregion, and is characterized by a rugged landscape dominated by exposed bedrock with extensive boulder tills. Small eskers are often associated with outwash plains, and both occur throughout the ecoregion. These deposits include a range of textures from sands to boulders. Permafrost is continuous and results in areas of frost-shattered bedrock and non-sorted circles where there are finer-textured till deposits. Turbic and Static Cryosolic soils have developed on the till veneers that overlie the bedrock. Organic Cryosol areas associated with the wetlands and high-centre peat polygons occur in low-lying areas (ECG 2012). The Coppermine River flows through the ecoregion to the northwest. Lac de Gras and Afridi, Courageous, Itchen, Mackay, Point, Thonokied and Yamba lakes are the largest waterbodies in the ecoregion.

The Contwoyto Upland Ecoregion encompasses the eastern portion of the ESA. Although rock exposures occur throughout the ecoregion, the bedrock is mostly overlain by deposits of bouldery till veneers and blankets and hummocky till deposits, with nearly continuous tundra cover (ECG 2012). Small eskers and kame deposits are scattered throughout the region, and permafrost is continuous. Non-sorted circles are the most widespread evidence of permafrost in the Contwoyto Upland Ecoregion. Turbic and Static Cryosolic soils have developed on glacial till hummocks, veneers, and blankets. Cryosolic soils are characteristic of deep, well-drained, coarse-textured landforms, while Organic Cryosolic soils are associated with low-lying wetlands (ECG 2012). Lac du Sauvage and Contwoyto (Fry Inlet), Glowworm, Muskox, Pellatt and Sterlet lakes are the largest waterbodies in this ecoregion.

10.1.5 Project Phases

The Project phases include construction, operation, and closure. Final closure of the Project generally occurs after the completion of reclamation. Many effects of the Project will end when operations cease or at closure, but effects on the geotechnical stability of waste rock storage areas may continue after Project closure. The Project phases are as follows:

- construction (2016 to 2019);
- operations (2019 to 2029); and,
- closure (2030 to 2033).

10.2 Existing Geotechnical Stability of the Proposed Waste Rock Storage Area

Waste rock and overburden excavated from the Jay Pit and waste generated during dike construction will be stored at the Jay waste rock storage area (WRSA). The existing Ekati Mine Waste Rock and Ore Storage Management Plan (WROMP) will be expanded to incorporate the Jay WRSA. The Jay WRSA will be located west of the Jay Pit on the shore of Lac du Sauvage (Section 3.5.5). The Jay WRSA has been designed to accommodate a volume of 120 million cubic metres (m^3), which includes approximately 9.6 million m^3 for contingency.

The existing WRSAs at the Ekati Mine include the Panda/Koala/Beartooth WRSA, the Fox WRSA, and the Misery WRSA, which cumulatively cover 1,031 ha of the ESA. The Jay WRSA will cover approximately 250 ha, resulting in a cumulative WRSA area within the ESA of 1,281 ha. The future Pigeon WRSA that is currently under construction will cover an area of approximately 48 ha when complete. The cumulative area that will be occupied by previous, existing and reasonably foreseeable WRSAs is predicted to be 1,329 ha.

None of the reasonably foreseeable developments identified in Section 6.5.2.4 are located within the ESA. The closest reasonably foreseeable development is the Courageous Lake Project, which is located approximately 73 km southwest of the Project and is outside the ESA.

The following sections describe the physical and chemical characteristics of waste rock and kimberlite ore produced at the Ekati mine, existing environmental conditions, and engineering designs for the Jay WRSA. This information was used to predict the effects from seismic activity and factors related to climate change on the stability of the Jay WRSA and other engineered structures.

10.2.1 Physical and Chemical Characteristics of Mine Rock and Kimberlite

The Panda/Koala/Beartooth WRSA is 537 ha and contains waste rock from the Panda, Koala, Koala North, and Beartooth developments. This WRSA also contains a coarse kimberlite reject storage area. The waste rock consists primarily of biotite granite with minor quantities of kimberlite from rock near the waste/ore geological contact (estimated to be much less than 3 percent [%] of the total waste rock quantity). Beartooth waste rock also includes small quantities of metasediments (less than 0.1% of total Beartooth waste rock). The Coarse Kimberlite Reject Management Area contains processed kimberlite from all pipes at the Ekati Mine. The coarse kimberlite rejects are composed of the mixture of sand to gravel-sized, light and dense minerals that remain after the diamonds have been recovered from the kimberlite. The grain size distribution is in the range of 0.5 to 25 millimetre (mm) diameter. For existing Ekati Mine operations, finer material (less than 0.5 mm) washed from the kimberlite ore during processing (fine processed kimberlite) is discharged as a slurry to the Long Lake Containment Facility.

The Fox WRSA is 383 ha. It is located in a horseshoe around the Fox Pit and covers the western, southern, and eastern areas immediately adjacent to the pit. The Fox WRSA consists of granite co-disposed with minor diabase, lake-bottom sediments, and till. Waste kimberlite is segregated and placed within the Fox WRSA in a south-central location and along the northwest side. Granite pads were pre-laid to avoid direct contact of waste kimberlite with tundra water and to promote freezing in the pile.

The Misery WRSA will be approximately 111 ha and consists of alternating layers of potentially reactive metasediments and weakly reactive granite and diabase. A 5 m thick granite cap was placed over the storage area in May and June of 2005 when mining at the Misery site was temporarily suspended. Construction of the WRSA resumed in 2012 as part of the open pit pushback and is currently underway.

Waste rock from the Jay Pit will be mainly non-potentially acid generating granite (estimated 70%), and the remainder will be metasediments and overburden (Section 3.5). All of the metasediment mined from the Jay Pit will be managed as potentially acid-generating material. Metasediment from the Jay Pit will be placed along with the non-potentially acid generating granite waste rock in the Jay WRSA. An encapsulating layer of non-potentially acid generating granite rock of at least 5 m thickness will be placed over the Jay WRSA with the objective that the metasediment be frozen into permafrost. Preferentially freezing the reactive materials into permafrost will provide an additional long-term environmental risk reduction, and it is the approach already in use at the Ekati Mine. The proportions of granite versus metasediment to be mined from the Jay Pit will provide ample granite for this cover layer.

10.2.2 Soil and Hydrological Conditions

The soils baseline field program was conducted from August 28 to September 1, 2013, to document soil characteristics in the ESA (Appendix 11A1.2). Soils were characterized, using the methods outlined by the Expert Committee on Soil Survey (Agriculture Canada 1981a) and the Mapping System Working Group (Agriculture Canada 1981b), to support the classification and mapping of soils in the ESA.

The majority of the 250 ha area within the Jay WRSA is composed of the Mineral-1 map unit. The Mineral-1 map unit within the WRSA is co-dominated by very stony to excessively stony well-drained to rapidly drained Turbic Cryosols, and by cryoturbated Orthic Dystric Brunisols developed on undulating coarse to moderately fine-textured glacial till. Substantial amounts of the area that the Jay WRSA will occupy are exposed bedrock outcrops and boulders.

Previous programs to collect hydrological baseline, operational, and monitoring data have focused on the operating mine areas within the Lac de Gras basin. Baseline hydrological data collected in August and September 2013 were intended to advance the understanding of the hydrology of the Lac du Sauvage basin, Paul Lake basin, and Lac de Gras outlet, and to provide data for use as input to, and initial calibration data for, the regional water balance model of the Lac de Gras basin (Hydrology Baseline Report Annex X; Section 3.3.2.1).

The Jay WRSA will not require any diversions of natural watercourses because the layout was designed to avoid surrounding waterbodies and drainage channels (Section 3.5.5). The WRSAs at the Ekati Mine are constructed to minimize runoff and encourage permafrost formation. The intent is that, over the long-term, water infiltrating the WRSA will encounter permafrost and freeze within the pile (Section 3.5.5).

10.2.3 Permafrost, and Ground Thermal and Ground Ice Conditions

Extensive geotechnical characterization has been conducted near the Project because of regional mining activities. A geotechnical field investigation was carried out in the Jay pipe area from February to May 2014. The structural model for the proposed Jay Pit indicates the occurrence of northwest-southeast and east-west trending faults. Inspection of the core from the geotechnical boreholes drilled during the 2014 Jay Pit field investigation indicates that the fault zones are infilled with material consisting mainly of clay and gouge. Based on the geotechnical core logging data, the majority of the faults logged exhibit a joint condition rating of 0 or 6 (Section 3.3.3).

Multiple geotechnical field investigations have been carried out for the Ekati Mine site since the 1990s. Nine thermistors (devices to measure temperature using electrical resistance) were installed by EBA Engineering Consultants Ltd. (EBA) from 1998 to 2008 (Annex IV; EBA 1998, 1999, 2008). Locations of these thermistors are Beartooth Pit (one), Panda Pit (one), Sable Pit (one), Misery Pit (one), and Misery site (five). Thermistor data from instruments installed by EBA (1998, 1999, 2008) were used to characterize permafrost. Detailed information on the exact location of thermistors and thermistor data is presented in the Permafrost Baseline Report (Annex IV). Mapping of periglacial processes (i.e., permafrost) and related landforms and ground ice distributions was conducted using data derived from interpretation of surficial deposits, vegetation, and drainage during the terrain mapping process (Golder 2014a).

The Project is located within a region of continuous permafrost. In this region, the layer of permanently frozen subsoil and rock is generally deep and overlain by an active layer that thaws during summer. The permafrost map of Canada (Natural Resources Canada 1995) indicates that the ground ice content is expected to be between 0% and 10% (dry permafrost), based on data compiled at the regional scale. Ice lenses (small bodies of ice in frozen soils) and ice wedges are likely to be present locally on land, as indicated by the electrical conductivity of the ground and by permafrost features such as palsas (mounds of alternating layers of ice and mineral soils). These areas of local ground ice are generally associated with low-lying areas of poor drainage.

In areas of continuous permafrost, there are two groundwater flow regimes: deep groundwater flow beneath permafrost, and shallow groundwater flow near the ground surface in the active (seasonally thawed) layer. Because of the deep layer of low permeability permafrost, there is little to no hydraulic connection between these two flow regimes in areas where there are no taliks.

Based on experience at the Ekati Mine and on groundwater chemistry data from other sites in the Canadian Shield, the salinity of groundwater increases with depth (Frape and Fritz 1987). Groundwater salinity will result in a lower freezing point and in the formation of a layer of perennially cryotic (less than 0˚C) but unfrozen ground at the base of the permafrost. This layer is termed the basal cryopeg. Although the basal cryopeg is part of the permafrost, it may contain unfrozen water, and groundwater flow may occur even though ground temperature is less than 0˚C. The thickness of this layer is related to the salinity of the deep groundwater, the geothermal gradient, and the depth below ground surface (freezing point depression due to pressure effects). Based on the total dissolved solids (TDS) data for the Panda and Koala underground mines (Klohn Crippen 2005; Rescan 2007), freezing point depression could be between -1°C and -2°C at 300 m and 400 m depth, respectively (Annex IV). Considering a -1°C to -2°C freezing point depression for the Ekati Mine, the depth to the basal cryopeg (where unfrozen groundwater may first be encountered) may be 185 to 415 metres below ground surface (mbgs) (Annex IV). Based on thermistor data, the depth of permafrost beneath the land mass of the Project is predicted to be 320 to 485 mbgs (Annex IV). Under islands and peninsulas, permafrost is predicted to extend to a maximum depth of 265 to 320 mbgs (Annex IV).

The shallow groundwater flow regime is active only during summer, and the magnitude of flow in this layer is expected to be several times less than runoff from snowmelt (Woo 2011). The water table in the active layer generally reflects the surface relief (topography of the land surface). Hydraulic gradients in the vicinity of the Project range from approximately 0.002 to 0.02 metres per minute (m/m), and annual groundwater velocities are in the order of 0.001 to 0.1 metres per day (m/day) (1×10^{-7} to 1×10^{-6} metres per second [m/s]). During winter, land is underlain by seasonal frost, which is in turn underlain by permafrost. Water in the active layer is stored in ground ice during the cold season, and is then released when it thaws in late spring or early summer, thus providing flow to surface waterbodies (Woo 2011). From late spring to early autumn, when temperatures are above 0°C, the seasonal frost in the active layer becomes thawed. During the warm season, groundwater in the active layer is recharged primarily by precipitation.

The thickness of the active layer is variable and depends on several factors. The most important factors are the thaw index, thermal resistance of the vegetation cover, moisture content, and composition of soil and/or rock. The depth of the active layer in the Misery Pit area, based on thermistor measurements, ranges from approximately 1.0 to 2.7 m (Annex IV).

Permafrost reduces the hydraulic conductivity of the bedrock by several orders of magnitude (Burt and Williams 1976; McCauley et al. 2002). Consequently, the permafrost in the rock would be virtually impermeable to groundwater flow. The shallow groundwater flow regime, therefore, has little to no hydraulic connection with the groundwater regime underlain by massive and continuous permafrost.

Under frozen foundation conditions, movements due to creep of ice-rich soils (greater than 30% moisture content or greater than 10% visible ice) can occur (Golder 2014b). The rate of creep in frozen soils is dependent on loading and temperature, with higher creep rates observed at higher temperatures and under higher shear loading conditions. Maximum creep rates occur at nearly thawed conditions. Seasonally, higher creep rates are, therefore, expected to be correlated with seasonal thawing of ice-rich soil foundations. Ice-rich soils are expected to be limited within the Jay WRSA footprint because there is limited fine-grained soil (silts and clays) within the footprint (Golder 2014b).

Creep strength laboratory testing has not been conducted on foundation soils from the Jay WRSA footprint; therefore, analyses were conducted by assigning a range of cohesion values to the foundation soils to obtain the associated factors of safety (Golder 2014b). The cohesion values associated with a factor of safety of 1.3 for the static cases were approximately 100 kiloPascals (kPa) and the cohesion values associated with a factor of safety of 1.0 for the pseudo-static cases were approximately 70 kPa. This means that if the Jay WRSA foundation soils have higher creep strengths for the maximum allowable strain rate than these calculated values, the minimum design factors of safety will be met for creep movement.

The majority of the proposed Jay WRSA is located in terrain polygons with Low to Moderate susceptibility to periglacial processes (e.g., freezing and thawing) (Golder 2014a). The active processes observed in this area are cryoturbation (mixing of materials from various horizons of the soil down to the bedrock due to freezing and thawing). A small polygon in the northwestern portion of the Jay WRSA footprint is mapped as having solifluction (gravitational downslope movement of saturated non-frozen overburden over permafrost). However, there is a possibility that the area mapped as having solifluction is actually a pocket of saturated, fine-textured thick till with ground ice present (Golder 2014a).

Areas with cryoturbation are typically associated with uplift and general freeze-thaw conditions, whereas areas with permafrost as a process are associated with thaw and settlement, and to a lesser extent uplift (i.e., peat mounds in organic deposits). Displacement hazard varies as the soil drainage class changes; well- to moderately well-drained soils are generally less vulnerable to freeze- and thaw-induced displacement than imperfectly- to poorly-drained soils. Terrain susceptibility ratings ranging from Low to High indicate an increasing potential for freeze- and thaw--induced soil displacement in a given area (polygon). A small proportion of the Jay WRSA appears to be located within over an area of active but low-hazard periglacial processes. This area will require site reconnaissance to confirm the soil conditions. Before waste rock is placed over the small polygon mapped as a solifluction lobe in the northwestern portion of the Jay WRSA, small continuous movements and depositing of sediment in the small hollow between bedrock outcrops is expected. Movements should subside after placement of waste rock due to the weight of the material and the aggradation of permafrost in the waste rock, which will reduce and eventually eliminate freeze-thaw cycles in the soils beneath the WRSA. No large-scale instabilities are predicted, and a large scale, deep-seated landslide related to solifluction is not expected.

10.2.4 Topography and Slope Stability

The mapping and assessment of terrain included a desktop review of existing literature and available terrain and surficial geology maps. Mapping of terrain in the study area was conducted according to British Columbia terrain classification methods and mapping standards. British Columbia standards are considered comprehensive (O'Leary 2002) and appropriate for use in the NWT. Terrain mapping for the ESA focused on the eastern portion where the Jay pipe development is proposed (Maps 10.2-1a through 10.2-1p; Golder 2014a).

Thick glacial till deposits mixed with interstitial "washed" till veneers and scattered bedrock outcrops are dominant in the ESA (Maps 10.2-1a through 10.2-1p). Glaciofluvial eskers, and hummocky terrain along waterbodies and pockets of discontinuous thick organic deposits associated with numerous waterbodies, are scattered throughout the ESA. The existing WRSAs cover approximately 882 ha, with the Panda/Koala/Beartooth WRSA covering 428 ha, the Fox WRSA covering 383 ha, and the Misery WRSA covering 71 ha. The Jay WRSA will cover approximately 250 ha. The majority of the Jay WRSA location is composed of terrain units containing bedrock outcrops, and veneers and blankets of glacial till deposits materials. The east portion of the Jay WRSA contains some sandy and gravelly glaciofluvial deposits.

Stability analyses of the Jay WRSA were carried out using GEO-SLOPE (2008) modelling software, which provides a general solution of slope stability through application of two-dimensional limit equilibrium methods (Golder 2014b). The Morgenstern-Price approach was used for calculation of inter-slice shear forces. Stability of the proposed Jay WRSA was assessed under both static and seismic (pseudo-static) loading conditions (Golder 2014b). The Jay WRSA foundation is generally flat, and areas of higher relief within the Jay WRSA footprint are typically bedrock outcrops. Therefore, the slope of the foundation is generally not a constraint for stability (Golder 2014b).

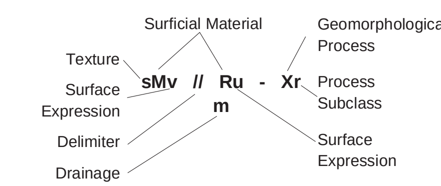
The Jay WRSA is expected to be constructed similarly to other WRSAs at the Ekati Mine and will incorporate designs that enhance the natural process for freezing into permafrost (Golder 2014b). The Jay WRSA will be built up from the bottom in 15 m benches with angle of repose slopes (1.3H:1V) and 25 m setbacks for each bench (Golder 2014b). This geometry will result in an overall 3H:1V slope for the pile (Golder 2014b).

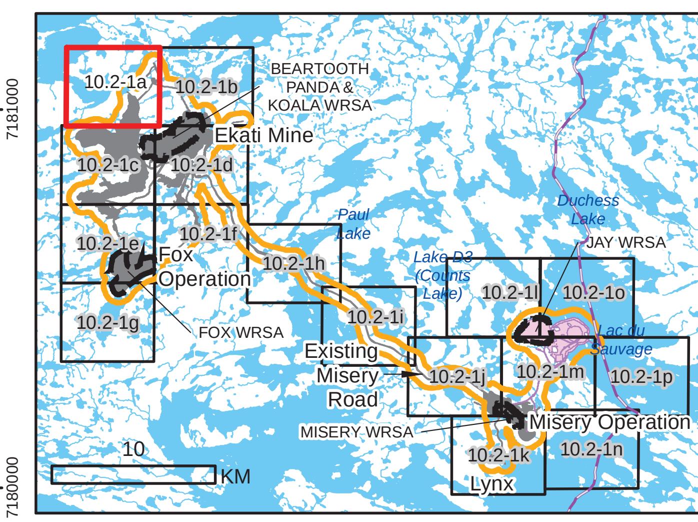
The critical stability of the Jay WRSA is predominantly controlled by the strengths of the foundation soils, where soil is encountered within the footprint. Frozen soils and bedrock have high strengths, and where the pile is founded on these materials it is expected to have a very high degree of stability. Finer-grained foundation soils in a thawed condition will present the weakest foundation structure.

LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- TERRAIN POLYGON BOUNDARY (APPROXIMATE)
- WASTE ROCK STORAGE AREA (WRSA)
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION





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DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

400 0 400

SCALE 1:20,000 METRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

TERRAIN UNITS WITHIN THE EFFECTS STUDY AREA

Golder Associates

PROJECT	13-1328-0041		DAR_Terr_003_GIS	
DESIGN	WM	04/03/14	SCALE AS SHOWN	REV 0
GIS	JG	06/10/14	MAP 10.2-1a	
CHECK	JF	06/10/14		
REVIEW	JV	06/10/14		

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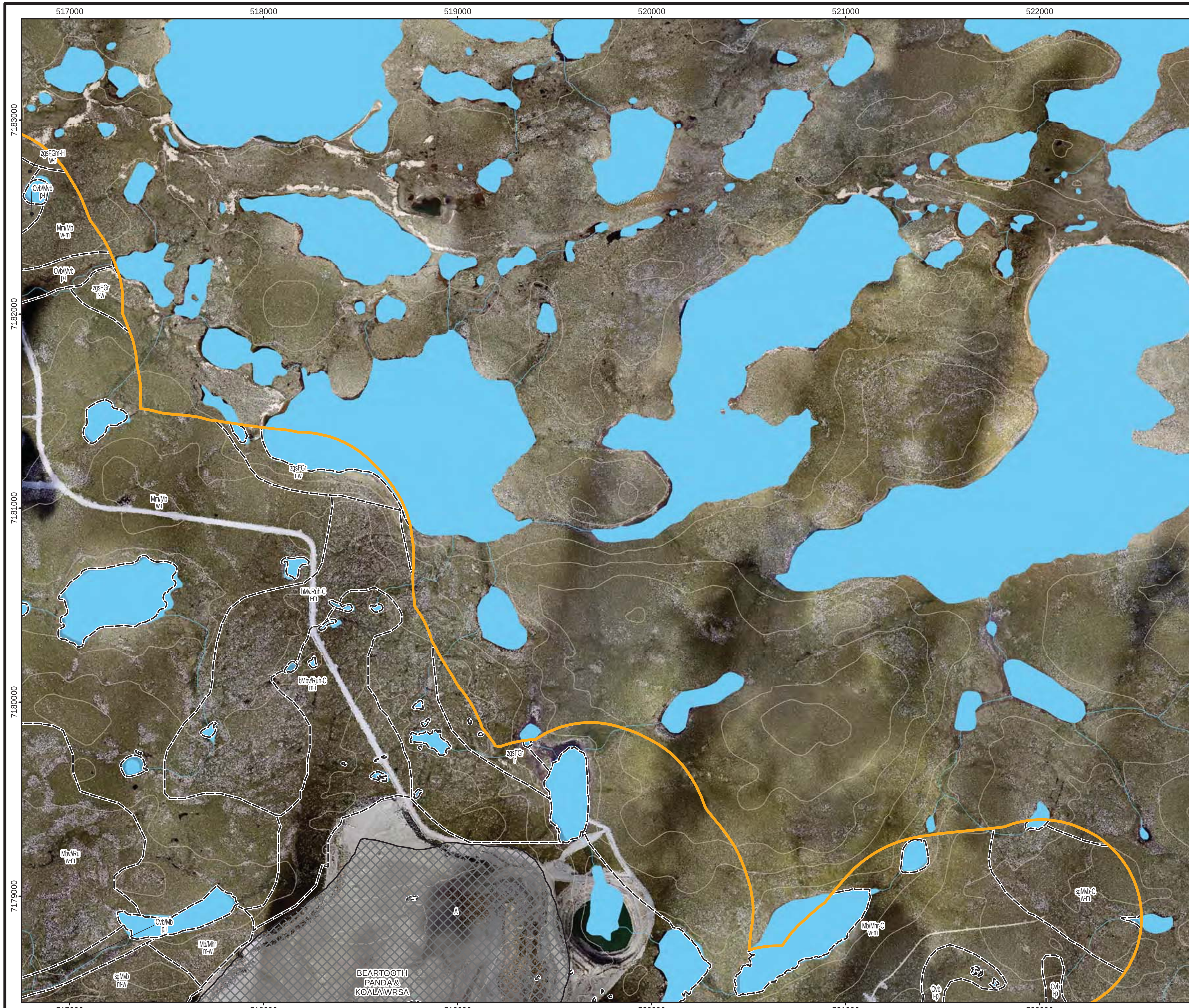

LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
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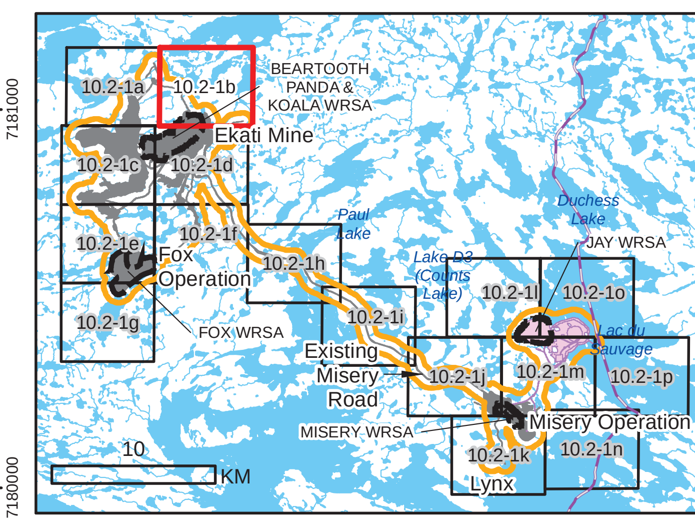
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION

Surficial Material; Geomorphological Process

Texture; Surface Expression; Delimiter; Drainage — sMv // Ru - Xr m — Process Subclass; Surface Expression



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TITLE

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GIS	JG	06/10/14	
CHECK	JF	06/10/14	MAP 10.2-1b
REVIEW	JV	06/10/14	

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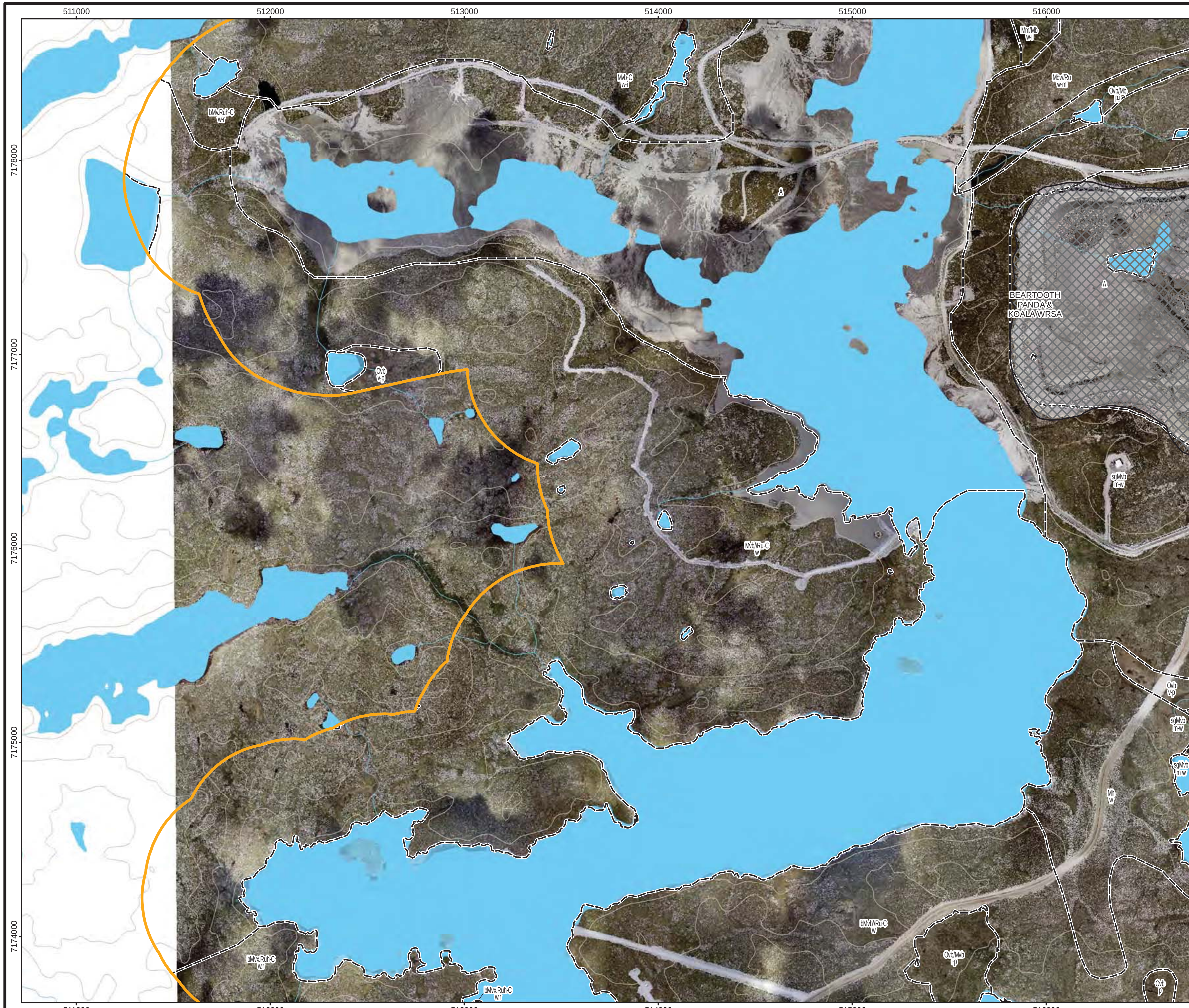

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LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
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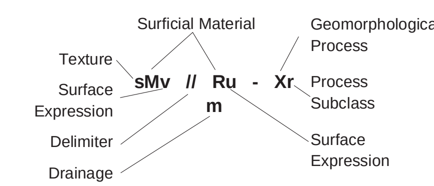
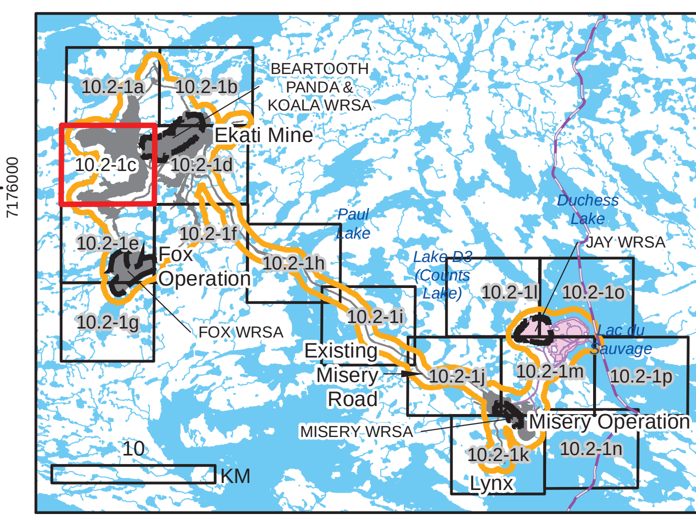
TERRAIN CLASSIFICATION





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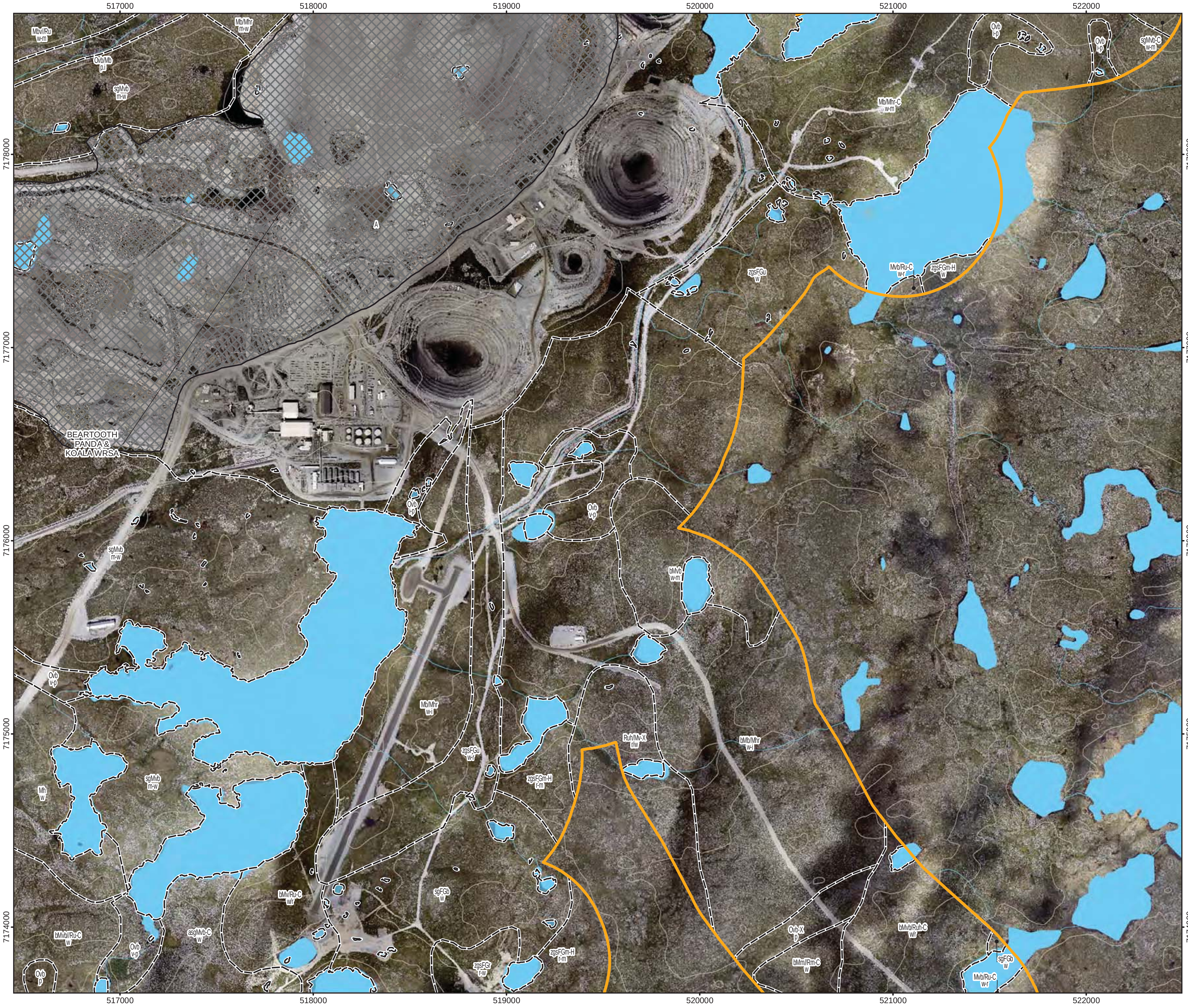

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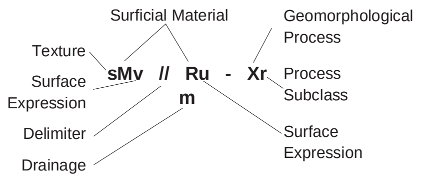
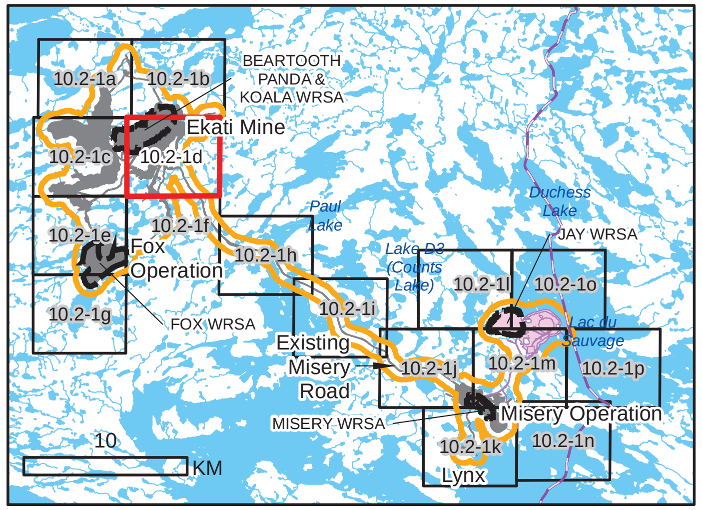
TERRAIN CLASSIFICATION





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GIS	JG	06/10/14	
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REVIEW	JV	06/10/14	

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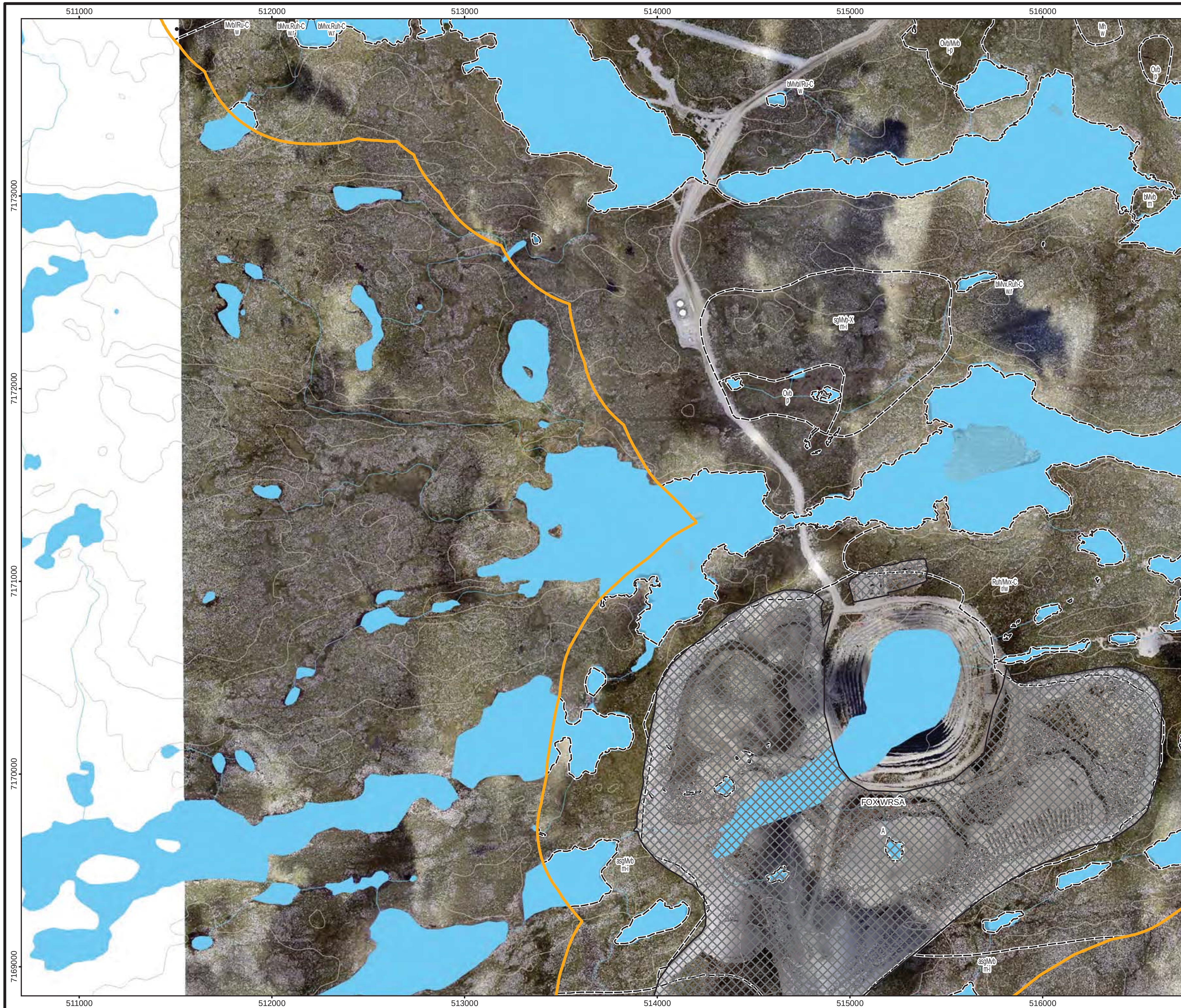

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LEGEND

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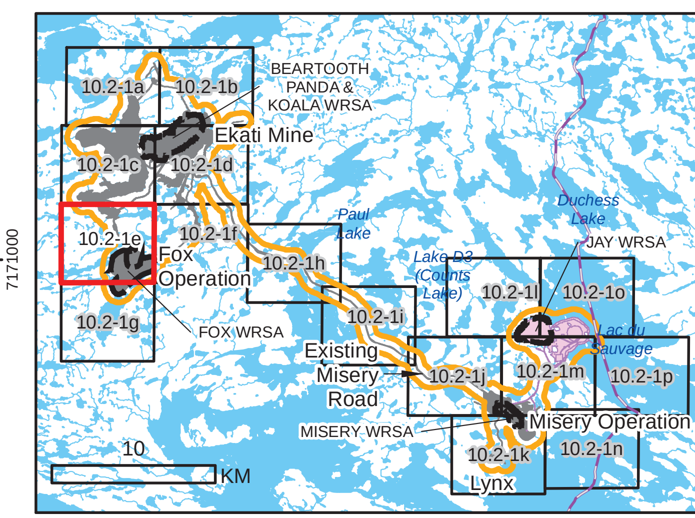
TERRAIN CLASSIFICATION

sMv // Ru - Xr
m

Texture; Surface Expression; Delimiter; Drainage; Surficial Material; Geomorphological Process; Process Subclass; Surface Expression



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NORTHWEST TERRITORIES, CANADA

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Golder Associates

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GIS	JG	06/10/14	MAP 10.2-1e
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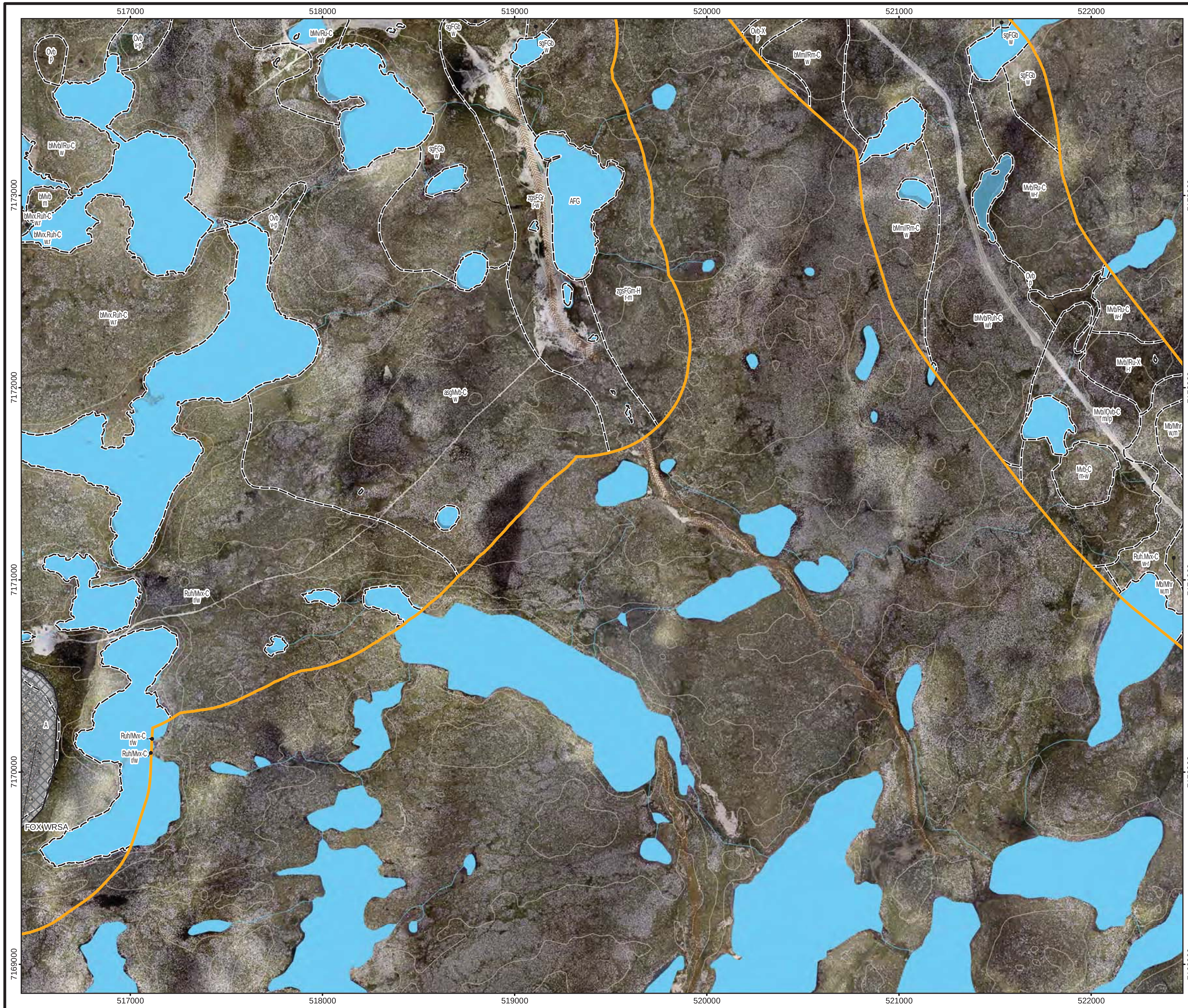

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LEGEND

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- PROPOSED JAY FOOTPRINT
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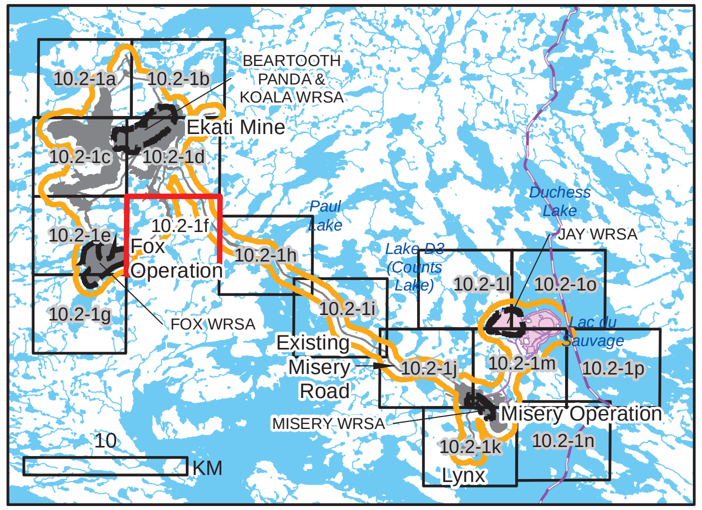
TERRAIN CLASSIFICATION

sMv // Ru - Xr
m

Texture; Surface Expression; Delimiter; Drainage; Surficial Material; Geomorphological Process; Process Subclass; Surface Expression



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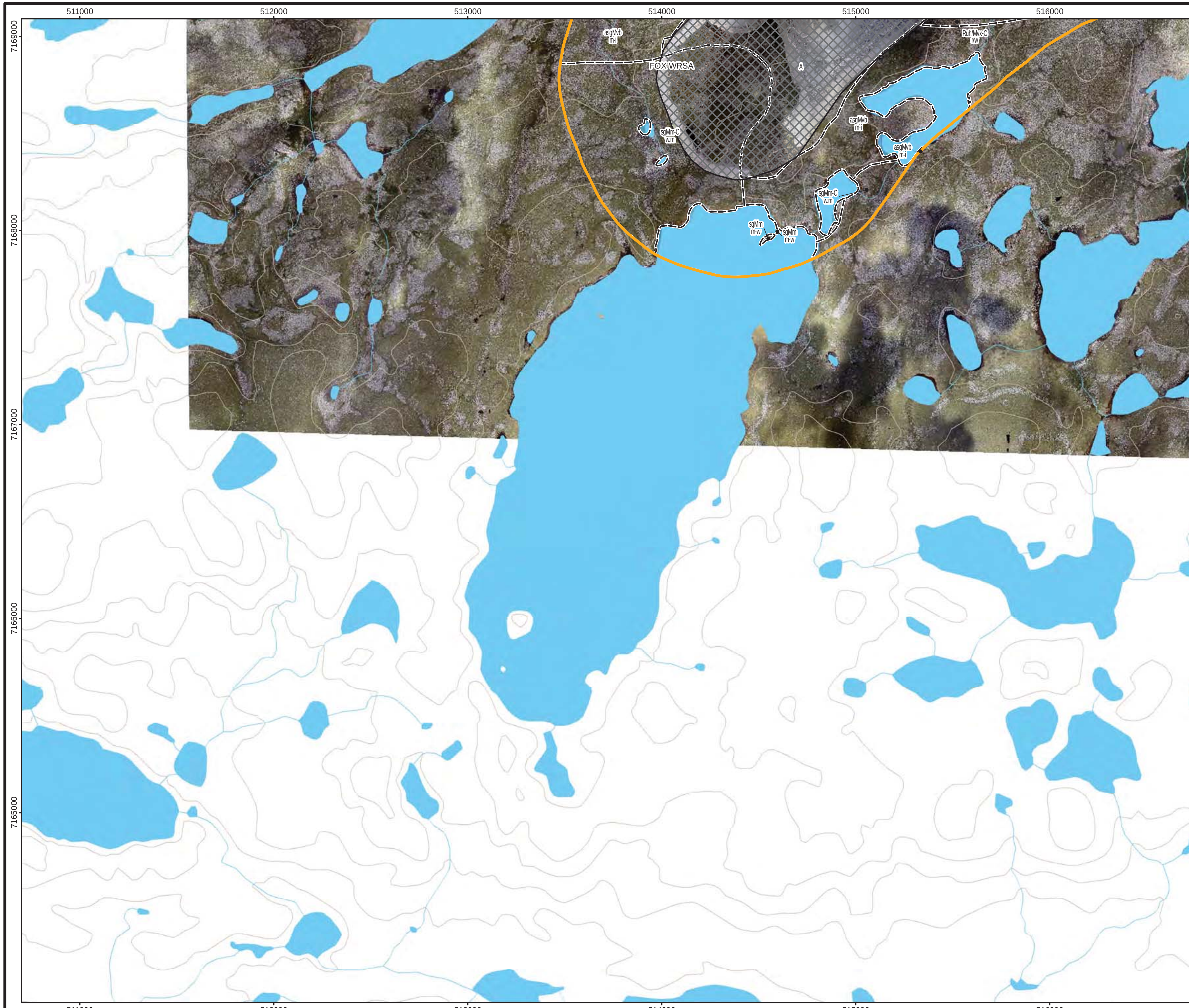

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LEGEND

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- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
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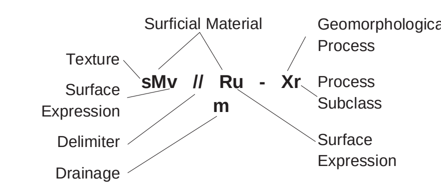
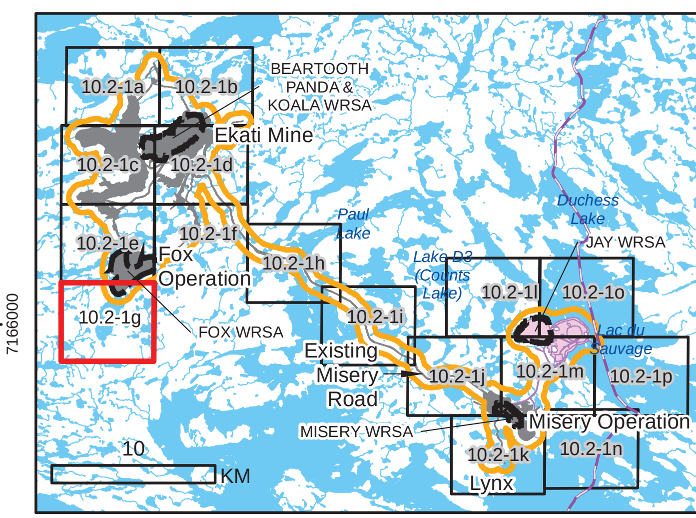
TERRAIN CLASSIFICATION





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REVIEW	JV	06/10/14	

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LEGEND

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- PROPOSED JAY FOOTPRINT
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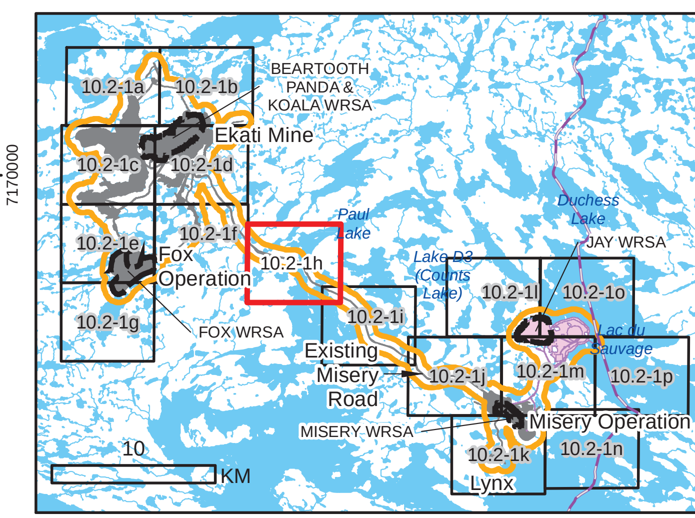
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION

sMv // Ru - Xr
m

Texture; Surficial Material; Surface Expression; Delimiter; Drainage; Geomorphological Process; Process Subclass; Surface Expression



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REVIEW	JV	06/10/14		

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LEGEND

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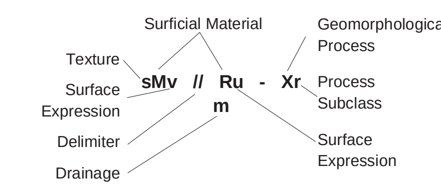
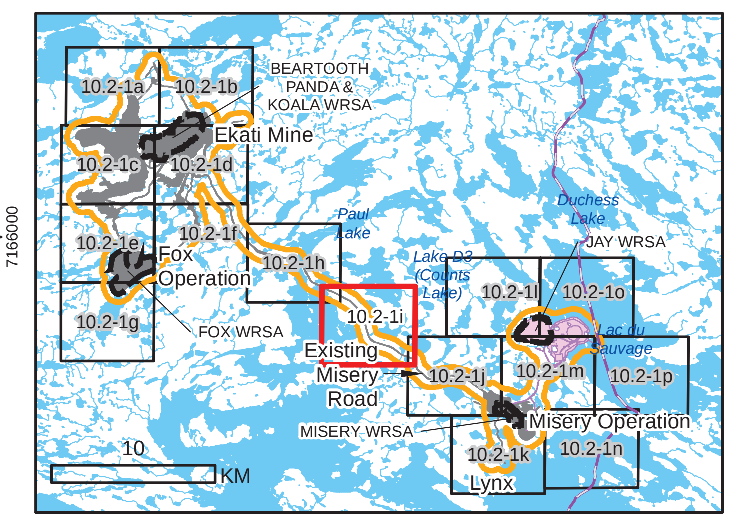
TERRAIN CLASSIFICATION





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LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
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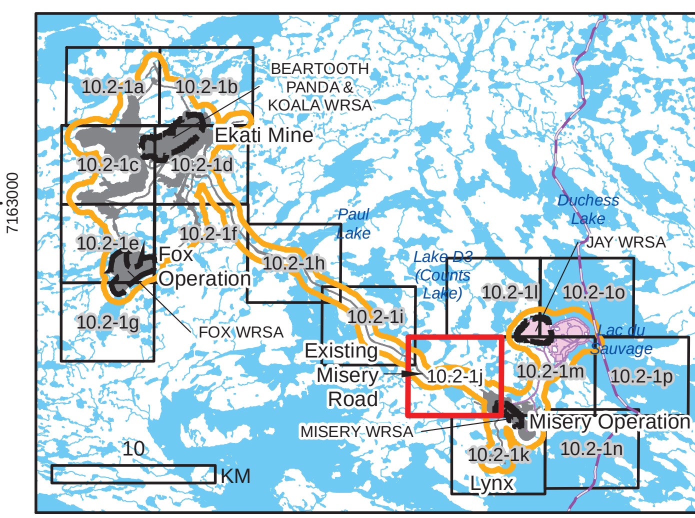
TERRAIN CLASSIFICATION

sMv // Ru - Xr
m

Surficial Material; Texture; Surface Expression; Delimiter; Drainage; Geomorphological Process; Process Subclass; Surface Expression



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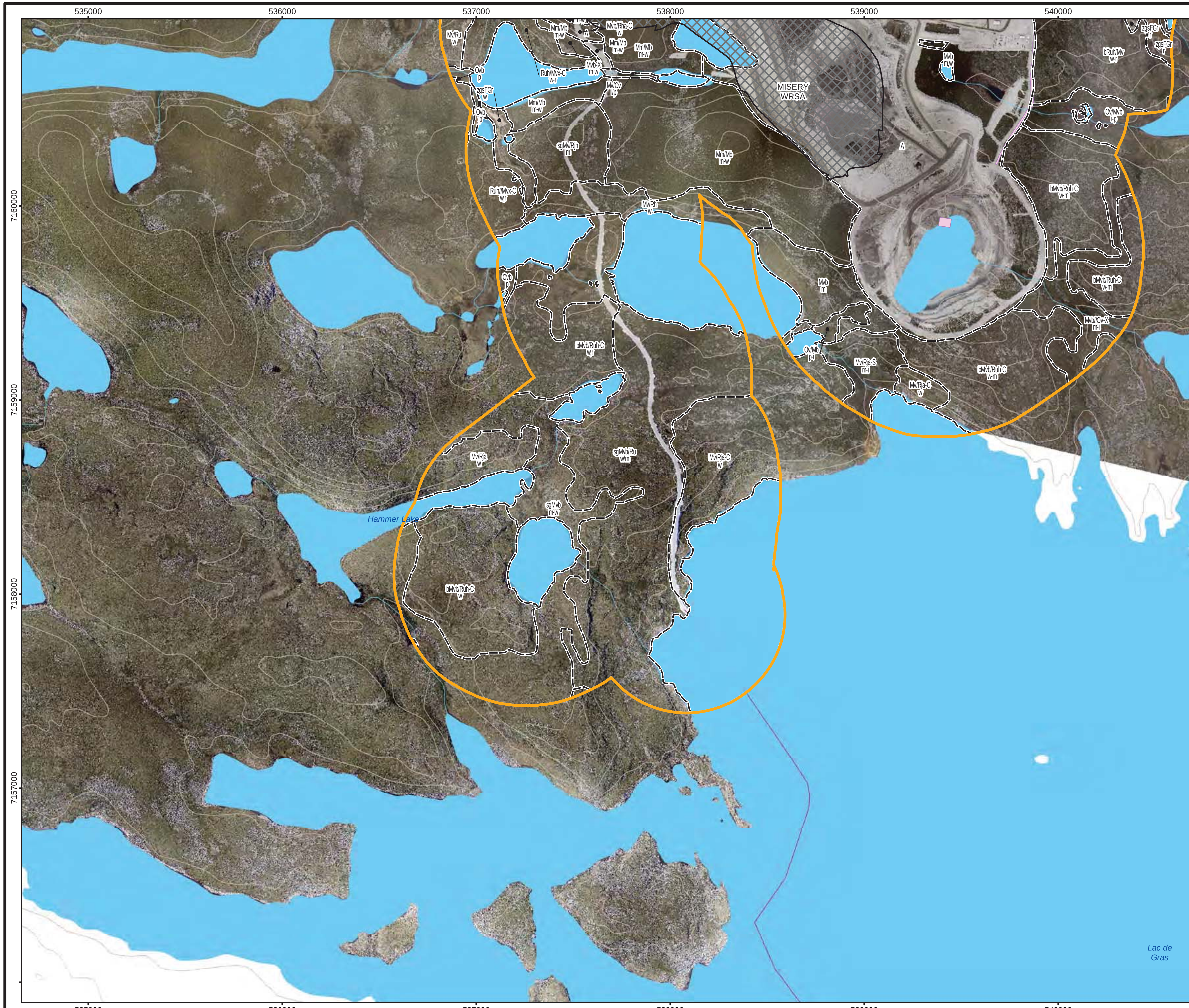

LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
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TERRAIN CLASSIFICATION

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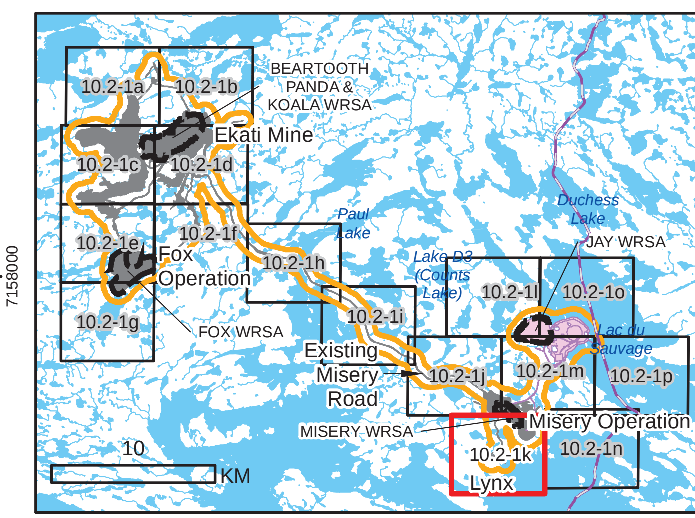

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REVIEW	JV	06/10/14	

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LEGEND

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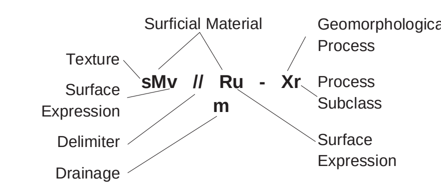

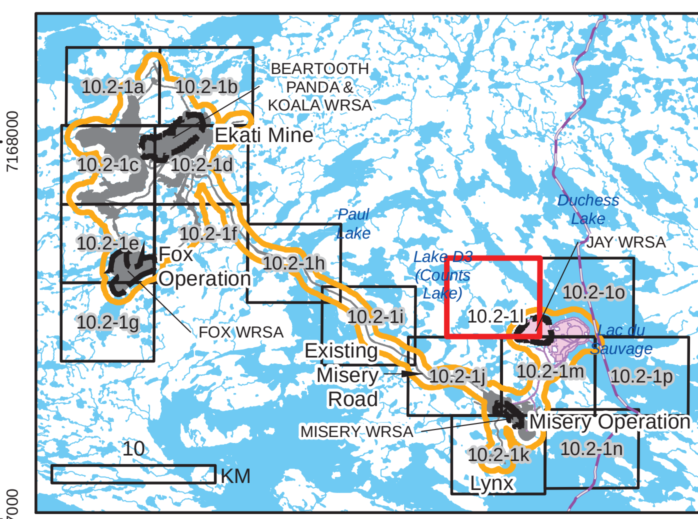

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DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

400 0 400

SCALE 1:20,000 METRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

TERRAIN UNITS WITHIN THE EFFECTS STUDY AREA

Golder Associates

PROJECT	13-1328-0041		DAR_Terr_003_GIS
DESIGN	WM	04/03/14	SCALE AS SHOWN REV 0
GIS	JG	06/10/14	MAP 10.2-1l
CHECK	JF	06/10/14	
REVIEW	JV	06/10/14	

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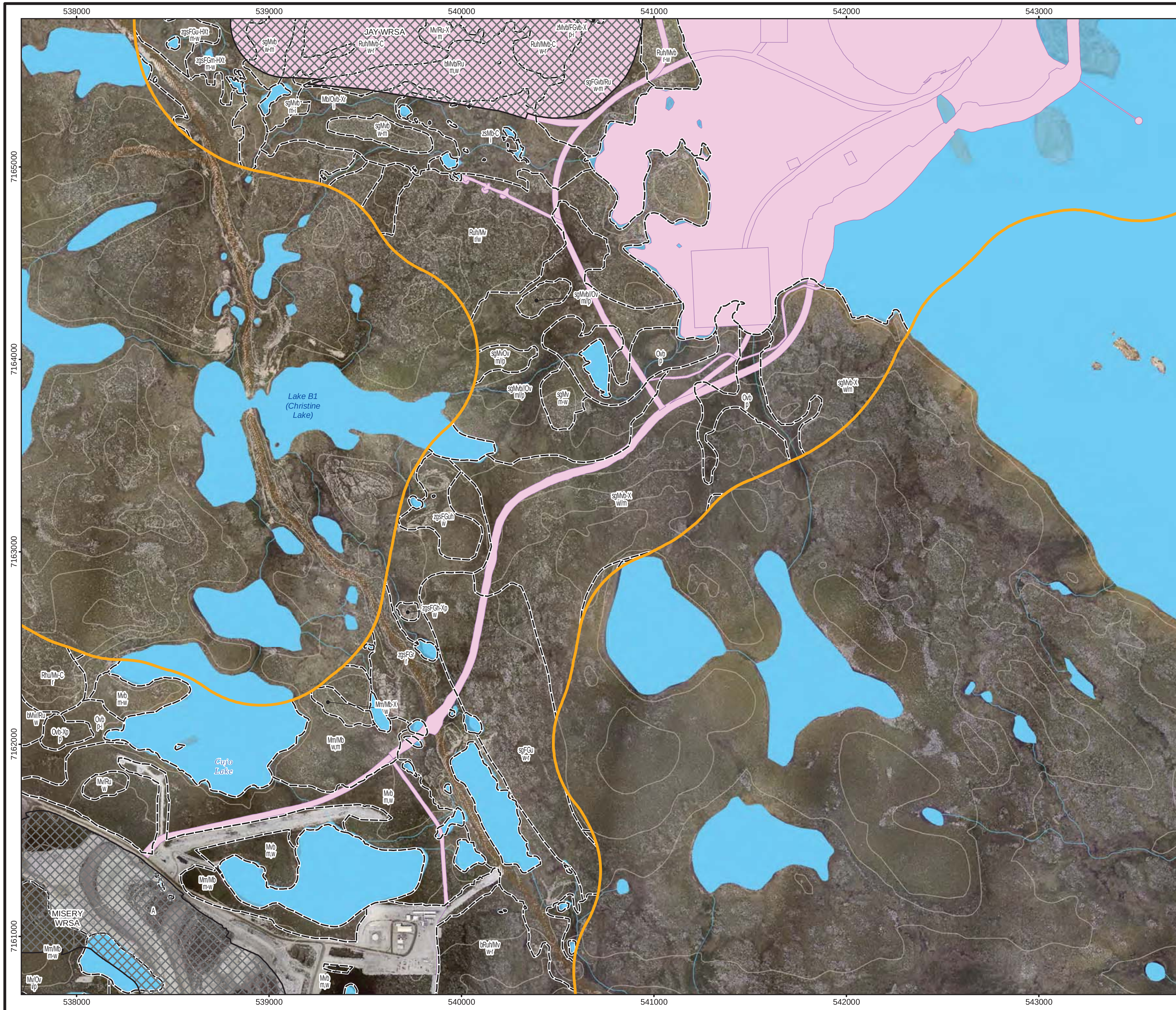
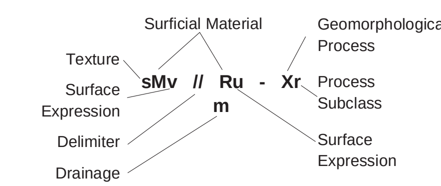
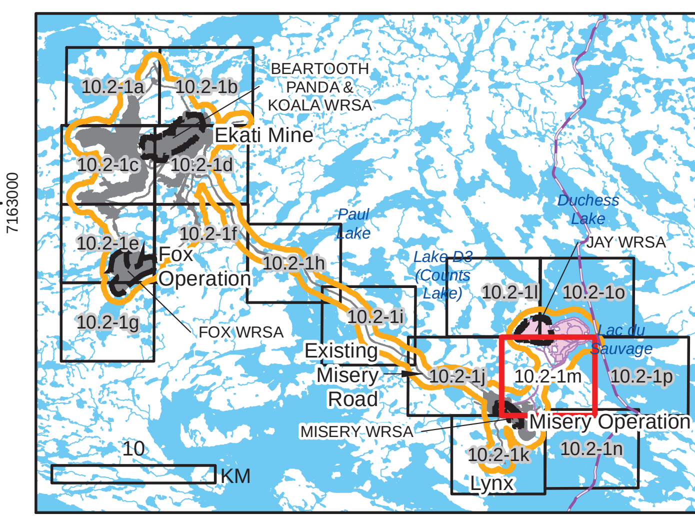


LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- TERRAIN POLYGON BOUNDARY (APPROXIMATE)
- WASTE ROCK STORAGE AREA (WRSA)
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION





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JAY PROJECT
NORTHWEST TERRITORIES, CANADA

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Golder Associates

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GIS	JG	06/10/14	**MAP 10.2-1m**	
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REVIEW	JV	06/10/14		

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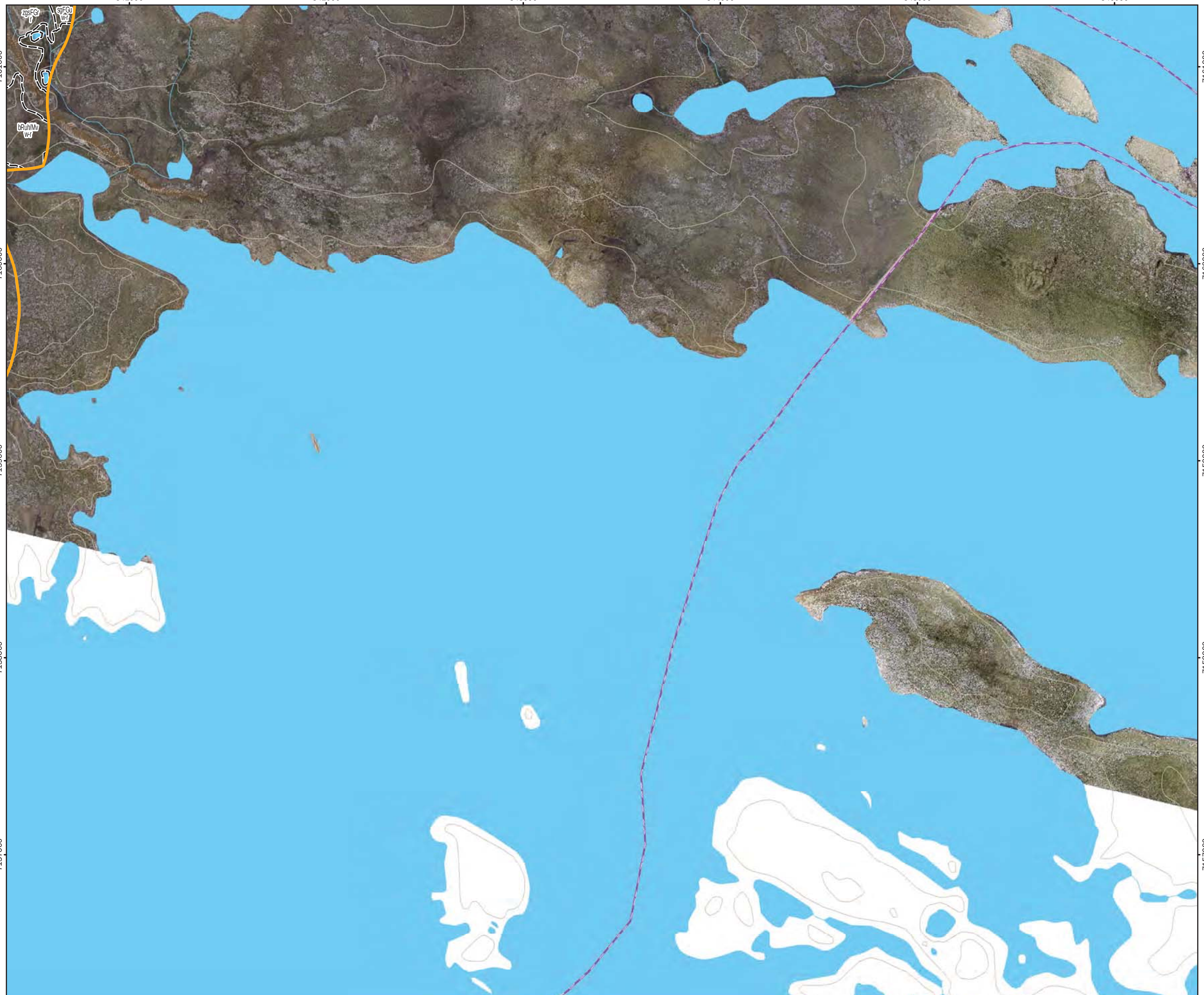

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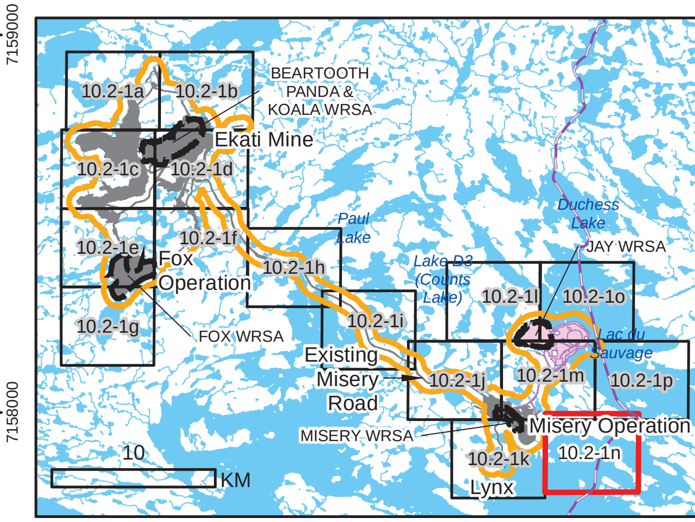
LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- TERRAIN POLYGON BOUNDARY (APPROXIMATE)
- WASTE ROCK STORAGE AREA (WRSA)
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION

Surficial Material
Geomorphological Process
Texture
sMv // Ru - Xr
m
Surface Expression
Process Subclass
Delimiter
Drainage
Surface Expression



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NORTHWEST TERRITORIES, CANADA

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Golder Associates

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GIS	JG	06/10/14	MAP 10.2-1n	
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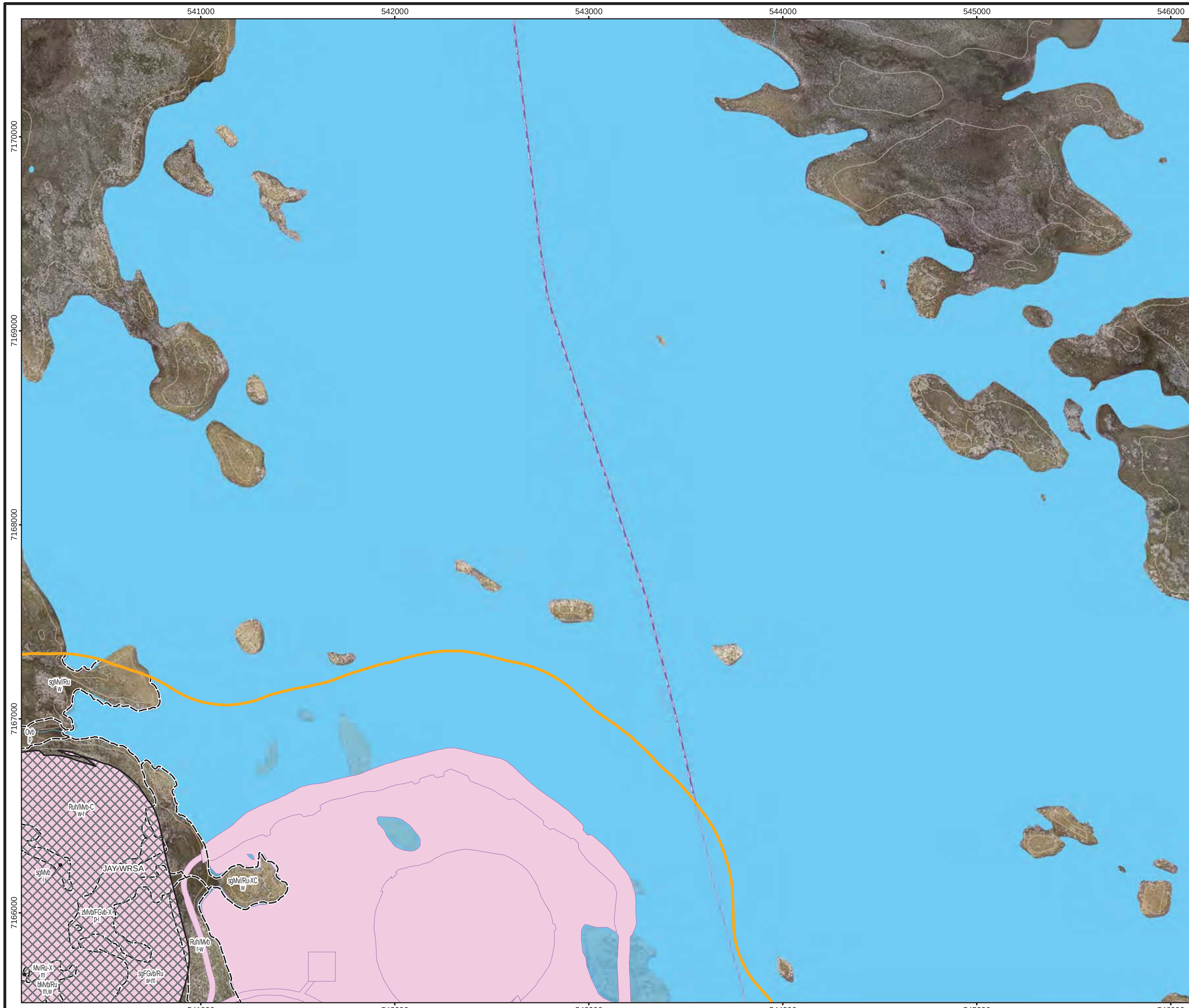

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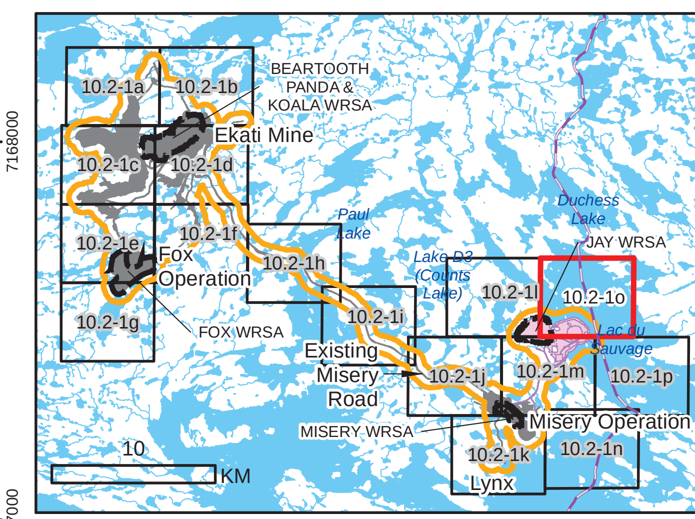
LEGEND

EKATI MINE FOOTPRINT
PROPOSED JAY FOOTPRINT
NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
ELEVATION CONTOUR (10 m INTERVAL)
WATERCOURSE
WATERBODY
TERRAIN POLYGON BOUNDARY (APPROXIMATE)
WASTE ROCK STORAGE AREA (WRSA)
EFFECTS STUDY AREA

TERRAIN CLASSIFICATION

Surficial Material; Geomorphological Process; Texture; Surface Expression; Process Subclass; Delimiter; Drainage; Surface Expression

sMv // Ru - Xr
m



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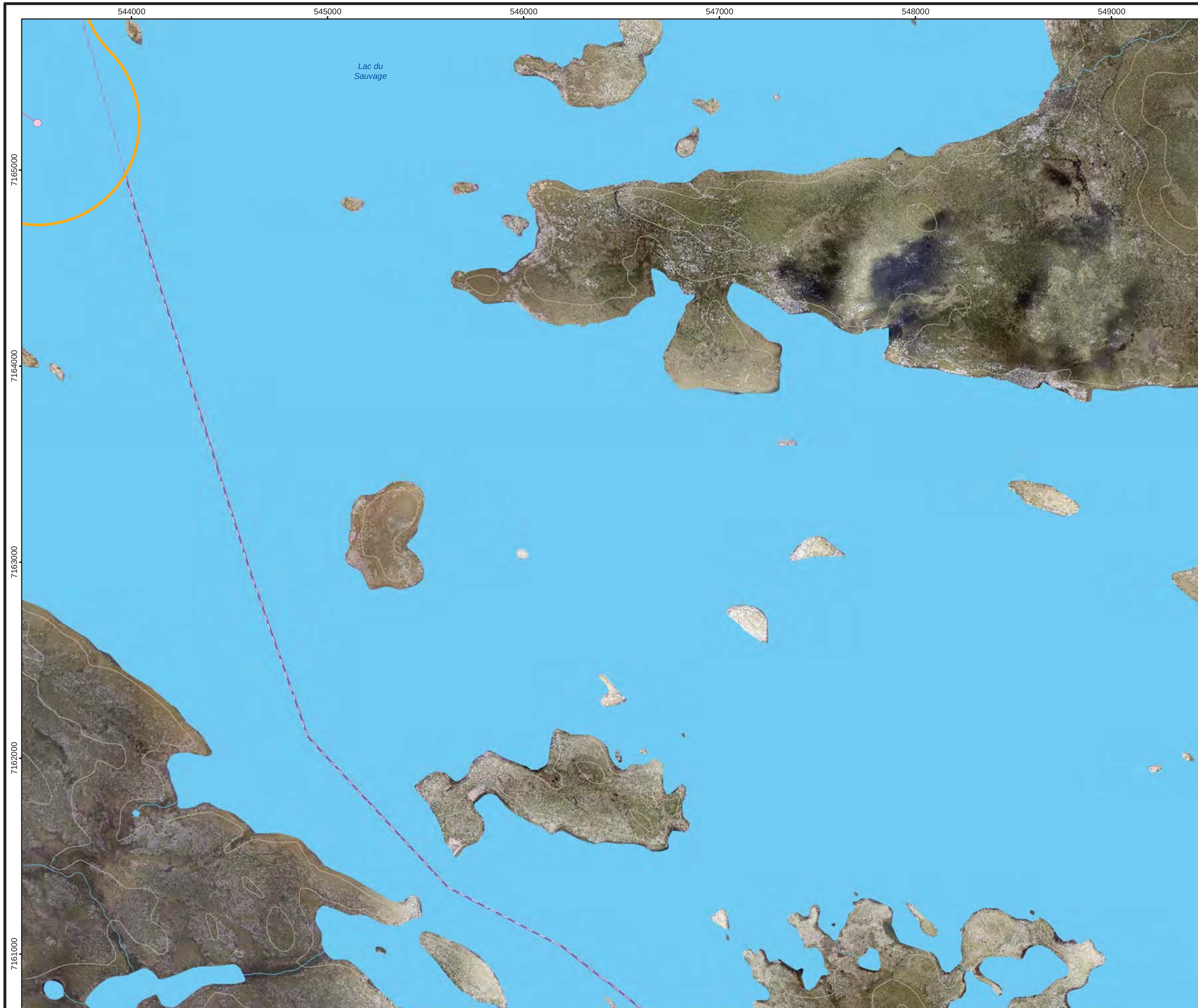

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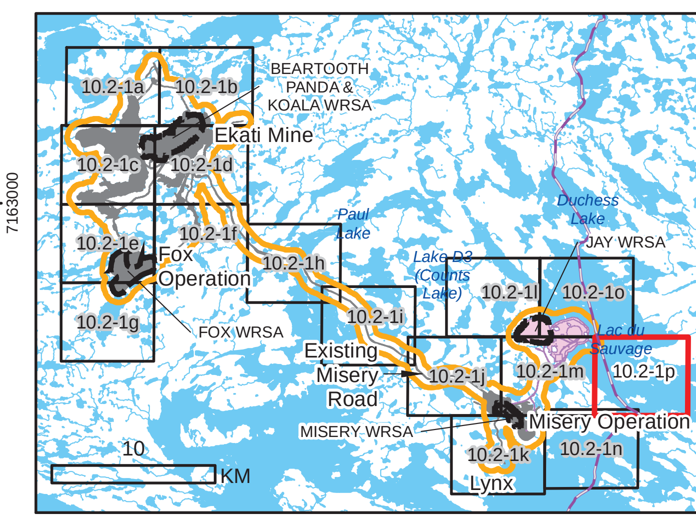
- WASTE ROCK STORAGE AREA (WRSA)
- EFFECTS STUDY AREA

TERRAIN CLASSIFICATION

sMv // Ru - Xr
m

Surficial Material; Texture; Surface Expression; Delimiter; Drainage; Geomorphological Process; Process Subclass; Surface Expression



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10.3 Environmental Effects on Geotechnical Stability of Engineered Structures

The Project will have a number of engineered structures that can be influenced by natural environmental factors. These engineered structures include the WRSA, the dike, sumps, and site access roads. Seismic activity can reduce or disrupt the geotechnical stability of physical structures. In addition, scientific evidence suggests that the Earth is undergoing a period of climate change. Predictions for climate change in northern environments include increased temperatures, increased precipitation in winter, and drier conditions in summer (Stewart et al. 1997). The geotechnical stability of engineered structures can also be influenced by climate-related changes to:

- temperature;
- permafrost;
- precipitation (including extreme precipitation events); and,
- seasonal flooding and melt patterns.

10.3.1 Climate Change-Related Effects

10.3.1.1 Temperature

10.3.1.1.1 Methods

Annual, seasonal, and monthly air temperatures were calculated from the derived long-term record of daily air temperature, and summary statistics were calculated to characterize mean and extreme conditions at the Project (Annex X). Mean air temperatures were used to describe mean site conditions, and standard deviations, minimum, and maximum values were used to indicate the variability of air temperatures. The distributions of mean seasonal and monthly air temperatures were also examined to identify the warmest and coldest periods of the year (Annex X).

A long-term time series of daily air temperature for the Project extending from 1959 to 2013 (55 years) was derived using temperature records from two regional climate stations operated by Environment Canada and two local climate stations at the existing Diavik and Ekati mines. Maximum and minimum daily air temperatures occurring over the 55-year record were extracted from the derived daily time series for each month of the year (Environment Canada 2013b). Trend analysis of annual air temperatures from 1959 to 2013 was conducted to detect changes over time in the dataset. The non-parametric Mann-Kendall test for trend was used, which does not rely on assumptions that the data are drawn from a given probability distribution (Helsel and Hirsch 2002). The significance of Kendall's tau correlation coefficient was tested at the 5% level to determine if there was a trend in the annual time series.

10.3.1.1.2 Results

Annual and seasonal air temperatures at the Project, calculated from the derived record of daily mean air temperatures extending from 1959 to 2013, are summarized in Table 10.3-1. Seasons are defined based on the occurrence of the March and September equinoxes and the June and December solstices over the same time period (Annex X).

Annual air temperature at the site ranges from -12.1°C to -6.0°C over the 55-year record, with a mean value of -9.6°C. Seasonal air temperatures remain below zero for three of the four seasons, from fall through to spring. Seasonal air temperatures are lowest in the winter, when the mean air temperature is -27.8°C, and are highest in the summer, when the mean air temperature is 10.0°C. The summer mean air temperature shows the least variability over the time period, with a lower standard deviation than the other seasonal mean air temperatures (Annex I).

Table 10.3-1 Derived Annual and Seasonal Air Temperatures, 1959 to 2013

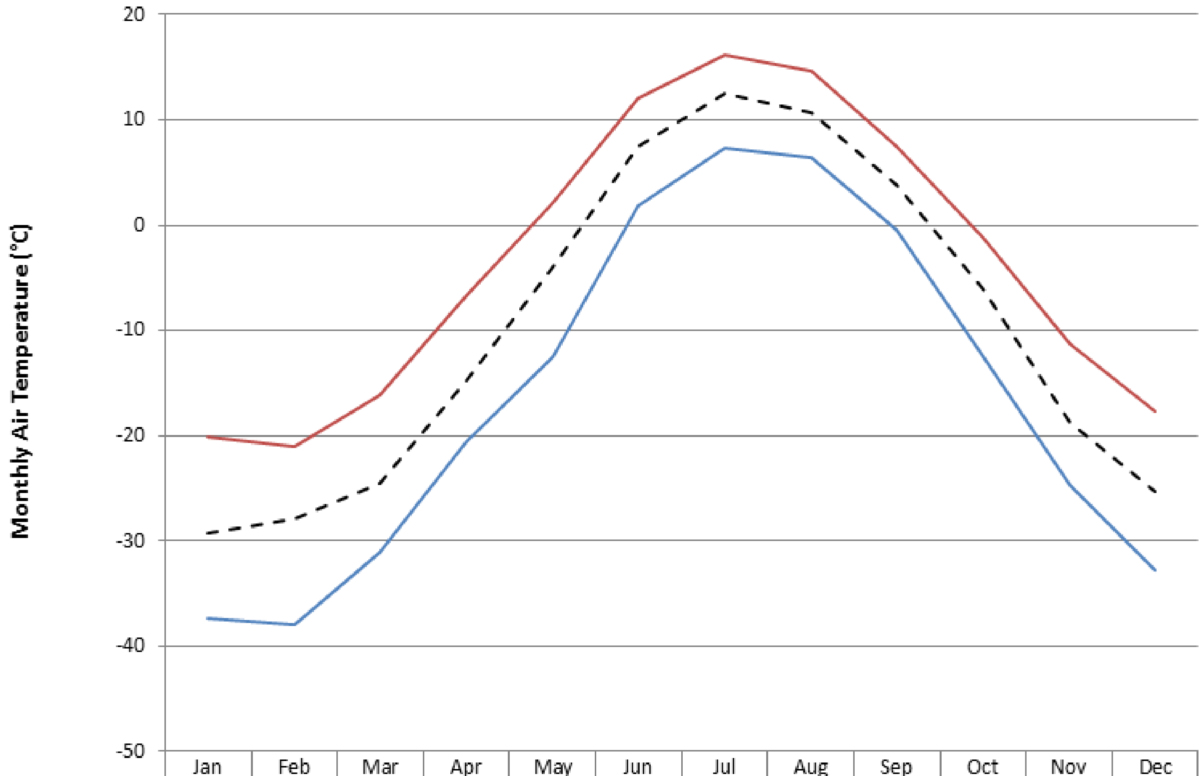
Year/Season	Period	Statistic	Air Temperature (°C)
Annual	Jan 1 – Dec 31	mean	-9.6
		standard deviation	1.4
Winter	Dec 21 – Mar 19	mean	-27.8
		standard deviation	2.4
Spring	Mar 20 – Jun 20	mean	-7.7
		standard deviation	2.2
Summer	Jun 21 – Sep 21	mean	10.0
		standard deviation	1.3
Fall	Sep 22 – Dec 20	mean	-13.8
		standard deviation	2.2

°C = degrees Celsius.

Mean, maximum, and minimum monthly mean air temperatures for the Project, calculated from the derived record of daily mean air temperatures from 1959 to 2013, are shown in Figure 10.3-1.

Monthly air temperatures are consistently below 0°C for seven months of the year, from October to April, and are consistently above 0°C for only three months, from June to August. Monthly air temperatures in May and September may be above or below 0°C. Maximum and minimum mean monthly temperatures are lowest in February, which has a mean air temperature of -27.9ºC. July is the warmest month, with a mean air temperature of 12.5°C. Monthly air temperatures over the 55-year record range from -38.0°C in February to 16.2°C in July (Annex I).

Figure 10.3-1 Derived Monthly Air Temperatures, 1959 to 2013



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	-29.30	-27.92	-24.63	-14.86	-3.96	7.42	12.53	10.63	3.81	-6.15	-18.84	-25.36
Maximum	-20.07	-21.08	-16.24	-6.71	2.14	12.00	16.23	14.60	7.43	-1.25	-11.28	-17.77
Minimum	-37.35	-37.98	-31.12	-20.61	-12.54	1.76	7.30	6.40	-0.53	-12.59	-24.68	-32.75

°C = degrees Celsius.

Extreme daily air temperatures from the record derived for the Project for the period 1959 to 2013 are shown in Table 10.3-2. Derived daily mean air temperatures range from -50.1°C on February 3, 1968, to 25.3°C on July 25, 1991.

Table 10.3-2 Derived Extreme Daily Air Temperatures, 1959 to 2013

Month	Maximum Daily Mean Air Temperature (°C)		Minimum Daily Mean Air Temperature (°C)	
	Value	Day/Year	Value	Day/Year
January	-3.86	20/1981	-46.43	26/1990
February	-5.27	4/2012	-50.08	3/1968
March	-3.44	28/2000	-42.88	4/1979
April	2.73	28/1989	-37.71	13/1961
May	12.36	25/1994	-24.23	2/1959
June	21.13	29/2013	-7.61	1/1959
July	25.33	25/1991	3.24	7/1991
August	22.50	14/1989	-1.63	24/1982
September	16.92	2/1997	-8.04	30/2005
October	8.61	7/1988	-25.85	29/1978
November	0.20	3/1983	-38.62	25/1978
December	-5.24	15/2002	-41.16	24/1970

°C = degrees Celsius.

Analysis of derived annual air temperatures from 1959 to 2013 indicates a positive trend that is significant at the 5% level. Annual air temperatures have increased at an estimated rate of 0.05°C per year. Climate change-related factors are predicted to not affect site roads, dams, and dikes.

The WRSA does not need to be frozen to maintain physical stability or for geochemical management; however, a frozen condition within the WRSA is beneficial. The Jay WRSA is anticipated to freeze by permafrost aggradation into the pile. Permafrost aggradation in to the WRSA can be promoted by minimizing oxidation of waste rock through geochemical management and by scheduling the timing of waste rock placement in key areas.

Recent thermal modelling for the design of the Pigeon WRSA at the Ekati Mine was provided to the Wek'èezhìi Land and Water Board (WLWB) as part of the Water Licence requirements for the Pigeon WRSA Design. The thermal modelling validated that a 5 m thick cover of granite provides adequate thermal protection to maintain frozen conditions within the material below the cover under a 100-year climate change scenario consistent with CSA (2010). Even with an increased active layer thickness, there remains a very low likelihood of long-term seepage from the WRSA that would require active management for water quality.

10.3.1.2 Permafrost Regime Changes

10.3.1.2.1 Methods

Multiple geotechnical field investigations have been carried out for the Ekati Mine site since the 1990s. Numerous thermistors (devices to measure temperature using electrical resistance) were installed at various sites. Thermistor data from instruments installed by EBA (1998, 1999, 2008) and by Dominion Diamond were used in the baseline permafrost characterization study (Annex IV). Data from thermistors installed by EBA (2006) in waste rock or fill materials were not used for the baseline study.

Methods for determining existing permafrost conditions can be found in Annex IV and Annex X.
The thermistor installations used in this study are summarized in Table 10.3-3 and the locations of the thermistors are presented in Map 10.3-1.

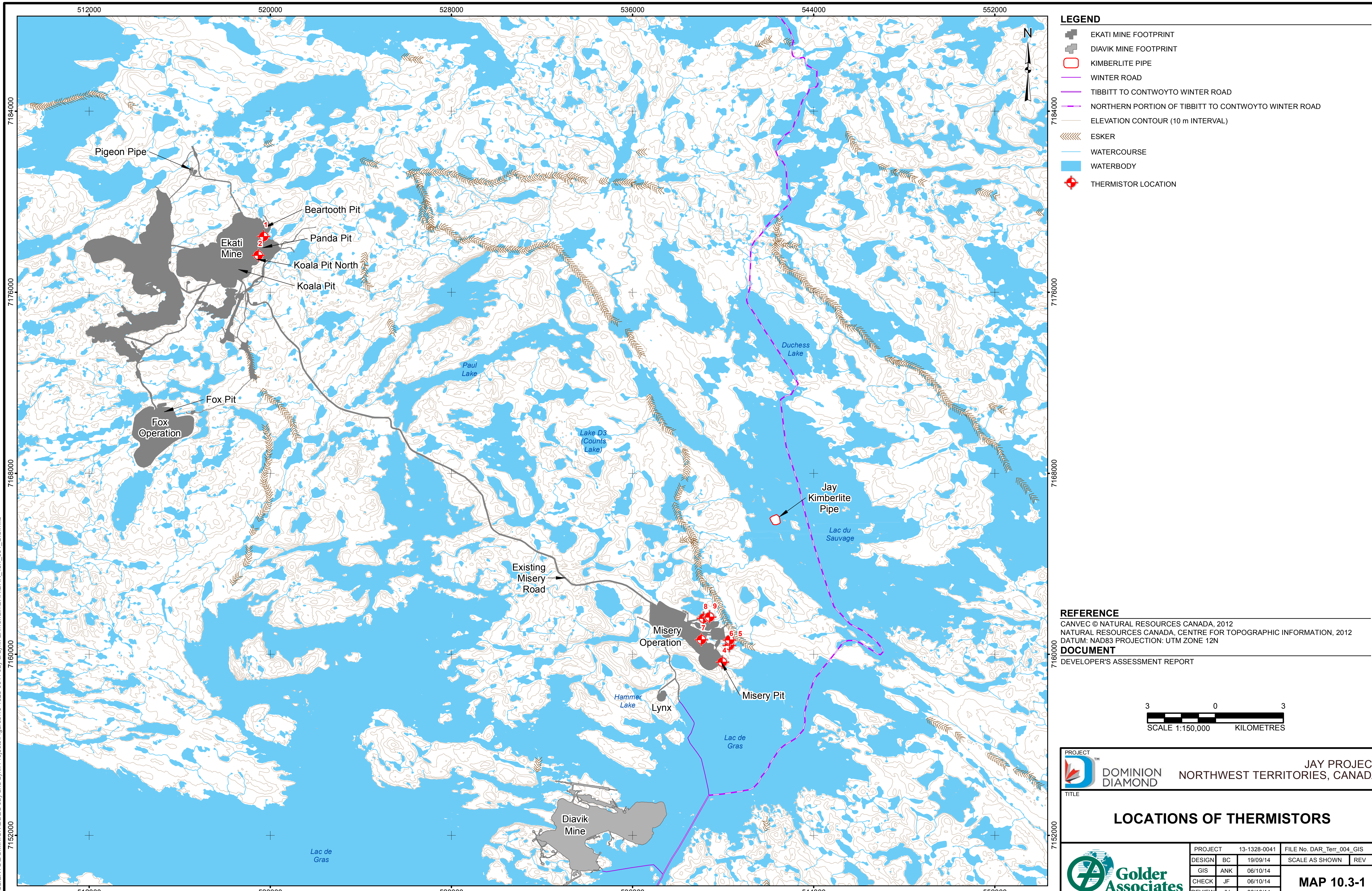
Thermal modelling for the Pigeon WRSA was conducted as part of the Waste Rock and Ore Management Plan (Dominion Diamond 2014). This model was developed as part of the submission of the WRSA Design Report to the WLWB for approval.

A 100-year climate warming scenario was integrated into the model to help predict long-term thermal effects. The Ekati Mine is located in Arctic Sector C1 as classified in Environment Canada and CSA (Dominion Diamond 2014). The predicted mean temperature changes from 1971 to 2000 baseline under the moderate greenhouse gas emission scenario at the Arctic Sector C1 (CSA 2010). The rates of the predicted temperature change were applied in the thermal analyses. Material properties used in the modelling were estimated from borehole logs and past experience with similar soils (Dominion Diamond 2014). The soil thermal properties were determined indirectly from well-established correlations with published soil index properties (Dominion Diamond 2014).

Table 10.3-3 Summary of Thermistor Installations

No.	Deposit Area	Borehole Name or No.	Thermistor Cable No.	Installation Date	Coordinates UTM Zone 12, NAD83 Northing (m)	Easting (m)	Ground Elevation (masl)	INCL (°)	AZ (°)	Cable Length (m)	Number of Thermistor Nodes	Source
1	Beartooth Pit	BGT-52	2148	25-Aug-08	7178465.02	519705.00	468.07	90	n/a	350	16	EBA 2008
2	Panda Pit	PGT-19	1344	14-Aug-99	7177640.06	519462.68	466.18	70	n/a	300	16	EBA 2008
3	Sable Pit	n/a	1471	25-Aug-01	7192457.20	523190.68	509.56	69.3	288.2	325	16	EBA 2008
4	Misery Pit	Lac de Gras	1472	12-Sep-01	7159665.58	539964.63	445.56	75	206	330	16	EBA 2008
5	Misery site	11580.018-01	1213	7-Apr-98	7160640.8	540283.5	432.07	90	n/a	15.4	10	EBA 1998
6	Misery site	11580.018-03	1211	8-Apr-98	7160408.3	540277.2	421.09	90	n/a	15.2	10	EBA 1998
7	Misery site	11580.018-08	1212	4-Apr-98	7160656.5	539036.5	448.28	90	n/a	15.4	10	EBA 1998
8	Misery site	11508.023-04	1291	16-Mar-99	7161592.5	539136.4	444.9	90	n/a	15	10	EBA 1999
9	Misery site	11508.023-09	1293	17-Mar-99	7161651	539397.6	445.6	90	n/a	15	10	EBA 1999

No. = number; UTM = Universal Transverse Mercator; NAD = North American Datum; m = metre; masl = metres above sea level; INCL = angle of inclination; AZ = azimuth; ° = degrees; n/a = not available.



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Beartooth Pit
Panda Pit
Ekati Mine
Koala Pit North
Koala Pit
Fox Pit
Fox Operation
Paul Lake
Lake D3 (Counts Lake)
Duchess Lake
Jay Kimberlite Pipe
Lac du Sauvage
Existing Misery Road
Misery Operation
Misery Pit
Hammer Lake
Lynx
Lac de Gras
Diavik Mine
Lac de Gras
LEGEND
EKATI MINE FOOTPRINT
DIAVIK MINE FOOTPRINT
KIMBERLITE PIPE
WINTER ROAD
TIBBITT TO CONTWOYTO WINTER ROAD
NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
ELEVATION CONTOUR (10 m INTERVAL)
ESKER
WATERCOURSE
WATERBODY
THERMISTOR LOCATION
REFERENCE
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JAY PROJECT
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TITLE
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Golder Associates
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REVIEW JV 06/10/14
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10.3.1.2.2 Results

The Jay Project is located within a region of continuous permafrost. The mean annual air temperature is about -9.6°C (Section 10.2.3 and Section 10.3.1.1.2).

Lac du Sauvage had a surface level of elevation 416.18 metres above sea level (masl) in the summer of 2013. The bathymetric survey indicates the deepest area of Lac du Sauvage is around the Jay kimberlite pipe, with the base at elevation 381 masl, which is 35 m below the lake surface.

In the summer, lake water temperatures at deep areas are typically similar to or slightly cooler than temperatures at shallow areas. Lac du Sauvage had an average temperature range of 12°C to 12.8°C in July to September 2006 at a measured depth up to 17.1 m (approximately half the depth of the lake). In the winter under ice, Lac du Sauvage water temperatures are typically warmer at deeper areas than temperatures at shallow areas. At a maximum measured depth of about 17 m, the average temperature was about 2.2°C from February to May 2006 (Rescan 2007). Since lake water temperatures increase with depth to a maximum of 4°C in winter, the water temperature at the maximum depth (35 m below the lake surface) was assumed to be 4°C.

Taliks (areas of unfrozen ground) are to be expected where lake depths are greater than the ice thickness. Formation of open taliks that penetrate through the permafrost may also be expected for relatively deeper and larger lakes in the ESA. Taliks can be open, where the ground beneath the lake is completely thawed, or closed taliks, where at some depth permafrost exists beneath the lake (Annex IV).

Critical lake sizes for open-talik formation were estimated using the analytical solutions for the Ekati Mine area, based on a mean annual ground temperature of -6°C, assumed mean annual lake-bottom temperatures of 4°C and 2°C, and mean annual terrace temperatures of -2°C, which gives the following findings:

- Taliks that extend through the permafrost will exist beneath circular lakes that have a minimum radius of 206 to 250 m, and beneath elongate lakes that have a minimum half width of 99 to 133 m, without considering lake terrace geometries.
- When terrace effects are included in the analyses, the critical radius for a circular lake increases to 219 to 263 m, and the critical half width for an elongate lake increases to 105 to 140 m, assuming that the terrace is 20% the total lake width or diameter.

Based on the open-talik formation calculation, an open talik would be expected beneath Lac du Sauvage due to its relatively large size. Permafrost is expected to exist under the islands and peninsulas in Lac du Sauvage, with the depths being a function of the sizes of the islands and peninsulas.

Permanently frozen soil and rock generally extends deep below the ground surface and is overlain by a seasonally thawed active layer. The thickness of the active layer in the Jay pipe area is expected to be similar to the thickness in the Misery Pit area (approximately 1 to 2.7 m) (Annex IV and Annex X).

The base of the permafrost is expected to be an irregular surface; therefore, the actual depth to permafrost will be variable. In the local context of the Project, the land surface is underlain by continuous permafrost, except under bodies of water too deep to freeze to the bottom during winter.

A thermistor (JGT-01) was installed on an island east of the Jay pipe as part of the 2014 winter investigation program. The depth of permafrost beneath the land mass at the Project site is estimated to be approximately 320 to 485 m, based on data from this thermistor. The extrapolated mean annual surface temperature estimated from the thermistor data is in the range of -4.0°C to -6.1°C. Preliminary thermal models estimate that the depth of the permafrost beneath a small island southeast of the Jay pipe is approximately 157 to 182 m. The estimated depth of the zero annual amplitude from the temperature profiles ranges from 15 to 30 centimetre (cm). The geothermal gradient ranges from 0.012 degrees Celsius per metre (°C/m) to 0.018°C/m, with an average of 0.015°C/m.

In April 2014, a second thermistor JGT-07 was installed on the same island as thermistor JGT-01 to monitor the thermal conditions of the upper soil layer. At the time of preparation of the DAR, measurements for thermistors had started to stabilize with a temperature approximately -3°C at a depth of about 16 mbgs (elevation 404 masl) (Annex IV). Additional readings will be collected to determine the maximum depth of the active layer and to confirm thermal ground conditions on this island.

The salinity level of the deep groundwater in the study area is expected to be elevated, which will result in freezing point depression so that the depth of frozen permafrost (depth to the basal cryopeg) is less than the depth of perennially cryotic ground (ground at a temperature less than 0°C) (Annex IV). A porewater salinity range of 1.3 to 9.5 parts per trillion (ppt) for 0 to 500 m depth has been reported in the literature for the Canadian Shield. An estimated freezing point depression of -0.4°C to -1°C for a porewater salinity range of 3 to 14 ppt was reported by EBA (2008) for the Ekati Mine. The TDS of groundwater samples from the Panda and Koala underground mines are typically high, and freezing point depression is estimated to be between -1.4˚C and -2˚C at 300 m and 400 m depth, respectively. Due to freezing point depression, the permafrost depth (depth to basal cryopeg) is estimated for the Ekati Mine as follows:

The depth of permafrost (depth to the basal cryopeg) for a -1°C freezing point depression is estimated to be between 250 m and 415 m below ground surface. The depth of permafrost (depth to the basal cryopeg) for a -2°C freezing point depression is estimated to be between 185 m and 350 m below ground surface. However, the groundwater salinity under Lac du Sauvage may be lower than salinity measured in the ground outside of large lakes, according to the reported groundwater TDS measurements from the Diavik Mine site near Lac de Gras (Annex IV).

For the Project, groundwater samples were collected from a Westbay monitoring well system installed in April 2014. The samples had TDS concentrations ranging from approximately 1,670 milligrams per litre (mg/L) to 2,390 mg/L, which is much lower than those observed at the Ekati Panda and Koala pits. Therefore, the TDS in the Lac du Sauvage area is less beneath the shores of Lac du Sauvage.
The estimate of freezing point depression discussed above is thus considered to be conservatively high for the Project.

Climate change concerns were considered during mine planning and for long-term sustainable reclamation of the environment. Freeze-induced displacement of soil (i.e., frost jacking) and thaw-induced displacement of soil (i.e., subsidence) are the main concerns related to permafrost degradation (i.e., loss or alteration). Changes to thaw penetration and thickness of the active layer can influence surface stability through thaw settlement, frost heave, and reduced bearing capacity, as well as through slope instability (Tarnoicai et al. 2004).

Degradation of the permafrost beneath the foundation of a road could lead to differential settlement, which would require maintenance to re-establish road grades and eliminate variation in the road surface or in culverts installed at select locations beneath the road. Along portions of the road with a greater thickness of fill, permafrost degradation could lead to sloughing of the fill and minor slope instability. Permafrost aggradation beneath the road fill material may also occur, such that the active layer will no longer penetrate as deeply into the existing soil foundation. In some areas with certain foundation soils, freeze-related uplift displacements could occur, which would require maintenance to re-establish road grades. These processes are not anticipated to result in any adverse effects during the construction and operational phases of the Project.

Degradation of the permafrost beneath the foundation of the dike near the abutments or islands could lead to differential settlement, which would require maintenance to re-establish design elevations. The presence of permafrost within the bedrock may reduce the penetrability of grout injection. Degradation of the permafrost could increase seepage through the dike. This is most likely to occur near the abutments or islands, where permafrost exists. Hydraulic head and associated gradient in these locations is relatively low; therefore, the quantity of seepage and the potential for erosion of the dike, or piping of the dike or foundation soils, would be limited. Permafrost aggradation may occur beneath the dike on the abutments and islands, such that the active zone will no longer penetrate as deeply into the existing soil foundation. The extent of this process is not anticipated to result in any adverse effects.

For the Pigeon WRSA, one-dimensional and two-dimensional thermal analyses were conducted to compare the maximum active layer thickness under mean air temperature conditions and A1B climate-change scenarios of 50 years and 100 years (Dominion Diamond 2014). The depth of the active layer, under all climate-change scenarios modelled, was predicted to increase with time (Dominion Diamond 2014). The model also predicted the unfrozen zones would be created in the Pigeon WRSA when the waste rock placement rate exceeds the rate of permafrost aggradation.

Modelling under a 100-year climate-warming scenario indicates that a design of the WRSA with a 5 m cover of granite waste rock will provide adequate thermal protection. Freeze-back of the waste rock material is expected to occur within 8 to 12 years, depending on the degree of internal heat generation from the potentially acid generating (PAG) material (Dominion Diamond 2014). Similarly, the Jay WRSA is anticipated to freeze by permafrost aggradation into the pile. Installation of thermistors within the pile will allow monitoring of the thermal performance.

10.3.1.3 Precipitation

10.3.1.3.1 Methods

Long-term records of daily rainfall and snowfall for the Project extending from 1959 to 2013 were derived from two regional climate stations operated by Environment Canada, two local climate stations at the existing Diavik and Ekati mines, and manual measurements taken at the Diavik Mine. Information about the stations is summarized in Table 10.3-4.

Table 10.3-4 Regional and Local Climate Stations used to Derive Precipitation Record

Station Name	Operated by	Latitude (north)	Longitude (west)	Distance from Project (km)	Elevation (masl)	Precipitation Record
Contwoyto Lake (ID 2200850)	Environment Canada	65°29'	110°22'	99	451.4	1959-1981
Lupin (ID 22026HN)	Environment Canada	65°46'	111°15'	141	490.1	1982-2012
Koala (Ekati)	Dominion Diamond Ekati Corporation	64°48'	110°56'	28	~479	1993-2014
Diavik Mine AWS	Diavik Diamond Mines Inc.	64°29'	110°21'	16	~440	1998-2014
Diavik Evaporation (Manual)	Diavik Diamond Mines Inc.	64°29'	110°20'	16	~440	1998-2014

AWS = automatic weather station; km = kilometre; masl = metres above sea level; ID = identification; ~ = approximately.

Precipitation recorded at the Diavik climate stations is considered representative of the Project site conditions because these stations are most proximate to the Project. Rainfall data recorded at the Diavik Mine automatic weather station (AWS) and snowfall data collected at Diavik Evaporation station were used without correction for location. Snowfall data from the Diavik Mine AWS were not used, as that station under-reported snowfall and had missing data (Annex X). Rainfall data recorded at Koala Station were also used, without correction for location, when Diavik Mine AWS data were unavailable. The Koala Station is 28 km from the Project (Table 10.3-4).

Precipitation datasets for Contwoyto Lake and Lupin Mine were joined to create a combined record (i.e., Lupin Combined), as these stations are located within 50 km of each other. Golder (2008) attributed differences in mean annual precipitation at Contwoyto Lake (1959 to 1981) and Lupin Mine (1982 to 2006) to the natural wet and dry cycles in precipitation over time, rather than to differences in location. The monthly magnitudes and distributions of precipitation were also similar. Golder (2008) derived correction factors for the Lupin Combined rainfall and snowfall data sets to estimate precipitation at Diavik Mine AWS. The correction factor for annual rainfall was estimated to be 1.03, and the correction factor for annual snowfall was estimated to be 1.05, based on regional isographs and interpolation between values at Lupin Combined and Yellowknife Airport (Yellowknife A). Corrected rainfall and snowfall data for Lupin Combined were used to derive Project values where data were unavailable for the Diavik Mine and Ekati Mine meteorological stations.

Undercatch can be an important factor affecting precipitation measurements in the Arctic, leading to underestimates of actual precipitation. Environment Canada prepared an Adjusted Precipitation Data set, corrected for precipitation undercatch, for climate-change analysis (Environment Canada 2013a), and adjusted precipitation data for Lupin Mine are included in that dataset. Golder (2008) compared adjusted and unadjusted monthly rainfall and snowfall data for Lupin Mine, and determined mean correction factors of 1.12 for unadjusted rainfall data and 1.32 for unadjusted snowfall. These correction factors were applied to precipitation data recorded at Lupin Combined, Diavik Mine AWS, and Ekati Mine AWS.

To summarize the methods, long-term (1959 to 2013) daily rainfall and snowfall time series for the Project were derived from regional and local precipitation records using:

- Lupin Combined rainfall from 1959 to 1997, when data for Diavik and Ekati mines were unavailable, adjusted for location by applying a correction factor of 1.03;
- rainfall recorded at Diavik Mine AWS from 1998 to 2008, uncorrected for location;
- rainfall recorded at Koala Station from 2009 to 2013, when data for Diavik Mine AWS were unavailable, uncorrected for location;
- Lupin Combined snowfall from 1959 to 2001, adjusted for location by applying a correction factor of 1.05; and,
- snowfall recorded at Diavik Evaporation station from 2002 to 2013, uncorrected for location.

The resulting data sets were then adjusted to account for undercatch by applying correction factors of 1.12 (rainfall) and 1.32 (snowfall). Estimates of daily total precipitation were obtained by summing the daily rainfall and snowfall time series.

Annual, seasonal, and monthly rainfall, snowfall, and total precipitation were calculated from the derived long-term records, and summary statistics were calculated to characterize mean and extreme conditions at the Project. Mean rainfall, snowfall, and total precipitation were used to describe average site conditions, and standard deviations were used to indicate the variability of precipitation. The magnitudes and distributions of mean seasonal and monthly precipitation were also examined to identify when precipitation falls as rain and when it falls as snow, and the wettest and driest periods of the year (Annex X).

Frequency analyses of the derived annual rainfall, snowfall, and total precipitation from 1959 to 2013 were conducted to estimate precipitation amounts over a range of return periods (2, 5, 10, 25, 50, and 100 years) to characterize extreme wet and dry conditions at the Project. Five probability distributions (Normal, Log Normal, Pearson III, Log Pearson III, and Gumbel) were fitted to each data set. The data were charted, and goodness-of-fit statistics (i.e., coefficient of determination, standard error, and Chi-square ratio) were calculated. Precipitation amounts at various return periods were then estimated using the probability distribution with the best fit (Annex X).

Maximum daily rainfall and snowfall totals over the 55-year period of record (1959 to 2013) were extracted from the derived daily time series for each month of the year to characterize extreme wet conditions. Extreme rainfall amounts with durations of one day or longer were also estimated. Annual maximum 1, 3, 5, 10, 30, and 60-day rainfall depths were derived from the daily rainfall data set and were subjected to frequency analyses to estimate rainfall depths with return periods of 2, 5, 10, 25, 50, 100, 200, and 500 years under extreme wet conditions. The Gumbel probability distribution was fitted to each data set, the data were charted, and goodness-of-fit statistics were calculated. Rainfall amounts for the selected return periods were then estimated from the distribution. The Gumbel probability distribution is used by Environment Canada to estimate short-duration rainfall intensity-duration-frequency data for climate stations across Canada, and was used for the Project for consistency (Annex X).

Extreme rainfall amounts with shorter durations ranging from 5 minutes to 24 hours were similarly estimated. Estimates were based on the derived annual maximum 1-day rainfall amounts with return periods of 2, 5, 10, 25, 50, and 100 years and on ratios of t-hour to 24-hour rainfall depths (where t is a number of hours less than 24) from rainfall intensity-duration-frequency data published by Environment Canada for the four regional climate stations summarized in Table 10.3-5.

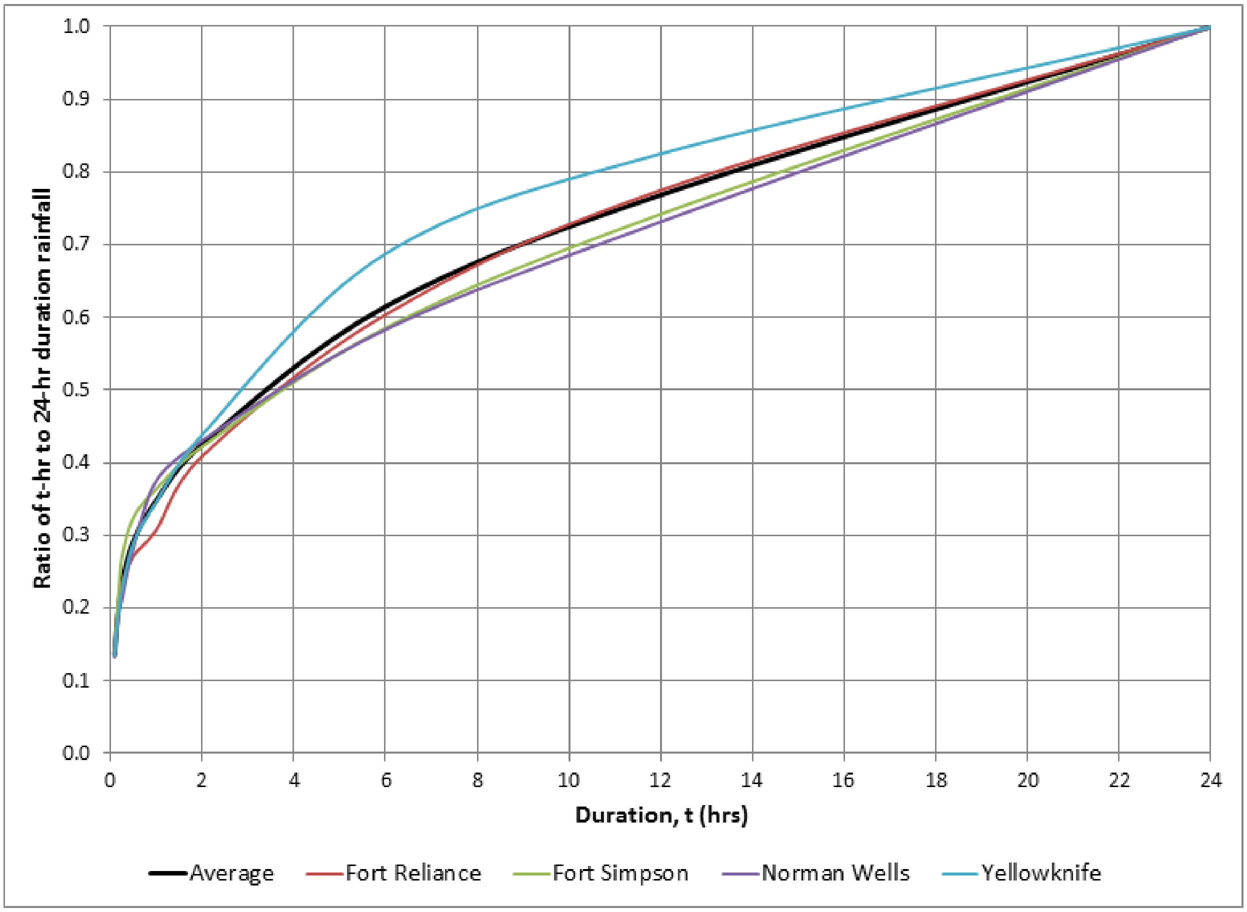
Table 10.3-5 Regional Climate Stations with Rainfall Intensity-Duration-Frequency Data

Station Name	Latitude (north)	Longitude (west)	Distance from Project (km)	Elevation (masl)	Record	Years
Fort Reliance (ID 2201900)	62°43'	109°10'	216	165	1972-1990	18
Yellowknife A (ID 2204100)	62°28'	114°26'	322	205	1963-1996	33
Fort Simpson A (ID 2202101)	61°46'	121°14'	644	169	1969-2007	35
Norman Wells A (ID 2202800)	65°17'	126°48'	793	72	1974-2007	28

A = airport; km = kilometre; masl = metres above sea level; ID = identification.

Similar ratios of t-hour to 24-hour rainfall depths (t less than 24) were calculated from rainfall intensity-duration-frequency data for all return periods at all four stations (Figure 10.3-2). Extreme rainfall depths at the Project for durations less than 24 hours were calculated using the means of the regional ratios. Analysis of annual rainfall, snowfall and total precipitation time series from 1959 to 2013 derived for the Project indicates no trend at the significant level of 5%.

Figure 10.3-2 Ratios of t-hour to 24-hour Duration Extreme Rainfall at Regional Stations



t = time; hrs / hr = hour(s).

10.3.1.3.2 Results

Mean Conditions

Mean annual and seasonal precipitation at the Project, calculated from the derived records of daily rainfall and snowfall from 1959 to 2013, are presented in Table 10.3-6. Seasons are defined based on the occurrence of the March and September equinoxes and the June and December solstices over the same time period (Annex X).

The mean annual total precipitation of 345 mm is composed of almost equal amounts of rainfall and snowfall. Seasonal total precipitation is highest in the summer, accounting for 142 mm or 41% of annual total precipitation in the average year. Seasonal total precipitation is lowest in the winter, representing 40 mm or 12% of annual total precipitation. Precipitation occurs mainly as rainfall in the summer, when rainfall accounts for 132 mm or 93% of total seasonal precipitation. In all other seasons, precipitation occurs mainly as snowfall and accounts for between 63% and 100% of total precipitation in the winter, spring, and fall. The variability of seasonal total precipitation and rainfall is highest in the summer, where standard deviations are the greatest. Conversely, the variability of seasonal snowfall is highest in the fall (Annex X).

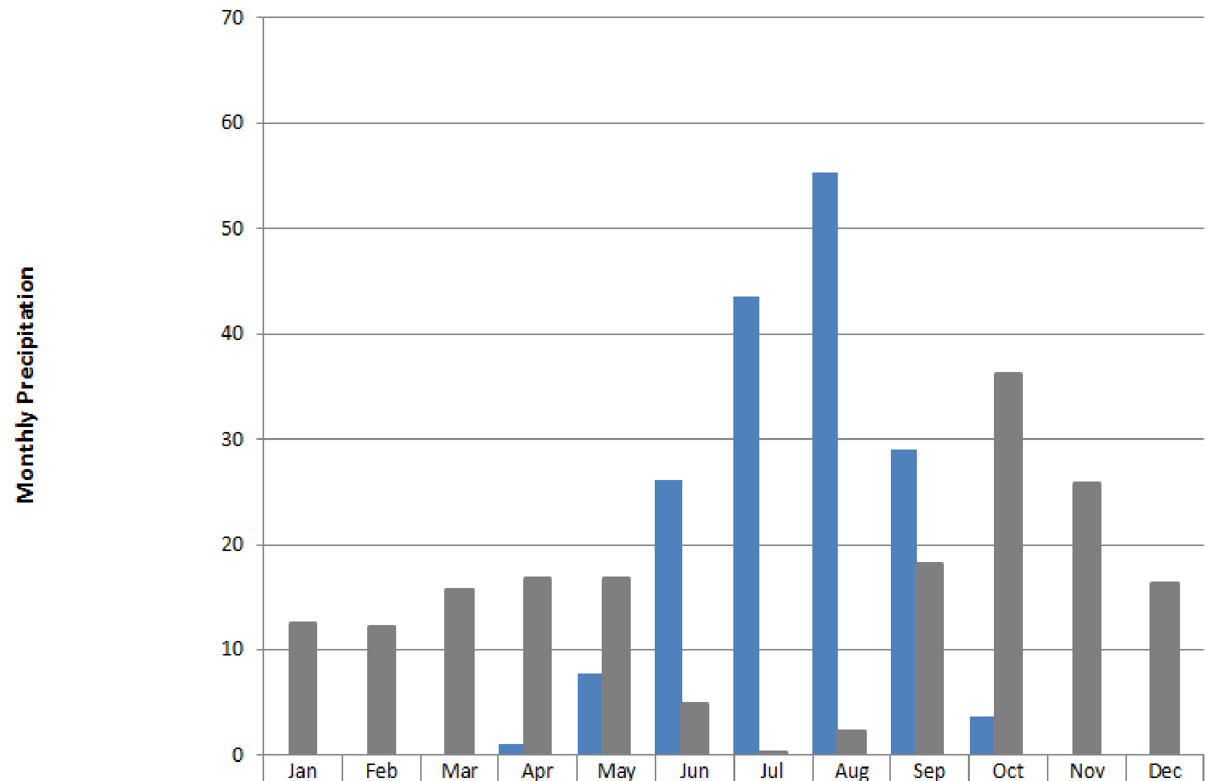
Table 10.3-6 Derived Annual and Seasonal Precipitation, 1959 to 2013

Year/ Season	Period	Statistic	Rainfall (mm)	Snowfall (cm)	Total Precipitation (mm)
Annual	Jan 1 – Dec 31	mean	167	178	345
		standard deviation	52.2	43.4	63.3
Winter	Dec 21 – Mar 19	mean	0.1	39.9	40.0
		standard deviation	0.32	16.5	16.4
Spring	Mar 20 – Jun 20	mean	25.4	43.5	68.9
		standard deviation	21.3	19.2	30.4
Summer	Jun 21 – Sep 21	mean	132	11.1	142
		standard deviation	46.1	11.3	47.4
Fall	Sep 22 – Dec 20	mean	9.8	83.4	93.2
		standard deviation	11.9	27.2	29.4

mm = millimetre; cm = centimetre.

Mean monthly rainfall, snowfall, and total precipitation, calculated from the derived records of daily rainfall and snowfall from 1959 to 2013, are shown in Figure 10.3-3. Precipitation occurs mainly as rainfall from June through September, with rainfall accounting for 61% to 99% of total precipitation in these four months. Precipitation occurs mainly as snowfall in the remaining eight months of the year (October to May), when snowfall represents from 68% to 100% of total precipitation. The wettest month of the year is August, when 58 mm or 17% of mean annual total precipitation occurs, and the driest month is February, when only 12.2 mm or 3.5% of mean annual total precipitation occurs (Annex X).

Figure 10.3-3 Derived Monthly Precipitation, 1959 to 2013



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	0.1	0.0	0.1	1.0	7.8	26.2	43.5	55.3	29.0	3.7	0.0	0.0
Snowfall (cm)	12.5	12.2	15.7	16.8	16.8	4.8	0.3	2.3	18.2	36.2	25.7	16.3
Total Precipitation (mm)	12.6	12.2	15.9	17.8	24.6	31.0	43.8	57.5	47.2	39.9	25.8	16.3

mm = millimetre; cm = centimetre.

Extreme Conditions

Annual Precipitation

Annual rainfall and snowfall, calculated from the derived record for 1959 to 2013, range from 85.5 mm to 364.7 mm, and from 53.4 mm to 208.2 mm, respectively. Annual total precipitation varies from 208.2 mm to 521.2 mm for the same time period (Annex X).

Frequency analysis of the derived data sets provided estimates of extreme annual rainfall, snowfall, and total precipitation, under wet and dry conditions, which are summarized in Table 10.3-7. The Gumbel probability distribution best fits the rainfall data, the Normal probability distribution best fits the snowfall data, and the Pearson III probability distribution best fits the total precipitation data; goodness of fit statistics are also provided in Table 10.3-7.

Table 10.3-7 Derived Annual Precipitation Under Extreme Conditions

Conditions	Return Period (years)	Rainfall (mm)	Snowfall (mm)	Total Precipitation (mm)
Wet	500	420	296	541
	200	379	284	519
	100	348	274	500
	50	317	263	481
	20	275	246	452
	10	243	232	427
	5	209	214	397
Median	2	158	180	343
Dry	5	121	146	291
	10	105	129	265
	20	92.9	114	244
	50	81.0	97.6	221
	100	73.7	86.6	206
	200	70.1	81.2	199
	500	68.0	78.0	194
Probability Distribution		**Gumbel**	**Normal**	**Pearson III**
Coefficient of Determination		0.972	0.975	0.986
Standard Error		8.87	6.44	7.68
Chi-square Ratio		0.437	0.502	0.209

Note: High rainfall years may not be coincident with high snowfall years, so the sum of the rainfall and snowfall columns in Table 10.3-7 are not expected to equal the value in the total precipitation column.

mm = millimetre.

Daily Precipitation

The derived maximum daily rainfall and snowfall occurring over the 55-year record (1959 to 2013) by month is summarized in Table 10.3-8. The maximum daily rainfall in the derived data set is 48.2 mm, occurring on July 9, 1983, and the maximum daily snowfall is 44.6 mm snow water equivalent, occurring on November 21, 2006 (Annex X).

Table 10.3-8 Maximum Derived Daily Precipitation, 1959 to 2013

Month	Maximum Daily Rainfall (mm)		Maximum Daily Snowfall (mm)	
	Value	Day/Year	Value	Day/Year
January	1.4	2/2009	24.0	2/2012
February	0.0	1/1959	19.7	1/1993
March	2.0	28/2000	27.8	21/2012
April	12.0	22/2005	19.1	8/1991
May	26.0	3/2002	20.9	4/2002

Table 10.3-8 Maximum Derived Daily Precipitation, 1959 to 2013

Month	Maximum Daily Rainfall (mm)		Maximum Daily Snowfall (mm)	
	Value	Day/Year	Value	Day/Year
June	42.5	13/1987	24.0	20/1963
July	48.2	9/1983	4.7	18/1985
August	46.6	12/1975	12.2	19/1985
September	39.0	1/1996	39.1	28/1967
October	12.5	8/1998	44.1	28/1998
November	1.1	1/2009	44.6	21/2006
December	0.0	1/1959	13.9	8/1987

mm = millimetre.

Long-Duration Rainfall

Extreme rainfall depths for durations of one day and longer were also derived for the Project, and are shown in Table 10.3-9. Frequency analysis of annual maximum 1, 3, 5, 10, 30, and 60-day rainfall provided estimates of long-duration rainfall under extreme wet conditions. The Gumbel probability distribution was fitted to the data sets, and goodness-of fit statistics are also provided in Table 10.3-9. Estimates are comparable to values provided for Diavik Mine in Golder (2008), although values are greater for return periods of 25 years or more (Annex X).

Table 10.3-9 Derived Long-Duration Extreme Rainfall

Return Period (years)	Rainfall Depth (mm)					
	1-day	3-day	5-day	10-day	30-day	60-day
500	74.6	96.3	105.4	142.1	223.5	311.8
200	66.5	86.0	94.2	126.7	200.3	280.3
100	60.3	78.2	85.8	115.1	182.7	256.4
50	54.0	70.4	77.3	103.5	165.1	232.5
25	47.8	62.5	68.8	91.7	147.4	208.4
10	39.3	51.8	57.3	75.9	123.4	175.8
5	32.7	43.4	48.2	63.4	104.5	150.1
2	22.6	30.6	34.4	44.5	75.9	111.2
Probability Distribution	**Gumbel**	**Gumbel**	**Gumbel**	**Gumbel**	**Gumbel**	**Gumbel**
Coefficient of Determination	0.984	0.971	0.969	0.991	0.938	0.956
Standard Error	1.3	2.3	2.5	1.9	7.4	9.5
Chi-square Ratio	0.274	1.282	0.935	0.424	0.833	0.800

mm = millimetre.

Short-Duration Rainfall

Extreme rainfall depths for short durations ranging from 5 minutes to 24 hours were derived for the Project and are summarized in Table 10.3-10. Frequency analysis of annual maximum 24-hour rainfall in the derived daily rainfall data set from 1959 to 2013 provided estimates of annual maximum 24-hour rainfall under extreme wet conditions. Extreme rainfall depths for shorter durations were calculated by multiplying by the mean of regional ratios of t-hour to 24-hour rainfall depths (t less than 24) charted in Figure 10.3-2 (Annex X).

Table 10.3-10 Derived Short-Duration Extreme Rainfall

	Return Period (years)					
	2	5	10	25	50	100
Duration	Rainfall Depth (mm)					
5 minutes	3.1	4.4	5.3	6.5	7.3	8.2
10 minutes	4.5	6.5	7.9	9.6	10.8	12.0
15 minutes	5.3	7.7	9.3	11.3	12.8	14.3
30 minutes	6.6	9.6	11.5	14.0	15.8	17.6
1 hours	7.9	11.4	13.7	16.7	18.8	21.0
2 hours	9.6	13.9	16.7	20.3	23.0	25.6
6 hours	13.9	20.1	24.2	29.4	33.2	37.1
12 hours	17.3	25.1	30.2	36.7	41.5	46.3
24 hours	22.6	32.7	39.3	47.8	54.0	60.3

mm = millimetre.

Probable Maximum Precipitation

Probable maximum precipitation (PMP) represents the maximum precipitation that is likely to occur over a specified period. Environment Canada (1997) estimated a one-day PMP of 383 mm and a 30-day PMP of 450 mm for the Project (Annex X).

Extreme precipitation in the form of snow is not anticipated to result in any adverse effects on the WRSA; however, extreme snowfall would require additional clearing of site roads and dikes. High snow banks could reduce visibility on roads. White-outs from blizzards or blowing snow could affect visibility, and could necessitate temporary cessation of construction and operation activities.

10.3.1.4 Seasonal Flooding and Melt Patterns

Lac du Sauvage is divided into five basins based on lake bathymetry results. It has a surface area of 86.5 km^2 and a basin area of 1,461 km^2. Lac du Sauvage is a tributary of Lac de Gras and receives inflows from tributary basins B, C, D, Duchess Lake, and tributary basins H, I, J, K, and L (Annex X).

Notable features of Lac du Sauvage include narrows at the outlet to Lac de Gras and at the inlet from Duchess Lake. At the Lac du Sauvage – Lac de Gras Narrows, the channel bed elevation is below the low water elevation of both lakes, meaning that water levels and discharges from Lac du Sauvage are governed, in part, by water levels at Lac de Gras. Similarly, at the Duchess Lake – Lac du Sauvage Narrows, the channel bed elevation is below the low water elevation of both lakes, meaning that water levels and discharges from Duchess Lake are governed, in part, by water levels at Lac du Sauvage (Annex X).

10.3.1.4.1 Methods

A water balance model was developed for the Lac de Gras basin to evaluate mean characteristics and natural variability of discharge and stage levels of lake outlets. The water balance model was developed using GoldSim software on a 4-hour time step for the period of 1959 to 2013, with results produced from 1964 to 2013 (Annex X).

The Lac du Sauvage water balance model was used to derive long-term characteristics of water level and discharge at the Lac du Sauvage outlet. The results of frequency analyses of water levels and discharges for selected return periods under wet (flood) and dry (low flow) conditions are presented in Tables 10.3-11 to 10.3-14 (Annex X).

Table 10.3-11 Derived Representative Discharges at the Lac du Sauvage Outlet – Baseline Conditions

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	39.6	3,398,172	3,345,893	182,488	208,193	215,608
	50	35.7	3,066,469	3,021,067	175,399	196,434	205,287
	20	30.7	2,633,426	2,596,595	165,324	180,802	191,185
	10	26.9	2,308,498	2,277,746	156,902	168,826	180,036
	5	23.1	1,976,873	1,951,956	147,326	156,340	168,026
Median	2	17.5	1,492,978	1,475,733	130,764	137,502	148,959
Dry	5	13.5	1,155,683	1,142,990	116,438	123,766	134,070
	10	12.0	1,022,261	1,011,120	109,963	118,138	127,635
	20	10.9	929,615	919,447	105,286	114,145	122,917
	50	9.8	840,975	831,643	100,903	110,244	118,161
	100	9.3	790,280	781,376	98,560	107,972	115,313

Q = discharge; m^3/s= cubic metres per second; m^3/d = cubic metres per day.

Table 10.3-12 Derived Representative Stages at the Lac du Sauvage Outlet – Baseline Conditions

Condition	Return Period (years)	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	1.51	1.51	1.50	0.647	0.661	0.671
	50	1.47	1.46	1.46	0.630	0.644	0.655
	20	1.40	1.40	1.39	0.607	0.621	0.634
	10	1.34	1.34	1.34	0.590	0.603	0.618
	5	1.28	1.28	1.27	0.572	0.585	0.600
Median	2	1.18	1.17	1.17	0.544	0.557	0.572
Dry	5	1.08	1.08	1.08	0.524	0.536	0.550
	10	1.04	1.04	1.04	0.516	0.527	0.541
	20	1.01	1.01	1.01	0.510	0.521	0.534
	50	0.975	0.975	0.972	0.504	0.515	0.527
	100	0.954	0.954	0.951	0.500	0.511	0.523

m = metre.

Table 10.3-13 Derived Monthly Mean Stages at the Lac du Sauvage Outlet – Baseline Conditions

Condition	Return Period (years)	Monthly Mean Stage (m)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	100	0.879	0.798	0.730	0.674	0.790	1.36	1.43	1.38	1.45	1.33	1.14	0.986
	50	0.851	0.773	0.708	0.656	0.744	1.30	1.39	1.35	1.40	1.29	1.11	0.956
	20	0.813	0.739	0.680	0.631	0.687	1.22	1.33	1.30	1.32	1.24	1.06	0.914
	10	0.783	0.714	0.658	0.612	0.648	1.14	1.28	1.25	1.27	1.20	1.02	0.881
	5	0.753	0.687	0.636	0.593	0.611	1.05	1.22	1.20	1.20	1.14	0.977	0.845
Median	2	0.705	0.648	0.602	0.564	0.562	0.900	1.104	1.105	1.093	1.055	0.902	0.787
Dry	5	0.670	0.619	0.578	0.543	0.533	0.768	0.992	1.015	1.009	0.974	0.840	0.742
	10	0.656	0.607	0.568	0.535	0.522	0.707	0.939	0.970	0.971	0.935	0.811	0.723
	20	0.645	0.599	0.561	0.529	0.516	0.659	0.900	0.934	0.943	0.905	0.790	0.710
	50	0.635	0.591	0.554	0.524	0.510	0.609	0.861	0.895	0.913	0.872	0.767	0.699
	100	0.629	0.586	0.551	0.520	0.507	0.578	0.840	0.870	0.895	0.851	0.753	0.693

m = metre.

Table 10.3-14 Derived Monthly Mean Discharges at the Lac du Sauvage Outlet – Baseline Conditions

Condition	Return Period (years)	Monthly Mean Discharge (m^3/d)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	100	374,032	292,517	240,114	212,393	473,119	2,400,912	2,906,610	2,539,087	2,694,332	1,729,010	877,199	525,856
	50	359,561	281,452	230,933	200,804	380,082	2,084,577	2,633,695	2,338,302	2,406,816	1,623,279	834,716	506,590
	20	338,843	265,699	217,872	185,387	287,242	1,684,705	2,269,224	2,062,547	2,049,922	1,473,342	773,517	478,179
	10	321,568	252,505	206,941	173,567	234,025	1,395,601	1,988,526	1,843,223	1,793,760	1,349,657	722,121	453,676
	5	301,906	237,475	194,500	161,232	191,408	1,111,596	1,694,245	1,608,574	1,543,612	1,210,453	663,193	424,795
Median	2	267,860	211,399	172,945	142,599	145,337	721,081	1,246,447	1,242,189	1,196,082	973,628	559,958	371,934
Dry	5	238,011	188,754	154,258	128,989	121,397	469,945	916,142	960,242	959,564	770,820	468,040	322,061
	10	223,903	178,491	145,798	123,405	113,218	376,696	779,576	837,812	864,255	676,683	424,076	297,124
	20	212,970	171,065	139,682	119,439	107,845	314,402	682,140	746,864	796,136	604,543	389,752	277,108
	50	201,350	164,097	133,946	115,563	102,890	256,958	586,472	653,768	728,665	528,698	353,015	255,109
	100	194,054	160,369	130,878	113,303	100,087	225,170	530,478	596,430	688,205	481,524	329,801	240,876

m^3/d = cubic metres per day.

10.3.1.4.2 Results

The model results show that Lac du Sauvage has a water level variability of approximately 0.64 m between the median (2-year) flood condition and the median 30-day low flow condition. The model results show that the median flood peak discharge is 17.5 cubic metres per second (m^3/s), and the 100-year flood peak discharge is 39.6 m^3/s. The highest flow months are July and August, and it is expected that flow is maintained between Lac du Sauvage and Lac de Gras year-round (Annex X).

Seasonal flooding and melting, and extreme precipitation in the form of rainfall, could result in elevated flows within streams in the vicinity of the roads, and could also result in elevated water level in Lac du Sauvage. If flows exceed the design capacity of culverts, water could pass through the granular fill of the site roads. As road fill material will be relatively coarse and the general grade in the vicinity of the roads is not substantial, it is anticipated that limited to no erosion of the site roads would occur. If water levels rose more than 0.4 m over the current Lac du Sauvage water level, additional fill could need to be placed to raise the elevation of the dike construction roads. Erosion of the dike is not anticipated due to the width and gradation of the rockfill of the dike's embankments.

There are no waterbodies in the form of ponds, lakes, or streams within the footprint of the WRSA. A minimum 30 m set back exists from nearest streams and waterbodies, and Lac du Sauvage is at least 100 m away from the proposed WRSA (Golder 2014b). As mentioned in Section 10.2.2, and outlined in detail in Section 3.5.5, the WRSA is constructed to minimize runoff and encourage permafrost formation. The waste rock will consist of coarse material in general and, therefore, will be able to accommodate large flows in the event of extreme precipitation.

10.3.2 Seismic Events

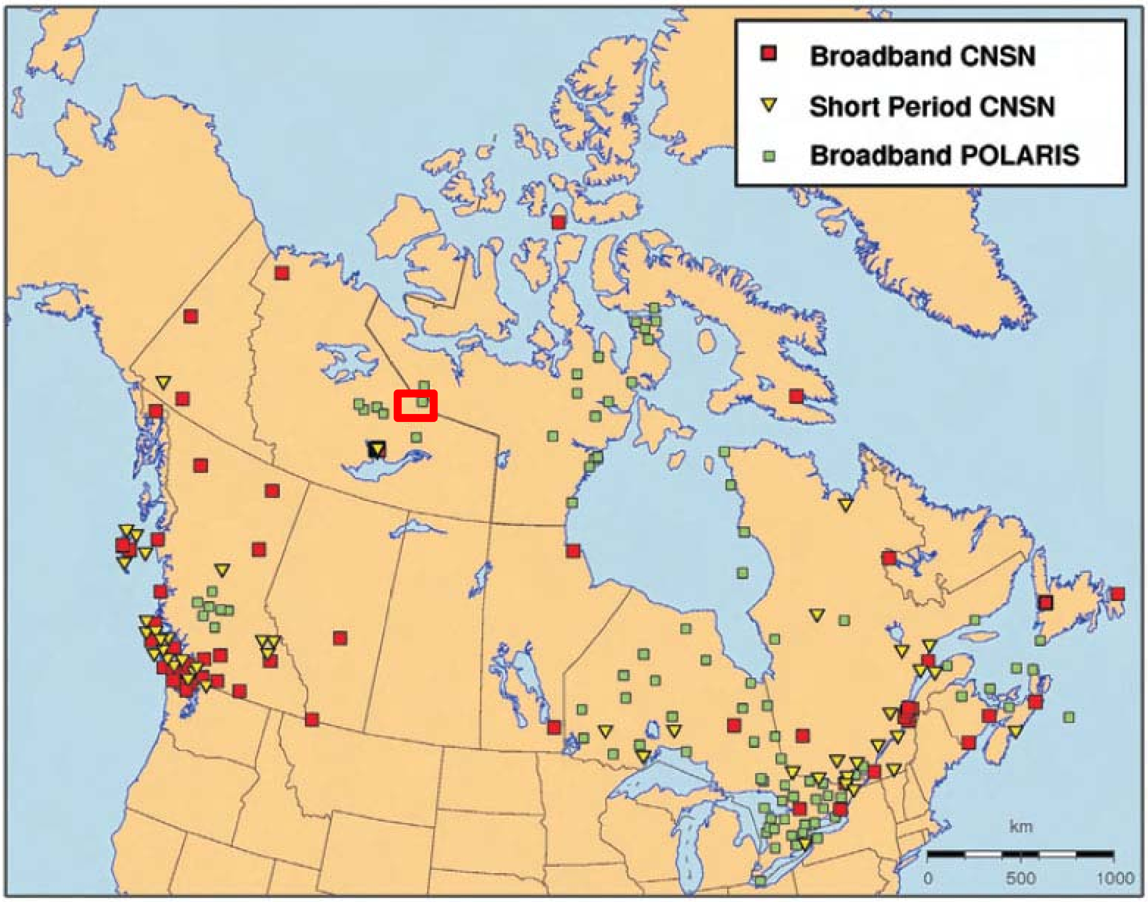
10.3.2.1 Methods

Two seismic networks currently cover the Canadian territories (Figure 10.3-4) (Cassidy et al. 2010):

- The Canadian National Seismograph Network (CNSN); and,
- The POLARIS seismic network.

As of 2009, there are more than 120 seismic stations operating within the CNSN, and there are more than 100 POLARIS sites in operation (Figure 10.3-4). A broadband POLARIS seismograph has been installed nearby the Project (red rectangle in Figure 10.3-4).

Figure 10.3-4 Seismographic Network in Canada



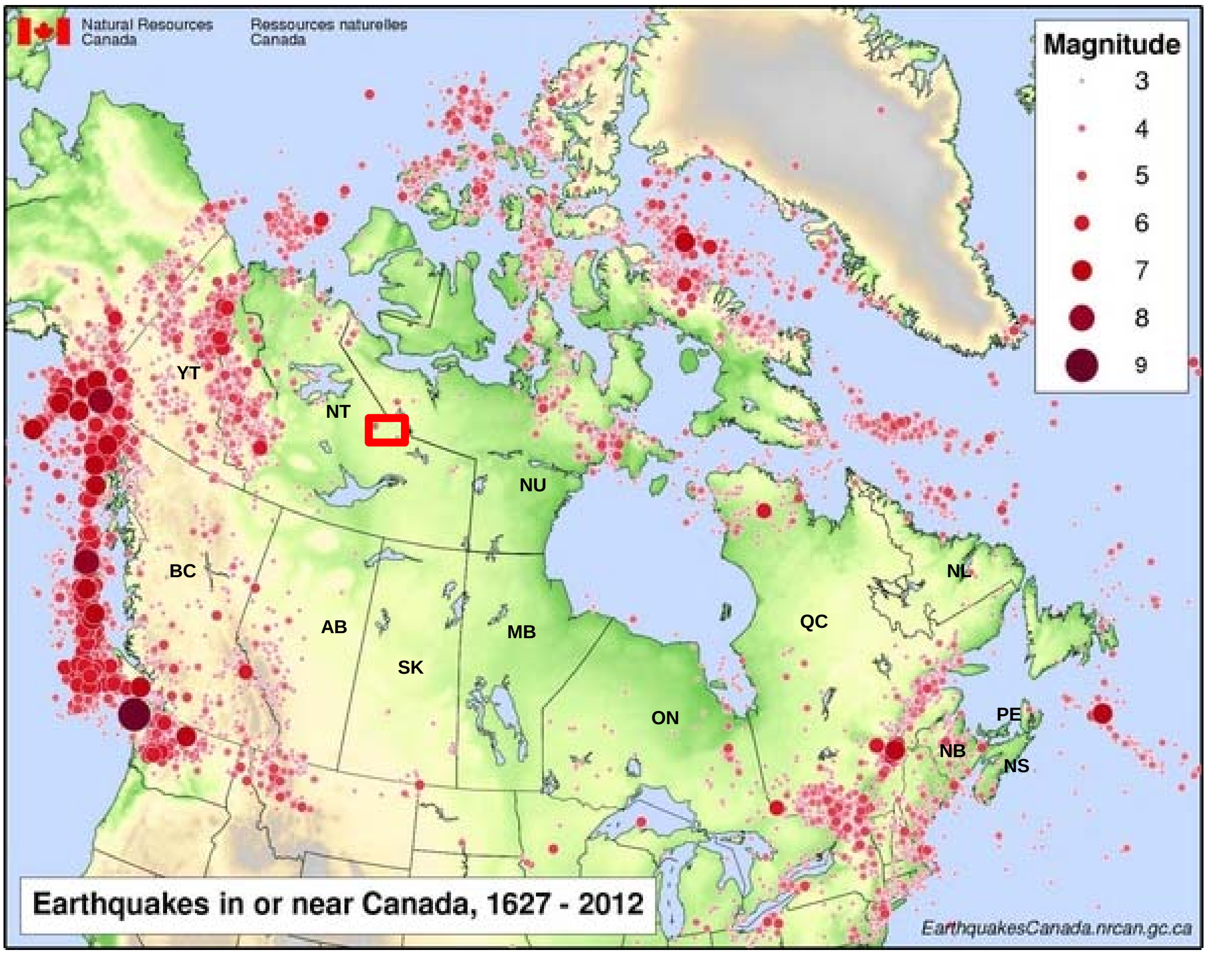
Source: Amended from Cassidy et al. (2010).
The red rectangle defines the approximate location of the Project.

10.3.2.2 Results

Most of the earthquakes recorded within Canada occur along an active plate boundary, especially along the west coast (Figure 10.3-5). The largest and most frequent earthquakes occur along the west coast (striking mainly British Columbia) (Cassidy et al. 2010). Significant seismic activity defines the Cordillera, particularly in the Yukon and Northwest Territories (Cassidy et al. 2010). Within the stable cratonic areas of the western Northwest Territories, Saskatchewan, and Manitoba, only few low magnitude (magnitude less than 6) earthquakes were recorded from 1627 to 2012.

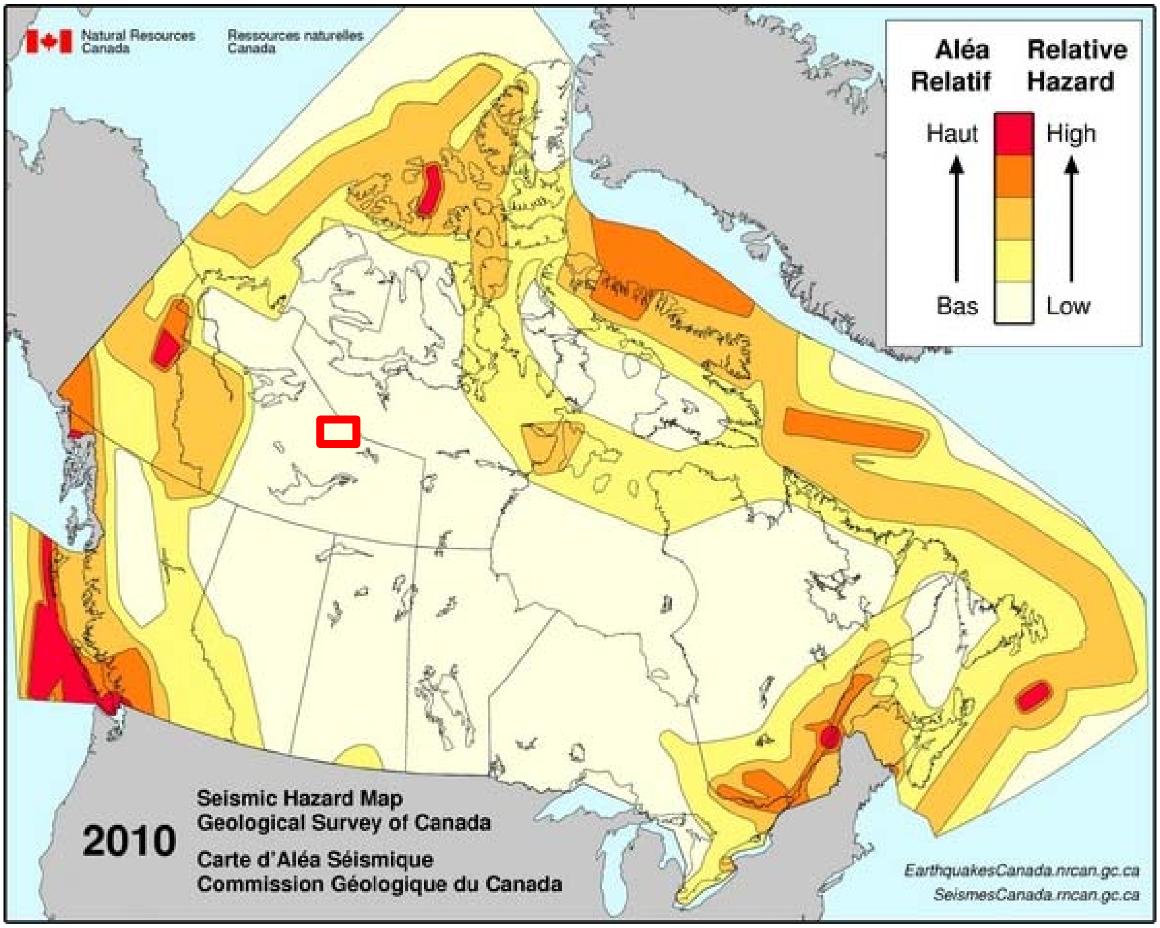
In the NWT, seismic activity is mainly restricted to the western sector at the Richardson and Mackenzie mountains (Golder 2014d). According to Natural Resources Canada (2013a), the Project appeared to be located in a relatively stable area, with a no historic record of moderate to high magnitude earthquakes (red rectangle in Figure 10.3-5). Due to the absence of seismogenic faults and the geodynamical stability of the cratonic area, the Project has been classified by Natural Resources Canada (2013b) as belonging to a low seismic hazard zone (Figure 10.3-6).

Figure 10.3-5 Earthquakes Distribution in Canada between 1627 and 2012



Source: Amended from Natural Resources Canada (2013a).
The red rectangle defines the approximate location of the Project.

Figure 10.3-6 Seismic Hazard Map of Canada



Source: Amended from Natural Resources Canada (2013b).
The red rectangle defines the approximate location of the Project.

In addition, site seismicity has been obtained from the fourth generation seismic hazard maps developed for the 2010 National Building Code of Canada (Golder 2014b). Horizontal peak ground accelerations (PGAs) for the site were obtained from the Hazard Calculator of the Geological Survey of Canada (Golder 2014c). A summary of the PGA values over a range of return periods is presented in Table 10.3-15 (Golder 2014d). Seismicity in the vicinity of the Project is low (PGA = 0.036 g for a 1:2,475 return period). Although an earthquake is unlikely to affect the site roads, any effects would likely be limited to minor settlement.

Table 10.3-15 Peak Ground Accelerations by Return Period for the Jay Project site based on Geological Survey of Canada Hazard Calculator

Return Period (years)	Peak Ground Acceleration[(a)] (g)
1 in 100	0.003
1 in 475	0.011
1 in 1,000	0.019
1 in 2,475	0.036

a) Spectral and peak hazard values are determined for firm ground (National Building Code of Canada 2010 soil class C – average shear wave velocity 360 to 750 m/s).

g = the acceleration due to Earth's gravity, equivalent to g-force; m/s = metres per second.

The Jay Dike is being designed to earthquake and climate conditions at return periods that are commensurate with the dike classification. Since seismicity in the vicinity of the Project is low, if any effect were to occur, it would most likely be settlement of the rockfill embankments and filters along portions of the dike where the thickness of soil is greater and where the soil consists of silt material that has not been loaded by glaciers.

A factor of safety of 1.3 for long-term slope stability of the WRSA was considered to be a reasonable design criterion, based on the following considerations (Table 10.3-16). Although a foundation site investigation program has not been conducted, a reasonable amount of information is available about the WRSA foundation conditions based on surficial geology mapping. In addition, a range of soil strength properties were assigned in the stability assessment to cover the uncertainty. The only infrastructure surrounding the WRSA consists of haul roads located on the east perimeter and southeast corner. The toe of the WRSA is a minimum of 30 m from the haul roads, and in most cases, more than 50 m. Therefore, the risk due to failure of the pile is considered to be low to moderate (Golder 2014b).

Table 10.3-16 Design Factors of Safety for the Waste Rock Storage Area

Loading Conditions	Minimum Design Factor of Safety	Source
Static	1.3 – long term	BC MWRPRC 1991
Pseudo-static	1.0 – long term	CDA 2007

Earthquake-induced seismic loads were incorporated in pseudo-static analyses. Pseudo-static analyses consist of conventional limit equilibrium slope-stability analyses conducted with horizontal and vertical pseudo-static acceleration coefficients that act upon the critical failure mass. Hynes-Griffin and Franklin (1984) indicate that a horizontal pseudo-static coefficient of one-half of the PGA (Table 10.3-15) and a vertical pseudo-static coefficient equal to zero should be used when seismic stability of slopes is evaluated not considering liquefaction. The horizontal pseudo-static acceleration coefficient used for the Jay WRSA stability analyses was one-half of the 1 in 1,000 year return period PGA, which is equal to 0.0095. As previously stated, since seismicity in the vicinity of the Project is low, an earthquake is unlikely to affect the WRSA.

10.4 Mitigation and Monitoring

10.4.1 Erosion Control Measures

Wind and water erosion can affect terrain by removing, transporting, and depositing soil materials (e.g., fine sediments, coarse fragments) from one location to another. The WRSA is anticipated to have low potential for water and wind erosion because of the rock content of the pile. However, erosion of soil at the base of the WRSA may affect the geotechnical stability of the Jay WRSA. Mitigation and erosion control measures that will be implemented to limit the extent of erosion include the following:

- Existing Ekati Mine erosion and sediment control measures (e.g., silt curtains, runoff management) will be used during construction, where appropriate, to limit the amount of suspended sediment transport.
- The Jay WRSA will be constructed as designed to provide a thermally protective surface cover over potentially acid-generating materials and to provide a relatively flat upper surface that discourages snow accumulation.

The riparian (shoreline) and littoral (shallow) areas within the diked area will be reclaimed where necessary to enable natural regrowth of riparian and aquatic vegetation. The reclamation work is envisioned to include localized repair of erosion and re-vegetation of select areas with aquatic and riparian plants. This work will be based on experience gained through operations, reclamation research, and closure of other areas of the Ekati Mine.

Monitoring closure and reclamation objectives and necessary maintenance of the reclaimed facilities will continue for a period of time after completion of the reclamation work (BHP Billiton 2011). The schedule and program for monitoring and maintenance will be designed to complement the post-reclamation monitoring schedule already developed for the existing Ekati Mine Interim Closure and Reclamation Plan. Monitoring of the physical stability of dike breaches is anticipated for a period after closure.

10.4.2 Prevention of Permafrost Degradation or Growth Encouragement

The WRSAs at the Ekati Mine are constructed to encourage permafrost formation (Golder 2014b). Because the Ekati Mine is located in the continuous permafrost zone, water infiltrating the WRSAs becomes trapped in the waste rock and turns to ice when it encounters sub-freezing temperatures inside the WRSA. The WRSAs currently at the Ekati Mine have permafrost aggregating into the piles, and this permafrost will continue to grow over time. Modelling indicates that a design of the WRSA with a 5 m cover of granite waste rock will provide sufficient thermal protection over a 100-year climate-warming scenario. Freeze-back of the waste rock material is expected to occur within 8 to 12 years, depending on the degree of internal heat generation from the PAG material (Dominion Diamond 2014). This model was developed as part of the submission of the WRSA Design Report to the WLWB for approval.

The Jay WRSA will be constructed using methods similar to methods used at other WRSAs on the Ekati Mine site. A base layer of granite rock will be placed over the foundation to keep the active layer within the waste rock, and to maintain frozen (permafrost) conditions within the foundation soils. Based on the preliminary permafrost assessment for the Jay Project site (Annex IV), the foundation of the Jay WRSA is expected to be within permafrost with seasonal thawing of a surficial active layer (typically 1 to 3 m). The reclamation goal is to maintain the permafrost within the WRSA. The design of the WRSA includes a stepped profile and a flat top that will prevent snow build-up to encourage permafrost formation for the long term.

Exposure and subsequent melting of permafrost can cause changes to hydrological patterns and decrease soil stability. Several approaches have been used to assess or address effects of exposing permafrost. These include the following:

- annual geotechnical inspections of mine structure;
- completing construction and soil excavation during winter in areas of permafrost where melting could contribute to sedimentation of lakes and streams;
- maximizing dewatering of lakes during ice-cover months;
- conducting exploratory drilling and temporary road construction during winter;
- capping exposed permafrost to reduce thermal degradation and erosion;
- using practices such as over-excavation and backfilling with thaw stable material to minimize disturbance to permafrost; and,
- using thermistors to monitor ground temperature before placing minewater into Beartooth Pit.

10.4.3 Monitoring of Geotechnical Stability Waste Rock Storage Areas, Dams, and Dikes

Monitoring activities will be an extension of existing programs in place at the Ekati Mine as required under the Water Licence. The Jay WRSA will be constructed as designed, which provides for long-term physical stability. Ground temperature cables will be installed in Jay WRSA and will be used to monitor permafrost. Seepage water quality will be monitored twice per year (spring and fall) as part of the annual seepage surveys.

Geotechnical instrumentation will be installed within the Jay dike structure and foundation to monitor the performance of the dike during dewatering and operation. The instrumentation will monitor the physical performance of the dike to confirm that the structure is operating according to the design intent. Monitoring with the instrumentation will be continued into back-flooding and closure until the dike is breached at closure.

10.4.4 Adaptive Management

Monitoring programs currently in place at the Ekati Mine are designed to detect unexpected environmental changes. If unexpected changes occur, the likely causes will be determined and appropriate response plans will be developed and implemented according to the conditions at hand. Following the implementation of appropriate adaptive management responses, Dominion Diamond will continue with sampling, monitoring, and evaluation of the situation and the suitability of the response.

10.5 Summary

Waste rock and overburden excavated from the Jay Pit, and waste generated during dike construction, will be stored at the WRSA. The WRSA has been designed to accommodate a volume of 120 million m^3, which includes approximately 9.6 million m^3 for contingency. The existing WRSAs at the Ekati Mine include the Panda/Koala/Beartooth WRSA (537 ha), the Fox WRSA (383 ha), and the Misery WRSA (111 ha), which cumulatively cover 1,031 ha. The Jay WRSA will cover an approximate area of 250 ha and will result in a cumulative area of 1,281 ha of the ESA occupied by WRSAs. The Pigeon WRSA that is currently under construction will cover an area of approximately 48 ha when complete. The cumulative area that will be occupied by previous, existing and reasonably foreseeable WRSAs is predicted to be 1,329 ha.

Waste rock from the Jay Pit will be mainly non-potentially acid generating granite (estimated 70%); the remainder will be metasediments and overburden. All of the metasediment mined from the Jay pit will be managed as potentially acid-generating material. The existing Ekati Mine WROMP will be expanded to incorporate the Jay WRSA.

The majority of the 250 ha area within the Jay WRSA is composed of the Mineral-1 soil map unit. The Mineral-1 map unit within the WRSA is co-dominated by very stony to excessively stony, well-drained to rapidly drained Turbic Cryosols, and cryoturbated Orthic Dystric Brunisols developed on undulating coarse-textured to moderately fine-textured glacial till. Substantial amounts of the area of the WRSA will occupy exposed bedrock outcrops and boulders.

The Jay WRSA will not require any diversions of natural watercourses because the layout was designed to avoid surrounding waterbodies and drainage channels. The WRSAs at the Ekati Mine are constructed to minimize runoff and encourage permafrost formation. A small proportion of the WRSA is located within areas of active, but low-hazard, periglacial processes (freezing and thawing). This area will require site reconnaissance to confirm the soil conditions. Before waste rock placement over the small polygon mapped as a solifluction lobe in the northwestern portion of the Jay WRSA, small continuous movements and depositing of sediment in the small hollow between the small hollow between bedrock outcrops is expected. Movements should subside after placement of waste rock due to the weight of the material and the aggradation of permafrost into the waste rock, reducing and eventually eliminated freeze-thaw cycles in the soils beneath the WRSA. No large-scale instabilities are predicted, and a large-scale, deep-seated landslide related to solifluction is not expected.

The Jay WRSA is expected to be constructed similarly to other WRSAs at the Ekati Mine and will incorporate designs that enhance the natural process for freezing into permafrost. Modelling indicates that a design of the WRSA with a 5 m cover of granite waste rock will provide adequate thermal protection under a 100-year climate-change scenario. Freeze-back of the waste rock material is expected to occur within 8 to 12 years, depending on the degree of internal heat generation from the PAG material (Dominion Diamond 2014).

Degradation of the permafrost beneath the foundation of a road could lead to differential settlement, which would require maintenance to re-establish road grades and eliminate variation in the road surface or in culverts installed at select locations beneath the road. Along portions of the road with a greater thickness of fill, permafrost degradation could lead to sloughing of the fill and minor slope instability. Permafrost aggradation beneath the road fill material may also occur such that the active layer will no longer penetrate as deeply into the existing soil foundation. In some areas with certain foundation soils, freeze-related uplift displacements could occur, which would require maintenance to re-establish road grades. These processes are not anticipated to result in any adverse effects during the construction and operational phases of the Project.

Degradation of the permafrost beneath the foundation of the dike near the abutments or islands could lead to differential settlement, which would require maintenance to re-establish design elevations. The presence of permafrost within the bedrock may reduce the penetrability of grout injection. Degradation of the permafrost could increase seepage through the dike. This is most likely to occur near the abutments or islands, where permafrost exists. Hydraulic head and the associated gradient in these locations is relatively low and, therefore, the quantity of seepage and the potential for erosion of the dike or piping of the dike or foundation soils would be limited. Permafrost aggradation may occur beneath the dike on the abutments and islands, such that the active zone will no longer penetrate as deeply into the existing soil foundation; however, this process is anticipated to result in no adverse effects.

Extreme precipitation in the form of snow would require additional clearing of site roads and dikes. High snow banks could reduce visibility on roads. White-outs from blizzards or blowing snow could affect visibility, and could necessitate temporary cessation of construction and operation activities.

Seasonal flooding and melting, and extreme precipitation in the form of rainfall, could result in elevated flows within streams in the vicinity of the roads, and could also result in elevated water level in Lac du Sauvage. If flows exceed the design capacity of culverts, water could pass through the granular fill of the site roads. As road fill material will be relatively coarse and the general grade in the vicinity of the roads is not substantial, it is anticipated that limited to no erosion of the roads would occur from an extreme precipitation event. If water levels rose more than 0.4 m over the current Lac du Sauvage water level, additional fill could be placed to raise the elevation of the dike construction roads. Erosion of the dike is not anticipated because of the width and gradation of the rockfill of the dike's embankments.

There are no waterbodies in the form of ponds, lakes, or streams within the footprint of the WRSA. A minimum 30 m setback from nearest streams and waterbodies will be used, and Lac du Sauvage is at least 100 m away from the proposed WRSA. The WRSA is constructed to minimize runoff and encourage permafrost formation. The waste rock consists of coarse material in general, and therefore, is able to accommodate large flows in the event of extreme precipitation.

Seismicity in the vicinity of the Project is low (PGA= 0.036 g for a 1:2,475 return period). Although an earthquake is unlikely to affect the site roads, any effect would likely be limited to minor settlement. The Jay Dike is being designed to earthquake and climate conditions at return periods that are commensurate with the dike classification. Because seismicity in the vicinity of the Project is low, if any effect were to occur, it would most likely be settlement of the rockfill embankments and filters along portions of the dike where the thickness of soil is greater and the soil consists of silt materials.

Monitoring of reclaimed facilities will continue for a period of time after completion of the reclamation work. The schedule and program for monitoring and maintenance will be designed to complement the post-reclamation monitoring schedule already developed for the existing Ekati Mine Interim Closure and Reclamation Plan. The monitoring program for the Ekati Mine proposes to use a combination of the current programs adapted to suit specific closure needs.

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10.7 Glossary

Term	Definition
Active layer	The active layer is the layer of ground subject to annual freezing and thawing in areas underlain by permafrost.
Assessment endpoint	Assessment endpoints are qualitative expressions used to determine the significance of effects on valued components (VCs) and represent the key properties of VCs that should be protected for future human generations (i.e., incorporate sustainability).
Average	A single statistical value used to characterize a series of data values. The average value is calculated as the sum of the data values divided by the number of data values. It represents the data centre value of a series of values, and does not differ substantially from the statistical median value when the data values are evenly and symmetrically distributed.
Basal cryopeg	The layer of perennially cryotic (temperature less than 0°C) ground with liquid saline or pressurized pore water that forms the base of permafrost. The thickness of this layer is related to the salinity of the groundwater regime, which can result in depression of the freezing point up to several degrees below zero.
Baseline	A surveyed or predicted condition that serves as a reference point with which later surveys are coordinated or correlated.
Baseline study area (BSA)	The area where direct effects and small-scale indirect effects from the Project are expected to occur.
Basin	A large area that is lower in elevation than surrounding areas and contains water. Basins are separated by land or shallow channels.
Bathymetric survey	A survey carried out to map the topography and features of the bed of an ocean, lake, river or other body of water.
Bathymetry	Measurement of the depth of an ocean or large waterbody.
Bedrock	The solid rock (harder than 3 on Moh's scale of hardness) underlying soils and the regolith in depths ranging from zero (where exposed to erosion) to several hundred metres.
Biotite	Common phyllosilicate mineral within the mica group, with the approximate chemical formula $K(Mg,Fe)_3AlSi_3O_{10}(F,OH)_2$.
Boulder	A large rounded mass of rock lying on the surface of the ground or embedded in the soil.
Canadian shield	Large area of exposed Precambrian igneous and high-grade metamorphic rocks (geological shield) that forms the ancient geological core of the North American continent (North American or Laurentia craton), covered by a thin layer of soil.[3] It is an area mostly composed of igneous rock which relates to its long volcanic history. It has a deep, common, joined bedrock region in Eastern and central Canada and stretches North from the Great Lakes to the Arctic Ocean, covering over half of Canada.
Clay	(i) As a particle size term: a size fraction less than 0.002 mm equivalent diameter, or some other limit (geology or engineering). (ii) As a rock term: a natural, earthy, fine grained material that develops plasticity with a small amount of water. (iii) As a soil term: a textural class. See also texture, soil. (iv) As a soil separate: a material usually consisting largely of clay minerals but commonly also of amorphous free oxides (sesquioxides) and primary minerals.
Climate	Weather averaged over a long period of time.
Climate Change	Refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from: • natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; • natural processes within the climate system (e.g., changes in ocean circulation); and, • human activities that change the atmosphere's composition (e.g., through burning fossil fuels) and the land surface (e.g., deforestation, reforestation, urbanization, desertification).
Continuous permafrost	Permafrost occurring everywhere beneath the exposed land surface throughout a geographic region with the exception of widely scattered sites, such as newly deposited unconsolidated sediments, where the climate has just begun to impose its influence on the thermal regime of the ground, causing the development of continuous permafrost.

Term	Definition
Continuous permafrost zone	The major subdivision of a permafrost region in which permafrost occurs everywhere beneath the exposed land surface with the exception of widely scattered sites.
Craton	Part of the earth's crust that has been stable and little deformed for a prolonged period of time.
Cryosolic soil	Cryosolic soils have horizons with permafrost. In some soils the frost action causes considerable mixing of soil horizons, which is termed cryoturbation. In these soils the permafrost layer must be within 2 m of the surface. If no strong cryoturbation has occurred the permafrost layer must be within 1 m of the surface
Cryotic ground	Soil or rock at temperatures of 0°C or lower. Cryotic and noncryotic refer solely to the temperature of the material described, independent of its water or ice content.
Cryoturbated phase, soil	Any non-permafrost soil having one or more cryoturbated (mixed) horizons.
Deposition, deposit	The accumulation of material left in a new position by a natural transporting agent such as water, wind, ice or gravity; or by the activity of man.
Dewatering	Removal of water from a natural waterbody by pumping or draining.
Diabase	A dark coloured, fine to medium-grained igneous intrusive rock.
Diavik Diamond Mines Inc. (Diavik Mine)	A diamond mine located on East Island in Lac de Gras, approximately 30 km southeast of the Ekati main camp and 10 km southwest of the Misery Pit.
Dike	A tabular body of igneous rock that cuts across the bedding or foliation of the rock it intrudes.
Discharge	The volumetric rate of flow of water in a watercourse at a specified point, expressed in units of cubic metres per second or equivalent.
Drainage	The removal of excess surface water or groundwater from land by natural runoff and percolation, or by means of surface or subsurface drains.
Duration	Defined as the length of time that an effect will occur.
Ecoregion	Relatively homogeneous subdivisions of an ecozone, which are characterized by distinctive climatic zones or regional landforms.
Ekati Mine	Ekati Diamond Mine, Canada's first diamond mine.
Erosion	(i) The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. (ii) Detachment and movement of soil or rock by water, wind, ice, or gravity.
Esker	A long, narrow ridge of stratified gravel and sand, which forms from glacial processes
Fault	Planar fracture or discontinuity in a volume of rock, across which there has been significant displacement along the fractures as a result of earth movement.
Footprint	The proposed development area that directly affects the components of the landscape.
Freezing point depression	The number of degrees by which the freezing point of an earth material is depressed below 0°C.
Frequency	Refers to how often an effect will occur. In Physics, it refers to the number of cycles per second.
Freshet	A sudden overflow of a stream caused by heavy rain or nearby thawing of snow or ice. Can be seasonal surface runoff associated with spring melt.
Geology	The study of the Earth's crust, its structure, the chemical composition and the physical properties of its components.
Geothermal gradient	An increase of soil temperature with depth due to the heat flux of the Earth core. An average geothermal gradient is approximately 2°C per 100 m.
Glacial	(i) Of or relating to the preglsence and activities of ice or glaciers, such as glacial erosion. (ii) Pertaining to distinctive features and materials produced by or derived from glaciers and ice sheets, such as glacial lakes. (iii) Pertaining to an ice age or region of glaciation.
Glacial till	Unsorted and unstratified glacial drift (generally unconsolidated) deposited directly by a glacier without subsequent reworking by water from the glacier. Consisting of a heterogeneous mixture of clay, silt, sand, gravel and boulders (i.e., drift) varying widely in size and shape.
Glaciofluvial	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.

Term	Definition
Granite	A coarsely crystalline igneous intrusive rock composed of quartz, potassium feldspar, mica, and/or hornblende.
Gravel	(i) As a deposit term: glaciofluvial or fluvial materials with 60% or more coarse fragments, usually subrounded to rounded and of variable size. (ii) As a particle size term: a size fraction between 4.75 and 75 mm diameter with rounded, subrounded, angular, or irregular shapes.
Gravelly	Containing appreciable amounts of rounded or subrounded rock or mineral fragments 2 mm to 8 cm in diameter. 'Angular gravelly' is used when the fragments are less rounded.
Ground ice	A general term referring to all types of ice contained in freezing and frozen ground. Ground ice occurs in pores, cavities, voids or other openings in soil or rock and includes massive ice. It may occur as lenses, wedges, veins, sheets, seams, irregular masses, or as individual crystals or coatings on mineral or organic particles. Perennial ground ice can only occur within permafrost bodies.
Groundwater	Water that is passing through or standing in the soil and the underlying strata in the zone of saturation. It is free to move by gravity.
Groundwater – shallow	Water that occupies pores and crevices in the rock and soil of the active layer above the permafrost layer.
Groundwater – deep	Ancient fossil or connate water that occupies pores and crevices in the bedrock below the permafrost layer.
Groundwater flow	The movement of water through interconnected voids in the phreatic zone.
Groundwater regime	Water below the land surface in a zone of saturation.
Historic	Refers to the period of time for which there are written records; also referred to as post-contact.
Hydraulic conductivity	The ability of a porous medium to conduct a fluid (e.g., water). It is the combined property of a porous medium and the fluid moving through it in saturated flow, which determines the relationship, called Darcy's Law, between the specific discharge and the head gradient causing it.
Hydraulic Gradient	A measure of the force of moving groundwater through soil or rock. It is measured as the rate of change in total head per unit distance of flow in a given direction. Hydraulic gradient is commonly shown as being dimensionless, since its units are metres/metre.
Hydraulic head	The level to which water will rise if a standpipe is installed.
Hydrology	Science that deals with the waters above the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings.
Ice lens	Small ice bodies, usually several centimetres thick, in frozen soils
Ice wedge	A large, usually wedge-shaped mass of foliated ground ice produced in permafrost, occurring as a vertical or inclined sheet, dike or vein, tapering downward, and generally measuring from a few millimetres to several meters wide and sometimes reaching 30 m depth. It originates by the freezing of water in narrow cracks or fissures produced by thermal contraction of the permafrost.
Inflow	Water flowing into a lake.
Infrastructure	Basic facilities, such as transportation, communications, power supplies and buildings, which enable an organization, project or community to function.
Kame	Ice contact deposits associated with the concurrent processes of melting ice and flowing meltwater.
Kimberlite	Igneous rocks that originate deep in the earth's mantle and intrude the earth's crust. These rocks typically form narrow pipe-like deposits that sometimes contain diamonds.
Kimberlite pipe	A more or less vertical, cylindrical body of kimberlite that resulted from the forcing of the kimberlite material to the Earth's surface.
Landform	A particular type of land formation.
Landscape	A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout. From a wildlife perspective, a landscape is an area of land containing a mosaic of habitat patches within which a particular “focal" or “target" habitat patch is embedded.

Term	Definition
Littoral	The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (approximately 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.
Long Lake Containment Facility (LLCF)	The processed kimberlite containment basin(s) and the associated engineering structures that are designed to contain processed kimberlite and that are regulated through the Water Licence. Long Lake has been divided into a series of cells modified to contain processed kimberlite after completion of the diamond extraction process.
Magnitude	A measure of the size, intensity, extent, or importance of something.
Map unit	A combination of kinds of soil, terrain, or other features that can be shown at a specified scale of mapping for the defined purpose and objectives of a particular survey.
Mean	Arithmetic average value in a distribution.
Measurement indicator	Measurement indicators represent properties or attributes of the environment and VCs that, when changed, could result in, or contribute to, an effect on assessment endpoints. Measurement indicators may be quantitative (e.g., concentrations of metals in surface water) or qualitative (e.g., movement and behaviour of wildlife from disturbance to habitat and travel corridors).
Median	A single statistical value used to characterize a series of data values. Half of the data values are larger than the median value, and half of the data values are less than the median value.
Metasediment	Sedimentary rocks that have been modified by metamorphic processes.
Mineral soil	Soils containing relatively low concentrations of organic matter. Soils that have evolved on fluvial, glaciofluvial, lacustrine, and morainal parent material.
Moisture content	Geotechnical moisture content defined as a ratio of weight of pore water to weight of rock/soil solids.
Morainal	Of or pertaining to moraine, which is a mound, ridge, or other distinct accumulation of unsorted, unstratified drift, predominantly till, deposited chiefly by direct action of glacier ice in a variety of topographic landforms that are independent of control by the surface on which the drift lies. It is now commonly used as a geomorphologic name for a landform composed mainly of till that has been deposited by a glacier.
Natural variability	Disparity in an environmental condition that occurs under natural conditions, without human-induced disturbance.
Non-sorted circles	A type of patterned ground where alternating freeze and thaw of soils develop geometric circular patterns surrounded by a circular margin of vegetation. Consists of unsorted mineral material.
Open talik	A talik that penetrates the permafrost completely, connecting a waterbody above permafrost to the sub-permafrost aquifer (e.g., below large rivers and lakes).
Outcrop	That part of a geologic formation or structure that appears at the surface of the earth.
Outwash	Stratified sediments (chiefly sand and gravel) deposited by meltwater streams in front of the end moraine or the margin of an active glacier.
Overburden	Materials of any nature, consolidated or unconsolidated, that overlie a deposit of useful materials. In the present situation, overburden refers to the soil and rock strata that overlie kimberlite deposits.
Palsa	A peaty permafrost mound possessing a core of alternating layers of segregated ice and peat or mineral soil material. Palsas are typically between 1 and 7 m in height and a few metres to 100 m in diameter.
Particle size	The effective diameter (grain size) of a particle measured by sedimentation, sieving, or micrometric methods.
Peat	A deposit consisting of decayed or partially decayed humified plant remains. Peat is commonly formed by the slow decay of successive layers of aquatic and semi-aquatic plants in swampy or water-logged areas, where oxygen is absent.

Term	Definition
Peat polygon (polygonal peat plateau)	A perennially frozen bog, rising approximately 1 m above the surrounding fen. The surface is relatively flat, scored by a polygonal pattern of trenches that developed over ice wedges. The permafrost and ice wedges developed in peat originally deposited in a non-permafrost environment. Polygonal peat plateaus are commonly found near the boundary between the zones of discontinuous and continuous permafrost.
Permafrost	Permanently frozen soil or rock and incorporated ice and organic material that remain at or below 0°C for a minimum of two years due to natural climatic factors. The occurrence of permafrost increases with latitude (i.e., more northern areas permafrost is continuous, and more southern areas patches of permafrost alternate with unfrozen ground).
Permafrost conditions	A general term, summarizing permafrost parameters within given area.
Permafrost regime	A general term, summarizing thermal parameters of permafrost, including its aggradation/degradation, temperature gradient, and mean annual temperature.
Permafrost zone	A major subdivision of a permafrost region. A permafrost region is commonly subdivided into permafrost zones based on the proportion of the ground that is perennially cryotic. The basic subdivision in high latitudes is into zones of continuous permafrost and discontinuous permafrost.
Permeability, soil	The ease with which gases and liquids penetrate or pass through a bulk mass of soil or a layer of soil. Because different soil horizons vary in permeability, the specific horizon should be designated.
Polygon	A map delineation that represents a tract of land with certain landform, soil, hydrologic, and vegetation features. The smallest polygon on a 1:50,000 scale map is approximately 0.5 cm^2 and represents a tract of approximately 12.5 ha.
Porewater	Water occurring in the pores of soils and rocks.
Quartz	The second most abundant mineral in the Earth's continental crust, after feldspar. It is made up of a continuous framework of SiO_4 silicon–oxygen tetrahedra, with each oxygen being shared between two tetrahedra, giving an overall formula SiO_2.
Recharge	The process by which water is absorbed and added to the subsurface zone of saturation (groundwater).
Reclamation	The process of reconverting disturbed land to its former or other productive uses.
Relief	The elevations or inequalities of the land surface when considered collectively.
Return period	The long-term average interval of time between events of a specified magnitude; also known as a recurrence interval.
Riparian	(i) The interface between an upland area and a river or stream. (ii) The floodplain portion of a river or stream corridor.
Rock	Any naturally formed, consolidated or unconsolidated material, other than soil, composed of two or more minerals or occasionally of one mineral, and having some degree of chemical and mineralogical constancy.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Saline	Salty.
Sand	As a particle size term: a size fraction between 0.05 and 2.0 mm equivalent diameter, or some other limit (geology or engineering).
Scale	The resolution at which patterns are measured, perceived, or represented. Scale can be broken into several components, including geographic extent, resolution, and other aspects.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.
Sedimentation	The process by which suspended particles in waste water settle to the bottom.
Seepage	Slow water movement in subsurface. Flow of water from man-made retaining structures. A spot or zone, where water oozes from the ground, often forming the source of a small spring.

Term	Definition
Silt	As a particle size term: a size fraction between 0.002 and 0.05 mm equivalent diameter, or some other limit (geology or engineering).
Slope	The degree of deviation of a surface from horizontal, measured in a numerical ratio, percent and degree.
Snow water equivalent	The depth of water that would result from melting the snow accumulated in a given area.
Software	The programs and other operating information used by a computer.
Soil	The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick that occurs at the earth's surface and is capable of supporting plant growth.
Standard deviation	A measure of the spread or dispersion of a set of data. It is calculated by taking the square root of the variance.
Standard error	A measure of the sampling variability or precision of an estimate. The SE of an estimate is expressed in the same units as the estimate itself. It is calculated as the standard deviation divided by the square root of the number of observations.
Stockpile	Pile or storage location for bulk materials, forming part of the bulk material handling process.
Subsoil	The layer of material under the upper soil horizons on the surface of the ground.
Surface Area	The area of the lake water surface, excluding islands.
Talik	A large volume of unfrozen soil in the permafrost region. It originates mainly under deep lakes, rivers and other places where the mean annual soil temperature is above zero.
Terms of Reference	The Terms of Reference identify the information required by government agencies for an Environmental Impact Assessment.
Terrace	A nearly level, usually narrow plain bordering a river or lake. Rivers sometimes are bordered by a number of terraces at different levels.
Terrain	The landscape or lay of the land. This term is considered to comprise specific aspects of the landscape, namely genetic material, material composition, landform (or surface expression), active and inactive processes that modify material and form, slope, aspect, and drainage conditions. Terrain analysis is the identification of the above land surface features, to a more or less defined depth and determining their areal extent. The identification of special features such as permafrost, erosion, and landforms indicating subsurface structures is included in such analyses
Thermal conditions	A synonym term for temperature conditions.
Thermal regime	The range in water temperature typically observed in a given waterbody.
Thermistor	A device whose electrical resistance, or ability to conduct electricity, is controlled by temperature. Used to measure temperature in soil, bedrock, or various media.
Till	Till is an unsorted glacial sediment. Glacial drift is a general term for the coarsely graded and extremely heterogeneous sediments of glacial origin. Glacial till is that part of glacial drift which was deposited directly by the glacier. It may vary from clays to mixtures of clay, sand, gravel, and boulders.
Topography	The physical features of a district or region, such as those represented on a map, taken collectively; especially the relief and contours of the land. On most soil maps topography may also mean topography classes that describe slopes according to standard ranges of percent gradient.
Total dissolved solids	The total concentration of all dissolved compounds solids found in a water sample.
Tributary	A stream that flows into a larger stream or lake.
Tundra	An area between the polar ice cap and taiga that is characterized by a lack of trees and permanently frozen subsoil.
Upland	Areas that have typical ground slopes of 1% to 3%, have better drainage, and are not wetlands.
Uncertainty	Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.

Term	Definition
Undercatch	The phenomenon whereby a rain or snow gauge measures less than the actual precipitation. Wind turbulence can deflect precipitation from being captured by the gauge, trace events may be too small to measure and wetting of the gauge surface, followed by evaporation, can all cause measured values to be smaller than actual.
Universal Transverse Mercator (UTM)	Universal Transverse Mercator coordinate system: a grid based method of specifying locations, employing a series of sixty zones each based on a specifically defined secant Transverse Mercator projection.
Valued Component (VCs)	Valued components represent physical, biological, cultural, social, and economic properties of the environment that are considered to be important by society.
Vegetation	A term to describe all of the plants or plant life of an area.
Veneer	Unconsolidated soil material too thin to cover the minor irregularities of the underlying material. Ranges from 10 to 100 cm in thickness.
Waste rock	Rock moved and discarded to access resources.
Water quality	A measure of concentrations of contaminants, or naturally occurring minerals, in water. Lower the concentrations of a particular contaminant lead to better water quality.
Water table	The upper surface of groundwater or that level below which the soil is saturated with water.
Watercourse	Riverine systems such as creeks, brooks, streams and rivers.
Wetland	Land having the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetlands or aquatic processes as indicated by hydric soils, hydrophytic vegetation and various kinds of biological activity which are adapted to the wet environment.