NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 2 Geoscientific Preliminary Assessment

Initial Findings

TOWN OF BLIND RIVER, CITY OF ELLIOT LAKE AND AREA, ONTARIO

APM-REP-01332-0220

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PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT

INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA

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Executive Summary

In 2015, a Phase 1 Geoscientific Desktop Preliminary Assessment was completed to assess whether the Blind River and Elliot Lake area contained general areas that have the potential to satisfy the geoscientific site evaluation factors outlined in NWMO's Adaptive Phased Management (APM) site selection process. The assessment was conducted using available geoscientific information and key geoscientific characteristics that could be realistically assessed at the desktop stage. The Phase 1 assessment revealed that the area contains at least three general areas that have the potential to satisfy NWMO's geoscientific site evaluation factors.

In 2016, as part of Phase 2 of the preliminary geoscientific assessment of the area, NWMO initiated a series of initial geoscientific field studies in one of the three general potentially suitable areas identified during Phase 1 preliminary assessment. The objective of these initial field studies was to advance understanding of the geology of the general potentially suitable area, and assess whether it is possible to identify general Potential Repository Areas (PRAs).

The initial Phase 2 geoscientific preliminary assessment included the following key activities:

- Acquisition and processing of high-resolution airborne geophysical (magnetic and gravity) data over one of the general potentially suitable areas identified in Phase 1 Geoscientific Desktop Preliminary Assessment;
- Detailed interpretation of the high-resolution geophysical (gravity and magnetic) data to better understand the bedrock geology (e.g. geological contacts, depth and extent of rock units, lithological and structural heterogeneity);
- Detailed interpretation of surficial and magnetic lineaments using the newly acquired high-resolution remote sensing and magnetic data to identify possible structural features such as fractures, shear zones and dykes; and
- Geological mapping to assess geologic characteristics, including lithology, structure, bedrock exposure and surface constraints.

A total of six general Potential Repository Areas (PRAs) were identified in the area. These are general areas that encompass geoscientific potentially suitable areas. They are defined as relatively smaller areas that have the potential to meet NWMO geoscientific site evaluation factors, and have a sufficient volume of suitable rock that can fit one or more repository footprints (i.e. 6 km^2 or larger). The boundaries of the general PRAs are rough in nature and are not intended to be interpreted as geoscientific features or precise demarcations. General PRAs were identified based on the interpretation of available information to date, including high-resolution geophysical data, lineament interpretations, and geological mapping.

Identified general PRAs in the area capture areas of lower density of integrated lineaments, with more favourable lithological and structural characteristics. While the identified general PRAs appear to have favourable geoscientific characteristics for hosting a deep geological repository, there remain uncertainties that would need to be addressed during subsequent stages of the site evaluation process through borehole drilling. Given the lack of subsurface information in the area, there is uncertainty on the structural and lithological character of the bedrock at depth. The presence of mafic dykes is also a source of uncertainty as some of the dykes encountered during the geological mapping lacked any significant geophysical contrast from the predominant granitic rock.

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1.0 INTRODUCTION

In 2014, a Phase 1 Geoscientific Desktop Preliminary Assessment was completed by Golder Associates Ltd. (Golder) to assess whether the Blind River and Elliot Lake area contained general areas that had the potential to satisfy the geoscientific site evaluation factors outlined in NWMO's Adaptive Phased Management (APM) site selection process (Golder, 2014; NWMO, 2010). The desktop preliminary assessment focused on the area shown on Figure 1.1, and built on initial screening studies conducted by Geofirma Engineering Inc. in 2012 (Geofirma, 2012a,b).

The Phase 1 Geoscientific Desktop Preliminary Assessment was conducted using available geoscientific information and key geoscientific characteristics that could be realistically assessed at the desktop stage. These included: bedrock geology; structural geology; interpreted lineaments; distribution and thickness of overburden deposits; surface conditions; and the potential for economically exploitable natural resources. The consideration of these key geoscientific characteristics revealed that the Blind River and Elliot Lake area contained at least three general areas that have the potential to satisfy NWMO's geoscientific site evaluation factors. The Phase 1 Preliminary Assessment study also identified geoscientific uncertainties associated with these areas, including the presence of numerous dykes, and the low resolution of available geophysical data (Golder, 2014). In order to facilitate Phase 2 field studies, portions of land were temporarily removed from staking for mineral claims in the three identified general potentially suitable areas. This summary report focusses on one of the withdrawal areas shown on Figure 1.2, which also shows the bedrock geology of the area.

In 2016, as part of the Phase 2 preliminary geoscientific assessment of the area, NWMO initiated a series of initial geoscientific field studies focused in one of the general potentially suitable areas. These initial field studies included the acquisition and interpretation of high-resolution airborne geophysical surveys and geological mapping, including Observing General Geological Features (OGGF) and Detailed Mapping. The objective of these initial field studies is to advance understanding of the geology of one of the three general potentially suitable areas identified in the Phase 1 Geoscientific Desktop Preliminary Assessment, and assess whether it is possible to identify general Potential Repository Areas (PRAs).

The high-resolution airborne geophysical surveys included both magnetic and gravity surveys that improved understanding of the geological characteristics of the area. The high-resolution surveys provided new information on rock type, homogeneity, and the depth and extent of the potentially suitable host rock formations. High-resolution geophysical and remote sensing data were then used to conduct a magnetic and surficial lineament interpretation to identify the presence of potential structural features such as fractures and dykes. Geological mapping, including OGGF and Detailed Mapping, was conducted to better understand the character of the land, and to assess the nature of key geological features such as fractures, rock types, extent of bedrock exposure and surface constraints. For the purpose of this report, OGGF and Detailed Geological Mapping will be collectively referred to as "Geological Mapping".

The results from the initial Phase 2 field studies are documented in three supporting documents including: Geophysics Interpretation report (SGL, 2017); Lineament Interpretation report (SRK, 2017); and Geological Mapping report (Golder, 2017). This report provides a summary of the findings from Phase 2 initial field studies conducted in the area from 2016 to 2017 as they relate to whether the area contains general PRAs. The main sections of this report provide: a description of the approach and evaluation factors used to conduct the Phase 2 preliminary geoscientific assessment (Sections 2 and 3); a summary of the initial Phase 2 field studies methods and findings (Sections 4 and 5); and the approach, rationale and identification of general PRAs (Section 6).

2.0 GEOSCIENTIFIC PRELIMINARY ASSESSMENT APPROACH

The objective of the geoscientific preliminary assessment is to evaluate whether the Blind River and Elliot Lake area contains general areas that have the potential to meet NWMO's site evaluation factors. The geoscientific preliminary assessment is conducted in two phases:

Phase 1 – Desktop Study: For all communities electing to be the focus of a preliminary assessment. This phase involves desktop studies using available geoscientific information and a set of key geoscientific characteristics and factors that can be realistically assessed at the desktop phase of the preliminary assessment.

Phase 2 – Preliminary Field Investigations: For a subset of communities selected by the NWMO, to further assess potential suitability. This phase involves the acquisition of high-resolution geophysical surveys, geological mapping and the drilling of deep boreholes.

A brief description of the project, the assessment approach and findings of the preliminary assessment are documented in the Blind River and Elliot Lake area integrated Phase 1 preliminary assessment report (NWMO, 2014a,b).

The subset of communities considered in Phase 2 of the preliminary assessment was selected based on the findings of the overall desktop preliminary assessment considering both technical and community well-being factors illustrated in the above diagram.

The Phase 1 Geoscientific Desktop Preliminary Assessment was completed for the area in 2014 (Golder, 2014). Initial Phase 2 field studies, including high-resolution airborne geophysical surveys, lineament interpretation and Geological Mapping were conducted from 2016 to 2017. This report focuses on summarizing the findings of these initial field studies.

3.0 GEOSCIENTIFIC SITE EVALUATION FACTORS

As discussed in the NWMO site selection process document (NWMO, 2010), the suitability of potential sites is evaluated in a step-wise manner through a series of progressively more detailed scientific and technical assessments using a number of geoscientific site evaluation factors, organized under five safety functions that a site would need to ultimately satisfy:

- Safe containment and isolation of used nuclear fuel: Are the characteristics of the rock at the site appropriate to ensuring the long-term containment and isolation of used nuclear fuel from humans, the environment and surface disturbances caused by human activities and natural events?
- Long-term resilience to future geological processes and climate change: Is the rock formation at the siting area geologically stable and likely to remain stable over the very long term in a manner that will ensure the repository will not be substantially affected by geological and climate change processes such as earthquakes and glacial cycles?
- Safe construction, operation and closure of the repository: Are conditions at the site suitable for the safe construction, operation and closure of the repository?

- Isolation of used fuel from future human activities: Is human intrusion at the site unlikely, for instance through future exploration or mining?
- Amenable to site characterization and data interpretation activities: Can the geologic conditions at the site be practically studied and described on dimensions that are important for demonstrating long-term safety?

In the Phase 1 geoscientific desktop preliminary assessment of the area the site evaluation factors were applied in two steps. The first step identified at least three general potentially suitable areas within the area using key geoscientific characteristics that could realistically be assessed at the desktop stage based on available information. The second step confirmed that the three identified areas had the potential to ultimately meet all of the safety functions outlined above.

The identification of general PRAs was conducted through a systematic and iterative process based on the updated understanding of the key geoscientific characteristics of the Blind River and Elliot Lake area, using the newly acquired Phase 2 data. These key geoscientific characteristics are described in Section 5 and include: bedrock geology; lineament analysis; structural geology; mafic dykes; bedrock exposure; protected areas; natural resources and surface constraints.

4.0 PRELIMINARY FIELD INVESTIGATIONS

The initial Phase 2 geoscientific preliminary assessment included the following key activities:

- Acquisition and processing of high-resolution airborne geophysical (magnetic and gravity) data over one of the general potentially suitable areas identified in Phase 1 Geoscientific Desktop Preliminary Assessment;
- Detailed interpretation of high-resolution geophysical (gravity and magnetic) data to better understand the bedrock geology (e.g. geological contacts, depth and extent of rock units, lithological and structural heterogeneity);
- Detailed interpretation of surficial and magnetic lineaments using newly acquired high-resolution remote sensing and magnetic data to identify possible structural features such as fractures, shear zones and dykes; and
- Geological mapping to assess geologic characteristics, including lithology, structure, bedrock exposure and surface constraints.

The findings from the above activities were analyzed and interpreted in an integrated manner to achieve the following objectives:

- Update understanding of key geoscientific characteristics that can be realistically assessed at this stage of the assessment to identify general Potential Repository Areas (PRAs);
- Assess whether it is possible to identify general PRAs within one of the general potentially suitable areas identified in the Blind River and Elliot Lake area in the Phase 1 desktop preliminary assessment.

The approach, methods and findings for each of the above activities are described in detail in three supporting documents (SGL, 2017; SRK, 2017; and Golder, 2017). This section provides a summary of the approach, methods and key results for each activity. The findings are discussed in an integrated manner in Section 5. The identification of general PRAs is discussed in Section 6.

4.1 High-resolution Airborne Geophysical Surveys

The objective of the airborne geophysical surveys was to provide additional information to further assess the geology of the area. Data acquired during the surveys can be used to estimate the geometry and thickness of potentially suitable host rock formations; the nature of geological contacts; bedrock lithology; the degree of geological heterogeneity and the nature of various intrusive phases; as well as the general characteristics of structural features (e.g., fractures and shear zones). The newly acquired geophysical data (SGL, 2017) provides significantly higher resolution data compared to the data available in the Phase 1 preliminary assessment (PGW, 2014).

Sander Geophysics Limited (SGL) completed a fixed-wing high-resolution airborne magnetic and gravity survey in the Blind River and Elliot Lake area from April 2016 to May 2016 and from February 2017 to March 2017 (SGL, 2017). The surveys were completed over one block located northeast of the city of Elliot Lake. The survey block was designed to cover the potentially suitable area in the Ramsey-Algoma granitoid complex identified in the Phase 1 preliminary assessment and capture relevant geological features.

The survey included a total of 10,057 km flight lines covering a surface area of approximately 1,600 km^2. Flight operations were conducted out of Elliot Lake Municipal Airport, Ontario using two Britten Norman Islanders. Data were acquired along traverse lines flown in a north-south direction spaced at 100 m, and control lines flown east-west spaced at 500 m. The survey was flown at an altitude of approximately 70 m above ground level, with an average ground speed of 95 knots (approximately 50 m/s).

Airborne magnetic and gravity data were acquired using equipment with very high sensitivity and accuracy. The airborne magnetic data were recorded using a magnetometer sensor mounted in a fibreglass stinger extending from the tail of the aircraft. The airborne gravity data were recorded using a gravimeter, which includes three orthogonal accelerometers that are mounted on a stabilized platform inside the cabin of the aircraft. Details regarding the planning, execution and processing of the survey data are provided in SGL (2017). Interpretation of geophysical survey data, included geophysical interpretation (Section 4.2; SGL, 2017) and lineament interpretation (Section 4.3; SRK, 2017).

4.2 Geophysical Data Interpretation

Interpretation of the newly acquired high-resolution magnetic and gravity data was conducted by SGL (2017) for the area. Interpretation of geophysical data involved both a qualitative interpretation of the data, as well as preliminary forward modelling along representative profile lines. Magnetic and gravity data were interpreted to assess geological contacts and bedrock lithology, and determine the coincidence of magnetic responses with mapped lithology and structures for the area. Magnetic anomalies and interpreted lithological contacts were compared to existing bedrock geological maps to identify similarities and/or changes in the contact locations. The magnetic and gravity data are presented on Figures 4.1 and 4.2, respectively. At the same time that the magnetic and gravity data were acquired, higher resolution Digital Elevation Model (DEM) topographic data were also generated from the airborne GPS and altimeter data (SGL, 2017), as shown on Figure 4.3.

In order to develop a rough approximation of the depth of the different rock units in the Blind River and Elliot Lake area, preliminary forward modelling was conducted by SGL (2017). The preliminary modelling used the newly acquired high-resolution geophysical data and readily available information on the mapped bedrock geology at surface to provide a preliminary interpretation of the geometry and subsurface extent of the different units. The preliminary modelling considered scenarios where the potentially suitable rock units have internal density variations or a constant density to assess influence on estimated depths. Findings from the geophysical interpretation are discussed in an integrated manner in Section 5.

4.3 Lineament Interpretation

The purpose of the Phase 2 lineament interpretation was to provide an updated interpretation of the geological and structural characteristics of the bedrock units within the potentially suitable areas identified in the Phase 1 desktop assessment (Golder, 2015). A magnetic and surficial lineament study was conducted for the survey block using the high-resolution magnetic and DEM data from the airborne survey, and purchased high-resolution digital aerial imagery (SRK, 2017).

Lineaments are linear or curvilinear features that can be observed in remote sensing and geophysical data, and which often represent geological structures. The presence of these features at depth would need to be confirmed through further field studies such as borehole drilling.

4.3.1 Lineament Interpretation Workflow

The lineament interpretation workflow was designed to limit issues of subjectivity and reproducibility that are inherent to lineament interpretations (SRK, 2017). The workflow follows a set of detailed guidelines involving three stages:

Step 1: Independent lineament interpretation by two separate interpreters for each data set and assignment of certainty level (low, medium or high certainty);

Step 2: Integration of lineament interpretations for each individual data set, and determination of reproducibility (i.e. presence of the same lineament within each data set (DEM, aerial imagery, magnetic) as interpreted by each interpreter); and

Step 3: Integration of lineament interpretations for the surficial data sets (DEM and aerial imagery) followed by integration of the combined surficial data set with the magnetic data set, with determination of coincidence in each integration step.

Over the course of these three stages, a comprehensive list of attributes for each lineament was compiled (SRK, 2017). The key lineament attributes and characteristics used in the assessment include certainty, length, density and orientation:

Lineament Certainty: Certainty (low, medium or high) was defined based on the clarity of the lineament interpreted in the data, which provides confidence in the feature being related to bedrock structure. For example, where a surface lineament could be clearly seen on exposed bedrock, it was assigned a certainty value of high. Where a lineament represented a bedrock feature that was inferred from linear features, such as orientation of lakes or streams or linear trends in texture, it was assigned a certainty value of either low or medium. For magnetic lineaments, a certainty value of high was assigned when a clear magnetic susceptibility contrast could be discerned and a certainty value of either low or medium was assigned when the signal was discontinuous or more diffuse. The certainty classification for all three data sets involved expert judgment and experience of the interpreter. For the purpose of this assessment, emphasis was put on lineaments interpreted with high and medium certainty.

Lineament Length: Interpreted lineaments within the area where new geophysics data were acquired (shown on Figure 5.1) were classified according to their length, which is calculated based on the sum of all segment lengths that make up a lineament. It is assumed that longer interpreted lineaments may extend to greater depths than shorter interpreted lineaments. In general, longer interpreted lineaments also tend to have higher certainty values.

Lineament Density: The density of interpreted lineaments was determined by examining the statistical density of individual lineaments using ArcGIS Spatial Analyst. A grid cell size of 50 m and a search radius of 1.25 km (equivalent to half the size of the longest boundary of the minimum area size of a potential siting area) were used for this analysis. The spatial analysis used a circular search radius examining the lengths of lineaments intersected within the circular search radius around each grid cell.

Lineament orientation: The orientation of interpreted lineaments was expressed in degrees ranging between 0 and 180. Lineament sets are defined by direction clustering of the data. The number of identified lineament sets, and their variation in orientation, provides a measure of the complexity of the potential individual fractures or fracture zones.

The following sections provide a summary of interpreted lineaments. A more detailed analysis is provided in Section 5.2 of this report and in SRK (2017).

4.3.2 Magnetic Lineaments

Magnetic lineaments were interpreted using the new high-resolution magnetic data, which provides a significant improvement to the overall resolution and quality of magnetic data compared with the data available during the Phase 1 preliminary assessment. Lineaments interpreted using the magnetic data are typically less affected by the presence of overburden than surficial lineaments. Magnetic lineaments interpreted with medium and high certainty in the area are shown on Figure 4.4. A detailed analysis of magnetic lineaments interpreted within the vicinity of each potentially suitable area is provided in Section 5.2.

4.3.3 Surficial Lineaments

Surficial lineaments were interpreted using newly acquired high-resolution topographic data (DEM) from the airborne survey (SGL, 2017), and purchased high-resolution digital aerial imagery (SRK, 2017). The digital aerial imagery data have a cell resolution of 0.4 m, which was a significant improvement compared to the lower resolution data (20 m) used during the Phase 1 preliminary assessment. Surficial lineaments were interpreted as linear traces along topographic valleys, escarpments, and drainage patterns such as river streams and linear lakes. These linear traces may represent the expression of fractures on the ground surface. However, it is uncertain whether the structures extend to significant depth. Figure 4.5 shows Phase 2 surficial lineaments interpreted for the area. The observed distribution and density of surficial lineaments is highly influenced by the presence of overburden cover and water bodies, which can mask the surface expressions of potential fractures. The distribution of overburden is shown on Figure 4.6. A detailed analysis of surficial lineaments interpreted within the vicinity of each potentially suitable area is provided in Section 5.2. Interpreted surficial lineaments for each area are discussed in Section 5.

4.4 Geological Mapping

As part of the Phase 2 preliminary assessment, geological mapping was carried out by Golder. The initial phase of the Phase 2 geological mapping, OGGF, was completed in June 2017 by two teams of two people each that visited a total of 151 stations. During OGGF the geological observations were collected at readily-accessible locations using the existing road and trail network in the area to provide preliminary geological field data in the general potentially suitable areas. OGGF also provided insight on ground conditions (i.e. bedrock exposure and overburden thickness), as well as accessibility constraints.

During July 2017, an additional 120 stations were visited in the area during Detailed Geological Mapping (Figure 4.7) to advance the understanding of the potentially suitable areas, with an emphasis on observation and analysis of bedrock structure and lithology in the context of the results from the Phase 2 geophysical data interpretation (SGL, 2017) and lineament interpretation (SRK, 2017). Detailed Geological Mapping was completed by two teams of two geologists using existing secondary roads, trail networks and water bodies, as well as off-trail hiking. All-terrain vehicles (ATVs) were used to access selected difficult-to-reach areas.

Geological mapping was conducted at pre-defined traverse areas in and around one of the potentially suitable areas identified during Phase 1. The intent of the geological mapping was to confirm and ground truth the presence and nature of key geological features, including: bedrock character (lithology, structure, magnetic susceptibility and geomechanical properties), fracture character, and bedrock exposure and surface constraints.

Photograph 1 shows an example of an exposed bedrock station where observations were collected. Photograph 2 shows a typical example of geological measurements taken during the geological mapping.

Photograph 1: Outcrop mapping in the Blind River and Elliot Lake area, July 6, 2017.

Photograph 2: Example of outcrop measurements (structural orientation of a joint and magnetic susceptibility, respectively), June 6, 2017.

A detailed description of the geological mapping approach, methods and observations is provided by Golder (2017). An overview of the mapping planning, logistics and use of local and traditional knowledge is provided in the following sections. The findings of the Geological Mapping are discussed in an integrated manner with findings from other initial Phase 2 field data throughout Section 5.

4.4.1 Mapping Plans and Logistics

Planning of the Phase 2 Geological Mapping comprised three stages: pre-mapping planning; mapping; and synthesis and reporting. The pre-mapping planning stage involved a review of all available information for the Blind River and Elliot Lake area, including access, and the definition of mapping traverse or traverse areas. This stage also included the development of a comprehensive list of source data, equipment and task requirements for the observation of key geological attributes.

For OGGF mapping activities, traverses were designed during the pre-mapping planning mostly along the existing road network and modified to accommodate the specific logistical considerations of the area. During the planning stage for Detailed Geological Mapping, potential outcrop locations were identified in GIS, filtered, and prioritized. The spatial distribution of the identified potential outcrop locations (Figure 4.7) was then combined with geophysical anomalies and lineament interpretation (SGL, 2017; SRK, 2017) and existing bedrock mapping to define traverses or traverse areas to cover all features of geological interest.

The key geological attributes to be investigated, along with the methods identified to observe and capture the relevant information at each bedrock outcrop location, were defined during the pre-mapping stage. Geological observations, for both the initial OGGF mapping and detailed mapping activities, were collected with the use of a digital data capturing method and software supplied by the NWMO, which allow for seamless integration into a GIS platform. Representative hand-size rock samples were collected to provide examples of different rock types within each mapping area. Geophysical characteristics of the rock were determined by collecting magnetic susceptibility measurements from fresh surfaces of outcrop or rock samples using a KT-20 magnetic susceptibility meter and measuring gamma radiation using a gamma ray spectrometer (RS-125) from representative outcrop surfaces. Field rock strength testing was completed on representative lithologies at each station. Preliminary geomechanical characterization of the rock mass was determined through visual estimation of fracture spacing/frequency for block size determination and a field hammer test (Golder, 2017).

Geological mapping in the area was primarily completed using a 4x4 vehicle, with the majority of travel on main roads and gravel logging roads. Some hiking, canoe, and ATV use were required to access outcrop locations where logging roads are not passable, or non-existent.

4.4.2 Local and Traditional Knowledge Activities

As part of NWMO's promise to develop partnerships with First Nation and Métis people, there is a commitment to interweaving local Traditional Knowledge in all phases of NWMO's work. Traditional Knowledge involves all aspects of Aboriginal people's unique understanding, relationship and how they connect the land to their way of life. This unique understanding influences the way in which Aboriginal people use the land. Prior to the commencement of mapping activities, all staff involved in Geological Mapping in the field participated in a Traditional Knowledge training at the NWMO offices. The training reminded both participating contractors and NWMO staff that as humans we are dependent on the land for sustaining life. Geological mapping activities were carried out in a manner that was respectful of the land. In addition, information sharing meetings and a ceremony involving NWMO staff and mapping contractors along with participating members of local Aboriginal communities took place. The ceremony reminded participating members that as humans we are dependent on the land for sustaining life.

5.0 KEY GEOSCIENCE CHARACTERISTICS

The following subsections provide an updated description of the key geoscientific characteristics that were used to identify general PRAs, based on both Phase 1 preliminary assessment and the newly acquired field data during initial Phase 2 field work. The updated description focuses on an area that was identified as potentially suitable in the Phase 1 Geoscientific Desktop Preliminary Assessment (Figure 1.2).

5.1 Bedrock Geology

The bedrock geology of the Blind River and Elliot Lake area was described in detail in the Phase 1 Geoscientific Desktop Preliminary Assessment based on publicly available reports and geological maps, as well as from the Phase 1 geophysical interpretation (PGW, 2014). This section provides an updated description of the bedrock geology of the general potentially suitable areas based on the integrated interpretation of Phase 2 field data.

The withdrawal area is located in its entirety within the Algoma plutonic domain of the Ramsey-Algoma granitoid complex. Geological observations during Phase 2 Geological Mapping indicate that the Algoma plutonic domain in the Blind River and Elliot Lake area is dominated by homogeneous crystalline bedrock consisting primarily of granite (Figure 1.2) with minor amounts of gneissic and meta-mafic xenoliths. The granite is typically inequigranular and composed of plagioclase, potassium feldspar, quartz with variable biotite and magnetite content. The average grain size of 1 – 10 mm (medium to coarse grained) varies locally and, rarely, igneous layering is recognized by grain size variations.

Xenoliths of variable composition occur primarily on the northern and southern margin of the withdrawal area. Note that the xenolith bearing areas do not show a distinct signature in the magnetic data (Figure 4.1)

The airborne gravity survey (Figure 4.2) revealed a gravity low at the southern end of the survey block that either represents the deepest portion of the Ramsey-Algoma Granitoid Complex or a local alternate phase of emplacement with a slightly lower density than the rest of the granite. A gravity high at the northern end of the surveyed area is interpreted to represent a dipping transition from the Ramsey-Algoma Granitoid Complex to a denser gneissic tonalite suite mapped along the northern margin of the granite to the north of the withdrawal area.

5.2 Lineament Analysis

This section provides an integrated analysis of interpreted lineaments (SRK, 2017) for the withdrawal area assessed in the Blind River and Elliot Lake area, using the newly acquired high-resolution magnetic, topographic and aerial imagery data (Section 4.1).

Lineaments interpreted by SRK (2017) were classified into three general categories based on a working knowledge of the structural history and bedrock geology of the Blind River and Elliot Lake area. These categories include form lines, brittle, and dyke lineaments, described as follows.

Form lines are features interpreted to represent the internal fabric of the rock units (including sedimentary or volcanic layering, tectonic foliation or gneissosity, and magmatic foliation). Form lines are typically characterized by semi-continuous linear to curvilinear magnetic highs that appear to define the grain of the rock units. Form lines were used in the lineament report (SRK, 2017) to provide context to the lineament interpretation, but were not included in the statistical analyses of the lineament data sets.

Brittle lineaments are commonly characterized by continuous, linear magnetic lows, and breaks in topography, vegetation, and/or linear shorelines. These features are interpreted as fractures (joints or joint sets, faults or fault zones, and veins or vein sets).

Dyke lineaments are features interpreted as dykes, on the basis of their distinct character (e.g., orientation, geophysical signature and topographic expression). Dykes were dominantly interpreted from the magnetic data set, and were typically characterized by continuous linear magnetic highs.

Magnetic lineaments of high and medium certainty are presented in Figure 4.4 for the withdrawal area. Areas of higher density of magnetic lineaments tend to correspond to bands of northwest-trending, tightly spaced dyke lineaments such as in the southwestern portion of the withdrawal area.

The high and medium certainty surficial lineaments in the withdrawal portion of the withdrawal area are shown on Figure 4.5. The density of surficial lineaments is variable throughout the withdrawal area, with a higher surficial lineament density observed in the form of northwesterly trending zones in the area northeast of Lac aux Sables and along the east side of the chain of lakes (Armstrong, Jackson, and Jeanne) in the northeastern part of the withdrawal area. It is possible that overburden cover may locally mask some of the surficial lineaments.

Figure 5.1 shows the density of integrated lineaments with high and medium certainty for the withdrawal area. Highest lineament density occurs in the southwest and the east of the withdrawal area. The southwestern portion is dominated by tightly spaced northwest-trending lineaments, which are mostly mafic dykes of the Matachewan and Sudbury swarms. A north-northwest trending band of high lineament density is formed by long north-northwest trending and northeast-trending brittle lineaments. Geological mapping in this area showed abundant observations of brittle deformation. A lower density of integrated lineaments is observed in the northwestern and central portions of the withdrawal area.

5.3 Structural Geology

The following sections provide a summary of the mapped ductile (igneous flow foliations, tectonic foliations, brittle-ductile and ductile shear zones) and brittle structures (joints, faults, veins) in the general potentially suitable areas.

Ductile and Brittle-Ductile Structures

The most common ductile structure measured in the Blind River and Elliot Lake area is weakly to moderately well-developed igneous flow foliation, which predominantly trends east-west and is steeply dipping. Tectonic foliation is weakly to moderately developed throughout the area. The tectonic foliation strikes east-west, parallel to the recognized igneous flow foliation.

Ductile shear zones are uncommon in the Blind River and Elliot Lake area, with only seven occurrences mapped. Fifty-seven brittle-ductile shear zones occur mainly in the northwest and south-central portions of the withdrawal area. Brittle-ductile shear zones dominantly strike northwest and dip steeply to the northeast and southwest. The width of these shear zones ranges mostly between 1-3 cm, but they are occasionally up to 0.3 m wide and with an anastomosing geometry. Brittle-ductile shear zones are associated with chlorite infill (42%), and occasionally with epidote (28%), quartz (20%), cataclasite (16%) and hematite (8%).

Brittle Structures

Joints, faults, and veins are the main brittle structure types documented in the Blind River and Elliot Lake area during Phase 2 Geological Mapping. A total of 660 joints were measured in the withdrawal area. Most of the measured joints are subvertical, with dominant joint orientations north-northeast to east-northeast and northwest to north-northwest. Mineral infilling was observed on approximately 7% of joint surfaces. Joint spacing is variable, ranging from <1 cm to several tens of meters, with most of the joints falling into the 100 to 500 cm spacing class. Overall, widely spaced (500–1000 cm) joints were observed in the central portion of the withdrawal area. Subhorizontal joints make up 13% of the overall joint population and are generally spaced several meters apart.

Faults

A total of 186 fault measurements were collected throughout the withdrawal area, with lesser faults occurring in the centre of the withdrawal area. The majority of the measured faults were steeply-dipping, with the dominant strike north-northeast and east-northeast, as well as a lesser population of northwest-striking faults. Damage zones of faults range from thin, single slip surfaces to metre wide zones parallel to the fault plane. Faults display mineral infill in the majority of occurrences (63%), the most common minerals are chlorite (25%) and epidote (23%). Cataclasite (17%), quartz (16%), and hematite (14%) are additional mineral infills observed on faults.

Veins

Veins occur only rarely in the withdrawal area. The majority of veins are extensional and filled with quartz, with lesser occurrences of chlorite and magnetite veins. The majority of observed veins are less than 3 cm in width. Veins strike mostly north to north-northeast and east-southeast and are steeply-dipping.

5.4 Mafic Dykes in the Blind River and Elliot Lake Area

Two major sets of mafic dykes have been mapped at the regional scale in the Blind River and Elliot Lake area. These belong to the Matachewan and Sudbury dyke swarms. The north-northwest to northwest-trending Matachewan dyke swarm (ca. 2.473 Ga; Buchan and Ernst, 2004) is one of the largest in the Canadian Shield. Matachewan dykes are mainly quartz-diabase dominated by plagioclase, augite, and quartz (Osmani, 1991). Centimeter-scale plagioclase phenocrysts are a characteristic feature of dykes of the Matachewan swarm. The younger (ca. 1.238 Ga; Krogh et al., 1987) Sudbury dyke swarm shares a roughly similar northwest trend but the dykes are generally narrower and appear to have filled the space of older northwest-trending faults (Easton, 2009). Sudbury dykes typically range in composition from olivine diabase, amphibole diabase, diabase, magnetite-bearing diabase to lamprophyre diabase, and show typical green to brown weathering and recessive topography.

Less common mafic dyke occurrences are the north-trending Marathon swarm dykes (ca. 2.473 Ga; Buchan and Ernst, 2004), northeast-trending Biscotasing dykes (ca. 2.167 Ga; Hamilton et al., 2002), west-northwest-trending North Channel dykes (ca. 1.6 to 2.5 Ga; OGS, 2011), and east-northeast-trending Grenville dykes (ca. 590 Ma; Kamo et al., 1995).

SRK (2017) interpreted dyke lineaments of six major dyke swarms within the Blind River and Elliot Lake area (Figure 4.4). Based on their orientation, most of the interpreted dyke lineaments in the withdrawal area are of the northwest-trending Matachewan and Sudbury dyke swarms. Lesser north-trending dyke lineaments in the centre and east of the withdrawal area were interpreted to correspond to the Marathon dyke swarm. Mostly short, discontinuous, east-northeast-trending dyke lineaments in the southern portion of the withdrawal area are attributed to the Grenville dyke swarm. One northeast-trending dyke lineament, composed of several short segments that combined form an approximately 13 km long lineament, is in the centre of the withdrawal area and interpreted as a dyke of the Biscotasing swarm. Dyke lineaments attributed to the North Channel swarm occur mostly along the margins of the withdrawal area, with one west-northwest-trending lineament interpreted in the southeast of the withdrawal area.

The orientations of the interpreted dyke lineaments are mostly consistent with observations collected during field mapping activities (Golder, 2017). However, several dykes interpreted from the magnetic data as Sudbury dykes (SRK, 2017) exhibit characteristic plagioclase phenocrysts (e.g. 17IL0031, 17IL0097, 17TC0107, 17TC0122) and were thus attributed to the Matachewan dyke swarm during geological mapping. The overlap in the range of strike orientations of Sudbury and Matachewan dyke swarms, as well the absence of recognizable olivine in any of the observed mafic dykes, indicates that some of the dykes interpreted to be part of the Sudbury dyke swarm may instead be a part of the Matachewan dyke swarm.

The majority of dykes that were observed in the field spatially coincide with dyke lineaments interpreted from the high-resolution magnetic data (SRK, 2017). In a few locations however, dykes observed in the field were not interpreted from the magnetic data. In the central portion of the withdrawal area (17TC0130), a 40 m wide north-northwest-striking dyke with a very high magnetic susceptibility (average 145.3 x 10^{-3} SI) was observed during geological mapping, but a dyke lineament was not interpreted in this location. Nearby, an irregularly-shaped dyke (at station 17TC0012) with a high magnetic susceptibility (average 28.1x 10^{-3} SI) is also unassociated with an interpreted dyke. Other examples of mafic dykes unassociated with an interpreted dyke (e.g. 17IL0140) were found to have low magnetic susceptibility and hence provided no magnetic contrast compared to the granitic country rock.

Conversely, several locations of expected dyke occurrence did not coincide with dyke observation during geological mapping. In one notable example, there was no evidence in the field of a mafic dyke in proximity to an interpreted north-trending Marathon dyke in an area of excellent exposure along a shoreline (17IL0159).

Dyke lineaments interpreted in the withdrawal area are, for the most part, under 5 km long (SRK, 2017). Based on the geological mapping data, the majority of the dykes are between 10 and 40 m in width. The majority (52%) of Matachewan dykes mapped in the field had a minimum thickness of 10 m, with 32% of the Matachewan dykes observed to have a thickness greater than 20 m. 7% of the mapped Matachewan dykes had a measured thickness between 1-5 m, with another 7% between 5 and 10 m. Five of eight (63%) mapped Sudbury dykes had a thickness between 10 and 20 m, while only 13% (1 of 8) had a thickness of more than 20 m and 26 % had a thickness less than 5 m.

The majority of the Matachewan dyke contacts are intact (i.e., no fractures localized at the contact between the dyke and the adjacent bedrock). Of the 29 locations where Matachewan dyke contacts were observed, four of the contacts were found to be faulted or brecciated. At a detailed scanline completed across one Matachewan mafic dyke, both of the dyke-granite contacts were marked by a contact-parallel fault. The two dominant joints within mapped Matachewan dykes were observed to be subvertical, and orthogonal and parallel to the northwest-striking dyke contacts.

Within the Sudbury dyke set, the main joint sets trend east and north, parallel and orthogonal to the dyke contact. Joints within the dyke are mostly spaced 3 to 100 cm, whereas joints in the host rock are spaced mostly 100 to 1,000 cm. In places, granite clasts within the dyke provide an indication of damage to the country rock during the intrusion of the dyke. Notably, brecciated dyke margins showed evidence of fracturing during emplacement.

Field observations indicate that while no significant damage zone surrounding the mafic dykes affects the country rock, the dykes themselves are locally characterized by more closely spaced joints and by faults and breccia along the dyke margins. Some of the steep-sided valleys within the withdrawal area also coincide with the interpreted traces of mafic dykes suggesting that at least some of the dykes formed along pre-existing zones of structural weakness or provided a zone of contrasting rock strength that served as a focus for post-emplacement faulting or fault reactivation.

5.5 Bedrock Exposure

The distribution and thickness of overburden cover is an important site characteristic to consider when assessing amenability to site characterization of an area. At this stage of the assessment, preference was given to areas with greater mapped bedrock exposures. The extent of area mapped as bedrock terrain in the Elliot Lake and Blind area is shown on Figure 4.6. These areas are expected to be covered, at most, with a thin veneer of overburden and therefore considered amenable to geological mapping. The predicted bedrock outcrops shown on Figure 4.7 generally confirmed areas where overburden had limited thickness.

During geological mapping many predicted locations of exposed bedrock identified for the withdrawal area were confirmed as such through visual inspection. Out of the 271 locations visited, 261 locations were positively identified as having exposed bedrock, while ten (10) were found to be overburden covered (Figure 4.7).

Visual inspection in the field suggests that the extent of bedrock outcrop is greater than the predicted extent owing to the masking effects of locally dense forest cover and the ubiquity of outcrop over some of the upland areas. Average (estimated) overburden thickness around the edges of exposed bedrock outcrop varies between 0.3 and

1.5 m. Thick overburden was generally restricted to wetland areas and to the flanks of river valleys where glaciofluvial deposits, such as outwash, are present. Three sand and gravel pits were observed within the withdrawal area, including one alongside the West Branch Road in the south-central part of the area and two others in the northwestern portion of the area.

5.6 Protected Areas

All provincial parks, conservation reserves and provincial nature reserves in the Elliot Lake area were excluded from consideration (Golder, 2014). The 36.5 km^2 River aux Sables Provincial Park is located to the west of the withdrawal area and the 43.5 km^2 Mozhabong Lake Conservation Reserve lies east of the withdrawal area (Figure 1.1).

5.7 Natural Resources

Areas with known potential for exploitable natural resources such as the rocks of the greenstone belts were excluded from further consideration for the identification of potentially suitable areas (Geofirma, 2012ab). Granitoid rocks of the Ramsey-Algoma complex have low potential for economically exploitable natural resources and no mineral deposits are known to occur within the withdrawal area (Figure 5.2). In addition to the information collected during the Phase 1 preliminary assessment (Golder, 2014), the newly acquired Phase 2 geophysical data (SGL, 2017) was used to identify geophysical anomalies that might be indicative of rock units that have mineral potential. No such significant anomalies were identified within the withdrawal area.

5.8 Potential Surface Constraints

An extensive network of logging roads occurs throughout much of the withdrawal area although locally heavy overgrowth and flooding is common, and substantial upgrades would be required to the roads to access some of the area. Portions of the eastern part of the withdrawal area lack any logging roads. Areas of steep slope, primarily associated with bedrock topography (ridges or cliffs), are common in portions of the withdrawal area.

6.0 GENERAL POTENTIAL REPOSITORY AREAS

This section describes how the key geoscientific characteristics and constraints presented in Section 5 were applied to further assess the suitability of the Blind River and Elliot Lake area. The ovals presented in Figures 6.1 to 6.6 represent general potential repository areas (PRAs) that are geoscientifically potentially suitable for further study. The boundaries of these general PRAs are approximate in nature and are not intended to be interpreted as geoscientific features or precise demarcations. The assessment to identify the general PRAs was conducted in a systematic and iterative manner using the key geoscientific characteristics, and the following general approach.

Bedrock Geology: Identify areas with the most favourable geological setting in terms of lithology and lithological homogeneity, using the high resolution magnetic and gravity data, as well as field observations. The estimated depth and extent of the potentially suitable host rock formations was also considered.

Structural Geology: Refine the location and extent of the areas based on updated understanding of the structural geology, high resolution magnetic, gravity and lineament data, as well as field observations. The refinements were focused on identifying bounding structures that could potentially define favourable rock volumes, taking into account the nature and complexity of structural features in the area such as faults, dykes, deformation zones, and geological boundaries.

Lineament Analysis: Use lineament characteristics to identify the most favourable structural domains for hosting a repository, using the following approach:

- Integrated lineament densities were used to guide the identification of general PRAs. Emphasis was put on density of integrated lineaments (dyke and brittle) of high and medium certainty (i.e., certainty 3 and 2, respectively). Areas of higher integrated lineament density, which often correspond to bands of tightly-spaced dyke lineaments, were avoided. General PRAs were defined to capture areas of lower integrated lineament density.
- Within the majority of the general PRAs, high and medium certainty lineaments (brittle and dyke) are present. Where faults were mapped sub-parallel to lineaments within the general PRAs, they were discrete narrow structures (i.e., generally less than 10 cm wide). Similarly, field observations on mafic dykes showed that damage to the host rock is limited to tighter joint spacing adjacent to the dyke contacts. At this point, field data do not provide evidence that these internal lineaments would be a limiting factor when designing repository layouts. It will require further field investigations, including borehole drilling, to determine whether these features would affect a potential repository layout at depth.
- At this stage of the assessment, interpreted lineaments, including dyke and brittle lineaments, were conservatively assumed to be potentially permeable features (i.e., hydraulically conductive). It is worth noting, however, that many of the interpreted lineaments may be sealed structures due to the higher rock stresses at depth and/or the presence of mineral infillings or gouge. Also, field observations revealed that most of the dyke contacts are intact at surface.

Protected Areas: The general potentially suitable areas identified in the Phase 1 preliminary assessment were all outside protected areas such as provincial parks, conservation reserves and provincial nature reserves (Golder, 2014).

Natural Resources: In addition to the information gathered during the Phase 1 preliminary assessment (Golder, 2014), the high resolution Phase 2 geophysical data were used to identify geophysical anomalies that may be indicative of rock units that have mineral potential. Mineral resources and claim maps were also updated as part of the initial Phase 2 assessment.

Overburden: The distribution and thickness of overburden cover is important to consider when assessing amenability to site characterization of an area. At this stage of the assessment, preference was given to areas with greater bedrock exposure, as indicated by available Quaternary mapping and by field observations.

Potential Surface Constraints: Areas of obvious topographic constraints (high density of steep slopes), large water bodies (wetlands, lakes), and accessibility are identified as potential constraints that would need to be considered in the selection of a repository site. Accessibility was documented during geological mapping (Golder, 2017).

The iterative consideration of the above key geoscientific characteristics, together with the geoscientific site evaluation factors, identified a number of general PRAs in the Blind River and Elliot Lake area. The general PRAs are located in the Ramsey-Algoma Granitoid Complex (North East) withdrawal area identified earlier in the Phase 1 desktop preliminary assessment (Figure 6.1).

6.1 Approach for Identifying Geoscientific Potential Repository Areas

The general PRAs in each withdrawal area were identified based on the integrated interpretation and understanding of geoscientific data gathered through the interpretation of high resolution airborne gravity and magnetic surveys (SGL, 2017), geophysical and surficial lineament interpretation (SRK, 2017) and geological mapping (Golder, 2017).

The key geoscientific characteristics used to guide the identification of the general PRAs were as follows:

a) Lithological character based on the interpretation of high-resolution airborne magnetic and gravity responses and geological mapping observations. Areas of greater lithological complexity were less preferred.

b) Structural character based on the interpretation of high-resolution airborne magnetic and gravity responses, lineament interpretation, and geological mapping observations. Areas of greater structural complexity were less preferred.

c) Lineament characteristics were generally used in the following manner:

   Integrated lineament densities were used to guide the identification of general PRAs. Emphasis was put on density of integrated lineaments (dyke and brittle) of high and medium certainty (i.e., certainties 3 and 2, respectively). Areas of higher integrated lineament density, which often correspond to bands of tightly-spaced dyke lineaments, were avoided. General PRAs were defined to capture areas of lower integrated lineament density.

   Within the majority of the general PRAs, high and medium certainty lineaments (brittle and dyke) are present. Where faults were mapped sub-parallel to lineaments within the general PRAs, they were discrete narrow structures (i.e., generally less than 10 cm wide). Similarly, field observations on mafic dykes showed that damage to the host rock is limited to tighter joint spacing adjacent to the dyke contacts. At this point, field data do not provide evidence that these internal lineaments would be a limiting factor when designing repository layouts. It will require further field investigations, including borehole drilling, to determine whether these features would affect a potential repository layout at depth.

   At this stage of the assessment interpreted lineaments, including dyke and brittle lineaments, were conservatively assumed to be potentially permeable features (i.e., hydraulically conductive). It is worth noting, however, that many of the interpreted lineaments may be sealed structures due to the higher rock stresses at depth and/or the presence of mineral infillings or gouge. Also, field observations revealed that most of the dyke contacts are intact at surface.

The extent of water bodies, presence of overburden, and access constraints were not considered for this exercise. These factors will be further assessed and considered when integrating the geoscience findings with the findings from other technical and social studies.

6.2 General Potential Repository Areas

Following the approach outlined above, a total of six general PRAs were identified within the Ramsey-Algoma Granitoid Complex in the Blind River and Elliot Lake area. These general PRAs are shown on Figure 6.1 (with bedrock geology) and 6-2 (showing mapping stations). The general PRA's are labelled as Ramsey-Algoma Granitoid Complex areas: RA-A, RA -B, RA-C, RA-D, RA-E and RA-F.

Identified general PRAs in the Ramsey-Algoma Granitoid Complex in the Blind River and Elliot Lake area were generally selected to capture areas of lower density of integrated lineaments, with more favourable lithological and structural characteristics. Bands of northwest and north, northwest-trending, tightly-spaced dyke lineaments were considered less favourable given the lithological and structural complexity added by the high density of dykes.

Within the majority of the general PRAs there are high and medium certainty lineaments interpreted. At this point, field data do not provide evidence that the lineaments interpreted within the general PRAs would be a limiting factor when designing repository layouts. It will require further field investigations, including borehole drilling, to determine whether these features would affect a potential repository layout at depth.

Figure 6.2 shows the six general PRAs identified in the Ramsey-Algoma Granitoid Complex area (RA-A, RA-B, RA-C, RA-D, RA-E and RA-F). Based on the distribution of remotely predicted outcrops, bedrock mapping locations and surficial geology maps (Figures 4.6 and 4.7), overburden cover in the general PRAs identified in the Ramsey-Algoma Granitoid Complex is relatively sparse and restricted wetland areas and flanks of river valleys where glaciofluvial deposits are present. In RA-B bedrock exposure is limited to the southern two thirds of the general PRA. Similarly, the central portions of RA-E and RA-F have sparse bedrock exposure. In the remaining general PRAs bedrock exposures are more evenly distributed.

The assessment of geoscientific data in the Ramsey-Algoma Granitoid Complex identified a number of areas considered less preferred from a suitability perspective, such as the bands of northwest and north, northwest-trending, tightly-paced dyke lineaments in the southwest, northeast and a narrower central portion of the withdrawal area (Figure 6.3). Within these bands the high density of dykes adds lithological and structural complexity. Outside of these less preferred areas, the six general PRAs within the Ramsey-Algoma Granitoid Complex comprise areas where the density of high and medium certainty integrated lineaments is relatively low.

The general PRAs in the Ramsey-Algoma Granitoid Complex are for the most part bounded by high certainty, long lineaments including both dyke and brittle lineaments on the lineament and lineament density map (Figure 6.3). Lineaments of high and medium certainty are interpreted within all six general PRAs). Field evidence for brittle and brittle-ductile lineaments in the Ramsey-Algoma Granitoid Complex withdrawal area was recorded. Most faults were less than 30 cm wide. Shear zones were mapped in the withdrawal area but none occurred within the selected general PRAs. Field observations on mafic dykes show that damage to the host rock is limited to tighter joint spacing adjacent to the dyke contacts. At this point, field data do not provide evidence that the lineaments interpreted within the general PRAs would be a limiting factor when designing repository layouts. It will require further field investigations, including borehole drilling, to determine whether these features would affect a potential repository layout at depth.

Bedrock within the withdrawal area of the Ramsey-Algoma Granitoid Complex is lithologically very homogeneous, with granite mapped at the majority of the outcrop stations (Figure 6.4). Where overburden cover limits the ability to characterize the bedrock in the field, the uniform geophysical response in addition to the geological mapping data provide a rationale for expecting similar uniform lithology across all six general PRAs. Few minor lithologies such as amphibolite, gneiss, gabbro and diorite are also mapped as xenoliths within the granite in the area (Figure 6.5). These xenoliths are located primarily in the northwest margin of the withdrawal area.

Figure 6.6 shows the distribution of mapped faults and shear zones for the withdrawal area in the Ramsey-Algoma Granitoid Complex area. Faults were mapped throughout the withdrawal area but there were clusters in the northwestern and northeastern portions near Jackson and Jeanne Lakes. Fault damage zones are relatively narrow, ranging from mm-scale single slip surfaces to metre-scale zones with multiple parallel fault planes and subordinate oblique fractures. Shear zones are generally evenly distributed, though they are less common in the southeastern, southwestern and northeastern parts of the withdrawal area. Joints are mapped throughout the Ramsey-Algoma Granitoid Complex withdrawal area and are mostly steeply dipping, with two main orientations broadly to the northeast, and southeast. Interpretation of geophysical data in conjunction with foliation measurements recorded during geological mapping suggest the presence of a regional, igneous flow foliation trending predominantly east-west, with only minor variations in the northwestern corner of the withdrawal area. The general uniformity in orientation of aligned feldspar phenocrysts throughout the mapping area suggests that this fabric is likely not entirely a product of emplacement of the granite, but is also influenced by tectonic processes.

Many of the dykes mapped in withdrawal area show a good correlation with interpreted dyke lineaments. About 1/3 of the occurrences of dykes observed in the field were not interpreted as a dyke lineament from the magnetic data. These occurrences of mafic dykes display a wide range of widths and magnetic susceptibility measurements. In addition, there were some cases where dyke lineaments were interpreted in the magnetic data but no dykes were observed in the field at that location, in spite of good bedrock exposure. It is possible that additional dykes are present, but are undetectable using magnetic data.

Given the lack of subsurface information in the Ramsey-Algoma Granitoid Complex general PRAs there is uncertainty on the distribution of fractures and the degree of lithological homogeneity at depth. As noted previously, sparse bedrock exposure in the northern portion of RA-B and the central portions of RA-E and RA-F adds uncertainty in the structural complexity of these general PRAs. Other uncertainties identified include the cluster of faults noted during geological mapping around Jeanne Lake within RA-C.

7.0 SUMMARY

A total of six general PRAs were identified in the Blind River and Elliot Lake area based on the interpretation of information available to date, including high-resolution geophysical data, lineament interpretation and geological mapping.

Each of these general PRA’s occurs within granite bedrock of the Ramsey-Algoma Granitoid Complex and are for the most part bounded by high certainty, long lineaments. Small scale faulting is present but generally sparse, as are mapped or interpreted mafic dykes. At this point, field data do not provide evidence that the lineaments interpreted within the general PRAs would be a limiting factor when designing repository layouts. It will require further field investigations, including borehole drilling, to determine whether these features would affect a potential repository layout at depth.

8.0 REFERENCES

Buchan, K.L. and R.E. Ernst, 2004. Diabase dyke swarms and related units in Canada and adjacent regions. Geological Survey of Canada, Map 2022A, scale 1:5,000,000.

Easton, R.M. 2009. Compilation Mapping, Pecors–Whiskey Lake Area, Southern and Superior Provinces; *in* Summary of Field Work and Other Activities 2010. Ontario Geological Survey, Open File Report 6240, 254 p.

Geofirma, 2012a. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, City of Elliot Lake, Ontario; Document ID: 10-214-5_Initial Screening Blind River_R0, August 24, 2012

Geofirma, 2012b. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Town of Blind River, Ontario; Document ID: 10-214-5_Initial Screening Elliot Lake_R0, August 24, 2012

Golder, 2014. Phase 1 Desktop Geoscientific Preliminary Assessment of Potential Suitability for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, City of Elliot Lake, Town of Blind River, Township of The North Shore, and Town of Spanish, Ontario. Report for the Nuclear Waste Management Organization (NWMO). NWMO report number: APM-REP-06144-009

Golder, 2017. Phase 2 Geoscientific Preliminary Assessment, Geological Mapping, Elliot Lake Blind River and Area, Ontario. APM-REP-01332-0219.

Hamilton, M.A., D.W. David, K.L. Buchan, and H.C. Halls, 2002. Precise U-Pb dating of reversely magnetized Marathon diabase dykes and implications for emplacement of giant dyke swarms along the southern margin of the Superior Province, Ontario. Geological Survey of Canada, Current Research 2002-F6, 10p.

Kamo, S.L., T.E. Krogh, and P.S. Kumarapeli, 1995. Age of the Grenville dyke swarm, Ontario – Quebec: implications for the timing of Iapetan rifting; Canadian Journal of Earth Science, v. 32, p. 273-280.

Krogh, T.E., F. Corfu, D.W. Davis, G.R. Dunning, L.M. Heaman, S.L. Kamo, N. Machado, J.D. Greenough and E. Nakamura, 1987. Precise U-Pb isotopic ages of diabase dykes and mafic to ultramafic rocks using trace amounts of baddeleyite and zircon; *in* Mafic dyke swarms. Geological Association of Canada, Special Paper 34, p. 147-152.

NWMO (Nuclear Waste Management Organization), 2010. Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel. May 2010. (Available at www.nwmo.ca)

NWMO, 2014a. Preliminary Assessment for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel; The Corporation of The City of Elliot Lake, Ontario Findings From Phase One Studies; APM-REP-06144-0097 (Available at www.nwmo.ca)

NWMO, 2014b. Preliminary Assessment for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel; The Corporation of The Town of Blind River, Ontario Findings From Phase One Studies; APM-REP-06144-0089 (Available at www.nwmo.ca)

OGS (Ontario Geological Survey), 2011. 1:250 000 Scale Bedrock Geology of Ontario, Miscellaneous Release – Data 126 – Revision 1. ISBN 978-1-4435-5704-7 (CD) ISBN 978-1-4435-5705-4 [zip file]

Osmani, I.A., 1991. Proterozoic mafic dyke swarms in the Superior Province of Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p. 661-681.

PGW (Paterson, Grant and Watson Limited), 2014. Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Geophysical Data, City of Elliot Lake, Town of Blind River, the Township of The North Shore, Town of Spanish, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0093.

SGL, 2017. Phase 2 Geoscientific Preliminary Assessment, Acquisition, Processing and Interpretation of High-Resolution Airborne Geophysical Data, Elliot Lake and Blind River Area, Ontario. APM-REP-01332-0217.

SRK, 2017. Phase 2 Geoscientific Preliminary Assessment, Lineament Interpretation, Elliot Lake and Blind River Area, Ontario. APM-REP-01332-0218.

Report Signature Page

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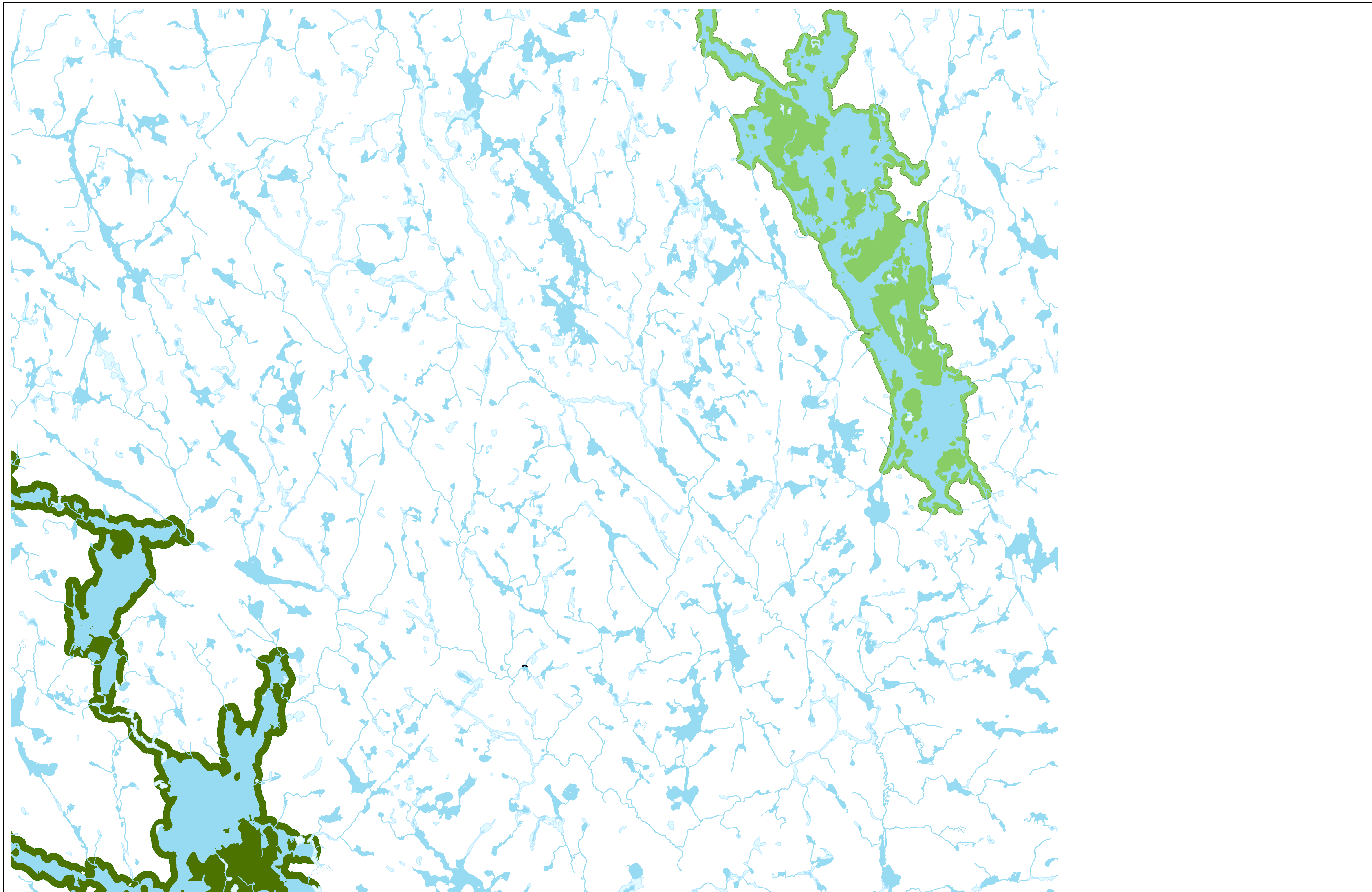

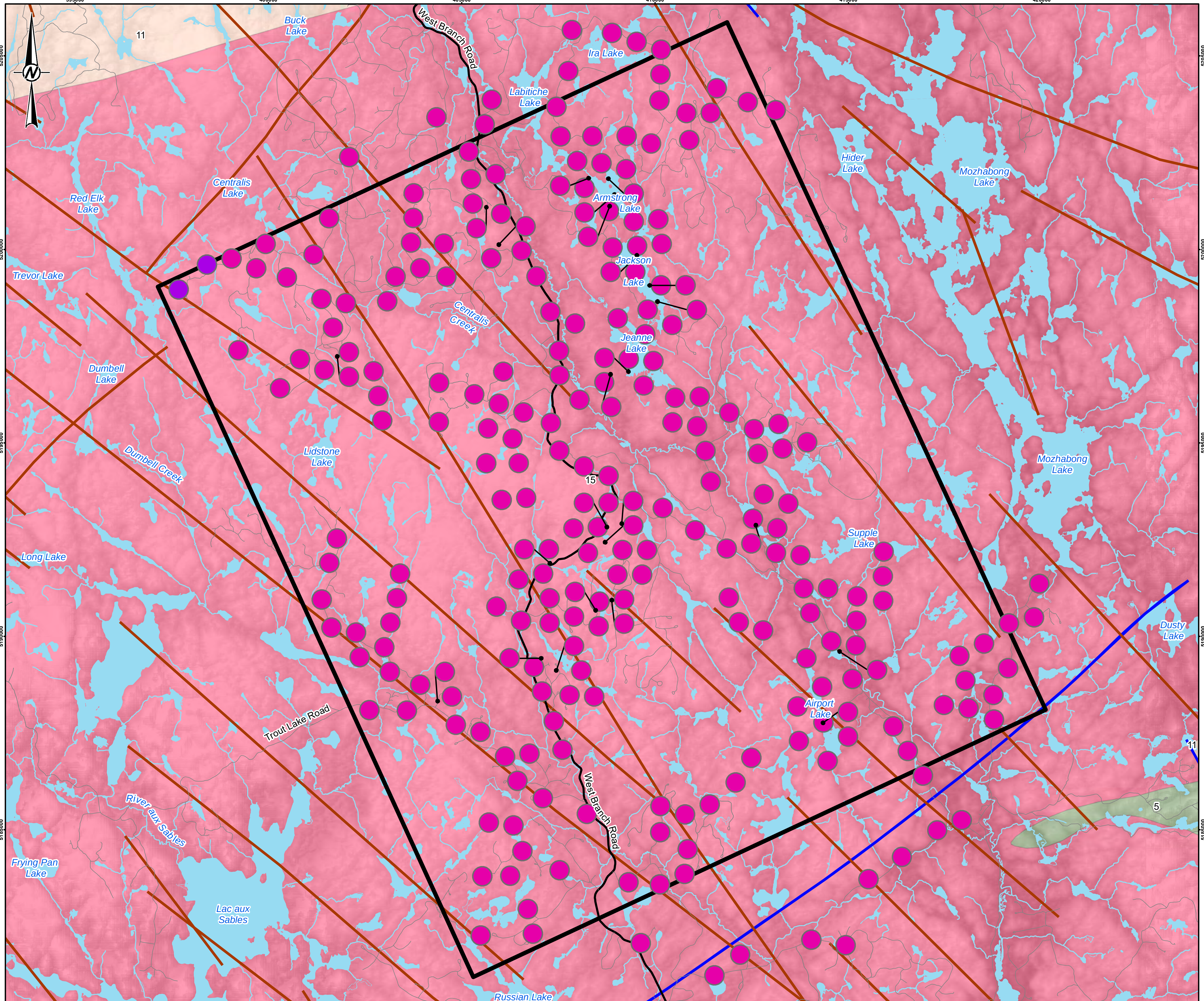

LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

Major Lithology

- Granite
- Granodiorite

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP

0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - BEDROCK GEOLOGY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
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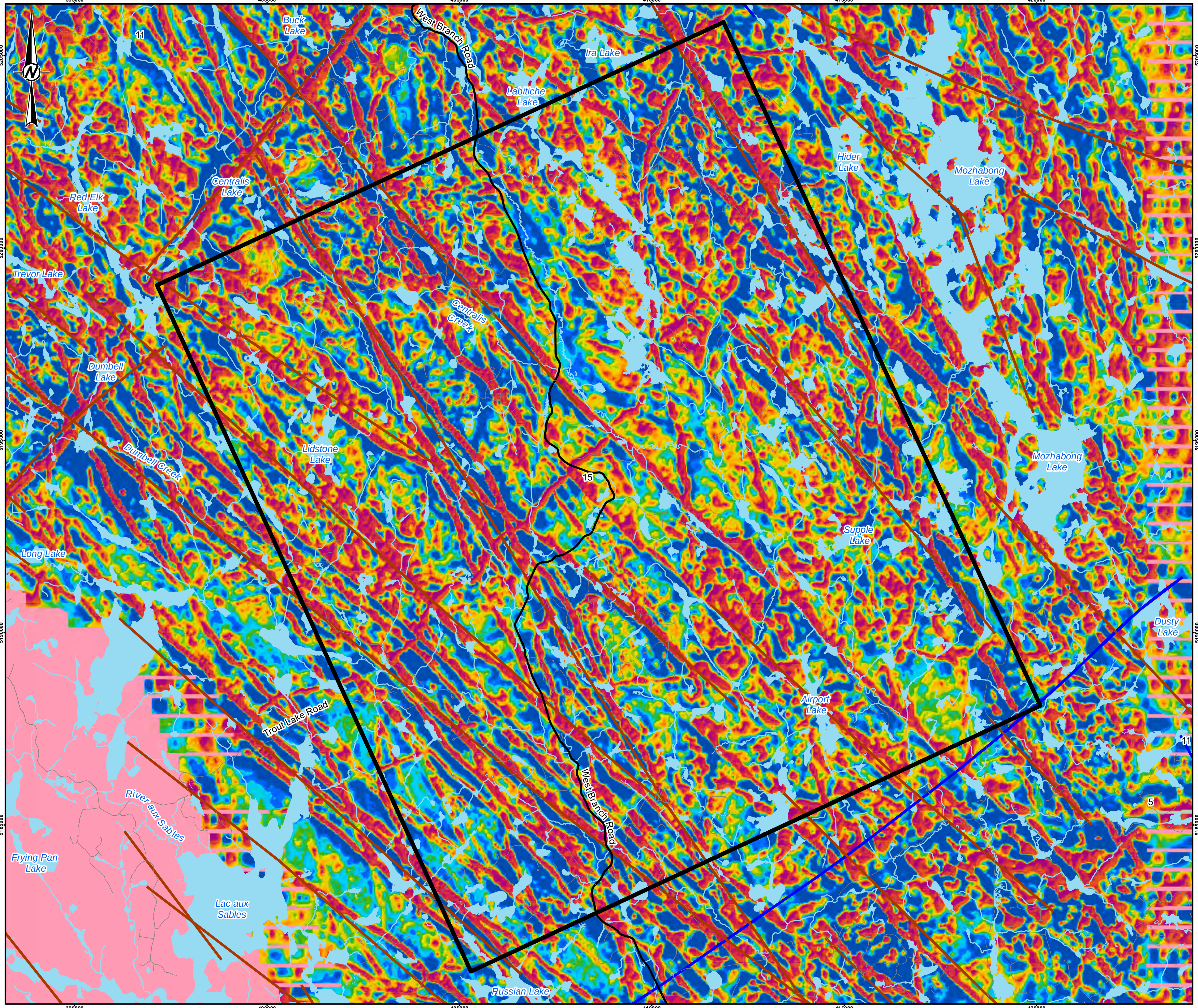


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

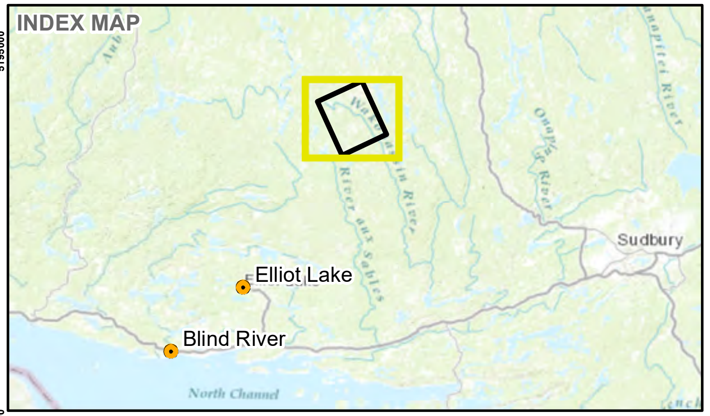
- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

First Vertical Derivative (nT/km)

High :137

Low : -354

INDEX MAP



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1:100,000 KILOMETRES

REFERENCE(S)

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CLIENT

NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

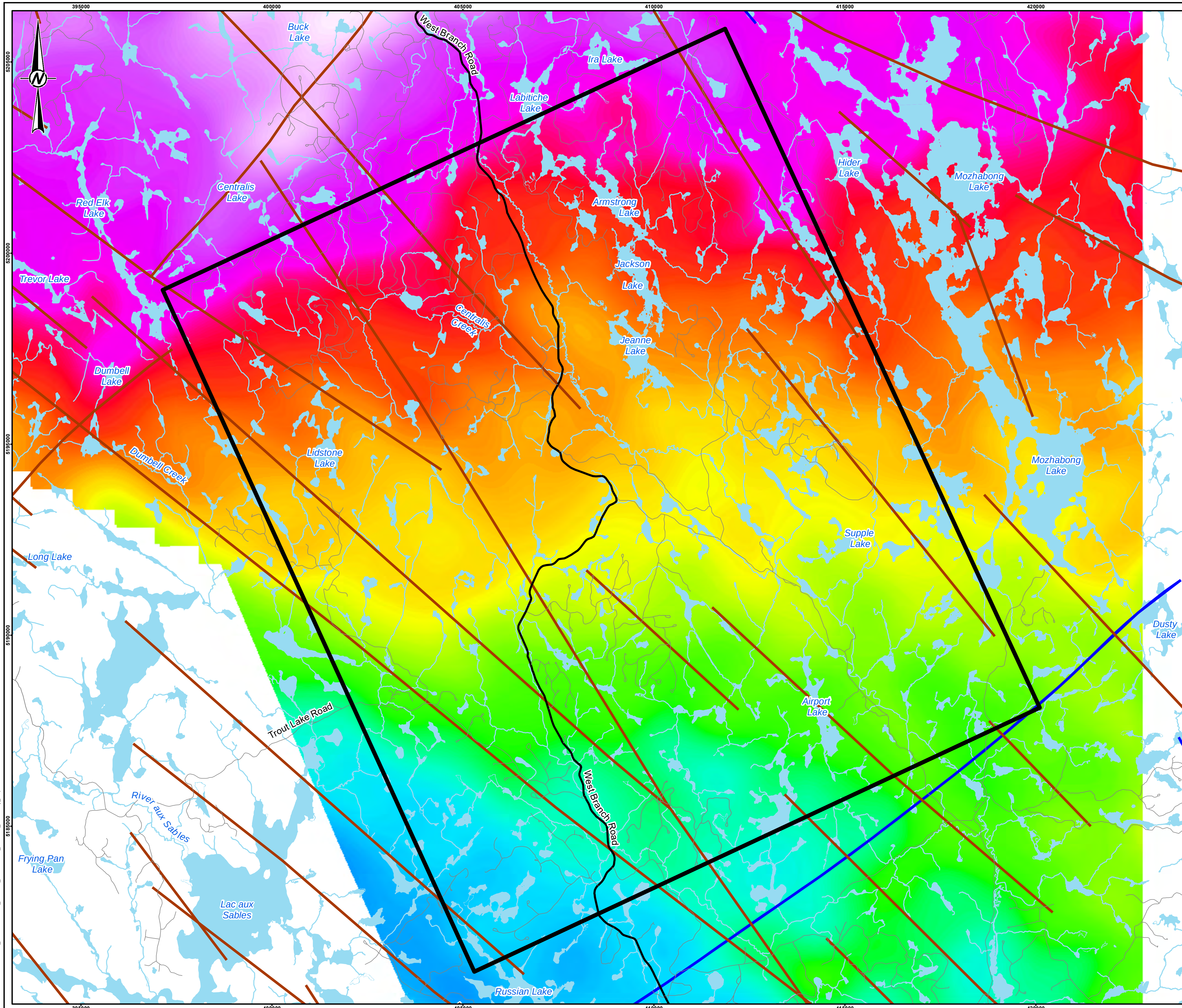
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - MAGNETIC DATA

CONSULTANT		
Golder Associates	YYYY-MM-DD	2017-11-03
	DESIGNED	JB
	PREPARED	LMM
	REVIEWED	CM
	APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.1



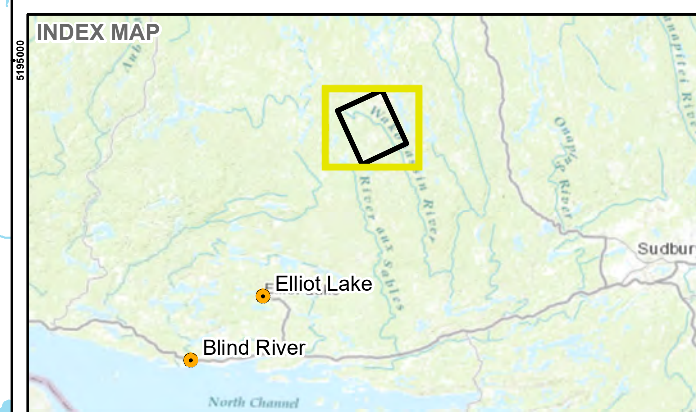
LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

Bouguer (mGal)

High : -55.5662

Low : -75.475



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1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. SANDER GEOPHYSICS LIMITED, (2017)
3. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO

BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - GRAVITY DATA

CONSULTANT

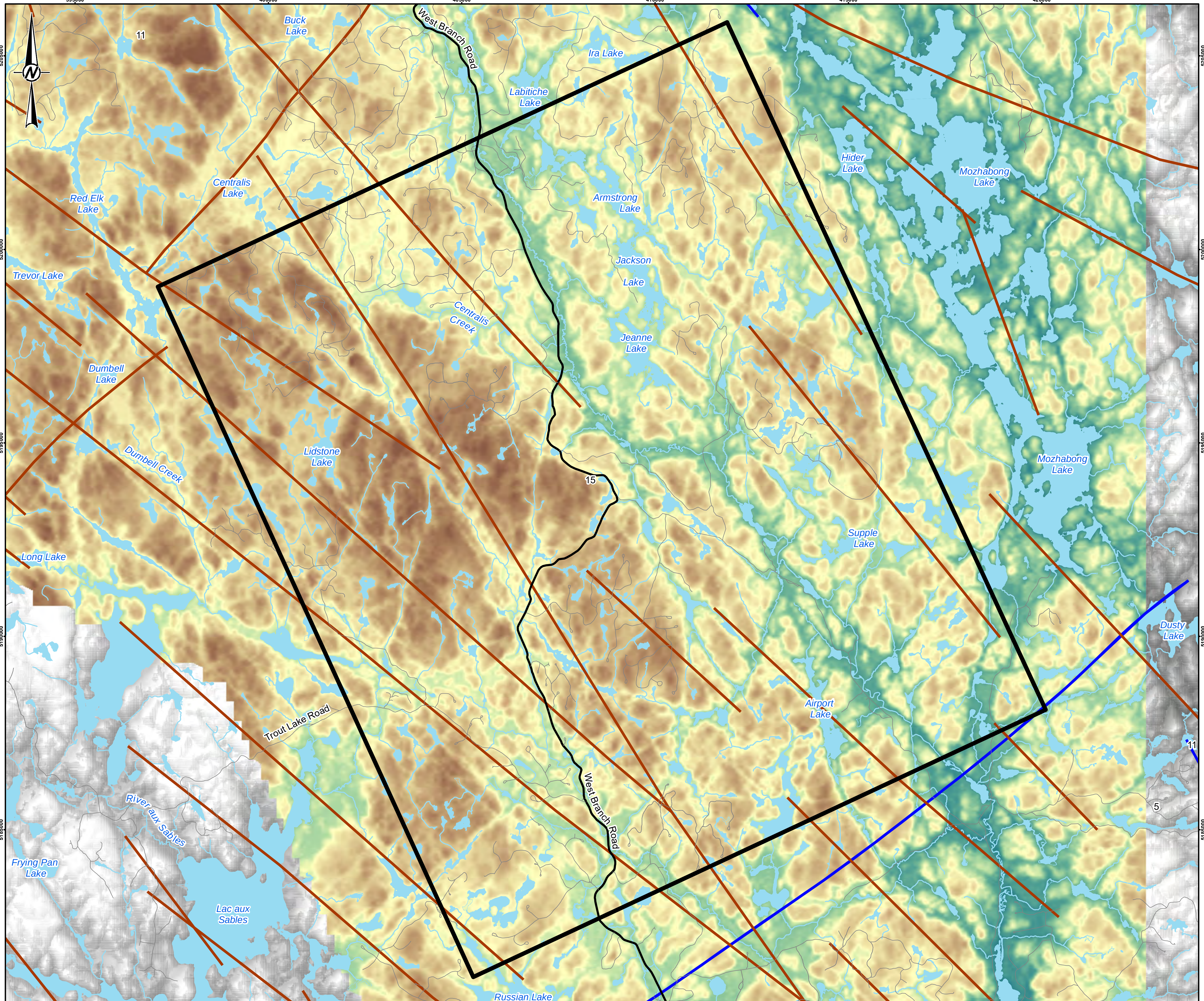
Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm



LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

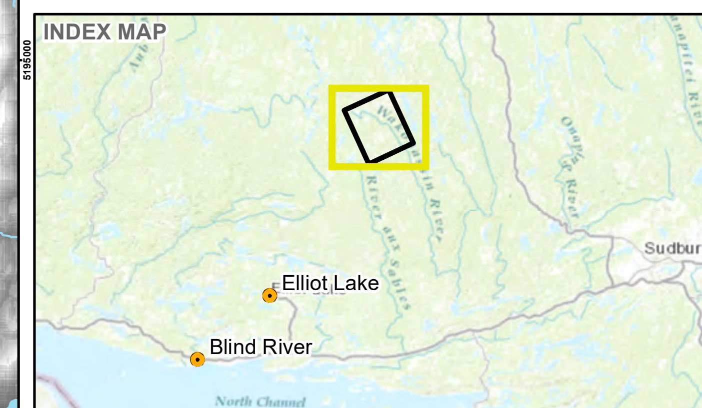
Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

Elevation (mASL)

High : 568

Low : 260



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)
1. LIO (2017).
2. SANDER GEOPHYSICS LIMITED, (2017).
3. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - DIGITAL ELEVATION MODEL (DEM) DATA

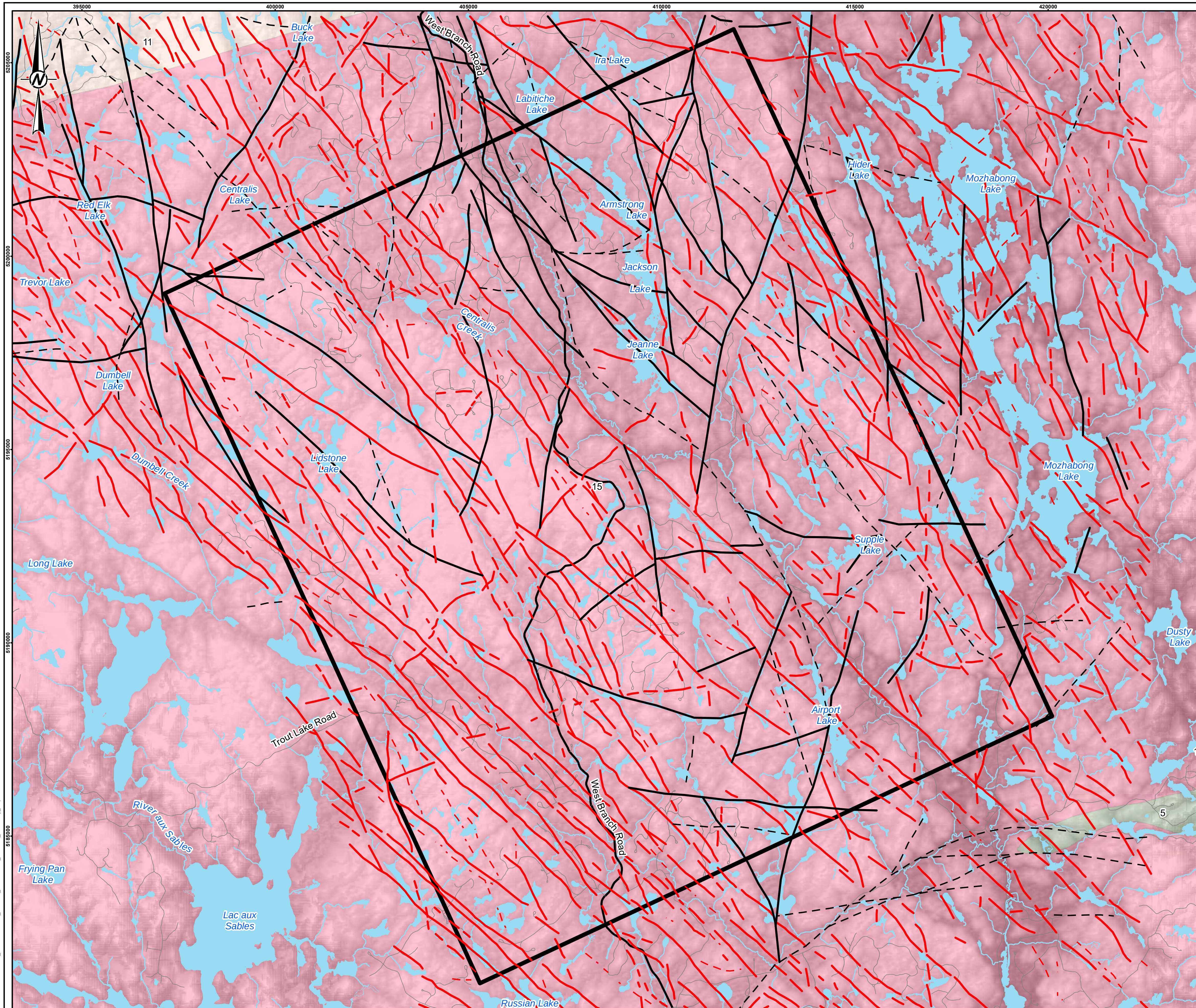
CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:



LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody

Magnetic Lineaments

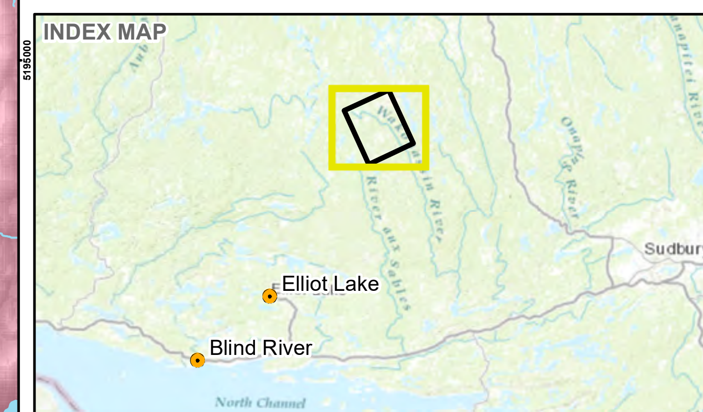
Object, Certainty

- Brittle - Medium Certainty
- Brittle - High Certainty
- Dyke - Medium Certainty
- Dyke - High Certainty

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
4. SRK CONSULTING (CANADA) INC., (2017).
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - MAGNETIC LINEAMENTS WITH HIGH AND MEDIUM CERTAINTY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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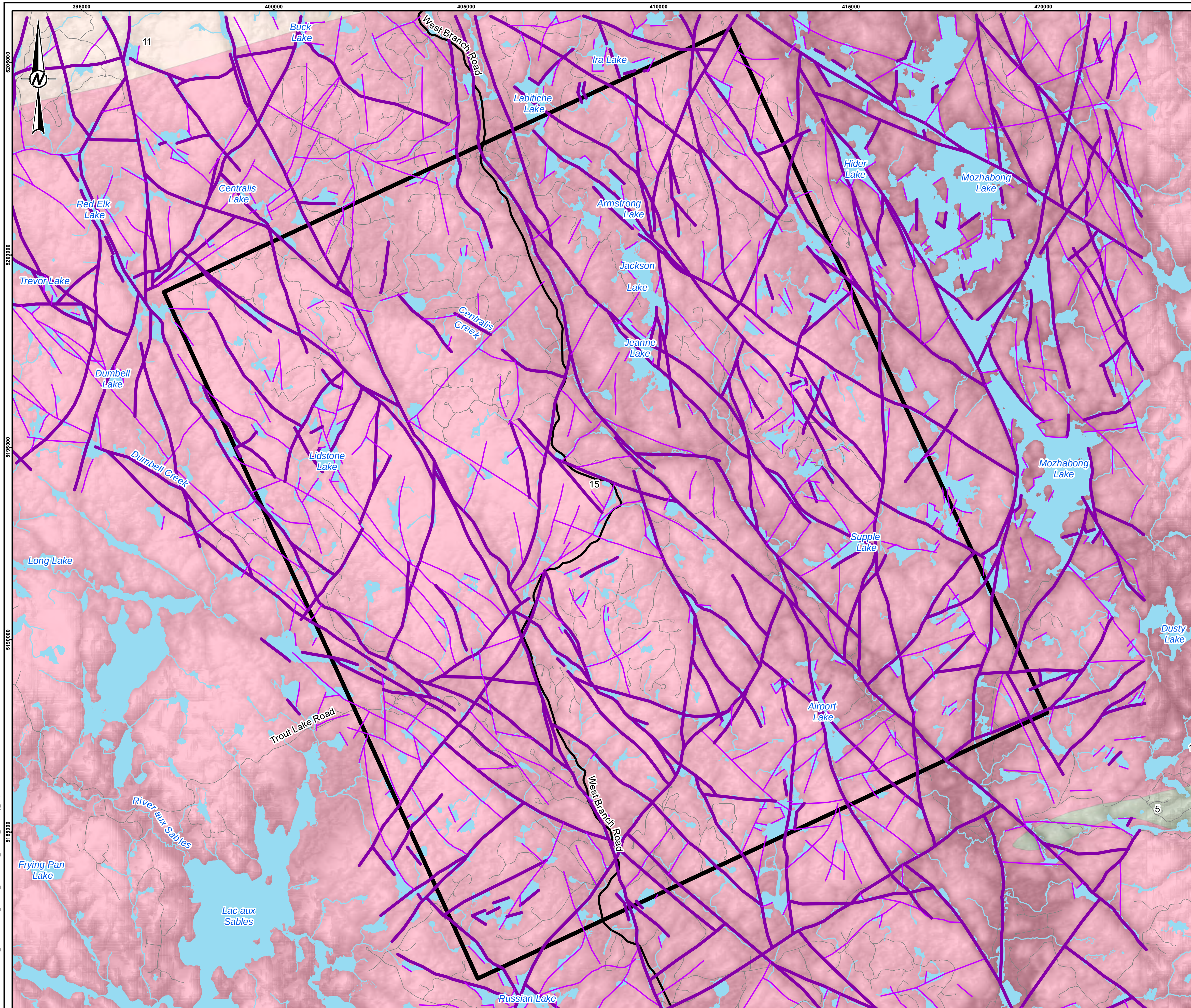


LEGEND

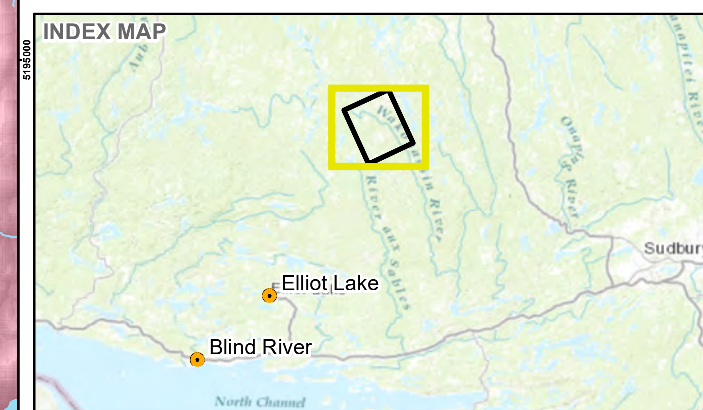
- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

Surficial Lineaments

- Medium Certainty
- High Certainty



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
4. SRK CONSULTING (CANADA) INC., (2017).
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - SURFICIAL LINEAMENTS WITH HIGH AND MEDIUM CERTAINTY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

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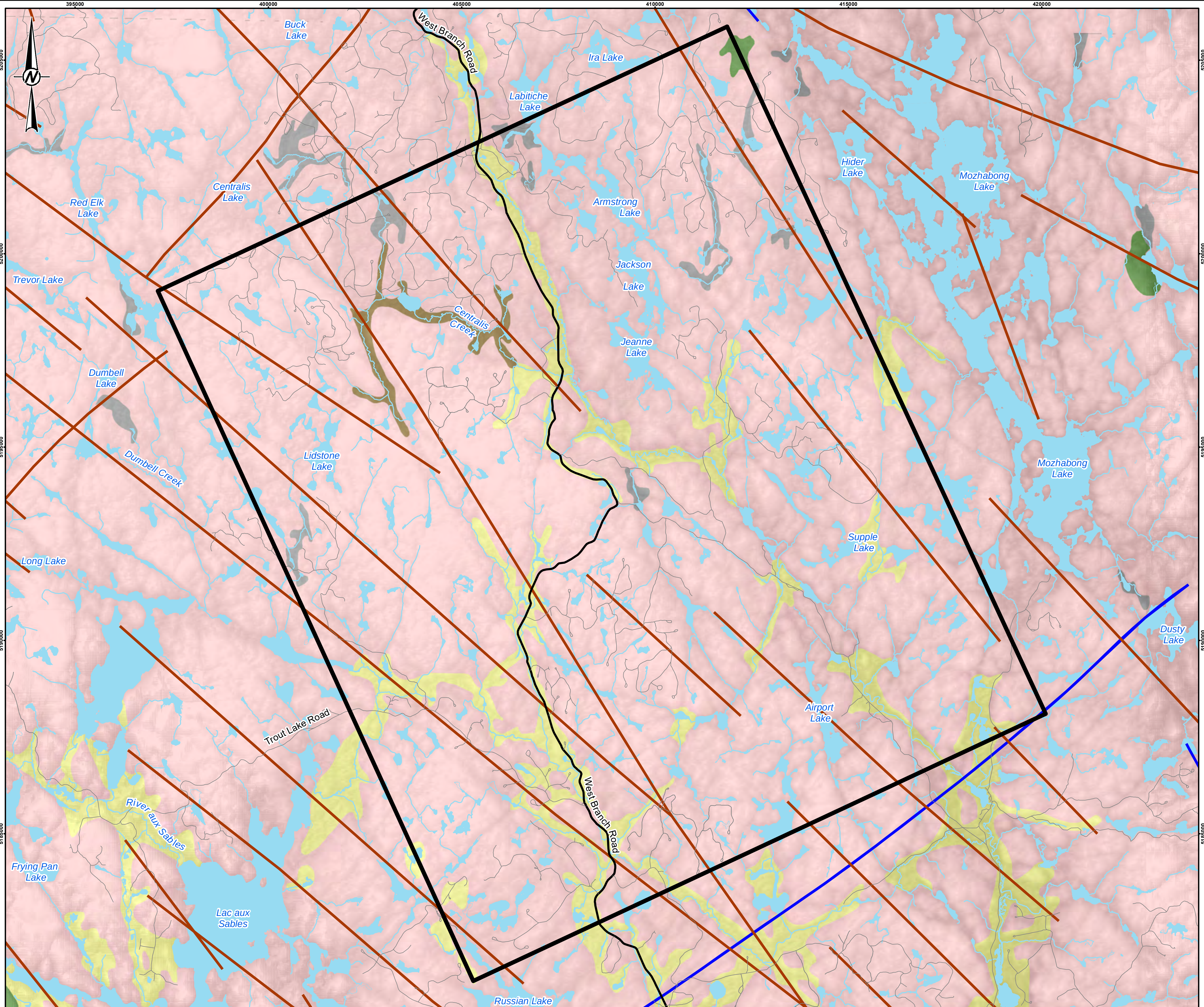


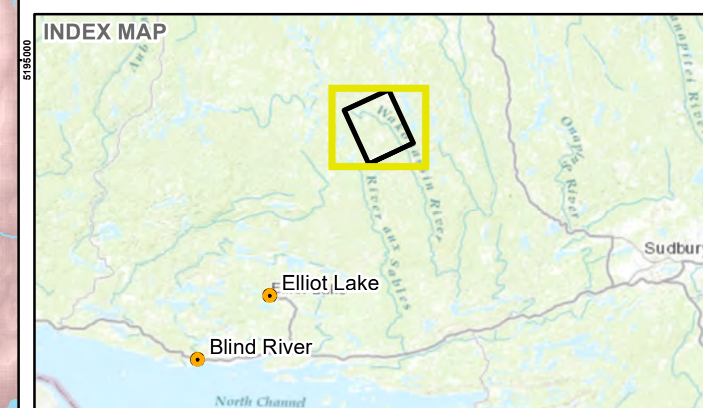
LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

Landform

- Organic Terrain
- Ground Moraine
- Outwash Plain
- Alluvial
- Organics
- Bedrock Knob
- Bedrock Ridge

INDEX MAP



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1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. DIGITAL NORTHERN ONTARIO ENGINEERING GEOLOGY TERRAIN STUDY (NOEGTS); ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE--DATA 160 2005.
3. SANDER GEOPHYSICS LIMITED, (2017).
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - SURFICIAL GEOLOGY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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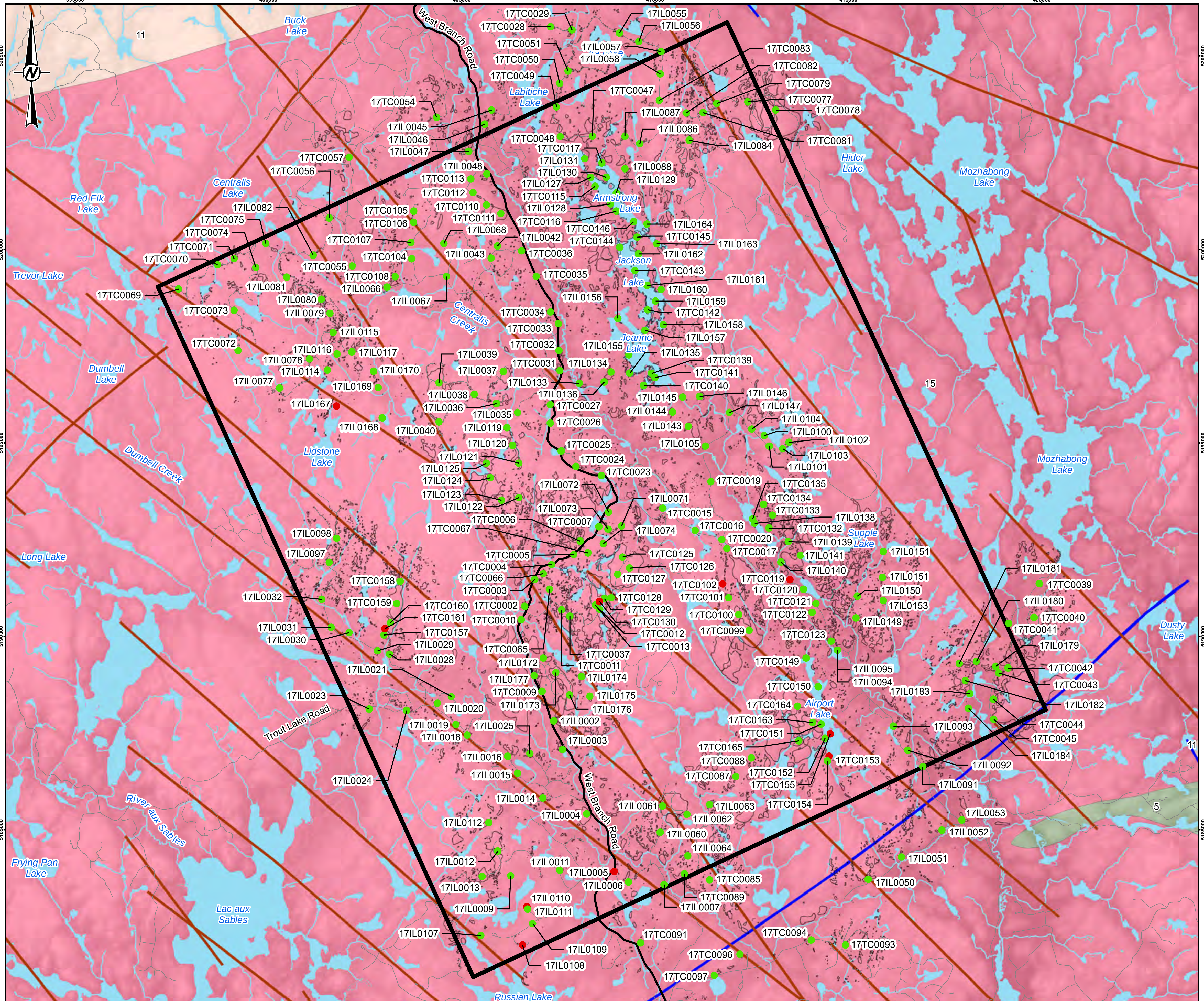


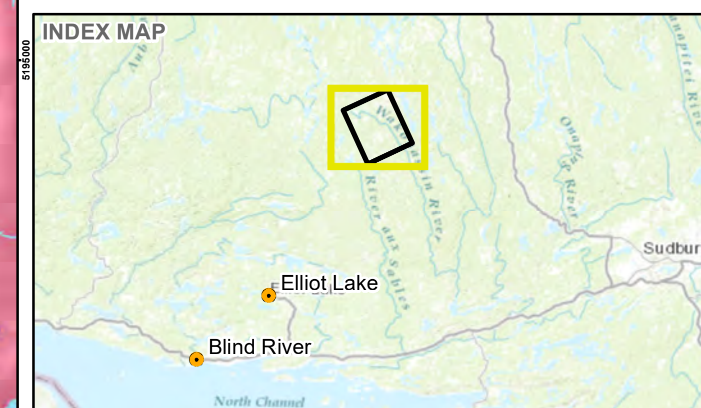
LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Overburden (10)
- Outcrop (261)
- OGS Mapped Fault
- OGS Mapped Dyke
- Predicted Outcrop

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
3. MAPPING STATION DATA FROM GEOLOGICAL MAPPING REPORT (GOLDER 2017)
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - PREDICTED OUTCROP AND MAPPING STATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			4.7

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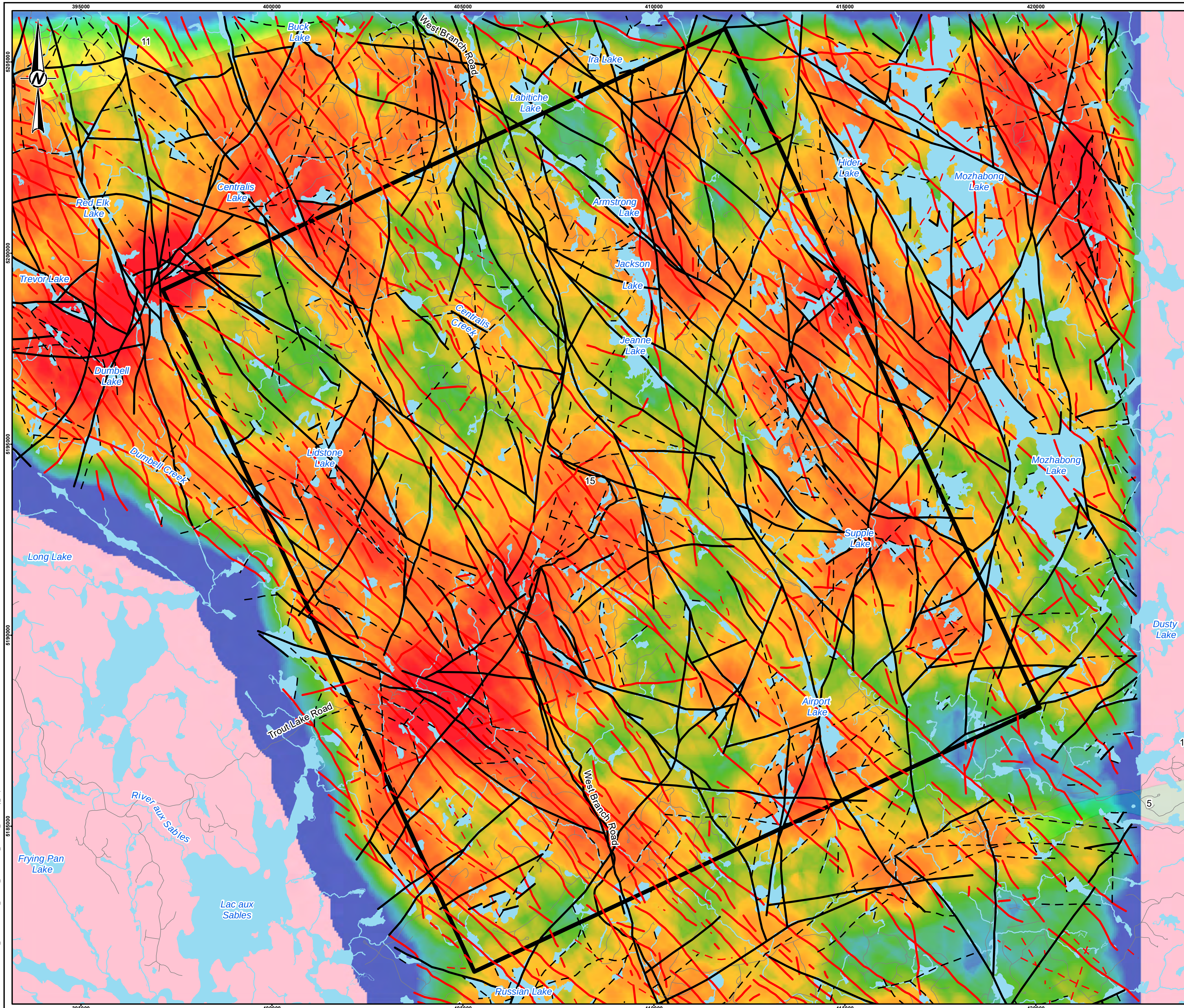


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

Integrated Lineament

- Dyke - Medium Certainty
- Dyke - High Certainty
- Brittle - Medium Certainty
- Brittle - High Certainty

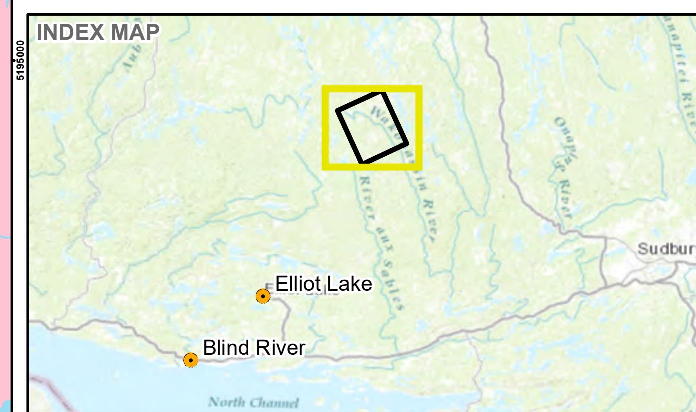
Lineament Density

Value

High : 5

Low : 0

INDEX MAP



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1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SRK CONSULTING (CANADA) INC., (2017).
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO

BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - INTEGRATED LINEAMENT DENSITY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			5.1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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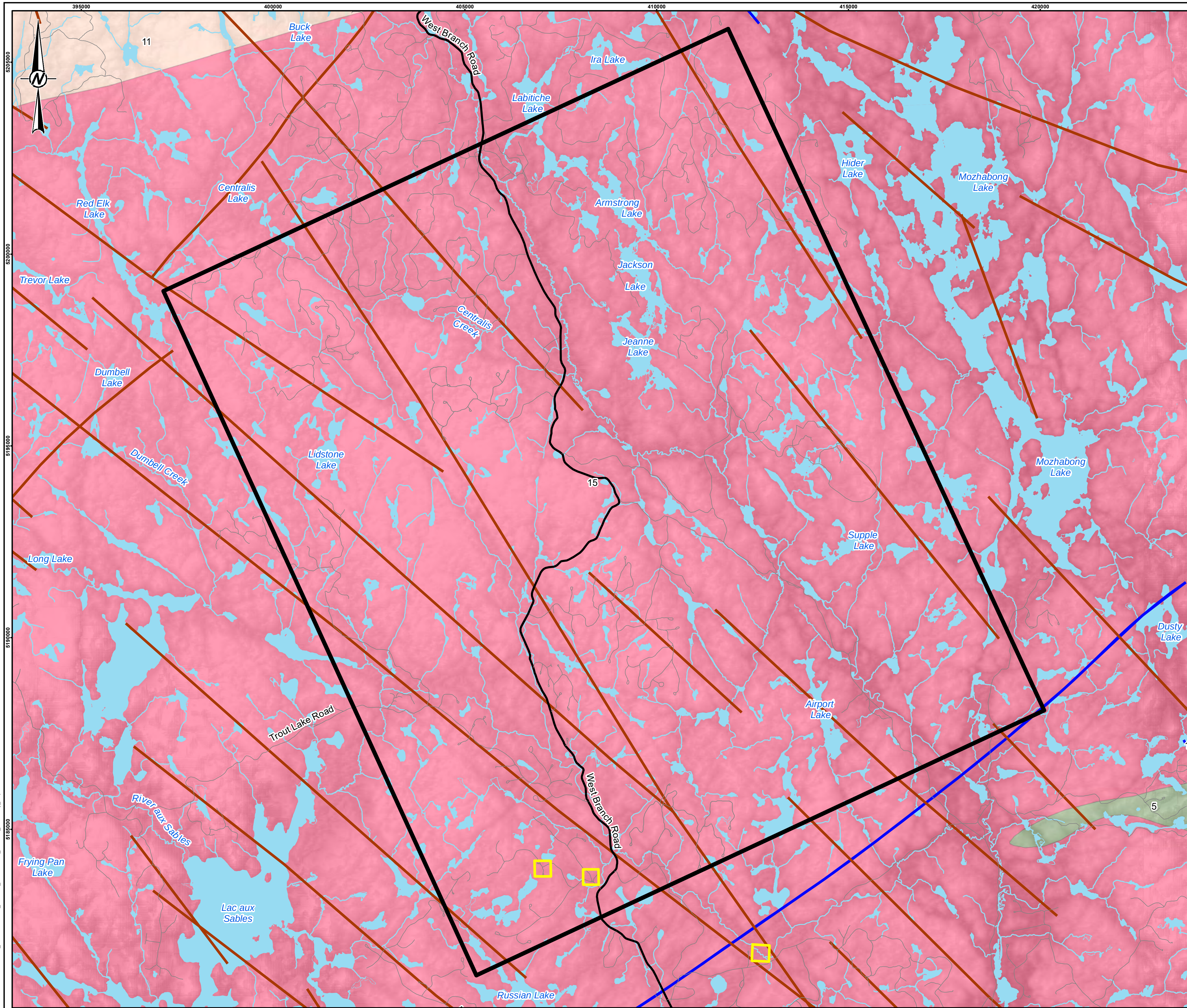
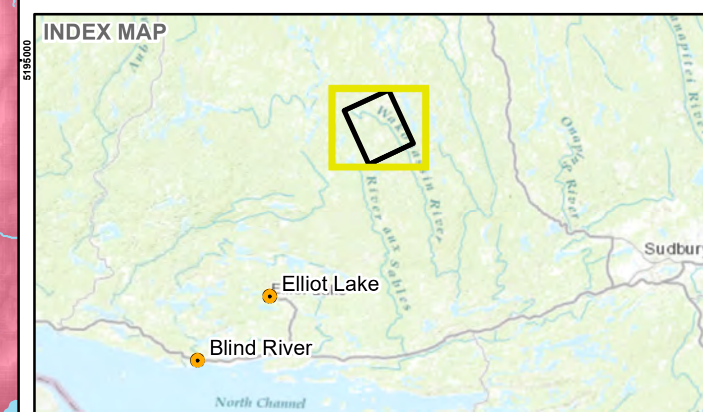


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke
- Active Claims (2017)

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks



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1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. ONTARIO GEOLOGICAL SURVEY, MINISTRY OF NORTHERN DEVELOPMENT AND MINES, AND NORTHEAST SCIENCE AND INFORMATION SECTION, MINISTRY OF NATURAL RESOURCES 2005.
4. SANDER GEOPHYSICS LIMITED, (2017).
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - MINERAL OCCURRENCES AND ACTIVE MINING CLAIMS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			5.2

25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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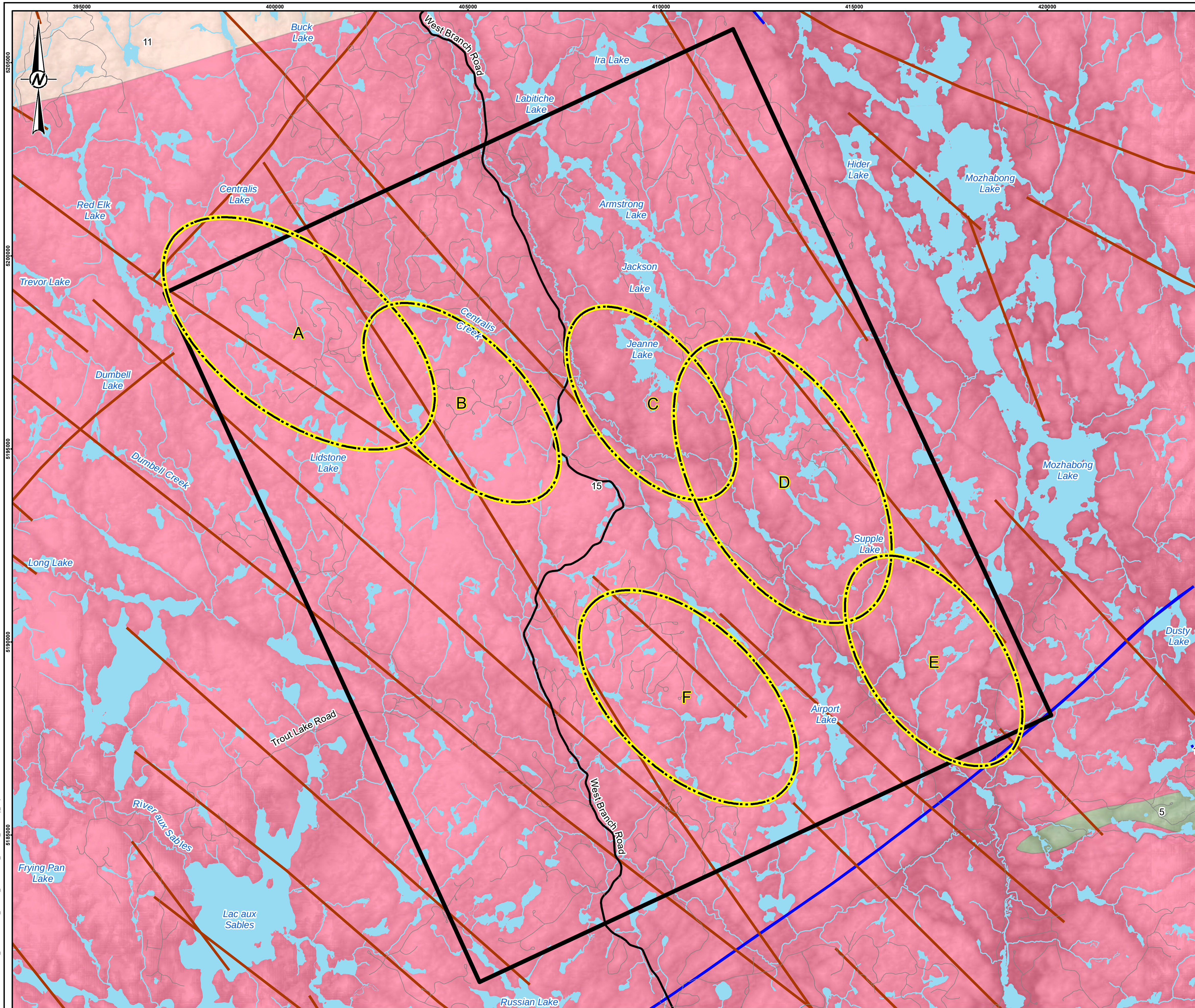


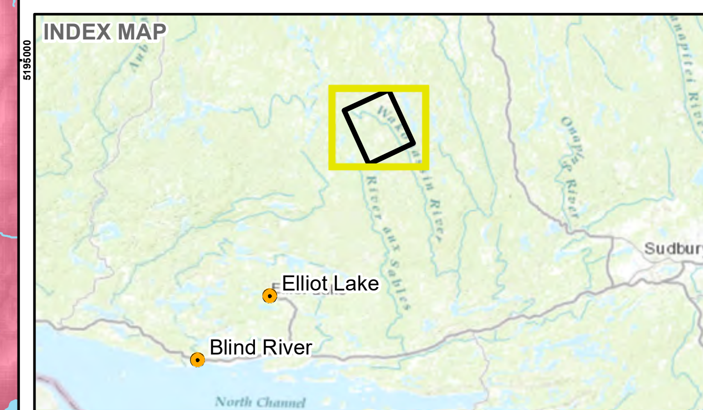
LEGEND

- Withdrawal Area
- General Potential Repository Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO

BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS WITH BEDROCK GEOLOGY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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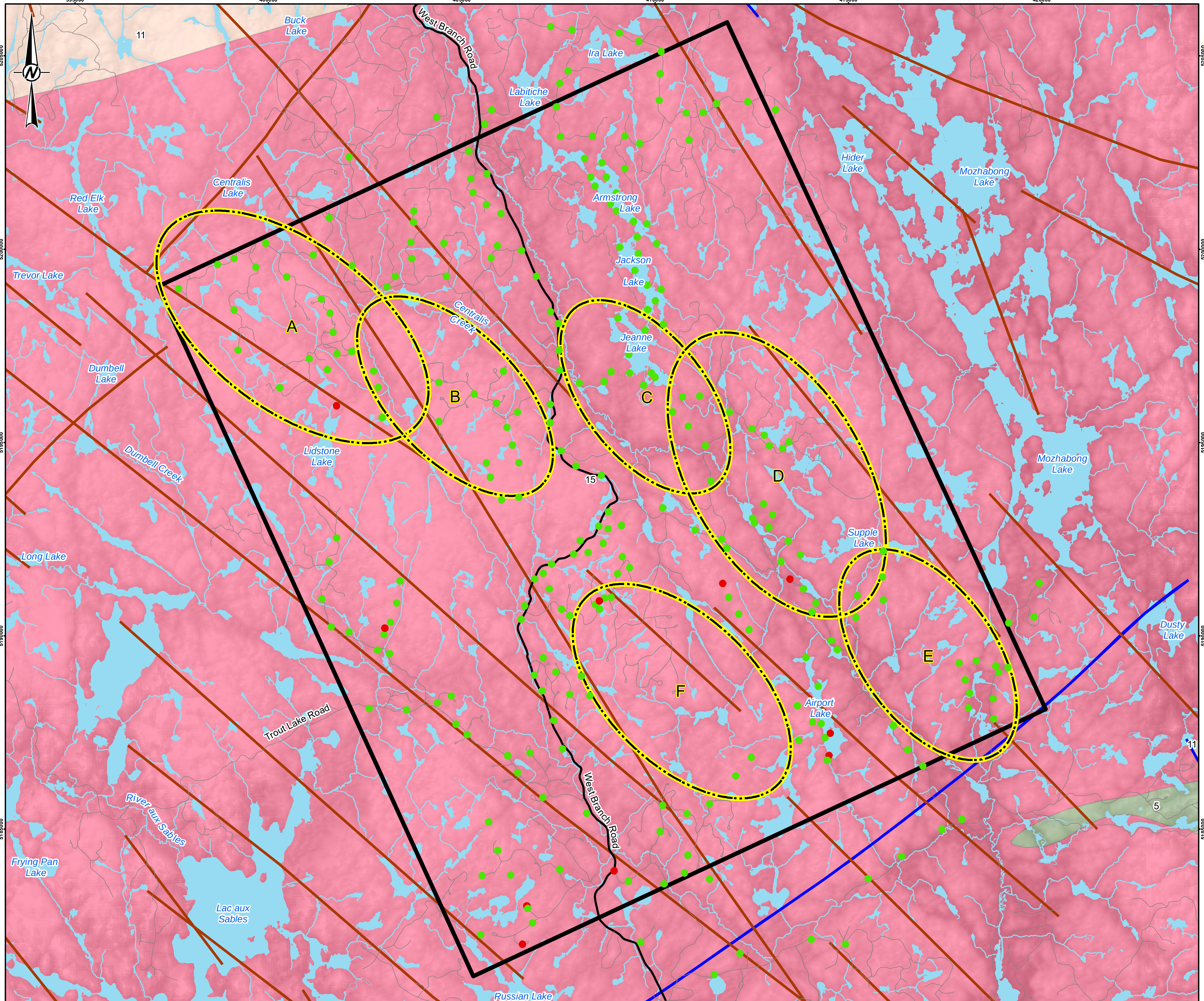


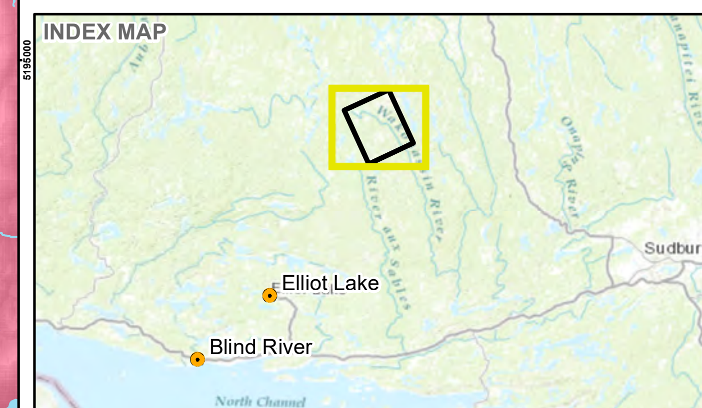
LEGEND

- Withdrawal Area
- General Potential Repository Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Overburden (10)
- Outcrop (261)
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. OVERBURDEN AND OUTCROP MAPPING STATIONS FROM GEOLOGICAL MAPPING REPORT (GOLDER 2017)
4. SRK CONSULTING (CANADA) INC., (2017).
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO

BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS AND MAPPING STATIONS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

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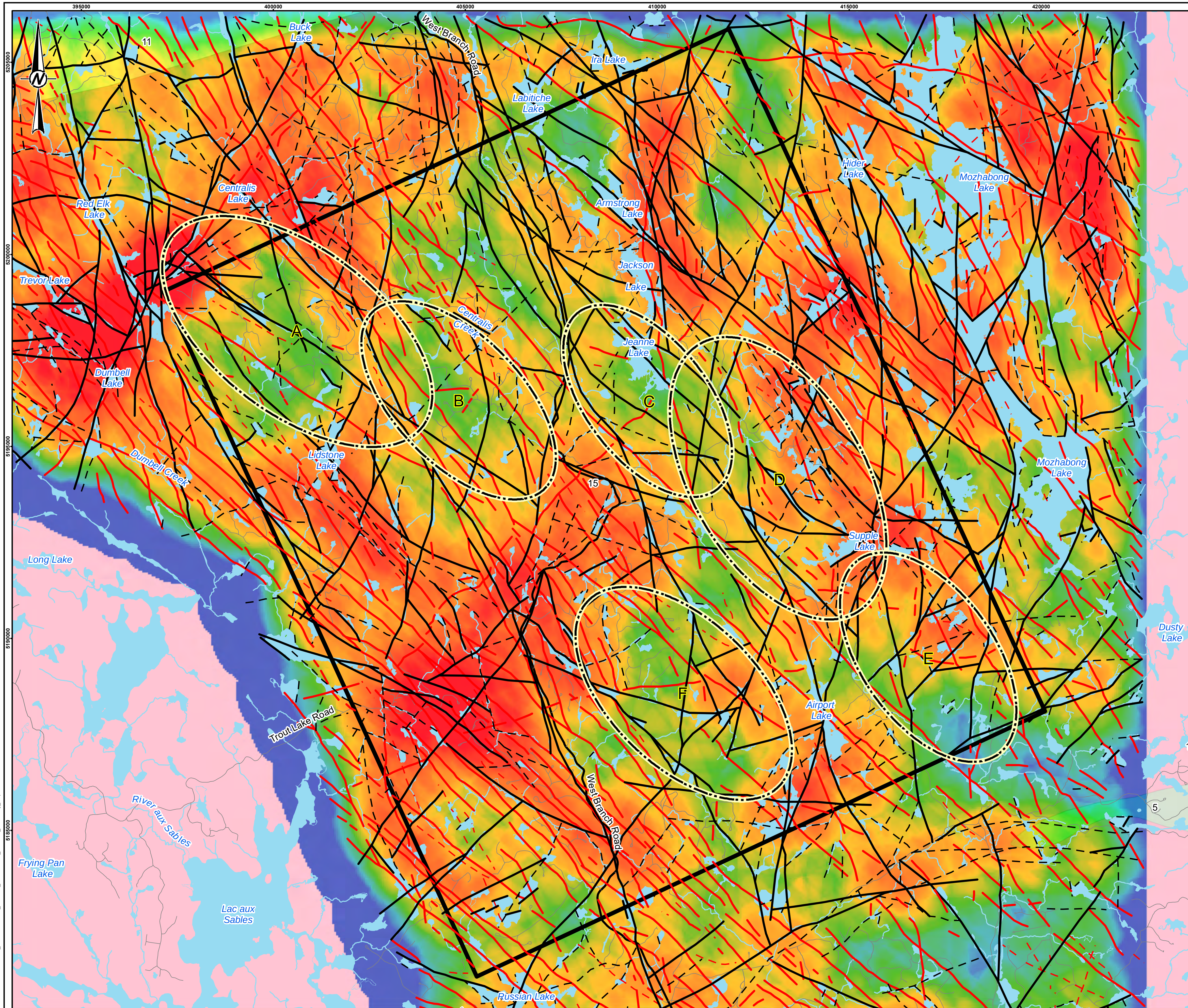

LEGEND

Withdrawal Area
General Potential Repository Area
Main Road
Local Road
Watercourse
Waterbody

Bedrock Geology

15 Massive granodiorite to granite
11 Gneissic tonalite suite
5 Mafic to intermediate metavolcanic rocks

Integrated Lineament

Dyke - Medium Certainty
Dyke - High Certainty
Brittle - Medium Certainty
Brittle - High Certainty

Lineament Density

Value

High : 5

Low : 0

INDEX MAP

0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SRK CONSULTING (CANADA) INC., (2017).
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS WITH LINEAMENTS AND LINEAMENT DENSITY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.3

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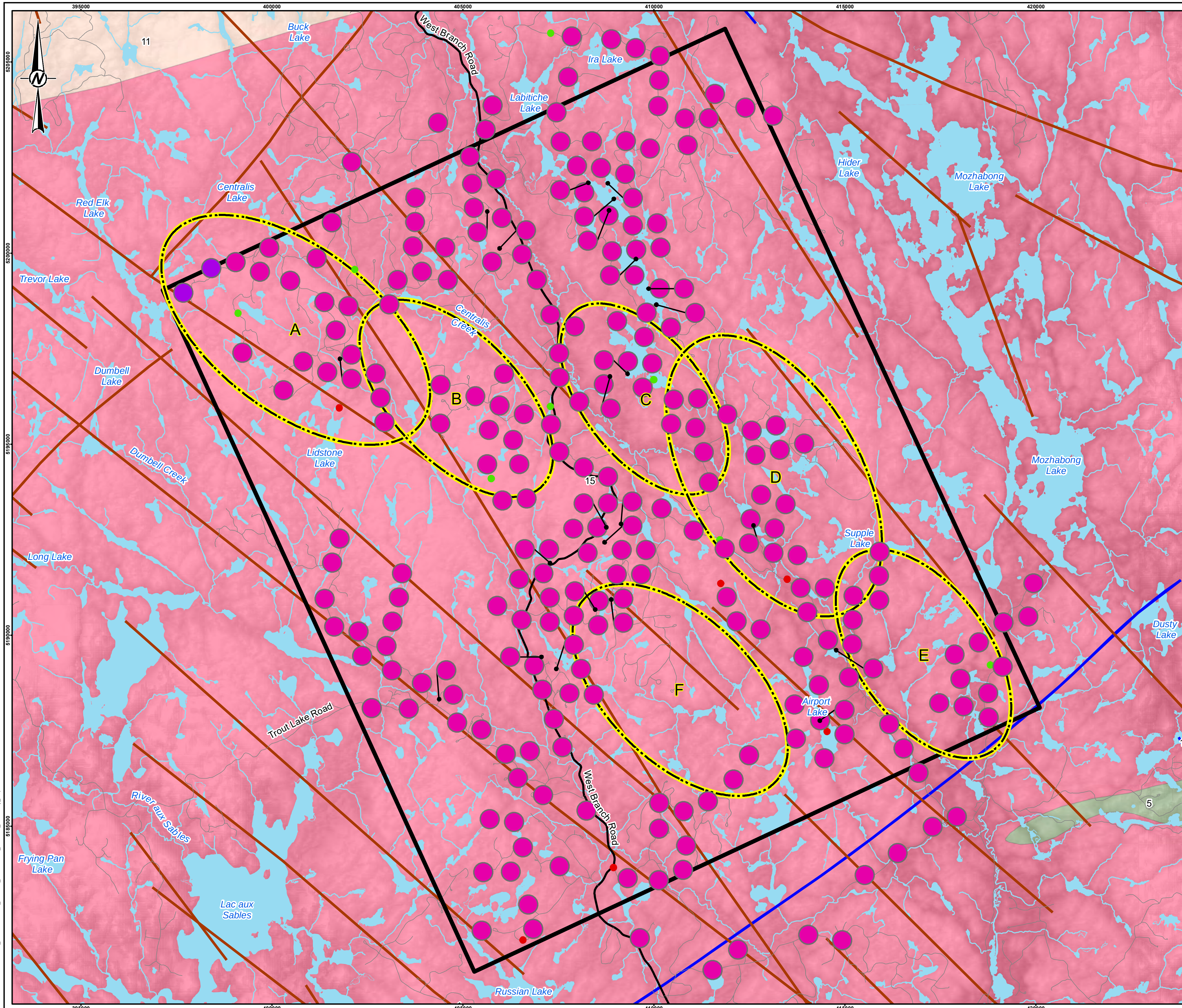


LEGEND

- Withdrawal Area
- General Potential Repository Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Outcrop (8)
- Overburden (8)

Major Lithology

- Granite (253)
- Granodiorite (2)
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP

0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. MAPPING STATION DATA FROM GEOLOGICAL MAPPING REPORT (GOLDER 2017)
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

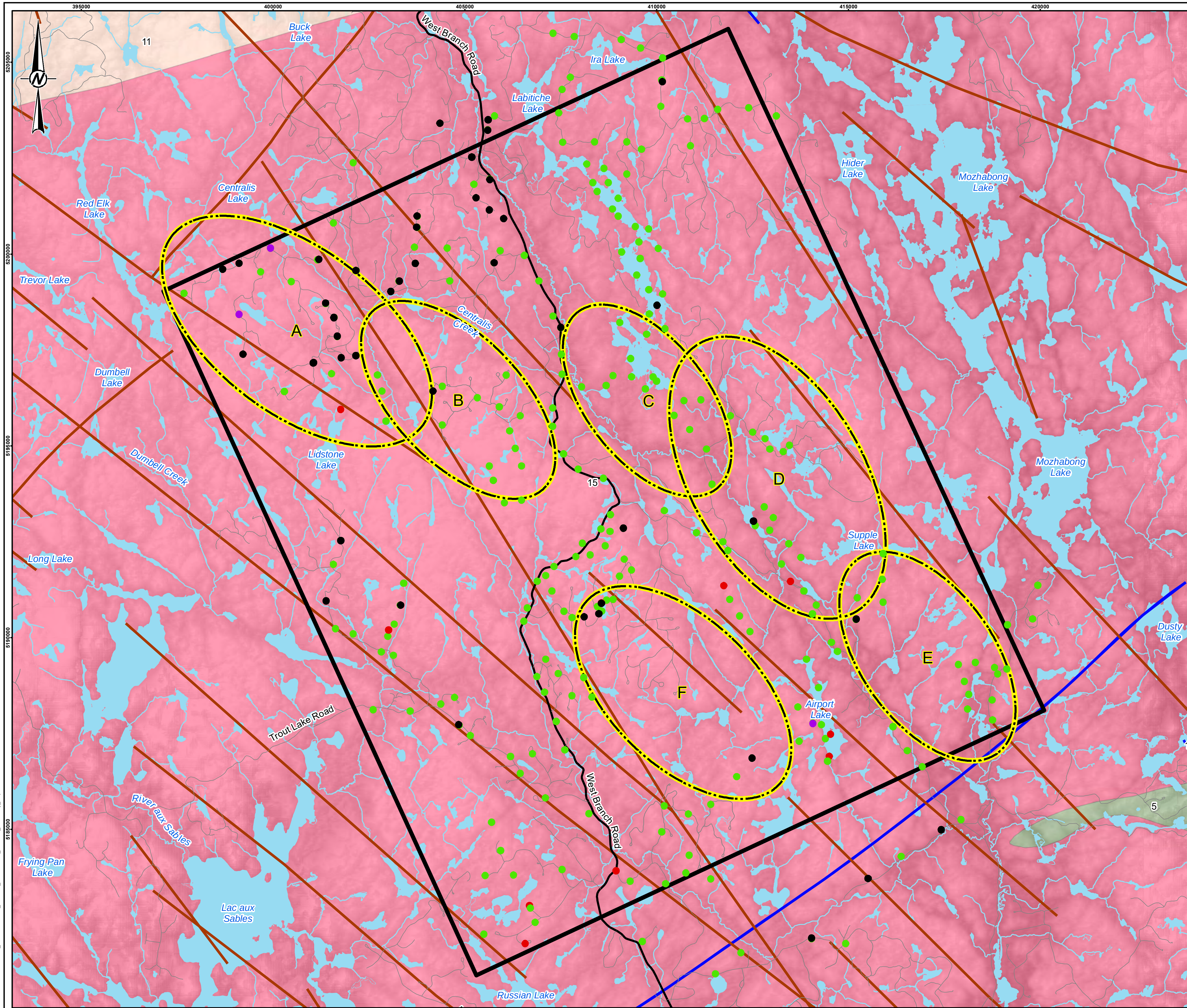
PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS WITH MAIN LITHOLOGIES

CONSULTANT

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.4



LEGEND

- Withdrawal Area
- General Potential Repository Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Outcrop (219)
- Overburden (10)

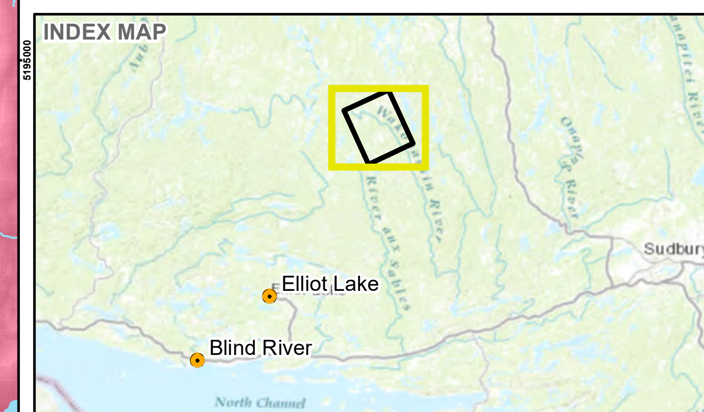
Minor Lithologies (Occurrence as Xenoliths)

- Xenolith: Mafic Protolith (50)
- Xenolith: Granite or Tonalite Protolith (3)
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks

INDEX MAP



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. MAPPING STATION DATA FROM GEOLOGICAL MAPPING REPORT (GOLDER 2017)
4. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT

NWMO

BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT

PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE

BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS WITH MINOR LITHOLOGIES

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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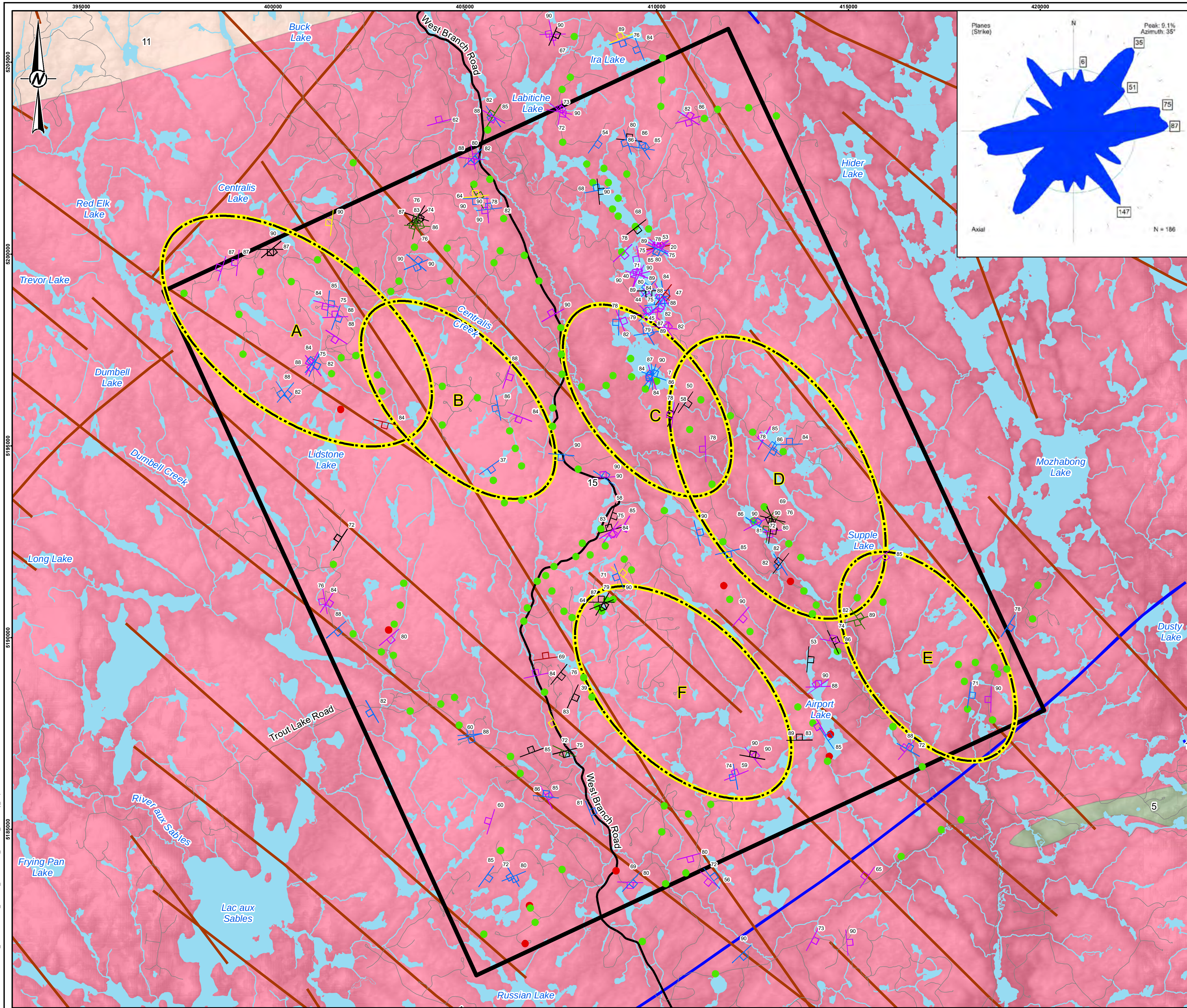
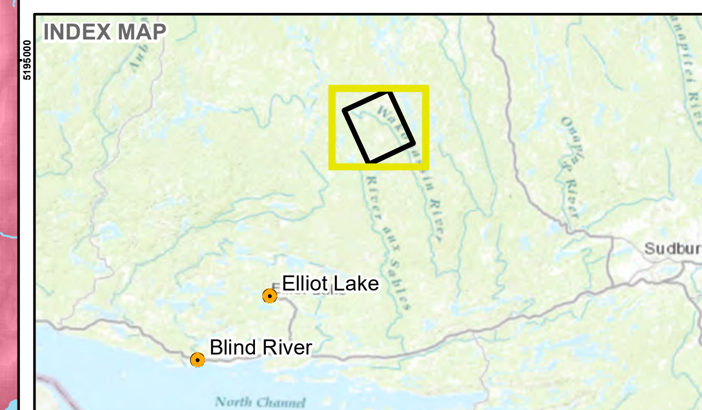


LEGEND

- Withdrawal Area
- General Potential Repository Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Outcrop (157)
- Overburden (9)
- Fault - Dextral (73)
- Fault - Sinistral (63)
- Fault - Dip slip (5)
- Fault - Normal (1)
- Fault - Reverse (4)
- Fault - Strike Slip (10)
- Fault - Unknown slip (30)
- OGS Mapped Fault
- OGS Mapped Dyke

Bedrock Geology

- 15 Massive granodiorite to granite
- 11 Gneissic tonalite suite
- 5 Mafic to intermediate metavolcanic rocks



0 4 8

1:100,000 KILOMETRES

REFERENCE(S)

1. LIO (2017).
2. BEDROCK GEOLOGY, MRD126 REV-1, OGS (2011).
3. SANDER GEOPHYSICS LIMITED, (2017).
4. MAPPING STATION DATA FROM GEOLOGICAL MAPPING REPORT (GOLDER 2017)
5. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2017.
6. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

CLIENT
NWMO
BLIND RIVER, ELLIOT LAKE AND AREA

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT, INITIAL FINDINGS, BLIND RIVER, ELLIOT LAKE AND AREA, ONTARIO

TITLE
BLIND RIVER AND ELLIOT LAKE AREA - GENERAL POTENTIAL REPOSITORY AREAS WITH FAULTS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-03
DESIGNED	JB
PREPARED	LMM
REVIEWED	CM
APPROVED	GWS

PROJECT NO.	CONTROL	REV.	FIGURE
1651985			6.6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

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