NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 2 Geoscientific Preliminary Assessment

Initial Findings

TOWNSHIP OF MANITOUWADGE AND AREA, ONTARIO

APM-REP-01332-0216

NOVEMBER 2017

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Phase 2 Geoscientific Preliminary Assessment

Initial Findings, Township of Manitouwadge and Area, Ontario

Report Prepared for

Nuclear Waste Management Organization

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Report Prepared by

SRK Consulting (Canada) Inc.
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Phase 2 Geoscientific Preliminary Assessment Initial Findings, Township of Manitouwadge and Area, Ontario

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Cover: Aerial view looking east of the Manitouwadge area, Ontario.

IMPORTANT NOTICE

Executive Summary

In 2014, a Phase 1 Geoscientific Desktop Preliminary Assessment was completed by AECOM Canada Ltd. (AECOM) to assess whether the Manitouwadge 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 Manitouwadge area contains at least four general areas that have the potential to satisfy NWMO’s geoscientific site evaluation factors (AECOM, 2014).

In 2015, as part of Phase 2 of the geoscientific preliminary assessment of the Manitouwadge area, NWMO commenced a series of initial geoscientific field studies in the four 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 these general potentially suitable areas, 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 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.
- Geological mapping to assess geologic characteristics, including lithology, structure, bedrock exposure and surface constraints.

Eighteen general PRAs were identified in the Manitouwadge area. General PRAs 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 square kilometres or larger). The boundaries of the general PRAs are simplified 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 Black-Pic batholith, the Fourbay Lake pluton, and the Quetico Subprovince in the Manitouwadge 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 several 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. Other uncertainties include the potential presence of narrow dykes not identifiable in aeromagnetic data and the thickness of the Fourbay Lake pluton. In the Quetico Subprovince, uncertainties relating to the general PRAs include the heterogeneous and difficult to predict lithological character of the bedrock; the effect of the low magnetic susceptibility of the bedrock on the ability to interpret brittle magnetic lineaments; and the potential brittle parting of the pervasive ductile fabric in the bedrock.

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1 Introduction

In 2014, a Phase 1 Geoscientific Desktop Preliminary Assessment was completed by AECOM Canada Ltd. (AECOM) to assess whether the Manitouwadge area contained general areas that had the potential to satisfy the geoscientific site evaluation factors outlined in the Nuclear Waste Management Organization's (NWMO) site selection process (AECOM, 2014; NWMO, 2010). The Phase 1 Geoscientific Desktop Preliminary Assessment expanded on an initial screening conducted by Geofirma Engineering Ltd. (Geofirma) in 2013 (Geofirma, 2013). The desktop preliminary assessment focused on the Township of Manitouwadge and its surrounding area, as shown on Figure 1.1.

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 evaluation of these geoscientific characteristics showed that the Manitouwadge area contains at least four general areas that have the potential to satisfy NWMO's geoscientific site evaluation factors. One of these is located in the metasedimentary rocks of the Quetico Subprovince, two are located in the Black-Pic batholith, and one in the Fourbay Lake pluton (AECOM, 2014).

The Phase 1 Geoscientific Desktop Preliminary Assessment also identified geoscientific uncertainties associated with these areas, including the area of influence of regional structural features, the presence of numerous dykes, and the effect of the variable degree of metamorphism that the metasedimentary rocks have experienced (AECOM, 2014). In order to facilitate Phase 2 geoscientific field studies, portions of land were temporarily removed from staking for mineral claims in the four identified general potentially suitable areas. These withdrawal areas are shown on Figure 1.2, which also shows the bedrock geology of the Manitouwadge area.

In 2015, as part of the Phase 2 Geoscientific Preliminary Assessment of the Manitouwadge area, NWMO initiated a series of initial geoscientific field studies focused in the four 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 the 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 greatly improved understanding of the geological characteristics of the Manitouwadge 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 lay of the land, and to assess the nature of key geological features such as fractures, rock types, extent of bedrock exposure and access constraints. For the purpose of this report, OGGF and Detailed 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, 2017a); and geological mapping report (SRK, 2017b).

This report provides a summary of the findings from Phase 2 initial field studies conducted in the Manitouwadge area from 2015 to 2016 as they relate to whether the Manitouwadge 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 Geoscientific Preliminary Assessment (Sections 2 and 3), a summary of the methods and findings for each of the Phase 2 initial geoscientific field studies (Sections 4 and 5); and the approach, rationale, and identification of general PRAs (Section 6).

2 Geoscientific Preliminary Assessment Approach

The objective of the geoscientific preliminary assessment is to assess whether the Manitouwadge 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 Phase 1 Geoscientific Desktop Preliminary Assessment are documented in the Manitouwadge integrated Phase 1 preliminary assessment report (NWMO, 2014).

The subset of communities considered in Phase 2 of the preliminary assessment was selected based on the findings of the overall Phase 1 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 Manitouwadge area in 2014 (AECOM, 2014). Initial Phase 2 field studies, including high-resolution airborne geophysical surveys, lineament interpretation studies, and geological mapping were conducted in 2016 (SGL, 2017; SRK, 2017a, 2017b). This report focuses on summarizing the findings of these field studies that form the basis for identifying general PRAs.

3 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 for 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 Manitouwadge area, the site evaluation factors were applied in two steps. The first step identified at least four general potentially suitable areas within the Manitouwadge area using key geoscientific characteristics that could realistically be assessed at the desktop stage based on available information. The second step confirmed that the four identified potentially suitable 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 Manitouwadge area, using the newly acquired Phase 2 data. The 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 Initial Field Studies

The Phase 2 Geoscientific Preliminary Assessment to-date has included the following key activities:

- Acquisition and processing of high-resolution airborne geophysical (magnetic and gravity) data over the four general potentially suitable areas identified in the 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 character).
- 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.
- Geological mapping to assess geologic characteristics, including lithology, structure, bedrock exposure, and access constraints.

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

- Update the understanding of key geoscientific characteristics that can be realistically evaluated at this stage of the assessment to identify general PRAs.
- Assess whether it is possible to identify general PRAs within the four general potentially suitable areas identified in the Manitouwadge area in the Phase 1 Geoscientific 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, 2017a; and SRK, 2017b). 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 Manitouwadge area. The interpretation of the data acquired during the airborne surveys can be used to estimate the geometry and thickness of the potentially suitable host rock formation; the nature of geological contacts; bedrock lithology; the degree of geological heterogeneity and the nature of intrusive phases within the plutons in the area; as well as the nature of structural features such as 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 Geoscientific Desktop Preliminary Assessment (PGW, 2014).

Sander Geophysics Limited (SGL) completed a fixed-wing high-resolution airborne magnetic and gravity survey in the Manitouwadge area between July 23 and October 7, 2015. The survey area comprised three survey blocks (Manitouwadge North, South, and East blocks) designed to cover the four potentially suitable areas in the Black-Pic batholith, Quetico metasedimentary rocks, and Fourbay Lake pluton identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (Figure 4.1).

The Phase 2 survey included a total of 13,957 kilometres of flight lines covering a surface area of approximately 1,040 square kilometres. Flight operations were conducted out of the Manitouwadge Municipal Airport, in Manitouwadge, Ontario using a Cessna 208B Grand Caravan. Data were acquired along traverse lines flown in a north-south direction spaced at 100 metres, and control lines flown east-west spaced at 500 metres. Five survey lines spaced 200 metres apart were continued from the Manitouwadge South block to the Manitouwadge North block, effectively tying the two blocks together. Similarly, five survey lines spaced 200 metres apart were also continued north and south 15 kilometres beyond the edge of the Manitouwadge East block.

The survey was flown at a nominal altitude of 80 metres above ground level, with an average ground speed of 100 knots (approximately 185 kilometres per hour or 50 metres per second). The airborne magnetic data was recorded using a magnetometer sensor mounted in a fibreglass stinger extending from the tail of the aircraft. The airborne gravity data was recorded using a gravimeter, which included three orthogonal accelerometers that were 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, 2017a).

4.2 Geophysical Data Interpretation

The Phase 2 geophysics interpretation was conducted for the Manitouwadge area using the newly acquired high-resolution magnetic and gravity data sets (SGL, 2017). The assessment of geological contacts and bedrock lithology in the Phase 2 geophysics interpretation was performed by analyzing the magnetic and gravity data, and determining the coincidence of magnetic responses with mapped lithology and structures for the Manitouwadge area. Magnetic anomaly characteristics and interpreted contacts were compared to the current bedrock geologic maps in order to identify similarities and/or changes in the lithological contact locations.

In some cases, the geophysical data provided a refined interpretation of the bedrock geological contacts, especially in areas of limited bedrock exposure (e.g., under overburden or water cover). The magnetic data and its vertical derivative products were used for interpreting geological contacts, identifying lithological heterogeneity, and assessing the nature of structural features through the surveyed area. In addition, the gravity data was valuable for interpreting geological contacts between rock units with differences in density. The magnetic and gravity data are shown on Figures 4.1 and 4.2, respectively. In addition to the magnetic and gravity data, a 25-metre resolution Digital Elevation Model (DEM) was also generated from the airborne GPS, and radar and laser altimeter data (SGL, 2017), as shown on Figure 4.3.

In order to develop a rough approximation of the depth of the main lithological units in the Manitouwadge area, preliminary forward modelling was conducted by SGL (2017). This modelling used the newly acquired high-resolution geophysical data and the compilation of mapped bedrock geology at surface (OGS, 2011) to provide a preliminary interpretation of the geometry and subsurface extent of the main metasedimentary and intrusive units as well as the Manitouwadge greenstone belt and smaller mafic intrusive units. 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 Geoscientific Desktop Preliminary Assessment. A magnetic and surficial lineament study was conducted for the survey blocks using the high-resolution magnetic and DEM data from the airborne survey, and purchased high-resolution digital aerial imagery (SRK, 2017a).

Lineaments are linear features that can be observed on remote sensing and geophysical data, which may represent geological structures. The presence of these features must be confirmed through further field studies such as detailed geological mapping and 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, 2017a). The workflow followed a set of detailed guidelines involving three stages:

- Step 1: Independent lineament interpretation by two individual interpreters for each data set and assignment of certainty level (low, medium and high certainty).
- Step 2: Integration of lineament interpretations for each individual data set and first determination of reproducibility (i.e. presence of the same lineament within each data set [DEM, aerial imagery, magnetic] as interpreted by each interpreter).
- Step 3: Integration of lineament interpretations for the surficial data sets (DEM and digital aerial imagery) followed by integration of the combined surficial lineament interpretation with the geophysical lineament interpretation, 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, 2017a). 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 high certainty value. 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 low or medium certainty value. For magnetic lineaments, a high certainty value was assigned when a clear magnetic susceptibility contrast could be discerned, and a low or medium certainty value was assigned when the signal was discontinuous or more diffuse. The certainty classification for all three data sets relied on the expert judgment and the experience of the interpreter. For lineament interpretation, emphasis was put on lineaments interpreted with a high and medium certainty.
- Lineament Length: Interpreted lineaments were classified according to their length, which was 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 metres and a search radius of 1.25 kilometres (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 recorded in degrees ranging between 0 and 180. Lineament sets were 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, and in the Phase 2 lineament interpretation report (SRK 2017a).

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 survey block 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 **Error! Reference source not found.**. An expanded view of interpreted m agnetic lineaments for each withdrawal area is shown in Section **Error! Reference source not found.**.

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, 2017a). The digital aerial imagery data has 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. It is uncertain what proportion of surficial lineaments represent actual geological structures and if so, whether the structures extend to significant depth.

Figure 4.5 shows Phase 2 surficial lineaments interpreted for the Manitouwadge 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.

4.4 Geological Mapping

Phase 2 geological mapping comprised both the observation of general geological features (OGGF) and detailed geological mapping, and was conducted by SRK in three separate site visits from July to October 2016. The OGGF component of the field mapping was conducted during the first site visit in July and focussed on collecting data at easily accessible locations to confirm the presence and nature of key geological features in the area, including: bedrock character (lithology, structure, magnetic susceptibility and rock strength); fracture character; bedrock exposure; and other surface constraints. The OGGF component of the geological mapping was intended to acquire a reasonablysized initial data set at easily accessible outcrops in order to define priority areas on which to concentrate during the subsequent detailed geological mapping component.

The subsequent two site visits for detailed geological mapping in August and October 2016 focused on increasing the number of observations in more difficult to reach areas. The data collected at each outcrop for both the OGGF and detailed mapping was the same. A detailed description of the approach, methods and observations is provided in the Phase 2 geological mapping report (SRK, 2017b). This section provides an overview of the mapping planning, logistics and use of local and Traditional Knowledge. The findings from the geological field mapping are discussed in an integrated manner with findings from other Phase 2 field studies throughout Section 5.

Geological mapping in the Manitouwadge area was focused within and adjacent to the four potentially suitable areas. These areas were identified by the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014), and were temporarily withdrawn from mineral staking (withdrawal areas) to provide an opportunity for the Phase 2 geological mapping field studies to be conducted. The four withdrawal areas (Figure 1.2) all lie within the three blocks that were the focus of the Phase 2 high resolution geophysical survey and lineament interpretation and in this report, are named based on their geological setting: Quetico area, Fourbay Lake pluton area, Black- Pic batholith area - west, and Black-Pic batholith area - east.

During the three site visits, the four withdrawal areas were visited over a total period of 57 days by two to three teams of two geologists, and with the aid of one or two local guides for logistical support. A total of 576 locations were observed during this period (Figure 4.8). Several GIS datasets were used as base maps for planning and undertaking the Phase 2 geological mapping, including predictive outcrop mapping generated by NWMO using remote sensing data, high-resolution satellite imagery, recently-acquired high-resolution geophysical data (SGL, 2017), and interpreted lineaments (SRK, 2017a).

4.4.1 Mapping Plans and Logistics

Planning for the Phase 2 geological mapping involved a review of all available information for the Manitouwadge area, including access. The planning also included the development of a comprehensive list of source data, equipment and task requirements for the observation of the key geological features (SRK, 2017b).

An important component of the planning phase was the creation of a georeferenced set of predicted outcrops (Figure 4.7). This was created by NWMO using a combination of a supervised object based image analysis of the FRI imagery and manual refinement of the initial results. The distribution of predicted outcrop locations was analyzed in relation to their distance to the existing road and trail network, and to the key geological features to be investigated during the Phase 2 geological mapping. The key geological features included interpreted lineaments, interpreted geophysical anomalies, and mapped geological bedrock unit contacts. This task involved filtering and categorizing each predicted outcrop in and around the withdrawal areas to define target locations to visit during the OGGF and detailed geological mapping components of the fieldwork. The subset of easily accessible outcrops identified to be visited during the initial OGGF component of mapping included predicted outcrops located within 100 metres of existing roads and trails (and where applicable, electrical power and rail corridors), whereas more remote outcrops were visited during the detailed mapping phase.

Observations made during the geological mapping were recorded using a digital data capturing method to allow for consistent data entry and seamless integration of the observations into a GIS platform. In addition, hand-sized rock samples were collected to provide a representative example of the different rock types observed in the field and representative photographs of each outcrop and relevant features were taken with a digital camera. Field magnetic susceptibility and gamma spectrometer measurements were obtained from fresh surfaces of outcrop using a KT-10 or KT-20 magnetic susceptibility meter and an RS-125 gamma spectrometer. Preliminary geomechanical characterization of the bedrock was undertaken by means of representative measurements of joint orientation and spacing, and a simple field-based hammer test for intact rock strength. Full details of the data collected and the methodology are described in the geological mapping report (SRK, 2017b).

The OGGF component of geological mapping in the Manitouwadge area was conducted using a 4X4 vehicle as the primary means of transportation, whereas the detailed mapping component required the use of ATVs, small boats, and helicopter/floatplane support, in addition to foot traverses to access the remainder of the four withdrawal areas.

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, the mapping team members participated in an Aboriginal Traditional Knowledge workshop hosted by NWMO. The workshop reminded both contractors and NWMO staff that as humans we are dependent on the land for sustaining life.

Through their knowledge of the land, local people greatly enhanced the planning of mapping activities. Informal meetings with members of the Manitouwadge community provided an opportunity to work collaboratively on planning to ensure activities would be carried out in a manner that was respectful of the land and local trap lines. Open dialogue was maintained during the execution of mapping activities. To facilitate this open dialogue, local guides were hired to provide logistical support and to bring local knowledge of the land.

5 Key Geoscientific Characteristics

The following subsections provide an updated description of the key geoscientific characteristics that were used to identify general PRAs based on both the Phase 1 Geoscientific Desktop Preliminary Assessment and recently acquired field data during the Phase 2 Geoscientific Preliminary Assessment. The updated description focuses on the four general areas that were identified as potentially suitable in the Phase 1 Geoscientific Desktop Preliminary Assessment. These include the Quetico area in the metasedimentary rocks of the Quetico Subprovince, the Fourbay Lake pluton area, and the Black-Pic batholith area - west and Black-Pic batholith area - east both within the Black-Pic batholith (Figure 1.2).

5.1 Bedrock Geology

The bedrock geology of the Manitouwadge 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 (AMEC, 2014; PGW, 2014). This section provides an updated description of the bedrock geology of each of the four general potentially suitable areas based on the integrated interpretation of the initial field studies of the Phase 2 Geoscientific Preliminary Assessment.

5.1.1 Quetico Area

Bedrock in the Quetico Subprovince consists of variably metamorphosed and migmatized metasedimentary rocks (Williams, 1991). Granitic intrusions are widely present throughout the Quetico Subprovince, whereas mafic to ultramafic intrusions occur sporadically (Williams, 1989; Sutcliffe, 1991). These clastic metasedimentary rocks were deposited between circa 2.700 to circa 2.688 billion years ago (Ga) and have undergone various degrees of metamorphism (Percival, 1989; Zaleski et al., 1999). Low-pressure, high temperature metamorphism in the Quetico Subprovince produced partial melting of the original sedimentary rocks, resulting in the formation of migmatites comprising two different lithological components: a metasedimentary protolith (i.e., paleosome) and a granitic component derived from the partial melting of the protolith (i.e., neosome).

During Phase 2 geological mapping two main lithology types were observed in the Quetico area: migmatitic metasedimentary rocks and east-west elongated lobate intrusions of granite (Figure 5.1), generally consistent with previous geological mapping (Coates, 1967). Locally, a higher percentage of partial melting of up to 60 percent is observed in the migmatites, and the granite occasionally transitions to granodiorite. Geological mapping identified that metasedimentary migmatite is present throughout the entire Quetico area, and is interpreted to represent approximately 70 percent of the underlying bedrock, with the remaining 30 percent comprised dominantly of granite. Typical migmatite comprises centimetre- to metres-wide layers of strongly foliated metasedimentary rocks interlayered with irregular, massive bands of neosome (i.e., product of partial melting) ranging from millimetres- to metres-thick.

The typical granite in the Quetico area is characterized by an equigranular, moderate to very coarse-grained massive texture, and typically contains biotite, and locally muscovite and garnet (SRK, 2017b). Intrusive granite units have a number of modes of occurrence. Granite forms centimetre- to multi-metre-wide layers and pods that are both concordant and discordant to foliated metasedimentary rocks, and is also present as separate granite intrusions cutting the migmatite. One large granite-granodiorite intrusion was identified in multiple outcrops in the northeast corner of the Quetico area. Regional mapping indicates that this intrusion is large (up to 20 kilometres wide and long), and extends as an east-west oriented lobe directly north of the northern boundary of the withdrawal area (Figure 5.1).

Distinct east-west trending magnetic and gravity anomalies are present within the Quetico Subprovince immediately north of the subprovince boundary, but south of the Quetico withdrawal area (SGL, 2017). These anomalies are associated with high grade metamorphism near and along the subprovince boundary (Williams and Breaks, 1996). The linear magnetic anomalies just south of the Quetico area (Figure 5.1) are interpreted to represent the northern limit of the regional magnetic high associated with the Quetico-Wawa subprovince boundary shear zone (SGL, 2017). Within the Quetico withdrawal area the magnetic data shows a more subtle pattern with a consistent east-west orientation, which may reflect discrete zones of higher grade metamorphism or localized zones of shearing (SGL, 2017). Overall, the magnetic background within the Quetico Subprovince is lower than that of the Wawa Subprovince. Magnetic susceptibilities measured in the field during Phase 2 geological mapping confirm the generally low magnetic values in the Quetico area as seen in the high resolution airborne survey.

Interpretation of high-resolution geophysical data identified a large magnetic anomaly in the southeastern portion of the Quetico withdrawal area (Figure 5.1). This anomaly was interpreted by SGL (2017) as potentially reflecting some degree of heterogeneity or deformation, and its western border was preliminarily interpreted by SRK (2017a.) as a dyke lineament based on magnetic data. Phase 2 geological mapping (SRK, 2017b.) identified this western boundary of the anomaly as a granitic body with a high content of magnetite that shallowly dips to the east-southeast.

A single gravity boundary is present in the Quetico area (Figure 5.1), interpreted from a textural change in the first vertical derivative of the Bouguer gravity (SGL, 2017). Based on previous mapping and results from Phase 2 geological mapping there is no clear correlation of this anomaly to any geological contact or structure.

Based on preliminary 2.5D modelling of the geophysical data, the thickness of the Quetico Subprovince metasedimentary rocks is interpreted to be approximately 7.50 kilometres and the granitic units are modelled as synclinal shaped intrusions with thicknesses of approximately 0.5 to 2.3 kilometres (SGL, 2017). When alternative constant density models are considered, a relatively uniform thickness of approximately 6 to 7 kilometres is estimated for the metasedimentary rocks in the Quetico area, and a maximum thickness of approximately 1.0 kilometre is interpreted for the granitic units (SGL, 2017).

5.1.2 Fourbay Lake Pluton Area

The Fourbay Lake pluton is an approximately 69-square-kilometre, elliptical-shaped intrusion located southwest of the Township of Manitouwadge that underlies most of the Fourbay Lake pluton area (Figure 5.2). This weakly foliated to massive pluton has a granodiorite to diorite composition and was emplaced at circa 2.678 Ga (Beakhouse, 2001). The pluton is entirely surrounded by rocks of the Black-Pic batholith.

Phase 2 geological mapping indicated that the bedrock in the Fourbay Lake pluton area varies mainly from diorite to granodiorite in composition (Figure 5.2). A single outcrop of tonalite was observed in the northeastern corner of the withdrawal area marginal to the pluton. Based on field data the Fourbay Lake pluton is typically homogeneous, and is locally intruded by multiple granitic dykes. Centimetre-scale, rounded xenoliths of more mafic composition are characteristic of the pluton. A large cluster of diorite observations occurs in the northern half of the withdrawal area, while granodiorite was observed in the remainder of the withdrawal area (Figure 5.2). This may suggest different compositional phases of the pluton, but the contact between the two was not sharply defined in the field, and is interpreted to be a gradational contact.

Several observations of Biscotasing and Marathon dykes were made during Phase 2 geological mapping, but the single Matachewan dyke interpreted from the lineament analysis (SRK, 2017a) was not exposed in outcrops visited during mapping. One Biscotasing dyke occurs in a magnetic low and may represent a reversely magnetized dyke (SRK, 2017b).

Phase 2 geophysical data show the pluton is characterized as a prominent magnetic anomaly with a more subtle gravity high. The magnetic boundary of the pluton is well-defined against rocks of the Black-Pic batholith (Figure 5.2), and correlates almost exactly with the mapped geologic boundary. High magnetic susceptibilities measured in the field confirm the generally high magnetic values obtained during the high resolution airborne survey, differentiating it from the adjacent Black-Pic batholith tonalite. The associated gravity anomaly is slightly broader than the magnetic boundary (Figure 5.2). At the north end of the pluton but outside the withdrawal area, both the magnetic and gravity data show an area of slightly elevated signal relative to the rest of the pluton. This may indicate some degree of physical property heterogeneity within the pluton (SGL, 2017).

Preliminary 2.5D modelling of the Phase 2 geophysical data interprets the Fourbay Lake pluton to extend to a maximum depth of approximately 1.1 kilometres below mean sea level (MSL), and thinning towards its centre to a minimum depth of approximately 0.4 kilometre below MSL (SGL, 2017). It is acknowledged, however, that the density value used for modelling for the Fourbay Lake pluton is anomalously high for a granite-granodiorite intrusion, and the pluton would have a deeper modelled base if lower density values were used.

5.1.3 Black-Pic Batholith Area - West

The Black-Pic batholith is a large, regionally-extensive intrusion that encompasses an area of approximately 3,000 square kilometres and forms the bedrock for the majority of the southern half of the Manitouwadge area (Figure 1.2). The Black-Pic batholith is a multi-phase intrusion that includes hornblende-biotite monzodiorite, foliated tonalite, and pegmatitic granite, with subordinate foliated diorite, granodiorite, granite, and cross-cutting aplitic to pegmatitic dykes (Williams and Breaks, 1989; Zaleski and Peterson, 1993). The age of emplacement of the Black-Pic batholith has been constrained by uranium-lead (zircon) dating of the oldest phase recognized, a tonalite at circa 2.720 Ga (Jackson et al., 1998). A younger monzodiorite phase has been dated at circa 2.689 Ga (Zaleski et al., 1999).

Phase 2 geological mapping confirmed that the bedrock in the Black-Pic batholith area - west consists predominantly of foliated to gneissic tonalite (Figure 5.3). The tonalite is commonly intruded by granitic dykes and diorite to granodiorite intrusions, and locally contains mafic gabbroic inclusions (xenoliths, dykes, rafts). Occurrences of granite and granodiorite to diorite were observed throughout the Black-Pic batholith area - west, predominantly in the northwest portion of the withdrawal area but also in the northeast portion. These lithological units exhibit an elevated magnetic susceptibility in a portion of the northwestern corner of the withdrawal area. Gabbro was observed to dominantly occur as narrow foliated dykes (less than 2 metres wide) intruding tonalite, and was also less commonly observed as enclaves or small intrusions.

Panels of foliated to gneissic mafic rocks occur in a domain in the southeast part of the withdrawal area, coincident with a stronger and more steeply dipping gneissosity, and corresponding to a magnetic anomaly (Figure 5.3; SGL, 2017). These panels represent phases of the tonalite complex, potentially either strongly deformed mafic phases, or relict panels of mafic metavolcanic rocks. They are strongly foliated in an orientation sub-parallel to the main fabric, suggesting they represent portions of the main Black-Pic batholith that have experienced strong ductile deformation. The magnetic anomaly identified in this area (Figure 5.3) may potentially represent steeply dipping foliation or layering within the Black-Pic batholith, or the presence of rocks with higher density (SGL, 2017). Phase 2 geological mapping and geophysical data suggest that this portion of the Black-Pic batholith area - west could potentially represent a northward extension of the Schreiber-Hemlo greenstone belt. In general, magnetic susceptibilities measured in during Phase 2 field mapping in the Black-Pic batholith area - west confirm the generally low magnetic values inferred from the high resolution airborne survey.

Many northwest-, north- to north-northeast-, and northeast-trending magnetic highs were interpreted to be Proterozoic mafic dykes of the Matachewan, Marathon, and Biscotasing dyke swarms respectively in the lineament interpretation (SRK, 2017a). Many of these were field verified (Figure 5.17) during the geological mapping (SRK, 2017b).

Generally, within the regionally extensive Black-Pic batholith area - west, the Bouguer gravity data displays increasing values north towards the subprovince boundary (Figure 4.2). The most distinct local gravity highs correlate with mapped mafic volcanic rock units adjacent to the Black-Pic batholith area - west, such as the Manitouwadge-Hornepayne greenstone belt, and intrusions contained within the Black-Pic batholith area - west (e.g., Fourbay pluton). The most prominent gravity lows occur centrally within the Black-Pic batholith area - west, such as the gravity anomaly identified in the southwestern portion of the withdrawal area (Figure 5.3). This gravity low anomaly corresponds to a structural dome mapped in the tonalite (SRK, 2017b) and is interpreted by SGL (2017) as representing either one of the thickest parts of the Black-Pic batholith, a different intrusive phase within the intrusion, or a combination of both scenarios.

Based on preliminary 2.5D modelling of the Phase 2 geophysical data, the thickest parts of the Black-Pic batholith area - west are interpreted to a depth of approximately 7.6 kilometres below MSL under the two gravity lows identified (Figure 5.3). Between the two gravity low anomaly areas, the thickness of the Black-Pic batholith area - west has been modelled to a depth of approximately 5.5 kilometres below MSL (SGL, 2017).

5.1.4 Black-Pic Batholith Area - East

Previous geological mapping described the bedrock in the Black-Pic batholith area - east as consisting mostly of gneissic tonalite as described in Section 5.1.3. Additionally, an unnamed, northeast-trending granite-granodiorite intrusion is depicted in the central portion of the Black-Pic batholith area - east on previous maps, as shown on Figure 5.4. This geological unit is present in the compilation map of the area (Johns and McIlraith, 2003), and is based on previous geological maps (Giguere, 1972).

Based on Phase 2 geological mapping data, bedrock in the Black-Pic batholith area - east mainly comprises a tonalite to granodiorite suite of the Black-Pic batholith (Figure 5.4). Tonalite to granodiorite are interpreted to represent greater than 90 percent of the underlying bedrock in the area, and are interpreted to be a single intrusive phase straddling the tonalite-granodiorite composition ranges (SRK, 2017b). The tonalite to granodiorite varies from homogenous to moderately heterogeneous, locally contains irregular xenoliths of diorite and rarely tonalite gneiss, and is intruded by leucocratic granitic and gabbroic dykes, and granodiorite to granite intrusions. The tonalite to granodiorite of the Black-Pic batholith area - east is more homogenous and has a weaker foliation than the tonalite of the Black-Pic batholith area - west.

Occurrences of granite and granodiorite to diorite were dominantly observed in the northern portion of the Black-Pic batholith area - east (Figure 5.4). The lack of foliation within these intrusions suggests they were emplaced relatively late in the tectonic history. The granodiorite to diorite intrusions are interpreted to be relatively small and discontinuous. In contrast, outcrops of granite locally form intrusive bodies of significant sizes (up to 1 kilometre wide). These granite units are approximately consistent with historical mapping (Giguere, 1972), although they are not interpreted to form a single large intrusion as previously mapped, and do not have a distinctive gravity or magnetic anomaly associated with them (Figure 5.4; SGL, 2017).

Field gamma spectrometer readings indicate the foliated tonalite to granodiorite rocks have the highest radioactivity compared to all the other lithological units in the Manitouwadge area, comparable to the foliated to gneissic tonalite in the Black- Pic batholith area - west (SRK, 2017b).

In the Black-Pic batholith area - east the gravity data also displays increasing values north towards the subprovince boundary that is observed to the west (Figure 4.2). North of the Black-Pic batholith area - east a gravity domain boundary is defined, along which less dense tonalites of the Black-Pic batholith area - east are in contact with the more dense volcanic rocks of the Manitouwadge-Hornepayne greenstone belt (Figure 5.4; SGL, 2017). The gravity domain boundary coincides with a magnetic anomaly domain boundary and agrees well with the mapped contact between the Manitouwadge-Hornepayne greenstone belt and the Black-Pic batholith (SGL, 2017; Figure 5.4; OGS, 2011).

Immediately south of the withdrawal area the Bulldozer Lake intrusion produces a distinct magnetic anomaly which also produces an associated gravity anomaly (Figure 5.4). The boundaries of the magnetic and gravity anomalies are approximately coincident, with the gravity showing a slight skew to the southeast possibly reflecting a southeast-dip to the body, or a slight widening at depth (SGL, 2017).

The only geophysical anomaly interpreted within the Black-Pic batholith area - east is a gravity anomaly in the southeastern part of the withdrawal area and is similar to two negative gravity anomalies in the Black-Pic batholith area - west. The gravity lows correlate to areas with no magnetic anomalies or magnetic textural variations. Magnetic susceptibilities measured in the field in the Black-Pic batholith area - east confirm the generally low magnetic values inferred from the high resolution airborne survey.

Based on preliminary 2.5D modelling of the geophysical data the Black-Pic batholith extends to a depth of approximately 7 kilometres in the Black-Pic batholith area - east. The granite-granodiorite intrusion shown in Figure 5.4 was incorporated into the model to honour historical mapping, but the unit itself produces no distinguishing signal and therefore its modelled subsurface geometry is unconstrained. When an alternative constant density model is considered the estimated thickness of the Black-Pic batholith in the area increases to approximately 8 kilometres.

5.2 Lineament Analysis

This section provides an integrated analysis of interpreted lineaments (SRK, 2017a) for each of the four general potentially suitable areas in the Manitouwadge 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 Manitouwadge area. These categories include unclassified, brittle, and dyke lineaments, described as follows:

- Unclassified lineaments are features interpreted to represent unclassified structures. This may include ductile shear zones (intensification of foliation across a narrow zone with associated fracturing) or brittle-ductile shear zones. Unclassified structures were typically characterized by curvi-linear magnetic lows and commonly truncated or offset the internal fabric of the rock (i.e., form lines). Alternatively, these unclassified structures may represent the internal fabric of the rock (foliation or gneissosity).
- Brittle lineaments are features interpreted as fractures (joints or joint sets, faults or fault zones, and veins or vein sets) and are commonly characterized by continuous, linear magnetic, and breaks in topography, vegetation, and/or linear shorelines.
- 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.

5.2.1 Quetico Area

Magnetic lineaments of high and medium certainty are presented in Figure 5.5 for the Quetico area. The majority of magnetic lineaments interpreted in this area, when unclassified lineaments are not considered, are classified as dyke lineaments. These interpreted magnetic dyke lineaments trend mostly northeast and northwest, with only a few magnetic brittle lineaments interpreted subparallel to the dyke lineaments. Areas of higher magnetic lineament density tend to correspond to where northwest-trending dyke lineaments and subparallel brittle lineaments intersect northeast-trending dyke lineaments and subparallel brittle lineaments. Areas of higher magnetic lineament density occur in the northwest corner and southeast corner of the withdrawal area and in a northeast-trending corridor running from the southwest to northeast corners of the area. The low number of magnetic brittle lineaments interpreted in the Quetico area may in part be due to the low magnetic susceptibility of the Quetico metasedimentary rocks, which may mask the presence of brittle structures.

Unclassified magnetic lineaments in the Quetico area were interpreted by SRK (2017, 2017a) mostly trending east-west, as shown in Figure 5.5. When these unclassified lineaments are considered, the magnetic lineament density is enhanced in broad zones that are typically elongated in an east-west orientation (Figure 5.5), such as in the southeast corner, the centre, and the northeast portion of the withdrawal area. Data from Phase 2 geological mapping suggests that many unclassified lineaments represent the dominant ductile fabric developed in the metasedimentary rocks or mark the contacts of high magnetic units of granite or metasedimentary rocks, most of which could not be confirmed as brittle-ductile or ductile shear zones. In contrast, the anastomosing pattern of unclassified lineaments in the southeast corner of the withdrawal area were confirmed by geological mapping as domains of increased deformation interpreted to be associated with ductile shear zones. Field observations of joint spacing of joints subparallel to foliation/gneissosity suggest that brittle reactivation or reuse of the ductile fabric is an important consideration in the Quetico area.

The distribution of surficial lineaments of high and medium certainty is relatively uniform throughout the Quetico area, as shown in Figure 5.6. However, areas of higher surficial lineament density are observed coinciding with areas where a larger number of shorter, medium certainty surficial lineaments are interpreted, such as in the northwestern portion of the withdrawal area around Lauri Lake (Figure 5.6). The presence of additional surficial lineaments may be masked by the significant amount of overburden covering the bedrock throughout the Quetico area (Figure 4.6).

The density of integrated brittle and dyke lineaments of high and medium certainty in the Quetico area, shown in Figure 5.7, is relatively variable. Zones of higher integrated lineament density are observed along a band of tight-spaced northeast-trending lineaments, and at the intersection of northwest- and northeast-trending dyke lineaments with brittle lineaments of different orientations in the northwestern portion of the withdrawal area.

5.2.2 Fourbay Lake Pluton Area

The density of brittle and dyke lineaments identified from the aeromagnetic data (Figure 5.8) is generally relatively low in the Fourbay Lake pluton area, compared to the other potentially suitable areas (SRK, 2017a). Most of the magnetic lineaments interpreted are brittle lineaments, with only one northwest trending dyke lineament interpreted in the withdrawal area. Areas of slightly higher magnetic lineament density in the south and north central portions of the withdrawal area density coincide with areas where lineaments of different orientations intersect.

Unclassified lineaments are interpreted from the magnetic data primarily in a curvi-linear domain adjacent and sub-parallel to the eastern boundary of the Fourbay Lake pluton (Figure 5.8). Ductile features observed during Phase 2 geological mapping in and around this area are weakly developed and may represent higher strain and magmatic fabrics associated with the intrusion of different phases of the Fourbay Lake pluton. The nature of the unclassified lineaments remains uncertain.

The Fourbay Lake pluton area is also characterized by relatively low surficial lineament density, with several broad but isolated zones of higher lineament density (Figure 5.9; SRK, 2017a). Zones of higher lineament density are observed in northwest-trending zones along the north and south boundaries of the area. In general the density of surficial lineaments is relatively lower in the western portion of the Fourbay Lake pluton area. The Fourbay Lake pluton is well-exposed, so the lower surficial lineament density is not caused by the presence of overburden cover.

Given that the density of both magnetic and surficial lineaments is relatively low, as described above, the integrated lineament density in the Fourbay Lake pluton area is also lower when compared to the other potentially suitable areas. Localized areas of higher density of integrated lineaments are identified at the south and north margins of the area where northwest-trending and northeast-trending lineaments intersect (Figure 5.10).

5.2.3 Black-Pic Batholith Area - West

Figure 5.11 shows the magnetic lineaments of high and medium certainty for the Black-Pic batholith area - west. Dyke lineaments interpreted in this area most commonly trend north- and north-northeast (Marathon dykes), followed by northwest-trending dyke lineaments (Matachewan dykes), with just a few northeast-trending dyke lineaments (Biscotasing dykes). North and north-northeast trending dyke lineaments in this area tend to occur in bands of tightly spaced lineaments, such as in the central and eastern portions of the withdrawal area. Magnetic brittle lineaments in the Black-Pic batholith area - west are mostly interpreted in the southwestern quadrant of the withdrawal area and in the area immediately west of it. Where dyke and brittle lineaments intersection in this southwestern portion of the area the density of magnetic lineaments is higher (Figure 5.11).

Unclassified lineaments are interpreted in several areas throughout the Black-Pic batholith area - west, including an east-west trending domain along the northern portion of the area, a north-northwest-trending domain in the northwest corner of the area, and a curvi-linear domain in the southeast corner of the withdrawal area (Figure 5.11). In the aforementioned zones of unclassified lineaments, foliation and gneissosity measured in the field during Phase 2 geological mapping are typically sub-parallel to the interpreted lineaments. Along the northern boundary and the northwest corner of the withdrawal area, several foliation, gneissosity and shear zones were observed directly along or adjacent and sub-parallel to the interpreted east-trending and northwest-trending unclassified lineaments. Field data suggests that unclassified lineaments in these areas may be associated with increased ductile deformation. In the southeast portion of the withdrawal area, where curvilinear unclassified lineaments were interpreted, the analysis of ductile fabrics observed during mapping suggests that this area may represent the boundary and abutting of multiple tonalite domes, and that the unclassified lineaments define a broad domain of increased ductile deformation. As described in Section 5.1.3, Phase 2 geological mapping and geophysical data suggest that this portion of the Black-Pic batholith area - west could also coincide with a northward extension of the Schreiber-Hemlo greenstone belt.

Figure 5.12 shows the surficial lineaments of high and medium certainty interpreted in the Black-Pic batholith area - west. The density of surficial lineaments in this area is fairly homogeneous, except in the south-central and southwestern portions of the withdrawal area where the density is lower; here overburden and low topography may hinder the interpretation of surficial lineaments (Figures 4.3 and 4.6). Surficial lineaments in the Black-Pic batholith area - west are for the most part northeast-trending lineaments, with a clear band of northeast-trending, long, high certainty lineaments interpreted through the centre of the withdrawal area. Northwest-trending surficial lineaments are less abundant and tend to be shorter (Figure 5.12).

The density of integrated lineaments in the Black-Pic batholith area - west is shown in Figure 5.13. Increased integrated lineament density in this area tends to coincide with the intersection of brittle and dyke lineaments trending in different orientations. One of these is a north-trending domain along and immediately west of the western boundary of the withdrawal area. Other areas of higher integrated lineament density are found around and immediately northeast of Agonzon Lake in the central portion of the withdrawal area (Figure 5.13).

5.2.4 Black-Pic Batholith Area - East

Magnetic lineaments within the Black-Pic batholith area - east exhibit a higher density relative to the other two potentially suitable areas (Figure 5.14). Dyke lineaments interpreted from geophysical data trend mostly northwest and northeast to north-northeast, with the former occurring often in bands of tightly spaced lineaments throughout the withdrawal area. Brittle lineaments are interpreted mostly with medium certainty and in general show more variability in their orientation. The southwestern quadrant of the Black-Pic batholith area - east exhibits a higher magnetic lineament density, due to tight-spaced clusters of brittle and dyke lineaments, and the intersections of these lineament clusters. Conversely, domains of lower density of magnetic lineaments are present in the southeast and central east parts of the area.

Most of unclassified lineaments in the Black-Pic batholith area - east are interpreted north of the withdrawal area, where the northeast-trending unclassified lineaments are subparallel to the boundary between the Black-Pic batholith and the greenstone belt to the north (Figure 5.14). The nature of these unclassified lineaments could not be observed during geological mapping.

The density of surficial lineaments in the Black-Pic batholith area - east is also higher compared to the Quetico area and the Black-Pic batholith area - west. There are relatively few small pockets of lower surficial lineament density and generally the surficial lineaments are evenly distributed (Figure 5.15). Surficial lineaments in the northern half of the withdrawal area tend to be of high certainty, while in the southern half most of the surficial lineaments were interpreted with medium certainty. It is possible that the topographic relief and the good bedrock exposure (Figures 5.3 and 5.6) in this area may have contributed to a higher density of interpreted surficial lineaments.

As shown in Figure 5.16, the density of integrated lineament density in the Black-Pic batholith area - east is relatively high. The highest density of integrated lineaments is observed in the southwestern portion of the withdrawal area, where clusters of northeast- and northwest-trending, tightly spaced lineaments intersect. Isolated zones of lower integrated lineament density are observed in the southeast corner, the central and east-central portions and in the northwestern portion of the withdrawal area (Figure 5.16).

5.3 Structural Geology

The east-west-trending Wawa-Quetico subprovince boundary transects the Manitouwadge area separating the Quetico area from the remaining three withdrawal areas (Figure 1.2). Zaleski et al. (1995) and Zaleski and Peterson (2001) deemed the Wawa-Quetico subprovince boundary in the Manitouwadge area to be transitional based on structural, lithological and metamorphic criteria. Williams et al. (1991) reported that the contact zone along the Wawa-Quetico subprovince boundary in the Manitouwadge area contains foliated to gneissose intrusive sheets of tonalite-granodiorite that are highly strained.

In the Manitouwadge area numerous faults are indicated on public domain geological maps (Figure 1.2), but few of these structures are named. These faults display four dominant orientations: north, northeast, northwest, and east. None of these mapped faults is within the Quetico area, and only portions of or shorter mapped faults are observed within the other three withdrawal areas (Figure 1.2).

Within the Manitouwadge area, but outside of the four withdrawal areas, several named structures are present, including: the north-trending Cadawaja, Slim Lake and Fox Creek faults, and the northwest-trending Mose Lake fault, all of which offset folded stratigraphy within the Manitouwadge greenstone belt (Chown, 1957; Peterson and Zaleski, 1999). The southern portions of the Cadawaja and Fox Creek faults extend into the northern portion of the Black-Pic batholith area - west (Figure 1.2). Named east-trending structures are also present in the area surrounding the three withdrawal areas, including the Agam Lake, Rabbitskin Lake, and Little Nama Lake faults, which mimic the outline of the Manitouwadge greenstone belt and subprovince boundary, and are typically offset by north-trending faults. The northwest-trending Pinegrove Lake fault is the only named fault in the Fourbay Lake pluton area, cutting through the southwest corner of the area. Mapping and interpretation of aeromagnetic data (e.g., Miles, 1998), indicates that all mapped faults offset the regional fabric throughout the Manitouwadge area.

Of the aforementioned mapped structures, the north-trending Cadawaja, Slim Lake and Fox Creek faults were mapped as sinistral strike-slip faults (Miles, 1998). The Fox Creek fault exhibits a 60-metre sinistral strike-separation of the Geco volcanogenic massive sulphide deposit combined with a minor east-side-up vertical displacement (Milne, 1969). The Cadawaja fault offsets the stratigraphy on the southern edge of the Manitouwadge greenstone belt by 500 metres (Miles, 1998). The east-trending Agam Lake fault was mapped primarily as a brittle strike-slip fault (Chown, 1957). This structure in part follows the volcanic-sedimentary contact and locally may represent a reactivated ductile shear zone (Peterson and Zaleski, 1999).

The north-, northwest- and northeast-trending faults are subparallel and locally adjacent to Marathon, Matachewan, and Biscotasing dykes. Locally, these dykes are offset by younger generations of brittle faulting (e.g., Miles, 1998).

5.3.1 Quetico Area

During Phase 2 Geological mapping, both ductile and brittle structures were observed throughout the Quetico area. Ductile structures include foliation, gneissic layering, shear zones, and folds. Brittle structures include joints, veins, and brittle faults.

Within the Quetico area, foliation and gneissosity represent a spectrum of planar fabrics resulting from the alignment and segregation of mineral grains due to progressive deformation. They exhibit similar orientations and minor variations in texture, and were interpreted to represent a single progressive deformation event. Foliation is well developed, and observed in the metasedimentary migmatites throughout the entirety of the area (SRK, 2017b). Penetrative planar fabrics are not developed in the granite intrusions and rarely in the neosome portions of the migmatites. Gneissosity is typically intense and was predominantly observed in the western portion of the block, suggesting that the intensity of deformation may have increased towards the west. Foliation and gneissosity typically strike west to west-southwest, and dip steeply to the north with local reversal to steeply south-dipping. Despite exhibiting an overall consistent orientation, on an outcrop scale foliated metasedimentary rocks locally anastomose and are rotated in various orientations around neosome and granite bodies (SRK, 2017b).

Shear zones measured in the Quetico area are all within the metasedimentary migmatites in the western and southern portions of the withdrawal area (SRK, 2017b). Observed ductile shear zones are less than 10 centimetres wide and are characterized by strong to intense foliation. They are moderate- to steep-dipping with northeast and north-northwest trends most common. These ductile shear zones are interpreted as minor structures associated with the main penetrative foliation and gneissosity forming deformation event.

Joints mapped in the Quetico area trend in one of six main orientations including a shallow-dipping set. Most joint sets are found across the entire area but not necessarily at the same outcrop. Joints with 100- to 500-centimetre spacing are the most common overall in the Quetico area, which is a higher average joint spacing compared to the other three withdrawal areas. When granitic intrusions and metasedimentary migmatites are present in one outcrop, joint spacing is tighter in the granitic portion of the outcrop, suggesting the rheological contrast in the units focussed brittle deformation in the granitic parts. Conversely, outcrops within large granite intrusions have some of the widest joint spacing. As in all other withdrawal areas, spacing of joint sets parallel to and in the immediate vicinity of well-defined lineaments identified in the Phase 2 lineament analysis (SRK, 2017a) is tighter than away from such lineaments. The majority of joints in the Quetico area do not contain any fill.

All the faults recorded in the Quetico area during Phase 2 geological mapping are within the western portion of the withdrawal area (SRK, 2017b), and observed in both the metasedimentary migmatites and the granitic intrusions. Brittle faults are characterized as discrete slip surfaces typically less than 5 centimetres wide, with minor (centimetre-scale) offsets. Most of these brittle faults are interpreted as minor structural features. However, certain faults are associated with series of sub-parallel joints, and are located adjacent to linear lakes and minor valleys indicating the influence of these faults beyond their immediate area. Brittle faults have north-northwest, east, and northeast trends and are typically steeply-dipping (SRK, 2017b). Most faults do not contain fill.

Very few veins were measured in the Quetico area in the metasedimentary migmatites, the granite, and within a northeast-trending mafic dyke (i.e., Biscotasing diabase dyke). Observed veins are typically less than 3 centimetres wide, exhibit extensional textures, and are filled with quartz, quartz-feldspar, biotite and/or chlorite. The three veins located in the northeast-trending mafic dyke are oriented parallel and orthogonal to the dyke and likely represent extensional veins. The majority of the remaining veins strike south-southwest and are moderate- to steep-dipping (SRK, 2017b).

Relatively few brittle lineaments were interpreted in the Quetico area (Figure 5.5; SRK, 2017a). Of these lineaments, a single northwest-trending low certainty brittle lineament located in the western portion of the mapping area was verified in the field (Figure 5.18). Bedrock evidence of this lineament includes a sub-parallel brittle fault and associated slickenlines located in massive granite directly adjacent to the interpreted lineament, and along the shore of a 2-kilometre long, narrow, northwest-trending linear lake. Faults were also measured parallel to two interpreted dyke lineaments.

First order analysis of additional joint observations throughout the Quetico area suggests that joint spacing may increase adjacent to interpreted brittle lineaments as well as several other stations with tight joint spacing in joint sets parallel to and proximal to interpreted dykes.

5.3.2 Fourbay Lake Pluton Area

Ductile and brittle structures were observed throughout the Fourbay Lake pluton area during Phase 2 geological mapping. Ductile structures include foliation, and shear zones. Brittle structures include joints, veins, and brittle faults.

Ductile structures observed in the Fourbay Lake pluton area include limited foliation, and a very limited number of ductile shear zones and mineral lineations. Foliation measurements were recorded dominantly within the central-eastern portion of the Fourbay Lake pluton area. In the remainder of the pluton, ductile fabrics are absent and the bedrock exhibits a homogeneous massive texture. Foliation measurements typically trend north to north-northeast and dip steeply to both the east and west. The style, intensity, aligned mineralogy and overall geometry of the foliation and lineation observations suggests that these structures may in part be magmatic in origin (i.e., igneous flow textures). A north-trending domain of increased foliation in the eastern half of the pluton is coincident with flattened, aligned mafic xenoliths. Furthermore, lithological observations indicate a gradational change in mafic content to the east of this domain. Variations in gamma-ray spectrometry readings and elevated magnetic susceptibility measurements along this trend, together with the alignment of this trend with the eastern margin of the pluton also suggest that this area may represent the margin of a separate magmatic domain within the Fourbay Lake pluton. Only two northwest-trending shear zones were measured in the area.

Brittle structures observed in the Fourbay Lake pluton area include joints, brittle faults and associated slickenlines, and occasional veins. Joints trend predominantly in four orientations, including a shallow-dipping joint set, with most joint sets found across the entire area but not necessarily at the same outcrop. Joints with 30- to 100- and 100- to 500-centimetre spacing are the most common overall in the Fourbay Lake pluton area. Tighter spaced joint sets (10 to 30 centimetres and 30 to 100 centimetres) are more common in the northeast and west-northwest sets. As with all other withdrawal areas, spacing of joint sets parallel to and in the immediate vicinity of well-defined, high-confidence lineaments identified in the Phase 2 lineament analysis (SRK, 2017a) have tighter joint spacing than away from such lineaments. The majority of joints in the Fourbay Lake pluton area did not contain any fill, although locally throughout the pluton, and in particular proximal to brittle faults, abundant hematite and minor epidote, quartz and chlorite were observed.

All brittle faults recorded in the Fourbay Lake pluton area are hosted within the diorite to granodiorite, and occur as discrete millimetre- to centimetre-wide slip surfaces. Locally, single discrete slip surfaces were observed, and in other instances, multiple close-spaced consecutive discrete slip surfaces were present. Where multiple discrete faults were present, a series of sub-parallel joints were also commonly observed. Offsets along brittle faults are typically minor (less than 10 centimetres). Brittle faults dip steeply and trend in two dominant orientations, west-northwest and north-northeast. A third minor set of east-northeast-trending brittle faults were also observed (SRK, 2017b). Mapped brittle faults commonly occur proximal or along brittle lineaments interpreted by SRK (2017a). Proximity to interpreted brittle lineaments often corresponds to an increase in discrete fault surfaces, and increased fault fill (i.e., hematite, epidote). Although most faults do not contain fill, a significant number brittle faults have associated alteration.

Veins measured in the Fourbay Lake pluton area are distributed mostly throughout the southeast portion of the withdrawal area (SRK, 2017b). Veins were observed to be steep-dipping, less than 10 centimetres wide, typically exhibit extensional textures, and to be filled with quartz feldspar and biotite (i.e., granitic veins). Often, veins are oriented sub-parallel to the dominant orientation of joints and brittle faults. Other veins are distributed in a range of orientations.

Two through-going northwest-oriented brittle lineaments were interpreted in the north and south of the withdrawal area. No brittle structures were observed along the northern, northwest-trending lineament; however, increased hematite alteration, and closely spaced sub-parallel joints (10 to 30 centimetres) were recorded in stations adjacent to the southern lineament (Figure 5.20).

Multiple northeast-oriented brittle lineaments were interpreted cross-cutting the Fourbay Lake pluton area. Field evidence of these lineaments was observed in multiple stations, including brittle faults, closely spaced lineament parallel joint sets, and extensive hematite alteration along fault and joint surfaces (Figures 5.19 and 5.20).

A single north-trending brittle lineament was interpreted bisecting the centre of the withdrawal area. Bedrock evidence of this lineament includes multiple discrete lineament-parallel brittle fault surfaces, adjacent to the interpreted lineament. Additional evidence includes narrow spacing (up to 3 to 10 centimetres) and hematite staining of lineament sub-parallel joints.

5.3.3 Black-Pic Batholith Area - West

Ductile and brittle structures were observed throughout the Black-Pic batholith area - west. Ductile structures include foliation, gneissosity, shear zones, and fold axes and axial planes. Brittle structures include joints, veins, and brittle faults.

Foliation and gneissosity in the Black-Pic batholith area - west often exhibit similar orientations and minor variations in texture, and are interpreted to represent a series of progressive deformation events. Foliation and gneissosity measurements were recorded dominantly within tonalite, and locally also within mafic dykes, diorite and granodiorite (SRK, 2017b).

In the Black-Pic batholith area - west the pattern of foliation and gneissosity measured during geological mapping defines intrusive tonalite dome structures, with moderate- to steep-dipping foliation and gneissosity associated with the edges of one of these domes along the northwestern boundary and the southeast portion of the withdrawal area. In the southeastern portion of the withdrawal area this dome edge also coincides with interpreted unclassified lineaments and a geophysical anomaly (Figures 5.3 and 5.11; Sections 5.1.3 and 5.2.3).

Shear zones were measured in the Black-Pic batholith area - west dominantly within tonalite, and in two instances within mafic dykes (SRK, 2017b). Observed discrete ductile shear zones were typically less than 1 metre wide, and characterized by strong to intense foliation and extensional shear bands. Ductile shear zones are located along the edges of tonalite domes and within the central-western portion of the withdrawal area. When located along the boundaries of intrusive domes, the ductile shear zones are oriented sub-parallel to the general trend of the dome and dip steeply, similar to the orientation of foliation and gneissosity in these areas. Ductile shear zones in the central-western portion of the study area form an east-west trend and dip shallowly to moderately to the north. These measured structures represent discrete ductile shear zones that could be observed in individual outcrops, but do not provide a complete representation of large scale high strain zones. However, examination of the strain intensity of ductile features across the withdrawal area reveals area-scale high strain zones, including a northeast-striking shear zone that bisects Agonzon Lake and ductile shear zones along the edges of tonalite domes in the southeast of the withdrawal area (SRK, 2017b).

Two of the brittle-ductile shear zones measured in the Black-Pic batholith area - west are part of a significant multi-metre wide, northeast-striking brittle-ductile shear zone that parallels the part of the Black River to the northwest of Agonzon Lake (Figure 5.3; SRK, 2017b). There is limited exposure of this fault, with the core of the fault lying under the river; however, field observations including alteration, brittle-ductile structures and foliation measurements provide evidence of this structure away from its core. This brittle-ductile shear zone is also interpreted as a high certainty magnetic brittle lineament (Figure 5.11), and is located in the core of a high ductile strain corridor, suggesting that this structural domain was reactivated in the brittle-ductile regime.

Brittle structures observed in the Black-Pic batholith area - west include joints, brittle faults, and occasional veins. Joint measurements recorded in the Black-Pic batholith area - west trend predominantly in one of six orientations including a shallow-dipping set (SRK, 2017b). Joints with 30- to 100-centimetre spacing are the most common overall in the area, and this narrower average spacing is the most distinct of all the withdrawal areas. The prevalence of narrow joint spacing (1- to 3- and 3- to 10-centimetre spacing) in the north-northwest-trending joint set is the most distinctive feature of the joint spacing analysis. This correlates with the corridor of strong brittle deformation observed on the west margin of the area subparallel to the Barehead Lake fault, as described later. Most joints throughout the Black-Pic batholith area - west contain no fill.

Brittle faults measured throughout the Black-Pic batholith area - west trend mostly west-northwest-, north-northwest-, and east-northeast (SRK, 2017b), and the majority occur as discrete millimetre- to centimetre-wide slip surfaces. Locally, single discrete slip surfaces were observed, and in other instances multiple, close-spaced, parallel, discrete slip surfaces were present. These form brittle fault zones that vary from a few centimetres to greater than 10 metres wide, and commonly form series of scarps and sub-parallel joints (SRK, 2017b). Offsets along individual, discrete brittle faults are typically minor (less than 10 centimetres). Brittle faults are typically very steep, to sub-vertical.

The distribution and orientation of stronger brittle faulting in the Black-Pic batholith area - west can be roughly divided into four domains:

- A north-trending domain of brittle faults located along the central part of the western boundary of the withdrawal area associated with the major north-trending brittle fault that passes through Barehead Lake.
- A northeast-trending domain of brittle faults originating from the southwestern boundary of the area and extending northeast through Agonzon Lake and up to Kaginu Lake, coincident with a major ductile high strain zone, a mapped major brittle-ductile shear zone, and numerous northeast-trending interpreted lineaments.
- A northwest-trending domain of brittle faults located along the central-eastern boundary of the withdrawal area, associated and coincident with a northwest-trending structural zone interpreted from ductile structures to represent the edge of a tonalite dome.
- A minor domain along the western half of the northern boundary of the withdrawal area comprising limited brittle faults, associated and coincident with an east-trending structural

zone observed in the regional magnetics, and interpreted from ductile structures to represent the edge of a dome.

Veins measured in the Black-Pic batholith area - west are typically located within tonalite and gabbro, and are not a significant structural feature. Veins are typically less than 3 centimetres wide, exhibit extensional textures, and are filled with either quartz, or quartz-feldspar-biotite (i.e., granitic veins). Veins are generally northwest- and northeast-trending and steep-dipping (SRK, 2017b).

Numerous brittle lineaments were interpreted throughout the Black-Pic batholith area - west (Figure 5.21). Field observations confirm the presence of two broad brittle deformation zones: the north-trending domain adjacent to Barehead Lake, and the northeast-trending domain bisecting Agonzon Lake and the northern portion of the Black River. Field observations also confirm the presence of multiple other discrete brittle lineaments (Figure 5.21).

Field observations along the central western border of the withdrawal area, adjacent to Barehead Lake confirm the presence of a broad brittle deformation zone surrounding a north-trending lineament that lies outside the withdrawal area (Figure 5.21). The northern extension of this lineament corresponds to the Cadawaja fault (Figure 1.2) and offsets the stratigraphy on the southern edge of the Manitouwadge greenstone belt by 500 metres (Miles, 1998). Evidence for this deformation zone includes series of discrete brittle faults that form brittle deformation zones up to 10 metres wide (Figure5.22a). The preferred presence of sub-parallel foliated mafic dykes in this domain suggests it is a long-lived structural zone. Jointing is pervasive in this area and often closely spaced. Collectively, these structures were observed up to 2.3 kilometres east of the interpreted lineament.

The northeast-trending brittle domain through Agonzon Lake is approximately 3 kilometres wide, is characterized in the lineament analysis by several continuous linear northeast-trending brittle lineaments (Figure 5.21). The lineament that trends along the northern portion of the Black River (west of Agonzon Lake; Figure 5.21) is characterized in the field by a progression from widely jointed and mildly hematite-stained gneissic tonalite on the fringes of the fault to a brittle-ductile strongly hematized fault rock at the core of the structure in a zone up to 10 metres wide (Figure 5.22b). Discrete brittle faults are present beyond the core of the brittle-ductile deformation zone. Discrete brittle faults are also present throughout the entire northeast-trending corridor and typically form narrow discrete surfaces, scarps, and cliff faces. These brittle faults are also coincident with multiple northeast-trending lineaments within this broad brittle deformation zone (Figure 5.21)

Several other brittle lineaments interpreted in the Black-Pic batholith area - west were confirmed and characterized during the field investigations, as show on Figure 5.21.

5.3.4 Black-Pic Batholith Area - East

Ductile structures were observed throughout the Black-Pic batholith area - east, and include foliation and limited gneissosity, and shear zones. Brittle structures include joints, veins, and brittle faults (SRK, 2017b).

Foliation and gneissosity in the Black-Pic batholith area - east are dominantly recorded within tonalite and granodiorite, and locally also within granite and diorite intrusions (SRK, 2017b). Foliation is typically weak to moderate, and gneissosity was only observed in a single station in what was interpreted to be xenolithic panels of gneiss. In general, ductile structures are much weaker in Black-Pic batholith area - east relative to Black-Pic batholith area - west. Foliation is dominated by sub-horizontal to shallow-dipping measurements suggesting that the area is largely at a structural dome or series of domes. Three shear zones were measured in tonalite in the central northern portion of the Black-Pic batholith area - east, all at the same outcrop. All the observed shear zones were less than 10 centimetres wide.

Brittle structures observed in the Black-Pic batholith area - east include extensive joints, brittle faults, and rare veins. Joints measured in the Black-Pic batholith area - east trend predominantly in one of six orientations, including a shallow-dipping set (SRK, 2017b). Steep sets generally trend northwest, north-northeast and northeast. Joints with 30- to 100-centimetre spacing are the most common overall in the Black-Pic batholith area - east, which is comparable to the average joint spacing in the Black-Pic batholith area - west. As in all other withdrawal areas, the spacing of joint sets parallel to and in the immediate vicinity of high certainty lineaments identified in the Phase 2 lineament analysis (SRK, 2017a) is tighter than away from such lineaments. Most joints throughout the Black-Pic batholith area - east do not contain fill, however a significant number contain secondary minerals as joint fill, including significant hematite staining, considerable epidote fill, and minor quartz and chlorite.

Brittle faults observed in the Black-Pic batholith area - east are dominantly recorded within the tonalite to granodiorite, but also within granite, and felsic and mafic dykes (SRK, 2017b). The majority of measured brittle faults occur as discrete millimetre- to centimetre-wide slip surfaces. However, in various other instances, multiple close-spaced consecutive discrete slip surfaces are present, forming brittle fault zones up to 10 metres wide, and often manifested as a series of scarps and sub-parallel joints, and incised valleys. Brittle faults dip moderately to sub-vertical, and occur in multiple orientations. Significant brittle faults (those greater than 10 centimetres wide) are often located adjacent to northwest-trending Matachewan dykes. In particular, the most significant of these faults (those greater than 1 metre wide) is located adjacent and oriented sub-parallel to clusters of tight-spaced Matachewan dykes. Offsets along brittle faults were observed in only limited instances, and are typically minor (less than 10 centimetres). Although most faults do not contain fill, a significant number brittle faults have associated alteration.

Only two veins were measured in the Black-Pic batholith area - east (SRK, 2017b). They are located in the southeast portion of the withdrawal area within tonalite, and are not a significant structural feature throughout the mapping area. Observed veins were typically less than 3 centimetres wide, steep-dipping, and are filled with quartz.

Numerous brittle lineaments are interpreted throughout the Black-Pic batholith area - east, as shown in Figure 5.16. Field observations provide evidence for a north-trending brittle lineament coincident with Longnega Lake, multiple northwest-oriented brittle lineaments, as well as two northeast-trending lineaments (Figures 5.23 and 5.24).

Field evidence for the north-trending brittle lineament along Longnega Lake includes sub-parallel discrete brittle faults, locally forming a series of scarps up to 5 metres wide within tonalite and granodiorite. Brittle faults sub-parallel to the lineament dip steeply to the east and west, and the spacing of joints sub-parallel to the lineament is relatively narrow (30 to 100 centimetres). Brittle structures adjacent to this lineament contain limited hematite.

Multiple northwest-trending brittle lineaments interpreted in the Black-Pic batholith area - east were verified during the field mapping. These lineaments are typically located adjacent to, or within clusters of northwest-trending Matachewan dykes (Figure 5.23). Evidence for these includes observed brittle faults with associated altered and tight-spaced joint sets.

Field evidence for two northeast- to east-northeast-trending lineaments or extensions of identified lineaments in the central and west-central parts of the withdrawal area includes discrete faults, domains of tight joint spacing and/or topographic scarps parallel to and adjacent to the interpreted lineaments.

5.4 Mafic Dykes in the Manitouwadge Area

Several diabase dyke swarms crosscut the Manitouwadge area (AECOM, 2014), including:

- Northwest-trending Matachewan dykes (circa 2.473 Ga; Buchan and Ernst, 2004). This dyke swarm is one of the largest in the Canadian Shield. Individual dykes are generally up to 10 metres wide, and have vertical to subvertical dips. The Matachewan dykes comprise mainly quartz-diabase dominated by plagioclase, augite, and quartz (Osmani, 1991) and are commonly porphyritic.
- North-trending Marathon dykes (circa 2.121 Ga; Buchan et al., 1996; Hamilton et al., 2002). These form a fan-shaped distribution pattern around the northern, eastern, and western flanks of Lake Superior. The Marathon dykes comprise quartz-diabase (Osmani, 1991) dominated by equigranular to subophitic clinopyroxene and plagioclase.
- Northeast-trending Biscotasing dykes (circa 2.167 Ga; Hamilton et al., 2002). Locally, Marathon dykes also trend northeast and cannot be separated with confidence from the Biscotasing suite dykes. On occasion, Biscotasing dykes appear to deflect at intersections with Matachewan-aged dykes. These deflections are thought to be due to a rheological contrast between the Matachewan-aged dykes and the surrounding country rock.

The lineament analysis of the Manitouwadge area (SRK, 2017a) identified three distinct dyke populations corresponding, based on orientation, to the three dyke swarms described above: Matachewan, Marathon and Biscotasing. Dyke lineaments may locally truncate and offset, and may be truncated and offset by all possible orientations of brittle lineaments. Similarly, Phase 2 Geological Mapping in the Manitouwadge area recorded three generations of Proterozoic mafic dykes based on their trend direction (SRK, 2017b). Field observations provided insight into the characteristics of these mafic dykes, which are summarized below.

Matachewan and Marathon dykes were observed throughout the Manitouwadge area, while only a limited number of Biscotasing dykes were encountered. Marathon dykes have also been documented to locally trend northeast, in which case they cannot be differentiated from Biscotasing dykes. Considering this, all northeast-trending dykes were interpreted as Biscotasing.

In general, the high-resolution aeromagnetic data (SGL, 2017) effectively identifies the presence of dykes of all three swarms in the Quetico, Black-Pic batholith - west, and Black-Pic batholith - east areas. Within the Fourbay Lake pluton only one dyke lineament was identified (Figure 5.10); it is possible that the lack of magnetic contrast between the strongly magnetic dykes and the strongly magnetic bedrock in the Fourbay Lake pluton does not facilitate the interpretation of dyke lineaments. A number of dyke lineaments interpreted from the aeromagnetic data in the four potentially suitable areas were verified in the field (Figures 5.17, 5.19, 5.21, 5.23), often at different locations along the lineament. In contrast, narrow dykes usually less than 1 metre thick were mapped in the field that are not identifiable from the aeromagnetic data. West and Ernst (1991) suggested that narrow dykes may produce anomalies of insufficient magnetic intensity to be traced with any confidence. Where contacts of Matachewan dykes were observed in the field, they were commonly displaced up to 60 metres to the southwest from the associated aeromagnetic anomalies.

Dykes observed in the field typically exhibit an equigranular texture characterized by a very fine to medium grained groundmass and are composed of dominantly mafic minerals. In coarse-grained dykes, the margins of the dyke are typically fine-grained and the core of the dyke is coarse-grained.

Dykes exhibit a consistent brown to green weathered colour, a dark green to dark grey fresh colour, and have high rock hardness (SRK, 2017b).

Contacts on both edges of dykes were rarely observed in the field, and so in most cases only a minimum dyke width could be measured. Width of Matachewan dykes varies from less than 1 metre up to 36.9 metres, with most of the dykes being thicker than 20 metres. Overall, Marathon dykes showed a broad range of measured widths, with observed widths in the field varying from less than a metre to up 19 metres. The majority of the widths of Biscotasing dykes observed in the field were in the 40- to 80-metre range.

Matachewan dykes occur as individual features, and also as series of close-spaced, sub-parallel dykes. Clusters of Matachewan dykes are most common in the Black-Pic batholith area - east. Marathon dykes typically occur as parallel sets of one to three, north- to north-northeast-trending dykes, and locally are segmented and step to the left and right. This phenomenon is typically attributed to intrusive offsets during dyke emplacement and not to fault offsets.

Contacts of all three dyke suites that were observed in the field are consistently steep-dipping and characterized by chilled margins that transition into fine-grained crystalline texture moving into the dyke away from the margins for up to 30 centimetres. While dykes and dyke contacts were observed to be linear on a regional scale, they often exhibit minor variability on the outcrop scale, including narrow dyke splays, step-overs, and interfingering of dyke segments.

Jointing was observed in the field associated with dykes of all three suites. In many cases, limited bedrock exposure inhibits the very detailed observations required to assess variability in joints and joint spacing within dykes, along the dyke contacts and within the surrounding rock. However, a few remarks can be made from field observations. Jointing within the dykes is generally pervasive, with joints sets oriented sub-parallel and at high angles to the trend of dykes. Joint spacing within the dyke generally decreases towards the contact. In most instances, no increased jointing in the host rock was observed directly adjacent to the dyke contact, and only in some instances joints were more closely spaced in the host rock up to 1 metre from the dyke contact. Beyond this distance, joint spacing in the host rock reflects the joint spacing characteristic of the regional structural domain in which the station resides. Joints within dykes are dominantly clean and exhibit minimal fill or alteration. Observations of the distribution of alteration minerals adjacent to and away from the dykes suggest that dykes locally, but not always, acted as conduits for later fluids, and that the evaluation of a dyke as a conduit for fluid must be undertaken on a case by case basis.

Multiple brittle faults are located proximal to, and along dykes, including brittle faults crosscutting dykes at high angles, low angles, and brittle faults located parallel and along or adjacent to dykes (SRK, 2017b). In general, the brittle faults associated with the Biscotasing dykes are fewer and less significant than brittle faults associated with the Matachewan and Marathon dykes. Brittle faults measured at a high angle to the dykes are also visible in the high-resolution aeromagnetic data, typically as magnetic lows that demagnetise and offset segments of the dykes (SRK, 2017a). These observations indicate that the brittle faults postdate emplacement of the dykes. Brittle faults located adjacent and oriented at low angles and sub-parallel to dykes were also observed, with relatively few brittle faults observed directly along dyke contacts or within dykes. Most of the contacts of field-verified dykes are intact and show no evidence of faulting. Brittle structures adjacent and subparallel to the dykes represent discrete brittle structures, and indicate that brittle structures exploited and were developed adjacent to pre-existing dykes.

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 bedrock exposure in the Manitouwadge area from the predicted outcrop exercise is shown on Figure 4.7, and Figure 4.6 and shows the distribution of previously mapped overburden deposits.

The Quetico area is located in an area previously mapped as bedrock terrain with considerable surficial cover (Figure 4.6; AECOM, 2014) and generally low relief. Previously mapped surficial cover consists of large areas of northeast-trending morainal terrain, and limited areas of organic terrain. Remotely predicted outcrops for the Quetico area were identified dominantly in the west and southwest parts of the withdrawal area, and typically occur as clusters of outcrops in areas of previous logging (SRK, 2017b). Field investigations confirm that predicted outcrops in the western portion of the area are typically exposed bedrock. In the eastern portion of the withdrawal area, predicted outcrops were confirmed to be either small outcrops of limited value (e.g., poor to moderate exposure, flat lying with a lack of relief, covered with a veneer of overburden) or overburden. Areas of overburden are characterized by extensive thick cover (minimum thickness greater than 1 metre).

The Fourbay Lake pluton area was previously mapped as comprising mostly bedrock terrain with very limited surficial cover (Figure 4.6). Remotely predicted outcrops in this area are evenly spaced and identified as a series of elongated northeast-trending clusters of relatively small outcrops, typically located along elevated ridges, and isolated outcrops located along previously excavated trails and the hydro corridor. Geological mapping confirmed that the best outcrop exposures occur as series of large scarps and rock faces along northeast-trending topographic ridges. Away from ridges, limited isolated outcrops were observed to occur in dense bush. Although previous surficial mapping (Figure 4.6) suggests a high exposure of bedrock, Phase 2 geological mapping confirmed that areas of no predicted outcrop are indeed characterized by extensive thick overburden (generally more than 1 metre in thickness). These areas of surficial cover were often observed to occur in broad northeast-oriented valleys.

The Black-Pic batholith area - west was previously mapped as bedrock terrain with limited surficial cover, which was restricted to a relatively narrow and linear northeast-trending zone of alluvial terrain, following the southern portion of the Black River and a northern tributary (Figure 4.6). Remotely predicted outcrops were identified throughout the Black-Pic batholith area - west, and typically occur as large northeast oriented zones of predicted bedrock and clusters of smaller, multiple, northeast oriented outcrops (SRK, 2017b). Fewer predicted outcrops were identified in the northeast-oriented zone previously mapped as overburden. Field investigations confirm that predicted outcrop in areas previously mapped as bedrock terrain were consistently exposed bedrock. Within the northeast-trending zone previously mapped as overburden, many remotely predicted outcrops were identified as overburden that are typically covered by light coloured moss (SRK, 2017b). Areas of overburden are characterized by extensive thick cover (minimum thickness greater than 1 metre).

The Black-Pic batholith area - east is located in an area previously mapped as bedrock terrain with surficial cover restricted to a zone of north- and northeast-trending glaciofluvial terrain along the eastern margin and in the southeast portion of the area, and isolated zones of organic and glaciofluvial terrain throughout the remainder of the area. Remotely predicted outcrops were identified throughout the Black-Pic batholith area - east, and typically occur as clusters of relatively small predicted outcrops extending in northwest, north, and northeast orientations. Limited predicted outcrops were identified in the areas previously mapped as overburden. Field investigations confirm that predicted outcrops in areas previously mapped as bedrock terrain are consistently exposed bedrock. The best exposures occurred along or adjacent to north- and northeast-trending physiographic features (lakes, ridges, valleys) and are particularly well-exposed in areas of recent logging (SRK, 2017b). Some of the predicted outcrops were identified during mapping as overburden, typically in or near areas previously mapped as glaciofluvial terrain. Areas of overburden are characterized by extensive thick cover (minimum thickness greater than 1 metre), that can be significantly thicker (greater than 10 metres) along eskers and where exposed in gravel pits.

5.6 Protected Areas

All provincial parks, conservation reserves and provincial nature reserves in the Manitouwadge area were excluded from consideration (AECOM, 2014). The two protected areas in the Manitouwadge area are the Isko Dewabo Lake Complex Conservation Reserve that straddles the southern boundary of the Manitouwadge area west of Highway 614 (29.67 square kilometres), and the North Thornhen Lake Moraine Conservation Reserve (4.54 square kilometres) located northeast of Hillsport (Figure 1.1). The northern edge of the Isko Dewabo Lake Complex Conservation Reserve was covered by the Phase 2 high resolution geophysical survey, but both protected areas lie entirely outside the four withdrawal areas under consideration for the Phase 2 geological mapping.

5.7 Natural Resources

Mineral exploration is active in the Manitouwadge area on the patented ground and numerous active mining claims held by prospectors and mining companies (MNDM, 2017). A large number of mining claims occur over the Manitouwadge greenstone belt, north and east of the patented/leased ground; smaller numbers of claims are located north and northeast of the boundary of the Township of Manitouwadge. 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 (AECOM, 2014). In addition to the information gathered during the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014), the newly acquired Phase 2 geophysical data (SGL, 2017) was used to identify geophysical anomalies that may be indicative of rock units that have mineral potential.

An area in the southwest part of the Black-Pic batholith area - west was identified as a magnetic anomaly (SGL, 2017; Figure 5.3) and was characterized by geological mapping as a panel of strongly foliated to gneissic mafic rocks, interpreted as the remnant keel of a greenstone belt deformed between two gneissic tonalite domes (SRK, 2017b). The small size and high metamorphic grade suggest limited mineral potential for this domain.

In addition to the information gathered during the Phase 1 Geotechnical Desktop Preliminary Assessment (AECOM, 2014), the mineral resources and claim maps were updated as part of the Phase 2 initial geoscientific field studies (Figure 5.25). There are two small mineral claims in the Quetico area, and seven claims in the Black-Pic batholith area - west (including three related to the Manitouwadge airport, and one representing a ballast pit along the now abandoned railway south of Manitouwadge). There are no mineral claims in the Fourbay Lake pluton area or the Black-Pic batholith area - east. At this stage of the assessment, areas of active mining claims located in geologic environments judged to have low mineral resource potential were not systematically excluded from consideration as candidate areas for detailed mapping.

5.8 Potential Surface Constraints

Areas of obvious topographic constraints (high density of steep slopes), large water bodies (wetlands, lakes), and areas of poor accessibility have been documented (AECOM, 2014; SRK, 2017a; SRK, 2017b). While areas with such constraints were not explicitly excluded from consideration, they are identified as potential surface constraints that would need to be considered when planning future field studies.

In general, the lakes in the Manitouwadge area have a surface area of less than 1.0 square kilometre (AECOM, 2014). Two of the larger water bodies (greater than 1.5 square kilometres) in the Manitouwadge area are the Macutagon and Agonzon lakes (Figure 1.2). In general, the topography of all withdrawal areas is moderately rugged with the exception of the western half of the Quetico area and the southern portion of the Black River valley directly south of the Township of Manitouwadge, which are dominated by overburden and have subdued topography. Particularly rugged relief and significant scarps are present along northeast and northwest trends in the Fourbay Lake pluton area and within the Black-Pic batholith area - west, southwest of Agonzon Lake (Figure 4.3).

Phase 2 geological mapping documented that access and surface constraints vary across the Manitouwadge withdrawal areas (SRK, 2017b). At the time, the Quetico area could be accessed via a network of logging roads originating from the Caramat industrial road (Figure 5.1). In preparation for renewed logging operations, two east-west roads (Harkness and Bishop Lake roads) were being rebuilt and upgraded in the central and south parts of the Quetico area during the Phase 2 geological mapping (SRK, 2017b). A series of older secondary single track mud and gravel logging roads (passable by 4x4 truck or ATV) originating from the Caramat industrial road provided partial access to the perimeter of the area. Locally, the secondary logging roads were obstructed by beaver dams and deteriorated into overgrown trails, limiting access. Tertiary logging roads were typically overgrown, not passable by ATV, and required foot traverses. Additional foot access to the Quetico area was provided by a rail corridor in the northeastern portion of the block. At the time of the 2016 field work, the central portion of the block was accessible only by helicopter (SRK, 2017b).

The Fourbay Lake pluton area could be accessed via a network of logging roads and trails originating from two secondary roads (Figure 5.2). Gaffhook Lake road, a maintained single track gravel road originating from the Caramat industrial road approximately 7 kilometres west of the Township of Manitouwadge, provided access to the northwestern portion of the area via a series of linked trails. The Barehead road provided access to a series of trails and an electric power transmission line and allowed crossing from northwest to southeast across the central-eastern portion of the area. The secondary and tertiary roads, in conjunction with foot traverses provided access to the majority of the area for the Phase 2 geological mapping, and no boat or helicopter access was required (SRK, 2017b).

The Black-Pic batholith area - west could be accessed from primary and secondary roads, and from a network of logging roads and trails originating from these roads (Figure 5.3). Highway 614 passes through the northwestern portion of the area before arriving at the Township of Manitouwadge. A series of tertiary roads originating from Highway 614 provided access to western portion of the area, including to boat access points on Agonzon Lake and the northern portion of the Black River. The west-trending Camp 70 road connects to the Twist Lake road, and these roads provided access to the southwest-trending Camp 60, Agonzon Lake, and Lampson Lake roads that traverse most of the Black-Pic batholith area - west. Collectively, for the Phase 2 geological mapping, the road and trail network, boat access along Agonzon Lake and the Black River, and foot traverses, provided access to most of the area. Helicopter support was required to efficiently access the south-central portions of the Black-Pic batholith area - west (SRK, 2017b).

The Black-Pic batholith area - east could be accessed from a network of primary, secondary and tertiary logging roads and trails (Figure 5.4). A single north-south primary double track gravel road (the 400 logging road) bisects the area from north to south and at the time, provides access to multiple secondary and tertiary roads. Numerous single track gravel and mud secondary and tertiary logging roads and trails originate from this road and additional logging roads were continually being built throughout the Phase 2 geological mapping campaign (SRK, 2017b). Trails in the area comprise abandoned logging roads that were partly traversable by ATV during mapping. Collectively, the secondary road network provided access to the north-central and northeastern portions of the mapping area. The 400 logging road provided limited access to the southeast portion of the area. The remainder of the area was only accessible by helicopter and extensive foot traverses (SRK, 2017b).

6 General Potential Repository Areas in the Manitouwadge Area

This section describes how the key geoscientific characteristics and constraints presented in Section 5 were applied to further assess the suitability of the Manitouwadge area. The ovals presented in Figures 6.1 to 6.21 represent general Potential Repository Areas (PRAs), which are general areas that encompass geoscientific potentially suitable areas. The boundaries of these general PRAs are simplified 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 key geoscientific characteristics, and the following general approach:

- **Bedrock Geology:** Areas with the most favourable geological setting in terms of lithology and lithological homogeneity were identified, 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:** The location and extent of the areas were refined 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:** Lineament characteristics were used 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., certainties 3 and 2, respectively). Interpreted unclassified lineaments were not considered in the lineament density calculations, but in certain occasions were used to help define general PRAs (i.e., coincident with geophysical anomalies). Based on the Phase 2 Geological Mapping data, most of the unclassified lineaments were thought to represent the fabric of the rock with no evidence of pervasive brittle deformation. 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 most of the general PRAs, high and medium certainty lineaments (brittle and dyke) were present. Where faults were mapped sub-parallel to lineaments within the general PRAs, they were discrete narrow structures (i.e., generally less than 30 centimetres wide). Similarly, field observations on mafic dykes showed that damage to the host rock was limited to tighter joint spacing adjacent to the dyke contacts. At this point, field data does not provide conclusive 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 Geoscientific Desktop Preliminary Assessment were all outside of protected areas such as provincial parks, conservation reserves and provincial nature reserves (AECOM, 2014).
- **Natural Resources:** In addition to the information gathered during the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 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 Phase 2 Geoscientific Preliminary 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 were identified as potential constraints that would need to be considered in the selection of a repository site. Accessibility was documented during geological mapping (SRK, 2017b.).

The iterative consideration of the above key geoscientific characteristics, together with the geoscientific site evaluation factors, identified several general PRAs in the Manitouwadge area. The general PRAs are in the four general potentially suitable areas identified earlier in the Phase 1 Geoscientific Desktop Preliminary Assessment, within and in the vicinity of the withdrawal areas.

6.1 Approach for Identifying General 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, 2017a.), and geological mapping (SRK, 2017b.).

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

- 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.
- 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.
- 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). Interpreted unclassified lineaments were not considered in the lineament density calculations, but in certain locations were used to help define general PRAs (i.e., coincident with geophysical anomalies). Based on geological mapping, data most of the unclassified lineaments are thought to represent either the ductile foliation/gneissosity of the rock or ductile to brittle-ductile shear zones, with little evidence of pervasive brittle deformation.

- Areas of higher integrated lineament density, which often correspond to bands of tight-spaced dyke lineaments, were avoided. General PRAs were defined to capture areas of lower integrated lineament density.
- Within most 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 1 centimetre wide), but could form fault domains up to several metres 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 (SRK, 2017b). At this point, field data does 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, are 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 (SRK, 2017b).

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 18 general PRAs were identified within the Quetico, the Fourbay pluton, and the Black-Pic batholith areas, within the Manitouwadge area. These general PRAs are shown on Figure 6.1 (with bedrock geology) and are labelled as follows:

- Quetico area: A, B, C, D, and E.
- Fourbay Lake pluton area: F, G, H, and I.
- Black-Pic batholith area - west: J, K, L, M, N, and O.
- Black-Pic batholith area - east: P, Q, and R.

Identified general PRAs in the Quetico area, the Fourbay Lake pluton area, and the Black-Pic batholith areas were generally defined to capture areas of lower density of integrated lineaments, with more favourable lithological and structural characteristics. Bands of tight-spaced dyke lineaments were considered less favourable given the lithological and structural complexity added by the high density of dykes. Similarly, areas interpreted as potentially lithologically and structurally more complex (e.g., greenstone slivers, fault corridors) were also considered less preferred. Within the Quetico area, lithology is characterized by a heterogeneous mix of metasedimentary migmatites and intrusive units, the distribution of which is difficult to predict. Based on field mapping, this complexity exists pervasively throughout all the general PRAs in the Manitouwadge area.

Within most of the general PRAs, there are high and medium certainty lineaments interpreted. At this point, field data does 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.

6.2.1 Quetico Area

Five general PRAs were identified in the Quetico area (Figure 6.2; A, B, C, D, and E). The degree of bedrock exposure is fairly high in the general PRA E and portions of C and D; outcrops encountered in the field are relatively large and predicted outcrops relatively evenly distributed in these general PRAs and their immediate vicinity. The ability to characterize the bedrock in the field in these general PRAs was, however, limited by access constraints. Overburden cover in the other two general PRAs in the Quetico area is extensive, with limited predicted outcrop interpreted and small outcrop locations observed in the field (Figure 6.3).

General PRAs defined in the Quetico area comprise areas of lower density of high and medium certainty integrated lineaments, which are interpreted to be areas with more favourable structural characteristics. Outside of the general PRAs the density of integrated lineaments is higher, mostly due to the intersection of northwest- and northeast-trending dyke lineaments with brittle lineaments of different orientations. It is worth noting that in the Quetico area only a few high and medium certainty magnetic brittle lineaments were interpreted in the withdrawal area. This is most likely due to the low magnetic susceptibility of the metasedimentary bedrock in the area. The distribution and density of magnetic unclassified lineaments (SRK, 2017a.) was not considered a key factor in defining general PRAs; based on field mapping data, the unclassified lineaments interpreted in the Quetico area are thought to represent the ductile fabric and ductile deformation of the bedrock, which is pervasive in the entire withdrawal area and vicinity and not a distinguishing geoscientific factor.

Bedrock lithology was also not considered a key differentiating factor to define general PRAs in the Quetico area. Bedrock throughout this area was mapped as a heterogeneous mix of metasedimentary migmatites and intrusive units including granite, granodiorite, and tonalite (Figures 6.4 and 6.5). The distribution of these different lithological units is random and difficult to predict. In addition, the metasedimentary migmatites comprise two different lithological components: a metasedimentary protolith (i.e., paleosome) and a granitic component derived from the partial melting of the protolith (i.e., neosome). The degree of partial melting of the metasedimentary migmatites is variable throughout the area. This heterogeneous lithological character of the bedrock is found in all five general PRAs identified. Interpretation of geophysical data (SGL, 2017.) identified a large magnetic anomaly in the southeastern portion of the withdrawal area, underlying general PRAs B and C. This anomaly was interpreted as potentially representing an area with some degree of heterogeneity or deformation, and its western border was preliminarily interpreted by SRK (2017a.) as a dyke lineament based on magnetic data. Subsequent geological mapping (SRK, 2017b.) identified this western boundary of the anomaly as a granitic body with a high content of magnetite that shallowly dips to the east-southeast. At this stage, it is uncertain what this large magnetic anomaly may represent in the subsurface.

A few high and medium certainty lineaments were interpreted within the general PRAs in the Quetico area, including both dyke and brittle lineaments. Field observations on mafic dykes show that damage to the host rock is limited to tighter joint spacing adjacent to the dyke contacts. Bedrock evidence of brittle lineaments was only recorded at one outcrop location in this area; this evidence included a five-metre wide zone of multiple, narrow (i.e., less than 1 centimetre) discrete brittle faults sub-parallel to and mapped adjacent to the lineament. At this point, field data does 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.

Faults and shear zones are recorded mostly on the western and southern portions of the withdrawal area (Figure 6.6). Ductile shear zones are mapped as small-scale structures, usually less than 10 centimetres wide and characterized by strong to intense foliation. Faults recorded are characterized as discrete slip surfaces typically less than 5 centimetres wide, with minor offsets, which in places form wider domains of increased faulting. Joints were recorded across the entire withdrawal area, with spacing commonly larger than 1 metre. Joints trend in several orientations, including an east-west strike subparallel to the main foliation and the unclassified lineaments interpreted in the area. The east-trending joint set has a relatively large subset of measurements with tighter spacing than the overall average in the Quetico area.

All the dykes mapped in Quetico area show good correlation with interpreted dyke lineaments. As opposed to the other withdrawal areas in the Manitouwadge area, the mapped dykes are all coincident with dyke lineaments interpreted from the magnetic data.

There is no direct subsurface information currently available for the five general PRAs identified in the Quetico area and there is uncertainty on the structural and lithological character of the bedrock at depth. Additional uncertainties associated with these five general PRAs include: the heterogeneous and difficult to predict lithological character of the bedrock; the effect that the low magnetic susceptibility of the bedrock may have on the ability to interpret brittle magnetic lineaments; and the potential brittle parting of the pervasive ductile fabric observed throughout the Quetico area. Also, it is unknown at this time what the magnetic anomaly identified under general PRAs B and C may represent at depth.

6.2.2 Fourbay Lake Pluton Area

Four general PRAs were identified in the Fourbay Lake pluton area (Figure 6.7; F, G, H, and I). Bedrock exposure is fairly good throughout the entire withdrawal area, with outcrop mapping stations and predicted outcrops relatively evenly distributed (Figures 4.7 and 6.8). Phase 2 geological mapping in general PRA I was only carried out in the northern portion and therefore there is no information (i.e., mapping stations or predicted outcrops) on bedrock exposure for most of this general PRA. Based on available Quaternary mapping and field information elsewhere in the Fourbay Lake pluton area, however, bedrock exposure is expected to be good for the entire general PRA I.

Overall, the density of integrated lineaments in the Fourbay Lake pluton area is relatively low, as shown in Figures 5.10 and 6.7. General PRAs are identified in a cluster that occupies most of the withdrawal area. The four general PRAs have similar geophysical, lithological, and structural characteristics and therefore it is challenging at this stage to further narrow down the extent or the number of general PRAs based on available geoscientific information, particularly in the absence of subsurface information.

Most of the general PRAs in the Fourbay Lake pluton area include medium and high certainty dyke and brittle lineaments. Field evidence was recorded for many brittle lineaments, which included small-scale brittle faults sub-parallel to the lineament, increased spacing of lineament-parallel joints, hematite staining, and coincident linear topographic features. 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 does 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.

The Fourbay Lake pluton area is lithologically fairly homogeneous, with bedrock mapped mainly as diorite to granodiorite with very few minor lithological units observed (Figures 6.9 and 6.10). Diorite is mapped in a cluster in the northern half of the withdrawal area, while granodiorite is observed elsewhere in the Fourbay Lake pluton area. These observations may indicate the presence of different compositional phases of the pluton, but the contact between the two is gradational. While two main lithological domains are identified, the lithological differences observed were not considered a key differentiating geoscientific factor to define general PRAs.

Faults and shear zones in the Fourbay Lake pluton area, shown on Figure 6.11, were mapped in clusters often in the vicinity of and sub-parallel to long northwest- and northeast-trending brittle lineaments. These faults and shear zones were characterized as discrete minor structures: the only two mapped shear zones were less than 2 centimetres wide and characterized by strong foliation, while mapped faults occur mostly as discrete millimetre- to centimetre-wide surfaces, with typically minor offsets (less than 10 centimetres).

The only dyke lineament interpreted from magnetic data in the Fourbay Lake pluton area could not be observed in the field. However, three examples of mafic dykes up to 6 metres thick were mapped which had not been identified as dyke lineaments from the high-resolution magnetic data (Figure 6.11). It is possible that additional dykes with narrow widths are present, but are not detectable using airborne magnetic data.

Given that no direct subsurface information is currently available for the general PRAs in the Fourbay Lake pluton area, there is uncertainty on the structural and lithological character of the bedrock at depth. Other uncertainties that would need to be further assessed for these four general PRAs include: the significance of some of the internal interpreted lineaments for which evidence was recorded in the field; and, the thickness of the intrusion which was interpreted by SGL (2017) to be less than 500 metres.

6.2.3 Black-Pic Batholith Area - West

Figure 6.12 shows the six general PRAs identified in the Black-Pic batholith area - west (J, K, L, M, N, and O). Overall bedrock exposure is fairly good in the six general PRAs identified, with relatively large outcrops predicted and mapping bedrock stations generally evenly distributed throughout the areas. One exception to this is general PRA N, where overburden and more restricted access limit the ability to characterize the bedrock in the field (Figures 4.6, 4.7 and 6.13).

The assessment of geoscientific data in the Black-Pic batholith area - west identified several areas considered less preferable from a suitability perspective, including areas of higher integrated lineament density. Increased lineament density in the Black-Pic batholith area - west tends to coincide with the intersection of brittle and dyke lineaments trending in different orientations, and to a certain extent with major fault domains identified from geological mapping data (Section 5.3.3; SRK 2017b). One of these is a north-trending domain immediately west of general PRAs J and O, where brittle faults were mapped in association with a major north-trending fault. This fault offsets the Manitouwadge greenstone belt north of the withdrawal area. Another domain is a northeast-trending structural zone that runs west of general PRAs K to N from the southwestern portion of the withdrawal area. In this zone, brittle faults were mapped associated with a ductile high strain zone and a mapped major brittle-ductile shear zone. The area east of general PRAs M and N and south of general PRA L was also considered less preferable, given its potential for increased structural and lithological complexity. The interpretation of geophysical data (SGL, 2017) in this area identified a magnetic anomaly thought to represent the northwards extension of the greenstone belt mapped immediately south of the withdrawal area. This interpretation is supported by the orientation of foliation measured in the field, and by the distribution and geometry of interpreted unclassified lineaments (SRK, 2017a.).

In comparison, the six general PRAs within the Black-Pic batholith area - west were defined to encompass areas with more favourable structural characteristics, where the density of high and medium certainty integrated lineaments is relatively low. Unclassified lineaments interpreted (SRK, 2017a.) were not considered a key factor in defining general PRAs; based on geological mapping data, unclassified lineaments in these areas are thought to represent the rock fabric with no evidence of pervasive brittle deformation.

Within the general PRAs in the Black-Pic batholith area - west, lineaments of high and medium certainty are interpreted. Field evidence of some of the brittle lineaments interpreted outside of the major fault corridors described above include discrete sub-parallel brittle faults and increased spacing of lineament-parallel joints. 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 does 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 Black-Pic batholith area - west is lithologically homogeneous, and mapped mostly as tonalite gneiss (Figure 6.14). Minor amounts of granite, granodiorite, and diorite are also mapped throughout the withdrawal area (Figure 6.15). Where overburden cover limits the ability to characterize the bedrock in the field, the uniform geophysical response in accordance with geological mapping data provides a rationale for expecting similar uniform lithology across all six general PRAs. The interpretation of geophysical data (SGL, 2017.) identified a number of point source anomalies within the general PRAs K and L; at this time it is unknown what these anomalies may represent.

Figure 6.16 shows the distribution of mapped faults and shear zones for the Black-Pic batholith area - west. As described earlier, the distribution of mapped faults in this withdrawal area allow for the interpretation of fault corridors. Mapped brittle faults mostly occur as single discrete millimetre- to centimetre-wide surfaces, and occasionally as multiple, close-spaced parallel discrete fault surfaces. Offsets are typically minor (i.e., less than 10 centimetres). Joints are mapped throughout the Black-Pic batholith area - west in multiple orientations, including a shallow-dipping joint set. Joints show overall a narrower average spacing (i.e., 30 to 100 centimetres) compared to other withdrawal areas in the Manitouwadge area, with a prevalence of narrow joint spacing (1 to 3 centimetres and 3 to10 centimetres) in the north-northwest-trending joint set sub-parallel to the deformation corridor observed west of general PRAs J and O. Interpretation of geophysical data in accordance with foliation measurements recorded during geological mapping suggest the presence of dome-like structures in the Black-Pic batholith area - west, with general PRAs M and N approximately located at the centre of one of these domes.

The majority of the mapped dykes were identified in the high-resolution aeromagnetic survey. However, some of the dykes observed in the field were relatively narrow (i.e., less than 1 metre) and did not coincide with interpreted dyke lineaments. It is possible that dykes with narrow widths are present, but are undetectable using airborne magnetic data.

Given the lack of subsurface information in the Black-Pic batholith area - west general PRAs there is uncertainty on the distribution fractures and the degree of lithological homogeneity at depth. Other uncertainties identified include the effect of extensive overburden in portions of the general PRAs on the identification of surficial lineaments, and the significance of point source magnetic anomalies in general PRAs K and L.

6.2.4 Black-Pic Batholith Area - East

Three general PRAs were identified in the Black-Pic batholith area - east (Figure 6.17; P, Q, and R). Bedrock exposure within the withdrawal area is generally good, with predicted outcrops and outcrop mapping stations evenly distributed (Figures 4.7 and 6.18). Within certain portions of the general PRAs (e.g., southern portion of R), however, the ability to characterize the bedrock in the field is limited by the presence of overburden and/or access constraints.

As shown in Figure 6.17, the density of integrated lineaments of high and medium certainty in the Black-Pic batholith area - east is relatively high, and general PRAs were defined where lower to moderate lineament density areas were observed. Although in some areas of the general PRAs (e.g., central portion of Q), the density of integrated lineaments is fairly high, field data indicates that lithological and structural characteristics of the bedrock in these general PRAs have some potential from a suitability perspective.

The Black-Pic batholith area - east is lithologically homogeneous. Bedrock was mostly mapped as tonalite and granodiorite, interpreted to be a single intrusive phase straddling the tonalite-granodiorite composition. Granodiorite is more commonly found in the centre of the withdrawal area, and tonalite in the eastern and western portions (Figure 6.19). Minor lithological units including diorite to granodiorite to granite intrusions, gabbroic dykes, and granitic dykes were mapped throughout the withdrawal area (Figure 6.20). Several faults were mapped in the Black-Pic batholith area - east, as shown in Figure 6.21. Many of them occur as discrete narrow (millimetre- to centimetre-wide) faults, with some characterized as multiple close-spaced discrete surfaces forming fault zones up to 10 metres wide. Offsets along faults are typically minor (less than 10 centimetres). Only a very few shear zones were mapped in the area, all of them less than 3 centimetres wide and recorded parallel to and located adjacent to an interpreted lineament.

There are lineaments of high and medium certainty interpreted within all three general PRAs in the Black-Pic batholith area - east. Field evidence of some of the interpreted brittle lineaments in the Black-Pic batholith area - east includes discrete generally narrow sub-parallel brittle faults, increased spacing of lineament-parallel joints and hematite staining to a certain degree. 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 does 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.

Most of the dykes in the Black-Pic batholith area - east were interpreted as dyke lineaments in the high-resolution magnetic data. However, a few mapped dykes were narrow and not interpreted from the magnetic data. It is possible that dykes with narrow widths are present, but are undetectable using airborne magnetic data.

There is no direct subsurface information currently available for the three general PRAs in the Black-Pic batholith area - east, and there is uncertainty on the structural and lithological character of the bedrock at depth. Other uncertainties that would need to be further assessed for these three general PRAs include: the significance of some of the internal interpreted lineaments for which evidence was recorded in the field; and, the effect of overburden extent on the interpretation of surficial lineaments.

7 Summary

Eighteen general Potential Repository Areas (PRAs) were identified in the Manitouwadge area. General PRAs 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 square kilometres or larger). The boundaries of the general PRAs are simplified 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 Black-Pic batholith, the Fourbay Lake pluton, and the Quetico withdrawal areas in the Manitouwadge area were generally defined to capture areas of lower density of integrated lineaments, with more favourable lithological and structural characteristics. Bands of tight-spaced dyke lineaments were considered less favourable given the lithological and structural complexity added by the high density of dykes. Similarly, areas interpreted as potentially being lithologically and structurally more complex (e.g., greenstone slivers, fault corridors) were also considered less preferable. Within the Quetico area, lithology is characterized by a heterogeneous mix of metasedimentary migmatites and intrusive units, the distribution of which is difficult to predict. Based on field mapping, this complexity exists pervasively throughout all the Quetico area general PRAs.

Most of the general PRAs include high and medium certainty lineaments. At this point, field data does not provide evidence that the lineaments interpreted within the 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.

Given the lack of subsurface information in the general PRAs identified in the Manitouwadge area, there is uncertainty as to the structural and lithological character of the bedrock at depth. Other uncertainties include the potential presence of narrow dykes not identifiable in aeromagnetic data and the thickness of the Fourbay Lake pluton. In the Quetico area, additional uncertainty relates to the heterogeneous and difficult to predict lithological character of the bedrock; the effect of the low magnetic susceptibility of the bedrock on the ability to interpret brittle magnetic lineaments; and the potential brittle parting of the pervasive ductile fabric observed throughout the area.

8 References

AECOM, 2014. Phase 1 Geoscientific Desktop Preliminary Assessment of Potential Suitability for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Township of Manitouwadge, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0075. 86p plus appendices and figures.

Beakhouse, G.P., 2001. Nature, timing and significance of intermediate to felsic intrusive rocks associated with the Hemlo greenstone belt and implications for the regional geological setting of the Hemlo gold deposit. Ontario Geological Survey, Open File Report 6020, 248p.

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

Buchan, K.L., Halls, H.C. and Mortensen, J.K. 1996. Paleomagnetism, U-Pb geochronology, and geochemistry of Marathon dykes, Superior Province, and comparison with the Fort Frances swarm. Canadian Journal of Earth Sciences, v. 33, p. 1583-1595.

Chown, E.H.M. 1957. The geology of the Wilroy property, Manitouwadge Lake, Ontario. MSc thesis, University of British Columbia.

Coates, M.E. 1967. Stevens sheet, Thunder Bay District; Ontario Department of Mines, Map 2141, scale 1:63,360 or 1 inch to 1 mile.

Geofirma (Geofirma Engineering Ltd.) 2013. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Township of Manitouwadge, Ontario. Prepared for Nuclear Waste Management Organization. 37p plus figures.

Giguere, J.F. 1972. Granitehill Lake area, Thunder Bay and Algoma districts. Ontario Department of Mines and Northern Affairs, Map 2219; scale 1:63 360 or 1 inch to 1 mile.

Hamilton, M.A., David, D.W., Buchan, K.L. and Halls H.C. 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.

Jackson, S.L., Beakhouse, G.P., and Davis, W.D. 1998. Regional Geological Setting of the Hemlo Gold Deposit; an Interim Progress Report. Ontario Geological Survey, Open File Report 5977.

Johns, G.W., and McIlraith, S. 2003. Precambrian geology compilation series – Hornepayne sheet. Ontario Geological Survey, Map 2668, scale 1:250,000.

Miles, W.F. 1998. An interpretation of high resolution aeromagnetic data over the Manitouwadge greenstone belt, Ontario, Canada. MSc Thesis, Ottawa-Carleton Geoscience Centre and University of Ottawa, Ottawa, Canada, 250p.

Milne, V.G., 1969. Progress report on a field study of the Manitouwadge area ore deposits [abs.]. Canadian Institute of Mining and Metallurgy. Annual Meeting, Montreal.

MNDM (Ministry of Northern Development and Mines). 2017. CLAIMaps Internet Application. https://www.mndm.gov.on.ca/en/mines-and-minerals/applications/claimaps

NWMO (Nuclear Waste Management Organization), 2010. Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel. Toronto, Canada. https://www.nwmo.ca/en/Site-selection/Steps-in-the-Process

NWMO (Nuclear Waste Management Organization), 2014. Preliminary Assessment for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel - The Corporation of the Township of Manitouwadge, Ontario - Findings from Phase One Studies. NWMO Report APM-REP-06144-0073. 146p.

OGS (Ontario Geological Survey). 2011. 1:250 000 scale bedrock geology of Ontario. Ontario Geological Survey, Miscellaneous Release---Data 126-Revision 1 (MRD126-REV1).

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

Percival, J.A. 1989. A regional perspective of the Quetico metasedimentary belt, Superior Province, Canada. Canadian Journal of Earth Sciences, v. 26, p. 677-693.

Peterson, V.L., and Zaleski, E. 1999. Structural history of the Manitouwadge greenstone belt and its volcanogenic Cu-Zn massive sulphide deposits, Wawa Subprovince, south-central Superior Province. Canadian Journal of Earth Sciences, v. 36, p. 605-625.

PGW (Paterson, Grant and Watson Ltd.). 2014. Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Geophysical Data, Township of Manitouwadge, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0077.

SGL (Sander Geophysics Ltd.). 2017. Phase 2 Geoscientific Preliminary Assessment, Acquisition, Processing and Interpretation of High-Resolution Airborne Geophysical Data, Township of Manitouwadge and Area, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-01332-0213

SRK (SRK Consulting (Canada) Inc.). 2014. Phase 1 Geoscientific Desktop Preliminary Assessment, Lineament Interpretation, Township of Manitouwadge, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0078.

SRK (SRK Consulting (Canada) Inc.). 2017a. Phase 2 Geoscientific Preliminary Assessment, Lineament Interpretation, Township of Manitouwadge and Area, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-01332-0214

SRK (SRK Consulting (Canada) Inc.). 2017b. Phase 2 Geoscientific Preliminary Assessment, Geological Mapping, Township of Manitouwadge and Area, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-01332-0215

Sutcliffe, R.H. 1991. Proterozoic geology of the Lake Superior area. *In* Geology of Ontario. Ontario Geological Survey, Special Volume 4, Part 1, p. 627-658.

Williams, H.R. 1989. Geological studies in the Wabigoon, Quetico and Abitibi-Wawa subprovinces, Superior Province of Ontario, with emphasis on the structural development of the Beardmore-Geraldton Belt. Ontario Geological Survey, Open File Report 5724, 189p.

Williams, H.R. 1991. The Quetico Subprovince. *In* The Geology of Ontario. Ontario Geological Survey, Special Volume 4, Part 1, p. 383-403.

Williams, H.R. and Breaks, F.W. 1989. Geological studies in the Manitouwadge-Hornepayne area. Ontario Geological Survey, Miscellaneous Paper 146, p.79-91.

Williams, H.R. and Breaks, F.W. 1996. Geology of the Manitouwadge-Hornepayne region, Ontario. Ontario Geological Survey, Open File Report 5953, 138p.

Williams, H. R., Stott, G.M., Heather, K.B., Muir T.L., and Sage, R.P. 1991. Wawa Subprovince. *In* Geology of Ontario. Ontario Geological Survey, Special Volume 4, Part 1, p. 485-525.

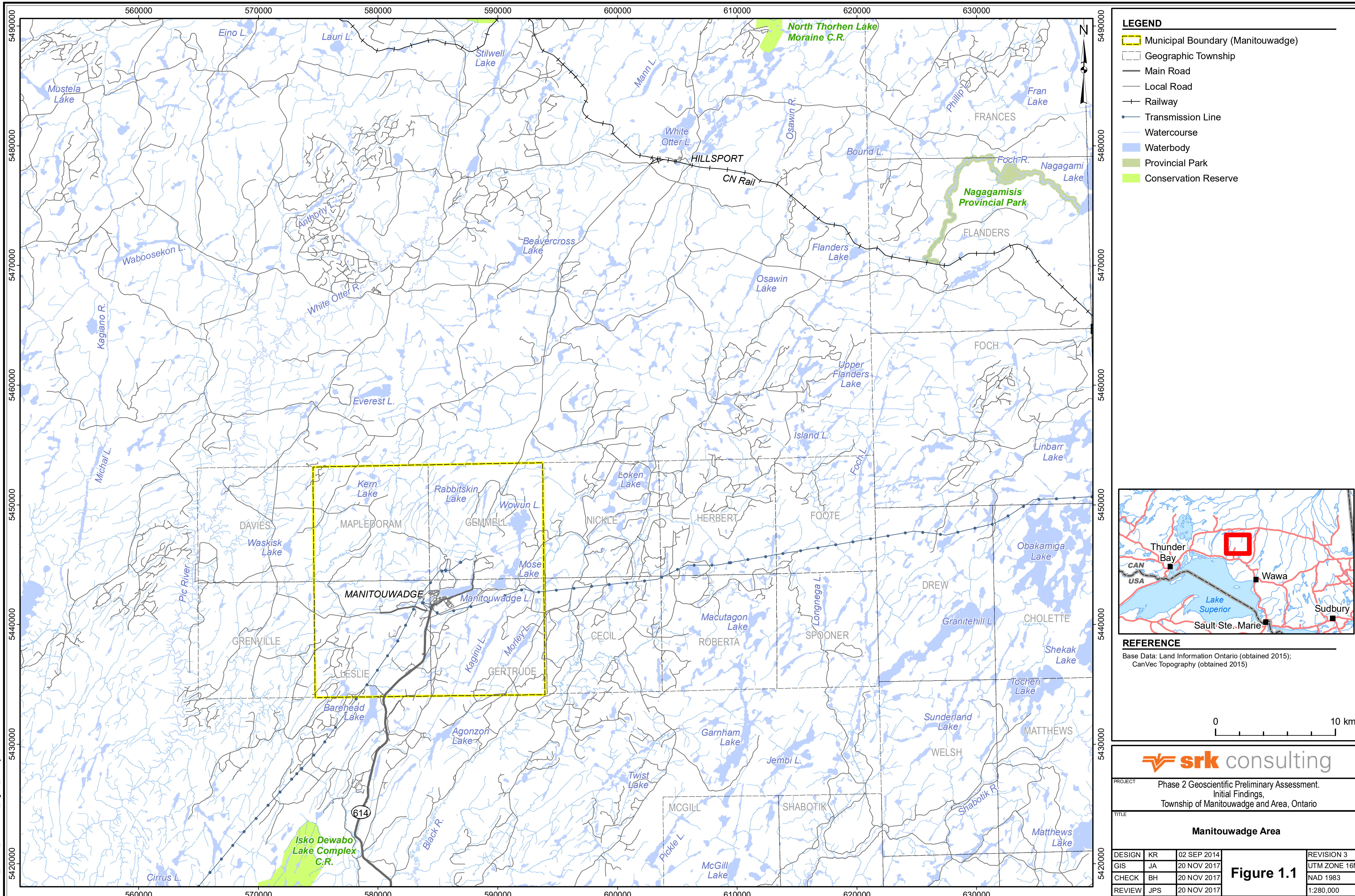
Zaleski, E. and Peterson, V.L. 1993. Lithotectonic setting of mineralization in the Manitouwadge greenstone belt, Ontario; preliminary results. *In* Current Research 1993-C. Geological Survey of Canada, p. 307-317.

Zaleski, E. and Peterson, V.L. 2001. Geology of the Manitouwadge greenstone belt and the Wawa-Quetico subprovince boundary, Ontario. Geological Survey of Canada, Map 1917A, scale 1:25,000.

Zaleski, E., Peterson, V.L., and van Breemen, O. 1995. Geological and age relationships of the margins of the Manitouwadge greenstone belt and the Wawa-Quetico subprovince boundary, northwestern Ontario. *In* Current Research 1995-C. Geological Survey of Canada, p. 35-44.

Zaleski, E., van Breemen, O., and Peterson, V.L. 1999. Geological evolution of the Manitouwadge greenstone belt and Wawa-Quetico subprovince boundary, Superior Province, Ontario, constrained by U-Pb zircon dates of supracrustal and plutonic rocks. Canadian Journal of Earth Sciences; v. 36, p. 945-966.

FIGURES



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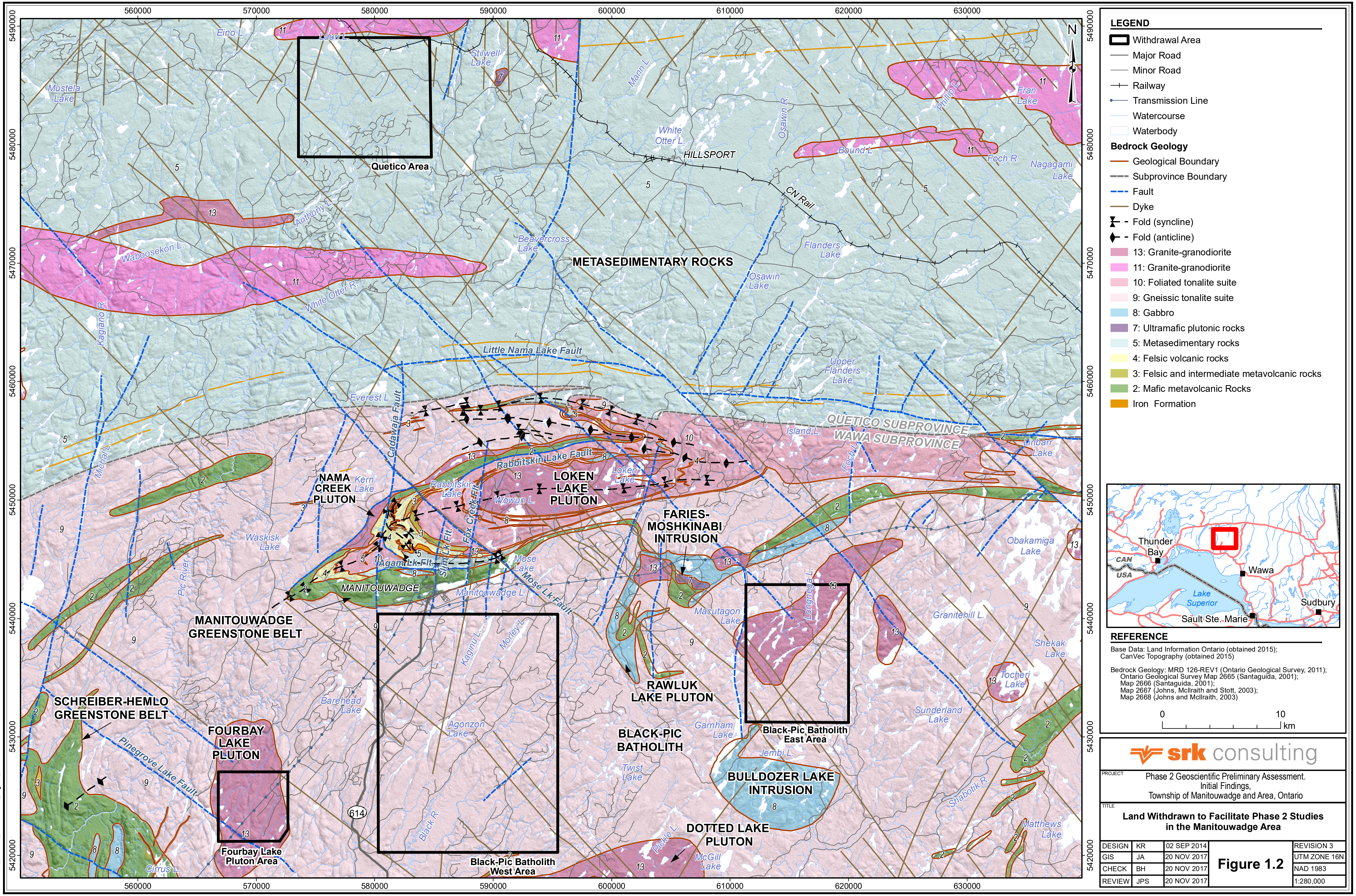

LEGEND
Withdrawal Area
Major Road
Minor Road
Railway
Transmission Line
Watercourse
Waterbody
Bedrock Geology
Geological Boundary
Subprovince Boundary
Fault
Dyke
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
11: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
4: Felsic volcanic rocks
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
METASEDIMENTARY ROCKS
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
Quetico Area
HILLSPORT
CN Rail
Little Nama Lake Fault
Rabbitskin Lake Fault
Cadawaja Fault
Fox Creek Flt.
Slim Lk Flt.
Agam Lk Flt.
Mose Lk Fault
Pinegrove Lake Fault
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
Fourbay Lake Pluton Area
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
Black-Pic Batholith West Area
Black-Pic Batholith East Area
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
Thunder Bay
CAN
USA
Lake Superior
Wawa
Sault Ste. Marie
Sudbury
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
0 10 km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Land Withdrawn to Facilitate Phase 2 Studies in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
REVISION 3
UTM ZONE 16N
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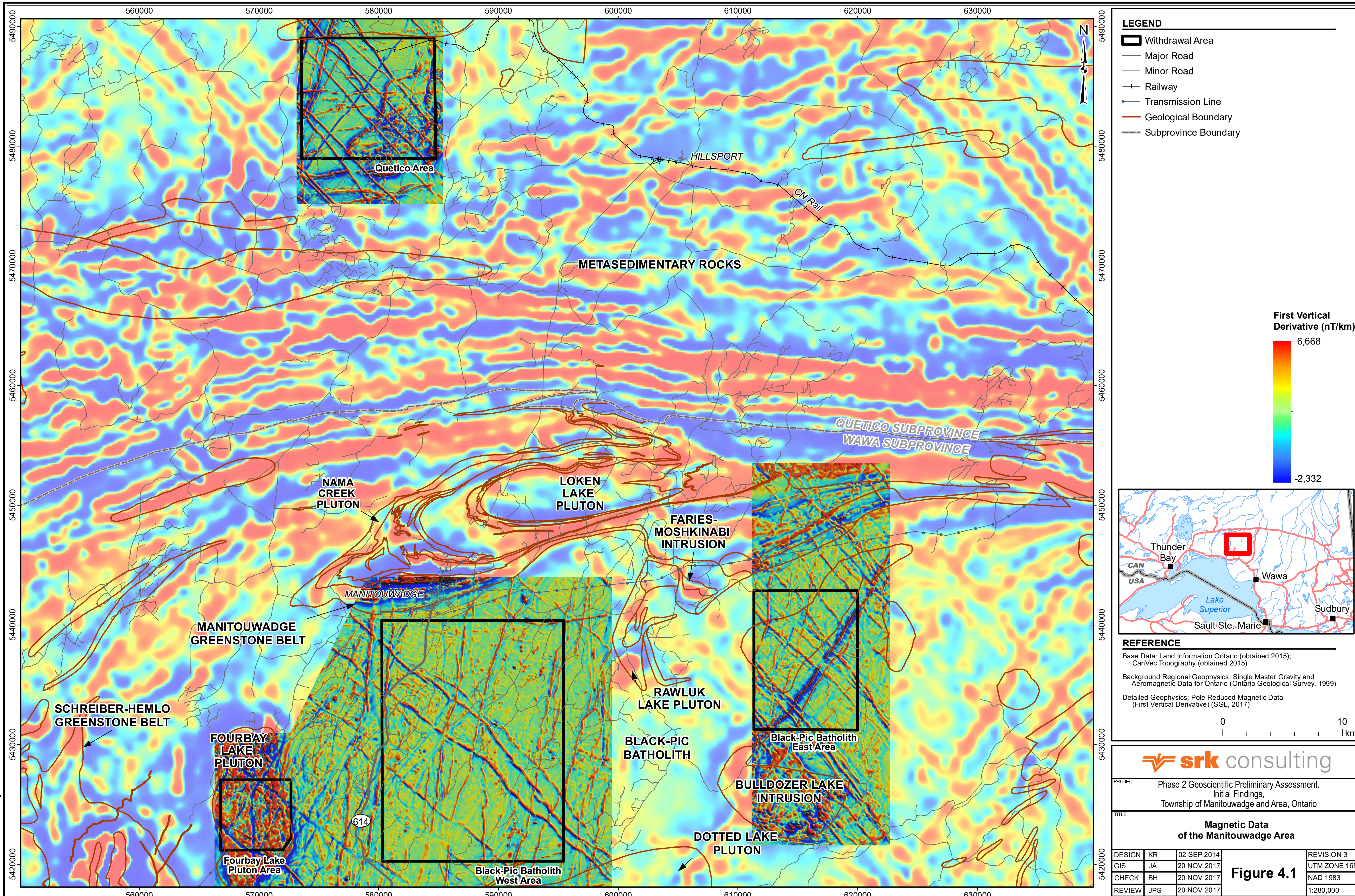
Figure 1.2



LEGEND
Withdrawal Area
Major Road
Minor Road
Railway
Transmission Line
Geological Boundary
Subprovince Boundary
First Vertical Derivative (nT/km)
6,668
-2,332
Thunder Bay
CAN
USA
Wawa
Lake Superior
Sudbury
Sault Ste. Marie
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Background Regional Geophysics: Single Master Gravity and Aeromagnetic Data for Ontario (Ontario Geological Survey, 1999)
Detailed Geophysics: Pole Reduced Magnetic Data (First Vertical Derivative) (SGL, 2017)
0
10
km
N
Quetico Area
HILLSPORT
CN Rail
METASEDIMENTARY ROCKS
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
Black-Pic Batholith East Area
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
BULLDOZER LAKE INTRUSION
614
DOTTED LAKE PLUTON
Fourbay Lake Pluton Area
Black-Pic Batholith West Area
560000
570000
580000
590000
600000
610000
620000
630000
5490000
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5450000
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srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Magnetic Data
of the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 4.1
REVISION 3
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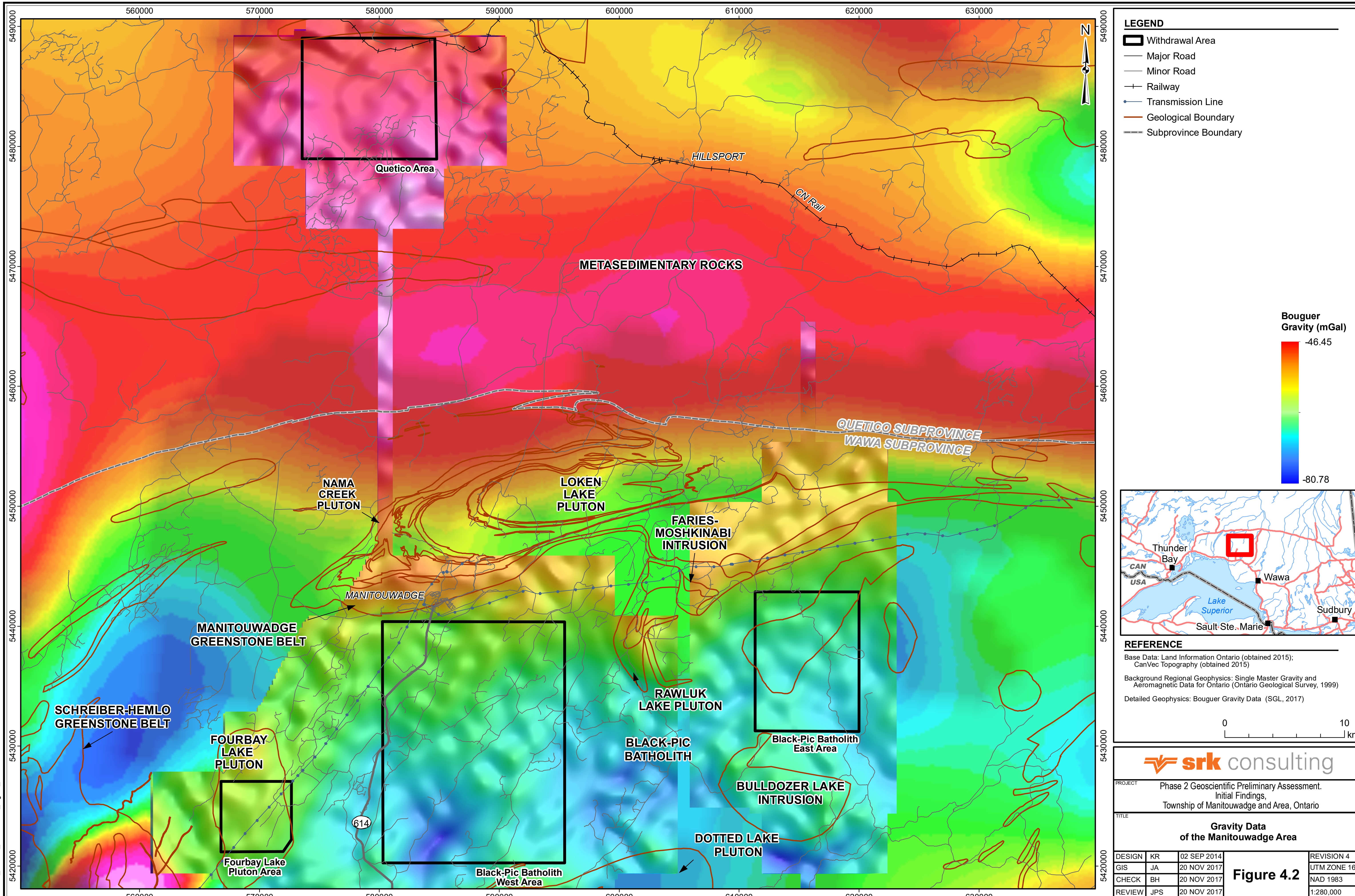

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Background Regional Geophysics: Single Master Gravity and Aeromagnetic Data for Ontario (Ontario Geological Survey, 1999)

Detailed Geophysics: Bouguer Gravity Data (SGL, 2017)

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PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: Gravity Data of the Manitouwadge Area

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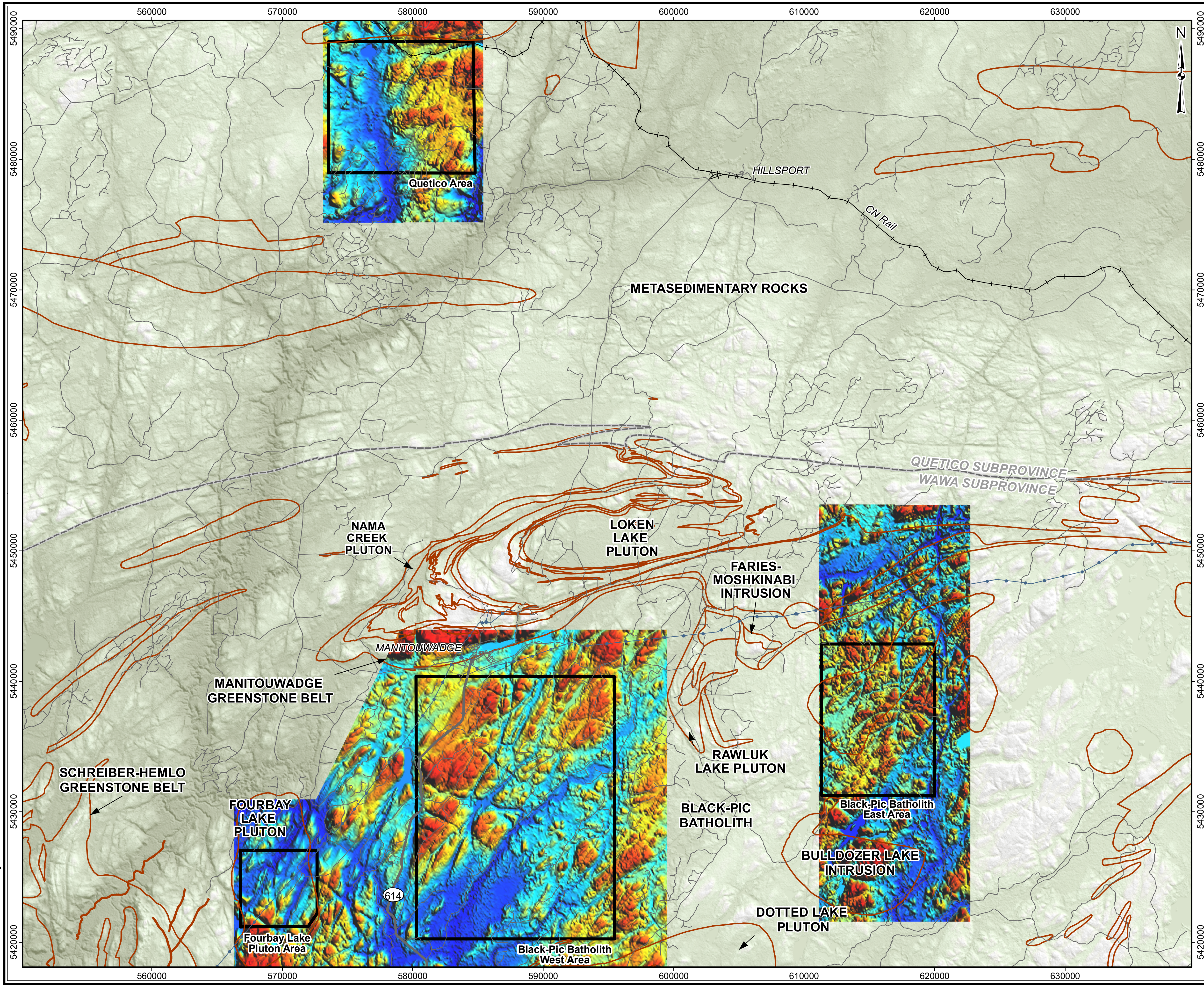


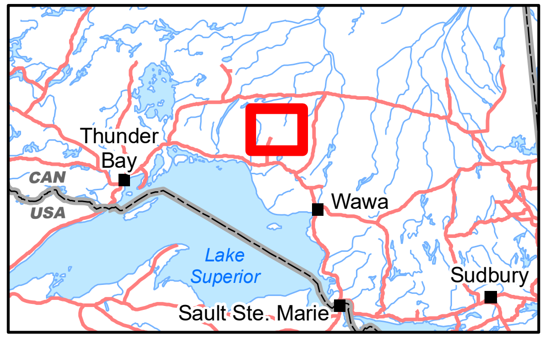
LEGEND

- Withdrawal Area
- Major Road
- Minor Road
- Railway
- Transmission Line
- Geological Boundary
- Subprovince Boundary

Elevation (masl)

487m

213



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Detailed DEM: SGL, 2017

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srk consulting

PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: **Digital Elevation (DEM) Data of the Manitouwadge Area**

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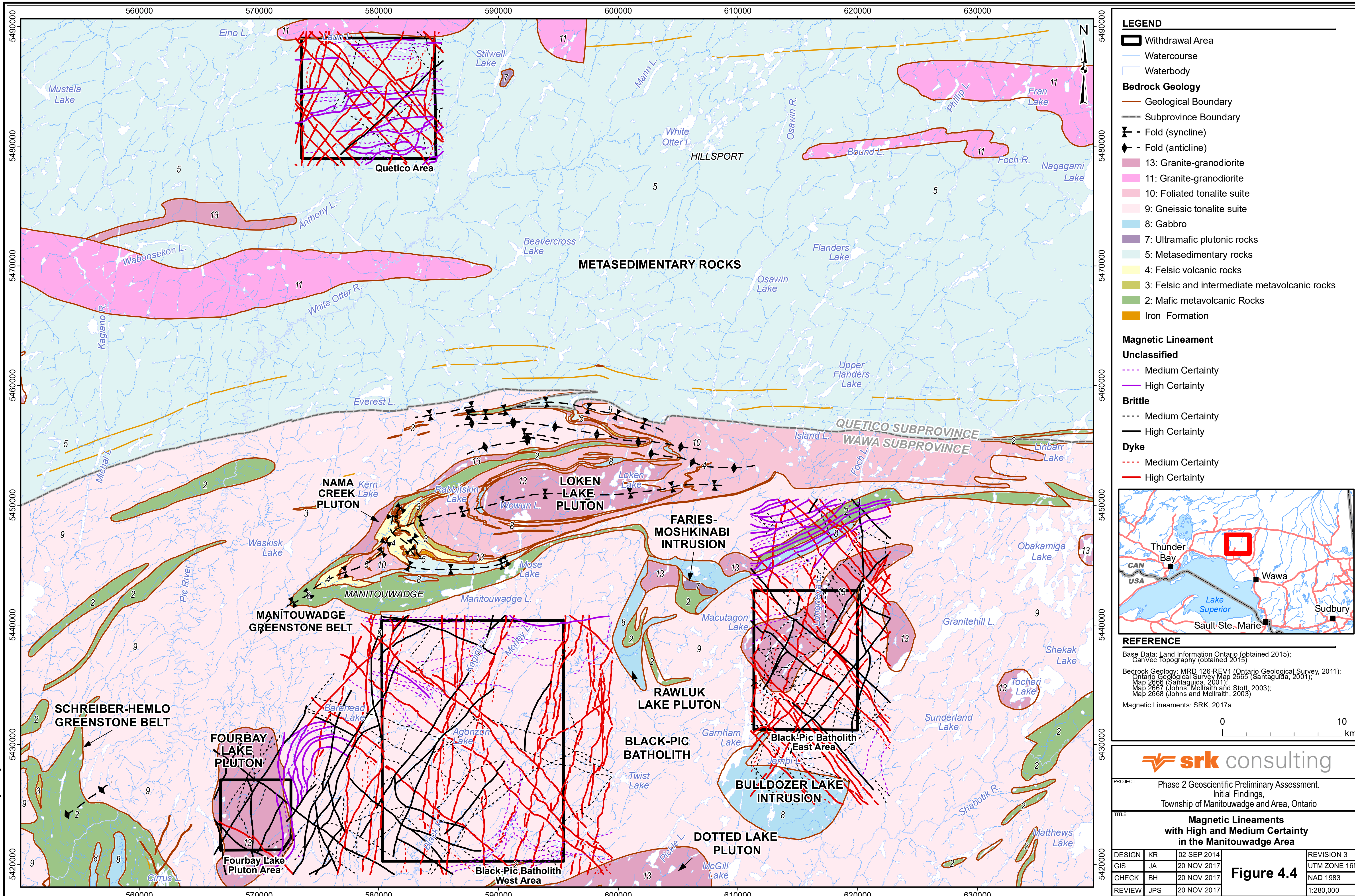

LEGEND
Withdrawal Area
Watercourse
Waterbody
Bedrock Geology
Geological Boundary
Subprovince Boundary
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
11: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
4: Felsic volcanic rocks
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
Magnetic Lineament
Unclassified
Medium Certainty
High Certainty
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
Thunder Bay
CAN
USA
Wawa
Lake Superior
Sault Ste. Marie
Sudbury
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Magnetic Lineaments: SRK, 2017a
0 10 km
N
Quetico Area
METASEDIMENTARY ROCKS
HILLSPORT
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
RAWLUK LAKE PLUTON
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
Fourbay Lake Pluton Area
Black-Pic Batholith West Area
Black-Pic Batholith East Area
Eino L.
Laurie L.
Stilwell Lake
Mustela Lake
Mann L.
Osawin R.
Phillip L.
Fran Lake
White Otter L.
Bound L.
Foch R.
Nagagami Lake
Anthony L.
Waboosekon L.
White Otter R.
Beavercross Lake
Flanders Lake
Osawin Lake
Kagiano R.
Upper Flanders Lake
Everest L.
Island L.
Linbarr Lake
Michael L.
Kern Lake
Rabbitskin Lake
Loken Lake
Wowun L.
Waskisk Lake
Mose Lake
Manitouwadge L.
Obakamiga Lake
Pic River
Macutagon Lake
Longrange L.
Granitehill L.
Shekak Lake
Tocheri Lake
Barehead Lake
Agonzon Lake
Garnham Lake
Sunderland Lake
Twist Lake
Jembi L.
Shabotik R.
Matthews Lake
Pickle L.
McGill Lake
Cirrus L.
560000
570000
580000
590000
600000
610000
620000
630000
5490000
5480000
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srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Magnetic Lineaments with High and Medium Certainty in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 4.4
REVISION 3
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NAD 1983
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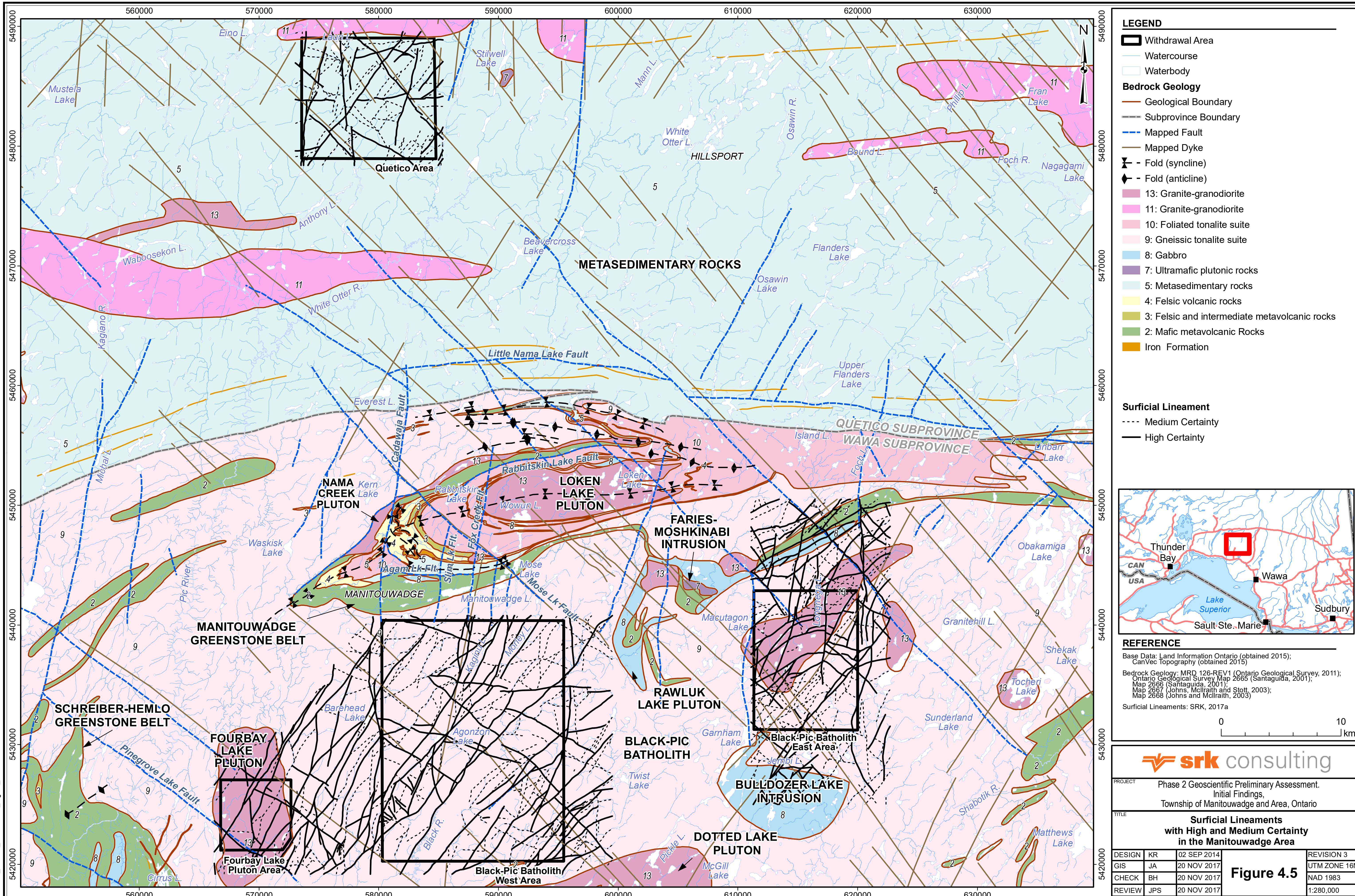

LEGEND
Withdrawal Area
Watercourse
Waterbody
Bedrock Geology
Geological Boundary
Subprovince Boundary
Mapped Fault
Mapped Dyke
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
11: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
4: Felsic volcanic rocks
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
Surficial Lineament
Medium Certainty
High Certainty
Thunder Bay
Wawa
Sudbury
Sault Ste. Marie
Lake Superior
CAN
USA
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Surficial Lineaments: SRK, 2017a
0
10
km
Quetico Area
METASEDIMENTARY ROCKS
HILLSPORT
Little Nama Lake Fault
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
Rabbitskin Lake Fault
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
Mose Lk Fault
Cadawaja Fault
Fox Creek Flt.
Slim Lk Flt.
Agam Lk Flt.
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
Black-Pic Batholith East Area
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
Black-Pic Batholith West Area
SCHREIBER-HEMLO GREENSTONE BELT
Pinegrove Lake Fault
FOURBAY LAKE PLUTON
Fourbay Lake Pluton Area
560000
570000
580000
590000
600000
610000
620000
630000
5490000
5480000
5470000
5460000
5450000
5440000
5430000
5420000
N
File: SRK_NWMO_ManFindExt_Fig4.5_SurfLin
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Surficial Lineaments with High and Medium Certainty in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 4.5
REVISION 3
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NAD 1983
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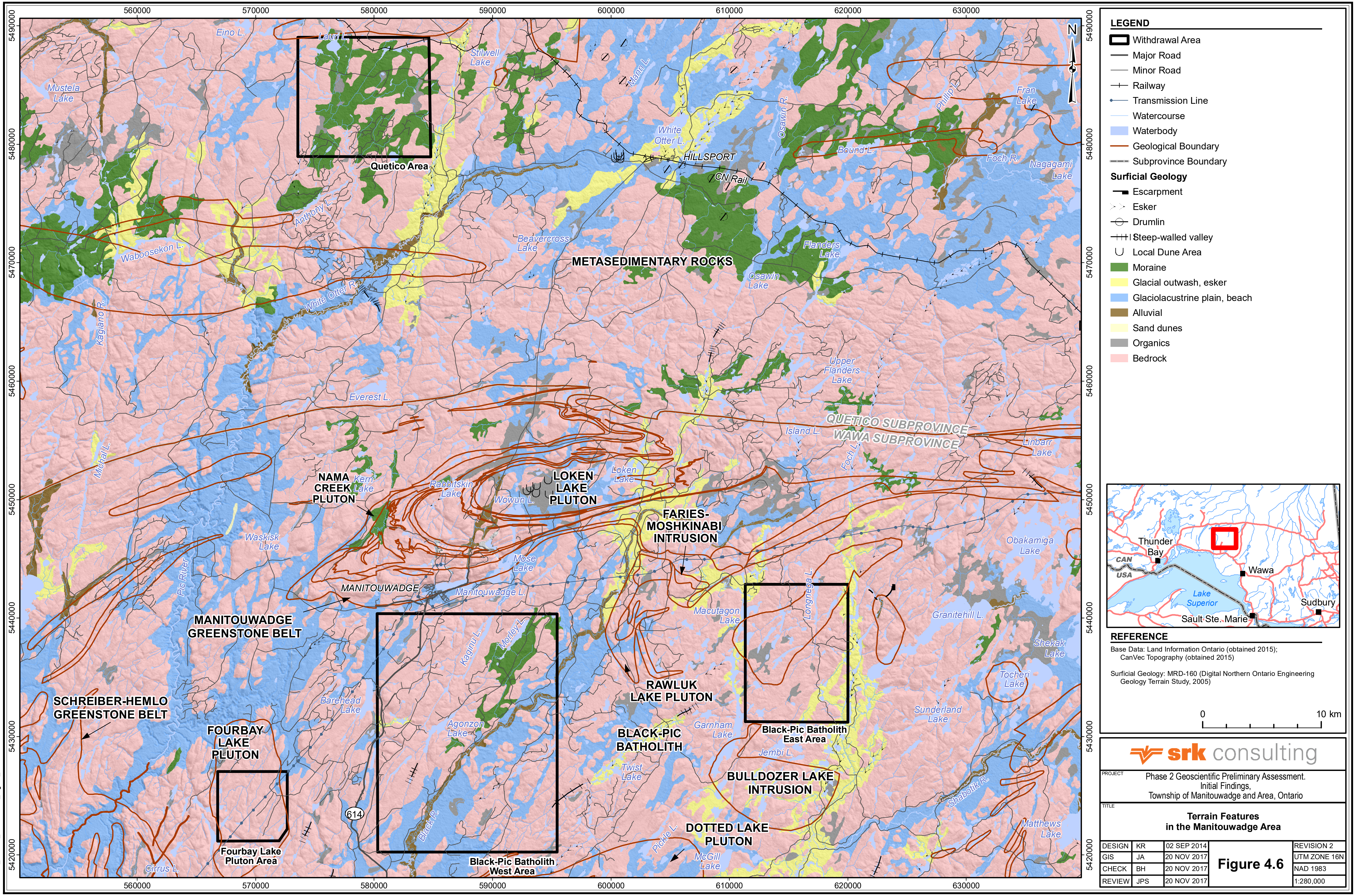
LEGEND
Withdrawal Area
Major Road
Minor Road
Railway
Transmission Line
Watercourse
Waterbody
Geological Boundary
Subprovince Boundary
Surficial Geology
Escarpment
Esker
Drumlin
Steep-walled valley
Local Dune Area
Moraine
Glacial outwash, esker
Glaciolacustrine plain, beach
Alluvial
Sand dunes
Organics
Bedrock
Quetico Area
METASEDIMENTARY ROCKS
HILLSPORT
CN Rail
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
Black-Pic Batholith East Area
Black-Pic Batholith West Area
Fourbay Lake Pluton Area
614
Thunder Bay
Wawa
Sudbury
Sault Ste. Marie
Lake Superior
CAN
USA
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Surficial Geology: MRD-160 (Digital Northern Ontario Engineering Geology Terrain Study, 2005)
0
10 km
srk consulting
PROJECT Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE Terrain Features in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 4.6
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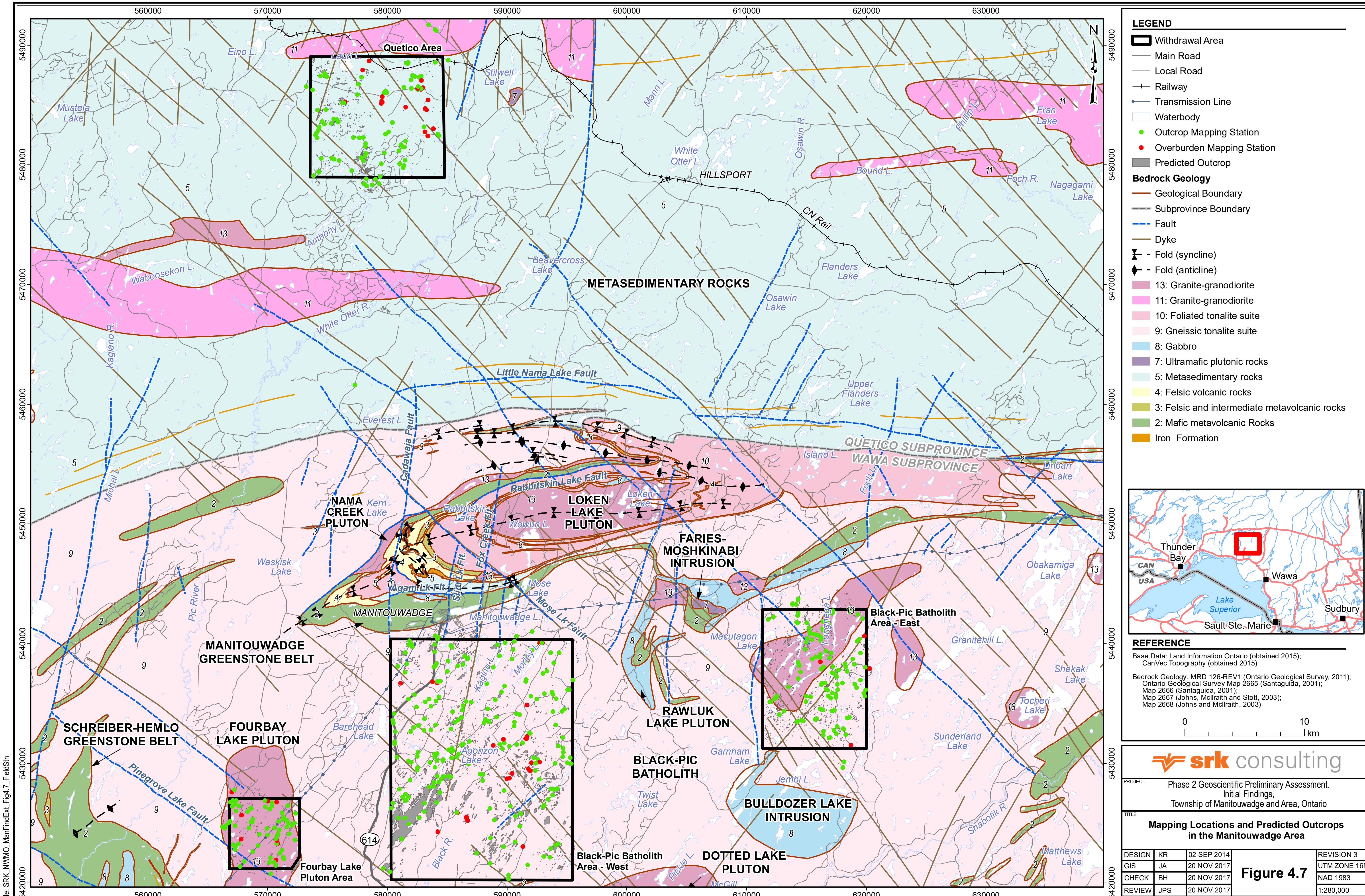
LEGEND
Withdrawal Area
Main Road
Local Road
Railway
Transmission Line
Waterbody
Outcrop Mapping Station
Overburden Mapping Station
Predicted Outcrop
Bedrock Geology
Geological Boundary
Subprovince Boundary
Fault
Dyke
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
11: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
4: Felsic volcanic rocks
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
REFERENCE
Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
0 10 km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Mapping Locations and Predicted Outcrops
in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 4.7
REVISION 3
UTM ZONE 16N
NAD 1983
1:280,000
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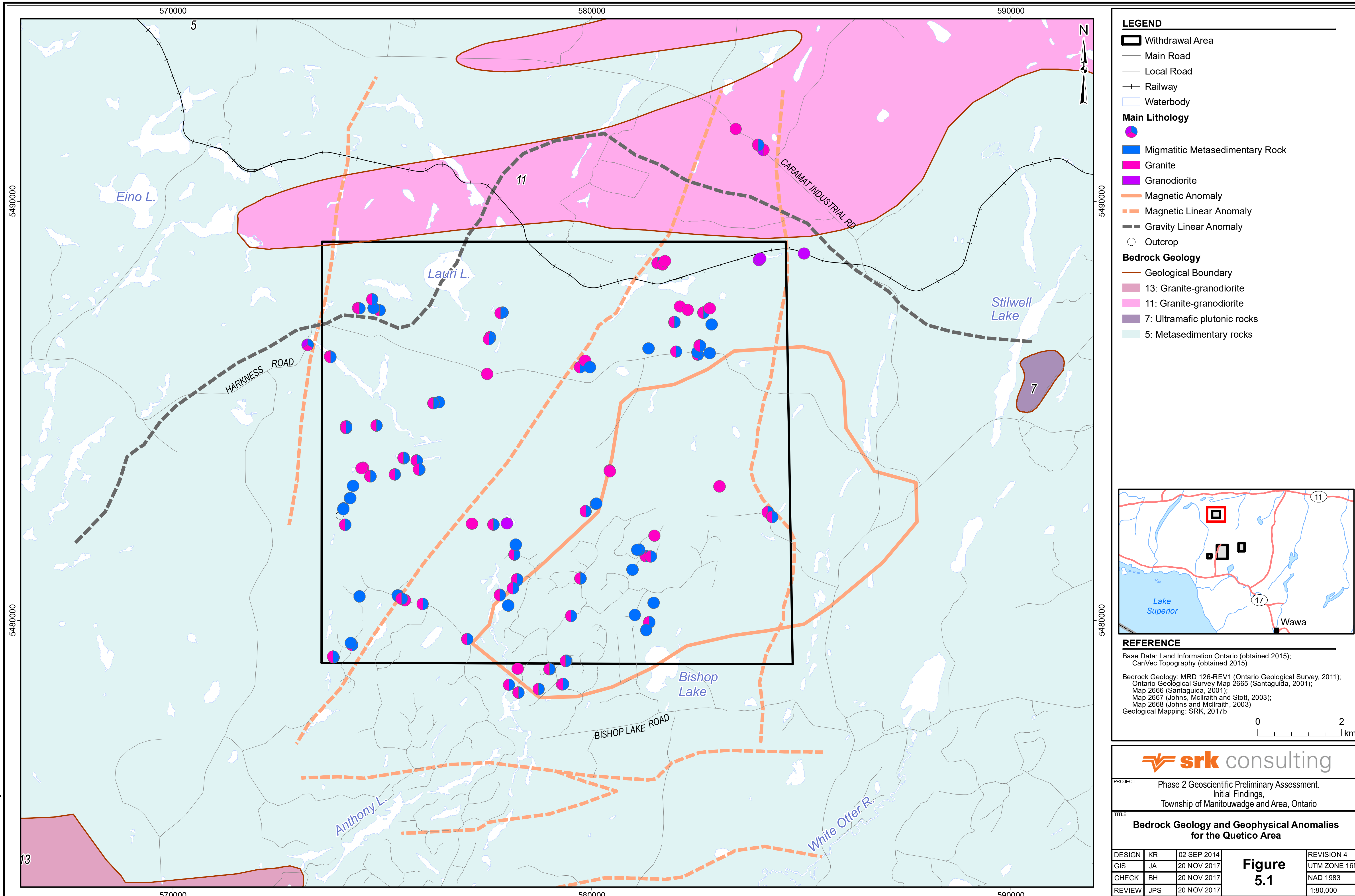
Quetico Area
METASEDIMENTARY ROCKS
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
Little Nama Lake Fault
Rabbitskin Lake Fault
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
Fourbay Lake Pluton Area
Black-Pic Batholith Area - West
Black-Pic Batholith Area - East
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
HILLSPORT
CN Rail
Cadawaja Fault
Mose Lk Fault
Pinegrove Lake Fault
Thunder Bay
Wawa
Sudbury
Sault Ste. Marie
Lake Superior
CAN
USA



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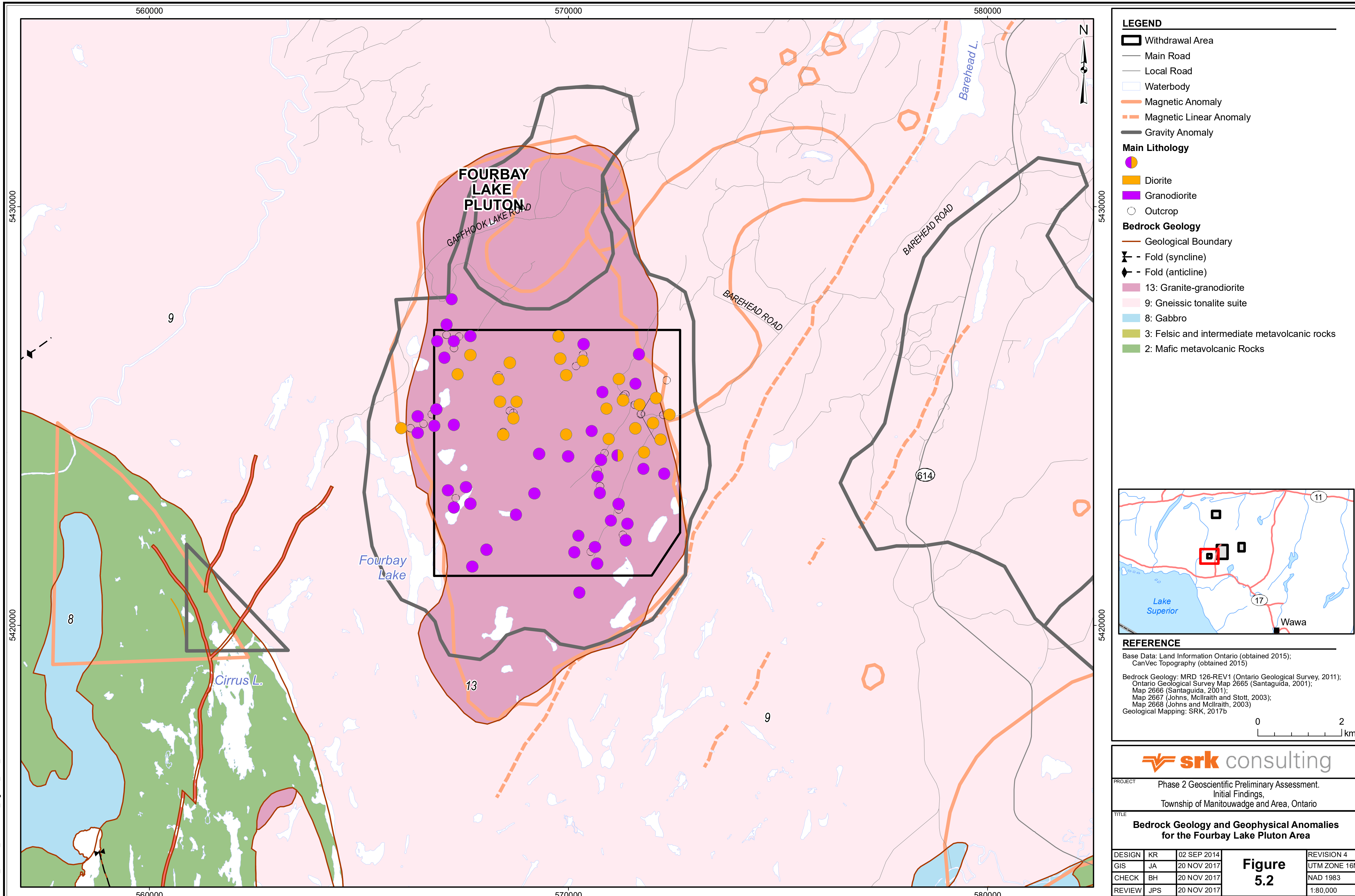

560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
GAFFHOOK LAKE ROAD
BAREHEAD ROAD
Barehead L.
Fourbay Lake
Cirrus L.
614
9
8
13
N
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Magnetic Anomaly
Magnetic Linear Anomaly
Gravity Anomaly
Main Lithology
Diorite
Granodiorite
Outcrop
Bedrock Geology
Geological Boundary
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Bedrock Geology and Geophysical Anomalies for the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 5.2
REVISION 4
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NAD 1983
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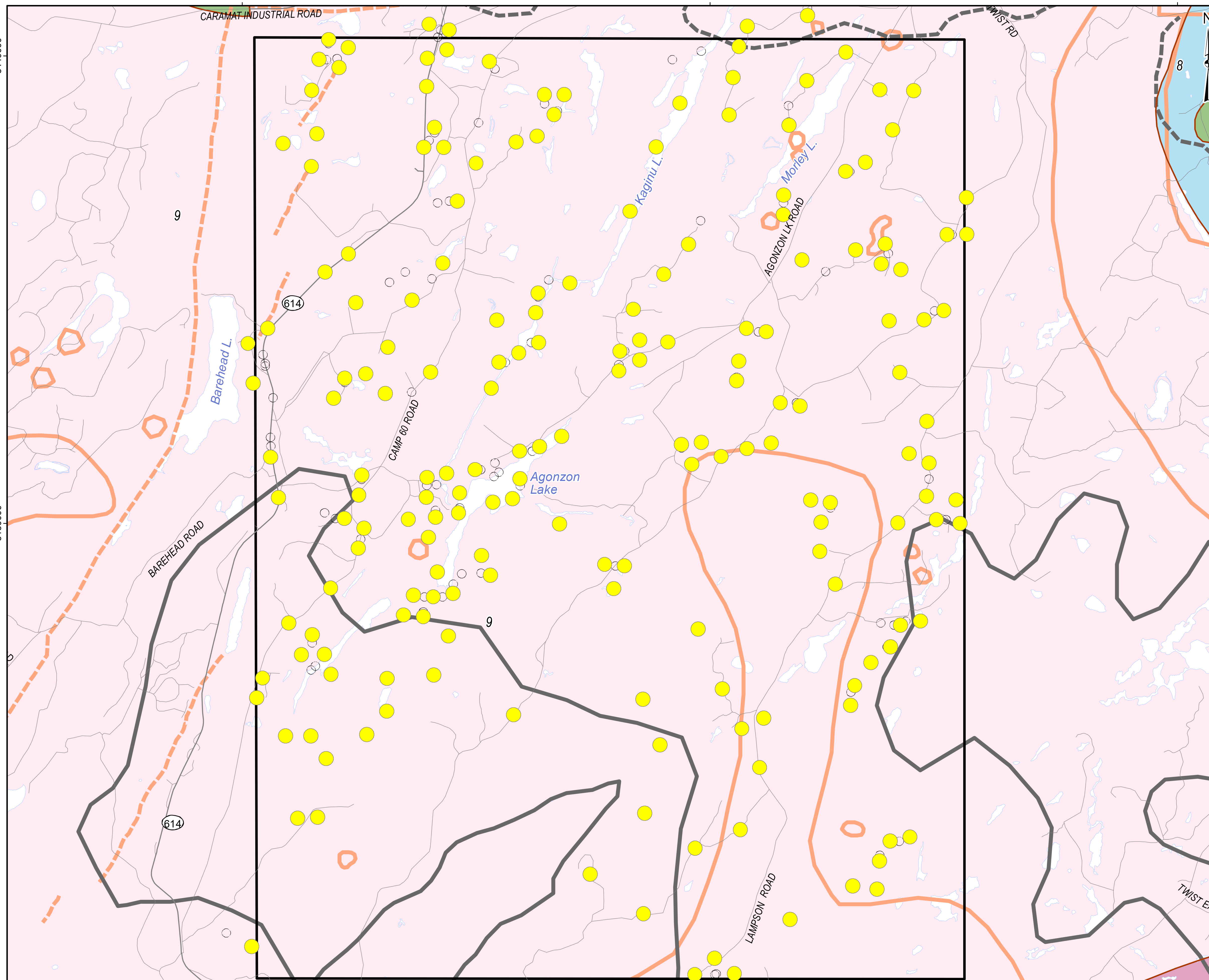


LEGEND

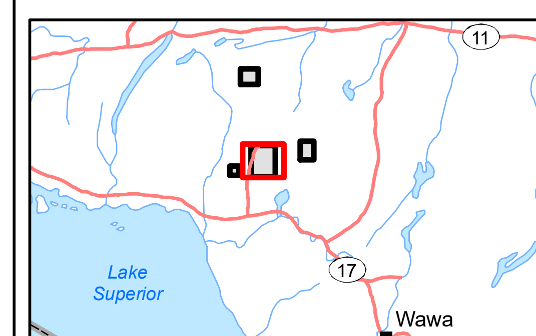
- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Magnetic Anomaly
- Magnetic Linear Anomaly
- Gravity Anomaly
- Gravity Linear Anomaly

Main Lithology

- Tonalite
- Outcrop

Bedrock Geology

- Geological Boundary
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Bedrock Geology and Geophysical Anomalies for the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	Figure 5.3	REVISION 4
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:81,000

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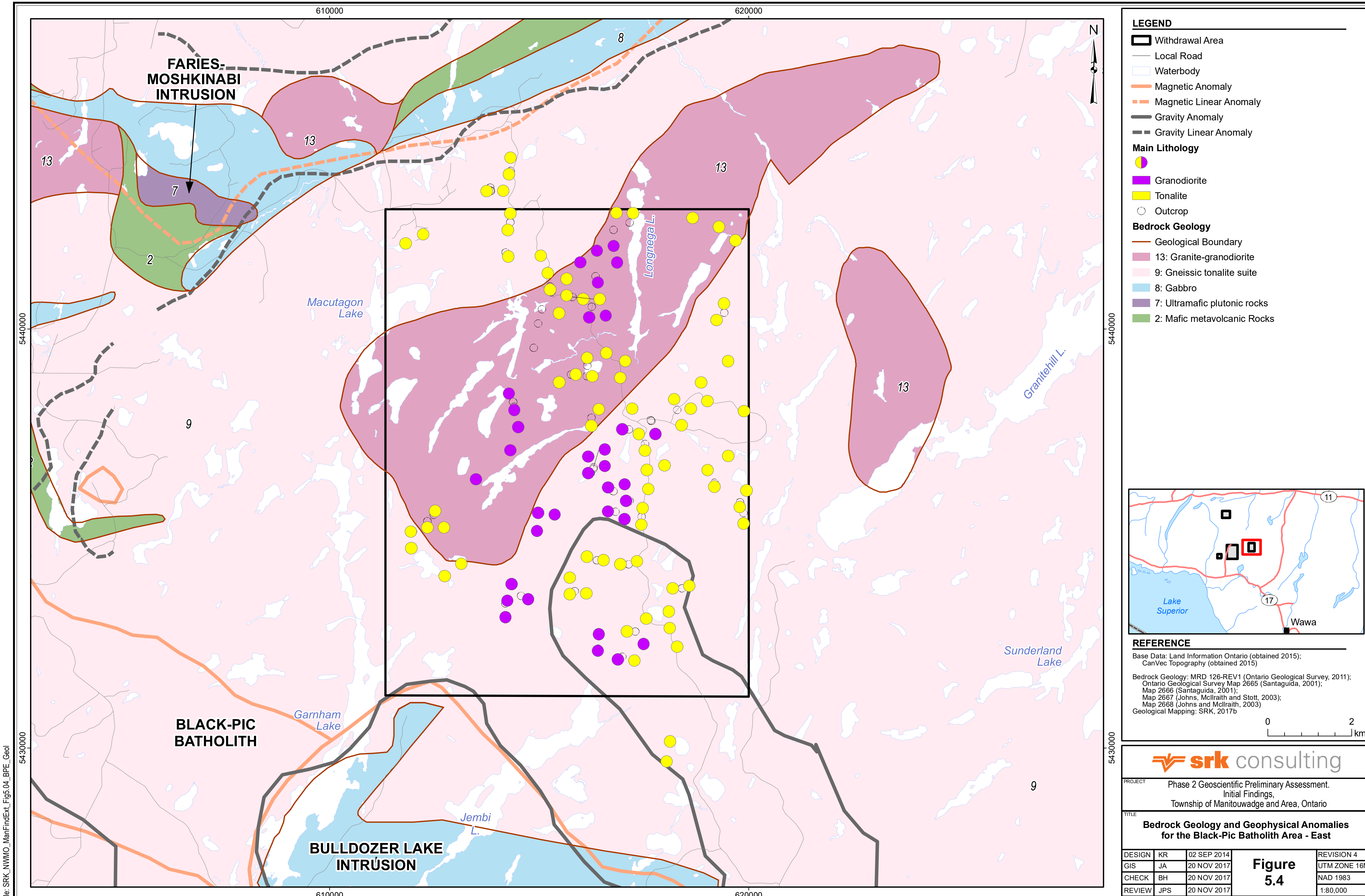
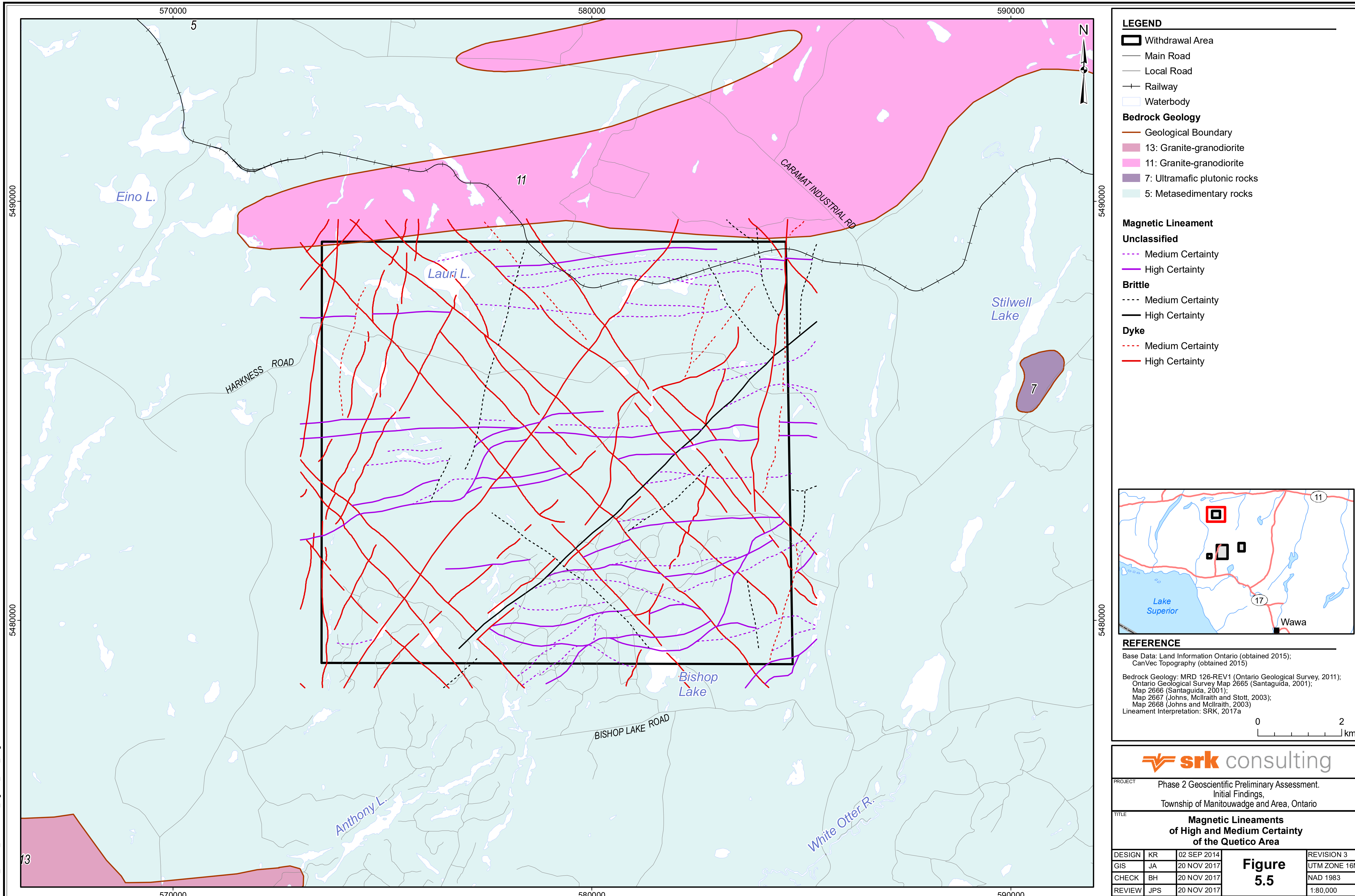


Bedrock Geology and Geophysical Anomalies for the Black-Pic Batholith Area - East

Figure 5.4



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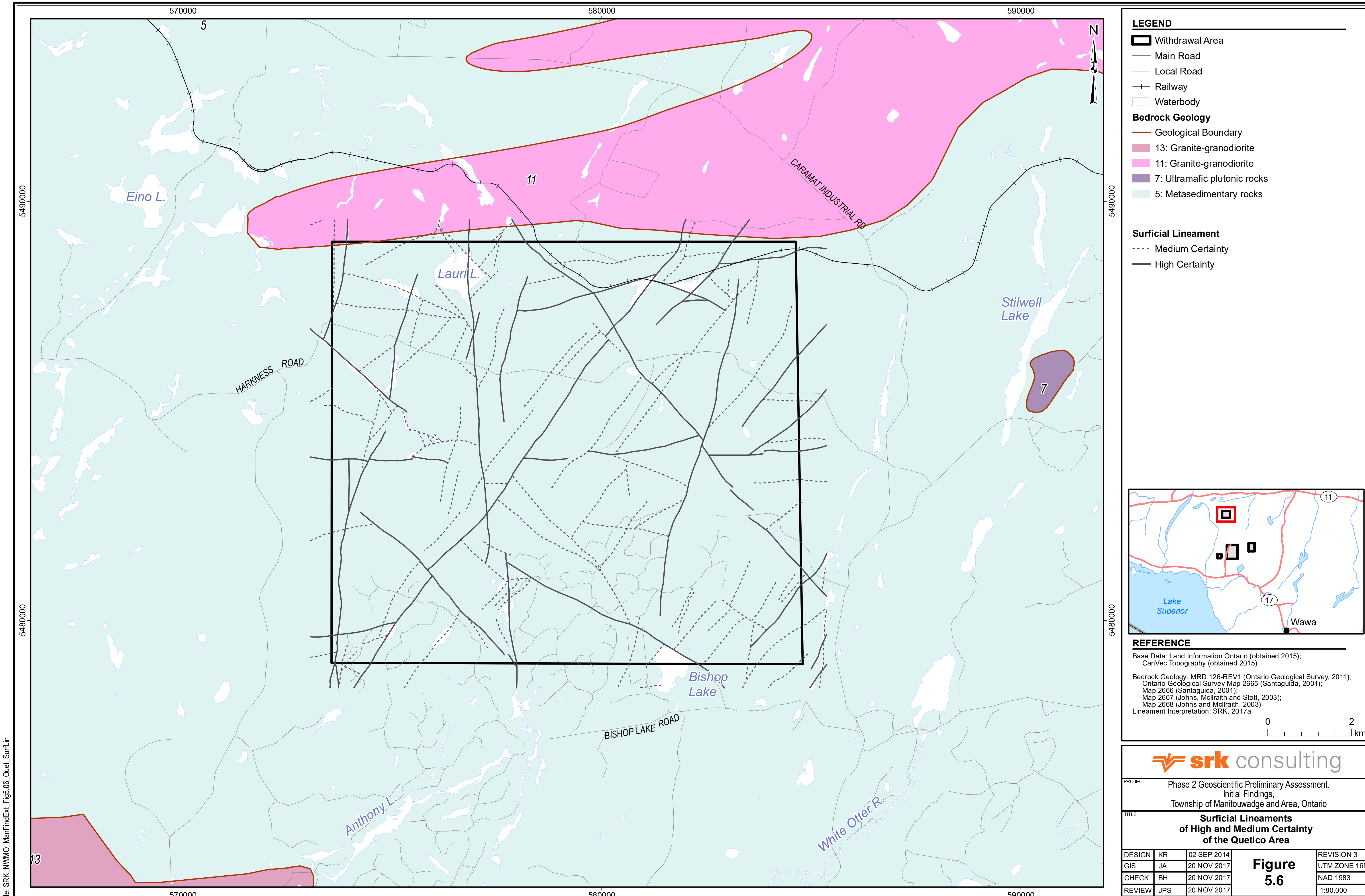

570000
580000
590000
5490000
5480000
5
11
7
13
Eino L.
Lauri L.
Stilwell Lake
Bishop Lake
Anthony L.
White Otter R.
HARKNESS ROAD
CARAMAT INDUSTRIAL RD
BISHOP LAKE ROAD
N
LEGEND
Withdrawal Area
Main Road
Local Road
Railway
Waterbody
Bedrock Geology
Geological Boundary
13: Granite-granodiorite
11: Granite-granodiorite
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
Surficial Lineament
Medium Certainty
High Certainty
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Surficial Lineaments of High and Medium Certainty of the Quetico Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 5.6
REVISION 3
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NAD 1983
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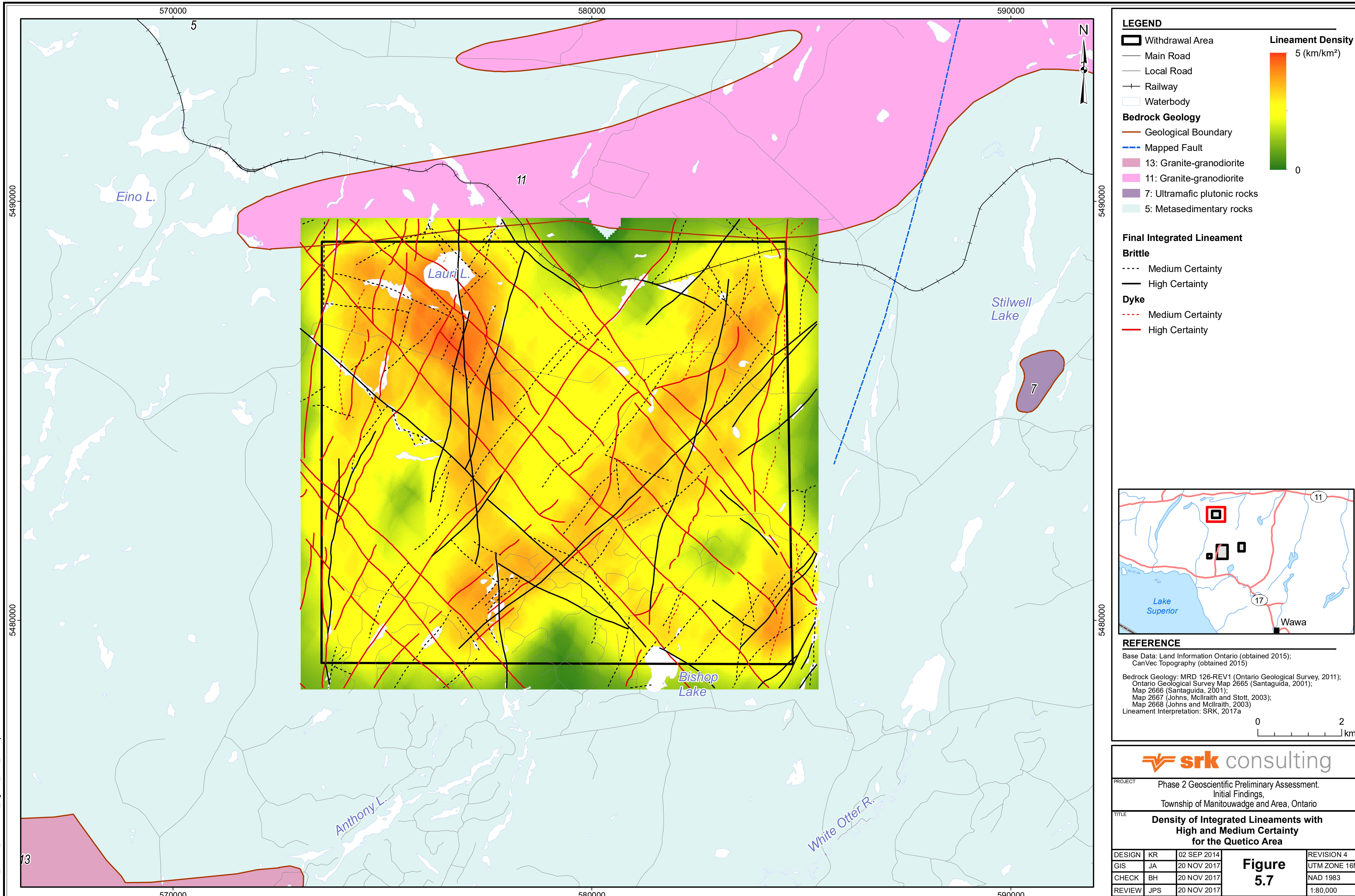
570000
580000
590000
5490000
5480000
5
11
13
7
Eino L.
Lauri L.
Stilwell Lake
Bishop Lake
Anthony L.
White Otter R.
N
LEGEND
Withdrawal Area
Main Road
Local Road
Railway
Waterbody
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
11: Granite-granodiorite
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
Lineament Density
5 (km/km²)
0
Final Integrated Lineament
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
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2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Density of Integrated Lineaments with
High and Medium Certainty
for the Quetico Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure
5.7
REVISION 4
UTM ZONE 16N
NAD 1983
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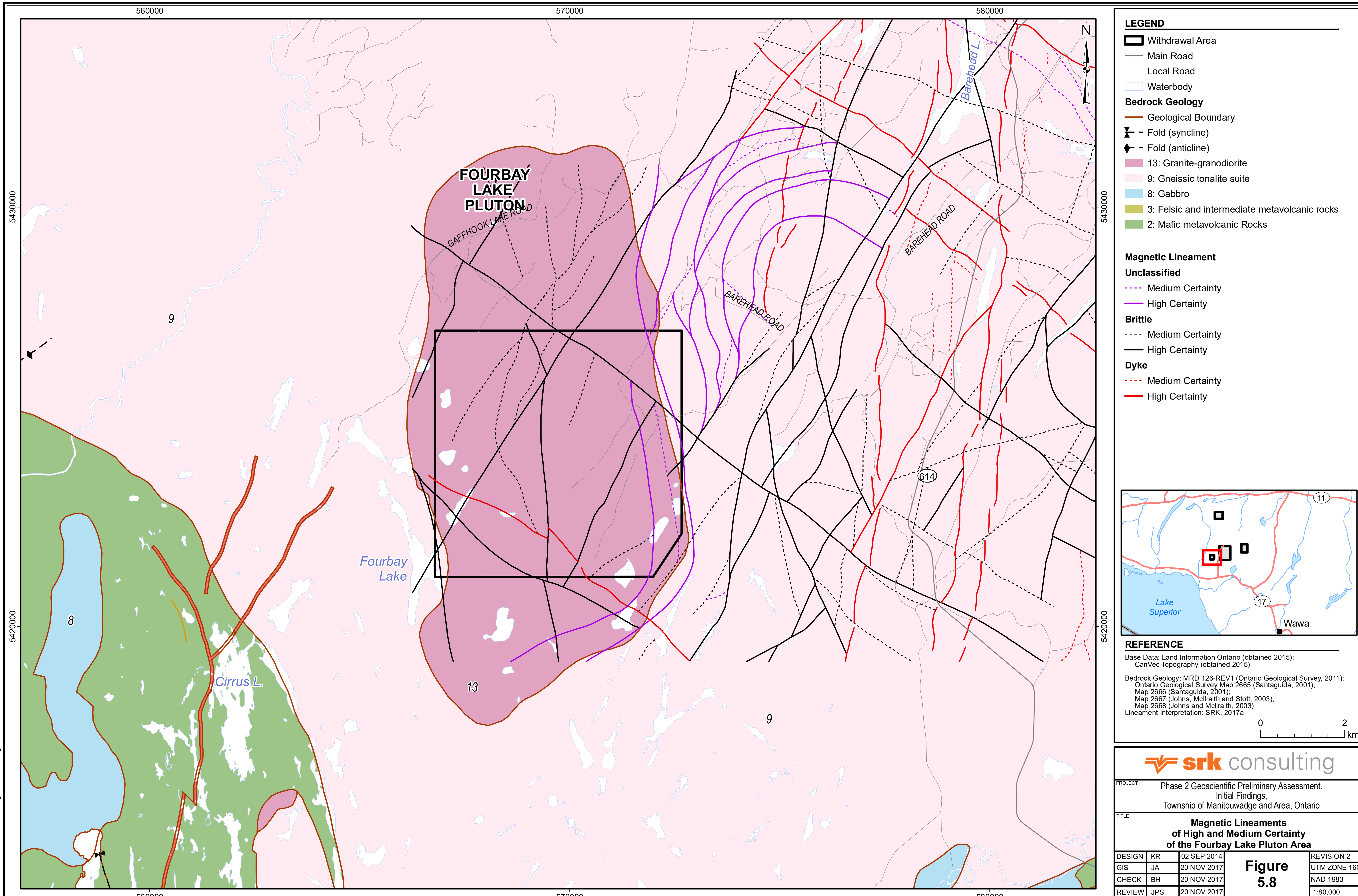

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Magnetic Lineaments of High and Medium Certainty of the Fourbay Lake Pluton Area

DESIGN	KR	02 SEP 2014	Figure 5.8	REVISION 2
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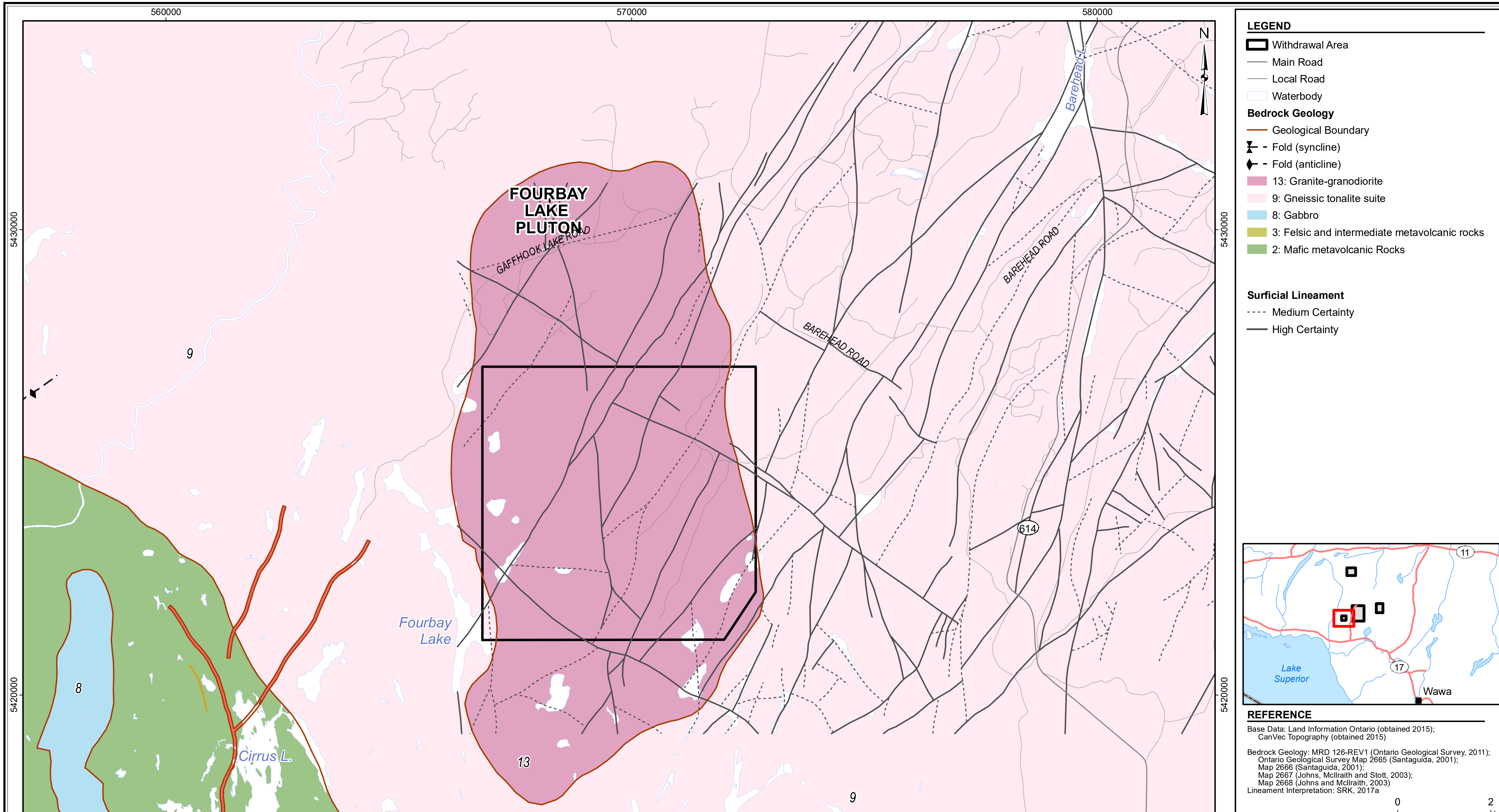
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000



REFERENCE

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CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

srk consulting

PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: **Surficial Lineaments of High and Medium Certainty of the Fourbay Lake Pluton Area**

DESIGN	KR	02 SEP 2014	**Figure 5.9**	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

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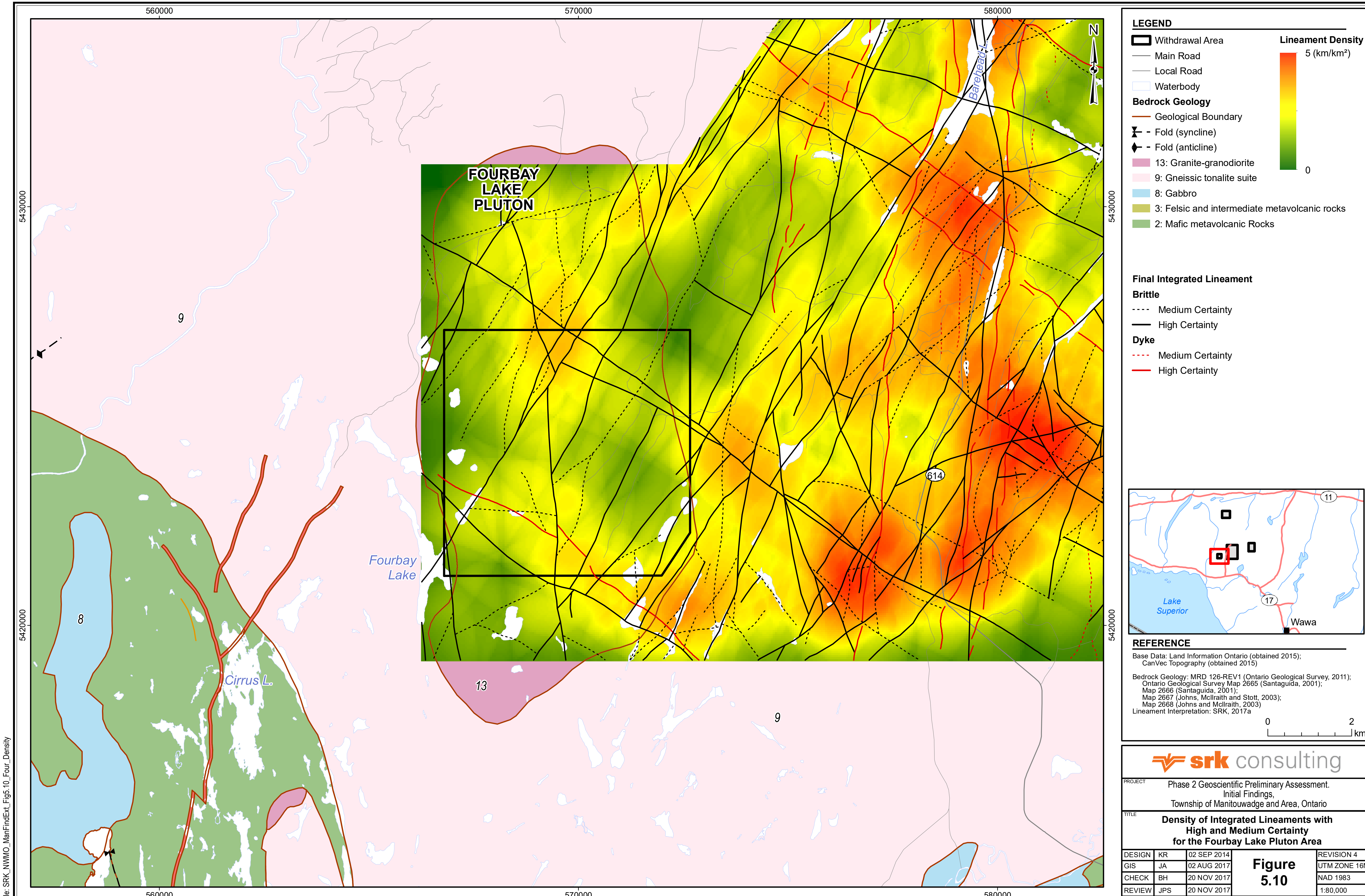

560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
Fourbay Lake
Cirrus L.
Barehead L.
614
9
8
13
N
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Bedrock Geology
Geological Boundary
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Lineament Density
5 (km/km²)
0
Final Integrated Lineament
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Density of Integrated Lineaments with
High and Medium Certainty
for the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 02 AUG 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 5.10
REVISION 4
UTM ZONE 16N
NAD 1983
1:80,000
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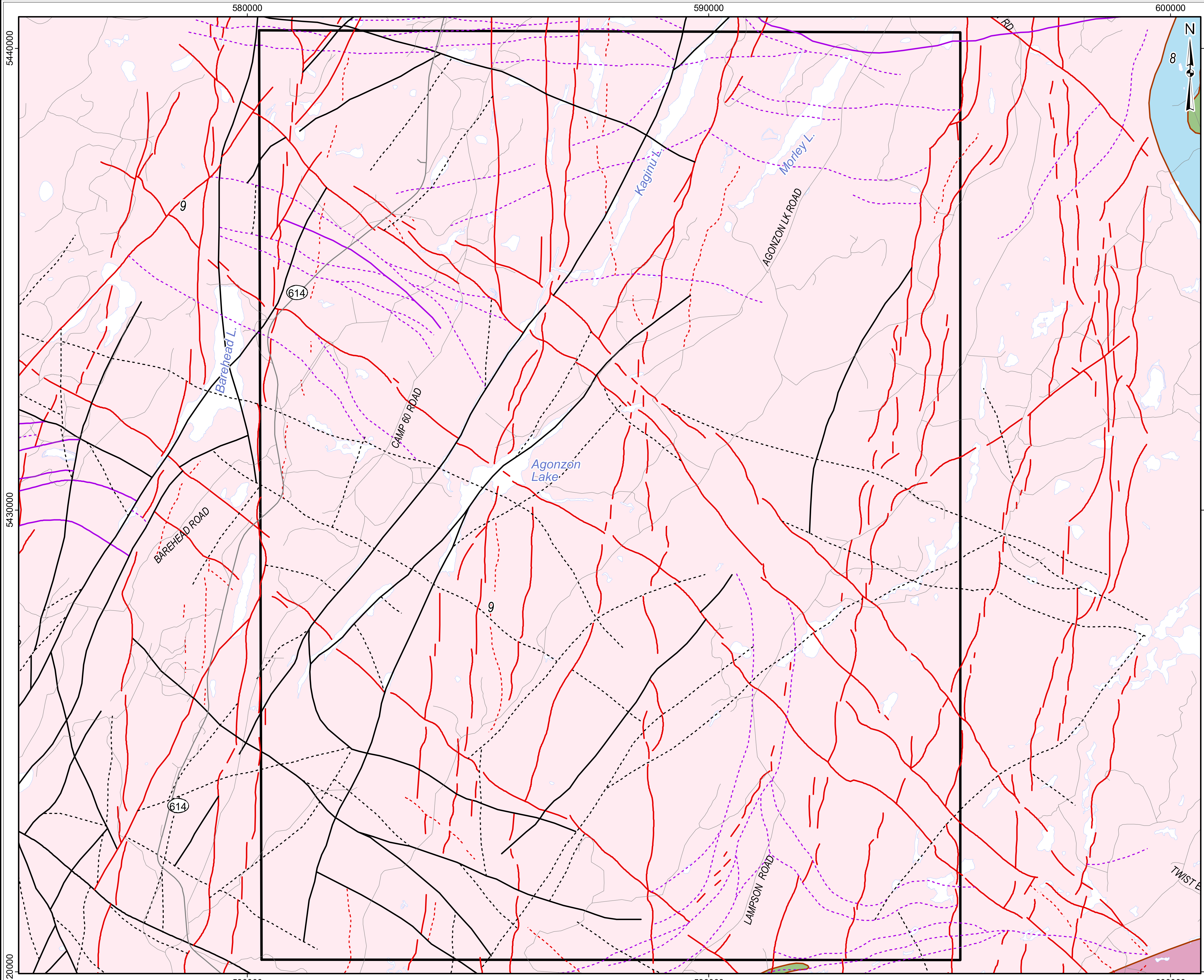


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody

Bedrock Geology

- Geological Boundary
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Magnetic Lineament

Unclassified

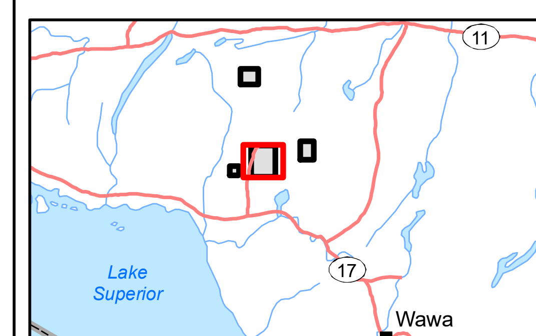
- Medium Certainty
- High Certainty

Brittle

- Medium Certainty
- High Certainty

Dyke

- Medium Certainty
- High Certainty



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)

Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: **Magnetic Lineaments of High and Medium Certainty of the Black-Pic Batholith Area - West**

DESIGN	KR	02 SEP 2014	Figure 5.11	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

File: SRK_NWMO_ManFindExt_Fig5.11_BPW_MagLin

LEGEND

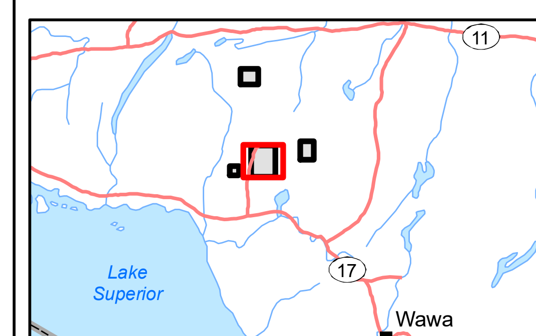
- Withdrawal Area
- Main Road
- Local Road
- Waterbody

Bedrock Geology

- Geological Boundary
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Surficial Lineament

- Medium Certainty
- Medium Certainty



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE **Surficial Lineaments of High and Medium Certainty of the Black-Pic Batholith Area - West**

DESIGN	KR	02 SEP 2014	**Figure 5.12**	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

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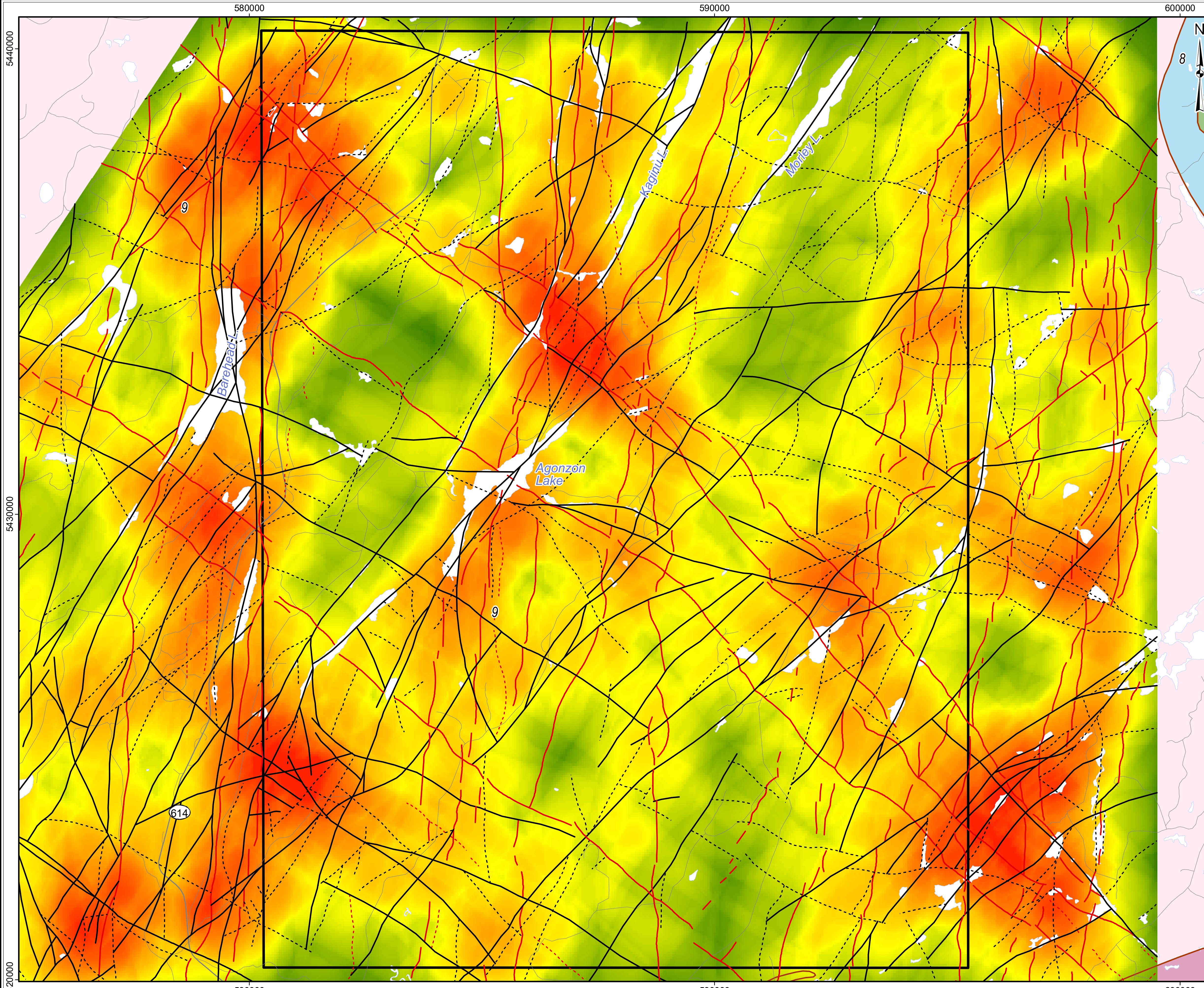


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody

Bedrock Geology

- Geological Boundary
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Lineament Density

5 (km/km²)

0

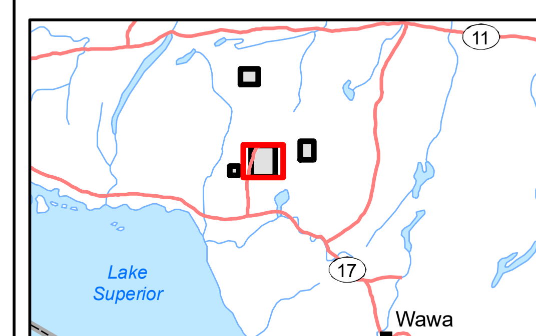
Final Integrated Lineament

Brittle

- Medium Certainty
- High Certainty

Dyke

- Medium Certainty
- High Certainty



REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

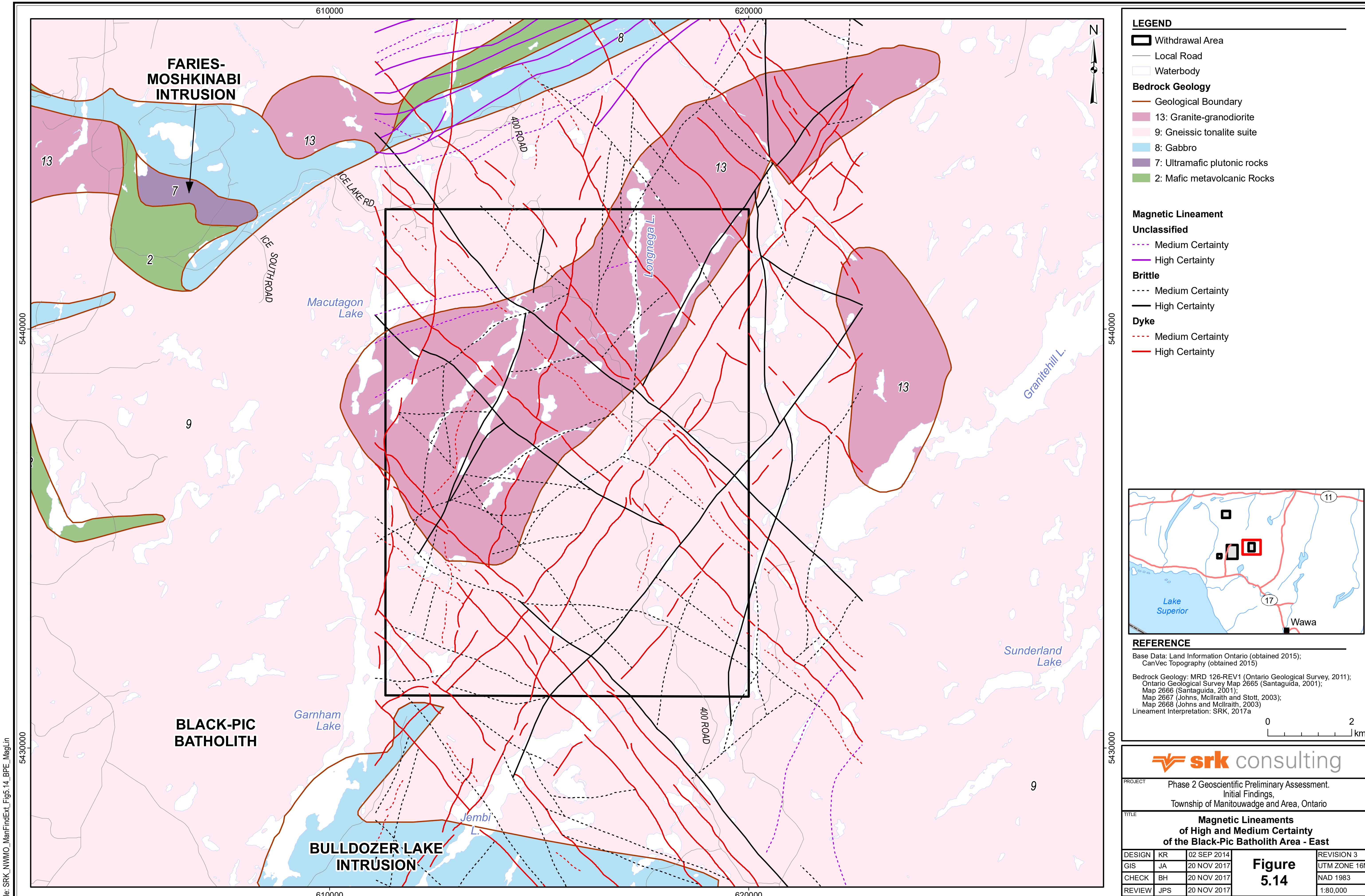
srk consulting

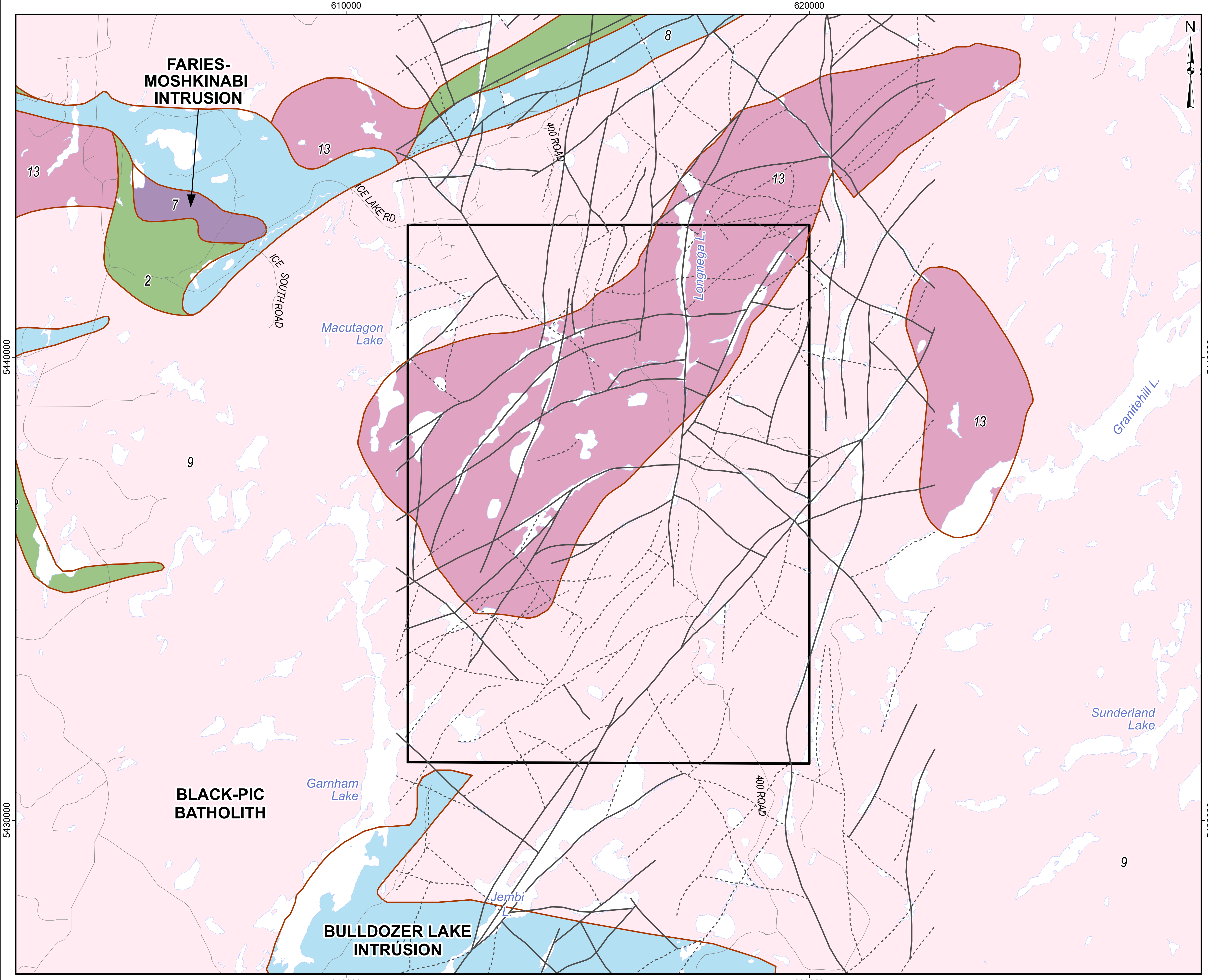
PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: **Density of Integrated Lineaments with High and Medium Certainty for the Black-Pic Batholith Area - West**

DESIGN	KR	02 SEP 2014	**Figure 5.13**	REVISION 4
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

File: SRK_NWMO_ManFindExt_Fig5.13_BPW_Density


610000
620000
5440000
5430000
FARIES-MOSHKINABI INTRUSION
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
Macutagon Lake
Garnham Lake
Jembi L.
Longnega L.
Granitehill L.
Sunderland Lake
400 ROAD
ICE LAKE RD
ICE SOUTH ROAD
13
7
2
8
9
N
LEGEND
Withdrawal Area
Local Road
Waterbody
Bedrock Geology
Geological Boundary
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks
Magnetic Lineament
Unclassified
Medium Certainty
High Certainty
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Magnetic Lineaments of High and Medium Certainty of the Black-Pic Batholith Area - East
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 5.14
REVISION 3
UTM ZONE 16N
NAD 1983
1:80,000
File: SRK_NWMO_ManFindExt_Fig5.14_BPE_MagLin



LEGEND

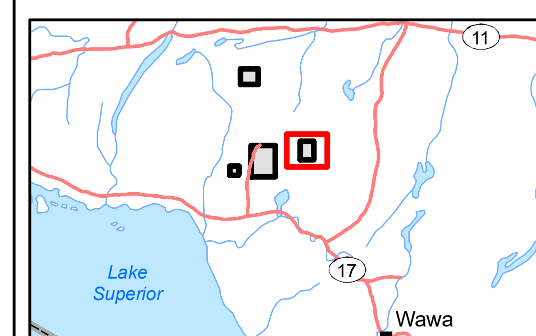
Withdrawal Area
Local Road
Waterbody

Bedrock Geology

Geological Boundary
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks

Surficial Lineament

Medium Certainty
High Certainty



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Surficial Lineaments of High and Medium Certainty of the Black-Pic Batholith Area - East

DESIGN	KR	02 SEP 2014	Figure 5.15	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

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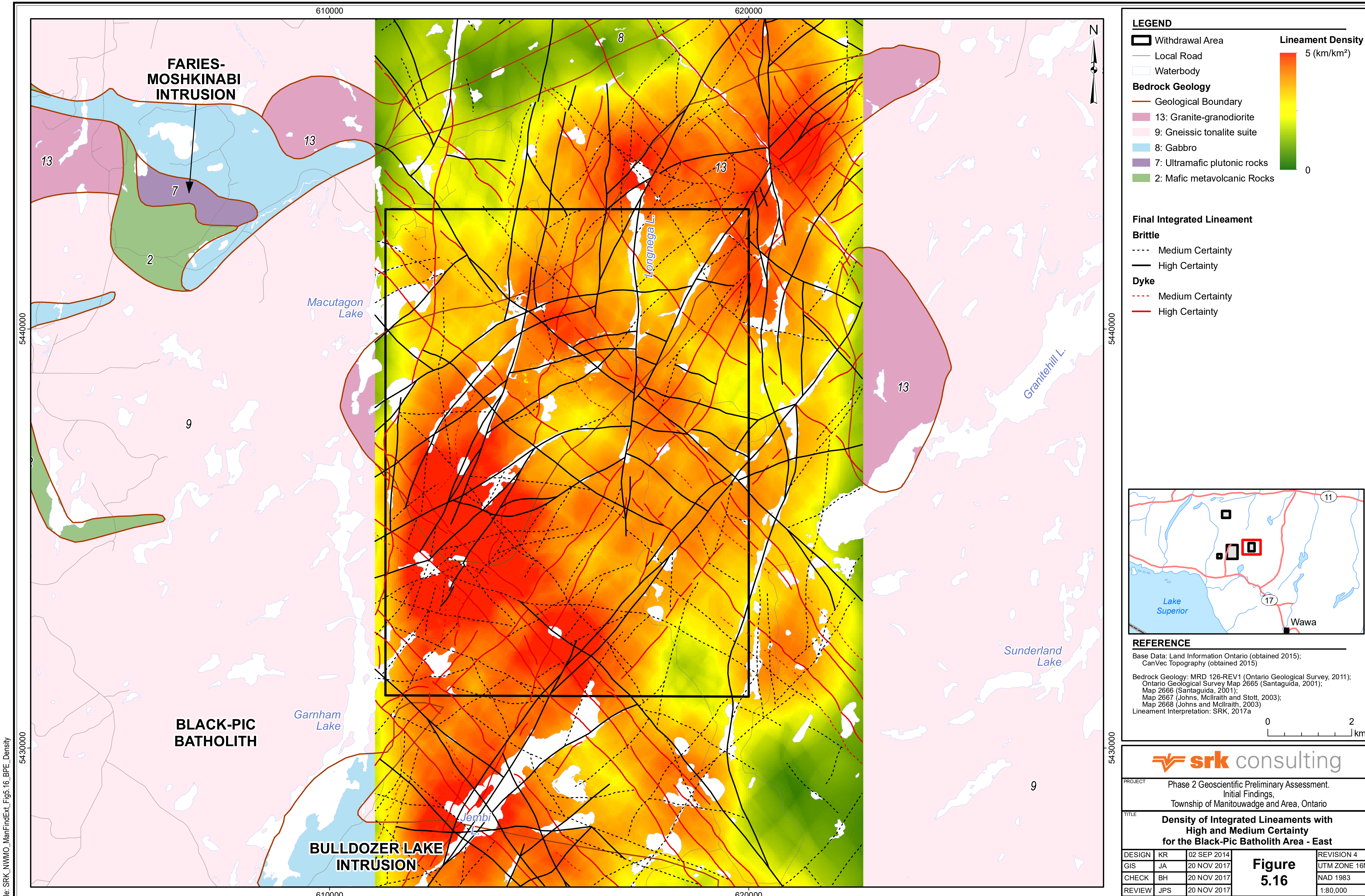
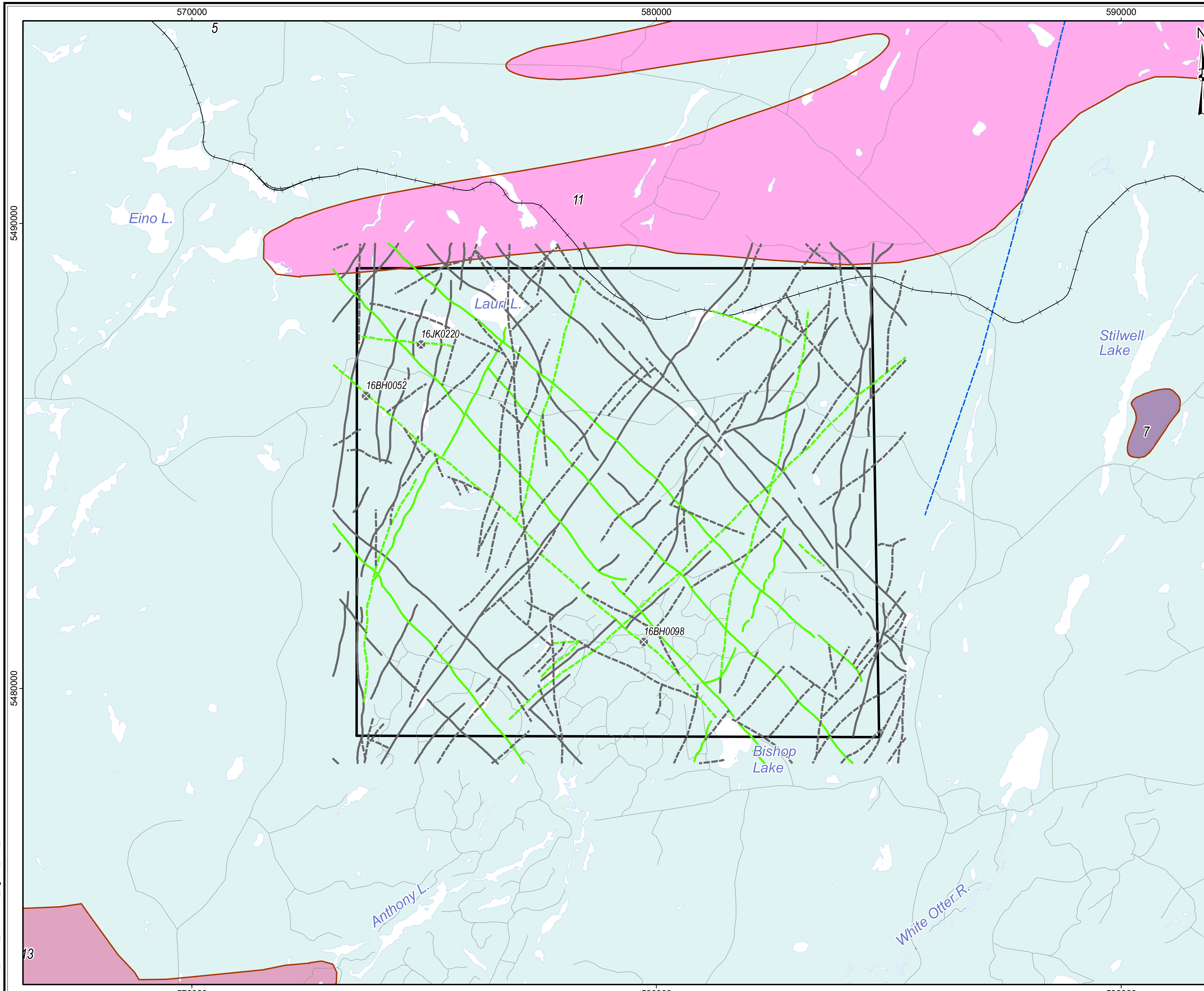


610000
620000
5440000
5430000
N
FARIES-
MOSHKINABI
INTRUSION
13
7
2
8
9
Macutagon
Lake
Longnega L.
Granitehill L.
Sunderland
Lake
Garnham
Lake
Jembi
BLACK-PIC
BATHOLITH
BULLDOZER LAKE
INTRUSION
LEGEND
Withdrawal Area
Local Road
Waterbody
Bedrock Geology
Geological Boundary
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks
Lineament Density
5 (km/km²)
0
Final Integrated Lineament
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
11
17
Lake
Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario
TITLE
Density of Integrated Lineaments with
High and Medium Certainty
for the Black-Pic Batholith Area - East
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure
5.16
REVISION 4
UTM ZONE 16N
NAD 1983
1:80,000
File: SRK_NWMO_ManFindExt_Fig5.16_BPE_Density



LEGEND

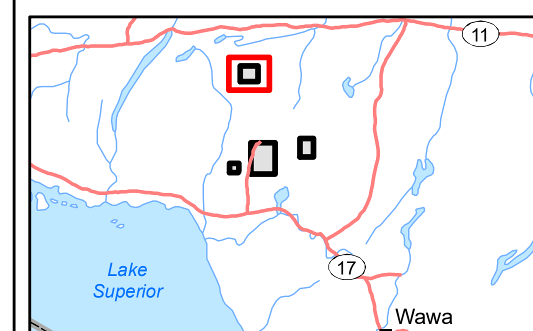
- Withdrawal Area
- Main Road
- Local Road
- Railway
- Waterbody

Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 11: Granite-granodiorite
- 7: Ultramafic plutonic rocks
- 5: Metasedimentary rocks

Integrated Lineaments

- Brittle - Field Verified
- Brittle - Not Field Verified
- Dyke - Field Verified
- Dyke - Not Field Verified
- Photo of Field Evidence of Lineaments



REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Field Verified Lineaments of the Quetico Area

DESIGN	KR	02 SEP 2014	Figure 5.17	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

File: SRK_NWMO_ManFindExt_Fig5.17_Quet_VerLin

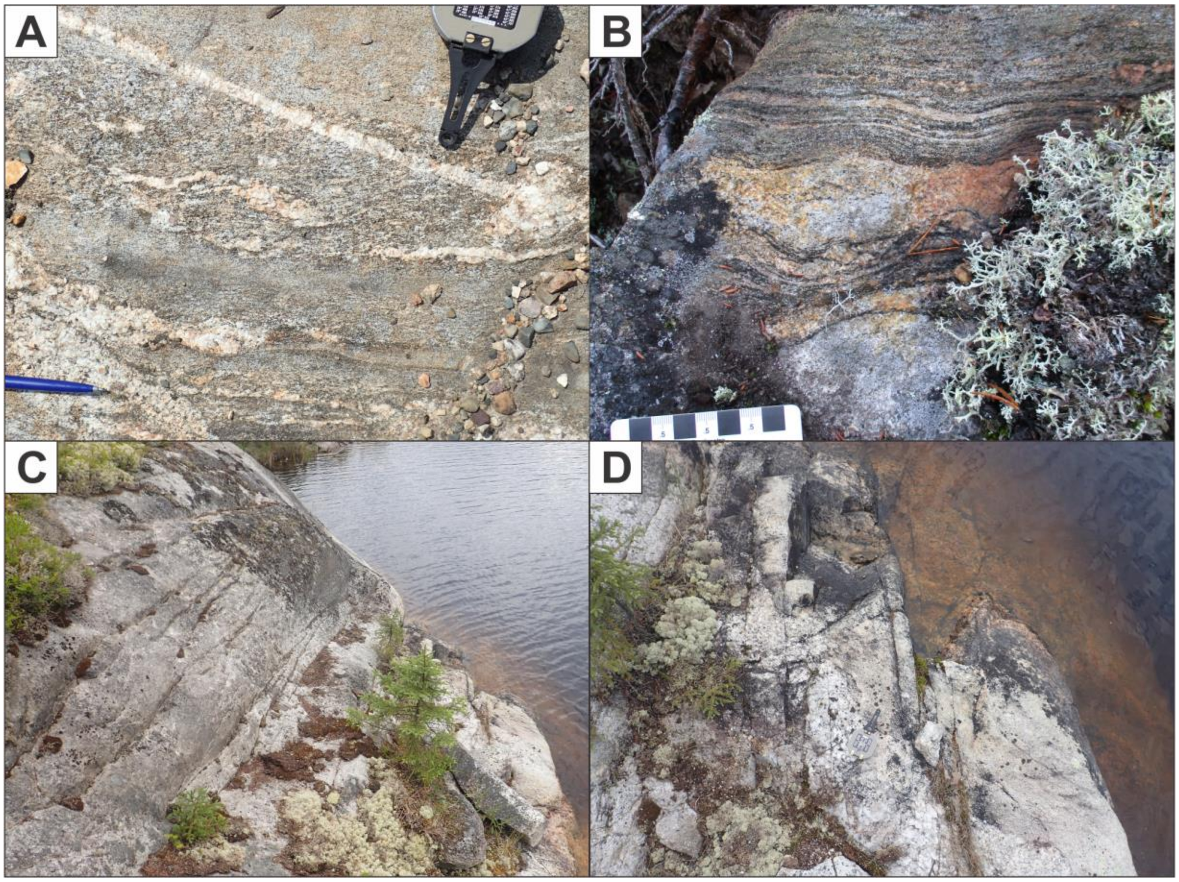


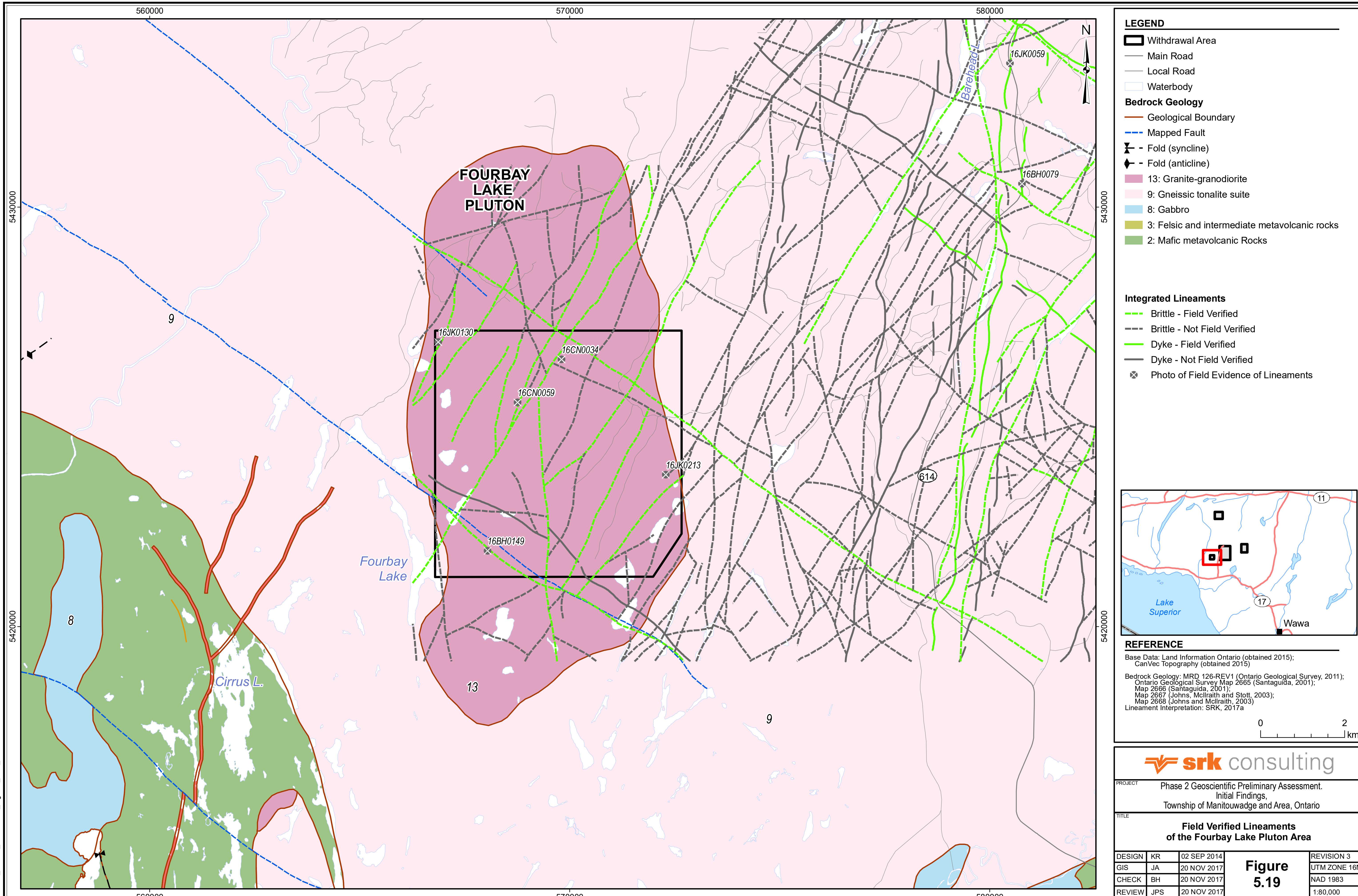
Figure 5.18: Photos of Field Evidence of Lineaments for the Quetico Area

A: Strongly foliated migmatitic metasedimentary rock oriented parallel and located adjacent to ductile lineament. (Stn 16BH0098, looking N, compass for scale).

B: Gneissic migmatitic metasedimentary rock oriented parallel and located adjacent to ductile lineament. (Stn 16JK0220, looking S, card for scale).

C: Well-developed joint sets oriented parallel to linear lake and brittle lineament. (Stn 16BH0052, looking NW, compass for scale).

D: Close-spaced joint sets (with local slickenlines – not visible), oriented subparallel to, and located adjacent to brittle lineament. (Stn 16BH0052, looking NW, compass for scale).



srk consulting

PROJECT Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE **Field Verified Lineaments of the Fourbay Lake Pluton Area**

DESIGN	KR	02 SEP 2014	Figure 5.19	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

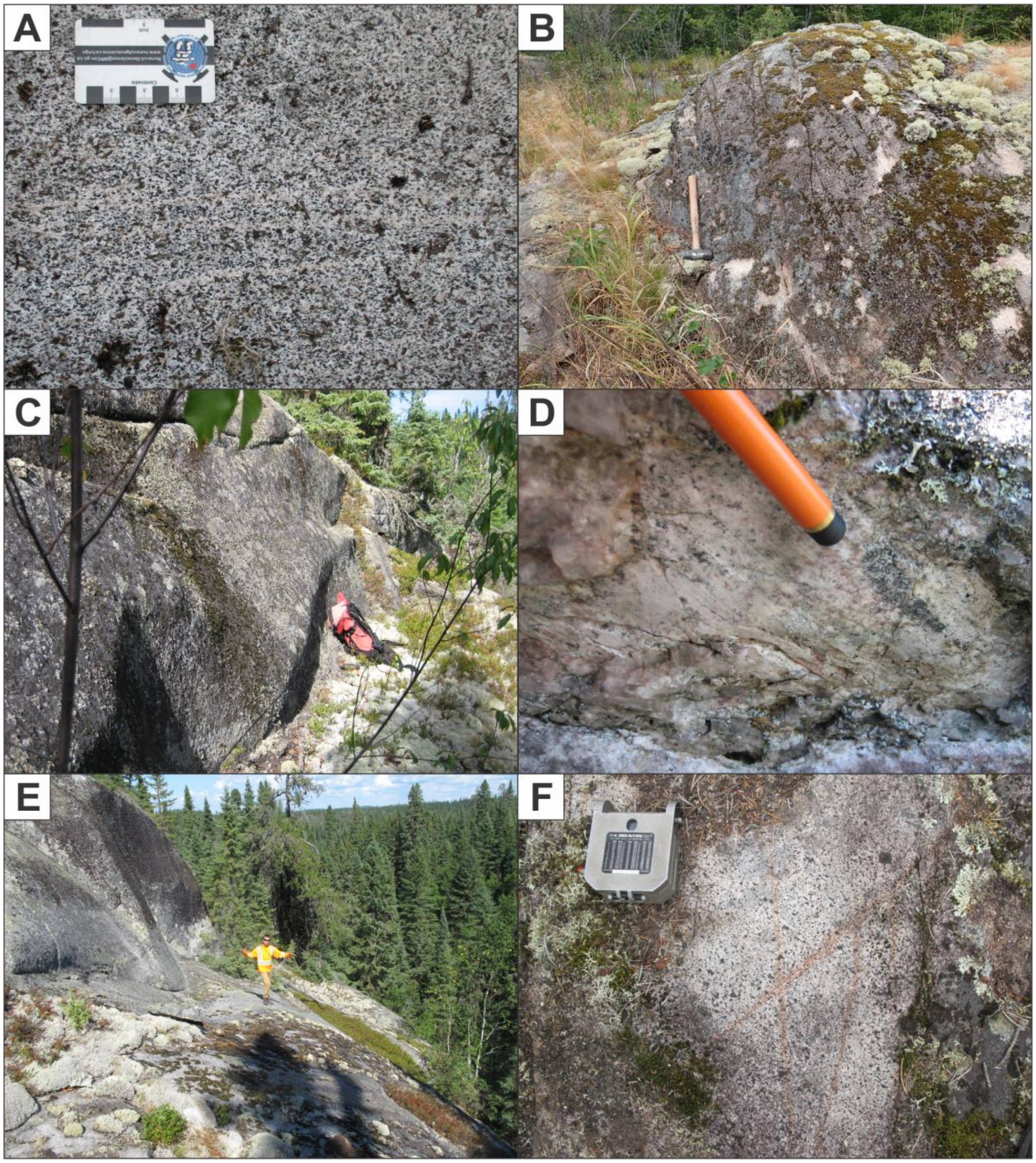


Figure 5.20: Photos of Field Evidence of Lineaments for the Fourbay Lake Pluton Area

A: Weakly foliated granodiorite oriented parallel and located adjacent to ductile lineament. (Stn 16JK0213, looking W, scale card for scale).

B: Close-spaced WNW striking hematite stained joint set oriented sub-parallel and located adjacent to mapped major brittle fault and brittle lineament. (Stn 16BH0149, looking W, hammer for scale).

C: Multi-metre scarps formed along joints and brittle faults oriented sub-parallel to and located along northeast-trending brittle lineament. (Stn 16JK0130, looking NE, backpack for scale).

D: Shallow-plunging slickenlines developed along northeast-trending brittle faults in picture (C), oriented sub-parallel and located adjacent to brittle lineament. (Stn 16JK0130, looking NE, pen for scale).

E: Series of multi-metre tall northeast-trending cliffs located adjacent to northeast-oriented brittle lineament. (Stn 16CN0059, looking NE, person for scale).

F: Typical hematite stained joints oriented northeast and east, located adjacent to northeast-trending brittle lineament. (Stn 16CN0034, looking NE, compass for scale).

LEGEND

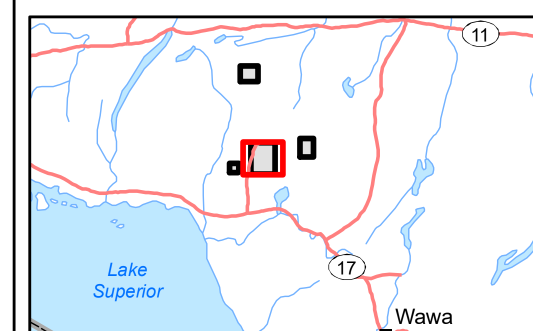
Withdrawal Area
Main Road
Local Road
Waterbody

Bedrock Geology

Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
2: Mafic metavolcanic Rocks

Integrated Lineaments

Brittle - Field Verified
Brittle - Not Field Verified
Dyke - Field Verified
Dyke - Not Field Verified
Photo of Field Evidence of Lineaments



REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Field Verified Lineaments of the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	Figure 5.21	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

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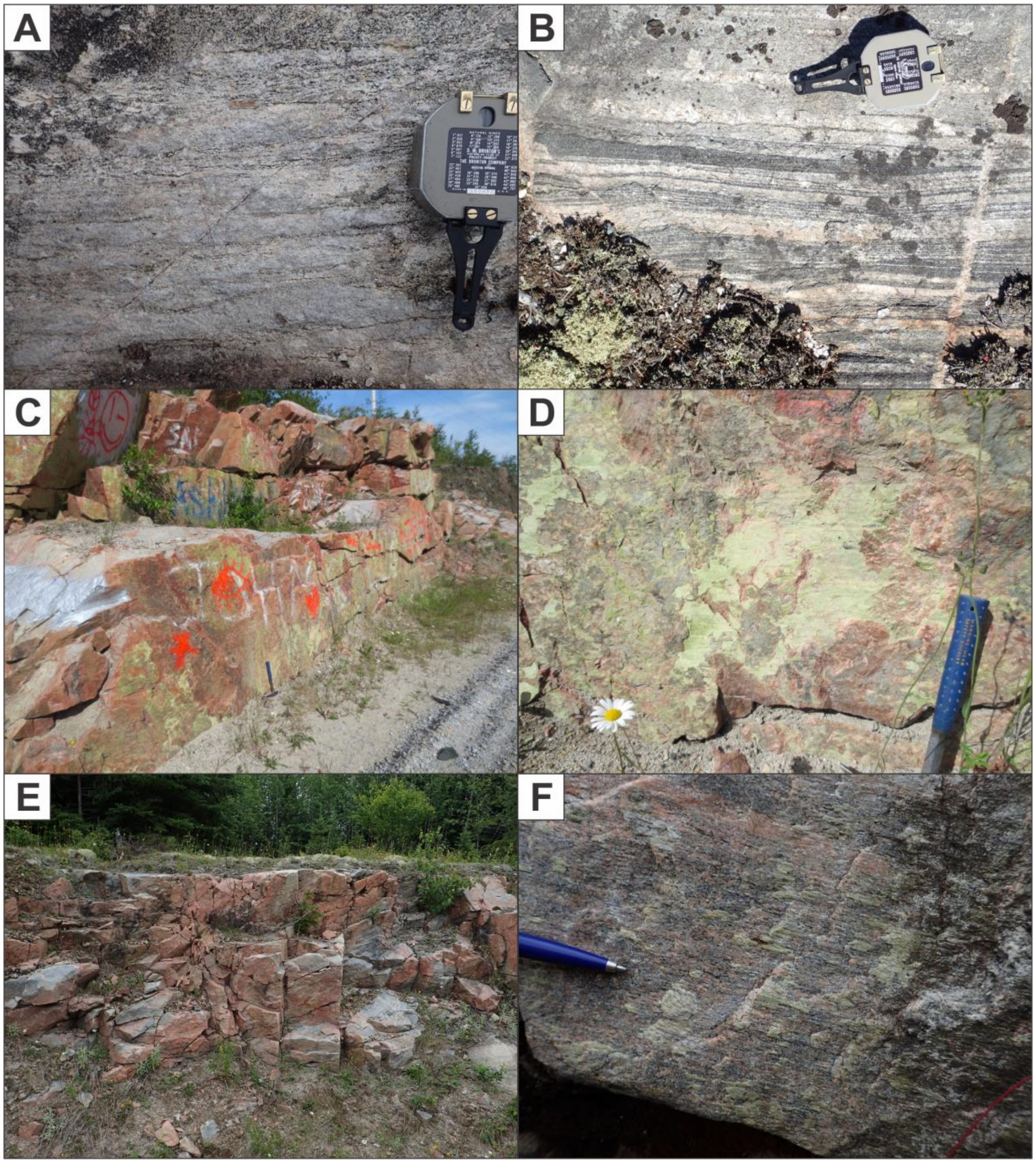


Figure 5.22a: Photos of Field Evidence of Lineaments for the Black-Pic Batholith Area - West

A: Domain of stronger foliated tonalite parallel and coincident with E-trending ductile lineament. (Stn 16BH0062, looking S, compass for scale).

B: Strong gneissic layering in tonalite oriented parallel and located adjacent to N-trending ductile lineament. (Stn 16BH0035, looking E, compass for scale).

C: N-trending fault scarp pervasively hematite and epidote altered, and located adjacent to the N-trending lineament defining the Barehead Lake fault zone. (Stn 16JK0059, looking NW, hammer for scale).

D: Sub-horizontal epidote slickenlines along hematite stained fault surface, located adjacent to N-trending lineament defining the Barehead Lake fault zone. (Stn 16JK0059, looking W, hammer for scale).

E: Pervasively hematite stained fault surfaces subparallel to N-trending lineament defining the Barehead fault zone, and cut by an orthogonal joint set. (Stn 16BH0079, looking NE, no scale).

F: Shallow-plunging epidote slickenlines and slickensteps along fault surface parallel and adjacent to N-trending lineament defining the Barehead Lake fault zone. (Stn 16BH0079, looking SW, pen for scale).

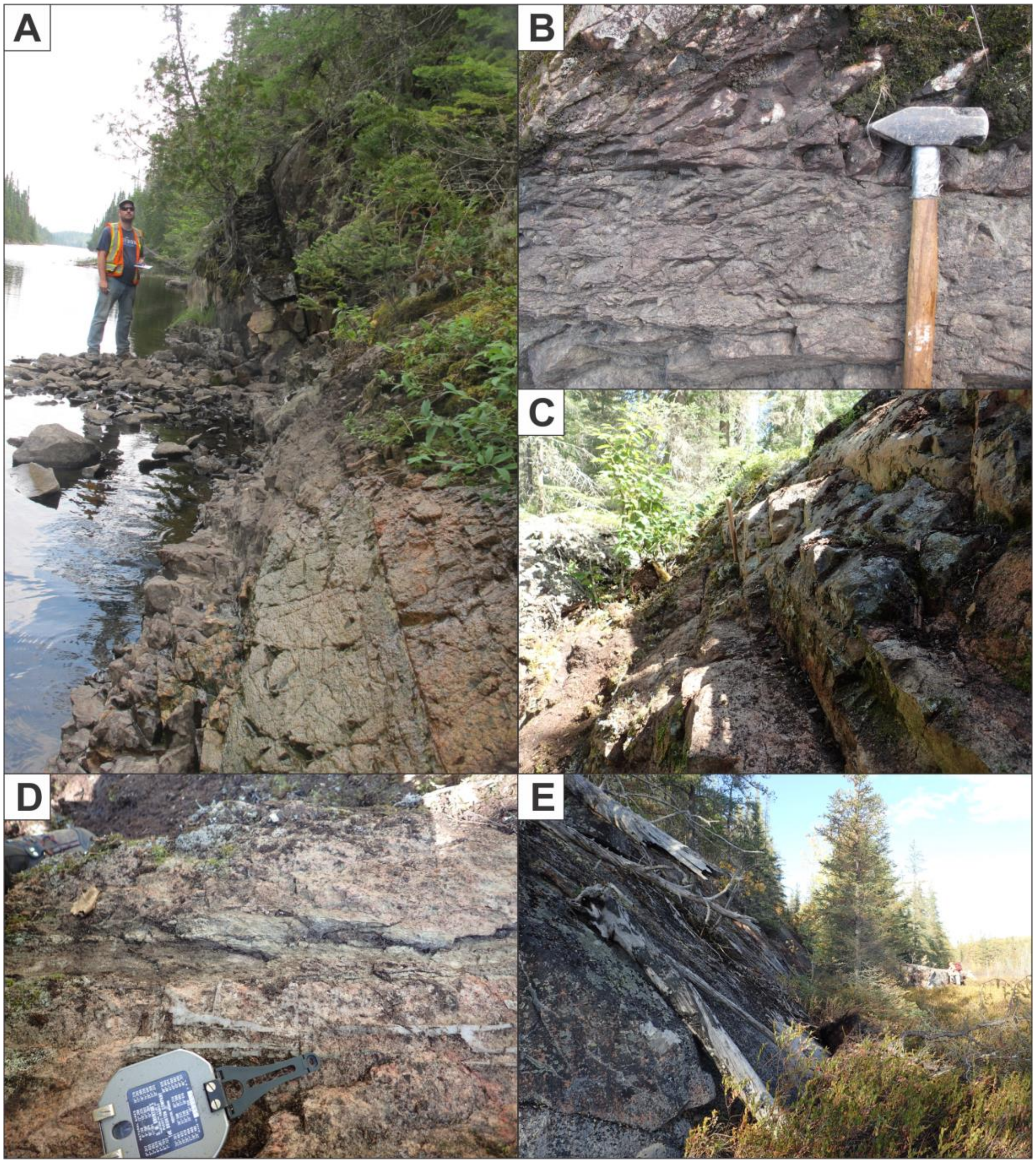


Figure 5.22b: Photos of Field Evidence of Lineaments for the Black-Pic Batholith Area - West (Continued)

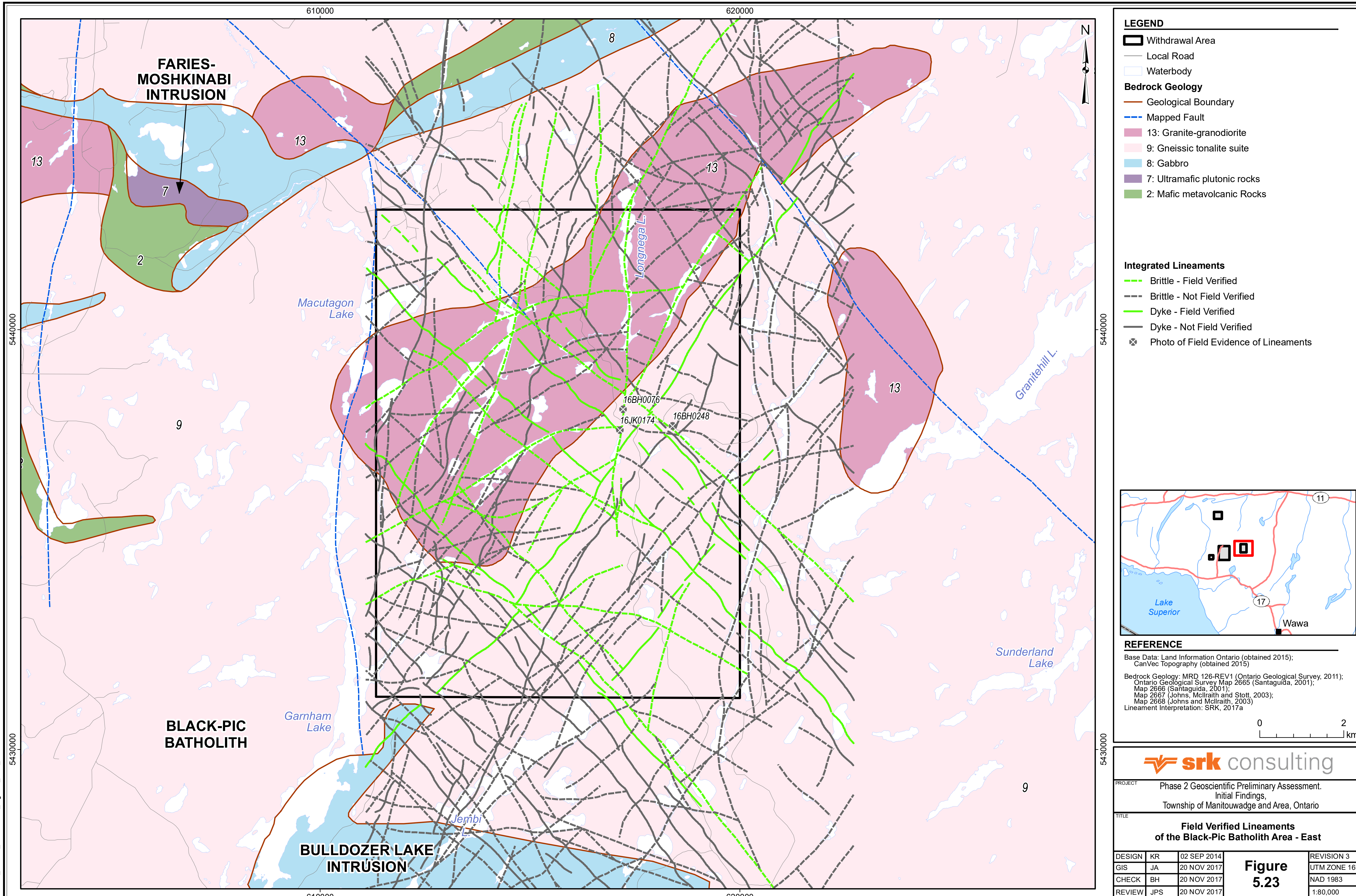
A: NE-trending brittle-ductile fault defining the Black River and coincident with a major NE-trending brittle lineament. (Stn 16CN0087, looking NE, person for scale).

B: Completely transposed brittle-ductile fabric developed within fault pictured in (A), indicating a dextral sense of motion. (Stn 16CN0087, looking SE, hammer for scale).

C: Strong and closely-spaced NE-trending joints and scarps oriented parallel and located adjacent to the Black River brittle-ductile fault and associated lineament. (Stn 16BH0157, looking NE, hammer for scale).

D: Brittle-ductile epidote shear zone and parallel extensional quartz veins defining the Black River fault and associated brittle lineament. (Stn 16JK0059, looking W, hammer for scale).

E: Multi-metre NE-trending fault scarp located adjacent and oriented sub-parallel to NE-trending brittle lineament. (Stn 16BH0236, looking N, person for scale).



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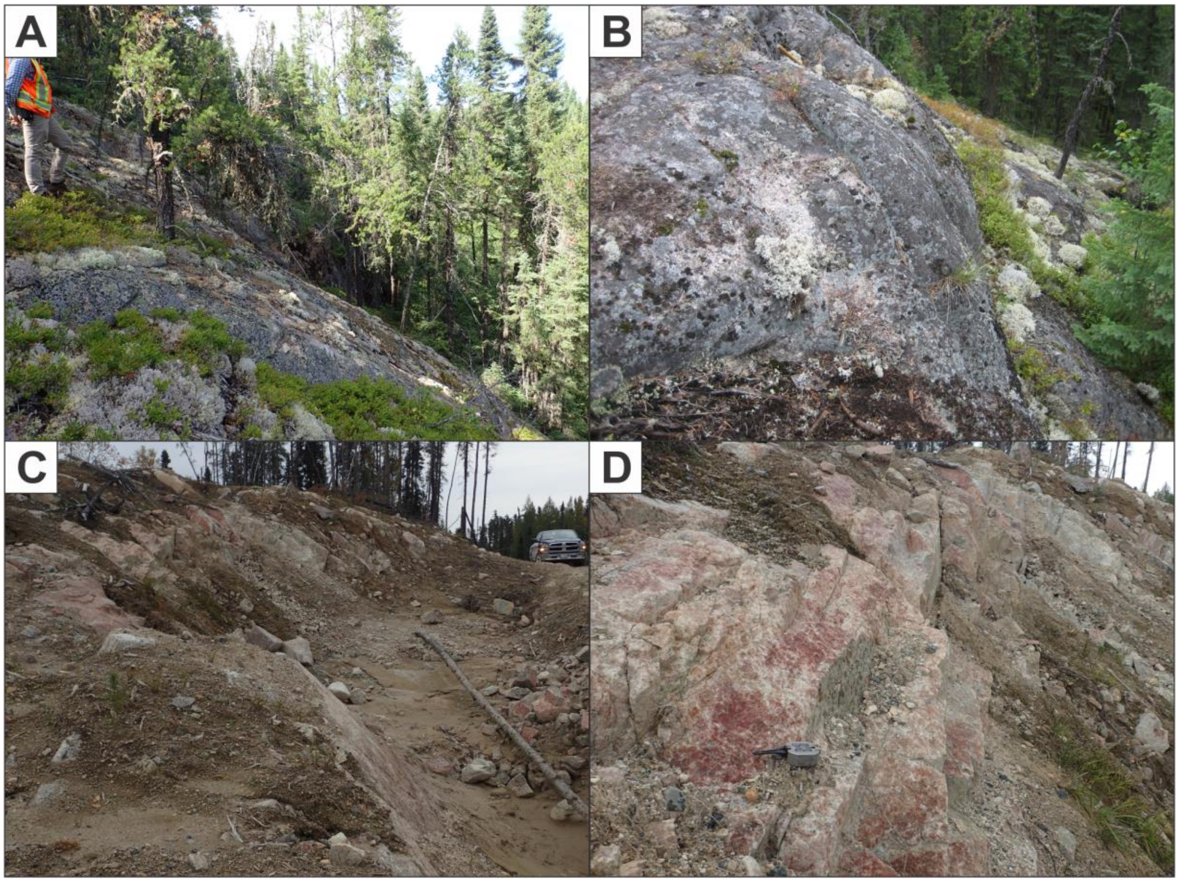


Figure 5.24: Photos of Field Evidence of Lineaments for the Black-Pic Batholith Area - East

A. NE-trending scarp forming secondary structure coincident with and related to N-trending brittle lineament. (Stn 16BH0076, looking NE, person for scale).

B. N- to NNE-trending scarps oriented sub-parallel and located adjacent to N-trending brittle lineament. (Stn 16JK0174, looking NE, hammer for scale).

C. Pervasively hematite altered outcrop with closely-spaced joints oriented parallel and located along NW-trending brittle lineament. (Stn 16BH0248, looking SE, truck for scale).

D. Close-spaced hematite stained joints oriented parallel and located along NW-trending brittle lineament. (Stn 16BH0248, looking SE, compass for scale).

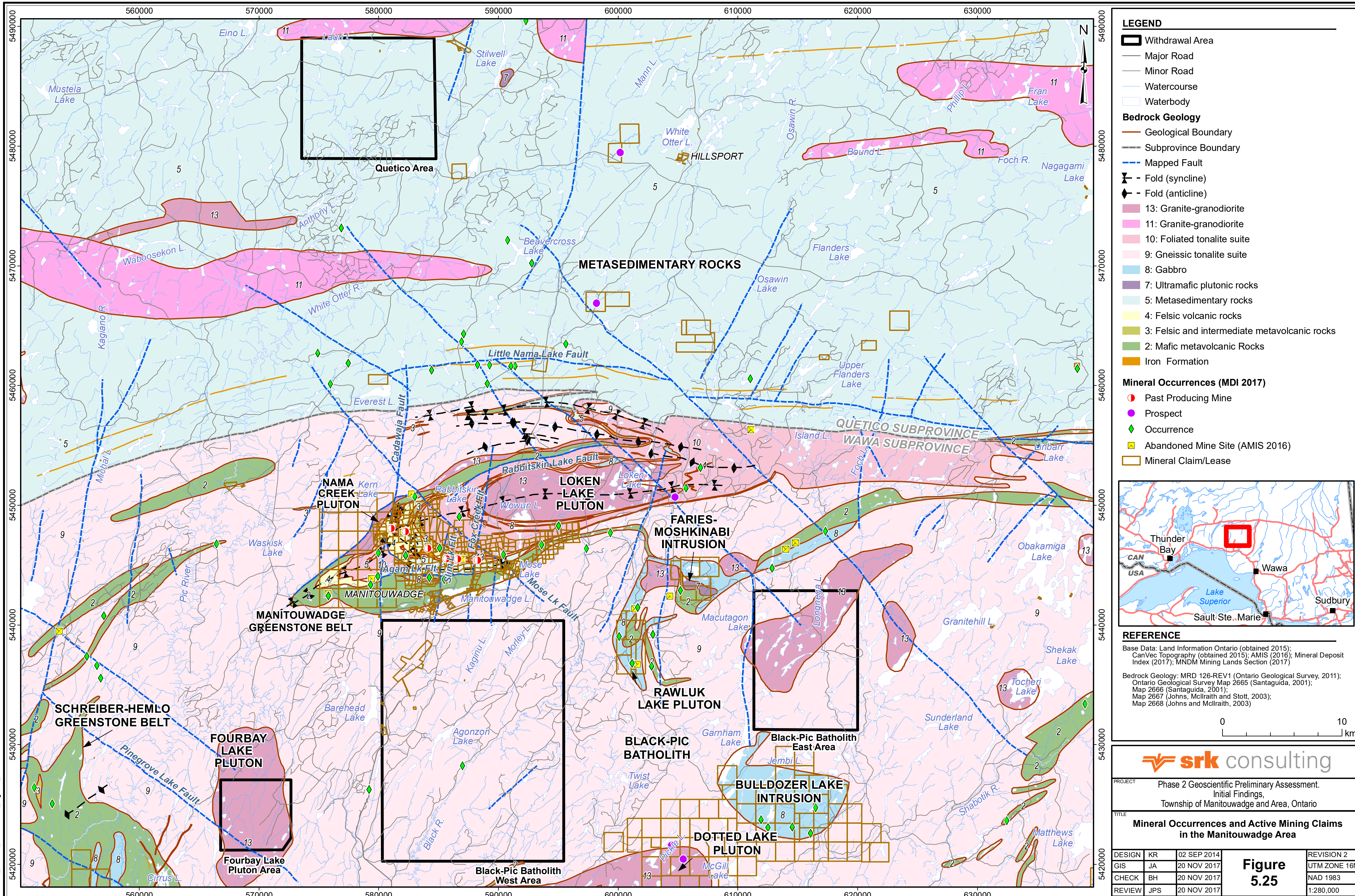
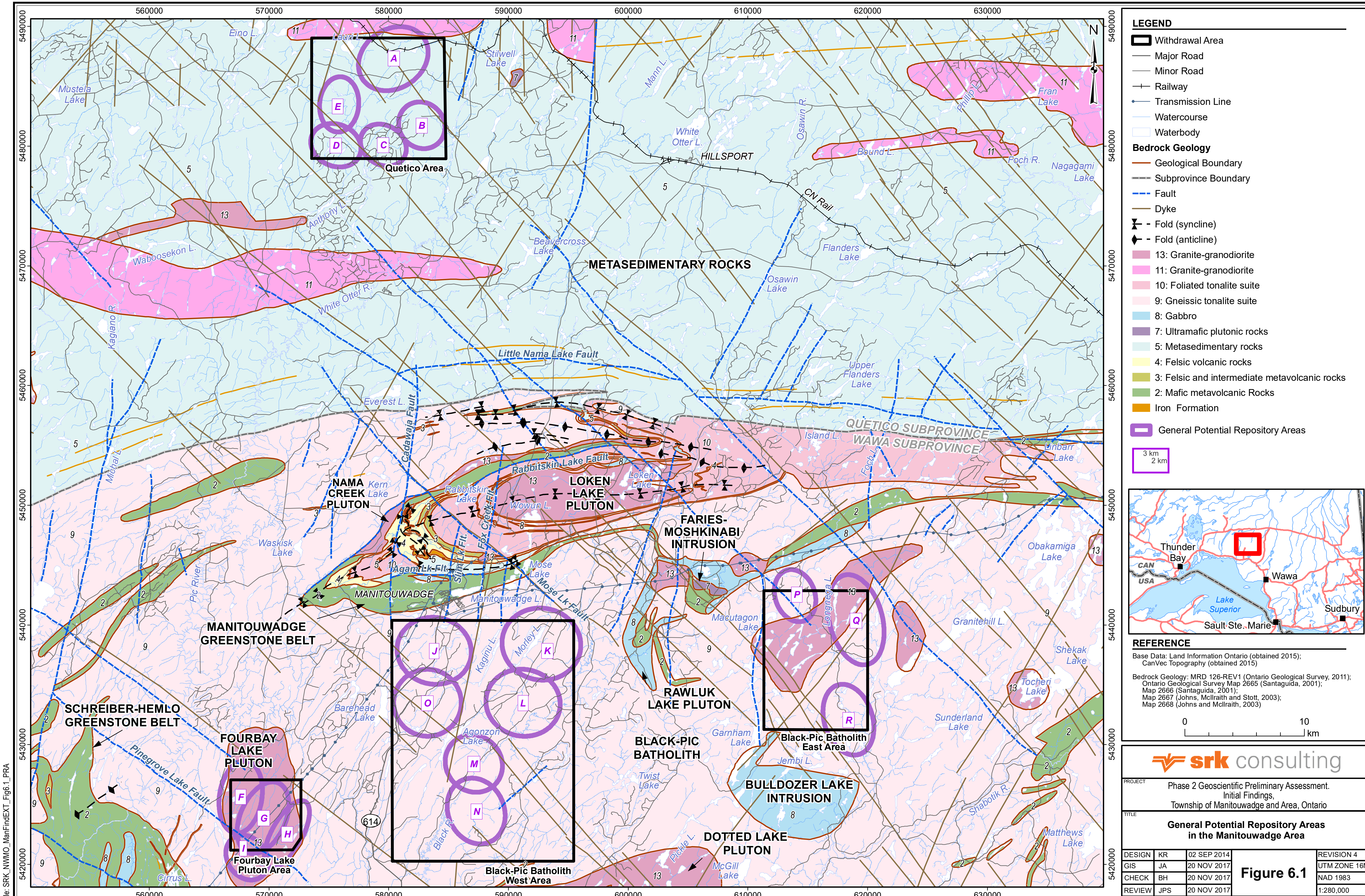


Figure 5.25

Mineral Occurrences and Active Mining Claims in the Manitouwadge Area


LEGEND
Withdrawal Area
Major Road
Minor Road
Railway
Transmission Line
Watercourse
Waterbody
Bedrock Geology
Geological Boundary
Subprovince Boundary
Fault
Dyke
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
11: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
4: Felsic volcanic rocks
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
General Potential Repository Areas
3 km
2 km
Thunder Bay
Wawa
Sudbury
Sault Ste. Marie
Lake Superior
CAN
USA
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
0
10
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
General Potential Repository Areas in the Manitouwadge Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.1
REVISION 4
UTM ZONE 16N
NAD 1983
1:280,000
METASEDIMENTARY ROCKS
QUETICO SUBPROVINCE
WAWA SUBPROVINCE
Quetico Area
HILLSPORT
CN Rail
Little Nama Lake Fault
Rabbitskin Lake Fault
NAMA CREEK PLUTON
LOKEN LAKE PLUTON
FARIES-MOSHKINABI INTRUSION
MANITOUWADGE
MANITOUWADGE GREENSTONE BELT
SCHREIBER-HEMLO GREENSTONE BELT
FOURBAY LAKE PLUTON
Fourbay Lake Pluton Area
Pinegrove Lake Fault
Mose Lk Fault
Cadawaja Fault
Agam Lk Flt.
Fox Creek Flt.
RAWLUK LAKE PLUTON
BLACK-PIC BATHOLITH
Black-Pic Batholith East Area
Black-Pic Batholith West Area
BULLDOZER LAKE INTRUSION
DOTTED LAKE PLUTON
A B C D E F G H I J K L M N O P Q R
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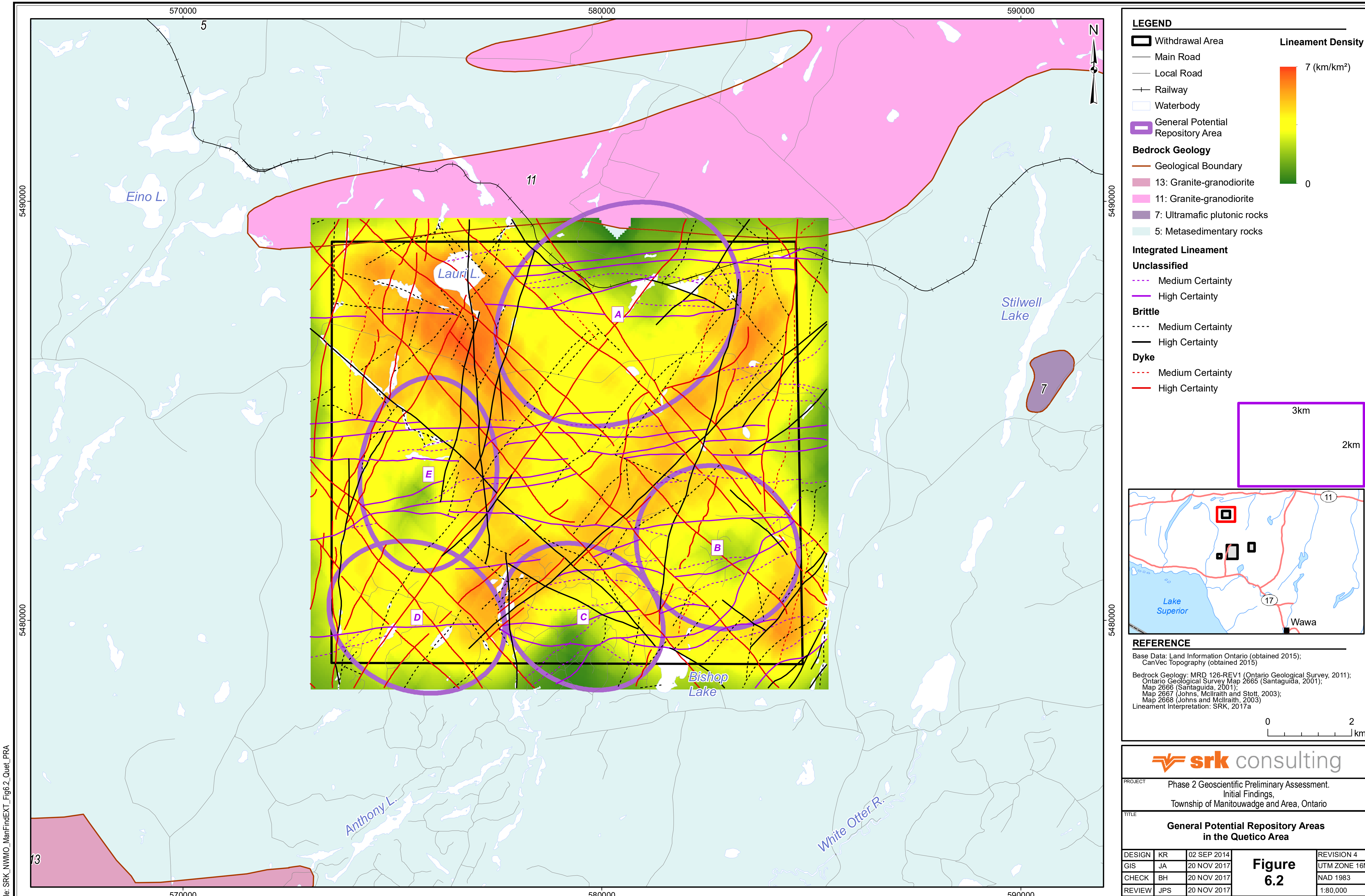

570000
580000
590000
5490000
5480000
5
11
Eino L.
Lauri L.
Stilwell Lake
Bishop Lake
Anthony L.
White Otter R.
A
B
C
D
E
7
13
N
LEGEND
Withdrawal Area
Main Road
Local Road
Railway
Waterbody
General Potential Repository Area
Bedrock Geology
Geological Boundary
13: Granite-granodiorite
11: Granite-granodiorite
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
Integrated Lineament
Unclassified
Medium Certainty
High Certainty
Brittle
Medium Certainty
High Certainty
Dyke
Medium Certainty
High Certainty
Lineament Density
7 (km/km²)
0
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
General Potential Repository Areas in the Quetico Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.2
REVISION 4
UTM ZONE 16N
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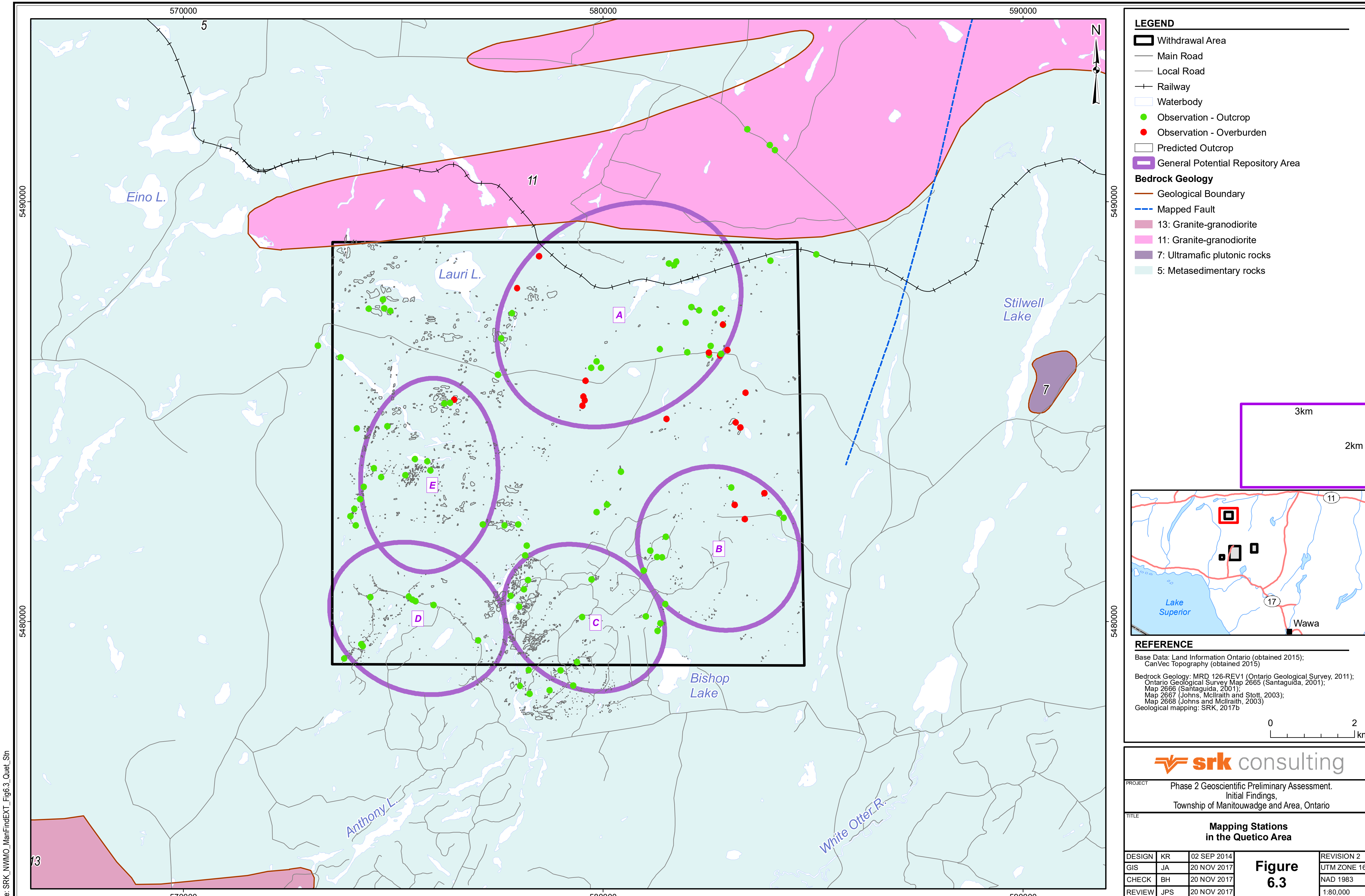
1:80,000
File: SRK_NWMO_ManFindEXT_Fig6.2_Quet_PRA

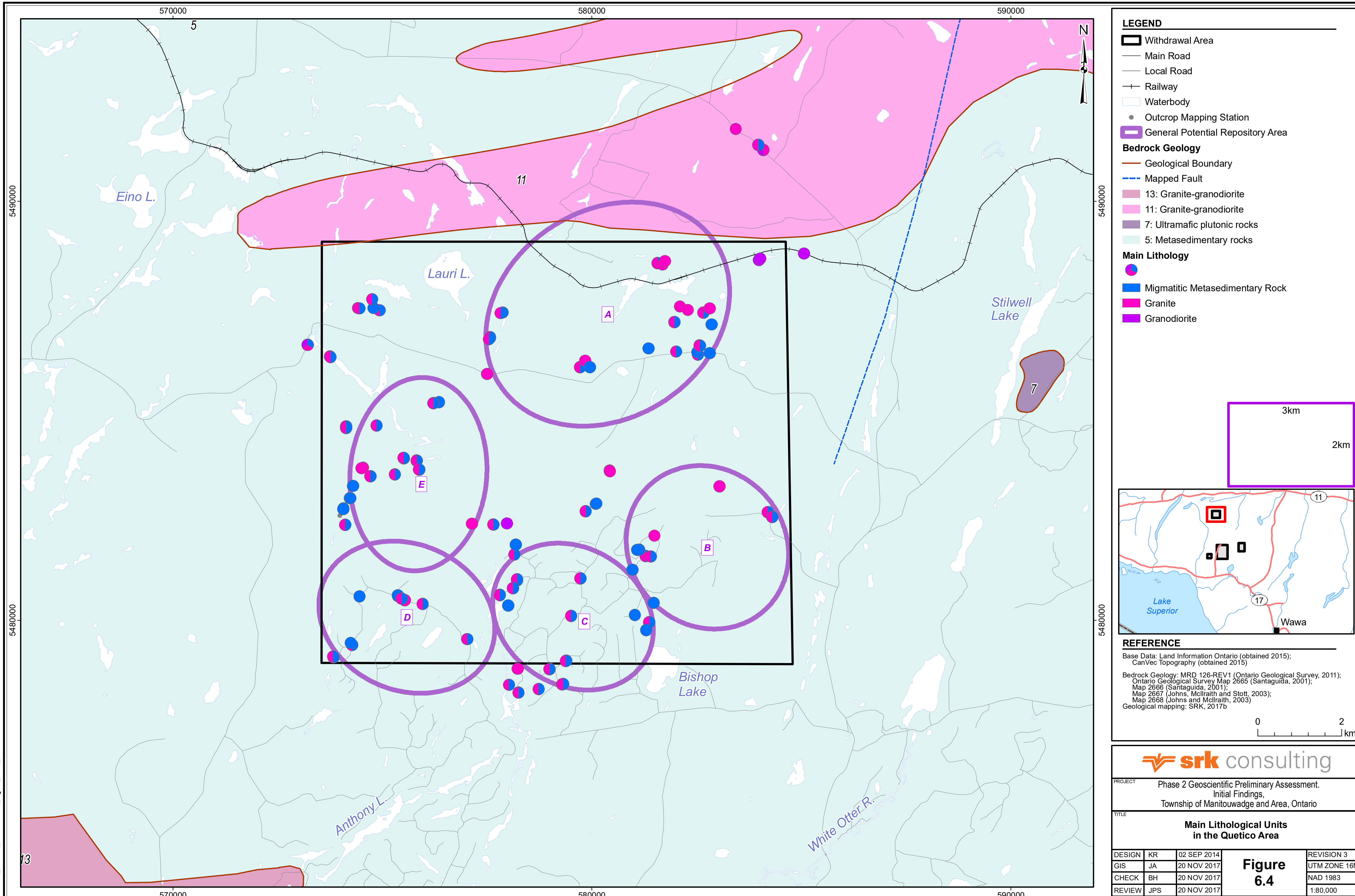


srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Mapping Stations in the Quetico Area

DESIGN	KR	02 SEP 2014	Figure 6.3	REVISION 2
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000


570000
580000
590000
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Eino L.
Lauri L.
Stilwell Lake
Bishop Lake
Anthony L.
White Otter R.
A
B
C
D
E
5
11
7
13
N
LEGEND
Withdrawal Area
Main Road
Local Road
Railway
Waterbody
Outcrop Mapping Station
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
11: Granite-granodiorite
7: Ultramafic plutonic rocks
5: Metasedimentary rocks
Main Lithology
Migmatitic Metasedimentary Rock
Granite
Granodiorite
3km
2km
Lake Superior
Wawa
11
17
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Main Lithological Units in the Quetico Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.4
REVISION 3
UTM ZONE 16N
NAD 1983
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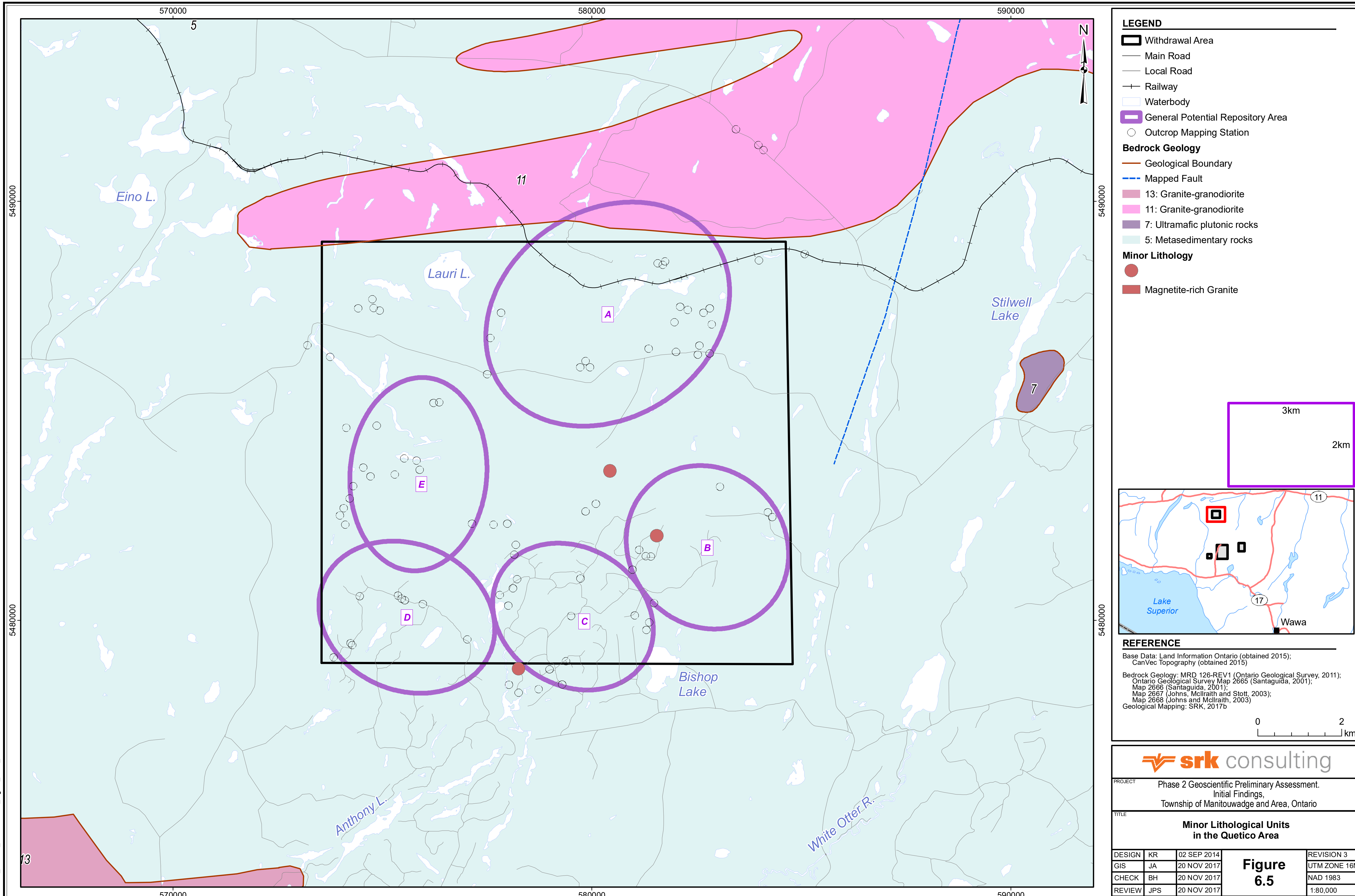

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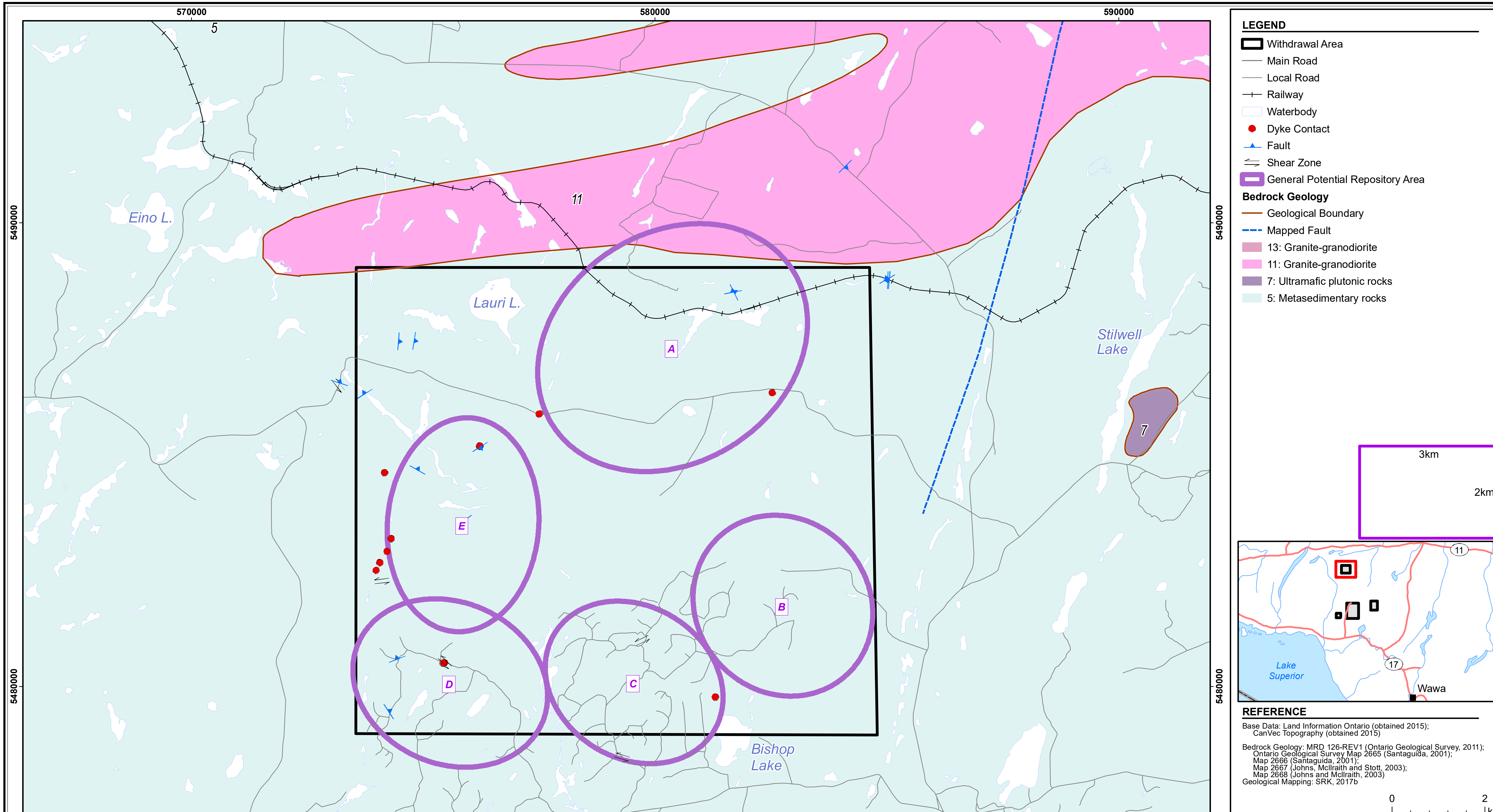

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Faults, Shear Zones and Dyke Contacts in the Quetico Area

DESIGN	KR	02 SEP 2014	Figure 6.6	REVISION 3
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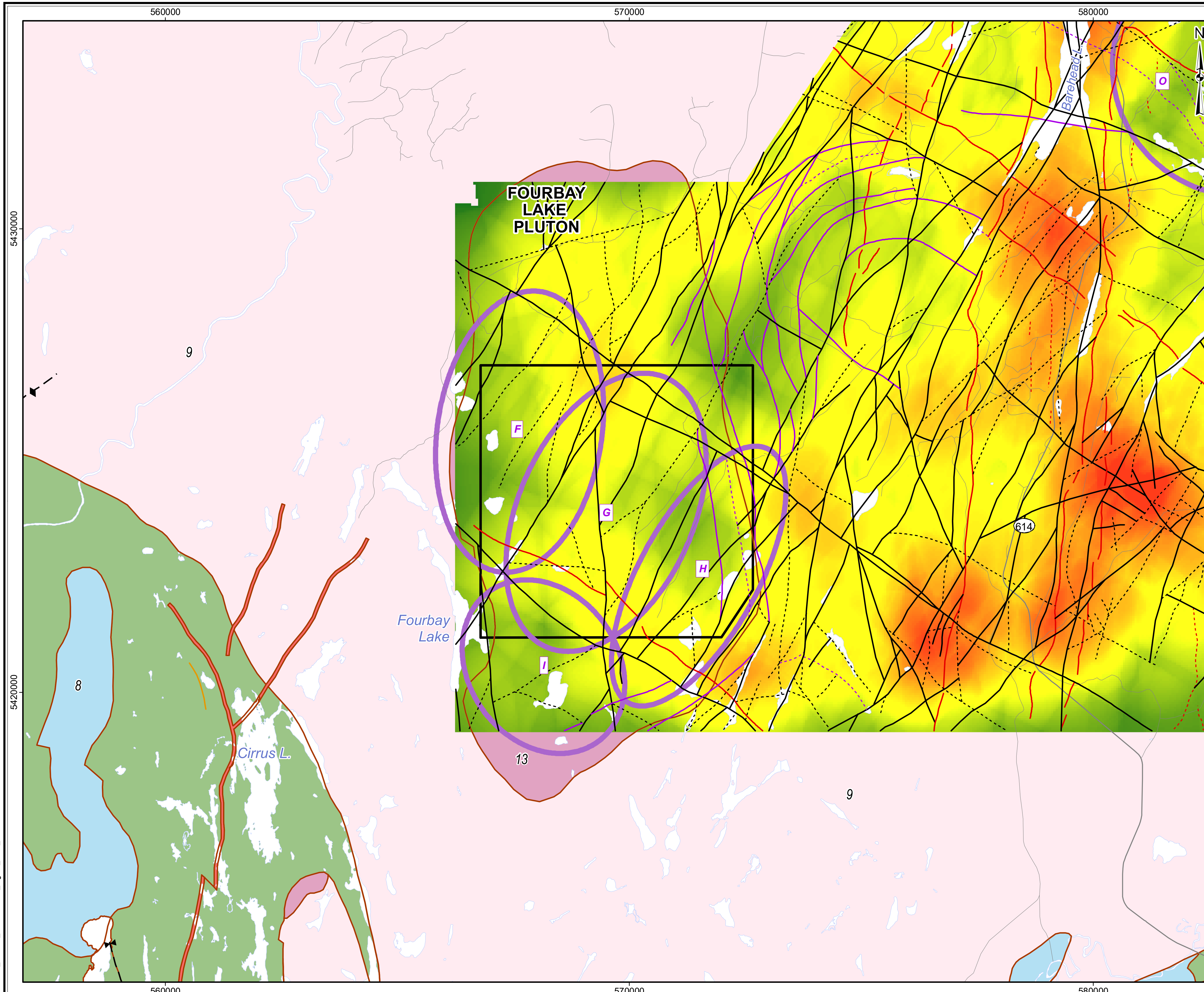
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000



LEGEND

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

Bedrock Geology

- Geological Boundary
- Fold (syncline)
- Fold (anticline)
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 3: Felsic and intermediate metavolcanic rocks
- 2: Mafic metavolcanic Rocks

Integrated Lineament

Unclassified

- Medium Certainty
- High Certainty

Brittle

- Medium Certainty
- High Certainty

Dyke

- Medium Certainty
- High Certainty

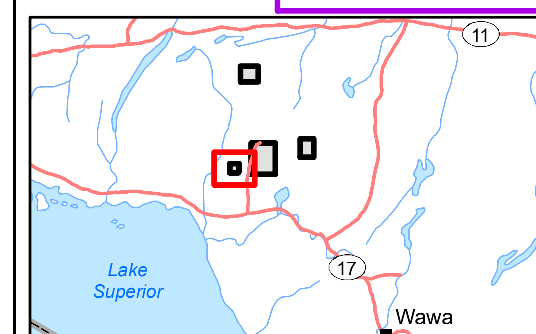
Lineament Density

7 (km/km²)

0

3km

2km



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)

Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT

Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE

General Potential Repository Areas in the Fourbay Lake Pluton Area

DESIGN	KR	02 SEP 2014	**Figure 6.7**	REVISION 4
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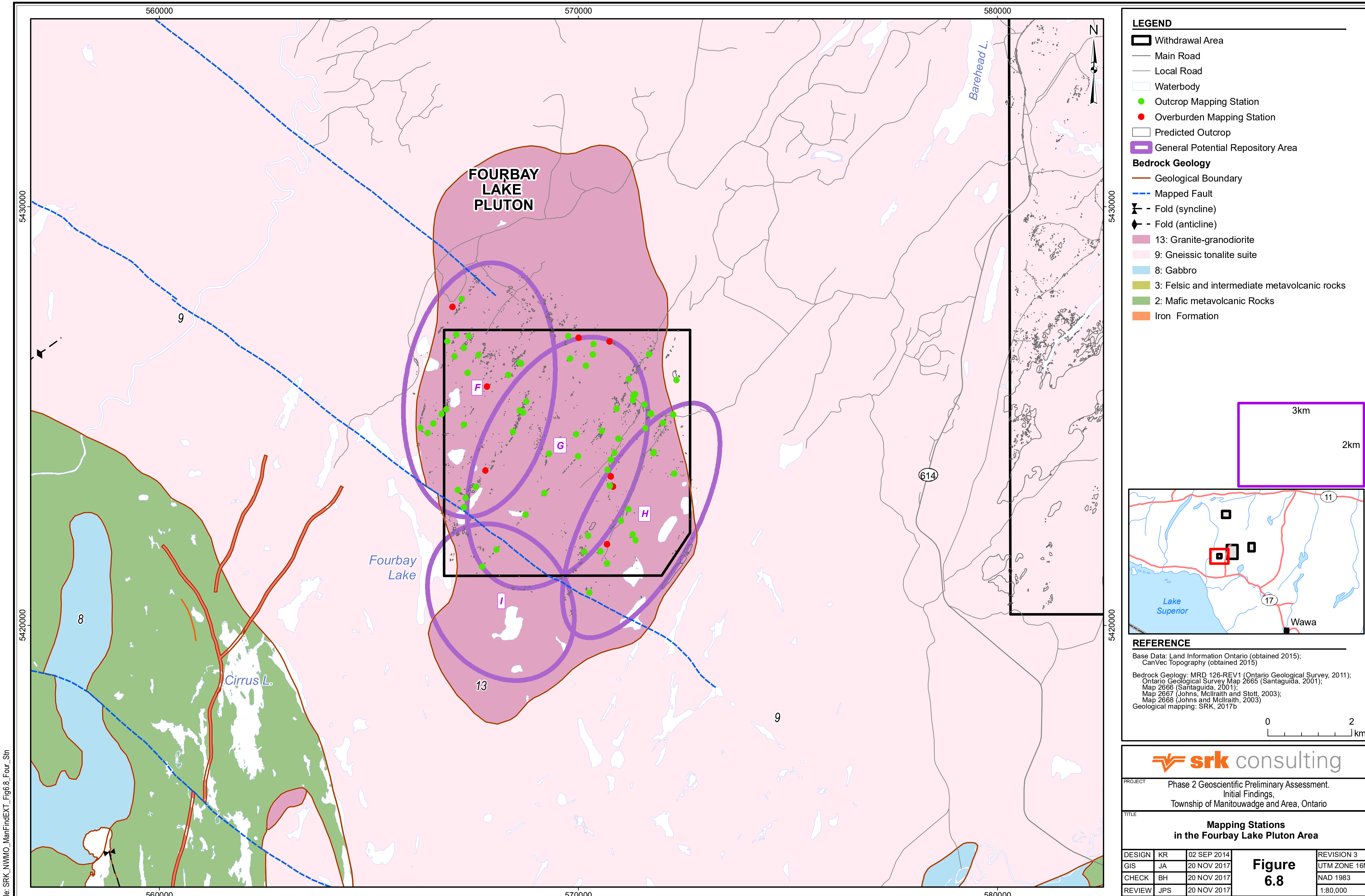
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000



560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
Barehead L.
Fourbay Lake
Cirrus L.
F
G
H
I
9
8
13
614
N
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop Mapping Station
Overburden Mapping Station
Predicted Outcrop
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Mapping Stations in the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.8
REVISION 3
UTM ZONE 16N
NAD 1983
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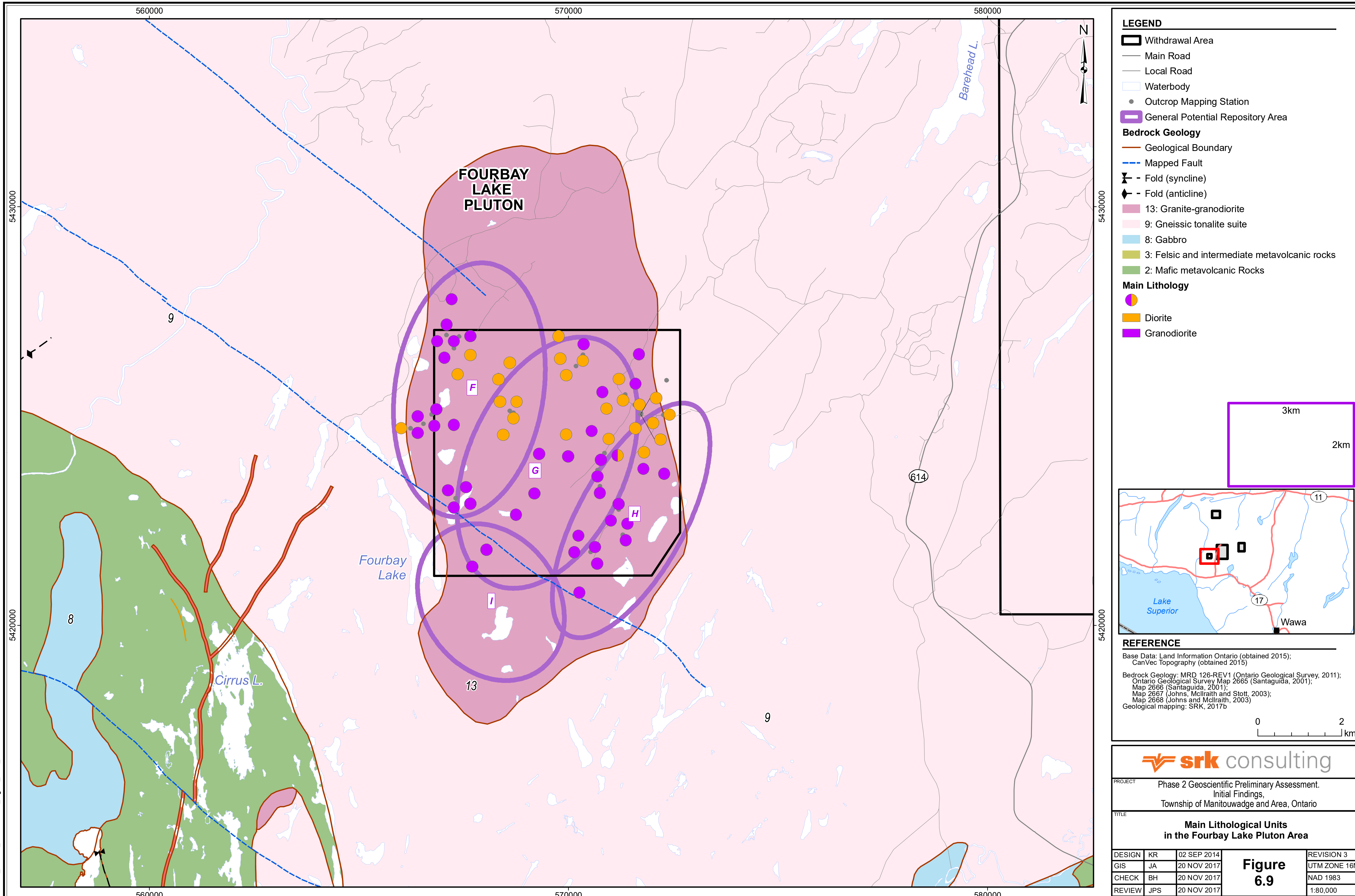
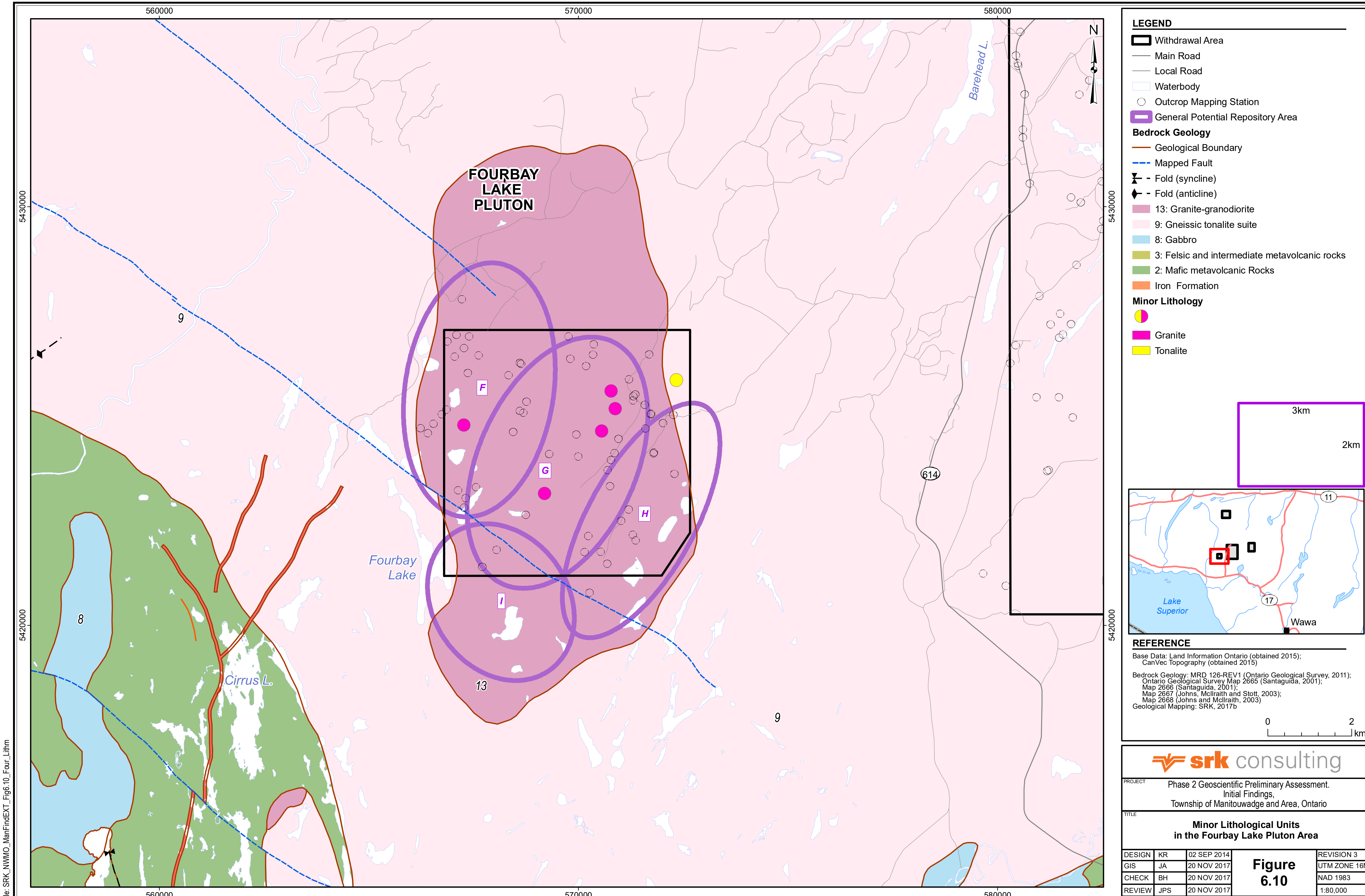


560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
Barehead L.
Fourbay Lake
Cirrus L.
9
8
13
F
G
H
I
614
N
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop Mapping Station
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Main Lithology
Diorite
Granodiorite
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Main Lithological Units in the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.9
REVISION 3
UTM ZONE 16N
NAD 1983
1:80,000
File: SRK_NWMO_ManFindEXT_Fig6.9_Four_Lith



560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
Fourbay Lake
Cirrus L.
Barehead L.
9
8
13
F
G
H
I
614
N
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop Mapping Station
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
Fold (syncline)
Fold (anticline)
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
Iron Formation
Minor Lithology
Granite
Tonalite
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Minor Lithological Units in the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.10
REVISION 3
UTM ZONE 16N
NAD 1983
1:80,000
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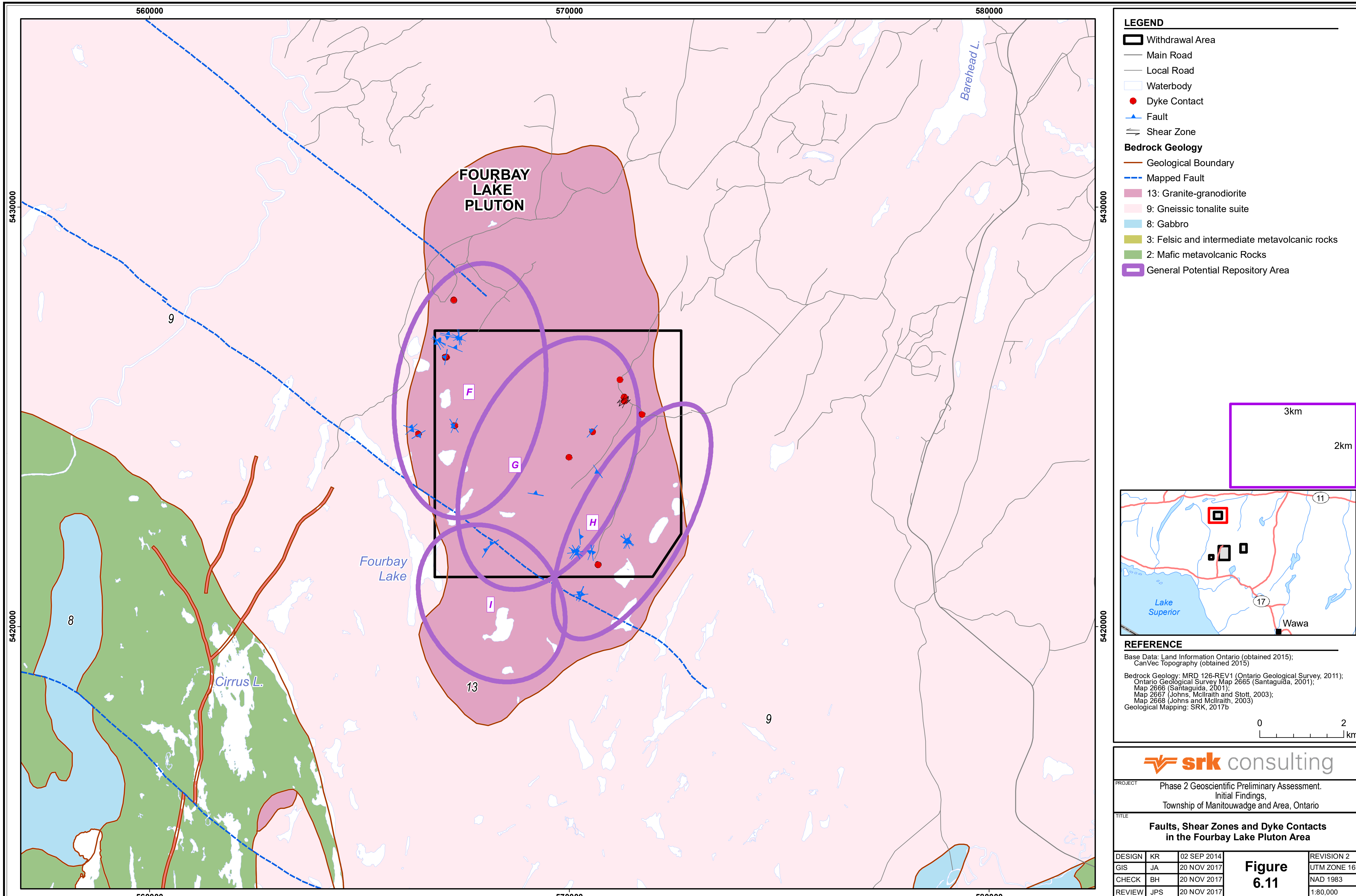
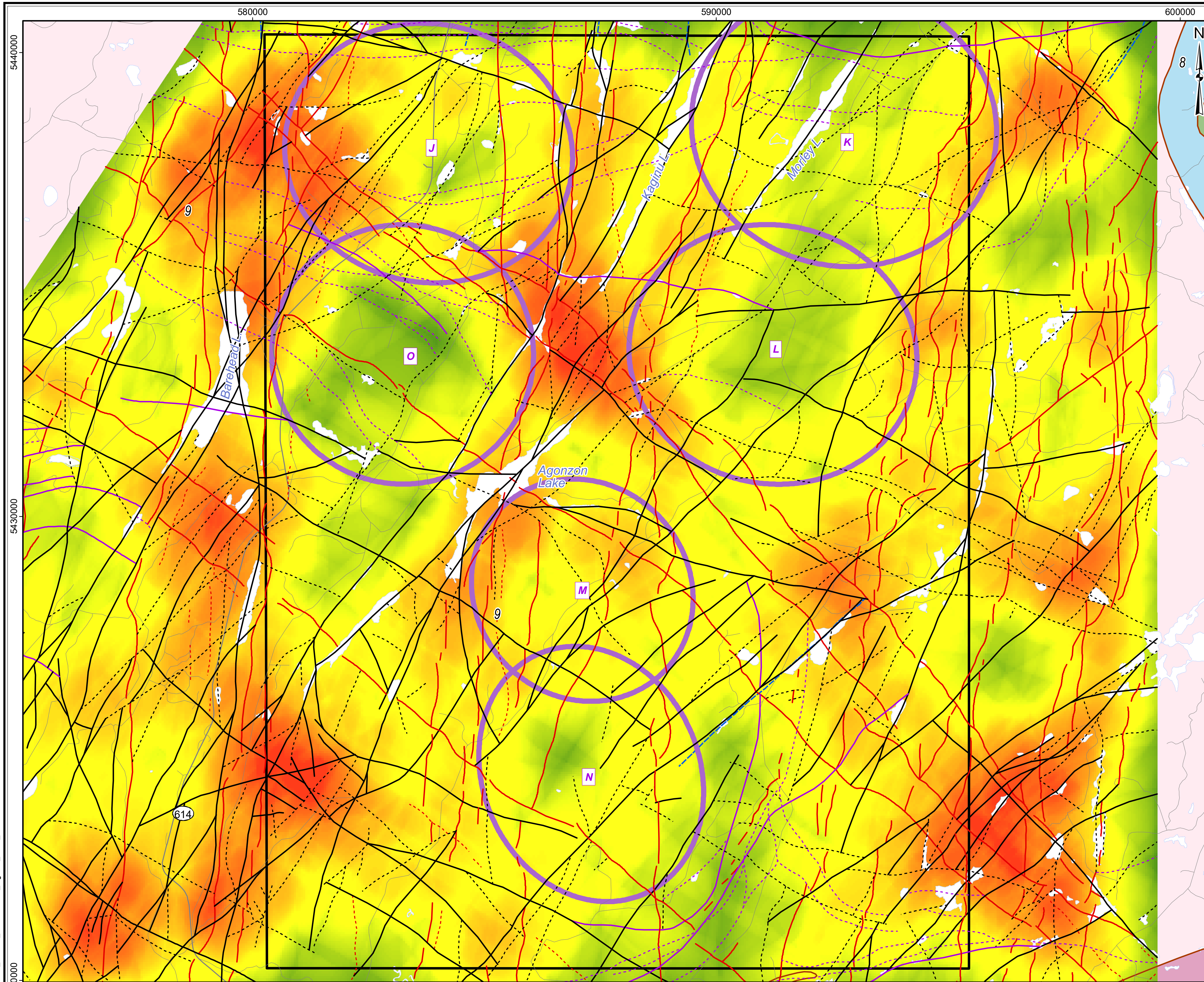


560000
570000
580000
5430000
5420000
FOURBAY LAKE PLUTON
Barehead L.
9
F
G
H
I
Fourbay Lake
8
Cirrus L.
13
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Dyke Contact
Fault
Shear Zone
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
3: Felsic and intermediate metavolcanic rocks
2: Mafic metavolcanic Rocks
General Potential Repository Area
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Faults, Shear Zones and Dyke Contacts in the Fourbay Lake Pluton Area
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.11
REVISION 2
UTM ZONE 16N
NAD 1983
1:80,000



LEGEND

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

Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Integrated Lineament

Unclassified

- Medium Certainty
- High Certainty

Brittle

- Medium Certainty
- High Certainty

Dyke

- Medium Certainty
- High Certainty

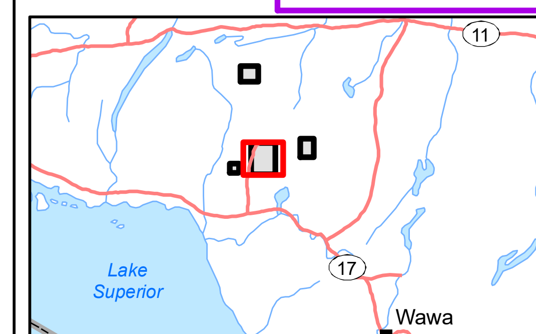
Lineament Density

7 (km/km²)

0

3km

2km



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)

Lineament Interpretation: SRK, 2017a

0 2 km

srk consulting

PROJECT: Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario

TITLE: **General Potential Repository Areas in the Black-Pic Batholith Area - West**

DESIGN	KR	02 SEP 2014	Figure 6.12	REVISION 4
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
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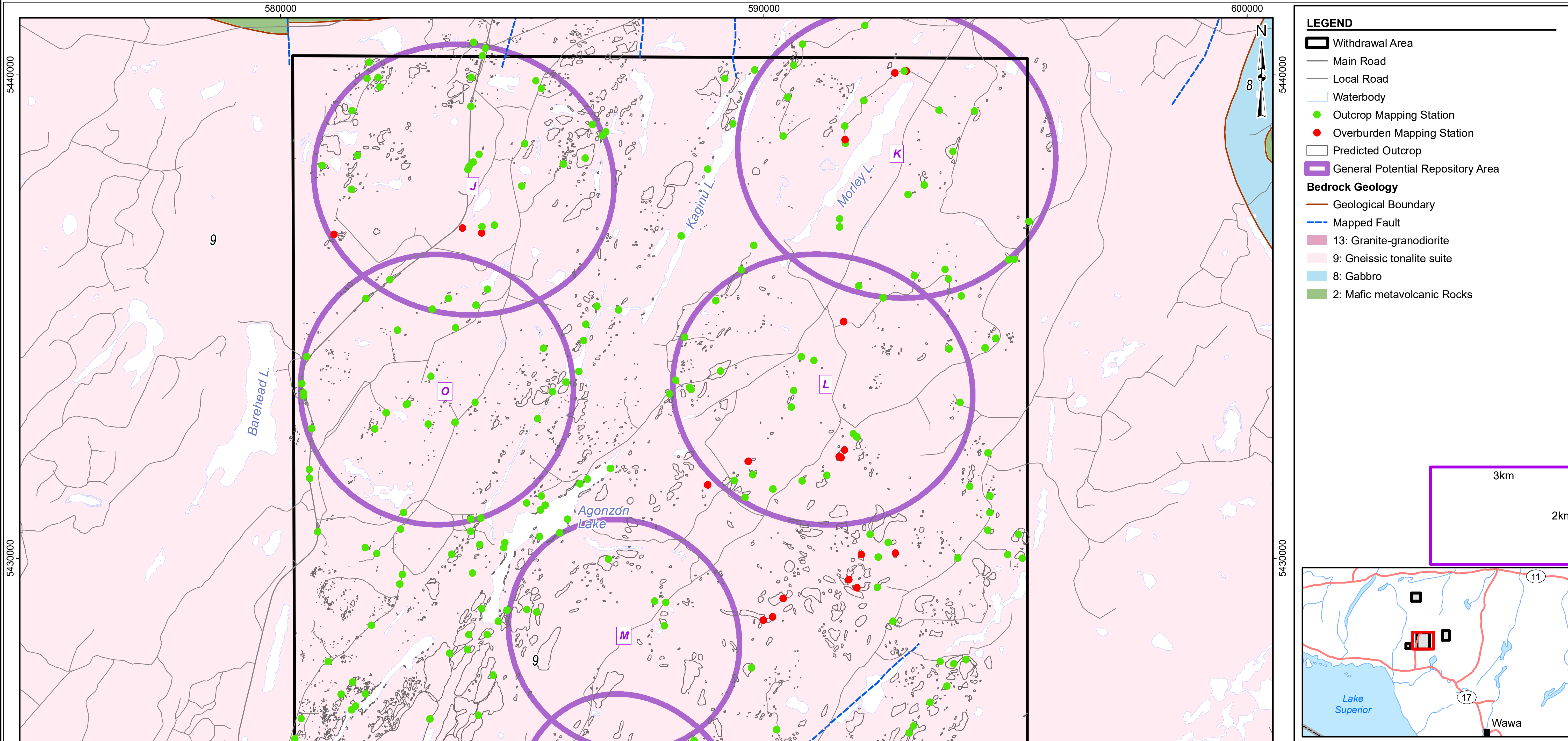

LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop Mapping Station
- Overburden Mapping Station
- Predicted Outcrop
- General Potential Repository Area

Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Mapping Stations in the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	**Figure 6.13**	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:81,000

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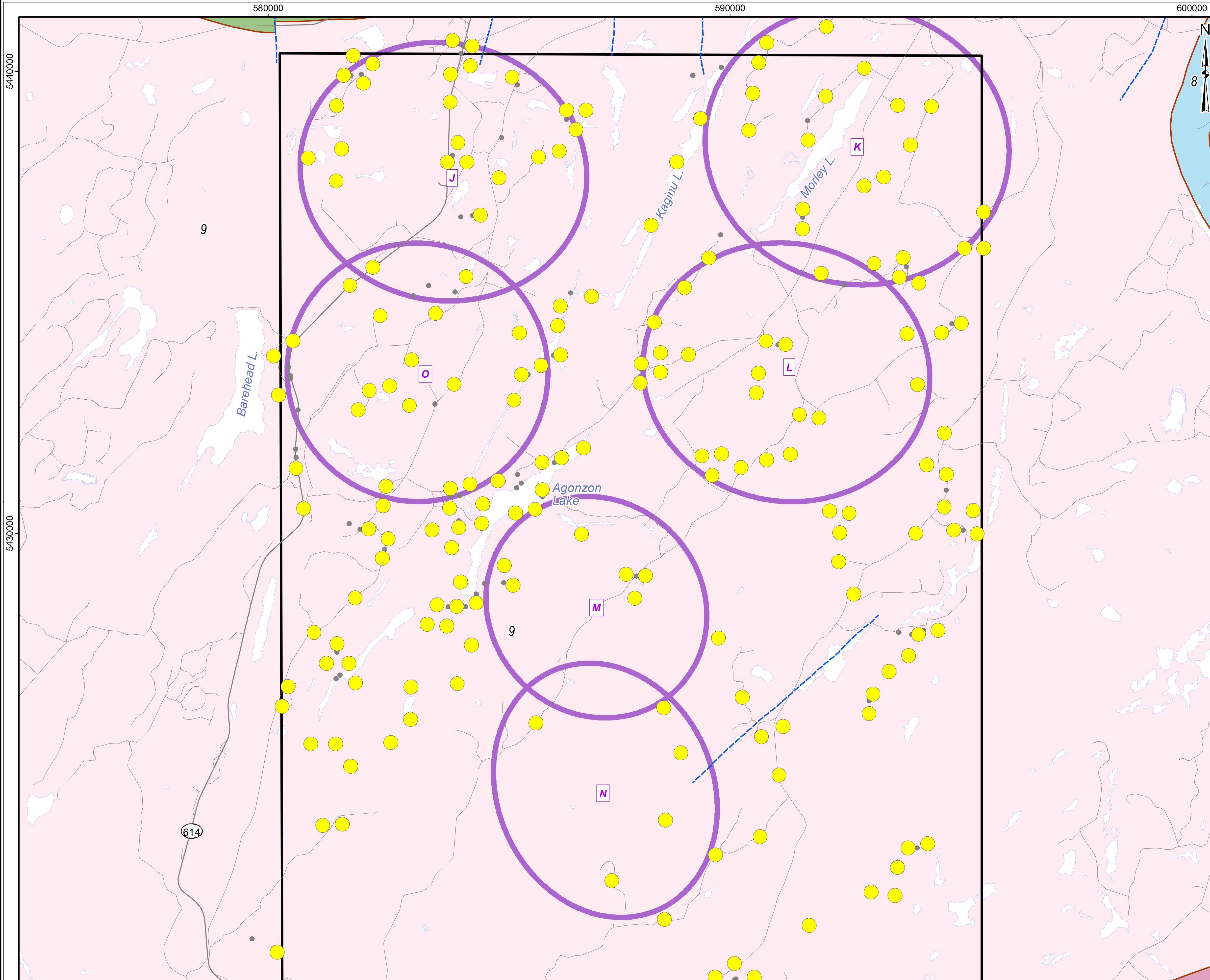


LEGEND

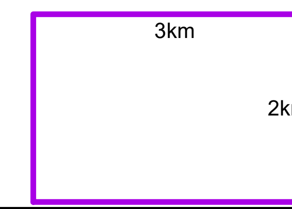
- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop Mapping Station (217)
- General Potential Repository Area

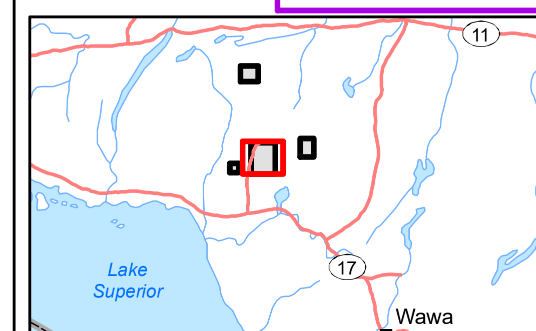
Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Main Lithology

- Tonalite





REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b

0 2 km

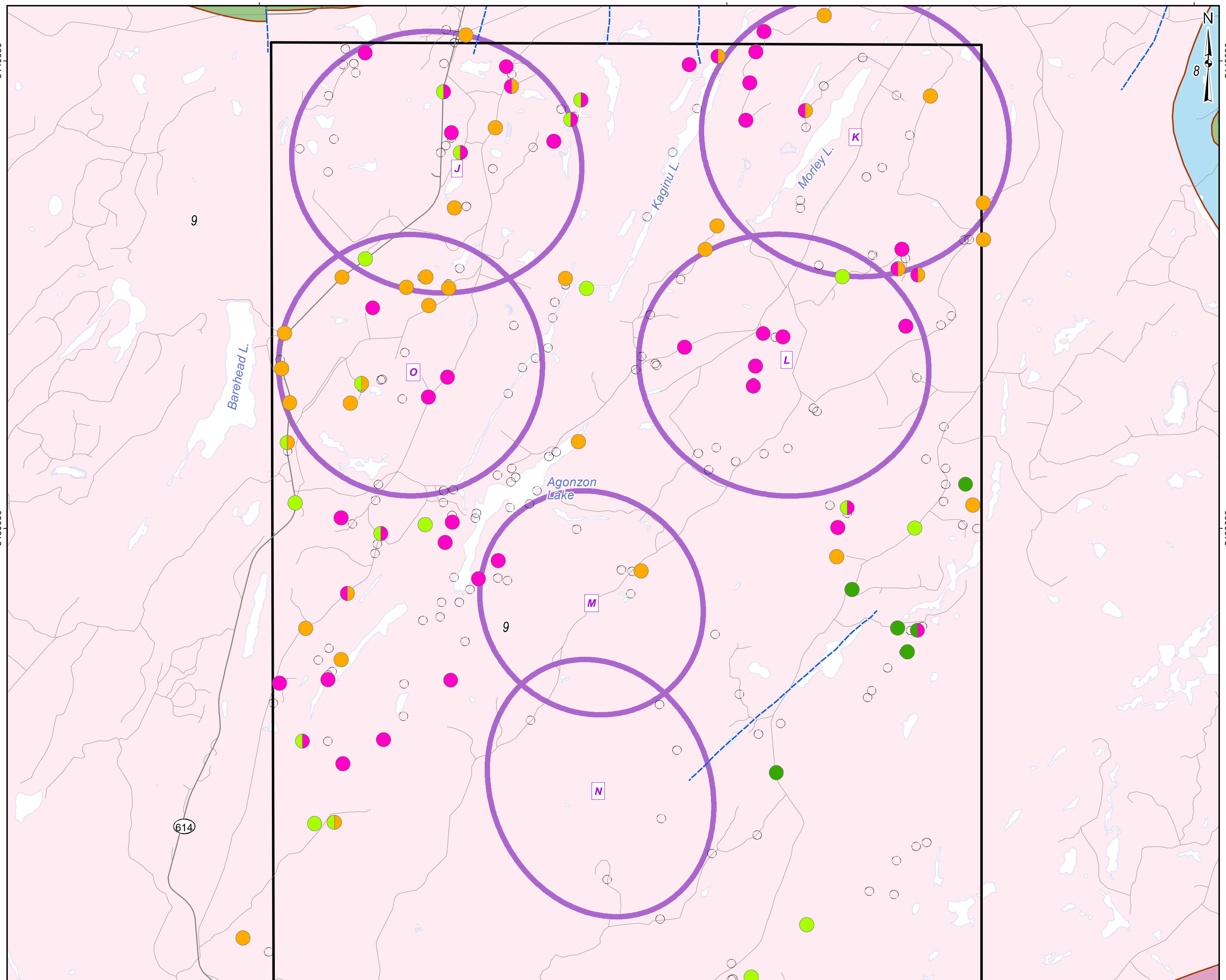
srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Main Lithological Units in the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	Figure 6.14	REVISION 4
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:81,000

File: SRK_NWMO_ManFindEXT_Fig6.14_BPW_Lith



LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop mapping Station
- General Potential Repository Area

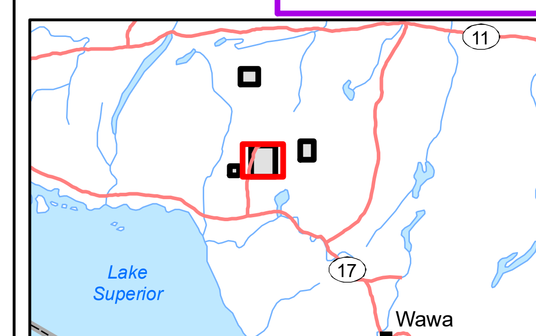
Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks

Minor Lithology

- Diorite to Granodiorite
- Granite
- Foliated to Gneissic Mafic Rocks
- Gabbro

3km
2km



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b

0 2 km

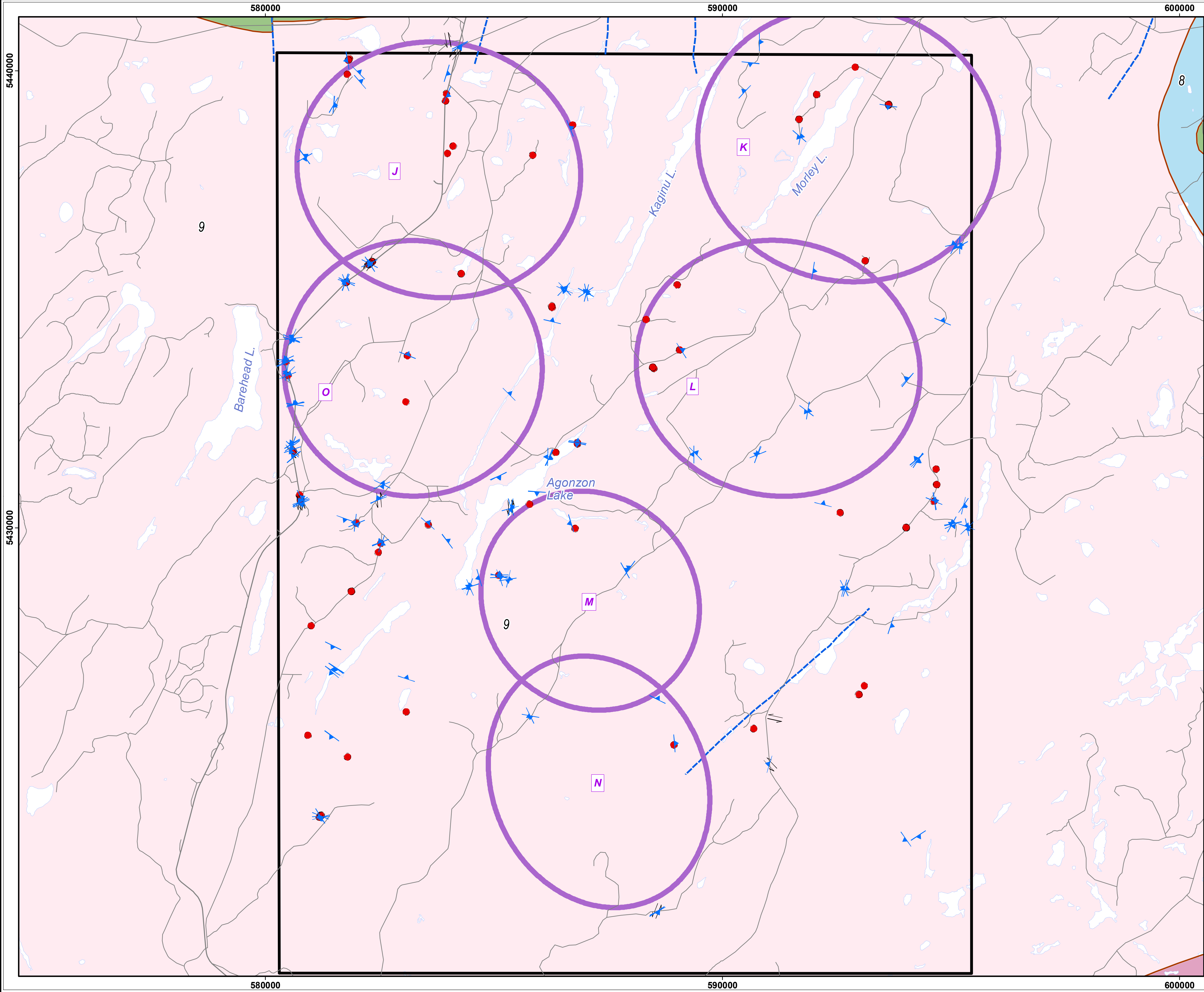
srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Minor Lithological Units in the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	**Figure 6.15**	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:81,000

File: SRK_NWMO_ManFindEXT_Fig6.15_BPW_Lithm

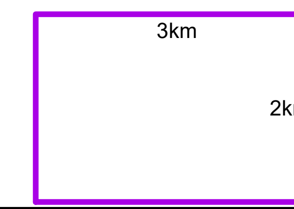


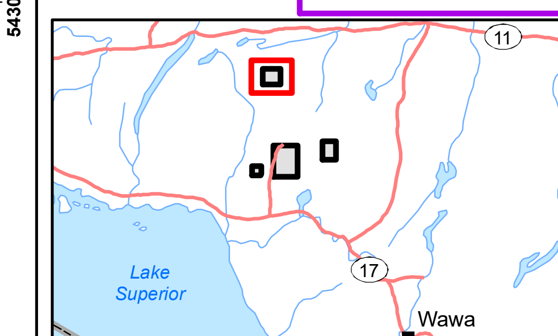
LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Dyke Contact
- Fault
- Shear Zone
- General Potential Repository Area

Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 2: Mafic metavolcanic Rocks





REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b

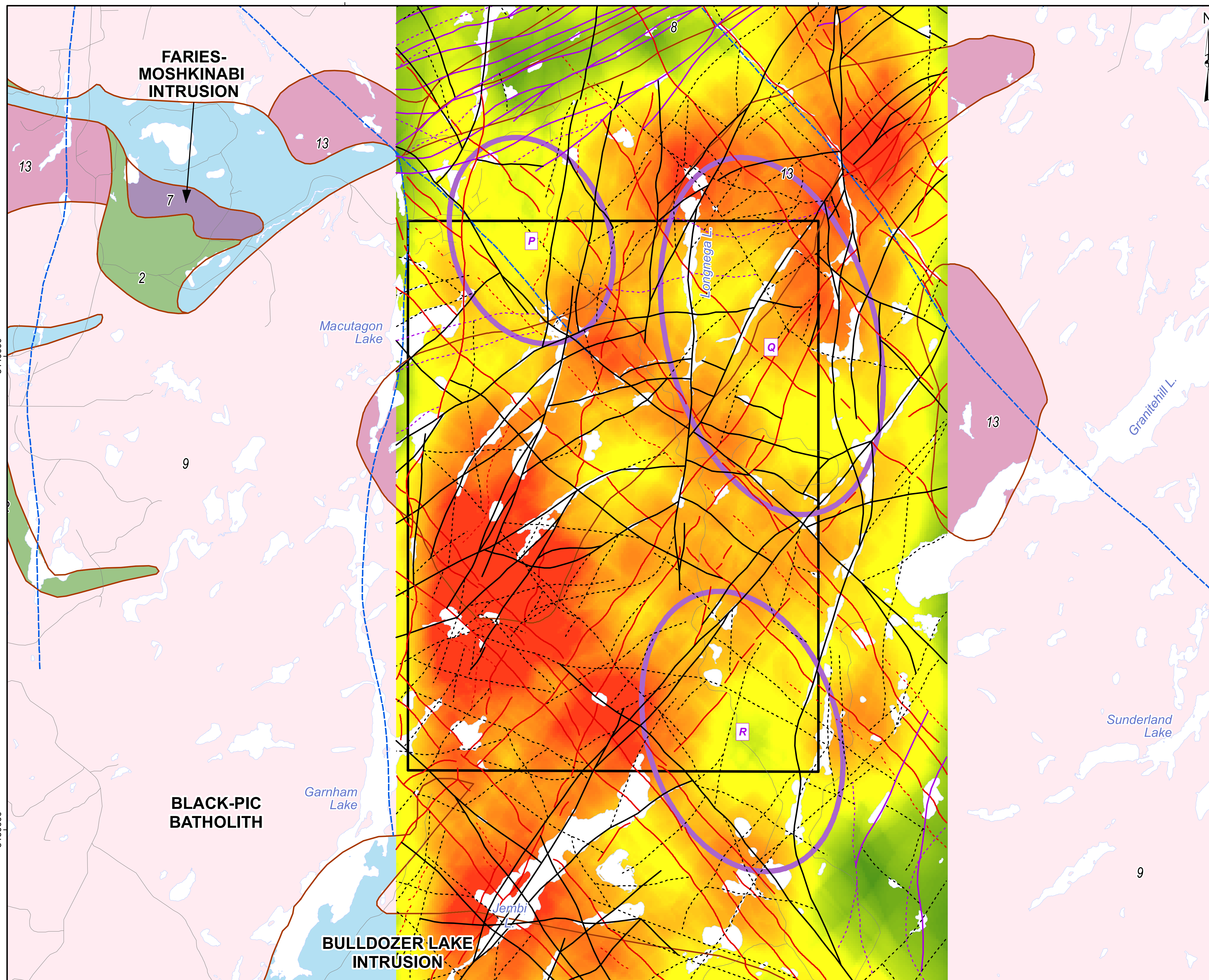
0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Faults, Shear Zones and Dyke Contacts in the Black-Pic Batholith Area - West

DESIGN	KR	02 SEP 2014	Figure 6.16	REVISION 2
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:81,000



LEGEND

Withdrawal Area
Local Road
Waterbody
General Potential Repository Area

Bedrock Geology

Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks

Integrated Lineament

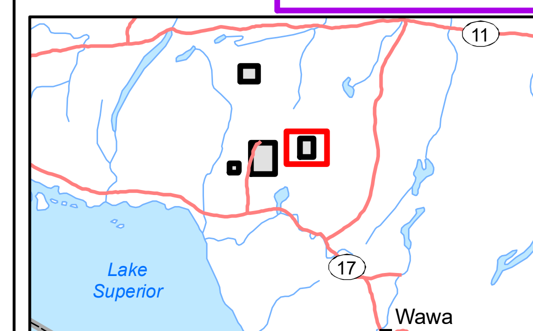
Unclassified
Medium Certainty
High Certainty

Brittle
Medium Certainty
High Certainty

Dyke
Medium Certainty
High Certainty

Lineament Density
7 (km/km²)
0

3km
2km



REFERENCE

Base Data: Land Information Ontario (obtained 2015);
CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011);
Ontario Geological Survey Map 2665 (Santaguida, 2001);
Map 2666 (Santaguida, 2001);
Map 2667 (Johns, McIlraith and Stott, 2003);
Map 2668 (Johns and McIlraith, 2003)
Lineament Interpretation: SRK, 2017a

0 2 km

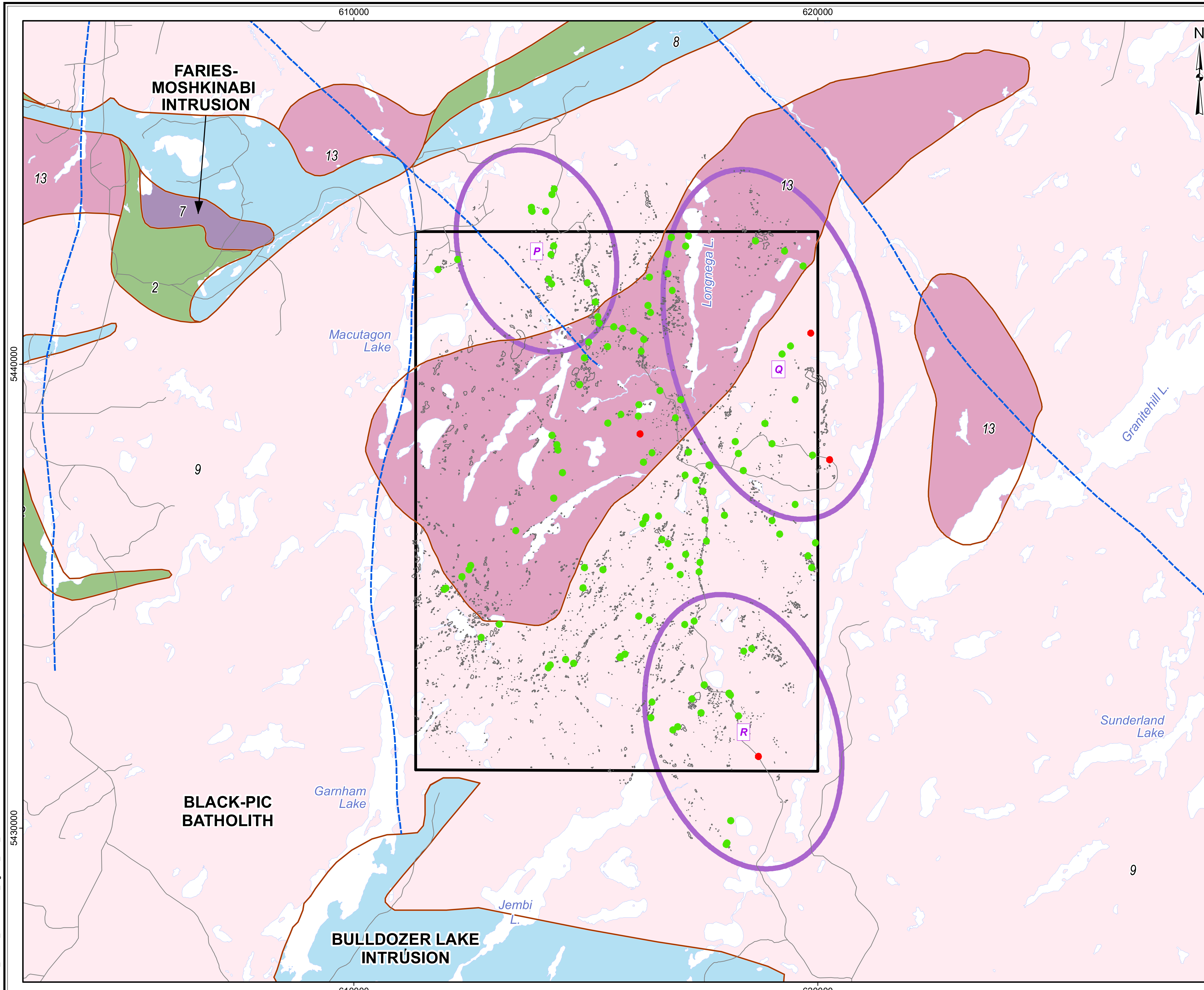
srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
General Potential Repository Areas in the Black-Pic Batholith Area - East

DESIGN	KR	02 SEP 2014	**Figure 6.17**	REVISION 4
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

File: SRK_NWMO_ManFindEXT_Fig6.17_BPE_PRA

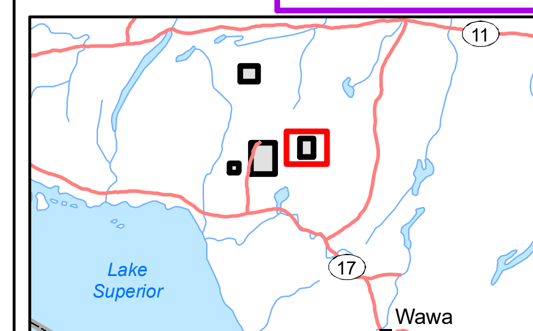


LEGEND

- Withdrawal Area
- Local Road
- Waterbody
- Outcrop Mapping Station (123)
- Overburden Mapping Station (4)
- Predicted Outcrop
- General Potential Repository Area

Bedrock Geology

- Geological Boundary
- Mapped Fault
- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 7: Ultramafic plutonic rocks
- 2: Mafic metavolcanic Rocks



REFERENCE

Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)

Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b

0 2 km

srk consulting

PROJECT
Phase 2 Geoscientific Preliminary Assessment.
Initial Findings,
Township of Manitouwadge and Area, Ontario

TITLE
Mapping Stations in the Black-Pic Batholith Area - East

DESIGN	KR	02 SEP 2014	Figure 6.18	REVISION 3
GIS	JA	20 NOV 2017		UTM ZONE 16N
CHECK	BH	20 NOV 2017		NAD 1983
REVIEW	JPS	20 NOV 2017		1:80,000

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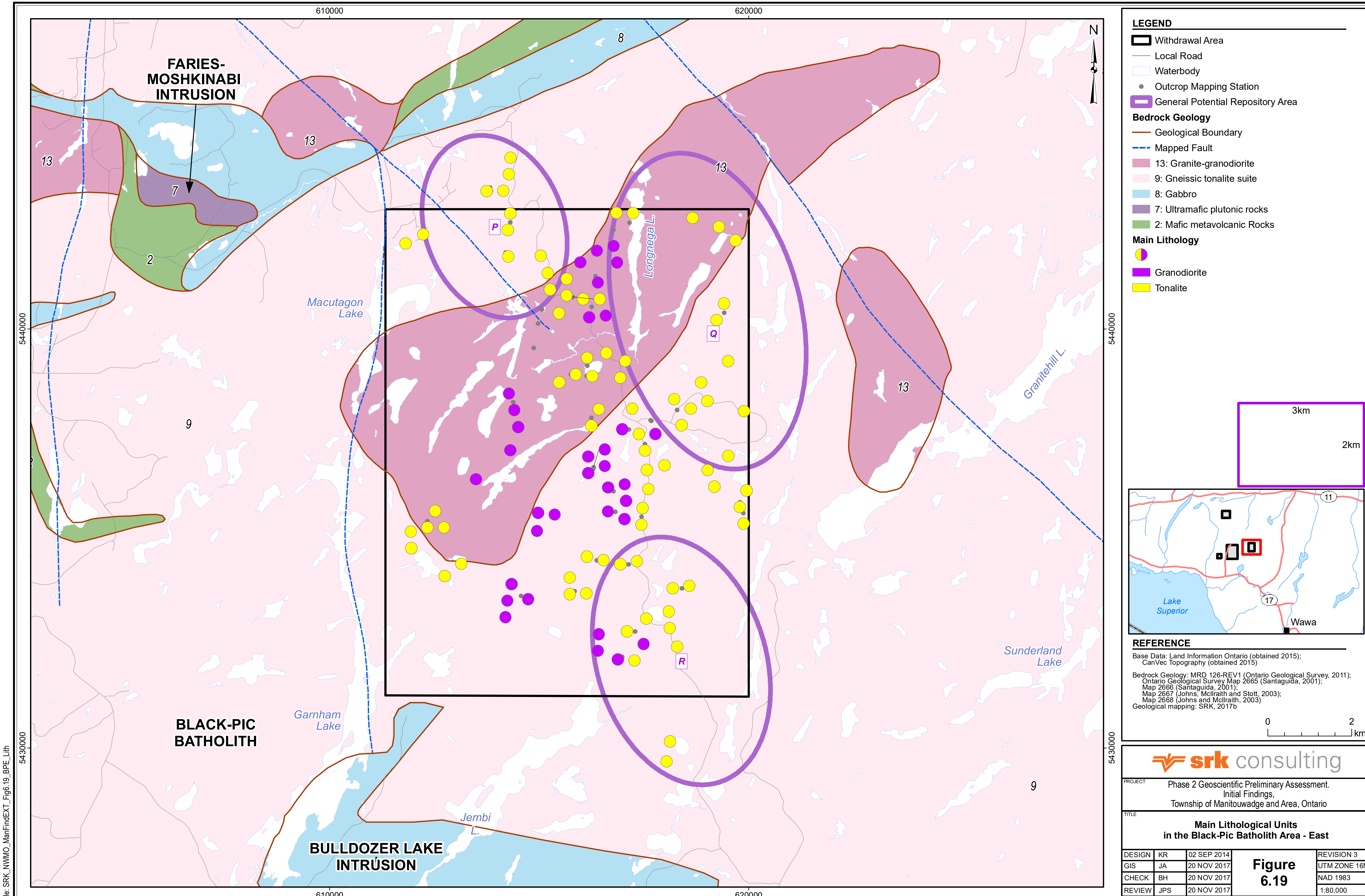

610000
620000
5440000
5430000
FARIES-MOSHKINABI INTRUSION
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
Macutagon Lake
Garnham Lake
Jembi L.
Longnega L.
Granitehill L.
Sunderland Lake
P
Q
R
13
9
8
7
2
N
LEGEND
Withdrawal Area
Local Road
Waterbody
Outcrop Mapping Station
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks
Main Lithology
Granodiorite
Tonalite
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Main Lithological Units in the Black-Pic Batholith Area - East
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.19
REVISION 3
UTM ZONE 16N
NAD 1983
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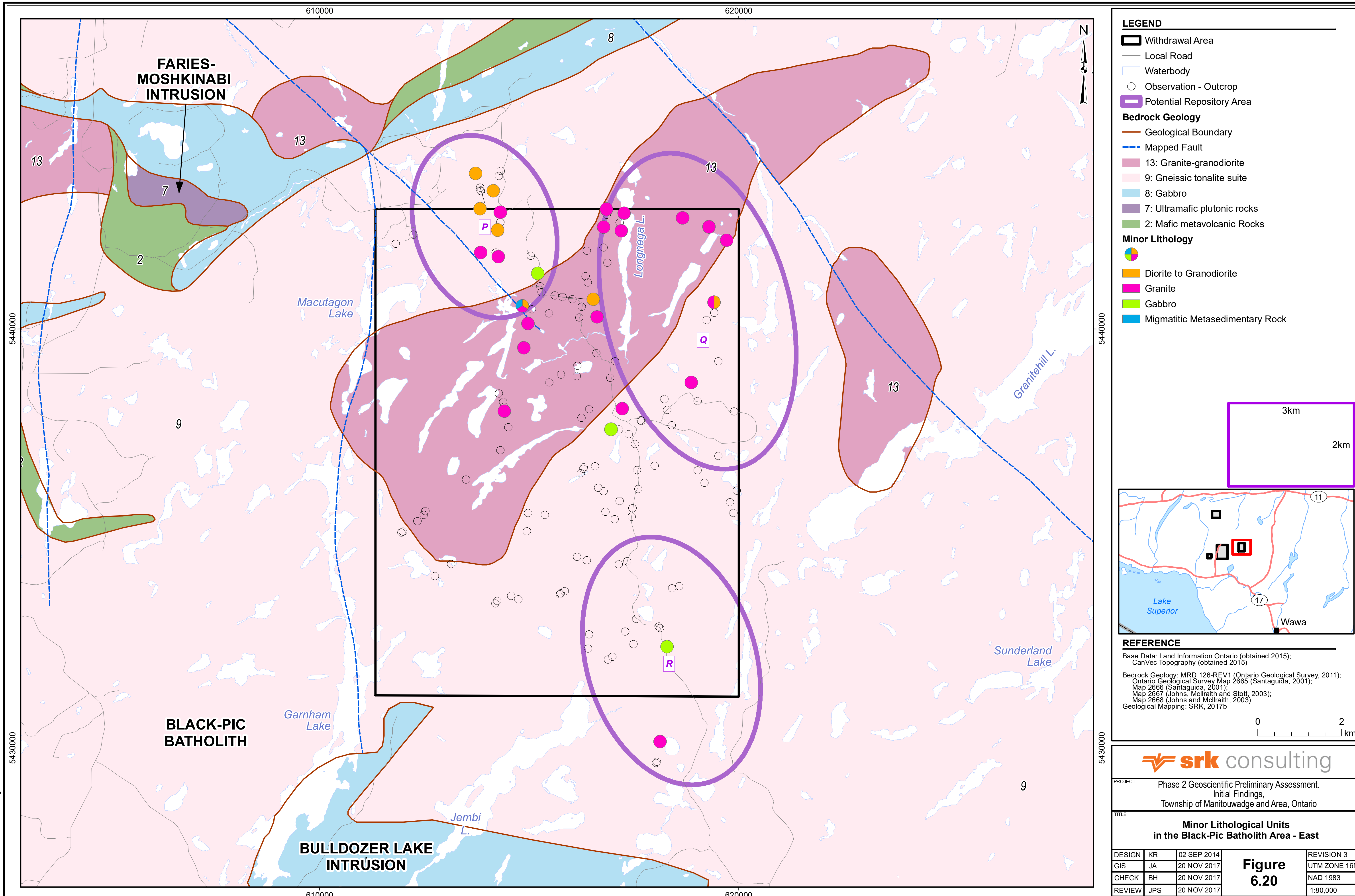

FARIES-MOSHKINABI INTRUSION
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
Macutagon Lake
Garnham Lake
Jembi L.
Sunderland Lake
Granitehill L.
Longnega L.
P
Q
R
610000
620000
5440000
5430000
N
3km
2km
LEGEND
Withdrawal Area
Local Road
Waterbody
Observation - Outcrop
Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks
Minor Lithology
Diorite to Granodiorite
Granite
Gabbro
Migmatitic Metasedimentary Rock
Lake Superior
Wawa
11
17
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b
0 2 km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Minor Lithological Units in the Black-Pic Batholith Area - East
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.20
REVISION 3
UTM ZONE 16N
NAD 1983
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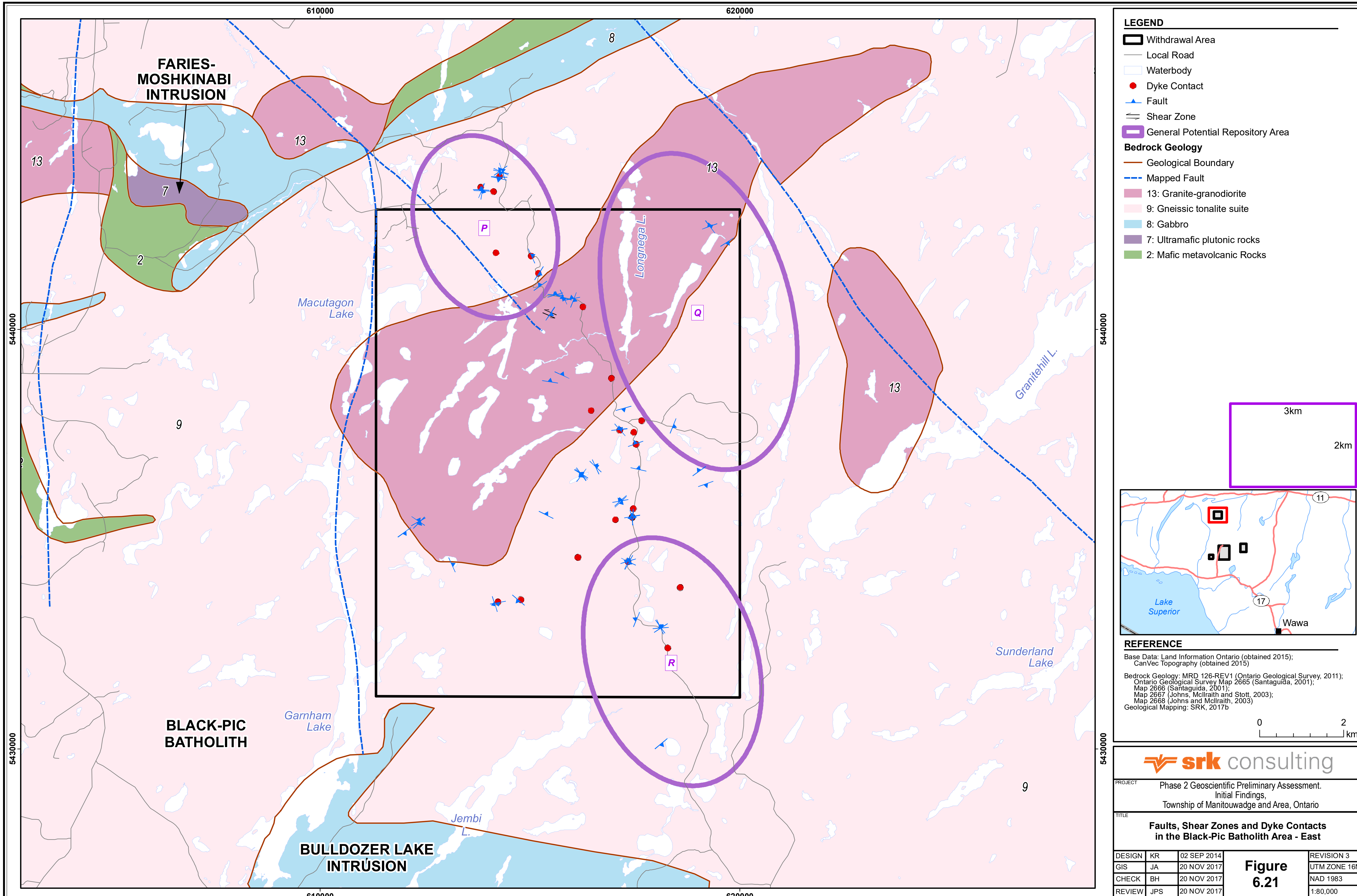
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620000
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FARIES-MOSHKINABI INTRUSION
BLACK-PIC BATHOLITH
BULLDOZER LAKE INTRUSION
Macutagon Lake
Longnega L.
Granitehill L.
Sunderland Lake
Garnham Lake
Jembi L.
P
Q
R
13
9
8
7
2
LEGEND
Withdrawal Area
Local Road
Waterbody
Dyke Contact
Fault
Shear Zone
General Potential Repository Area
Bedrock Geology
Geological Boundary
Mapped Fault
13: Granite-granodiorite
9: Gneissic tonalite suite
8: Gabbro
7: Ultramafic plutonic rocks
2: Mafic metavolcanic Rocks
3km
2km
11
17
Lake Superior
Wawa
REFERENCE
Base Data: Land Information Ontario (obtained 2015); CanVec Topography (obtained 2015)
Bedrock Geology: MRD 126-REV1 (Ontario Geological Survey, 2011); Ontario Geological Survey Map 2665 (Santaguida, 2001); Map 2666 (Santaguida, 2001); Map 2667 (Johns, McIlraith and Stott, 2003); Map 2668 (Johns and McIlraith, 2003)
Geological Mapping: SRK, 2017b
0
2
km
srk consulting
PROJECT
Phase 2 Geoscientific Preliminary Assessment. Initial Findings, Township of Manitouwadge and Area, Ontario
TITLE
Faults, Shear Zones and Dyke Contacts in the Black-Pic Batholith Area - East
DESIGN KR 02 SEP 2014
GIS JA 20 NOV 2017
CHECK BH 20 NOV 2017
REVIEW JPS 20 NOV 2017
Figure 6.21
REVISION 3
UTM ZONE 16N
NAD 1983
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