NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 2 Geoscientific Preliminary Assessment, Findings from Initial Field Studies

TOWN OF CREIGHTON, SASKATCHEWAN

APM-REP-06145-0009

FEBRUARY 2015

This report has been prepared under contract to the NWMO. The report has been reviewed by the NWMO, but the views and conclusions are those of the authors and do not necessarily represent those of the NWMO.

All copyright and intellectual property rights belong to the NWMO.

For more information, please contact:
Nuclear Waste Management Organization
22 St. Clair Avenue East, Sixth Floor
Toronto, Ontario M4T 2S3 Canada
Tel 416.934.9814
Toll Free 1.866.249.6966
Email contactus@nwmo.ca
www.nwmo.ca

February 2015

Phase 2 Geoscientific Preliminary Assessment

FINDINGS FROM INITIAL FIELD STUDIES THE TOWN OF CREIGHTON, SASKATCHEWAN

Submitted to:
Nuclear Waste Management Organization
22 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 2S3

NWMO Report: APM-REP-06145-0009

REPORT

Report Number: 12-1152-0026 (8200A)

Distribution:

PDF copy - NWMO
PDF copy - Golder Associates

Golder Associates

Executive Summary

In 2013, a Phase 1 geoscientific desktop preliminary assessment was completed by Golder Associates Ltd. (Golder) to assess whether the Creighton area contained general areas that had the potential to satisfy the geoscientific site evaluation factors outlined in NWMO's 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 Creighton area contained two general areas that have the potential to satisfy NWMO's geoscientific site evaluation factors.

In 2014, as part of the Phase 2 preliminary geoscientific assessment of the Creighton area, NWMO initiated a series of initial geoscientific field studies including the acquisition and interpretation of high-resolution airborne geophysical data and initial geological mapping to observe and ground truth general geological features. 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 candidate areas for further field studies, beginning with detailed geological mapping. The Phase 2 preliminary geoscientific assessment included the following key activities:

- Acquisition and processing of high-resolution airborne geophysical (magnetic and gravity) data over the general area identified in the Phase 1 Geoscientific Desktop Preliminary Assessment;
- Detailed interpretation of high-resolution gravity and magnetic data to better understand the bedrock geology such as 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 surveys to identify possible structural features; and
- Observation of general geological features to confirm/ground truth geologic characteristics, including lithology, structure, bedrock exposures and surface constraints.

The interpretation of the new Phase 2 data and field observations confirmed the presence of geological complexities that reduce the potential for identifying repository sites that would ultimately meet NWMO's geoscientific site evaluation factors in the Creighton area.

The assessment identified only one candidate area that could be considered for detailed mapping. The area is located in the western portion of the Annabel Lake pluton, which is a fairly narrow elongated granitoid intrusion. However, this potential area is only marginally sufficient in size for hosting a deep geological repository. In addition, the area contains numerous interpreted subsurface fractures that could have an impact on the long-term performance of a deep geological repository. Avoiding subsurface fractures would generally require a larger repository footprint at depth. However, there is limited opportunity for expanding the repository footprint in the Creighton area as the size of the potential host geological formation, the Annabel Lake pluton, is fairly small and bounded by major shear zones and unsuitable rocks.

Table of Contents

1.0 INTRODUCTION 1

2.0 PRELIMINARY ASSESSMENT APPROACH 3

3.0 GEOSCIENTIFIC SITE EVALUATION FACTORS 5

4.0 PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT APPROACH (INITIAL FIELD STUDIES) 6

4.1 High-resolution Airborne Geophysical Surveys 6

4.2 Geophysics Interpretation 7

4.3 Lineament Interpretation 8

4.3.1 Lineament Interpretation Workflow 8

4.3.2 Magnetic Lineaments 9

4.3.3 Surficial Lineaments 9

4.4 Observing General Geological Features (Initial Geological Mapping) 10

4.4.1 Mapping Plans and Logistics 11

4.4.2 Local and Traditional Knowledge Activities 11

5.0 KEY GEOSCIENTIFIC CHARACTERISTICS 12

5.1 Bedrock Geology 12

5.2 Structural Geology 14

5.3 Lineament Analysis 14

5.4 Bedrock Exposure 16

5.5 Protected Areas 16

5.6 Natural Resources 16

5.7 Potential Surface Constraints 17

6.0 CANDIDATE AREAS FOR DETAILED GEOLOGICAL MAPPING IN THE CREIGHTON AREA 18

6.1 Candidate Area for Detailed Geological Mapping in the Annabel Lake Pluton 19

7.0 SUMMARY OF INITIAL PHASE 2 GEOSCIENTIFIC FINDINGS FOR THE CREIGHTON AREA 21

8.0 REFERENCES 22

PHOTOGRAPHS

Photograph 1 SGL's Britten-Norman BN-2 Islander

Photograph 2 Observing General Geological Features of the Annabel Lake Pluton in the Creighton Area

Photograph 3 Example of Biotite Granodiorite from the Annabel Lake Pluton in the Creighton Area

FIGURES

Figure 1-1 The Creighton Area

Figure 1-2 Potentially Suitable Area Identified in Phase 1 Preliminary Assessment

Figure 4-1 Airborne Survey Block in the Creighton Area

Figure 4-2 Magnetic Data in the Airborne Survey Block for the Creighton Area

Figure 4-3 Gravity Data in the Airborne Survey Block for the Creighton area

Figure 4-4 Digital Elevation Model (DEM) Data in the Airborne Survey Block for the Creighton Area

Figure 4-5 Magnetic Lineaments in the Airborne Survey Block with Medium and High Certainty

Figure 4-6 Surficial Lineaments in the Airborne Survey Block with Medium and High Certainty

Figure 4-7 Quaternary Geology of the Creighton area

Figure 4-8 Outcrop Mapping Locations in the Airborne Survey Block in the Creighton Area

Figure 5-1 Domain Boundaries and Observed Fracture Density Variations of the Annabel Lake Pluton

Figure 5-2 Mineral Occurrences and Active Mining Claims in the Creighton Area

Figure 6-1 Magnetic Lineaments of High and Medium Certainty in the candidate Area in the Western part of the Annabel Lake Pluton

Figure 6-2 Surficial Lineaments of High and Medium Certainty in the Potential Area in the Western part of the Annabel Lake Pluton

1.0 INTRODUCTION

In 2013, a Phase 1 Geoscientific Desktop Preliminary Assessment was completed by Golder Associates Ltd. (Golder) to assess whether the Creighton area contained general areas that have the potential to satisfy the geoscientific site evaluation factors outlined in NWMO's site selection process (Golder, 2013; NWMO, 2010). The desktop preliminary assessment built on an initial screening conducted by Golder in 2011 (Golder, 2011). The preliminary assessment focused on the Creighton area and its periphery, 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 consideration of these key geoscientific characteristics revealed that the Creighton area contained two general areas that had the potential to satisfy NWMO's geoscientific site evaluation factors. One of the areas extends over most of the Annabel Lake pluton. The other area was in the south-central portion of the Reynard Lake pluton. The latter area was removed from further consideration as it is located on land classified as Crown Reserve (Canadian Forces Station Flin Flon). As such, the only area of interest in the Creighton area is on the Annabel Lake pluton (Figure 1-2). The Phase 1 preliminary assessment identified a number of geoscientific uncertainties that would need to be addressed, including the relatively small extent of the potentially suitable geological formation within the Creighton area, the proximity of major shear zones and mapped faults, and the high mineral potential of the surrounding greenstone belts.

In 2014, as part of Phase 2 of the preliminary geoscientific assessment of the Creighton area, NWMO initiated a series of initial geoscientific field studies including the acquisition and interpretation of high-resolution airborne geophysical surveys and initial geological mapping to observe and ground truth general geological features. The objective of these initial field studies is to advance understanding of the geology of the general potentially suitable area identified in the Phase 1 Geoscientific Desktop Preliminary Assessment, and assess whether it is possible to identify candidate areas for further field studies, beginning with detailed geological mapping.

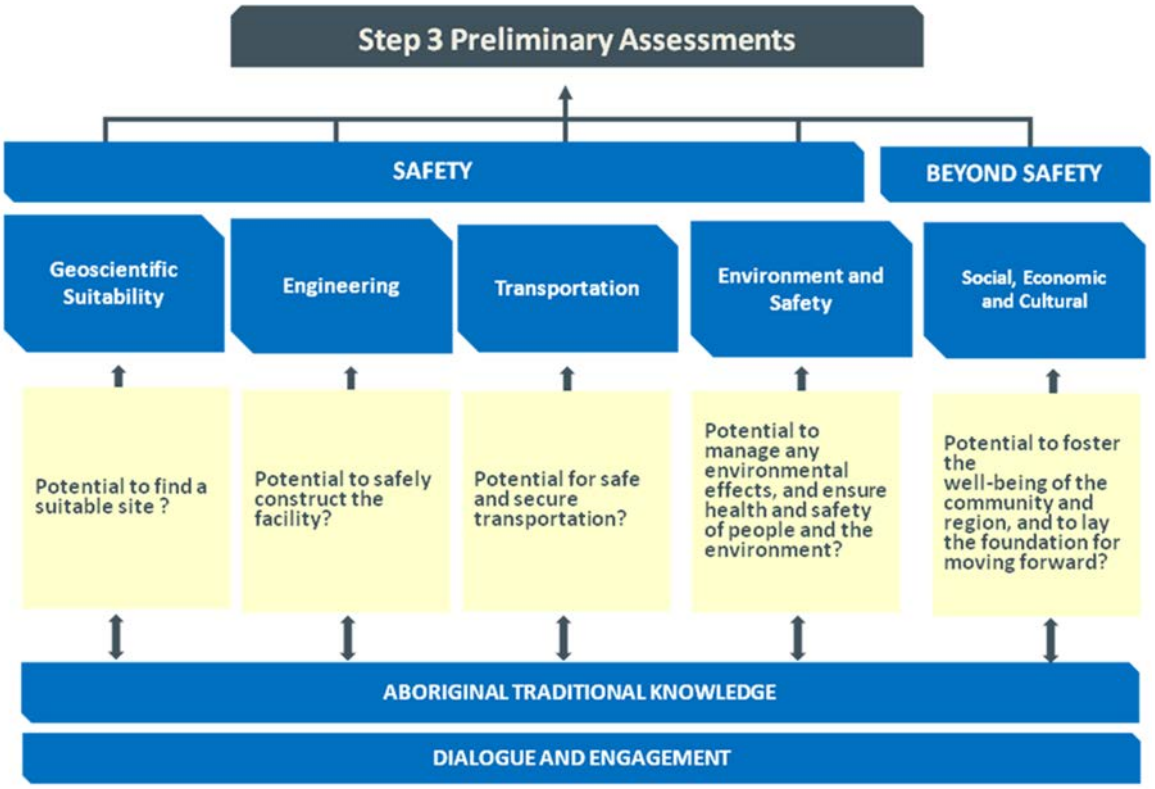
The high-resolution airborne surveys included both magnetic and gravity surveys that greatly improved understanding of the geological characteristics of the Creighton area. The high-resolution surveys provided information on rock type, homogeneity, and the depth and extent of the potentially suitable host rock formation. High-resolution geophysical and remote sensing data were used to conduct a geophysical and surficial lineament interpretation to identify the presence of potential structural features such as fractures and dykes. Initial geological mapping, also referred to as "observing general geological features", was conducted to better understand the lay of the land, and to confirm the presence and nature of key geological features such as fractures, rock types, extent of bedrock exposure and surface constraints. The results from the initial Phase 2 field studies are documented in three supporting documents: Geophysics Interpretation report (SGL, 2015); Lineament Interpretation report (SRK, 2015); and Observation of General Geological Features report (SRK and Golder, 2015).

This report provides the findings of Phase 2 initial field studies conducted in the Creighton area in 2014 as they relate to whether the Creighton area contains candidate areas suitable for further field studies, beginning with detailed geological mapping.

The main sections of this report provide: a description of the approach and evaluation factors used to conduct the Phase 2 preliminary geoscientific assessments; a summary of the initial Phase 2 field studies methods and findings; and the approach, rationale and identification of candidate areas for further studies.

2.0 PRELIMINARY ASSESSMENT APPROACH

The overall preliminary assessment is a multidisciplinary study integrating both technical and community well-being assessments as illustrated in the diagram below. The five components of the preliminary assessment address geoscientific suitability, engineering, transportation, environment and safety, as well as social, economic and cultural considerations. A brief description of the project, the assessment approach and findings of the Phase 1 preliminary assessment are documented in the Creighton integrated Phase 1 preliminary assessment report (NWMO, 2013).



The objective of the geoscientific preliminary assessment is to assess whether the Creighton 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 includes a series of initial field studies such as:

  a) Acquisition and interpretation of high-resolution airborne geophysical surveys, geophysical and surficial lineament interpretation, and initial geological mapping (referred to as "observing general geological

features"). The outcome of these initial field studies is to identify potentially suitable candidate areas for detailed geological mapping;

b) Detailed geological mapping to inform the location of potentially suitable sites for borehole drilling; and
c) Drilling of deep boreholes at a selected location within each community.

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

The Phase 1 Geoscientific Desktop Preliminary Assessment was completed for the Creighton area in 2013 (Golder, 2013). Initial Phase 2 field studies, including high-resolution airborne geophysical surveys and observing general geological features were conducted in 2014. This report focuses on summarizing the findings of these initial field studies.

3.0 GEOSCIENTIFIC SITE EVALUATION FACTORS

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

- Safe containment and isolation of used nuclear fuel: Are the characteristics of the rock at the site appropriate to ensuring the long-term containment and isolation of used nuclear fuel from humans, the environment and surface disturbances caused by human activities and natural events?
- Long-term resilience to future geological processes and climate change: Is the rock formation at the siting area geologically stable and likely to remain stable over the very long term in a manner that will ensure the repository will not be substantially affected by geological and climate change processes such as earthquakes and glacial cycles?
- Safe construction, operation and closure of the repository: Are conditions at the site suitable for the safe construction, operation and closure of the repository?
- Isolation of used fuel from future human activities: Is human intrusion at the site unlikely, for instance through future exploration or mining?
- Amenable to site characterization and data interpretation activities: Can the geologic conditions at the site be practically studied and described on dimensions that are important for demonstrating long-term safety?

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

The identification of candidate areas for detailed geological mapping was conducted through a systematic and iterative process based on the updated understanding of the key geoscientific characteristics of the Creighton area, using the newly acquired Phase 2 data. These key geoscientific characteristics are described in Section 5 and include: bedrock geology; structural geology; lineament analysis; bedrock exposure; protected areas; natural resources and surface constraints.

4.0 PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT APPROACH (INITIAL FIELD STUDIES)

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 area 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, etc.);
- 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 and shear zones; and
- Observation of general geological features to confirm/ground truth geologic characteristics, including lithology, structure, bedrock exposures and surface constraints.

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

- Update understanding of key geoscientific characteristics that can be realistically assessed at this stage of the assessment to identify candidate areas for detailed mapping; and
- Assess whether it is possible to identify candidate areas for detailed mapping within the general potentially suitable area identified in the Creighton area in the Phase 1 desktop preliminary assessment.

The approach, methods and findings for each of the above activities are described in detail in three supporting documents (SGL, 2015; SRK, 2015; and SRK and Golder, 2015). 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 candidate areas for additional Phase 2 field work 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 Creighton 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, 2015) provides significantly higher resolution data compared to the data available in the Phase 1 preliminary assessment (PGW, 2013).

Sander Geophysics Limited (SGL) completed a fixed-wing high-resolution airborne magnetic and gravity survey in the Creighton area between May 4 and May 16, 2014 (SGL, 2015). The survey area included one survey block located west of the Town of Creighton (Figure 4-1). This survey block was designed to cover the potentially suitable area identified in the Phase 1 preliminary assessment, and to cover relevant geological features in the area (Figure 1-2).

The airborne survey in the Creighton area included a total of 2,402 kilometres of flight lines covering a surface area of approximately 150 square kilometres. Flight operations were conducted out of the Flin Flon Airport, Flin Flon, Manitoba using a Britten-Norman BN-2 Islander (Photograph 1, below). 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. The survey was flown at a nominal altitude of 80 metres above ground level, with an average ground speed of 100 knots (185 kilometres per hour).

Airborne magnetic and gravity data were acquired along the flight lines using equipment on board the plane that have very high sensitivity and accuracy. 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 includes three orthogonal accelerometers that are mounted on a platform inside the cabin of the aircraft. A detailed description of the planning, execution and processing of the survey data is provided in SGL (2015). The interpretation of the survey data included both a geophysics interpretation (Section 4.2; SGL, 2015) and a lineament interpretation (Section 4.3; SRK, 2015).



Photograph 1: SGL's Britten-Norman BN-2 Islander

4.2 Geophysics Interpretation

The geophysics interpretation was conducted for the Creighton area using the newly acquired high-resolution magnetic and gravity data sets (SGL, 2015). The assessment of geological contacts and bedrock lithology in the Phase 2 assessment was performed by analyzing the magnetic and gravity data, and determining the coincidence of magnetic responses with mapped lithology and structures for the Creighton 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 outcrop exposure (e.g. under overburden and drainage 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 4-2 and 4-3, respectively. At the same time that the magnetic and gravity data were acquired, higher resolution Digital Elevation Model (DEM) topographic data was also generated from the airborne GPS and altimeter data (SGL, 2015), as shown on Figure 4-4. The magnetic, gravity and DEM data were all incorporated into preliminary forward model calculations to estimate the thickness and geometry of the pluton and adjacent greenstone units (SGL, 2015). 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 potentially suitable bedrock unit located within the survey area using the newly acquired high-resolution data. A geophysical and surficial lineament study was conducted for the survey area using the high-resolution magnetic and DEM data from the airborne survey, and purchased high-resolution satellite imagery (SRK, 2015).

Lineaments are linear features that can be observed on remote sensing and geophysical data, which may represent geological structures. The presence of these features at depth would need to 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, 2015). The workflow follows a set of detailed guidelines involving three stages:

- Step 1: Independent lineament interpretation by two separate interpreters for each data set and assignment of certainty level (low certainty, medium certainty, or high certainty);
- Step 2: Integration of lineament interpretations for each individual data set, and determination of reproducibility (i.e. presence of the same lineament in each data set used (topography, satellite, magnetic) as interpreted by each interpreter); and
- Step 3: Integration of lineament interpretations for the surficial data sets (topography and satellite) followed by integration of the combined surficial data set with the magnetic data set, with determination of coincidence in each integration step.

Over the course of these three stages, a comprehensive list of attributes for each lineament was compiled (SRK, 2015). 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 surficial lineament could be clearly seen on exposed bedrock, it was assigned a certainty value of high. Where a lineament represented a bedrock feature that was inferred from linear features, such as orientation of lakes or streams or linear trends in texture, it was assigned a certainty value of either low or medium. For magnetic lineaments, a certainty value of high was assigned when a clear magnetic susceptibility contrast could be discerned and a certainty value of either low or medium was assigned when the signal was discontinuous or more diffuse in nature. The certainty classification for all three data sets

ultimately came down to expert judgment and experience of the interpreter. For the purpose of this assessment, emphasis was put on lineaments interpreted with high and medium certainty.

- Lineament Length: Interpreted lineaments were classified according to their length which is calculated based on the sum of all segment lengths that make up a lineament. It is assumed that longer interpreted lineaments may extend to greater depths than shorter interpreted lineaments. In general, longer interpreted lineaments also tend to have higher certainty values. For the purpose of the assessment, lineaments were classified according to four length bins (shorter than 1 kilometre, between 1 and 2.5 kilometres, between 2.5 and 5 kilometres, and longer than 5 kilometres).
- 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 1.5 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 expressed in degrees ranging between 0 and 180. Lineament sets are defined by direction clustering of the data. The number of identified lineament sets, and their variation in orientation, provides a measure of the complexity of the potential individual fractures or fracture zones.

The following sections provide a summary of the interpreted lineaments. A more detailed analysis is provided in Section 5.3, and in SRK (2015).

4.3.2 Magnetic Lineaments

Magnetic lineaments were interpreted using the new high-resolution magnetic data, which provides an 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, and more likely reflect potential structures at depth that may or may not have surficial expressions. Magnetic lineaments interpreted with medium and high certainty in the survey area are shown on Figure 4-5. A more detailed analysis of magnetic lineaments interpreted within the vicinity of the potentially suitable area is provided in Sections 5.3 and 6.

4.3.3 Surficial Lineaments

Surficial lineaments were interpreted using newly acquired high resolution topographic data (DEM) from the airborne survey (SGL, 2015), and purchased high resolution satellite imagery (SRK, 2015). The satellite data contained a cell resolution of 0.46 m, which was a significant improvement compared to the lower resolution data (20 m) used during the Phase 1 preliminary assessment. Surficial lineaments were interpreted as linear traces along topographic valleys, escarpments, and drainage patterns such as river streams and linear lakes. These linear traces may represent the expression of fractures on the ground surface. However, it is uncertain whether surficial lineaments represent actual structures and if so, whether the structures extend to significant depth. Figure 4-6 shows Phase 2 surficial lineaments interpreted for the Creighton area. The observed distribution and density of surficial lineaments may be highly influenced by overburden and water body cover, which can mask the surface expressions of potential fractures. This could be a factor in the Creighton area, because only a portion of the area is mapped as exposed bedrock. The distribution of overburden is shown on Figure 4-7. A

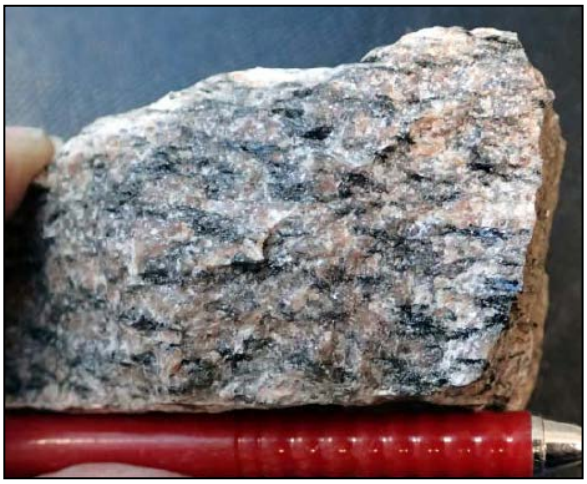
more detailed analysis of surficial lineaments interpreted within the vicinity of the potentially suitable area is provided in Sections 5.3 and 6.

4.4 Observing General Geological Features (Initial Geological Mapping)

An initial geological mapping campaign was conducted by SRK and Golder in September 2014 to observe general geological features in the Creighton area (SRK and Golder, 2015). These observations were conducted at select locations to better understand the lay of the land and to confirm the presence and nature of key geological features in the area (e.g., Photographs 2 and 3), including: bedrock character (lithology, structure, magnetic susceptibility and rock strength); fracture character; bedrock exposure and other surface constraints. A detailed description of the approach, methods and observations is provided by SRK and Golder (2015). This section provides an overview of the mapping planning, logistics and use of local and Traditional Knowledge. The findings from the initial observations are discussed in an integrated manner with findings from other initial Phase 2 field data throughout Section 5.



Photograph 2: Observing General Geological Features of the Annabel Lake Pluton in the Creighton Area



Photograph 3: Example of Biotite Granodiorite from the Annabel Lake Pluton in the Creighton Area

The general potentially suitable area of the Annabel Lake pluton was investigated over a period of nine mapping days by one team of two geologists with the aid of one local guide for logistical support (SRK and Golder, 2015). A total of 41 locations were observed during this time (Figure 4-8). Several GIS data sets were used as base maps for the Phase 2 initial geological mapping, including georeferenced historical geological outcrop mapping, high-resolution satellite imagery, and high-resolution geophysical data.

4.4.1 Mapping Plans and Logistics

Planning of the Phase 2 initial geological mapping involved a review of all available information for the Creighton 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 and Golder, 2015).

The observations incorporated the use of a digital data capturing method to allow for 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. Field and sample magnetic susceptibility measurements were obtained from fresh surfaces of outcrop or from the rock samples using a KT-10 magnetic susceptibility meter. Preliminary geomechanical characterization of the bedrock was undertaken by means of a visual estimation of fracture spacing, primarily of joints, for block size determination and a simple field-based hammer test for intact rock strength (SRK and Golder, 2015).

The initial geological mapping was conducted using various means of transportation. The majority of the area located along the southern shore of Annabel Lake was accessible by boat with daily traverses extending further south away from the lake. A fixed wing float plane was used to access the southern part of the area landing on several long lakes distributed along the length of the pluton. Much of the eastern part of the area was accessible by foot from the highway.

Observations made during the initial geological mapping were generally consistent with previous mapping in the area that defined a relatively uniform granodiorite lithology for the Annabel Lake pluton. In addition, observations generally confirmed the existing understanding of bedrock exposure in the area, which indicates that glacial deposits in the Creighton area form a thin, discontinuous cover less than one metre thick, which reflects the bedrock topography (SRK and Golder, 2015; Golder, 2013).

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 peoples' 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, information sharing meetings and a ceremony involving NWMO staff and mapping contractors along with participating members of local Aboriginal communities took place. The ceremony reminded participating members of the local Aboriginal and non-Aboriginal communities, contractors and NWMO staff that as humans, we are dependent on the land for sustaining life.

Through their knowledge of the land, local Aboriginal and non-Aboriginal people greatly enhanced the planning of mapping activities. Meetings held 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.

5.0 KEY GEOSCIENTIFIC CHARACTERISTICS

The following subsections provide a description of the key geoscientific characteristics that were used to identify areas for detailed geological mapping based on both the Phase 1 preliminary assessment and the newly acquired field data during Phase 2 initial field work. The updated description focuses on the geoscientific characteristics of general area on the Annabel Lake pluton (Figure 1-2) that was identified as potentially suitable in the Phase 1 Geoscientific Desktop Preliminary Assessment (Golder, 2013).

5.1 Bedrock Geology

The bedrock geology of the Creighton area was described in detail in the Phase 1 Preliminary Assessment based on publically available reports and geological maps, as well as from the Phase 1 geophysical interpretation (Golder, 2013; PGW, 2013). This section provides an updated description of the bedrock geology of the general potentially suitable area identified in the Creighton area, based on the newly acquired field data.

The Annabel Lake pluton is a lobe-shaped intrusion about 25 kilometres long and 5 kilometres wide at its widest, with a total area of approximately 84 square kilometres. The pluton consists of medium to coarse-grained foliated granodiorite. It also has two fairly distinct zones including an oval-shaped magnetically quiet area to the northwest, similar to the southeast portion of the Reynard Lake pluton, and a more magnetic area to the southeast, where foliation that conforms to the bounding shear zones and neighbouring greenstone belts is evident. The pluton is elongated parallel to, and flanked by, shear zones on its northern and southern boundaries (Golder, 2013). The outline of the Annabel Lake pluton, as reflected in the magnetic data from Phase 1 (PGW, 2013), was consistent with the mapped bedrock geology. The rest of this section provides an updated description of the bedrock geology of the Annabel Lake pluton based on newly acquired field data.

The results from the Phase 2 interpretation of high-resolution magnetic data acquired over the Annabel Lake pluton overall show subtle internal variability in character of the magnetic data as a gradual increase in intensity from west to east, which could be indicative of a change in the mineral composition in the pluton (SGL, 2015). The magnetic data provides some evidence of structural complexity and lithological heterogeneity throughout the Annabel Lake pluton. There is a well-defined pattern of alternating high and low magnetic response that in general trends east-west throughout the pluton that likely represents its internal compositional variation. This compositional variation highlights a complexity in the eastern part of the pluton that suggests multiple generations of folding have occurred. In contrast, a relatively simple elliptical pattern that defines an east and west plunging dome structure is evident in the western part of the pluton. Although pre-existing bedrock geology maps indicate some internal lithology variations, the magnetic data provides a means to refine these units and highlights additional unmapped units. This is particularly evident in the central and eastern parts of the pluton.

The northern boundary of the Annabel Lake pluton is sharply defined by a uniform linear magnetic high that coincides closely with the location of mapped greenstone belt units and metasedimentary units within the Annabel Lake shear zone. In the northeastern portion of the pluton there appears to be a broad area of relatively consistent magnetic character that encompasses both the mapped Annabel Lake pluton and the mapped greenstone belt units. This suggests that the greenstone belt units to the north are likely shallow, and underlain by the Annabel Lake pluton. In this case the magnetic anomalies may be originating from the pluton beneath the greenstone belt units. In contrast, the southern boundary of the pluton is defined by a linear magnetic low adjacent to the West Arm shear zone, suggesting the greenstone belt units in this area may have a different

mineralogical character. There are no cross-cutting intrusive rocks (e.g. mafic dykes) identified within the magnetic data. Numerous potential fractures are identified as linear magnetic lows in the data.

Gravity data in the Annabel Lake pluton shows an elongated low that generally coincides with the extent of the mapped pluton (Figure 4-3). The southern boundary of the pluton shows a gradual transition into a pronounced gravity high associated with the greenstone belt and metasedimentary rock units within the shear zone, and into the Reynard Lake pluton (SGL, 2015). This southern boundary of the Annabel Lake pluton can be roughly inferred using the gravity data, in particular the first vertical and horizontal derivatives of the gravity data. The inferred southern boundary does not have a significantly high magnetic anomaly as typically associated with the greenstone belt units (SGL, 2015). On the southern edge of the pluton, the gravity data indicates that the greenstone belt units potentially dip underneath the pluton towards the north. There is a less well defined gravity signature on the northern edge of the pluton.

The gravity data along the northern boundary of the pluton shows a more diffuse nature that does not clearly coincide with the mapped contact (Figure 4-3), despite there being an expected strong density contrast between the pluton and the greenstone. This may indicate that the greenstone belt in this area is shallow, and is underlain by the pluton. Similarly, the gravity data also indicates that the eastern edge of the Annabel Lake pluton may extend beneath the greenstone belt units. Within the Annabel Lake pluton, the gravity data also suggests thickness variations along the length of the pluton coincident with two lower gravity anomalies (Figure 4-3).

In order to develop a rough approximation of the depth of the batholith, preliminary 2.5D forward modelling was conducted by SGL (2015). The preliminary modelling used the newly acquired high-resolution geophysical data and readily available information on the mapped bedrock geology at surface to provide a preliminary image of the geometry and subsurface extent of the batholith. The modelling results suggest that the western part of the pluton extends to a depth of approximately 2.0 kilometres, then thins to approximately 1.6 kilometres in the central portion, and thickens to approximately 3.0 kilometres depth further to the east (SGL, 2015). The modelling results also suggest that the pluton is shallower in the southern portion and deeper along the northern boundary, adjacent to the mapped greenstone belt units and the Annabel Lake shear zone, with a depth of approximately 4.8 km.

During the Phase 2 preliminary geological mapping, six domains were defined for the Annabel Lake pluton and surrounding supracrustal rocks (SRK and Golder, 2015), primarily on the basis of variation in their structural and lithological character, including variations in fracture density (Figure 5-1). The initial geological mapping observations are generally consistent with previous mapping that defines a relatively uniform granodiorite lithology for the Annabel Lake pluton (Golder, 2013). Observed mineralogical variation during the initial geological mapping, including noting the existence of biotite or hornblende as the predominant mineral phase and the presence of mafic xenoliths near the pluton boundaries, was used by SRK and Golder (2015) to define the domain boundaries.

There is a generally good correspondence between the mapped domains determined during preliminary geological mapping and variations in the magnetic character interpreted across the pluton (SGL, 2015). In particular, Domain 1 identified in the western part of the pluton during preliminary geological mapping as an area where the lithology and structure are relatively simple and uniform, coincides well with the oval-shaped magnetically quiet area described above (Figure 5-1). The absence of visible indications of alteration during preliminary geological mapping may indicate that the magnetic minerals are primary in origin. Based on visual observations, magnetite is the largest contributor to the measured magnetic susceptibility values (SRK and

Golder, 2015). The mapped shear zones were associated with low magnetic susceptibility values. The internal variations in the measured magnetic susceptibility values for the Annabel Lake pluton are consistent with the identified domains.

5.2 Structural Geology

For the purpose of identifying areas for additional field work, the preliminary assessments focused on the presence and significance of major structural features such as faults and shear zones. The Phase 1 preliminary assessment (Golder, 2013) noted the main structural features in the Annabel Lake area, including the Annabel Lake and West Arm ductile shear zones, as well as several mapped brittle faults occurring mainly in the surrounding greenstone belts (Figure 1-2). These mapped brittle faults are concentrated around the eastern margin of the pluton where several sets of inter-related structures together comprise the Ross Lake fault system. This set of structures, in turn, may be related to the regional-scale Tabbernor fault zone located approximately 80 kilometres west of the Annabel Lake pluton. The Tabbernor fault zone is a deep rooted, splayed fault system displaying topographic, geophysical and geological expression over a distance greater than 1,500 kilometres. The fault has a northerly strike, displays sinistral movement and has had a long history of reactivation that may have continued until the Mesozoic Era (e.g., Byers, 1962; Elliott, 1996).

Previous mapping of bedrock structure within the Creighton area highlighted the elongate east-west nature of the Annabel Lake pluton, as well as its doubly-plunging nature (Golder, 2013 and references therein). The field observations provide additional detail on the spatial structural variation, including variation in foliation and lineation development across the area (SRK and Golder, 2015). Domain 1, the ellipsoidal dome (corresponding to the oval-shaped magnetically quiet zone) in the western part of the Annabel Lake pluton (Figure 5-1), was observed to exhibit a strong mineral lineation that parallels the west-northwest-oriented long axis of the pluton, and a relatively weak, northwest-trending, foliation. Towards the southern and northern margins of the pluton, approaching the shear zones, the foliation was observed to become more dominant, although locally the foliation overprint was heterogeneous. Additionally, the field observations identified outcrop-scale shear zones in all domains, indicating that the shear zone overprint was likely penetrative across the pluton and not only within the mapped shear zone extents (SRK and Golder, 2015). Additional results from the initial geological mapping are included in the discussion of lineaments below.

5.3 Lineament Analysis

This section provides an integrated analysis of interpreted lineaments (SRK, 2015) for the Annabel Lake pluton in the Creighton area, using the newly acquired high-resolution magnetic, topographic, and satellite imagery data (Section 4.2). For the purpose of the analysis, and as outlined in Section 6, magnetic lineaments with high and medium certainties were given emphasis in the analysis, as these lineaments are considered most likely to represent potential bedrock structures that may exist at depth. Surficial lineaments were also considered, in particular in areas where the overburden cover was low or non-existent (SRK, 2015).

Magnetic lineaments interpreted in the Annabel Lake pluton (SRK, 2015) are shown on Figure 4-5. The density of magnetic lineaments in the Annabel Lake pluton is variable. In general the density is highest in the east and associated with tight lineament spacing of approximately 0.3 kilometres when medium and high certainty magnetic lineaments are considered. The spacing between lineaments with highest certainty ranges between 0.3 and 1.5 kilometres. Further towards the western part of the pluton the lineament density is generally relatively lower, associated with wider lineament spacing of up to 0.6 kilometres when medium and high certainty

magnetic lineaments are considered. In this area, when considering only the high certainty lineaments, the spacing is wider and up to 2 kilometres. This is apparent only in the oval-shaped magnetically quiet area in the western part of the pluton. The nature of the higher lineament density in the eastern area may be a reflection of the increased structural complexity as evidenced by the large scale folding pattern observed in the magnetic data. Length analysis of magnetic lineaments shows that longer lineaments (greater than 2.5 kilometres) are broadly distributed across the entire Annabel Lake pluton. The highest density of long lineaments coincides with an area south of the oval-shaped magnetically quiet area where lineaments are traced along the well-defined east-trending compositional variation (SRK, 2015). There is some uncertainty as to whether or not the compositional variation reflects a lithological or structural feature (e.g. fractures). Lineaments that are less than 2.5 kilometres are also broadly distributed, with a slightly higher density in the east.

Surficial lineaments interpreted in the Annabel Lake pluton are shown on Figure 4-6. The surficial lineament density is uniformly high over the entire Annabel Lake pluton, with some areas showing extremely high density in the east. The high surficial lineament density can be attributed, in part, to the extensive bedrock exposure in the east, and to the use of high-resolution satellite imagery. The lowest density areas coincide with locations of large water bodies, in particular, over the footprint of Annabel Lake. Surficial lineament spacing in the Annabel Lake pluton is uniformly tight (less than 0.4 kilometres) when medium and high certainty surficial lineaments are considered. Focusing only on the high certainty lineaments the spacing tends to be more variable. Spacing is generally up to 0.5 kilometres between lineaments in the east and 0.8 kilometres between lineaments in the west. Length analysis of surficial lineaments shows that both long and short lineaments are broadly distributed across the area, and predominantly trend west to northwest. At this stage of the assessment, it is uncertain if surficial lineaments represent real bedrock structures and how far they extend to depth, particularly the shorter lineaments.

Observations during the preliminary geological mapping (Section 4.4) identified outcrop scale fractures throughout the Annabel Lake pluton (SRK and Golder, 2015). A variation in fracture density was observed between identified domains, ranging from sparsely fractured within the western ellipsoidal dome region to abundantly fractured towards the eastern extent of the pluton and in close proximity to the mapped shear zones (Figure 5-1; SRK and Golder, 2015). Importantly, during preliminary geological mapping this variation was recognized in north-south traverses as gradational and occurring over an approximately 750 m wide transition zone. Intact rock strength was, in general, found to be consistently very strong throughout the pluton, in contrast to weak rock observed in the bounding shear zones (SRK and Golder, 2015).

Three steeply-dipping fracture orientations were identified during the observing general geological features activity. This included north-northwest, west-northwest and north-northeast trending sets as well as one shallowly-dipping west-northwest trending set. Some variation in the absolute range of these fracture orientations was recognized in the different domains, and additional less systematic fracture orientations were observed to be locally present throughout the pluton (SRK and Golder, 2015). The most prominent, west-northwest oriented fractures correspond to the orientation of the pluton-bounding Annabel Lake and West Arm shear zones as well as a set of interpreted long (>5 km) west-northwest trending lineaments (SRK and Golder, 2015; SRK, 2015). A tighter fracture spacing was identified in proximity to observed northwest- to north-trending linear surface features (SRK and Golder, 2015). The west-northwest fracture orientation also coincides with that of the dominant lineation that defines the elongated domal nature of the west end of the pluton. In addition, both the Triangle Lake fault and Ross Lake fault are located to the east of this area and are also oriented to the

northwest. In general, all of the fracture observations made during the preliminary geological mapping are consistent with the results of the Phase 2 lineament interpretation (SRK, 2015).

5.4 Bedrock Exposure

The distribution and thickness of overburden cover is an important site characteristic to consider when assessing the amenability to site characterization of an area. At this stage of the assessment preference was given to areas with greater mapped bedrock exposures (JDMA, 2013). The extent of bedrock exposure in the Creighton area is shown on Figure 4-7. Areas mapped as bedrock terrain are assumed, based on initial field observations, to be covered, at most, with a thin veneer of overburden and are therefore considered amenable to geological mapping. Based on previously existing information, there is a general increase from approximately 30 % bedrock exposure in the west to approximately 100 % bedrock exposure in the eastern part of the pluton.

Phase 2 preliminary geological mapping observations of bedrock exposure are generally consistent with the existing understanding of overburden cover in the area (SRK and Golder, 2015). The overburden forms a thin (veneer like), less than one metre thick, discontinuous drift cover that reflects the bedrock topography. The field observations confirmed the presence of moderate bedrock exposure over most of the western part of the Annabel Lake pluton. Bedrock was observed to be well-exposed along the shoreline of Annabel Lake. Further inland to the south-southwest, lower topographic areas were found to be swampy or muskeg-covered and are characterized by thicker overburden deposits. Higher topographic areas, if not showing exposed bedrock, are most commonly thinly moss-covered. In the eastern part of the area, a major forest fire has resulted in a very large area of nearly complete exposure with scattered muskeg preserved between the regions of exposed bedrock. Bedrock exposures in the eastern part of the pluton are also separated by few large lakes (SRK and Golder, 2015).

5.5 Protected Areas

All provincial parks, conservation reserves and provincial nature reserves in the Creighton area were excluded from consideration (Golder, 2013). The only protected area within the Creighton area is the Amisk Lake Recreation Site located approximately 11 kilometres southwest of the settlement area of Creighton along Highway 167 on the northeast shore of Amisk Lake and covers an area of about 3.5 square kilometres. The preliminary Phase 2 assessment confirmed that the candidate area is outside of protected areas.

5.6 Natural Resources

Areas with known potential for exploitable natural resources such as the rocks of the greenstone belts were excluded from further consideration (Golder, 2013). The Annabel Lake pluton in the Creighton area has a low potential for economically exploitable natural resources. In addition to the information gathered during the Phase 1 preliminary assessment (Golder, 2013), the newly acquired Phase 2 geophysical data (SGL, 2015) did not identify geophysical anomalies that may be indicative of rock units that have mineral potential within the general potentially suitable area. Mineral resources and claim maps were also updated as part of the initial Phase 2 assessment (Figure 5-2). 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 a potential area for detailed mapping.

5.7 Potential Surface Constraints

Areas of obvious topographic constraints (high density of steep slopes), large water bodies (wetlands, lakes), and areas of poor accessibility were documented. Distribution of large lakes in the Creighton area is variable (Figure 1-1). The northern portion of the Annabel Lake pluton has extensive lake cover. While lake coverage is generally considered a constraint for conducting detailed mapping, observations made during preliminary geological mapping indicated that lake shores provide good bedrock exposures for the purpose of geological mapping (SRK and Golder, 2015). Topography in the Creighton area is generally relatively flat.

Phase 2 preliminary geological mapping observations indicate that access and surface constraints vary across the Annabel Lake pluton (SRK and Golder, 2015). A major surface constraint observed was the association of topographic low points to broad swampy areas between the higher topographic ridges. It was also observed that the extreme southwestern part of the pluton could not easily be reached except by using aircraft (SRK and Golder, 2015). Access to the northern portions of the Annabel Lake pluton is generally straightforward, either by water or road, followed by short distance hiking. The majority of the central and western parts of the Annabel Lake pluton are best accessed by boat. The eastern part of the Annabel Lake pluton has fewer surface constraints and can be easily accessed by foot from Highway 106.

6.0 CANDIDATE AREAS FOR DETAILED GEOLOGICAL MAPPING IN THE CREIGHTON AREA

This section describes how the key geoscientific characteristics and constraints described in Section 5 were applied to further assess the suitability of the Creighton area and determine whether it is possible to identify candidate areas for further field studies, beginning with detailed geological mapping. The assessment was conducted in a systematic and iterative manner based on the updated understanding of the key geoscientific characteristics and constraints discussed in Section 5, using the following general approach:

a) Bedrock Geology: Identify areas with the most favourable geological setting in terms of rock type, lithology and homogeneity, using the newly interpreted magnetic and gravity data, as well as initial field observations. The estimated depth and extent of the potentially suitable host rock formations were also considered.
b) Structural Geology: Refine the location and extent of the areas based on updated understanding of the structural geology based on the newly interpreted magnetic, gravity and lineament data, as well as initial 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 prominent structural geological features in the area such as faults, shear and deformation zones, and geological boundaries.
c) Lineament Analysis: Use lineament analysis (geophysical and surficial) to identify most favourable structural domains for hosting a repository, using the following approach:

   - Identify areas with lower lineament density, as these areas have a higher potential to contain structurally favourable rock volumes for hosting a repository. In identifying the potentially suitable areas, emphasis was put on magnetic lineaments, as their interpretation is relatively unaffected by the presence of overburden. Surficial lineaments were also considered, particularly in areas with greater bedrock exposure.

   - Emphasis was also put on lineaments which were interpreted as high and medium certainty, and on longer lineaments, as they are considered more likely to extend to greater depth.

   - At this stage of the assessment, all interpreted lineaments were conservatively assumed to be potentially permeable features (i.e. hydraulically conductive), noting that many of these interpreted lineaments may be sealed due to the higher rock stresses at depth and/or the presence of mineral infillings.

d) Protected Areas: The general potentially suitable areas identified in the Phase 1 preliminary assessment were all outside protected areas such as provincial parks, conservation reserves and provincial nature reserves (Golder, 2013). The initial Phase 2 assessment confirmed that any identified candidate areas for detailed geological mapping remain outside of protected areas.
e) Natural Resources: In addition to the information gathered during the Phase 1 preliminary assessment (Golder, 2013), the newly acquired Phase 2 geophysical data was used to look for geophysical anomalies that may be indicative of rock units that have mineral potential. Mineral resources and claim maps were also updated as part of the initial Phase 2 assessment.
f) Overburden: 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 better bedrock exposure, as indicated by available Quaternary mapping (Golder, 2013) and by preliminary field observations, as these areas are more amenable to detailed geological mapping.

g) Potential Surface Constraints: Areas of obvious topographic constraints (high density of steep slopes), large water bodies (wetlands, lakes), and accessibility are identified as potential constraints that would need to be considered in the selection of a repository site. Accessibility was documented during the preliminary field observations (SRK and Golder, 2015b).

The interpretation of the new Phase 2 field data confirmed the presence of geological complexities that reduce the potential for identifying candidate areas in the Creighton area that would ultimately meet NWMO's geoscientific site evaluation factors. The iterative consideration of the above key geoscientific characteristics and constraints identified only one candidate area that could be considered for detailed geological mapping. However, as discussed in the next section, this area is only marginally sufficient in size to accommodate the required repository footprint, and has a number of unfavourable geoscientific characteristics.

The identified candidate area is located in the western portion of the Annabel Lake pluton (Figures 6-1 and 6-2). The figures also show interpreted magnetic and surficial lineaments, respectively, along with other geoscientific constraints such as geology, protected areas, water bodies and active mining claims. The legend in each figure shows a 2 x 3 kilometre box which illustrates the approximate required underground repository footprint.

6.1 Candidate Area for Detailed Geological Mapping in the Annabel Lake Pluton

The candidate area that could be considered for detailed geological mapping is located in the western portion of the Annabel Lake pluton which is an elongated granitic intrusion that is flanked to the north and south by two major shear zones and greenstone belts (Figures 6-1 and 6-2). The identified candidate area is fairly small in size and has a narrow oval shape that is about 2 by 8 kilometres. The outline of the identified candidate area extends slightly west of the potentially suitable area identified in Phase 1.

As shown on Figure 4-2 and discussed in Section 5.1, the outline of the identified candidate area coincides with a distinct oval-shaped magnetically quiet area in the western portion of the Annabel lake pluton. This oval western portion was identified primarily because its magnetic response is more uniform than the rest of the pluton, which exhibits more complexity. This magnetically quiet area is also inferred to be lithologically more homogeneous, which was confirmed by the field observations. Based on available information and the gravity modelling conducted as part of this assessment (Section 5.1), the Annabel Lake pluton has an estimated thickness of approximately 2 kilometres (SGL, 2015), which is sufficient for the purpose of a deep geological repository.

The location and extent of the candidate area for detailed geological mapping was also guided by the density of interpreted magnetic and surficial lineaments. As shown on Figure 6-1 and discussed in Section 5.3, the density of magnetic lineaments in the selected area is generally lower than in other areas of the pluton, but remains fairly high. The spacing between magnetic lineaments with high and medium certainty in the western area is up to 0.6 kilometres (Figure 6-1). A wider spacing up to 2 kilometres is observed between high certainty lineaments. As shown on Figure 6-2, the density of surficial lineaments in the area is also high over the entire Annabel Lake pluton, especially in its eastern part. The spacing between surficial lineaments with high and medium certainty in

the western portion of the pluton is lower and up to 0.4 kilometres. The spacing between high certainty surficial lineaments tends to be more variable with up to 0.8 kilometres between lineaments in the western area.

As discussed in Section 5.1, field observations during the preliminary geological mapping are consistent with the lineament interpretation. The domain within the oval shape in the western portion of the pluton appears to be less fractured than other areas of the pluton (Figure 5-1). A gradational variation in fracture density occurring over an approximately 750 m wide transition zone was also observed in north-south traverses approaching the mapped shear zones. The field observations identified outcrop-scale shear zones in all domains, indicating that the shear zone overprint was likely penetrative across the pluton and not simply within the mapped shear zone extents.

The interpreted spacing between both magnetic and surficial lineaments reveals that a typical 2 by 3 kilometre repository underground footprint could potentially contain numerous significant fractures (Figures 6-1 and 6-2). Avoiding these lineaments, which could potentially be significant subsurface fractures, would require a much larger repository footprint. However, the potential for expanding the repository footprint in the Creighton area is limited, as the size of the potential candidate area is fairly small and is bounded to the north and south by mapped shear zones and greenstone belts which are unsuitable for hosting a deep geological repository.

The northern and central part of the candidate area is generally accessible by boat from Annabel Lake, while the southern part of the area is considerably less accessible. The area has reasonable bedrock exposure, except for topographic lows associated with broad swampy areas. The largest lake in the area (Annabel Lake) is located in the north and northwest portion of the area. The candidate area is outside of protected areas. There is a limited number of gold and base metal occurrences (Figure 5-2) in the surrounding Flin Flon greenstone belt along the contact zone with the Annabel Lake pluton, with no occurrences within the identified candidate area.

In summary, the assessment identified only one candidate area that could be considered for detailed mapping. The area is located in the western portion of the Annabel Lake pluton, which is a fairly narrow elongated granitoid intrusion. However, this potential area is only marginally sufficient in size for hosting a deep geological repository. In addition, the area contains numerous interpreted subsurface fractures that could have an impact on the long-term performance and layout of a deep geological repository. Avoiding significant subsurface fractures would generally require a larger repository footprint at depth. However, there is limited potential for expanding the repository footprint in the Creighton area as the size of the potential host geological formation, the Annabel Lake pluton, is fairly small and bounded by major shear zones and unsuitable surrounding rocks such as the Flin Flon greenstone belt and the Missi metasedimentary rocks.

7.0 SUMMARY OF INITIAL PHASE 2 GEOSCIENTIFIC FINDINGS FOR THE CREIGHTON AREA

This report provides the findings of the initial Phase 2 geoscientific studies conducted in the Creighton area in 2014. These studies were conducted to advance understanding of the geology in the Creighton area, and to assess whether it is possible to identify potentially suitable candidate areas for further field studies, beginning with detailed geological mapping. The assessment included the following key activities:

- Acquisition and processing of high-resolution airborne geophysical (magnetic and gravity) data over the general area identified in the Phase 1 Geoscientific Desktop Preliminary Assessment;
- Detailed interpretation of high-resolution gravity and magnetic data to better understand the bedrock geology such as 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 surveys to identify possible structural features; and
- Observation of general geological features to confirm/ground truth geologic characteristics, including lithology, structure, bedrock exposures and surface constraints.

The interpretation of the new Phase 2 data and field observations confirmed the presence of geological complexities that reduce the potential for identifying repository sites that would ultimately meet NWMO's geoscientific site evaluation factors in the Creighton area.

The assessment identified only one candidate area that could be considered for detailed mapping. The area is located in the western portion of the Annabel Lake pluton, which is a fairly narrow elongated granitoid intrusion. However, this potential area is only marginally sufficient in size for hosting a deep geological repository. In addition, the area contains numerous interpreted subsurface fractures that could have an impact on the long-term performance of a deep geological repository. Avoiding subsurface fractures would generally require a larger repository footprint at depth. However, there is limited opportunity for expanding the repository footprint in the Creighton area as the size of the potential host geological formation, the Annabel Lake pluton, is fairly small and bounded by major shear zones and unsuitable rocks.

8.0 REFERENCES

Byers, A.R., 1962. Major Faults in Western Part of Canadian Shield with Special Reference to Canada. In Stevenson, J.S. (ed.), The Tectonics of the Canadian Shield, Royal Society of Canada, p40-59.

Elliot, C.G., 1996. Phanerozoic Deformation in the “Stable” Craton, Manitoba, Canada. Geology, Vol. 24, No. 10, p. 909-912.

Golder (Golder Associates Ltd.), 2011. Initial Screening for Siting a Deep Geological Repository for Canada’s Used Nuclear Fuel. The Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). Golder Report 10-1152-0110(6000). Mississauga, Canada.

Golder (Golder Associates Ltd.), 2013. Phase 1 Geoscientific Desktop Preliminary Assessment of Potential Suitability for Siting A Deep Geological Repository for Canada's Used Nuclear Fuel, Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0051. Mississauga, Canada.

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. (Available at www.nwmo.ca)

NWMO (Nuclear Waste Management Organization), 2013. Preliminary Assessment for Siting a Deep Geological Repository, Saskatchewan – Findings from Phase One Studies. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0049. Toronto, Canada.

PGW (Paterson, Grant and Watson Ltd.), 2013. Phase 1 Geoscientific Desktop Assessment, Processing and Interpretation of Geophysical Data, Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06144-0053. Toronto, Canada.

Saskatchewan Industry and Resources, 2010. Geological Atlas of Saskatchewan. URL:http://www.infomaps.gov.sk.ca/wesite/SIR Geological Atlas/viewer.htm

SRK (SRK Consulting Inc.), 2015. Phase 2 Geoscientific Preliminary Assessment, Lineament Interpretation, Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06145-0011 Toronto, Canada.

SRK (SRK Consulting Inc.) and Golder (Golder Associates Ltd.), 2015. Phase 2 Geoscientific Preliminary Assessment, Observation of General Geological Features, Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06145-0012. Toronto, Canada.

SGL (Sander Geophysics Ltd.), 2015. Phase 2 Geoscientific Preliminary Assessment, Acquisition, Processing and Interpretation of High-Resolution Airborne Geophysical Data, Town of Creighton, Saskatchewan. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report APM-REP-06145-0010. Ottawa, Canada.

Report Signature Page

GOLDER ASSOCIATES LTD.





Alex Man, Ph.D., P.Eng.
Senior Geotechnical Engineer - Associate

George Schneider, M.Sc., P.Geo.
Senior Geoscientist - Principal

AM/GWS/

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

c:\gws-work\1 - active\12-1152-0026 workshop\04 creighton\05 creighton final report\r2\12-1152-0026 8200a creighton synthesis report 23feb2015 apm-rep-06145-0009.docx

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

Golder Associates

675000 680000 685000 690000 695000 700000

6085000 6080000 6075000 6070000 6065000 6060000

N

Deadhorse Lake
Precipice Lake
Beatty Lake
Johnson Lake
106
Nesootao Lakes
Annabel Lake
Ahrens Lake
Black Lake
Saskatchewan
Manitoba
Cliff Lake
Hamell Lake
Arner Lake
Alder Lake
Batty Lake
Limit Lake
Flin Flon Lake
Flin Flon
Wilson Lake
Raft Lake
Creighton Lake
Creighton
Meridian Lake
Reddy Lake
Grassy Lake
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Phantom Lake
Patmore Lake
Mosher Lake
167
Wekach Lake
Laural Lake
Reynard Lake
Amisk Lake Recreation Site
Ledge Lake
Boot Lake
Cougal Lake
Hambly Lake
Birch Lake
Schist Lake
Denare Beach
Echo Lake

INDEX MAP
Pukatawagan
Thompson
Nelson House
La Ronge
Flin Flon
SASKATCHEWAN
MANITOBA
Norway House
The Pas
Prince Albert
Lake Winnipeg
Lake Winnipegosis

LEGEND

- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Wetland
- Waterbody
- Park and Recreation Area

REFERENCE

Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:100,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

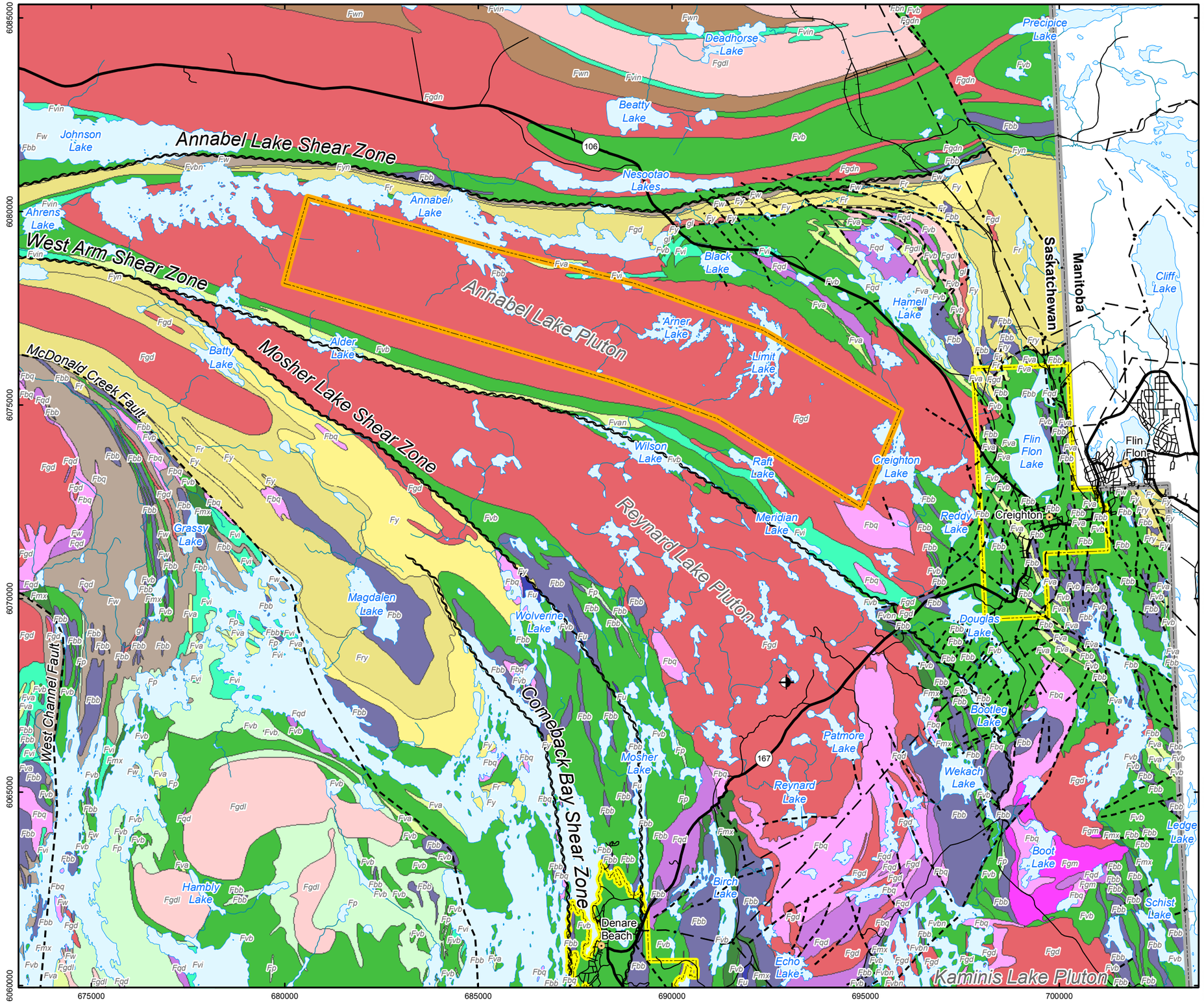
TITLE
The Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 1-1

G:\Projects\2012\12-1152-0026_NWMO_Phase1_FeasibilityGIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig1-1_CreightonArea.mxd



LEGEND

- Potentially Suitable Area
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

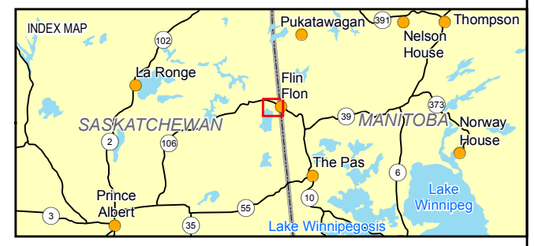
Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:100,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Potentially Suitable Area Identified in Phase 1 Preliminary Assessment

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026		SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	
GIS	JB/CP	23 Feb. 2015	
CHECK	AM	23 Feb. 2015	
REVIEW	GWS	23 Feb. 2015	

FIGURE: 1-2

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig1-2_PotentiallySuitableArea.mxd

675000 680000 685000 690000 695000 700000

6085000 6080000 6075000 6070000

Tyrrell Lake Pluton
Annabel Lake Shear Zone
Annabel Lake Pluton
West Arm Shear Zone
Mosher Lake Shear Zone
McDonald Creek Fault
West Channel Fault
Comeback Bay Shear Zone
Reynard Lake Pluton
Saskatchewan
Manitoba
Le Barre Lake
Little Otonadah Lake
Otonadah Lake
Tyrrell Lake
Deadhorse Lake
Precipice Lake
Beatty Lake
Johnson Lake
Nesootao Lakes
Annabel Lake
Black Lake
Arner Lake
Hamell Lake
Limit Lake
Alder Lake
Batty Lake
Wilson Lake
Raft Lake
Creighton Lake
Flin Flon Lake
Meridian Lake
Reddy Lake
Creighton
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Patmore Lake
Mosher Lake
106
167

N

LEGEND

- Airborne Survey Block
- Potentially Suitable Area
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- FgdI - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

INDEX MAP
Pukatawagan 391 Thompson
Nelson House
102 La Ronge
Flin Flon
SASKATCHEWAN 2 106 MANITOBA 39 373 Norway House
The Pas 6
3 Prince Albert 55 10 35 Lake Winnipegosis
Lake Winnipeg

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Airborne Survey Block in the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 4-1

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-1_AirborneSurveyBlock.mxd

675000 680000 685000 690000 695000

6085000 6080000 6075000 6070000

Tyrrell Lake Pluton
Annabel Lake Shear Zone
Annabel Lake Pluton
West Arm Shear Zone
Mosher Lake Shear Zone
McDonald Creek Fault
West Channel Fault
Comeback Bay Shear Zone
Reynard Lake Pluton
Le Barre Lake
Little Otonadah Lake
Otonadah Lake
Tyrrell Lake
Deadhorse Lake
Beatty Lake
Johnson Lake
Nesootao Lakes
Annabel Lake
Black Lake
Arner Lake
Alder Lake
Batty Lake
Limit Lake
Hamell Lake
Wilson Lake
Raft Lake
Creighton Lake
Meridian Lake
Reddy Lake
Flin Flon Lake
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Patmore Lake
Mosher Lake
106
167

N

LEGEND

First Vertical Derivative (nT/km)

469.3
237.3
237.3
237.2
178.7
136.6
105.2
78.4
56.4
37.4
21.4
7.1
-6.0
-18.0
-28.7
-38.3
-47.6
-56.8
-65.8
-75.2
-85.4
-96.4
-108.3
-121.9
-137.0
-153.2
-170.6
-189.9
-214.6
-246.9
-296.4
-390.7
-415.1

- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody (within magnetic data extents)
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

INDEX MAP
Pukatawagan 391 Thompson
Nelson House
102 La Ronge
Flin Flon
39 373
SASKATCHEWAN MANITOBA
Norway House
2 106
The Pas
6
3 Prince Albert 55 10
35 Lake Winnipegosis
Lake Winnipeg

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Geophysical Data - SGL 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

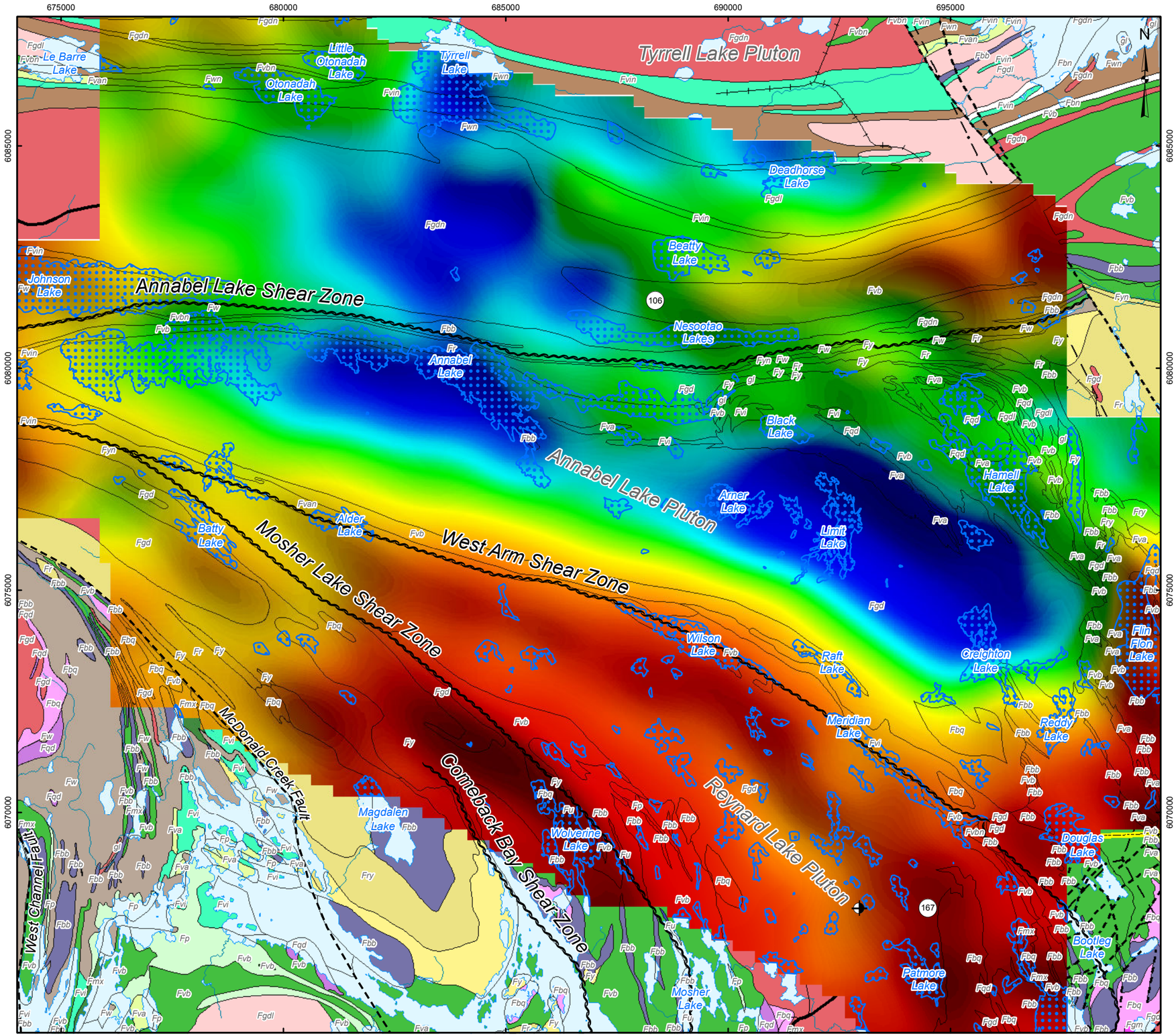
PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Magnetic Data in the Airborne Survey Block for the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	FIGURE: 4-2	
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

G:\Projects\2012\12-1152-0026_NWMO_Phase1_FeasibilityGISMXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-2_MagneticData.mxd



LEGEND

Bouguer Gravity (mGal)

-49.1
-50.0
-51.0
-52.0
-53.0
-53.9
-54.9
-55.9
-56.9
-57.8
-58.8
-59.8
-60.8
-61.7
-62.7
-63.7
-64.6
-65.6
-66.6

- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody (within gravity data extents)
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

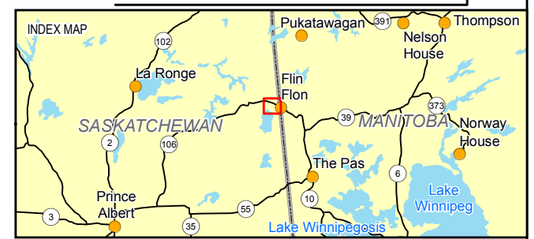
Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Geophysical Data - SGL 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

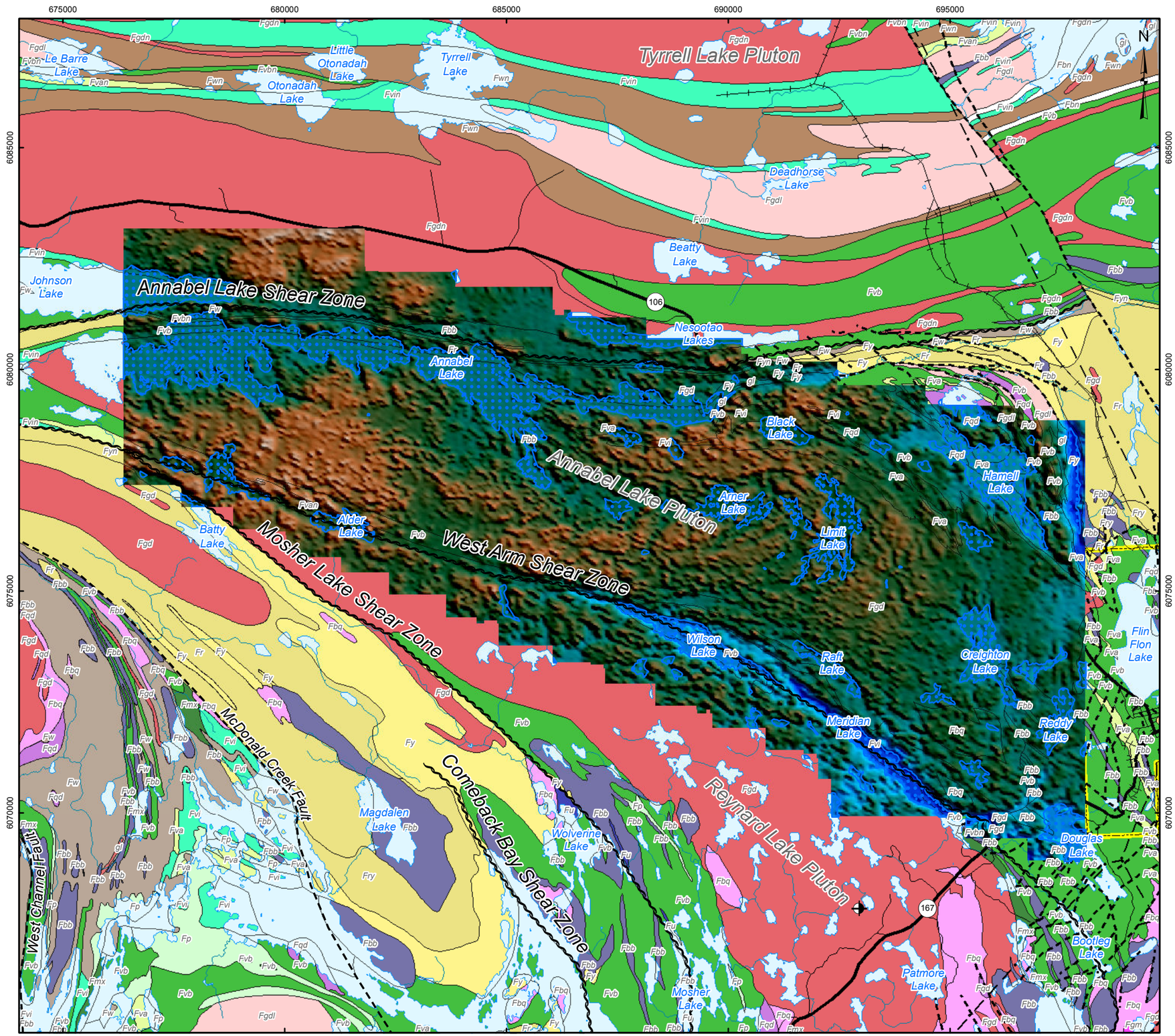
TITLE
Gravity Data in the Airborne Survey Block for the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 4-3

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-3_GravityData.mxd



LEGEND

Elevation (mAMSL)

370.8
369.2
367.5
365.9
364.3
362.6
361.0
359.4
357.7
356.1
354.4
352.8
351.2
349.5
347.9
346.3
344.6
343.0
341.3
339.7
338.1
336.4
334.8
333.2
331.5
329.9
328.2
326.6
325.0
323.3
321.7
320.1

- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody (within DEM extents)
- Waterbody

- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

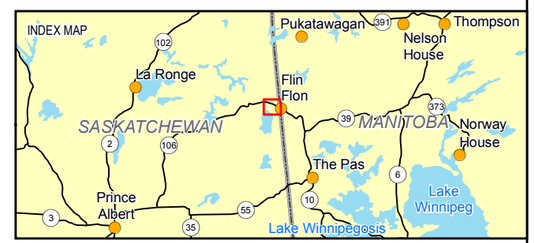
Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzogranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
DEM - SGL 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

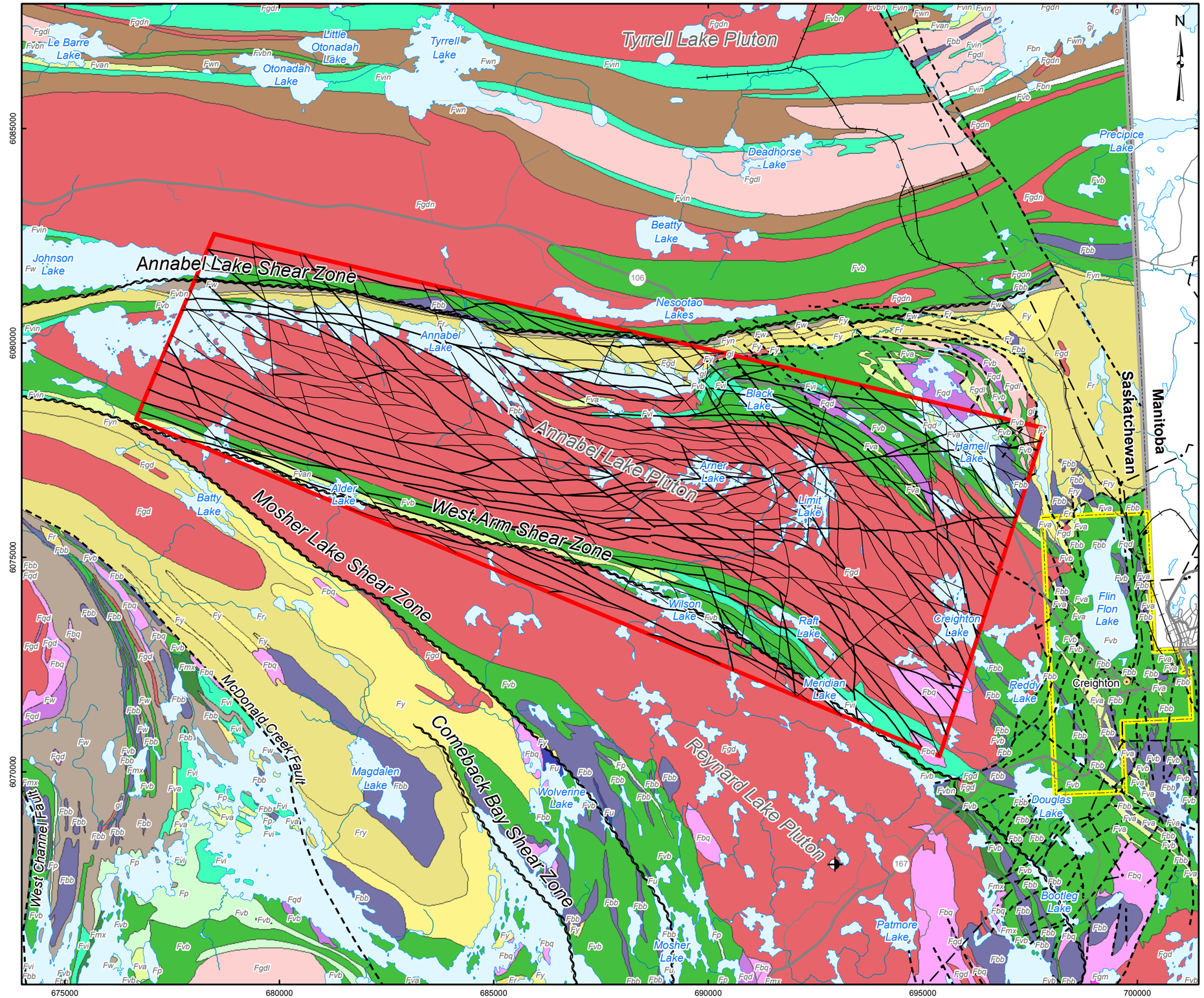
TITLE
Digital Elevation Model (DEM) Data in the Airborne Survey Block for the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 4-4

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-4_DEMData.mxd



LEGEND

- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Magnetic Lineaments

- Medium Certainty
- High Certainty

Bedrock Geology

Missi Group

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Flin Flon Greenstone Belt

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- FgdI - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Lineaments - SRK 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

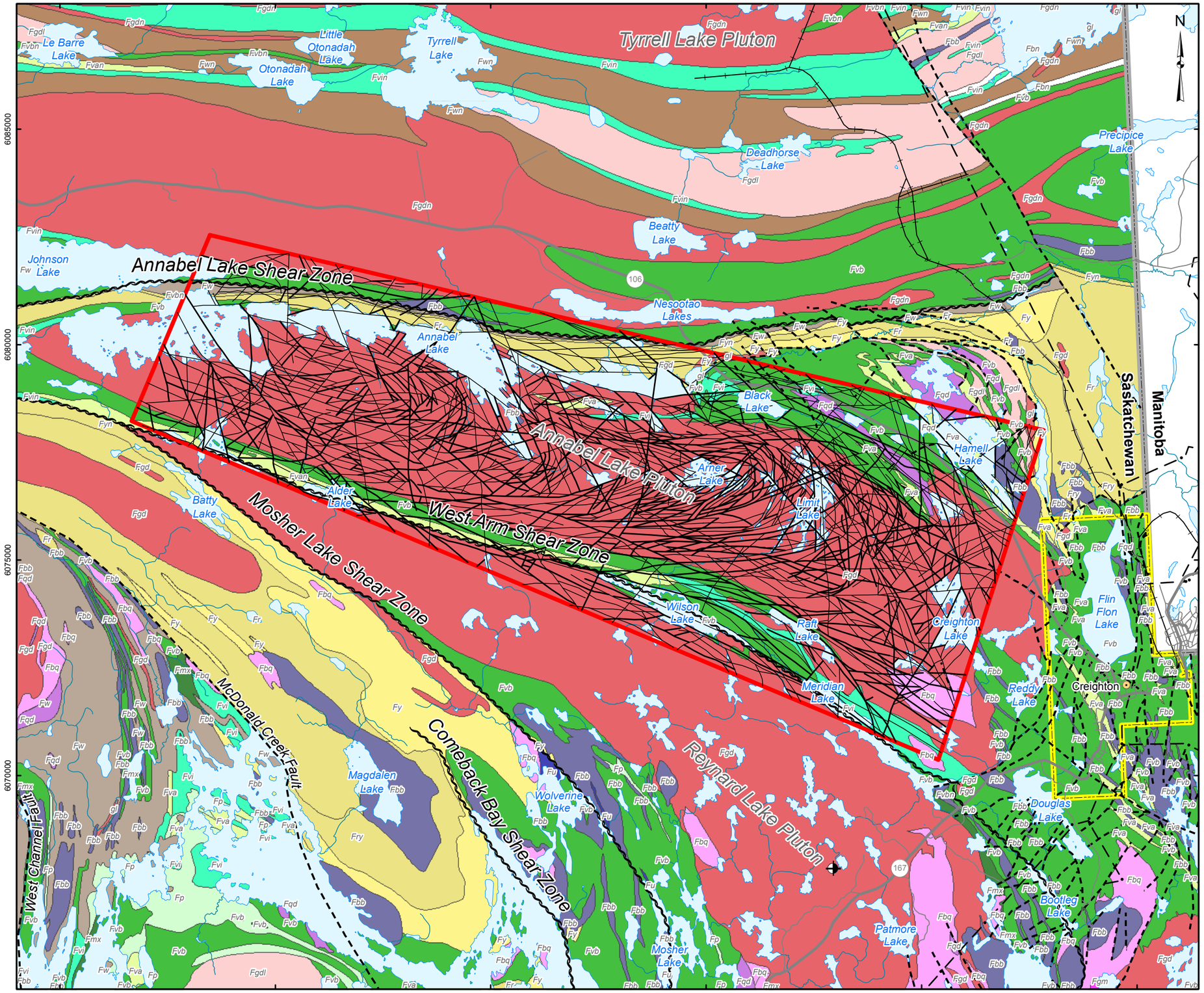
PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Magnetic Lineaments in the Airborne Survey Block with Medium and High Certainty

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	FIGURE: 4-5	
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-5_MagneticLineaments.mxd



LEGEND

- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Surficial Lineaments

- Medium Certainty
- High Certainty

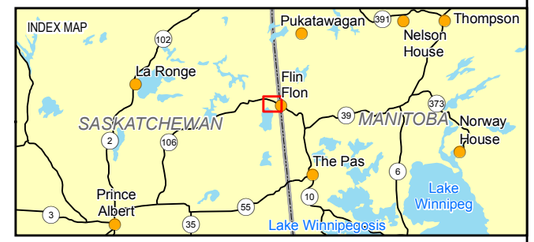
Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- FgdI - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Lineaments - SRK 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Surficial Lineaments in the Airborne Survey Block with Medium and High Certainty

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	
GIS	JB/CP	23 Feb. 2015	
CHECK	AM	23 Feb. 2015	
REVIEW	GWS	23 Feb. 2015	

FIGURE: 4-6

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-6_SurficialLineaments.mxd

675000 680000 685000 690000 695000 700000

6085000 6080000 6075000 6070000

Le Barre Lake
Little Otonadah Lake
Otonadah Lake
Tyrrell Lake
Deadhorse Lake
Precipice Lake
Beatty Lake
Johnson Lake
Nesootao Lakes
Annabel Lake
Black Lake
Hamell Lake
Arner Lake
Batty Lake
Alder Lake
Limit Lake
Wilson Lake
Raft Lake
Creighton Lake
Flin Flon Lake
Meridian Lake
Reddy Lake
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Patmore Lake
Mosher Lake
Laural Lake
Wekach Lake

106
167

Saskatchewan
Manitoba
Creighton

N

LEGEND

- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982

Landform

- 7b - Fen peat
- 7a - Bog peat
- 6 - Alluvial
- 5c - Glaciolacustrine nearshore
- 5b - Glaciolacustrine offshore blanket
- 5a - Glaciolacustrine offshore veneer
- 3c - Glaciofluvial subaqueous outwash
- 3b - Glaciofluvial ice-contact
- 3a - Sand and gravel of undetermined origin
- 2 - Till blanket
- 1 - Till veneer
- R - Bedrock

INDEX MAP

Pukatawagan, Thompson, Nelson House, La Ronge, Flin Flon, SASKATCHEWAN, MANITOBA, Norway House, The Pas, Prince Albert, Lake Winnipeg, Lake Winnipegosis

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
GSC Map 1919A/2010A
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

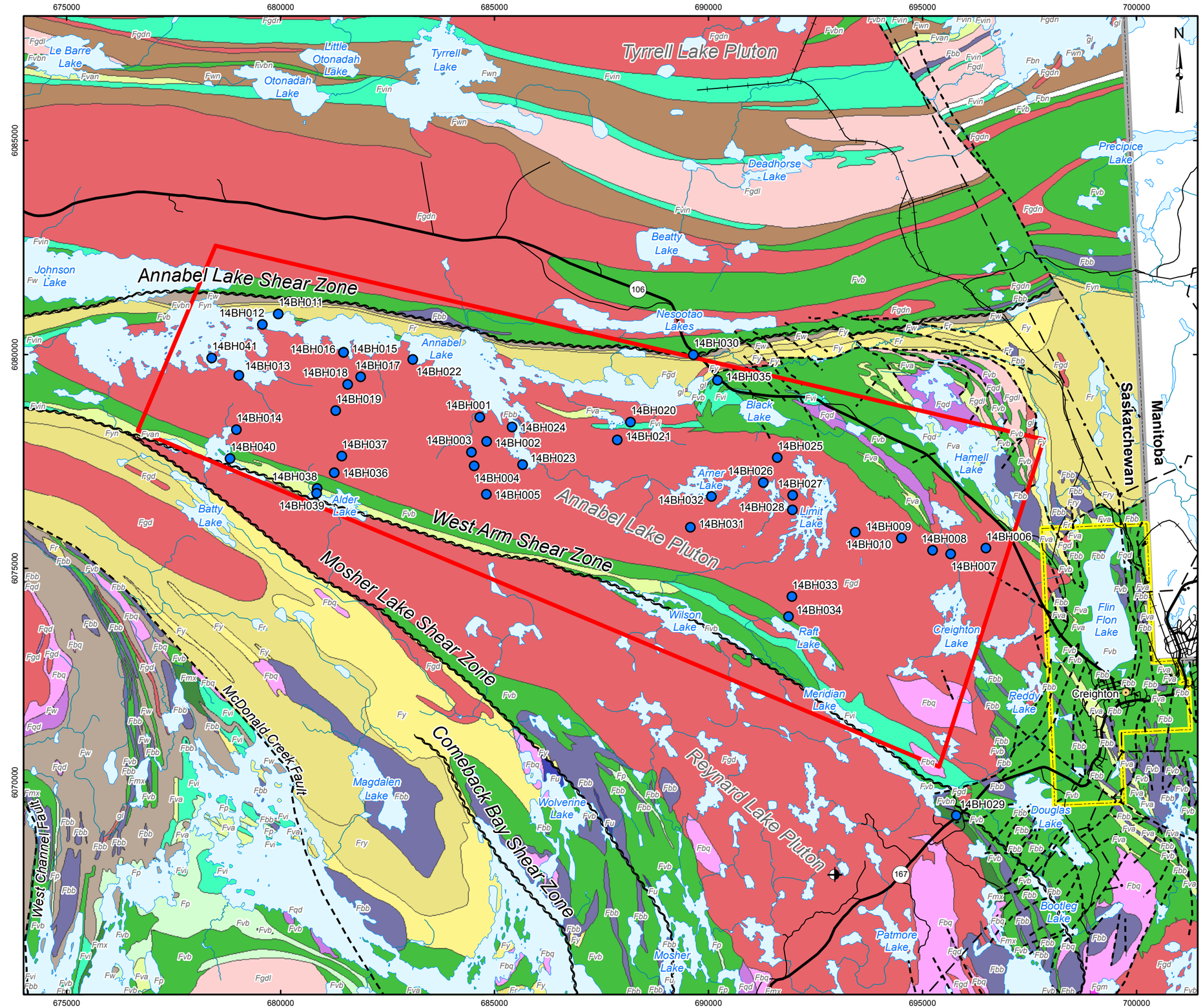
TITLE
Quaternary Geology of the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 4-7

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-7_QuaternaryGeology.mxd



LEGEND

- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Outcrop Mapping Location
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

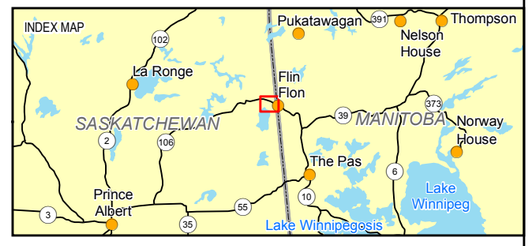
Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- FgdI - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt



REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Mapping Locations: SRK and Golder 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Outcrop Mapping Locations in the Airborne Survey Block in the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 4-8

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig4-8_OutcropMappingLocations.mxd

675000 680000 685000 690000 695000 700000

6085000 6080000 6075000 6070000

Tyrrell Lake Pluton
Annabel Lake Shear Zone
West Arm Shear Zone
Mosher Lake Shear Zone
McDonald Creek Fault
West Channel Fault
Comeback Bay Shear Zone
Annabel Lake Pluton
Reynard Lake Pluton
Saskatchewan
Manitoba
Domain 1
Domain 2
Domain 3
Domain 4
Domain 5
Domain 6
SPARSE
MODERATE
ABUNDANT
Le Barre Lake
Little Otonadah Lake
Otonadah Lake
Tyrrell Lake
Deadhorse Lake
Precipice Lake
Beatty Lake
Johnson Lake
Annabel Lake
Nesootao Lakes
Black Lake
Limit Lake
Batty Lake
Wilson Lake
Raft Lake
Creighton Lake
Flin Flon Lake
Reddy Lake
Creighton
Meridian Lake
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Patmore Lake
Mosher Lake
106
167

N

LEGEND

- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody
- Interpreted Domain Boundary
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- FgdI - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

INDEX MAP
Pukatawagan, Thompson, Nelson House, La Ronge, Flin Flon, SASKATCHEWAN, MANITOBA, Norway House, The Pas, Prince Albert, Lake Winnipeg, Lake Winnipegosis

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Domains: SRK and Golder 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
INITIAL PHASE 2 GEOSCIENCE FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Domain Boundaries and Observed Fracture Density Variations of the Annabel Lake Pluton

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	
GIS	JB/CP	20 Feb. 2015	
CHECK	AM	20 Feb. 2015	
REVIEW	GWS	20 Feb. 2015	

FIGURE: 5-1

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig1-1_CreightonArea.mxd

675000 680000 685000 690000 695000 700000

6085000 6080000 6075000 6070000

Tyrrell Lake Pluton
Annabel Lake Shear Zone
Annabel Lake Pluton
Mosher Lake Shear Zone
West Arm Shear Zone
McDonald Creek Fault
West Channel Fault
Comeback Bay Shear Zone
Reynard Lake Pluton
Le Barre Lake
Little Otonadah Lake
Otonadah Lake
Tyrrell Lake
Deadhorse Lake
Precipice Lake
Johnson Lake
Beatty Lake
Nesootao Lakes
Annabel Lake
Black Lake
Hamell Lake
Arner Lake
Limit Lake
Batty Lake
Alder Lake
Wilson Lake
Raft Lake
Creighton Lake
Meridian Lake
Reddy Lake
Creighton
Flin Flon Lake
Magdalen Lake
Wolverine Lake
Douglas Lake
Bootleg Lake
Patmore Lake
Mosher Lake
106
167
Saskatchewan
Manitoba

N

LEGEND

- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody

Mineral Status (January 2015)*

- Prospect
- Developed Prospect with Reserves
- Developed Prospect without Reserves
- Producing Mine
- Occurrence
- Mineral Location
- Mining Claim (January 2015)*
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzogranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

INDEX MAP
Pukatawagan 391 Thompson
Nelson House
102 La Ronge
Flin Flon
373 39
SASKATCHEWAN MANITOBA
Norway House
2 106
The Pas 6
Prince Albert 10
3 55 35
Lake Winnipeg
Lake Winnipegosis

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
* Mineral Status and Mining Claims accessed January 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

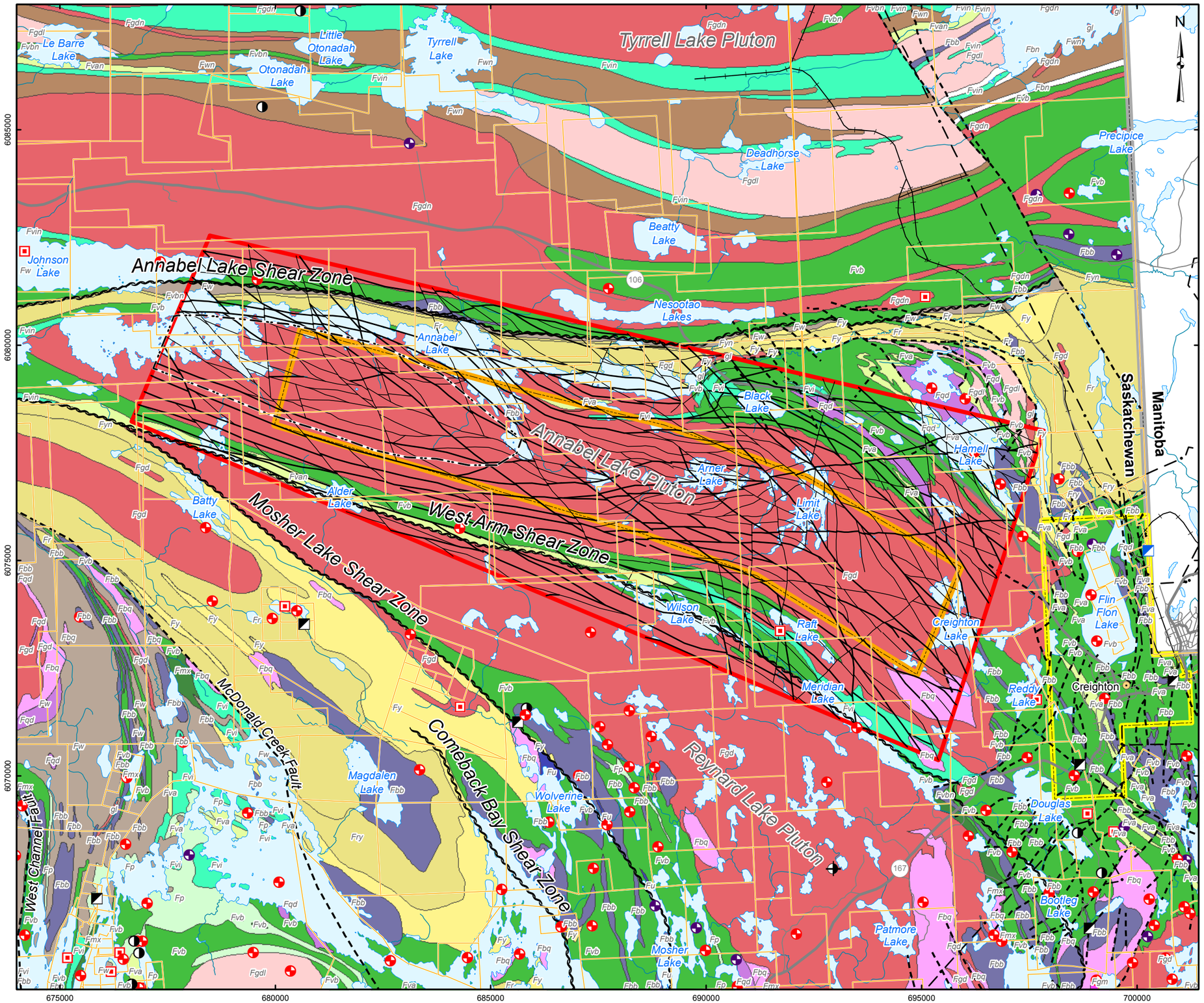
PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Mineral Occurrences and Active Mining Claims in the Creighton Area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015	FIGURE: 5-2	
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

G:\Projects\2012\12-1152-0026_NWMO_Phase1_FeasibilityGISMXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig5-2_MinResrcActvClaims.mxd



LEGEND

- Candidate Area for Phase 2 Detailed Mapping
- Potentially Suitable Area
- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody

Mineral Status (January 2015)*

- Prospect
- Developed Prospect with Reserves
- Developed Prospect without Reserves
- Producing Mine
- Occurrence
- Mineral Location
- Mining Claim (January 2015)*

Magnetic Lineaments

- Medium Certainty
- High Certainty
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

Approximate Underground Repository Footprint (3 X 2 KM)

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Lineaments - SRK, 2015
* Mineral Status and Mining Claims accessed January 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

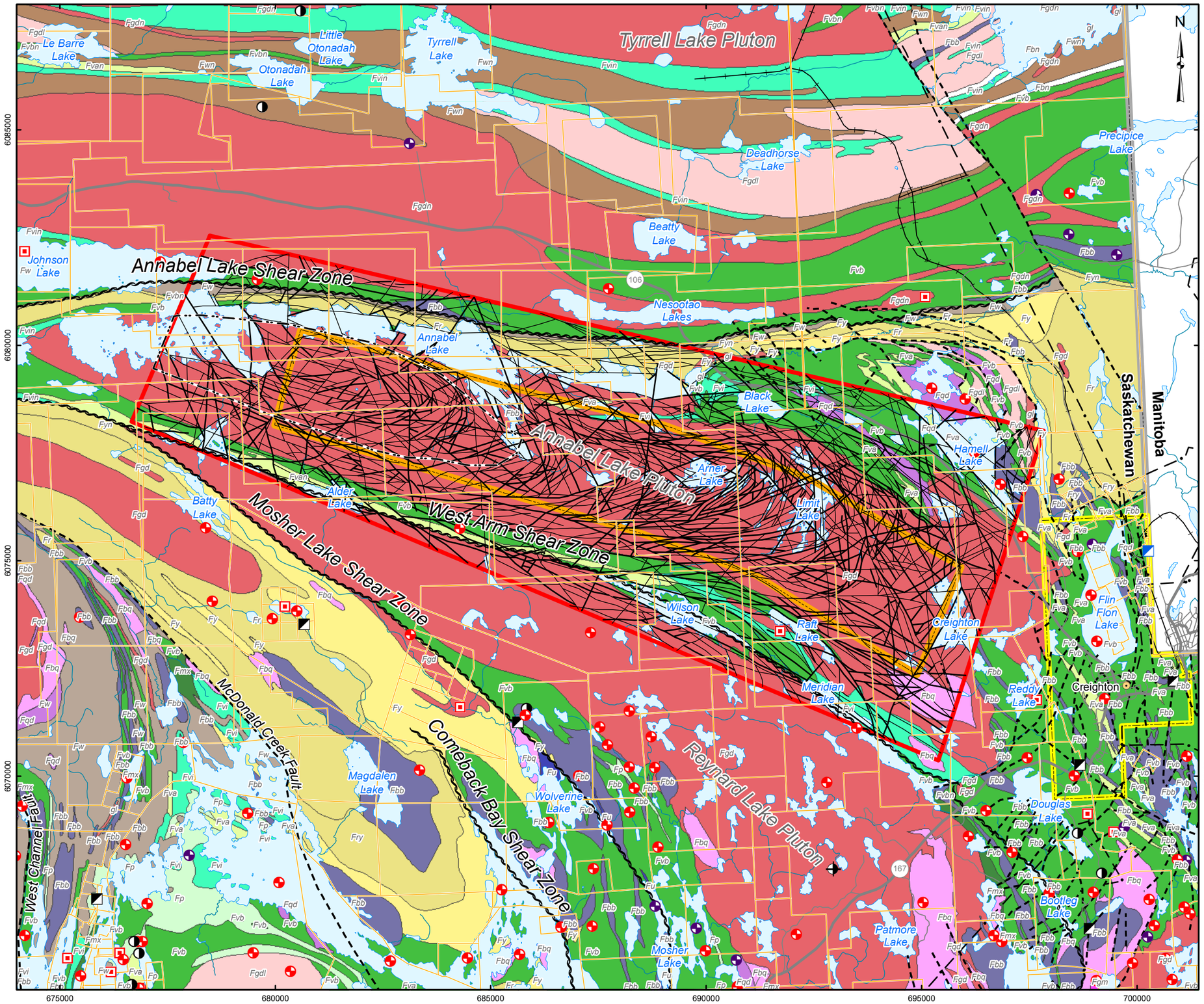
TITLE
Magnetic Lineaments of High and Medium Certainty in the Candidate Area in the Western part of the Annabel Lake Pluton

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 6-1

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_ReportCreighton - Fig6-1_MagneticLineamentsPlusCandidateArea.mxd



LEGEND

- Candidate Area for Phase 2 Detailed Mapping
- Potentially Suitable Area
- Airborne Survey Block
- Community
- Main Road
- Local Road
- Railway
- Transmission Line
- Urban Municipality
- Provincial Boundary
- Watercourse
- Waterbody

Mineral Status (January 2015)*

- Prospect
- Developed Prospect with Reserves
- Developed Prospect without Reserves
- Producing Mine
- Occurrence
- Mineral Location
- Mining Claim (January 2015)*

Surficial Lineaments

- Medium Certainty
- High Certainty
- Location of JXWS Borehole Interpreted from Davis and Tammemagi, 1982
- Shear Zone
- Fault

Bedrock Geology

- Orr - Dolomitic Lime Mudstone/Wackestone and Dolostone
- gl - Alaskite-Aplogranite
- Fr - Sandstone, Crossbedded Sandstone
- Fry - Pebbly Sandstone, Pebble Conglomerate, Sandstone
- Fy - Polymitic Conglomerate, Sandstone
- Fyn - Conglomerate Gneiss, Local Psammitic Gneiss
- Fw - Metagreywacke
- Fwn - Metagreywacke Gneiss

Missi Group

- Fgm - Granite-Monzongranite-Quartz Monzogranite
- Fgdl - Leucogranodiorite-Tonalite
- Fgd - Granodiorite-Tonalite
- Fgdn - Foliated to Gneissic Granodiorite-Tonalite
- Fbq - Tonalite-Quartz Diorite
- Fqd - Quartz Diorite - Granodiorite-Diorite
- Fmd - Diorite-Quartz Monzonite-Monzodiorite
- Fbb - Gabbro-Diorite
- Fu - Ultramafic Rock
- Fmx - Mafic Protomylonite to Mylonite
- Fp - Rhyolite, Dacite, Quartz Porphyry
- Fva - Acid Volcanics
- Fvan - Felsic Gneiss Derived from Felsic Volcanics
- Fvi - Intermediate Volcanics
- Fvin - Mafelsic Gneiss Derived from Intermediate to Mafic Volcanics
- Fvb - Basic Volcanics
- Fvbn - Mafic Gneiss Derived From Basic Volcanics

Flin Flon Greenstone Belt

Approximate Underground Repository Footprint (3 X 2 KM)

REFERENCE

Geological Atlas of Saskatchewan
Saskatchewan Energy and Resources
NTS Mapsheets 63 K/L
Natural Earth 2015
Lineaments - SRK, 2015
* Mineral Status and Mining Claims accessed January 2015
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13N

1.5 0.75 0 1.5 3 4.5
SCALE 1:90,000 KILOMETRES

PROJECT
PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT
FINDINGS FROM INITIAL FIELD STUDIES
THE TOWN OF CREIGHTON, SASKATCHEWAN

TITLE
Surficial Lineaments of High and Medium Certainty in the Candidate Area in the Western part of the Annabel Lake Pluton

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	CP	20 Feb. 2015		
GIS	JB/CP	23 Feb. 2015		
CHECK	AM	23 Feb. 2015		
REVIEW	GWS	23 Feb. 2015		

FIGURE: 6-2

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Creighton\Synthesis_Report\Creighton - Fig6-2_SurficialLineaments

PlusCandidateArea.mxd