nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

June 17, 2011

Township of Red Rock
PO Box 447
Red Rock, ON P0T 2P0

Attn: Mr. Kal Pristanski, Chief Administrative Officer/Clerk/Treasurer

Re: **Adaptive Phased Management Initial Screening – The Township of Red Rock**

Dear Mr. Pristanski,

Further to the Township of Red Rock's request to Learn More about the Adaptive Phased Management program and request for an initial screening, I am pleased to attach a report outlining the findings from the initial screening, as described in the *Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel* (May, 2010). As you know, the purpose of the initial screening in Step 2 of the process is to determine whether, based on readily-available information and five screening criteria, there are any obvious conditions that would exclude the Township of Red Rock from further consideration in the site selection process. The process for identifying an informed and willing host community for a deep geological repository for the long-term management of Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future.

The review of readily available information and the application of the five initial screening criteria show that the Red Rock area is unlikely to contain geological formations that would be potentially suitable for hosting a deep geological repository. The various geological formations within the area considered for this screening are either not amenable to site characterization or are unlikely to meet the safe containment and isolation function of a deep geological repository. Therefore, the Township of Red Rock is not considered as a suitable candidate for continuing in the NWMO site selection process.

Should you have any questions about the screening results, please do not hesitate to contact the NWMO through Peter Simmons. We would be pleased to review the report with you.

Once again, I thank you for taking the time to learn about Canada's plan for the safe and secure management of Canada's used nuclear fuel.

Sincerely,

Kathryn Shaver

Kathryn Shaver,
Vice President, APM Public Engagement and Site Selection

c. Mayor Gary Nelson

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June 2011

# INITIAL SCREENING FOR SITING A DEEP GEOLOGICAL REPOSITORY FOR CANADA'S USED NUCLEAR FUEL

# Township of Red Rock, Ontario

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

REPORT

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**Report Number:** 10-1152-0110 (7000)
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# EXECUTIVE SUMMARY

On February 25, 2011, the Township of Red Rock expressed interest in learning more about the Nuclear Waste Management Organization (NWMO) site selection process to find an informed and willing community to host a deep geological repository for Canada's used nuclear fuel (NWMO, 2010). This report presents the findings of an initial screening, conducted by Golder Associates Ltd., to evaluate the potential suitability of the Red Rock area against five initial screening criteria using readily available information. The purpose of the initial screening is to identify whether there are any obvious conditions that would exclude the Township of Red Rock from further consideration in the site selection process. The initial screening focused on the Township of Red Rock and its periphery, which are referred to as the "Red Rock area". Areas within or in closer proximity to neighbouring Townships were not included in the initial screening.

The five initial screening criteria are defined in the site selection process document (NWMO, 2010), and relate to: having sufficient space to accommodate surface facilities, being outside protected areas and heritage sites, absence of known groundwater resources at repository depth, absence of known natural resources and avoiding known hydrogeologic and geologic conditions that would make an area or site unsuitable for hosting a deep geological repository. The process for identifying an informed and willing host community for a deep geological repository for Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future.

The review of readily available information and the application of the five initial screening criteria show that the Red Rock area is unlikely to contain geological formations that would be potentially suitable for hosting a deep geological repository. The various geological formations within the area considered for this screening are either not amenable to site characterization or are unlikely to meet the containment and isolation function of a deep geological repository. Therefore, the Township of Red Rock is not considered a suitable candidate for continuing in the NWMO site selection process.

The criteria that did not meet the requirements of the initial screening are discussed further below.

## Availability of Land

Review of available mapping and satellite imagery shows that the Township of Red Rock and its periphery contain few constraints that would prevent the development of the repository's surface facilities. Residential, industrial infrastructure and constraining topographic features occupy a small portion of the Red Rock area. As discussed later, the Township does not contain geological units that are suitable for hosting a deep geological repository and associated underground facilities.

## Protected Areas, Heritage Sites, Provincial Parks and National Parks

The Red Rock area contains sufficient land outside protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities. There are two provincial parks and a conservation reserve that occupy a small portion of the Red Rock area. The only park within the Township of Red Rock is the Black Sturgeon River Provincial Park, which occupies a small area near the western boundary of the Township. There is evidence to conclude that archaeological potential is high, particularly along the banks of the Nipigon River and along the shore of Lake Superior, but currently there are no registered archaeological sites in the Township of Red Rock, and only one known heritage site present in the Red Rock area. This site is a collection of pictographs almost at the mouth of the Nipigon River on the opposite shore north of the Township of Red Rock. There are no national historic sites in the Red Rock area.

## Absence of Known Groundwater Resources at the Repository Depth

The review of available information did not identify any known groundwater resources at repository depth (approximately 500 m) for the Red Rock area. The Ontario Ministry of the Environment Water Well Record database shows that all water wells known in the Red Rock area obtain water from overburden or shallow bedrock sources at depths ranging from 1 to 159 m, with most wells between 30 to 60 m deep. The geology of the Red Rock area at repository depth (approximately 500 m) is dominated by metasedimentary rocks that are part of the crystalline rocks of the Canadian Shield. Experience in similar geological settings across the Canadian Shield suggests that the potential for deep groundwater resources at repository depths is low throughout the Red Rock area.

## Absence of Economically Exploitable Natural Resources as Known Today

Based on the review of readily available information, the Red Rock area contains sufficient land, free of known economically exploitable natural resources, to accommodate the required repository facilities. The Red Rock area generally has a low potential for oil and gas resources. There are no current or past mining operations in the Red Rock area, and the potential for metallic minerals resources remains low and generally associated with localized geological formations in the area. Commercial potential for peat exists in some areas, but no peat extraction has occurred.

## No Known Geological and Hydrogeological Characteristics That Would Prevent the Site from Being Safe

The review of readily available geoscientific information identified characteristics suggesting that the Red Rock area is unlikely to contain geological units that would be potentially suitable for hosting a deep geological repository. The various geological formations within the area considered for this screening are either not amenable to site characterization or are unlikely to meet the containment and isolation function of a deep geological repository.

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# 1.0 INTRODUCTION

On February 25, 2011, the Township of Red Rock expressed interest in learning more about the Nuclear Waste Management Organization (NWMO) nine-step site selection process to find an informed and willing community to host a deep geological repository for Canada's used nuclear fuel (NWMO, 2010). This report presents the results of an initial screening, conducted by Golder Associates Ltd., as part of Step 2 in the site selection process to evaluate the potential suitability of the Red Rock area against five screening criteria using readily available information. The initial screening focused on the Township of Red Rock and its periphery, which are referred to as the "Red Rock area" in this report. Areas within or in closer proximity to neighbouring Townships were not considered in the initial screening.

## 1.1 Background

The ultimate objective of Adaptive Phased Management (APM) is long-term containment and isolation of used nuclear fuel in a deep geological repository in a suitable rock formation. The NWMO is committed to implementing the project in a manner that protects human health, safety, security and the environment, while fostering the long-term well-being of the community and region in which it is implemented (NWMO, 2005).

In May 2010, the NWMO published and initiated a nine-step site selection process to find an informed and willing community to host the repository (NWMO, 2010). The site selection process is designed to address a broad range of technical and social, economic and cultural factors as identified through dialogue with Canadians and Aboriginal peoples, and draws from experiences and lessons learned from past work and processes developed in Canada to site facilities for the management of other hazardous material. It also draws from similar projects in other countries pursuing the development of deep geological repositories for used nuclear fuel. The suitability of potential candidate sites will ultimately be assessed against a number of site evaluation factors, both technical and social in nature.

The geoscientific suitability of candidate sites will be assessed in three main phases over a period of several years, with each step designed to evaluate the site in progressively greater detail upon request of the community. The three site evaluation phases include: Initial Screenings to evaluate the potential suitability of the community against a list of initial screening criteria, using readily available information (Step 2); Feasibility Studies to determine if candidate sites within the proposed areas are potentially suitable for developing a safe deep geological repository for used nuclear fuel (Step 3); and Detailed Site Evaluations, at one or more selected sites, to confirm suitability based on detailed site evaluation criteria (Step 4). It is up to the communities to decide whether they wish to continue to participate in each step of the process.

## 1.2 Objectives and Approach for Conducting Initial Screenings

The overall objective of the initial screening is to evaluate proposed geographic areas against a list of screening criteria using readily available information. Initial screening criteria (NWMO, 2010) require that:

1) The site must have enough available land of sufficient size to accommodate the surface and underground facilities.

2) This available land must be outside of protected areas, heritage sites, provincial parks and national parks.

3) This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.

4) This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

5) This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the safety factors outlined in Section 6 of the Site Selection Document (NWMO, 2010).

The initial screening step involves the systematic consideration of each of the five initial screening criteria on a qualitative basis using readily available information from provincial, federal, municipal and other sources of information. It is not the intent of the initial screening study to conduct a detailed analysis of all available information, but rather to identify any obvious conditions that would exclude a community from further consideration in the site selection process. For example, a site with known economically exploitable natural resources or geological or hydrogeological characteristics that are clearly unfavourable would be excluded from further consideration.

For cases where readily available information is limited and where assessment of some of the criteria is not possible at the screening stage, the area would be advanced to the feasibility study stage for more detailed evaluation, provided the community remains interested in continuing to participate in the siting process.

The initial screening commences with an analysis of readily available information in order to develop an overall understanding of the geoscientific and other relevant characteristics of the site. The initial screening criteria are then applied in a systematic manner based on the understanding of the proposed area or site. The tasks involved include the following:

- Reviewing the regional and local physical geography, geology, seismicity, structural geology and Quaternary geology (surface geology);
- Reviewing the hydrogeology, including, regional groundwater flow, deep and shallow aquifers and hydrogeochemistry;
- Reviewing the economic geology, including petroleum resources, and metallic and non-metallic mineral resources;
- Applying the screening criteria; and
- Summarizing the findings with regards to potential suitability.

# 2.0 PHYSICAL GEOGRAPHY

## 2.1 Location

The Township of Red Rock is located on the western shore of Lake Superior's Nipigon Bay, approximately 80 km northeast of Thunder Bay, and 5 km south of Nipigon, as shown on Figure 2.1. The Township of Red Rock is approximately 68.5 $km^2$ in area extending from Nipigon Bay westward to the Black Sturgeon River. The Township is bordered immediately to the north by the Township of Nipigon. Satellite imagery for the Red Rock area (Landsat 7, taken in 2006) is presented on Figure 2.2.

## 2.2 Topography

The Township of Red Rock is located in the Canadian Shield physiographic region, a low-relief, dome-like, gently undulating land surface with an elevation of about 150 masl (meters above sea level) in the north, increasing to about 450 masl towards the south. Figure 2.3 shows the general physiographic regions of Ontario (Thurston, 1991), including the subdivision of the Canadian Shield physiographic region into the Severn Upland, the Nipigon Plain, the Port Arthur Hills, the Abitibi Upland and the Laurentian Highlands.

The Township of Red Rock lies in the Port Arthur Hills physiographic subdivision, which borders the shores of Lake Superior and comprises a rugged terrain dominated by plateaux, ridges and cuestas defined by the underlying folded bedrock sequence (Thurston, 1991).

The Digital Elevation Model (DEM) for the Red Rock area is presented on Figure 2.4. The terrain in the north and northwestern portions of the Red Rock area is dominated by a number of ridges, plateaux, and hills, including the prominent Red Rock Hill, which rises some 200 m higher than the surrounding lands and reaches an elevation of more than 400 masl, immediately south of the Red Rock settlement area. A similar topographic high occurs to the north of the Red Rock settlement area and extends beyond the Township boundaries into the neighbouring Township of Nipigon. The most prominent topographic feature of the Red Rock area is the Black Sturgeon River canyon which confines the Black Sturgeon River between cliff faces as high as 200 m in height and partly runs along the western margin of the Township of Red Rock. Topography in the southern sector of the Red Rock area tends to be relatively flat, with elevations averaging approximately 200 masl.

The highest elevations within the Township of Red Rock occur in the extreme southwest, on the southwest side of the Black Sturgeon River, where elevations reach 450 masl. From these upland areas, the terrain falls away steeply to between 250 and 200 masl and remains relatively flat over most of the central portion of the Township. The lowest elevations in the area occur along the Lake Superior shoreline at an elevation of approximately 183 masl.

## 2.3 Drainage

Surface water drainage for the Red Rock area is shown on Figure 2.5. Drainage is easterly to southeasterly into Lake Superior from the watershed along the north side of Lake Nipigon and extending west as far as the Lac Des Iles area. This height of land separates the Atlantic Watershed (via Lake Superior) from the Arctic Watershed (via Hudson Bay). The Nipigon River is the largest river in the area draining the lake of the same name and entering Lake Superior to the north of the Township of Red Rock at Nipigon.

In the Red Rock area, the most prominent drainage feature is the Black Sturgeon River which originates in Black Sturgeon Lake near the southern margin of Lake Nipigon, and which flows in a southeasterly direction for a distance of approximately 70 km before entering Lake Superior. For most of its length, the river follows a meandering path within a river valley occasionally bounded by steep cliffs. Approximately 5 km to the south of

the Township of Red Rock, the river makes an abrupt 90-degree turn and flows in a southwesterly direction to its outlet into Black Bay. A number of small creeks are tributary to the Black Sturgeon River including Moseau Creek, which flows in a southeasterly direction to its confluence with the Black Sturgeon River in the west part of the Township of Red Rock. Little Trout River flows in a parallel direction to Moseau Creek to its confluence with Big Trout River in the south central part of the Township of Red Rock. Big Trout River enters the Nipigon Bay at the Red Rock settlement area. In addition to these larger drainage systems, much of the land bordering Lake Superior drains directly to the lake via a number of small and generally unnamed creeks.

Lands to the south of the Township of Red Rock are flat-lying and low with generally poor drainage and numerous bogs and wetlands.

## 2.4 Protected Areas

### Parks and Reserves

There are two provincial parks and one conservation reserve in the Red Rock area. Figure 2.1 shows the location of these protected areas. Only a portion of the Black Sturgeon River Provincial Park occurs within the Township boundaries.

The Black Sturgeon River Provincial Park is some 72 km in length and covers 244 $km^2$ in area. The park extends from the north end of Black Sturgeon Lake and generally follows the Black Sturgeon River to just south of the Township of Red Rock, crossing the western part of the Township diagonally from northwest to southeast. Within the Township boundaries the Black Sturgeon River Provincial Park has an approximate width of 1 to 1.5 km.

The Ruby Lake Provincial Park covers an area of 27 $km^2$ on the east side of the mouth of the Nipigon River, bordering the extreme northeast of the Township of Red Rock. The Black Bay Bog Conservation Reserve is located approximately 10 km to the south of the Township of Red Rock, but only a small portion of it (0.5 $km^2$) falls within the Red Rock area.

### Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Red Rock area, using the Ontario Archaeological Sites Database. According to the database, there are no registered archaeological sites within the Township of Red Rock (Figure 2.1). There are no national historic sites in the Red Rock area. However, there is significant evidence to conclude that archaeological potential for pre-contact Aboriginal sites and historic Aboriginal and Euro-Canadian archaeological sites are high, particularly along the banks of the Nipigon River and along the shore of Lake Superior.

Archaeological potential is established by determining the likelihood that archaeological resources may be present on a subject property. In archaeological potential modeling, a distance to water criterion of 300 m is generally employed for primary water courses, including lakeshores, rivers and large creeks, as well as secondary water courses, including swamps and small creeks (Ontario Ministry of Tourism and Culture, 2011).

The Nipigon River was considered a major transportation route for both Aboriginal and Euro-Canadian people. There is also a high concentration of pre-contact Aboriginal sites along Lake Nipigon, north of the Red Rock area (Filteau, 1978). Outside of the Township of Red Rock on the opposite shore north of Red Rock is a collection of pictographs (Young, 1995) which provide evidence of past First Nations activity in the region. Red Rock Hill is also assumed to be an integral part of both past and present Aboriginal culture and served as a meeting place for the First Nations of the area. It was considered to be sacred ground and rock from the mountain was used

for making calumets or peace-pipes (Young, 1995). As well, the French had expanded their St. Lawrence based fur trade into the north western shores of Lake Superior and had established small posts as far as Lake Nipigon and the Rainy River by the late 17th century (Ray, 1978).

Euro-Canadian settlers entered the Township of Red Rock by the late 19$^{th}$ and early 20$^{th}$ century and formed a small farming community. In the 1930's, the town saw economic growth through the establishment of the Lake Sulphite Pulp Company pulp and paper mill (Figure 2.1). But the boom ended after only two years when the company went into receivership and the settlement area was abandoned (Young, 1995), later becoming a Prisoner of War camp during the Second World War.

# 3.0 GEOLOGY AND SEISMICITY

## 3.1 Regional Bedrock Geology

The geology of the Red Rock area consists of Mesoproterozic-aged sedimentary rocks and unconsolidated Quaternary deposits overlying 3 to 2.5 billion year old bedrock of the Canadian Shield – a stable craton that forms the core of the North American continent. The Canadian Shield is a collage of Archean plates and accreted juvenile arc terranes and sedimentary basins of Proterozoic age that were progressively amalgamated.

As shown on Figure 3.1, the Township of Red Rock is situated on the boundary between the Superior Province and the Southern Province of the Canadian Shield The Superior Province covers an area of approximately 1,500,000 $km^2$ stretching from the Ungava region of northern Québec through the northern part of Ontario and the eastern portion of Manitoba, and extending south through to Minnesota and the northeastern part of South Dakota. The Southern Province of the Canadian Shield borders the Superior Province on the south from the Sudbury area through to Thunder Bay and is comprised of younger volcanic and sedimentary basins of Proterozoic age, deposited over the Archean basement.

The Superior Province has been divided into various subprovinces based on lithology, age, genesis and metamorphism (Thurston, 1991). These subprovinces are also shown on Figure 3.1. The Township of Red Rock is situated on the boundary of the Quetico Subprovince of the Superior Province and the Southern Province. Figure 3.2 shows the general bedrock geology and main structural features of the Red Rock area and surroundings.

The Quetico Subprovince consists primarily of Archean clastic metasedimentary rocks that have undergone regional melting and recrystallization (migmatization), and are intruded by 2.70 to 2.65 billion year old granitic intrusive rocks (Williams, 1991). In the southern and western portions of the Red Rock region (Figure 3.2), the Proterozoic sedimentary rocks of the Animikie and Sibley Groups overlie Archean rocks of the Quetico Subprovince. The Animikie and Sibley Groups were deposited unconformably on the Archean metasedimentary rocks of the Quetico Subprovince.

A major structural feature in the region is the Black Sturgeon River Fault Zone (Figure 3.2), which comprises a series of northwest-trending faults following the course of the Black Sturgeon River, and forms the northeastern border of a graben structure. Rocks to the northeast of the fault zone are uplifted by a few hundred metres compared to rocks to the southwest. The fault zone is marked by a steep valley, approximately 1 km wide and 200 m deep, through which the Black Sturgeon River flows in the northwest part of the Red Rock area. The fault zone is of unknown dip and width. Other northeast-trending faults are also present, but they are less well defined and appear to parallel the fabric of the rocks of the Quetico Subprovince (Hart, 2005). The DEM for the Red Rock area shows lineaments in the rocks of the Quetico Subprovince, and these are discussed further in the local bedrock geology (Section 3.2).

A generalized geologic sequence for the Red Rock area is presented in Table 3-1. The geological history of the Red Rock area can be summarized as follows: the metasedimentary rocks of the Quetico Subprovince were deposited approximately 2.698 to 2.690 billion years ago, and were deformed and metamorphosed prior to about 2.66 billion years ago with the subsequent emplacement of ultramafic dikes and sills, and discrete large granitic bodies. Rocks of the Quetico Subprovince were overlain by sedimentary rocks of the Sibley Group approximately 1.45 to 1.34 billion years ago (Heaman et al., 2006). The metasedimentary rocks of the Quetico Subprovince and the sedimentary rocks of the Sibley Group in the Red Rock area were intruded by ultramafic

intrusions, such as the Hele Intrusion, and diabase-like sills, such as the Nipigon Sill Complex (Hart, 2005), approximately 1.115 to 1.105 billion years ago (Heaman et al., 2006).

**Table 3-1: Generalized Geologic Sequence – Red Rock Area, Ontario**

| Eon | Lithology | Group/Formation | | Description |
|---|---|---|---|---|
| Proterozoic | | | Osler Volcanic Group (Keweenawan Supergroup) | Mafic metavolcanics |
| | | | Diabase Sills | Diabase |
| | | Sibley Group | Nipigon Bay Formation | Sandstone |
| | | | Outan Island Fm. – Hele Member | Sandstone/siltstone |
| | | | Outan Island Fm. – Lyon Member | Siltstone/mudstone |
| | | | Kama Hill Fm. | Red shale with minor sandstone |
| | | | Rossport Fm. – Fire Hill Member | Conglomerate overlain by mudstone |
| | | | Rossport Fm. – Middlebrun Bay Member | Stromatolitic limestone |
| | | | Rossport Fm. – Channel Island Member | Dolomitic mudstone |
| | | | Pas Lake Fm. – Fork Bay Member | Sandstone |
| | | | Pas Lake Fm. – Loon Lake Member | Conglomerate |
| | | | English Bay Complex (north of Red Rock area) | Granite/rhyolite |
| | | Animikie Group | Rove Fm. | Black shale–sandstone |
| | | | Gunflint Fm. | Black slate/shale, carbonates, chert |
| Archean | X X X X X X | | Quetico Subprovince | Metasedimentary rocks |

## 3.2 Local Bedrock Geology

The bedrock geology of the Red Rock area is shown on Figure 3.3, noting that the more recent mapping by Hart (2005) has been used where it is available (i.e. west of the white line on Figure 3.3). The Township of Red Rock is located on the boundary between the metasedimentary rocks of the Quetico Subprovince of the Superior Province and the sedimentary rocks of the Sibley Group of the Southern Province of the Canadian Shield.

There are five distinct geologic units in the Red Rock area (Figure 3.3), which comprise the metasedimentary rocks and granites of the Quetico Subprovince, sedimentary rocks of the Sibley Group, Nipigon diabase sills and the ultramafic Hele Intrusion.

Archean metasedimentary rocks and migmatites of the Quetico Subprovince comprise the bedrock at surface in the north central and northwestern parts of the Township of Red Rock (covering approximately 15% of the Township area). These metasedimentary rocks extend beyond the Township boundaries to the north into the Township of Nipigon, east of the Black Sturgeon River Fault Zone. In the southern portion of the Township of Red Rock, these metasedimentary rocks are unconformably overlain by the unmetamorphosed, undeformed sedimentary rocks of the Sibley Group. The sedimentary rocks of the Sibley Group extend significantly beyond the boundaries of the Township to the south, west and northwest along the west side of the Black Sturgeon River Fault Zone. An approximately 11 $km^2$ body of Archean granite of the Quetico Subprovince comprises the bedrock at surface in the northwest part of the Township of Red Rock; similar granitic intrusive bodies occur north-northwest of the Township within the metasedimentary rocks of the Quetico Subprovince (Figure 3.3). In a number of places in the Red Rock area there are localized outcrops of mafic intrusions, diabase sills and dykes, which intrude both Archean metasedimentary rocks and the sedimentary rocks of the Sibley Group and include the Nipigon Sill Complex (Figure 3.3). Within the Township of Red Rock, Nipigon Sills outcrops cover less than 5% of the Township area. Immediately west of the Black Sturgeon River Fault Zone in the southwest corner of the Township of Red Rock is the ultramafic Hele Intrusion, which comprises less than 10% of the bedrock at surface within the Township. The Hele Intrusion extends beyond the Township boundaries to the west.

The gravity response (Figure 3.4) within the Red Rock area shows a marked transition from a relative gravity high to the north associated with the Superior Province, to a relative gravity low to the south associated with the Southern Province, reflecting the change in lithology. The highest gravity response is associated with the metasedimentary rocks and migmatites of the Quetico Subprovince north of the Township of Red Rock and immediately east of the Black Sturgeon River Fault Zone. There is very little difference in gravity response across the Black Sturgeon River Fault Zone, consistent with the displacement across this zone being only on the order of a few hundreds of metres. There is no significant gravity response associated with the ultramafic Hele Intrusion, suggesting that it does not extend to significant depths.

The airborne magnetic and radiometric survey data for the Red Rock area, shown on Figures 3.5 and 3.6 respectively, features high resolution data recently acquired to support the mapping work by Hart (2005), covering the western half of the Township of Red Rock, as well as areas to the north and west. The remaining magnetic and radiometric data shown on the figures was acquired at significantly lower resolution.

The magnetic responses of the metasedimentary rocks and migmatites of the Quetico Subprovince and the sedimentary rocks of the Sibley Group are generally seen to be subdued (Figure 3.5). By contrast, intrusive bodies such as the Archean granites of the Quetico Subprovince and the Hele Intrusion show positive distinct magnetic responses. The positive magnetic response over the Hele Intrusion shows criss-crossing linear features striking approximately $25^o$ and $100^o$, coincident with prominent topographic lineaments (Figure 2.4). These linear features have been interpreted to be faults (Coates, 1972; Hart, 2005) as are a number of similar

lineaments elsewhere in the Red Rock area. The Nipigon Sills have a distinctly low magnetic response in comparison to their surrounding host rocks as a result of their remnant magnetization from the time of emplacement.

The radiometric data presented on Figure 3.6 (presented as equivalent uranium response) also appears to correlate to the lithologies of the Red Rock area. The sedimentary rocks of the Sibley Group are seen to have a relatively low radiometric response in comparison to the Archean metasedimentary rocks of the Quetico Subprovince to the north. Within the Archean metasedimentary rocks, there are several radiometric highs to the north and northwest of the Township of Red Rock. The Hele Intrusion has a low radiometric response, owing to its gabbroic composition. The Nipigon intrusions are also generally seen to have relatively low radiometric responses.

The main geological units in Red Rock area are further described below.

### 3.2.1 Lithologies

#### Archean Metasedimentary Rocks

Archean metasedimentary rocks of the Quetico Subprovince (Figure 3.3) underlie the Red Rock area, and constitute the uppermost bedrock unit in the northwest and north-central part of the Township of Red Rock and in the area north of the Township. Hart (2005) classified the major portion of the metasedimentary rocks of the Quetico Subprovince in the Red Rock area as migmatites. Migmatites in the Red Rock area formed by partial melting of precursor sedimentary rocks, resulting in the formation of rocks (migmatites) comprised of two or more petrographically distinct components. The migmatites in the Red Rock area have been suggested by Hart (2005) to have formed by partial melting of the metasedimentary rocks due to the intrusion of felsic granitic intrusive rocks, mostly of biotite granite composition, either as thin layers interspersed with the sedimentary rocks or as discrete metre-scale irregular dike swarms. Depositional ages of the original sediments of the Quetico Subprovince are dated from 2.698 to 2.690 billion years (Percival et al., 2006).

Migmatitic rocks in the Red Rock area are mostly comprised of a gneissic and a granitic component. The gneissic component predominantly consists of amphibolite, which is a black to medium grey rock composed of fine- to medium-grained hornblende, plagioclase and quartz. These rocks show weak to moderate foliation. In the Red Rock area, however, amphibolites are most often found mixed with leucocratic quartz-feldspar granite dikes in the form of irregular interbanding to chaotic mixtures of the two rock types.

Although in the Red Rock area, the thickness of the metasedimentary rocks and related migmatites is not reported in the literature, a regional thickness of up to 18 km approximately has been interpreted from regional geophysical studies (Culshaw et al., 2006; Percival et al., 2006). Few lineaments have been mapped as faults in the metasedimentary rocks to the east of the Black Sturgeon River Fault Zone (Hart, 2005) (Figure 3.3). Most of these lineaments follow a northwest trend and are spaced about 1.5 to 2 km apart.

#### Archean Granites

The metasedimentary migmatites of the Quetico Subprovince in the Red Rock area have been intruded by several irregular shaped granitic bodies, mapped by Hart (2005) as metamorphosed biotite granite. One of these granitic bodies is mapped to be outcropping over an approximately 11 $km^2$ area in the northwest portion of the Township of Red Rock, and several others are located north and northwest of the Township, east of the Black Sturgeon River Fault Zone (Figure 3.3).

Archean granitic intrusions in the Red Rock area consist of light pinkish, grey to light pink granite composed of quartz and feldspar with less than 10% biotite. These rocks are massive and medium to coarse grained, with rare very coarse grained to pegmatitic sections. Often these granitic intrusions contain xenoliths of the surrounding amphibolites, which are a few metres in diameter. These granitic bodies are in some places cut by pegmatitic dikes.

Based on conceptual regional geological cross-sections by Hart (2005), the granitic intrusion within the Township of Red Rock seems to extend to at least 300 m depth. Such interpretation is based on sparse diamond drillhole information and on airborne geophysical data over the region. Three major lineaments mapped as faults by Hart (2005) cut across the biotite granite body occurring on the northwest portion of the Township of Red Rock with a northwest trend and an approximate spacing of 1 to 2 km. The dip and depth of these structures is unknown.

## Sedimentary Rocks of the Sibley Group

The Sibley Group is an unmetamorphosed, relatively flat-lying sedimentary rock sequence that unconformably overlies the Archean rocks of the Quetico Subprovince (Figure 3.3).

The rocks of the Sibley Group in the Red Rock area range from approximately 1.6 to 1.3 billion years in age and have been divided into five formations (Rogala et al., 2005; Hart, 2005), three of which are present in the Township of Red Rock. According to Rogala et al. (2005), the lowermost unit, the Pass Lake Formation, consists of conglomerates overlain by sandstones; the middle unit, the Rossport Formation, consists of dolomite-siltstone layers on the bottom, stromatolites in the middle and mudstone on the top; the uppermost unit, the Kama Hill Formation, is composed of shales and siltstones.

As noted on the conceptual geological cross-sections developed by Hart (2005) and shown on Figure 3.7, the complete sequence of sedimentary rocks of the Sibley Group are estimated to reach up to approximately 200 m in thickness where they occur in the Red Rock area. These cross-sections were developed using sparse diamond drillhole information and airborne geophysical data in the area.

## The Hele Intrusion

The Hele Intrusion covers a total area of approximately 40 $km^2$ and is located adjacent to the west side of the Black Sturgeon River Fault Zone in the Red Rock area. Part of the Hele Intrusion (4 $km^2$) underlies the southwest corner of the Township of Red Rock (Figure 3.3). The Hele Intrusion is underlain by sedimentary rocks of the Sibley Group and has a reported maximum thickness of approximately 130 m (Hart, 2005), based on diamond drillhole information and modeling of available airborne magnetic data.

The Hele Intrusion was emplaced about 1.106 billion years ago (Heaman et al., 2006), related to a failed intracontinental rifting event, and is composed of altered peridotite interlayered with olivine gabbro and feldspathic peridotite. The peridotite is a high weathered and serpentinized rock containing numerous, subparallel serpentine and chlorite-rich fractures (Hart, 2005). Few major lineaments, mapped by Hart (2005) as faults, cut across the Hele Intrusion in north and east-southeast orientations, the latter with spacings of 1 to 2.5 km apart (Figure 3.3).

## Nipigon Diabase Sill Complex

Nipigon diabase sills intrude, and sometimes overlie, the other rock types in the Red Rock area. Several small diabase sills occur at surface in the southwest portion of the Township of Red Rock; they are less than 1 $km^2$ in size and seem to be less than 100 m thick (Hart, 2005), as seen on Figure 3.7. A larger diabase sill approximately nine square kilometres in size outcrops in the northeast portion of the Township, but is also

thought to be thin. Several other sills are mapped throughout the Red Rock area at surface (Hart, 2005). In some locations in the Red Rock area, Nipigon (diabase) Sills intrude the older rocks in the area at depth and occur as extensive, relatively flat and thin (less than 50 m) intrusive layers (Hart, 2005).

There are no obvious textural or mineralogical differences between the sills; the diabase is commonly medium brown to brownish grey, massive, medium to coarse-grained feldspar and pyroxene with trace olivine and magnetite (Hart and Magyarosi, 2004). Their emplacement is interpreted by Coates (1972), Sutcliffe (1991) and others to be related to the Midcontinent Rift event (Section 3.1). The intrusion of these sill bodies has been constrained to have occurred in the period 1.115 to 1.105 billion years (Heaman et al., 2006).

Lineaments mapped by Hart (2005) as faults (Figures 3.3) cut across a few of the sills located southwest of the Township boundary, with either northeast, east or northwest orientations and either intersecting each other or spaced about 5 km apart.

### 3.2.2 Deformation and Metamorphism

Deformation in the Red Rock area is interpreted to have occurred in four stages, from approximately 2.698 to 2.667 billion years ago (Valli et al., 2004). Deformation produced folding and faulting as well as development of schistosity in the metasedimentary rocks of the Quetico Subprovince. Syndeformational high grade metamorphism to amphibolites facies was reached during the second stage. Emplacement of metamorphosed, weakly to fully-deformed granite bodies (e.g. granitic intrusion within the Township of Red Rock) 2.7 to 2.65 billion years ago (Williams, 1991) would have been coeval with the fourth deformation stage. Sedimentary rocks of the Sibley Group are unmetamorphosed except for contact metamorphism with the Nipigon Sills and related intrusive rocks.

Major faulting has occurred in the Red Rock area, with the Black Sturgeon River Fault Zone being the most noticeable structural feature.

Major lineaments in the Red Rock area, mapped as faults by Hart (2005), consist of a series of subparallel, north-trending faults, and a series of northwest-trending faults, as exhibited by the Black Sturgeon River Fault itself (Figure 3.3). These two major regional fault trends define the Black Sturgeon River Fault Zone (Coates, 1972; Hart 2005). The Black Sturgeon River Fault Zone follows a northwest trend, giving direction to the river of same name and has produced a canyon that is, on average, approximately 1.2 km wide. A 5.5 km long stretch of this fault zone runs through the western part of the Township of Red Rock, occupying approximately 6.5 $km^2$ of the Township area. North-trending faults are spaced from approximately 2.5 to 6.5 km apart, whereas northwest-trending faults are spaced as close as approximately 1.5 km apart. An east-trending subset of faults with spacings from 1.5 to 2 km has been identified in the Hele Intrusion.

Hart and Magyarosi (2004) and Hart (2005) found little lateral displacement on the north- and northwest-trending faults based on the correlation of the iron formations across Black Sturgeon Lake. Vertical displacement by north-trending faults in some areas has been up to 350 m, as is the case of the Black Sturgeon River Fault as shown on Figure 3.7. Elsewhere, the vertical displacement on these faults is variable and often uncertain. These faults may have controlled the emplacement of ultramafic intrusions.

Timing and magnitude of displacement of the faults in the Red Rock area is poorly constrained. North- and northwest-trending faults appear to have been active approximately 1.100 billion years ago, based on stratigraphic relationships between faults and geological units. In particular, relationships between the Black Sturgeon River Fault and rocks of the Sibley Group suggest that the fault is either as old as the Sibley Group rocks, or is older and was kept active during sedimentation, or that the fault was reactivated after sedimentation

(Hart, 2005). The northwesterly trending fault pattern is related to the Mid-Continental Rift, and represents a fault bounded basin in which the Sibley Group was deposited. This fault-bounded basin is considered to be a failed arm of the opening Mid-Continent Rift zone (Sutcliffe, 1991).

## 3.3 Quaternary Geology

The Quaternary geology of the Red Rock area (Figure 3.8) comprises different types of glacial deposits including tills, glaciofluvial sands, and glaciolacustrine sediments deposited during late Pleistocene Wisconsinan glaciations, as well as more recent fluvial and organic deposits. This period of glaciation began approximately 115,000 years ago and peaked about 21,000 years before present, at which time the glacial ice front extended south of Ontario into what is now Ohio and Indiana (Barnett et al., 1991). Partial retreat of glacial ice from the Superior basin began approximately 10,000 years ago with the final deglaciation of the Red Rock area beginning approximately 9,500 years ago (Burwasser, 1977). Over the next 500 years, water levels fluctuated through a series of glacial lake stages as different drainage outlets became activated.

Figure 3.8 shows the distribution of Quaternary deposits in the Red Rock area and the location of the wells from which information on overburden thickness was obtained. Approximately two thirds of the Township of Red Rock is covered by Quaternary deposits. In the remainder of the Township, typically in areas of higher elevation, the bedrock is either exposed or covered by a thin layer of drift. At the periphery of the Township of Red Rock Quaternary deposits are mostly found in the low lying areas south of the Township and in localized areas to the northwest and northeast. North and west of the Township the bedrock is mostly exposed. Mapping indicates that Quaternary deposits in the Red Rock area mostly comprise glaciolacustrine deposits, with lesser amounts of glaciofluvial, fluvial and organic deposits (Figure 3.8).

Information on the thickness of Quaternary deposits in the Red Rock area was obtained from a number of water well records in the Red Rock area. Figure 3.8 shows the locations of wells from the Ministry of Environment (MOE) and diamond drill holes from the Ministry of Northern Development, Mines and Forestry (MNDMF). Overburden thicknesses within the Red Rock area typically range from 15 to 30 m, with the greatest thickness reported to be 53.3 m.

## 3.4 Neotectonic Activity

Neotectonics refers to deformations, stresses and displacements in the earth's crust of recent age or which are still occurring. The geology of the Red Rock area is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years (Shackleton et al., 1990; Peltier, 2002). The most recent of these glacial cycles (referred to as the Wisconsinan glaciation) occurred between approximately 115,000 and 10,000 years ago.

During the maximum extent of the Wisconsinan glaciation, approximately 21,000 years ago (Barnett, 1992), the earth's crust was depressed by more than 340 m in the Minnesota/North Dakota area (Brevic and Reid, 1999), due to the weight of glacial ice. The amount of crustal depression in the Red Rock area would be of a similar magnitude, but somewhat greater due to its closer proximity to the main centre of glaciation beneath Hudson's Bay.

Post-glacial isostatic rebound began with the waning of the continental ice sheets and is still occurring across most of Ontario. The greatest rates of crustal rebound (approximately 12 mm/a) are recorded in the Hudson Bay region, where the thickest glacial ice occurred (Sella et al., 2007). As a result of the glacial unloading, horizontal stresses are created locally in shallow bedrock in many areas of Ontario. Natural stress release features include

elongated compressional ridges or pop-ups such as those described in White et al. (1973), McFall (1993), and Karrow and White (2002).

No detailed identification and interpretation of neotectonic structures was found in readily available literature for the Red Rock area. It is therefore useful to review the findings of previous field studies involving fracture characterization and evolution as it may pertain to glacial unloading. McMurry et al. (2003) summarized several studies conducted in a number of plutons in the Canadian Shield and in the crystalline basement rocks in Western Ontario. These various studies found that fractures below a depth of several hundred metres in the plutonic rock are often ancient features. Early-formed fractures have tended to act as stress domain boundaries. Subsequent stresses, such as those caused by plate movement or by continental glaciation, generally have been relieved by reactivation along the existing zones of weakness rather than by the formation of large new fracture zones.

In summary, no neotectonic structural features are known to occur in the Red Rock area.

## 3.5 Seismicity

The Township of Red Rock lies on the Canadian Shield, where large parts have remained tectonically stable for the last 2.5 billion years (Percival and Easton, 2007). Hayek et al. (2009) indicate that this area of the Canadian Shield has experienced a number of low magnitude, shallow seismic events. Figure 3.9 presents the location of earthquakes with a magnitude 3 or greater that are known to have occurred in Canada from 1627 until 2009. Figure 3.10 shows the locations and magnitudes of seismic events recorded in the National Earthquake Database (NEDB) for the period between 1985 and 2010 in the Red Rock area (NRC, 2010). Three low magnitude (less than magnitude 3) seismic events occurred in the last 25 years within 20 km of the Township of Red Rock, and eight low magnitude seismic events have occurred within 75 km of the Township of Red Rock within the last 25 years.

In summary, available literature and recorded seismic events indicate that the Red Rock area is located within a region of low seismicity: the tectonically stable northwest portion of the Superior and Southern Provinces of the Canadian Shield.

# 4.0 HYDROGEOLOGY

Information concerning groundwater in the Red Rock area was obtained from the Ontario Ministry of the Environment (MOE) Water Well Record (WWR) database. The Township of Red Rock obtains its municipal water supply from the Nipigon Bay on Lake Superior, however, a large number of wells exist in the Red Rock area serving individual private residences. Most of these are located along the Trans Canada Highway (as shown on Figure 4.1) and obtain water from the overburden or the shallow bedrock. The MOE Water Well Record database contains a total of 459 water well records for the Red Rock area. A summary of these wells is provided in the table below.

**Table 4-1: Summary of Water Well Records – Red Rock Area, Ontario**

| Water Well Type | Number of Wells | Total Well Depth (m) | Static Water Level (m below surface) | Tested Well Yield (L/min) | Depth to Top of Bedrock (m) |
|---|---|---|---|---|---|
| Overburden | 199 | 1 to 99 | 0 to 30 | 1 to 100 | N/A |
| Bedrock | 260 | 5 to 159 | 0 to 46 | 1 to 200 | 0 to 100 |

## 4.1 Overburden Aquifers

There are 199 water well records in the Red Rock area that can be confidently assigned to the overburden aquifer, which is generally found in the sand and gravel deposits above bedrock and at the base of the glaciolacustrine deposits that form the most widespread surficial soil materials. The overburden wells are generally 5 to 40 m deep, but depths of up to 99 m have been recorded. Well yields are variable with recorded values ranging from 1 L/min to 100 L/min. These values reflect the purpose of the wells (private residential supply) and do not necessarily reflect the maximum sustained yield that might be available from the aquifer.

## 4.2 Bedrock Aquifers

In the Red Rock area, there are 260 well records that can be confidently assigned to the shallow bedrock aquifer. These wells range from 5 to 159 m in depth, with most wells between 30 to 60 m deep. Measured pumping rates in these wells are variable and range from 1 L/min to 200 L/min with yields typically between 3 to 5 L/min. These values reflect the purpose of the wells (private residential supply) and do not necessarily reflect the maximum sustained yield that might be available from the aquifers. Long-term groundwater yield in fractured bedrock will depend on the number and size of fractures, their connectivity, transmissivity, storage and on the recharge properties of the fracture network in the wider aquifer.

Metasedimentary rocks of the Canadian Shield are present at repository depth (approximately 500 m) in the Red Rock area. The review of readily available information did not identify any known groundwater resources at repository depth in the Red Rock area or anywhere else in the Ontario part of the Canadian Shield. Experience from other areas in the Canadian Shield has shown that active groundwater flow is generally confined to shallow fractured localized systems. In these regions, flow tends to be dependent on the secondary permeability created by fractures (Singer and Cheng, 2002). For example, in Manitoba's Lac du Bonnet Batholith, groundwater movement is largely controlled by a fractured zone down to about 200 m depth (Everitt et. al., 1996). At greater depths, hydraulic conductivity tends to decrease as fractures become less common and less interconnected (Stevenson et al., 1996; McMurry et al., 2003). Increased vertical and horizontal stresses at depth tend to close

or prevent fractures thereby reducing permeability and resulting in diffusion-dominated groundwater movement (Stevenson et al., 1996; McMurry et al., 2003).

## 4.3 Hydrogeochemistry

No information on groundwater hydrogeochemistry was found for the Red Rock area. Existing literature, however, has shown that groundwater within the Canadian Shield can be subdivided into two main hydrogeochemical regimes: a shallow, generally fresh water flow system, and a deep, saline water flow system (Singer and Cheng, 2002).

Gascoyne et al. (1987) investigated the saline brines found within several Precambrian plutons and identified a chemical transition at around 300 m depth marked by a uniform, rapid rise in total dissolved solids and chloride. This was attributed to advective mixing at above 300 m, with a shift to diffusion-controlled flow below that depth. It was noted that major fracture zones within the bedrock can, where present, extend the influence of advective processes to greater depths.

In the deeper regions, where groundwater transport in unfractured or sparsely fractured rock tends to be very slow, long residence times on the order of a million years or more have been reported (Gascoyne, 2000; 2004). Groundwater research carried out in AECL's Whiteshell Underground Rock Laboratory (URL) in Manitoba found that crystalline rocks from depths of 300 to 1,000 m have total dissolved solids (TDS) values ranging from 3 to 90 g/L (Gascoyne et al. 1987; Gascoyne 2000; 2004). However, total dissolved solids exceeding 250 g/L have been reported in some regions of the Canadian Shield at depths below 500 m (Frape et al., 1984).

# 5.0 ECONOMIC GEOLOGY

## 5.1 Petroleum Resources

The Township of Red Rock is located in a largely crystalline geological setting with Mesoproterozoic sedimentary rocks overlying the crystalline rocks in some areas. There are no known hydrocarbon exploration activities in the Red Rock area and the potential for petroleum resources is considered to be low.

## 5.2 Metallic Mineral Resources

Figure 5.1 shows the areas of active exploration interest in the Red Rock area based on active mining claims, as well as known mineral occurrences identified in the Ontario Geological Survey's Mineral Deposit Inventory Version 2 (OGS, 2004). There is no record of metallic mineral production in the past in the Red Rock area. A few mineral occurrences have been identified at the periphery of the Township of Red Rock, but their economic potential has not been proven. As shown on Figure 5.1 there are currently a number of exploration active claims west of the Township of Red Rock. These are held by HTX Minerals, which is currently exploring the potential for Platinium and PGE-Ni-Cu in relation to the Hele Intrusion. To date, however, the economical viability of such potential has not been confirmed (HTX Minerals, 2011).

Metallic mineral occurrences in the Red Rock area include: cobalt-copper-nickel-platinum group metals, silver-lead-zinc, rare metals and radioactive element-enriched pegmatites. All of the occurrences are considered to be sub-economic.

### Platinum Group Elements (PGE)

The Hele Intrusion in the southwest corner of the Township of Red Rock is mineralogically similar to the Seagull Intrusion (about 40 km northwest of the Township of Red Rock), which contains sub-economic platinum group element (PGE) mineralization (Hart and Magyarosi, 2004). The potential feeder zones to the Hele Intrusion have been suggested to have potential for PGE and nickel-copper mineralization (Hart, 2005). Anomalous concentrations of PGE have been identified in the Foxden Occurrence (described under 'Nickel and Copper' below). As mentioned above, HTX Minerals Corp. is currently exploring the Hele intrusion for PGE-Ni-Cu.

### Nickel and Copper

The Foxden Cu-Ni Occurrence is located west of the Hele intrusion, approximately 8 km west of the Township of Red Rock (Figure 5.1). The occurrence is contained within an extension of the Hele Intrusion and is hosted in medium-grained pyroxenite in contact with dolostone of the Rossport Formation. A grab sample collected by OGS staff yielded 412 ppm Cu, 1,011 ppm Ni, 36 ppb Pt, and 27 ppb Pd (Schnieders et al., 2002).

The Hughes Point Copper Occurrence is located on the west side of Hughes Point, approximately 4 km east of the Township of Red Rock. Calcareous sedimentary rocks of the Sibley Group host a number of narrow, Cu-mineralized calcite veinlets near the upper contact with a flat lying, diabase sill.

### Silver, Lead, and Zinc

The Nipigon Silver Occurrence is located approximately 3.5 km north of the Township of Red Rock and consists of sub-economic traces of argentiferous galena and sphalerite.

### Uranium

The Hele Township Uranium Occurrence is located along the east side of the Black Sturgeon River, approximately 6 km northwest of the Township of Red Rock. It consists of a number of granitic dikes in granite gneisses. The main dike strikes east-west and dips 40 degrees N. A grab sample assayed 0.096% $U_3O_8$

(Robertson and Gould, 1983). Hart (2005) reported that a number of properties in the Red Rock area were explored for uranium between 1977 and 1980. Uranium was found at Black Sturgeon Lake, at Eagle Mountain, at Malborne Lake and at Jessie Lake, but that no economic uranium mineralization was reported from this work.

Narrow but high grade veins of pitchblende occur in the Eagle Mountain area and east of Black Sturgeon Lake. Grades of up to 12% U have been reported (Scott, 1987) in the Black Sturgeon Lake area. Quetico subprovince rocks are anomalous in uranium, and the uranium has been remobilized into faults and geochemical traps and veins associated with the unconformity between the Archean and the Sibley Group.

## 5.3 Non-Metallic Mineral Resources

Known non-metallic mineral resources within the Red Rock area include sand and gravel, stone, amethyst, and peat. Quarrying for stone and/or manufactured aggregate has been carried out at a number of locations in the Red Rock area, including the Nipigon River Marble Quarry. Small sand and gravel pits are also likely to be present within the Red Rock area, although there is no available inventory of sites. The Stenlund Amethyst Occurrence is located approximately 5 km east of the Highway 11 turnoff at Nipigon.

A number of peat deposits are identified within the wetlands of the Black Bay Peninsula south of the Township of Red Rock, however no commercial peat extraction is known to have occurred in the area. Although the potential for the Canadian Shield to host economic diamond deposits has been demonstrated by a number of mines in the Northwest Territories and Ontario, no diamond occurrences have been identified in the Red Rock area.

# 6.0 INITIAL SCREENING EVALUATION

This section provides an evaluation of each of the five initial screening criteria (NWMO, 2010) for the Red Rock area based on the readily available information presented in Sections 2 to 5. The intent of this evaluation is not to conduct a detailed analysis of all available information or identify specific potentially suitable sites, but rather to identify any obvious conditions that would exclude the Township of Red Rock from further consideration in the site evaluation process.

Initial screening criteria (NWMO, 2010) require that:

1) The site must have enough available land of sufficient size to accommodate the surface and underground facilities.

2) This available land must be outside of protected areas, heritage sites, provincial parks and national parks.

3) This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.

4) This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.

5) This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the outlined safety factors in Section 6 of the site selection document (NWMO, 2010).

For cases where readily available information is limited and where the assessment of some of the criteria is not possible at the initial screening stage, the area would be advanced to the feasibility study stage for more detailed evaluation, provided the community remains interested in continuing to participate in the siting process.

## 6.1 Screening Criterion 1: Land Availability

***The site must have enough available land of sufficient size to accommodate the surface and underground facilities.***

Surface facilities associated with the deep geological repository will require a surface land parcel of about 1 km by 1 km (100 ha) in size, although some additional space may be required to satisfy regulatory requirements. The underground footprint of the repository is about 1.5 km by 2.5 km (375 ha) at a typical depth of about 500 m.

This criterion was evaluated by assessing whether the Red Rock area contains parcels of land that are large enough to accommodate the surface facilities and whether there is a sufficient volume of rock at depth to accommodate the underground facilities. The available land areas should be accessible for the construction of surface facilities and for the various field investigations that are necessary to characterize the rock volume required to accommodate the footprint of the repository (e.g. drilling of boreholes).

Availability of land was assessed by identifying areas with potentially suitable host rocks based on information presented in Section 3, and then considering potential surface constraints, such as the presence of natural features (e.g. large water bodies, topographic constraints), land use (e.g. developed areas, infrastructure), accessibility and construction challenges, based on the information presented in Section 2.

Review of available mapping and satellite imagery shows that the Township of Red Rock contains few constraints that would prevent the development of the repository's surface facilities (Figure 2.1 and 2.2). The main constraints include prominent topographic features (Figure 2.4) near the eastern edge of the Black Sturgeon River Fault Zone (western edge of the Township) and the Red Rock Hill in the southeastern part of the Township. Residential and industrial infrastructure occupies a very small portion of the Township, with developments limited mainly to roadways and the settlement area. The areas at the periphery of the Township of Red Rock are also largely undeveloped, with few natural or physical constraints such as major infrastructure or permanent water bodies but land to the north is within or in closer proximity to the neighbouring Township.

While the Township of Red Rock contains sufficient land to potentially accommodate the repository's surface facilities, there is a concern that the Township does not contain geological units that are suitable for hosting a deep geological repository, as discussed in detail in Section 6.5.

*Based on the review of readily available information, the Township of Red Rock contains sufficient land to accommodate the repository's surface and underground facilities. However, as discussed in Section 6.5, the area does not contain geological units that are suitable for hosting a deep geological repository.*

## 6.2 Screening Criterion 2: Protected Areas

***Available land must be outside of protected areas, heritage sites, provincial parks and national parks.***

The assessment of this criterion is needed to assure that the remaining available land, after excluding protected areas, is large enough to allow for the construction of the repository's facilities. For the purpose of this initial assessment protected areas are considered to include protected areas, heritage sites or parks, as defined by provincial or federal authorities.

The Red Rock area was screened for federal, provincial and municipal parks, conservation areas, nature reserves, national wildlife areas and archaeological and historic sites using available data from the Ontario Ministry of Natural Resources (Land Information Ontario) and the Ontario Ministry of Tourism and Culture.

Figure 2.1 shows that the two provincial parks and one conservation reserve that are present within the Red Rock area occupy small portions of land. The Black Sturgeon River Provincial Park is some 72 km in length and covers 244 $km^2$ in area, but only a small portion of the park occurs within the Township boundaries where it forms a 1 to 1.5 km wide band in the western corner of the Township. The Ruby Lake Provincial Park covers an area of 27 $km^2$ on the east side of the mouth of the Nipigon River, bordering the extreme northeast of the Township of Red Rock. The Black Bay Bog Conservation Reserve is located approximately 10 km to the south of the Township of Red Rock, but only a small portion of it (0.5 $km^2$) falls within the Red Rock area.

As mentioned in Section 2.4, there are no registered archaeological sites within the Township of Red Rock (Figure 2.1). However, there is evidence to conclude that archaeological potential is high, particularly along the banks of the Nipigon River and along the shore of Lake Superior, but currently there is only one known heritage site present in the Red Rock area. This site is a collection of pictographs almost at the mouth of the Nipigon River on the opposite shore north of the Township of Red Rock. There are no national historic sites in the Red Rock area.

*Based on the review of readily available information, the Red Rock area contains sufficient land outside protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities.*

## 6.3 Screening Criterion 3: Known Groundwater Resources at Repository Depth

***Available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.***

In order to minimize the future risk of human intrusion during the long post-closure period, the repository should be sited in a host rock formation that does not contain significant groundwater resources at repository depth (typically 500 m) that may encourage future generations to access those resources and potentially compromise the long-term performance of the repository.

The review of available information did not identify any known groundwater resources at repository depth for the Red Rock area. As discussed in Section 4, the Ontario Ministry of the Environment (MOE) Water Well Record (WWR) database shows that all water wells known in the Red Rock area obtain water from overburden or shallow bedrock sources at depths ranging from 1 to 159 m, with most wells between 30 to 60 m deep.

The geology of the Red Rock area at repository depth (approximately 500 m) is dominated by metasedimentary rocks that are part of the crystalline rocks of the Canadian Shield. Experience from other areas in the Canadian Shield has shown that active groundwater flow is generally confined to shallow fractured localized systems (Singer and Cheng, 2002). In deeper regions, hydraulic conductivity tends to decrease as fractures become less common and less interconnected (Stevenson et al. 1996; McMurry et al., 2003).

MOE Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths in the Red Rock area or anywhere else in Northern Ontario. Groundwater at such depths is generally saline and very low groundwater recharge at such depths limits the potential yield, even if suitable water quality were to be found.

*The review of available information did not identify any known groundwater resources at repository depth for the Red Rock area. Experience in similar geological settings suggests that the potential for deep groundwater resources at repository depths is low throughout the Red Rock area.*

## 6.4 Screening Criterion 4: Known Natural Resources

***Available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.***

As with the assessment of groundwater resources, the need to minimize the risk of future human intrusion requires that the repository be sited in a host rock formation having a low potential for economically exploitable natural resources. Readily available information on past and potential future occurrence for natural resources such as oil and gas and metallic and non-metallic mineral resources was reviewed in Section 5.

The review indicates that there is no evidence of past or present exploration or development activities associated with oil and gas resources and the potential for petroleum hydrocarbon resources in the Red Rock area is low.

There are no current or past mining operations in the Red Rock area. The potential for metallic minerals resources remains low and generally associated with localized geological formations in the area, such as the Nipigon and the Hele intrusions. Identified metallic mineralization occurrences in the Red Rock area include: cobalt-copper-nickel-platinum group metals, silver-lead-zinc, rare metals and radioactive element-enriched pegmatites. All of the occurrences are considered to be sub-economic. Commercial potential for peat exists in some low-lying areas but no peat extraction has occurred in the Red Rock area (Figure 5.1). In summary, in the Red Rock area, the potential for natural resources is limited.

*Based on the review of readily available information, the Red Rock area contains areas free of known economically exploitable natural resources.*

## 6.5 Screening Criterion 5: Unsafe Geological or Hydrogeological Features

***Available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the outlined safety factors in Section 6 of the site selection document (NWMO, 2010).***

The site should not be located in an area of known geological or hydrogeological features that would make the site unsafe, as per the following five geoscientific safety-related factors identified in the site selection process (NWMO, 2010):

1) 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?

2) Long-term resilience to future geological processes and climate change. Is the rock formation at the site 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 natural disturbances and events such as earthquakes and climate change?

3) Safe construction, operation and closure of the repository. Are conditions at the site suitable for the safe construction, operation and closure of the repository?

4) Isolation of used fuel from future human activities. Is human intrusion at the site unlikely, for instance, through future exploration or mining?

5) 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?

At this early stage of the site evaluation process, where limited data at repository depth exist, the five safety-related geoscientific factors are assessed using readily available information, with the objective of identifying any obvious unfavourable hydrogeological and geological conditions that would exclude the Township of Red Rock from further consideration.

The review of readily available information identified characteristics suggesting that the Red Rock area is

unlikely to contain geological formations that would be potentially suitable for hosting a deep geological repository and is therefore not considered a suitable candidate for continuing in the NWMO site selection process. As discussed below, these characteristics relate to safe containment and isolation and amenability to site characterization (safety-related factors 1 and 5). Since the geology of the Red Rock area does not satisfy the safety-related factors 1 and 5, the other safety-related factors (2, 3 and 4) are not discussed.

## Safe Containment and Isolation and Amenability to Site Characterization

The geological and hydrogeological conditions of a suitable site should promote long-term containment and isolation of used nuclear fuel and retard the movement of any potentially released radioactive material. This requires that the repository be located at a sufficient depth, typically around 500 m, in a sufficient rock volume with characteristics that limit groundwater movement.

Readily available information on the regional and local geology and hydrogeology was reviewed in Sections 3 and 4, respectively. The geology of the Red Rock area is composed of five distinct geologic units (Figure 3.3). These include the sedimentary rocks of the Sibley Group, the Hele Intrusion, the Nipigon Sills, the granitic intrusions and the metasedimentary rocks of the Quetico Subprovince. Potential suitability of these various geological formations within and at the periphery of the Township is assessed in the sections below, with reference to Figure 6.1.

### *Sedimentary Rocks of the Sibley Group*

More than half of the Township is underlain by sedimentary rocks of the Sibley Group, which overlay the metasedimentary rocks that form most of the rock at repository depth in the Red Rock area (Figure 6.1). The sedimentary rocks of the Sibley Group cover the southern and eastern parts of the Township and extend significantly beyond the boundaries of the Township to the west and northwest along the west side of the Black Sturgeon River Fault Zone. The sedimentary rocks of the Sibley Group are estimated to be approximately 200 m thick in the Red Rock area. An approximately 500 m deep geological repository in these areas would necessarily have to be developed in the underlying metasedimentary rocks. One of the key criteria in assessing the suitability of a site relates to having a host rock that is amenable to site characterization in order to develop a good understanding of the geoscientific characteristics of the site and a robust safety case. Because of the nature of the structural characteristics of these metasedimentary rocks (e.g. fracture geometry and frequency), the presence of the overlying 200 m thick sedimentary rocks would greatly reduce the ability to adequately characterize them at repository depth. Therefore, all the areas within and outside the Township that are covered by the sedimentary rocks of the Sibley Group are excluded from further consideration. These areas include a very large portion of the Township and the surrounding areas to the south, west and northwest of the Township (Figure 6.1).

### *The Hele Intrusion and Nipigon Diabase Sills*

The Hele Intrusion covers a small portion of the southwest corner of the Township and extends to the west. Similarly to the sedimentary rocks of the Sibley Group, the Hele Intrusion has an estimated maximum thickness of approximately 130 m and does not extend to repository depth. A deep geological repository in this area would necessarily have to be developed in the underlying metasedimentary rocks, which would be difficult to adequately characterize due to the overlying Hele intrusion. Therefore, the area of the Hele Intrusion is also excluded from further consideration. The Nipigon Sills in the Red Rock area are mapped in several localized areas at surface (Figure 6.1). These are approximately 100 m thick layers of intrusive rocks that are generally too thin to be considered potentially suitable.

### *Granitic Intrusions*

There are a number of granitic intrusions of the Quetico Subprovince in the Red Rock area, with only one located in the northwest of the Township. This granitic intrusion may have a sufficient lateral extent to host a repository within the Township, but its thickness is unknown. Also, as shown on Figure 6.1, a number of faults have been interpreted at surface with an approximate spacing of 1 to 2 km. While it is unknown if these faults extend to repository depth, their presence and the proximity of the Black Sturgeon River Fault Zone may indicate that these granitic rocks have experienced substantial brittle deformation, which would not be favourable for containment and isolation. The granitic intrusions located north of the Township are within or in closer proximity to the neighbouring Township, which has not been included in the initial screening.

### *Metasedimentary Rocks*

The metasedimentary rocks of the Quetico Subprovince cover small portions of northwest corner and north-central part of the Township of Red Rock and extend north into the neighboring Township and west to the Black Sturgeon River Fault Zone (Figure 6.1). While there is limited information on the degree of homogeneity of these metasedimentary rocks at repository depth, the high degree of metamorphism and partial melting they have experienced in the past would suggest that their physical characteristics could mimic those of granitic rock.

The areas north of the Township that are underlain by metasedimentary rock are located within or in closer proximity to the neighbouring Township, which has not been included in the initial screening. The metasedimentary rocks in the northwest corner of the Township are marginally sufficient in volume within the Township, but a greater concern is their proximity to the approximately 1 km wide Black Sturgeon River Fault Zone, which may have greatly altered the quality of the rock at depth. They are also partly covered by the Black Sturgeon River Provincial Park. While the remaining small area of metasedimentary rocks in the north-central part of the Township are potentially suitable to host a deep geological repository, they would be difficult to adequately characterize at depth because they are entirely covered by a fairly thick overburden layer.

In summary, the various geological units within the area considered for this screening are unlikely to be suitable for hosting a deep geological repository. They are either not amenable to site characterization or are unlikely to meet the containment and isolation function.

*Based on the review of readily available geoscientific information, there are characteristics that would make the Red Rock area potentially unsuitable for hosting a deep geological repository. These include characteristics related to the ability of the rock to safely contain and isolate used nuclear fuel and the amenability to site characterization and data interpretation.*

# 7.0 INITIAL SCREENING FINDINGS

This report presents the results of an initial screening to assess the potential suitability of the Red Rock area against five initial screening criteria using readily available information. The initial screening focused on the Township of Red Rock and its periphery, which are referred to as the "Red Rock area" in this report. Areas within or in closer proximity of neighbouring Townships were not included in the initial screening.

As outlined in NWMO's site selection process (NWMO, 2010), the five initial screening criteria relate to: having sufficient space to accommodate surface facilities, being outside protected areas and heritage sites, absence of known groundwater resources at repository depth, absence of known natural resources and avoiding known hydrogeologic and geologic conditions that would make an area or site unsuitable for hosting a deep geological repository.

Review of readily available information and the application of the five initial screening criteria show that the Red Rock area is unlikely to contain geological formations that would be potentially suitable for hosting a deep geological repository. The various geological formations within the area considered for this screening are either not amenable to site characterization or are unlikely to meet the containment and isolation function of a deep geological repository. Therefore, the Township of Red Rock is not considered as a suitable candidate for continuing in the NWMO site selection process.

The bedrock geology of the Red Rock area at repository depth is dominated by metasedimentary rocks that could be potentially suitable for hosting a deep geological repository. However, within large areas of the Township and its periphery, these metasedimentary rocks are overlain by a fairly thick sedimentary rock cover (about 200 m) that would make them difficult to characterize. The remaining small areas within the Township that are underlain by metasedimentary rocks and not covered by sedimentary rock are either unlikely to be suitable because of their proximity to the regional Black Sturgeon River Fault Zone or are covered by a fairly thick overburden layer that would also make them difficult to characterize at depth. Other geological units within and outside of the Township such as the Hele Intrusion and the various localized Nipigon Sills and the granitic intrusions have been found to be not suitable. This is either because of their insufficient volume or due to the presence of faults that may affect the containment and isolation function of a deep geological repository.

The process for identifying an informed and willing host community for a deep geological repository for Canada's used nuclear fuel is designed to ensure, above all, that the site which is selected is safe and secure for people and the environment, now and in the future.

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# 9.0 REPORT SIGNATURE PAGE

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Senior Geoscientist

George Schneider, M.Sc., P.Geo.
Principal

CWM/GWS/wlm

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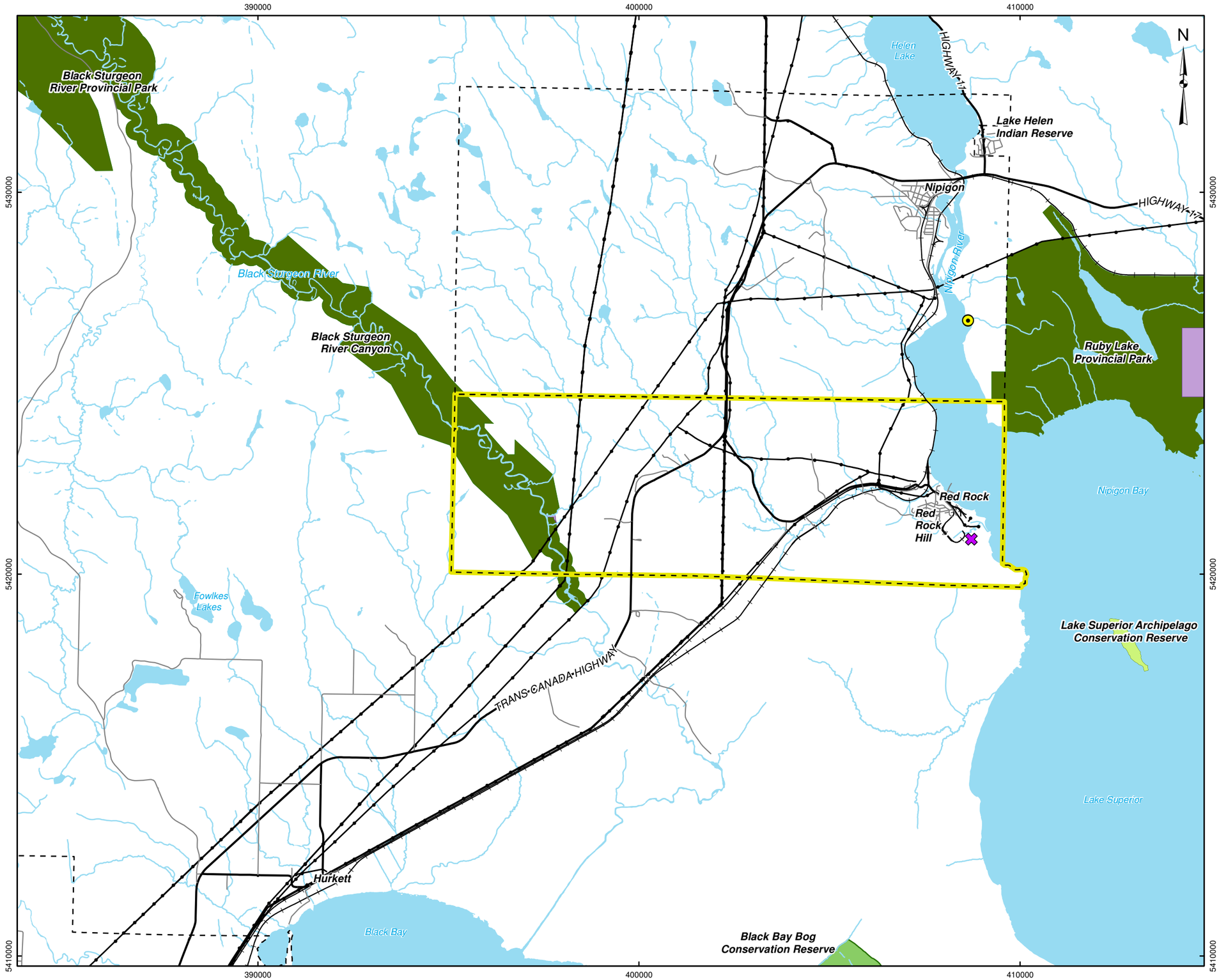
# FIGURES




## LEGEND

- Lake Sulphite Pulp & Paper Co.
- Pictograph Site
- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Watercourse, Permanent
- Watercourse, Intermittent
- Water Area, Permanent
- Recommended Conservation Reserve
- Forest Reserve
- Conservation Reserve
- Provincial Park


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

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PROJECT
NWMO Desktop Level Initial Screening

TITLE
**Red Rock Area**

Golder Associates
Mississauga, Ontario

| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
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| DESIGN | PRM | 27 Jan. 2011 | | |
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**FIGURE: 2.1**

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**LEGEND**

- Township of Red Rock
- Road
- Water Area, Permanent


**REFERENCE**

Imagery: Spot 5 , Obtained from Geobase (2005 to 2008, 10 m resolution)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

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PROJECT

NWMO Desktop Level Initial Screening

TITLE

**Satellite Imagery of the Red Rock Area**

Golder Associates
Mississauga, Ontario

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**FIGURE: 2.2**

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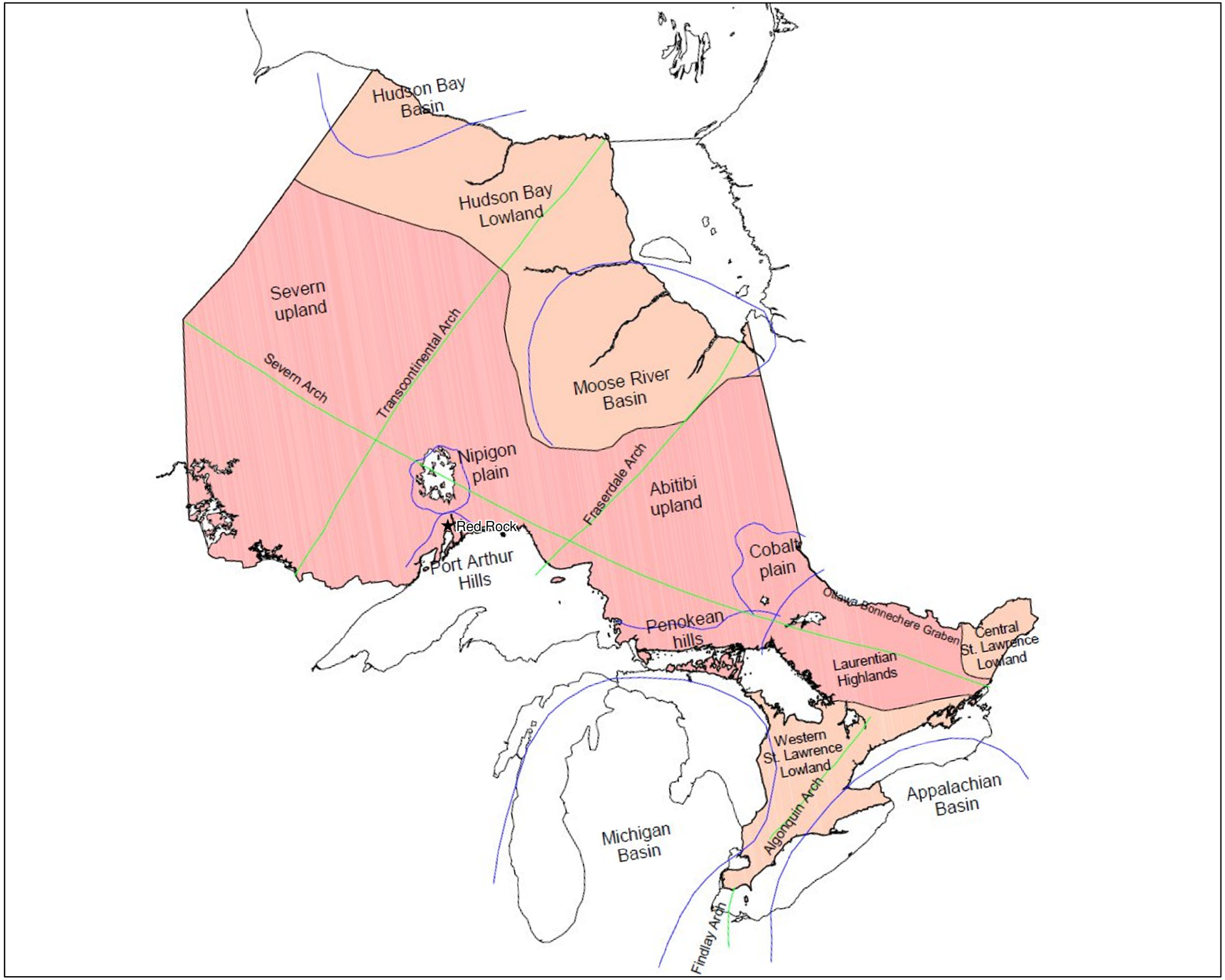


**LEGEND**

- ★ Township of Red Rock
- Arch
- Basin Boundary
- Phanerozic Borderlands
- Precambrian Canadian Shield

**REFERENCE**

Base Data - ESRI Digital Chart of the World, 2010
Physiography: Physiographic regions in Ontario based on Bostock (1970)
(from Thurston et al. 1991)
Projection:NA

PROJECT

NWMO Desktop Level Initial Screening

TITLE

**Physiographic Regions of Ontario**

Golder Associates
Mississauga, Ontario

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| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
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**FIGURE: 2.3**

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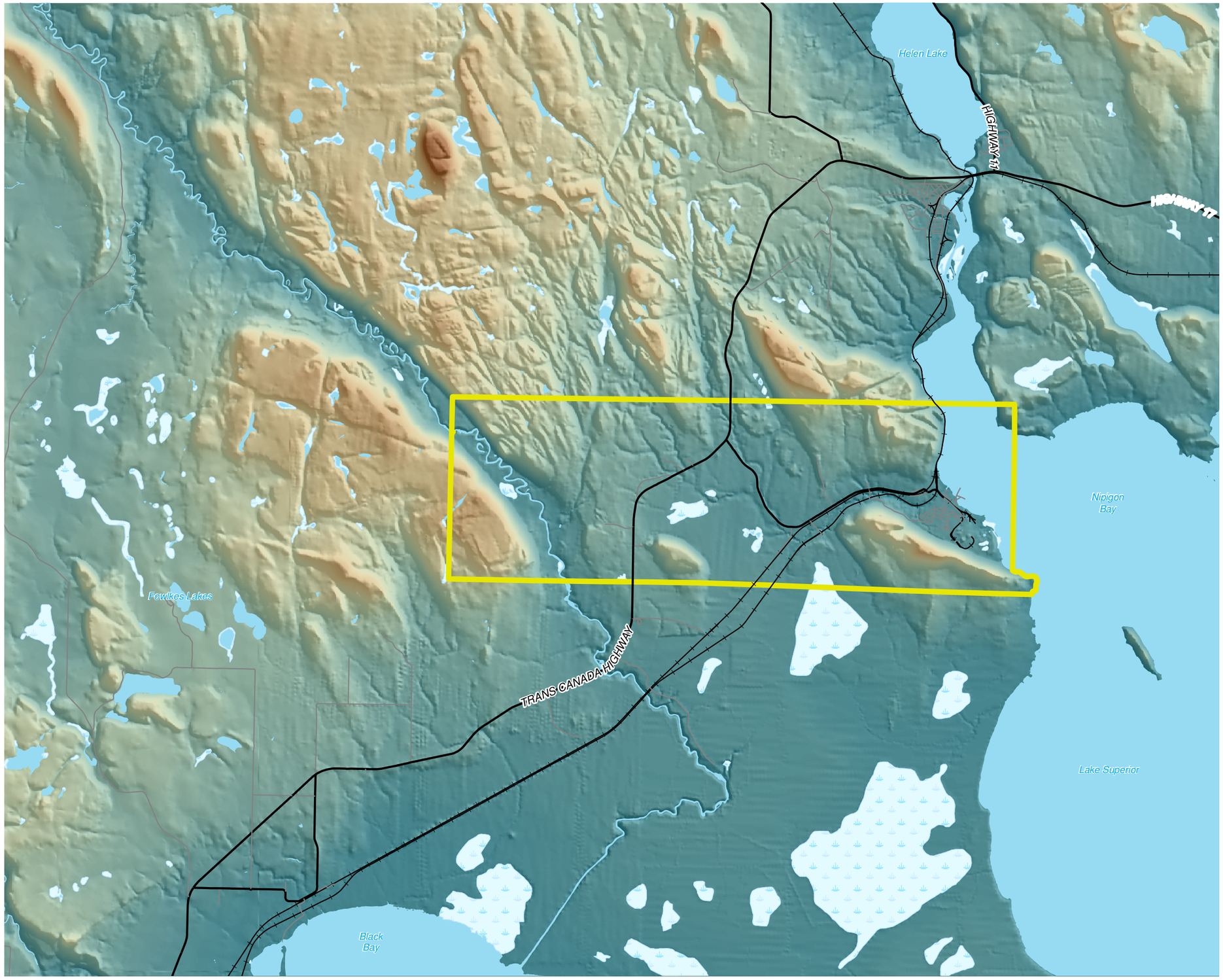
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Nipigon Bay
Lake Superior
Fowlkes Lakes
TRANS CANADA HIGHWAY
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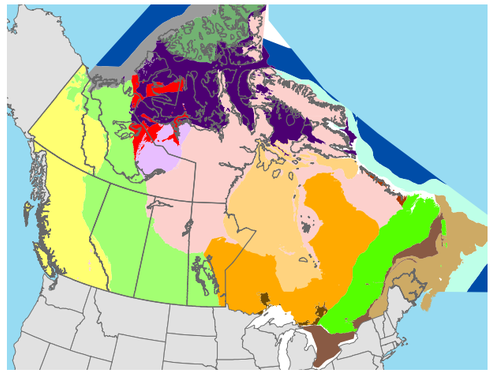
LABRADOR TROUGH
Minto
Hudson Bay
James Bay
Thompson Belt
TRANS-HUDSON OROGEN
Manitoba
Ontario
Pikwitonei
Winisk
Sachigo
SUPERIOR PROVINCE
Berens River
Uchi
English River
Bird River
Winnipeg River
Wabigoon
Quetico
Wawa
Minnesota River Valley
Bienville
Ashuanipi
La Grande River
Opinaca River
Kapuskasing Structural Zone
Opatica
Abitibi
Pontiac
GRENVILLE PROVINCE
SOUTHERN PROVINCE
Red Rock
Canada
USA
Quebec
Ontario
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario

## LEGEND

- Township of Red Rock
- Provincial Boundary
- International Boundary
- Limit of Exposed Archean Rock
- Southern Province

Superior Province (Archean)

- Sub-Province Gneissic - Plutonic
- Sub-Province Plutonic
- Sub-Province Metasedimentary
- Sub-Province Volcanic - Plutonic



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Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Physiographic Regions of Ontario - Thurston, P. C. 1991 Geology of Ontario: Introduction in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.26-57
Geology: Geological Map of Canada 1996, Map D1860A
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PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Provinces of the Canadian Shield

Golder Associates
Mississauga, Ontario

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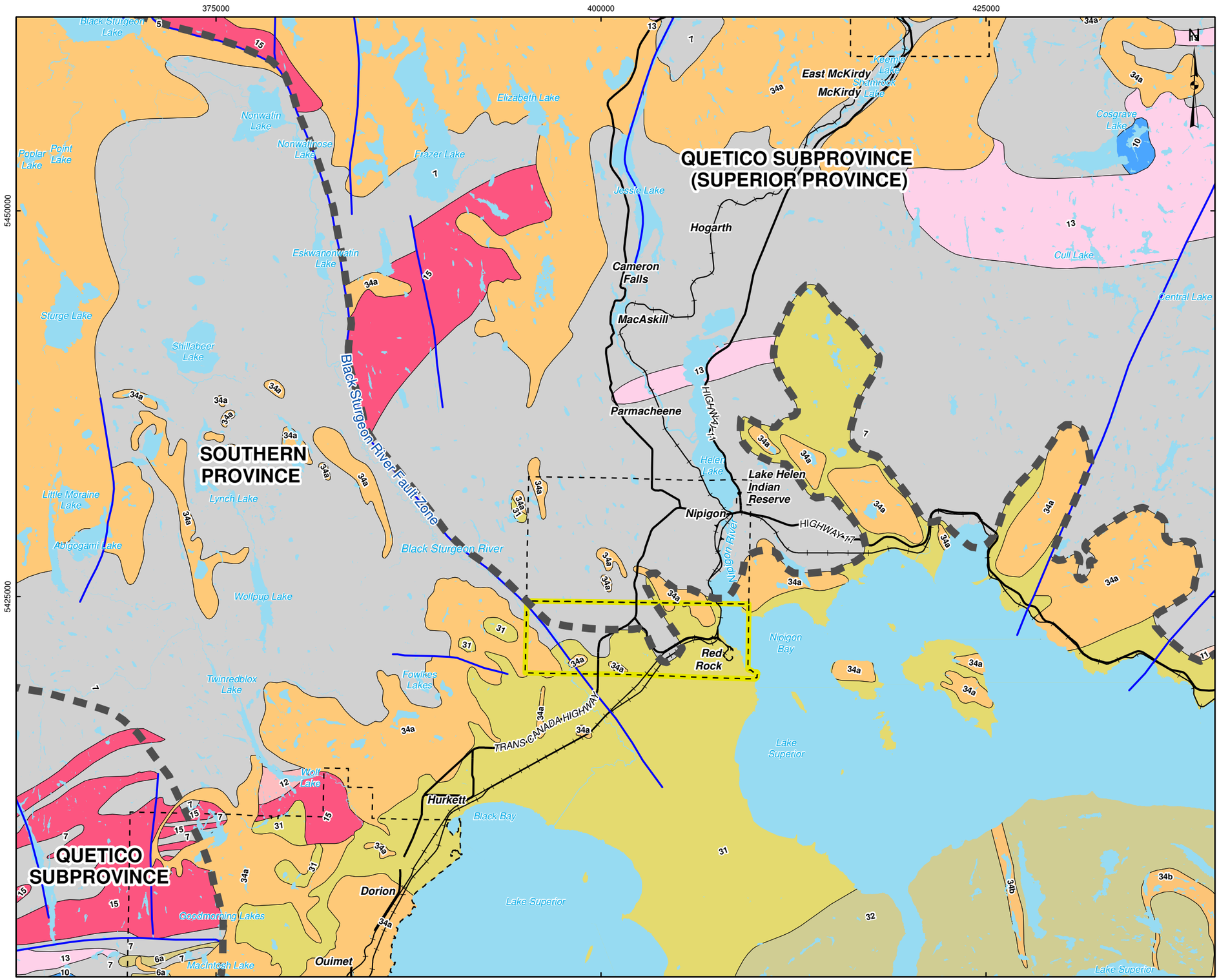


## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Railway
- Utility Line
- Water Area, Permanent
- Geological Fault
- 34 Mafic and related intrusive rocks (Keweenawan age)
  - 34a Logan and Nipigon sills (1109 Ma): diabase sills
  - 34b Pigeon River and Pukaskwa swarms: diabase dikes
- 32 Osler Gp., Maminse Point Fm., Michipicoten Island Fm.
- 31 Sibley Gp.
- 15 Massive granodiorite to granite
- 13 Muscovite-bearing granitic rock
- 12 Foliated tonalite suite
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
- 7 Metasedimentary rocks (Paragneisses and Migmatites)
- 6 Felsic to intermediate metavolcanic rocks
  - 6a Dacitic and Andesitic flows, tuffs and breccias
- 5 Mafic to intermediate metavolcanic rocks

## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Geology: MRD126-Bedrock Geology of Ontario, 2007
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Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

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PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Regional Bedrock Geology of Red Rock and Surrounding Area

Golder Associates
Mississauga, Ontario

| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
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| DESIGN | PRM | 27 Jan. 2011 | | |
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**FIGURE: 3.2**

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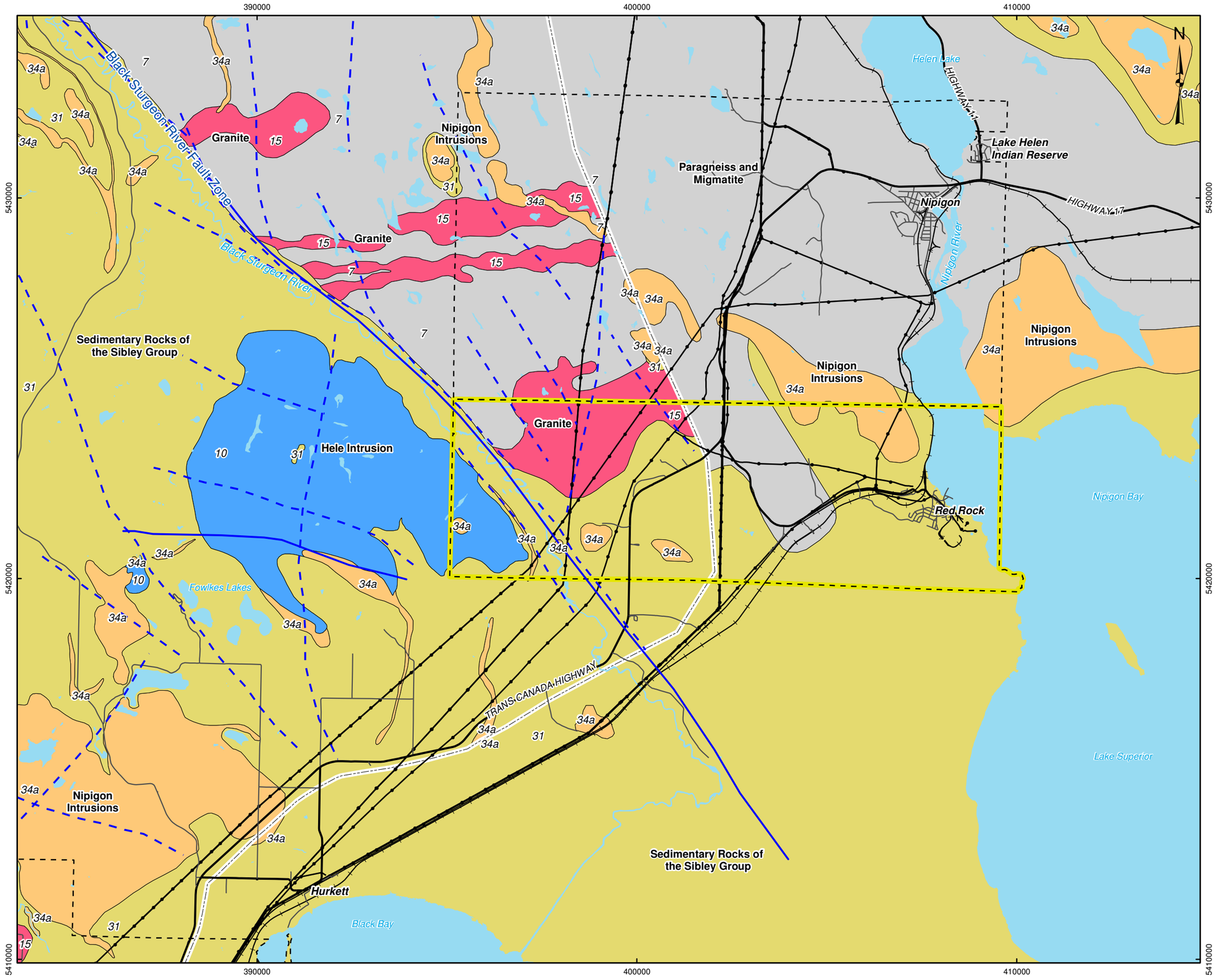


## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Water Area, Permanent
- Geological Fault
- Lineament / Fault (Hart, 2005)
- Geological Contact
- Revised Mapping (Hart, 2005)
- 34 Mafic and related intrusive rocks (Keweenawan age)
- 34a Logan and Nipigon sills (1109 Ma): diabase sills
- 31 Sibley Gp.
- 15 Massive granodiorite to granite
- 15a Potassium feldspar megacrystic units
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
- 10a Gabbro
- 10b Anorthosite
- 7 Metasedimentary rocks (Paragneisses and Migmatites)


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Geology: Modified MRD126-Bedrock Geology of Ontario (2007) incorporating detailed mapping published by Hart (2005)
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2009
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
KILOMETRES
SCALE 1:100,000

PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Bedrock Geology of the Red Rock Area

Golder Associates
Mississauga, Ontario

| | | | | |
|---|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PRM | 27 Jan. 2011 | FIGURE: 3.3 | |
| GIS | PRM | 27 May. 2011 | | |
| CHECK | CM | 27 May. 2011 | | |
| REVIEW | GS | 27 May. 2011 | | |

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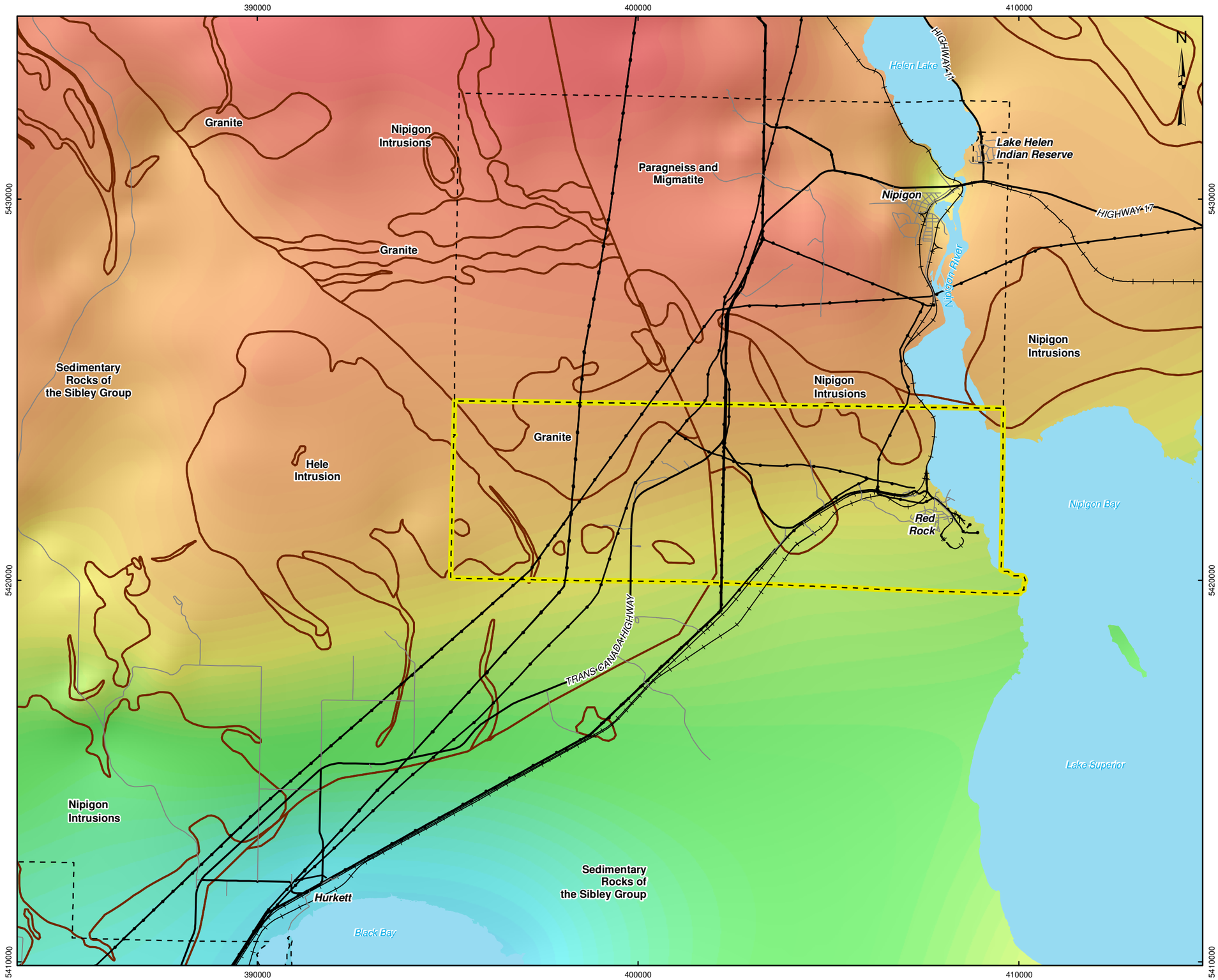
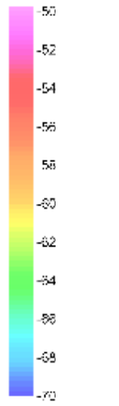



## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Water Area, Permanent
- Geological Contact

Gravity Anomaly (mGal)





## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geophysics: Ontario Prospectors Association, 2004. Ground Gravity Survey Lake Nipigon
Geoscience Intiative; Ontario Geological Survey, GDS1052
Geology: Modified MRD126-Bedrock Geology of Ontario (2007) incorporating detailed
mapping published by Hart (2005)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

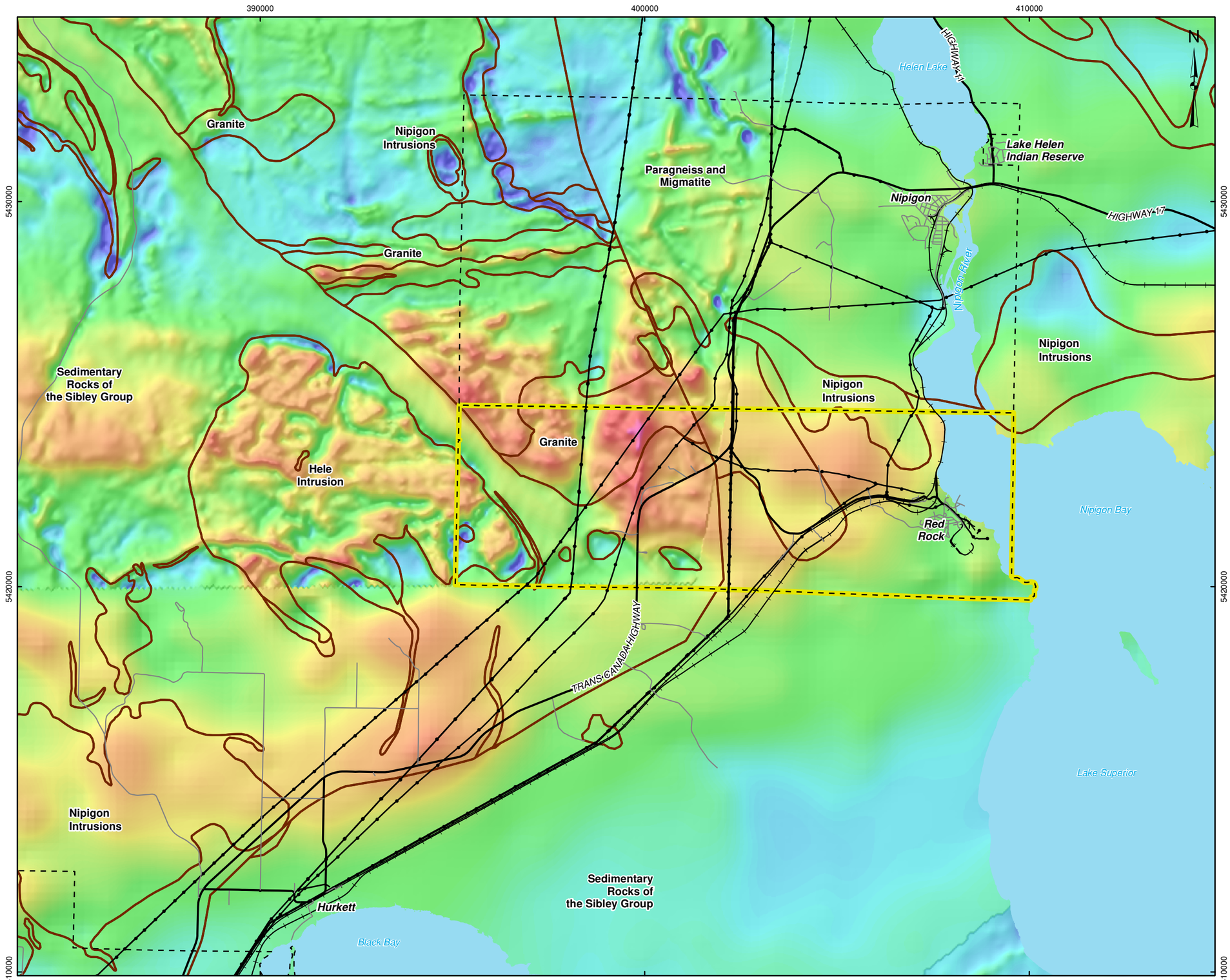
PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Gravity Map of the Red Rock Area

Golder Associates
Mississauga, Ontario

| | | | | |
|---|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PRM | 27 Jan. 2011 | FIGURE: 3.4 | |
| GIS | PRM | 18 Mar. 2011 | | |
| CHECK | JF | 18 Mar. 2011 | | |
| REVIEW | GS | 18 Mar. 2011 | | |

g:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\GravityMapRedRock.mxd




## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Water Area, Permanent
- Geological Contact

Residual Total Magnetic Field (nT)

400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geophysics: Ontario Geological Survey 2004. Ontario airborne geophysical surveys, magnetic and gamma-ray spectrometer data, Lake Nipigon Embayment Area; Geophysical Data Set1047
Geology: Modified MRD126-Bedrock Geology of Ontario (2007) incorporating detailed mapping published by Hart (2005)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

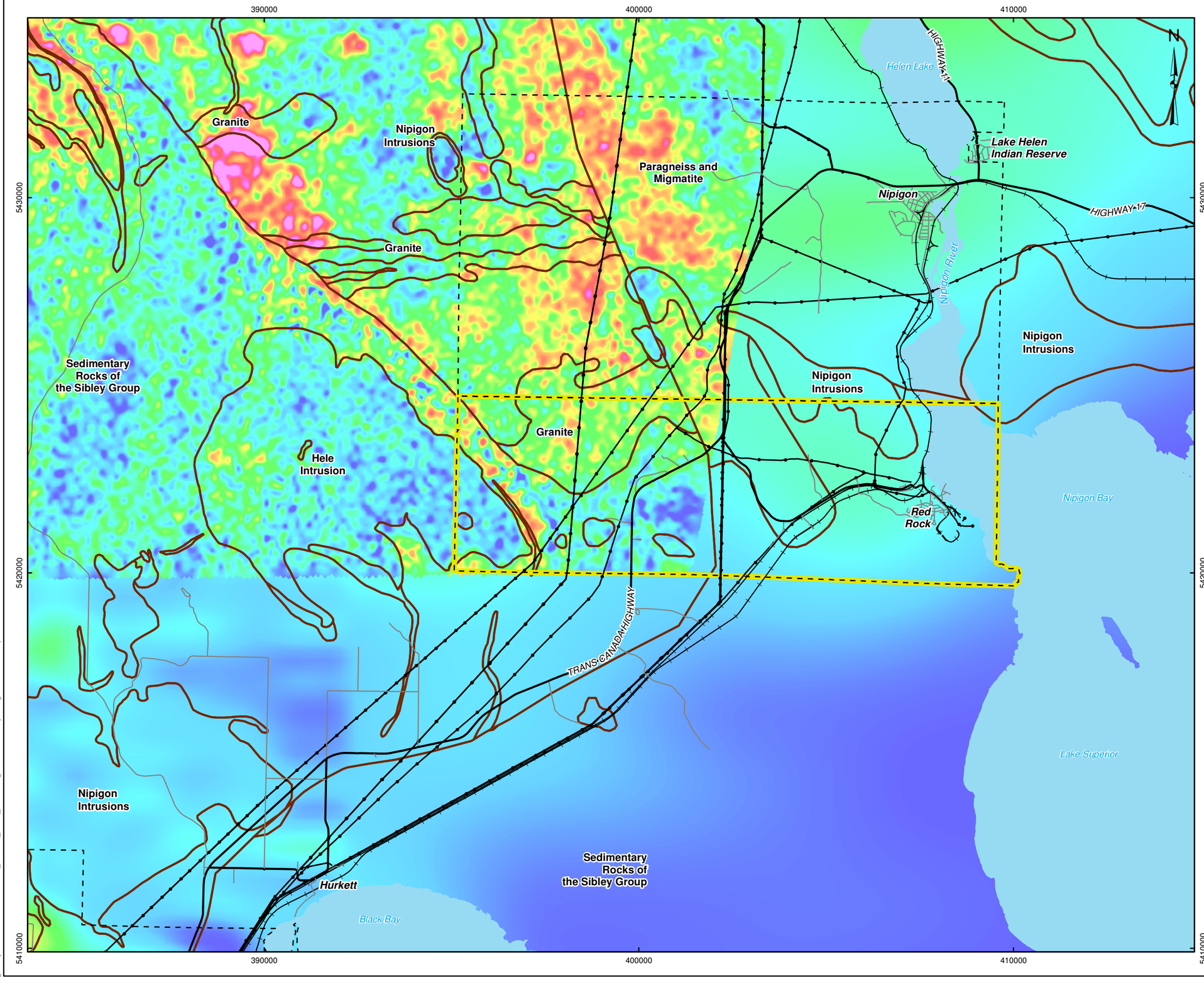
PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Residual Total Magnetic Field of the Red Rock Area

Golder Associates
Mississauga, Ontario

| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
|---|---|---|---|---|
| DESIGN | PRM | 27 Jan. 2011 | FIGURE: 3.5 | |
| GIS | PRM | 18 Mar. 2011 | | |
| CHECK | JF | 18 Mar. 2011 | | |
| REVIEW | GS | 18 Mar. 2011 | | |

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\ResidualMagneticTotalFieldRedRock.mxd




## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Water Area, Permanent
- Geological Contact

Equivalent Uranium (ppm)

3.5
3
2.5
2
1.5
1
0.5
0


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Radiometrics: Ontario Geological Survey 2004. Ontario airborne geophysical surveys, magnetic and gamma-ray spectrometer data, Lake Nipigon Embayment Area; Geophysical Data Set 1047;
Geology: Modified MRD126-Bedrock Geology of Ontario (2007) incorporating
detailed mapping published by Hart (2005)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

PROJECT
NWMO Desktop Level Initial Screening

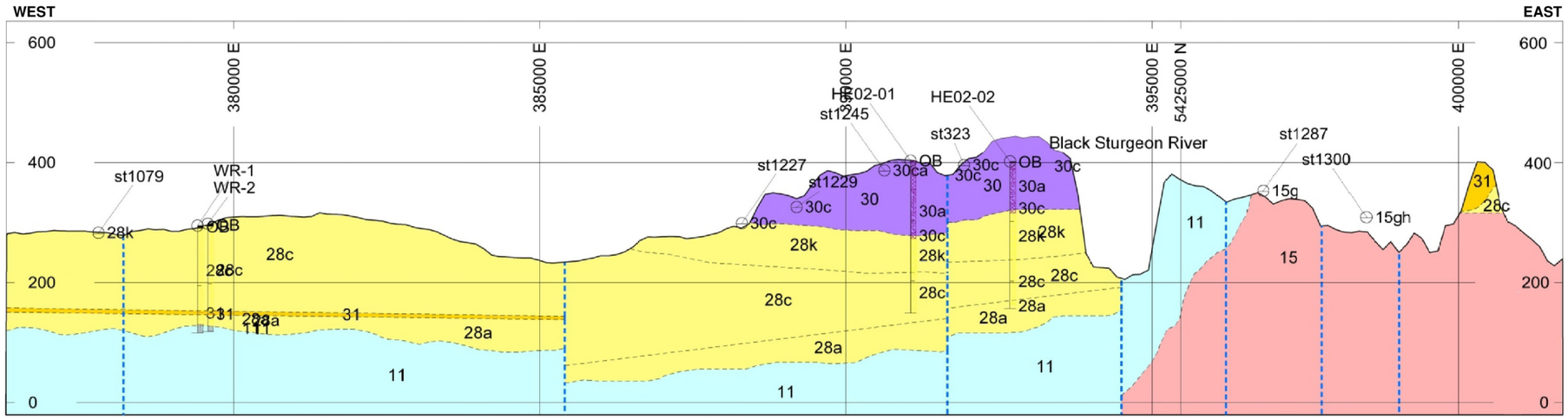
TITLE
# Equivalent Uranium of the Red Rock Area

Golder Associates
Mississauga, Ontario

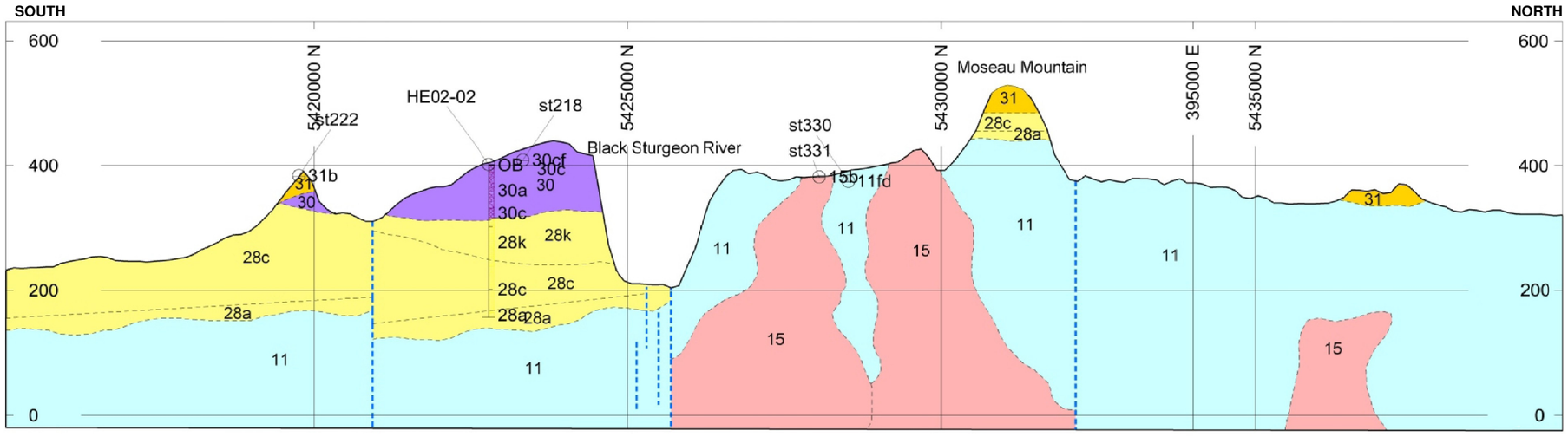
| | | | | |
|---|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PRM | 27 Jan. 2011 | FIGURE: 3.6 | |
| GIS | PRM | 18 Mar. 2011 | | |
| CHECK | JF | 18 Mar. 2011 | | |
| REVIEW | GS | 18 Mar. 2011 | | |

g:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\EquivalentUraniumRedrock.mxd

## SECTION B-I

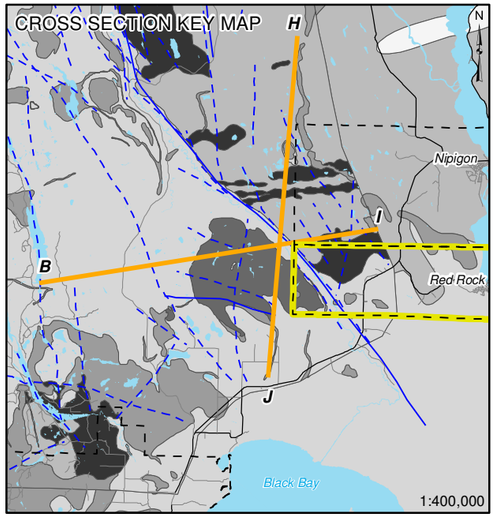



## SECTION J-H




**LEGEND**

- 31 - Mafic Intrusive Rocks (Nipigon Sills)
- 30 - Mafic to Ultramafic Intrusive Rocks
- 28 - Sibley Group Sedimentary Rocks
- 15 - Biotite Granite Suite
- 11 - Gneissic to Migmatitic Suite




**REFERENCE**

Hart, 2005, Precambrian Geology of the Southern Black Sturgeon River and Seagull Lake Area

PROJECT

NWMO Desktop Level Initial Screening

TITLE

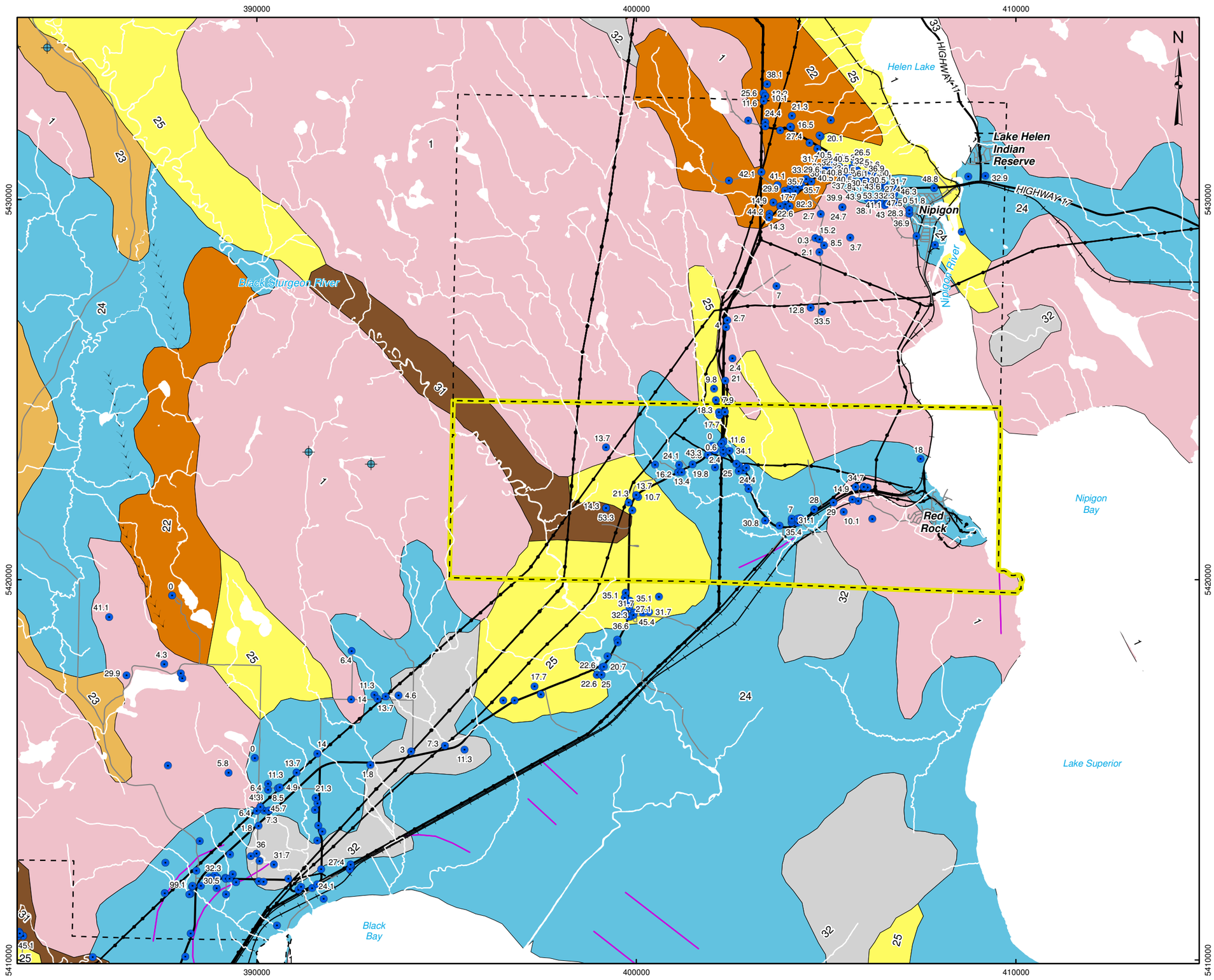
**Conceptual Geological Cross Section Near Red Rock Area**

Golder Associates
Mississauga, Ontario

| | | | | |
|---|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PB | 30 Aug. 2010 | | |
| GIS | PRM | 27 May. 2011 | | |
| CHECK | JF | 27 May. 2011 | | |
| REVIEW | GS | 27 May. 2011 | | |

**FIGURE: 3.7**

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\ConceptualGeologicalCrossSection.mxd




## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- MOE Well Location (Overburden Thickness - m)
- Diamond Drill Hole
- Esker or Area of Eskers
- Drumlin or Area of Drumlins
- Terrace Escarpment (Abandoned Shore Bluff)
- Terrace Escarpment; Fluvial
- Trend of End Moraine Crest
- 1: Bedrock
- 18: Till
- 22: Glaciofluvial Ice
- 23: Glaciofluvial Outwash deposits
- 24: Glaciolacustrine Deposits – Fine Grained
- 25: Glaciolacustrine Deposits – Coarse Grained
- 28: Fluvial Deposits - Pleistocene
- 31: Fluvial Deposits - Recent
- 32: Organic deposits
- 33: Water Area


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geology: Modified EDS014-Surficial Geology of Ontario 1:1,000,000, 2000
Wells: Ministry of the Environment, 2010
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

PROJECT
NWMO Desktop Level Initial Screening

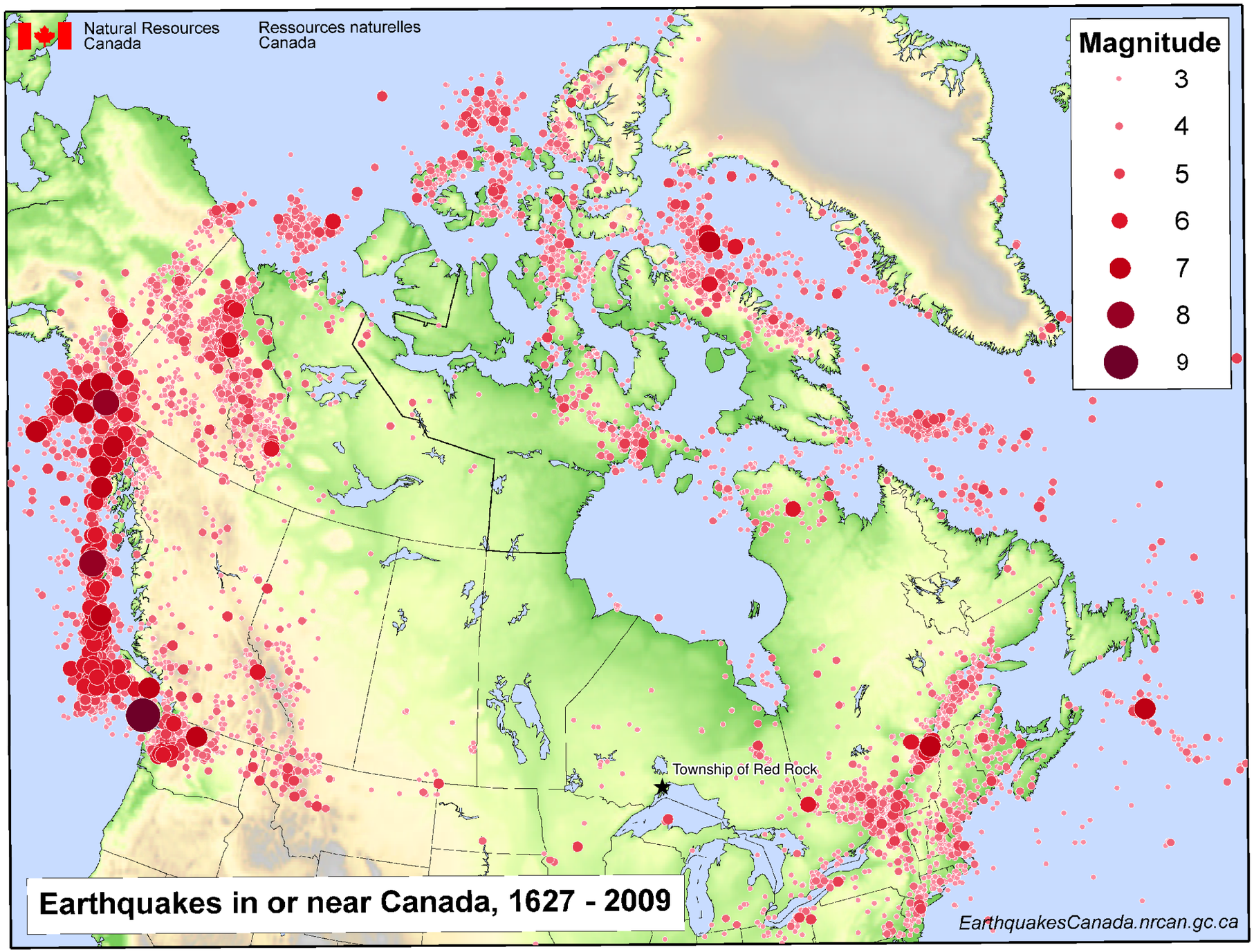
TITLE
# Quaternary Geology of the Red Rock Area

Golder Associates
Mississauga, Ontario

| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
|---|---|---|---|---|
| DESIGN | PRM | 27 Jan. 2011 | | |
| GIS | PRM | 27 May. 2011 | | |
| CHECK | CM | 27 May. 2011 | | |
| REVIEW | GS | 27 May. 2011 | | |

**FIGURE: 3.8**

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\QuaternaryGeologyRedRock.mxd




**LEGEND**

★ Township of Red Rock

**REFERENCE**

Base Data - ESRI Digital Chart of the World,2010
Seismic: NRCAN, Earthquake Map of Canada 1627-2007
Projection:NA

PROJECT

NWMO Desktop Level Initial Screening

TITLE

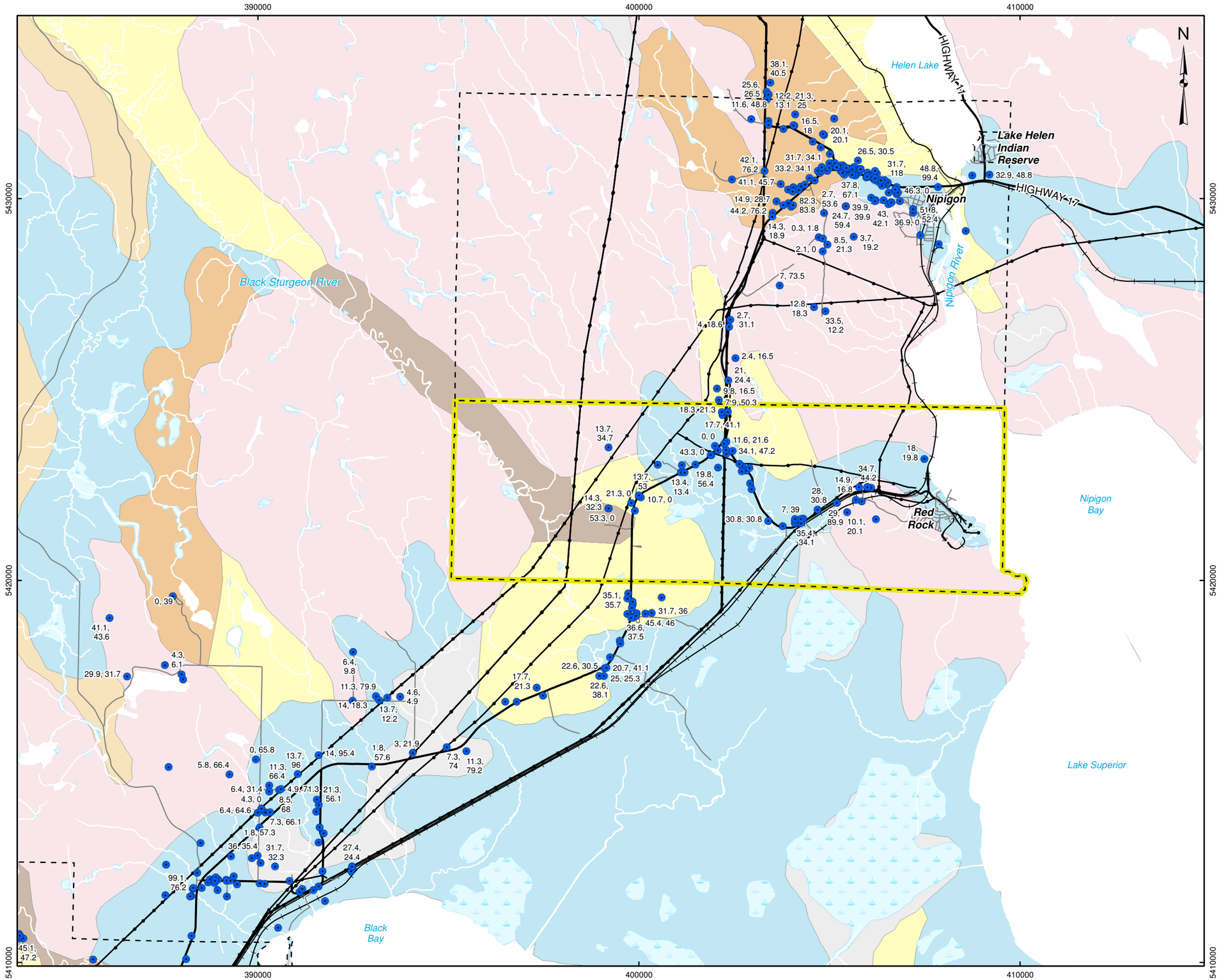
**Earthquakes Map of Canada 1627-2009**

Golder Associates
Mississauga, Ontario

| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
|---|---|---|---|---|
| DESIGN | PB | 30 Aug. 2010 | | |
| GIS | PRM | 27 May. 2011 | | |
| CHECK | JF | 27 May. 2011 | | |
| REVIEW | GS | 27 May. 2011 | | |

**FIGURE: 3.9**

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\EarthquakesMap\Canada1627to2009.mxd




## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Local Road
- Railway
- Utility Line
- Wetland Area, Permanent
- MOE Well (Depth to Bedrock - m, Depth to Water - m)
- 1: Bedrock
- 18: Till
- 22: Glaciofluvial Ice
- 23: Glaciofluvial Outwash deposits
- 24: Glaciolacustrine Deposits – Fine Grained
- 25: Glaciolacustrine Deposits – Coarse Grained
- 28: Fluvial Deposits - Pleistocene
- 31: Fluvial Deposits - Recent
- 32: Organic deposits
- 33: Water Area

## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Geology: Modified EDS014-Surficial Geology of Ontario 1:1,000,000, 2000
Wells: Ministry of the Environment, 2010
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

PROJECT
NWMO Desktop Level Initial Screening

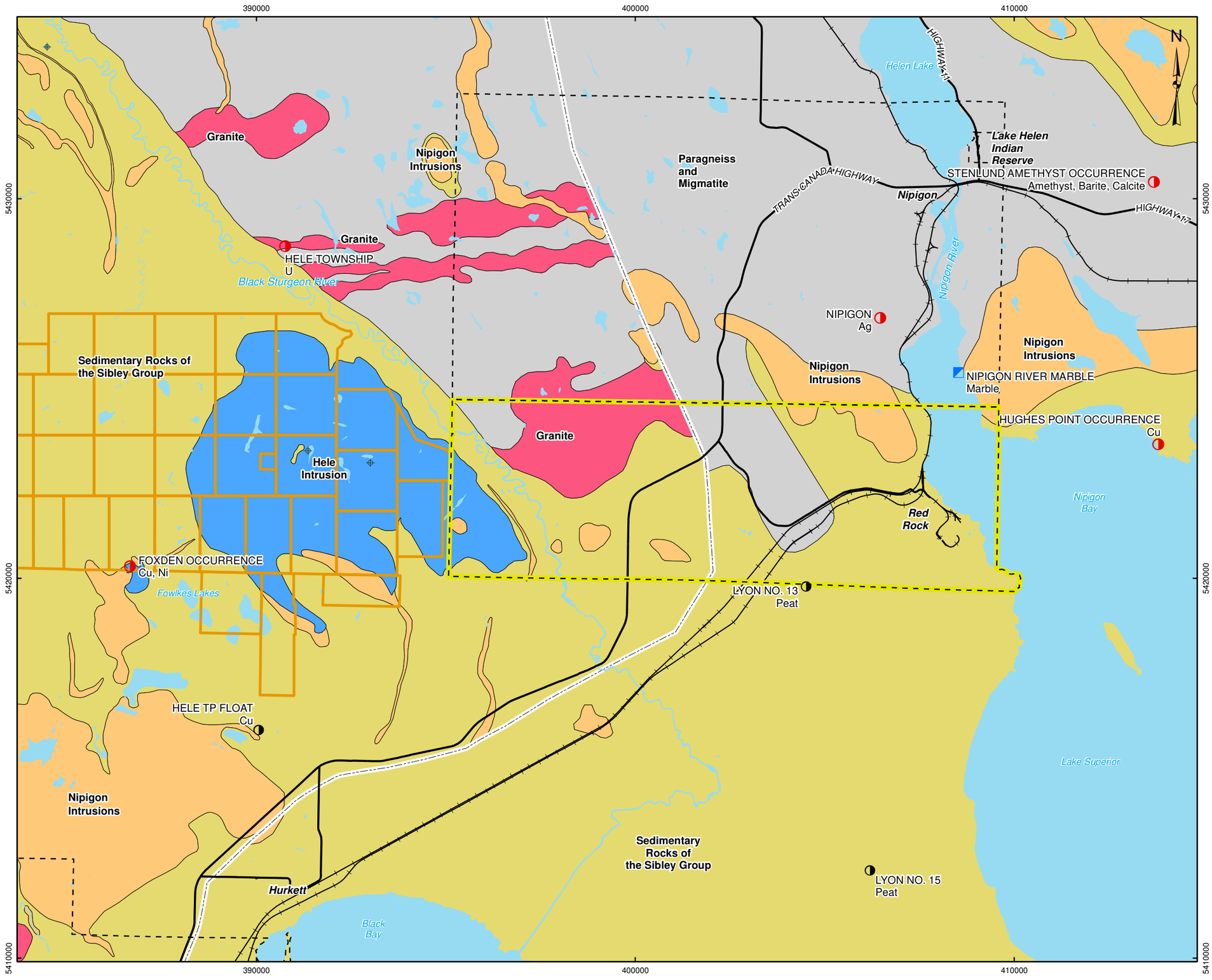
TITLE
**Water Well Records of the Red Rock Area**

Golder Associates
Mississauga, Ontario

| | | | |
|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PRM | 27 Jan. 2011 | |
| GIS | PRM | 27 May. 2011 | |
| CHECK | CM | 27 May. 2011 | |
| REVIEW | GS | 27 May. 2011 | |

**FIGURE: 4.1**

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\WaterWellRecordsoftheRedRockArea.mxd




## LEGEND

- Township of Red Rock
- Municipal Boundary, Lower Tier
- Main Road
- Railway
- Water Area, Permanent
- Discretionary Occurence
- Occurence
- Past Producing Mine with Reserves
- Diamond Drill Hole
- Active Mining Claims
- Revised Mapping (Hart, 2005)
- 34 Mafic and related intrusive rocks (Keweenawan age)
  - 34a Logan and Nipigon sills (1109 Ma): diabase sills
- 31 Sibley Gp.
- 15 Massive granodiorite to granite
  - 15a Potassium feldspar megacrystic units
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
  - 10a Gabbro
  - 10b Anorthosite
- 7 Metasedimentary rocks (Paragneisses and Migmatites)


## REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2006.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2009
Claims: Ministry of Northern Mines and Development July 2010
Mineral Inventory: Mineral Deposit Inventory of Ontario v2, 2004
Geology: Modified MRD126-Bedrock Geology of Ontario (2007) incorporating
detailed mapping published by Hart (2005)
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 16N

2 1 0 2 4 6
SCALE 1:100,000 KILOMETRES

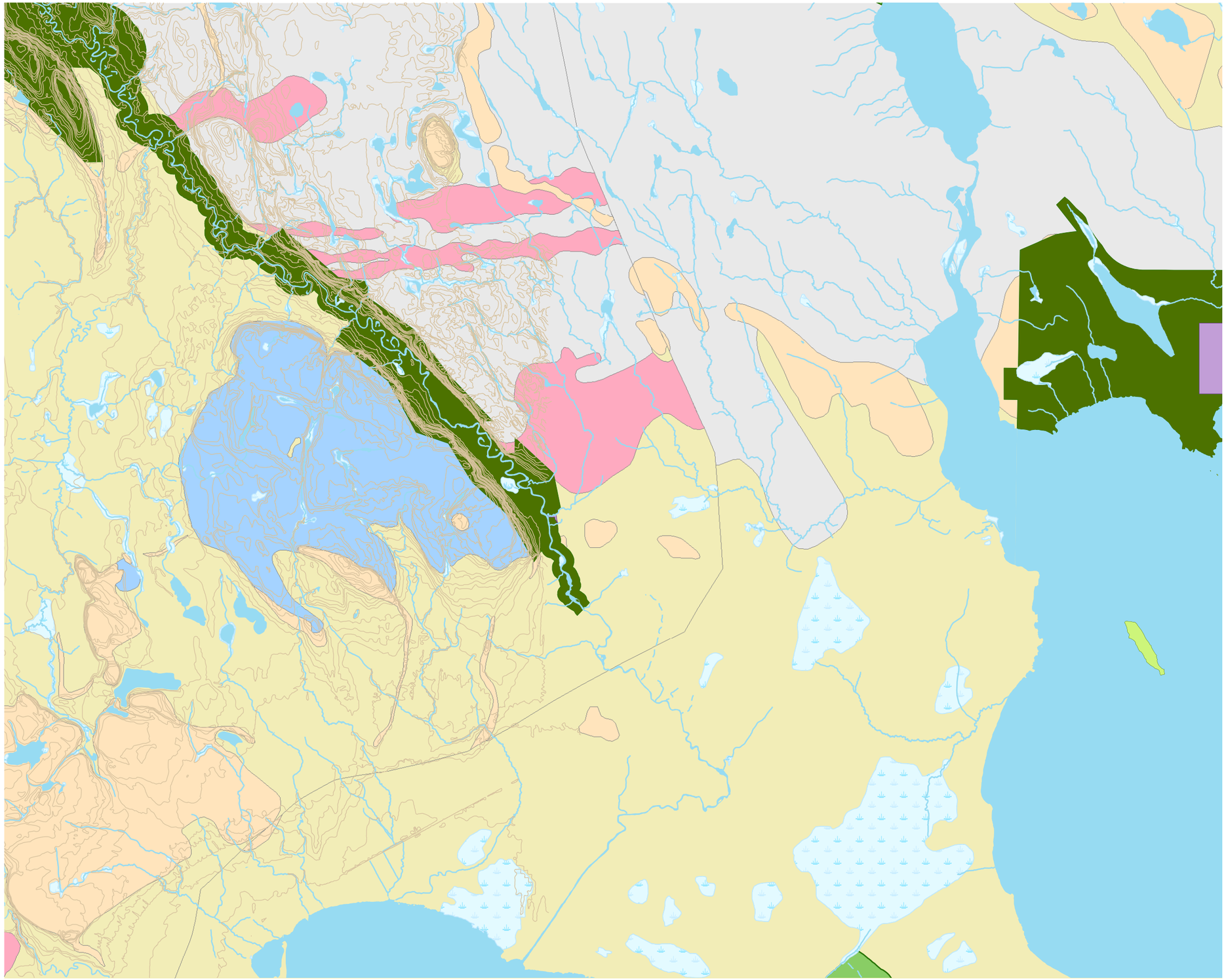
PROJECT
NWMO Desktop Level Initial Screening

TITLE
# Mining Claims and Mineral Potential in the Red Rock Area

Golder Associates
Mississauga, Ontario

| | | | | |
|---|---|---|---|---|
| PROJECT NO. 10-1152-0110 | | | SCALE AS SHOWN | REV. 1.0 |
| DESIGN | PRM | 27 Jan. 2011 | FIGURE: 5.1 | |
| GIS | PRM | 27 May. 2011 | | |
| CHECK | CM | 27 May. 2011 | | |
| REVIEW | GS | 27 May. 2011 | | |

G:\Projects\2010\10-1152-0110_NWMO_Initial_Screening\GIS\MXDs\Reporting\Phase7000\MiningClaimsandMineralPotentialintheRedRockArea.mxd



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| Europe | + 356 21 42 30 20 |
| North America | + 1 800 275 3281 |
| South America | + 55 21 3095 9500 |

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**Golder Associates Ltd.**
**2390 Argentia Road**
**Mississauga, Ontario, L5N 5Z7**
**Canada**
**T: +1 (905) 567 4444**


Golder Associates