NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

March 4, 2011

Chief Ralph Paul
English River First Nation
Box 30,
Patuanak, SK S0M 2H0

Re: **Adaptive Phased Management Initial Screening – English River First Nation**

Dear Chief Paul,

Further to your 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 English River First Nation from further consideration in the site selection process.

As the report indicates, the review of readily-available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude English River First Nation from further consideration in the NWMO site selection process. The initial screening indicates that there are a number of English River First Nation reserve areas that are potentially suitable for hosting a deep geological repository for Canada's used nuclear fuel. Should your community choose to continue to explore its potential interest in the project, your area would be the subject of progressively more detailed assessments against both technical and social factors to confirm the suitability of your community. Several years of studies would be required to confirm whether a site within your area could be demonstrated to safely contain and isolate used nuclear fuel.

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 NWMO expects that the selection of a preferred site would take between seven to ten years. It is important that any community which decides to host this project base its decisions on an understanding of the best scientific and social research available and its own aspirations. Should English River First Nation continue to be interested in exploring the project, over this period there would be ongoing engagement of your community, surrounding communities and others who may be affected. By the end of this process, English River First Nation as a whole community would need to clearly demonstrate that it is willing to host the repository in order for this project to proceed.

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February 2011

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

# English River First Nation, Saskatchewan

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

REPORT

**Report Number:** 10-1152-0110 (4000)

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# EXECUTIVE SUMMARY

On September 13, 2010, the English River First Nation 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 summarizes the findings of an initial screening, conducted by Golder Associates Ltd., to evaluate the potential suitability of thirteen English River First Nation reserve areas against five 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 English River First Nation from further consideration in the site selection process. The five initial screening criteria are defined in the site selection process document (NWMO, 2010) and relate to: having sufficient space to accommodate surface and underground facilities, being outside protected areas and heritage features, 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.

For the purpose of the screening, the thirteen reserves were grouped into three distinct regions based on the similarity of their geology: the three reserves within the sedimentary rocks of the Athabasca Basin (Region 1); the seven reserves within the Canadian Shield (Region 2); and the three reserves within the sedimentary rocks of the Western Canada Sedimentary Basin (Region 3). The surface area within the boundaries of some of the English River reserves would not be sufficient to accommodate the repository surface facilities. Therefore, as per discussions between NWMO and the Band Council, the initial screening was conducted to also assess whether there are areas at the periphery of the reserves that would meet the initial screening criteria. In this report, the lands within the English River First Nation reserves and their periphery are also referred to as the "the reserve areas".

The review of readily available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the English River First Nation from being further considered in the NWMO site selection process. There are a number of English River First Nation reserve areas that are potentially suitable for hosting a deep geological repository. These include the seven reserve areas located on the Canadian Shield (Region 2). All the English River First Nation reserve areas located within the sedimentary rocks of the Athabasca Basin (Region 1) and the Western Canada Sedimentary Basin (Region 3) were excluded from further consideration as they do not meet some of the screening criteria.

It is important to note that the intent of the initial screening is not to confirm the suitability of the proposed reserve areas, but rather to provide early feedback on whether there are known reasons to exclude the English River First Nation from further consideration. Should the English River First Nation remain interested in continuing with the site selection process, more detailed studies would be required to confirm and demonstrate whether the English River First Nation reserve areas contain sites that can safely contain and isolate used nuclear fuel. 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.

## Reserve Areas Not Meeting Screening Criteria

The reserve areas located within the Athabasca Basin (Regions 1) and the Western Canada Sedimentary Basin (Region 3) do not meet all the screening criteria and have, therefore, been excluded from further consideration. The reserve areas within the Athabasca Basin (Region 1) include the Cable Cree Lake, the Cree Lake and the Barkwell Bay Indian Reserves. All three reserves do not meet the screening criteria related to the presence of

known groundwater resources at repository depth; the presence of known economically exploitable resources; and the presence of known unfavourable geological and hydrogeological characteristics that make the reserve areas unsuitable for hosting a deep geological repository.

The reserves areas located within the Western Canada Sedimentary Basin (Region 3) include the Wapachewunak, the Ile-a-la-Crosse and the La Plonge Indian Reserves. They all fail to meet the screening criteria related the presence of known unfavourable geological and hydrogeological characteristics that make them unsuitable for hosting a deep geological repository.

## Reserve Areas Meeting Screening Criteria

All seven reserve areas located within the crystalline rocks of the Canadian Shield (Region 2) meet the screening criteria. They include the Haultain Lake, the Flatstone Lake, the Porter Lake Island, the Dipper Rapids, the Primeau Lake, the Knee Lake, and the Elak Dase Indian Reserves.

A brief summary of the assessment of these seven reserve areas against each of the initial screening criterion is provided below.

### Availability of Land

The English River First Nation reserve areas within the Canadian Shield (Region 2) contain land and geological formations that are sufficient to accommodate the surface and underground facilities associated with a repository and could be accessible for construction and field investigation activities. These reserve areas are largely undeveloped, with no major infrastructure present. No obvious topographic features that would prevent construction and site characterization were identified.

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

Based on the review of readily available information, the English River First Nation reserve areas within the Canadian Shield (Region 2) contain sufficient land outside protected areas, heritage sites, provincial parks and national parks to accommodate facilities associated with a repository. The nearest protected area is the Gordon Lake Recreation Site which is located approximately 10 km east of the Elak Dase reserve. There are several known heritage sites within the English River First Nation reserve areas. These are small areas that occupy a very small fraction of the available land within the reserve areas. The absence of other locally protected areas would need to be confirmed in discussion with the community and Aboriginal peoples in the area during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

### Absence of Known Groundwater Resources at the Repository Depth

The review of available information did not identify any known groundwater resources at repository depth in the seven reserves areas within the Canadian Shield (Region 2). The Saskatchewan Watershed Authority Water Well Records database has no records of any water wells within these reserve areas. Based on experience in similar crystalline rock settings in the Canadian Shield, the likelihood of the existence of exploitable aquifers at typical repository depth (approximately 500 m) in the English River First Nation reserve areas within the Canadian Shield is low. Active groundwater systems in comparable geological settings across the Canadian Shield are usually limited to shallow fractured zones. The absence of groundwater resources at repository depth would need to be confirmed during subsequent site evaluation stages, if the community remains interested in the site selection process.

## Absence of Economically Exploitable Natural Resources as Known Today

The English River First Nation reserve areas within the Canadian Shield (Region 2) contain sufficient areas, free of known economically exploitable natural resources, to accommodate the required repository facilities. The review of known mineral deposits, exploration activity, and mineral potential indicates that these reserve areas have a generally low economic mineral potential. There is no evidence of past or present exploration or development activities associated with oil and gas resources. There are currently no operating or past producing mines and only a few mineral occurrences have been identified in the area of the reserves.

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

The review of readily available geoscientific information did not identify any obvious geological or hydrogeological conditions that would clearly exclude the English River First Nation reserve areas within the Canadian Shield (Region 2) from further consideration in the site selection process. These reserve areas contain geological units with geometric, structural and hydraulic characteristics that are potentially suitable for a deep geological repository. An example of these geological units is the felsic gneiss that dominates the geology of the reserve areas.

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# 1.0 INTRODUCTION

On September 13, 2010, the English River First Nation of Saskatchewan 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. (Golder) to evaluate the potential suitability of the thirteen English River First Nation reserve areas against five screening criteria using readily available information. These reserves are shown on Figure 1.1. The surface area within the boundaries of some of the English River First Nation reserves would not be sufficient to accommodate the repository surface facilities. Therefore, as per discussions between NWMO and the Band Council, the initial screening was conducted to also assess whether there are areas at the periphery of the reserves that would meet the initial screening criteria. In the following, the lands within the English River First Nation reserves and their periphery are also referred to as the "the reserve areas".

## 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, social, economic and cultural factors as identified through dialogue with Canadians, and draws from experiences and lessons learned from past work and processes developed in Canada to site facilities for the management of 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 these steps in the process.

## 1.2 Objective 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 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 participating 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.

## 1.3 English River First Nation Reserve Areas

For the purpose of this initial screening and as outlined in Table 1.1, the thirteen reserves were grouped into three distinct regions based on the similarity of their geology: the three reserves within the sedimentary rocks of the Athabasca Basin (Region 1); the seven reserves within the Canadian Shield (Region 2); and the three reserves within the sedimentary rocks of the Western Canada Sedimentary Basin (Region 3). Geographically, the Athabasca Basin is the northernmost region, while the Western Canada Sedimentary Basin is the southernmost region.

**Table 1.1: English River First Nation Reserve Areas by Region**

| Region | English River First Nation Reserve Areas Associated with Region[(a)] |
|---|---|
| Region 1<br>Athabasca Basin (northernmost region) | ■ Cable Cree Lake I. R. 192M (Cable Cree Lake IR)<br>■ Cree Lake I. R. 192G (Cree Lake IR)<br>■ Cree Lake - Barkwell Bay I. R. 192I (Barkwell Bay IR) |
| Region 2<br>Canadian Shield (central region) | ■ Haultain Lake I. R. 192K (Haultain Lake IR)<br>■ Flatstone I. R. 192L (Flatstone Lake IR)<br>■ Porter Lake Island I. R. 192H (Porter Lake Island IR)<br>■ Dipper Rapids Addition I. R. 192C (Dipper Rapids IR)<br>■ Primeau Lake I. R. 192F (Primeau Lake IR)<br>■ Knee Lake I. R. 192B (Knee Lake IR)<br>■ Elak Dase I. R. 192A (Elak Dase IR) |
| Region 3<br>Western Canada Sedimentary Basin (southernmost region) | ■ Wapachewunak Addition I. R. 192D (Wapachewunak IR)<br>■ Ile-a-la-Crosse I. R. 192E (Ile-a-la-Crosse IR)<br>■ La Plonge I. R. 192 (La Plonge IR) |

(a) Names shown in brackets are the abbreviated names that will be used throughout the text to refer to each specific area

# 2.0 PHYSICAL GEOGRAPHY

This chapter provides a general overview of the reserve locations, topography, drainage and protected areas within each of the three geological regions being considered.

## 2.1 Region 1 – Athabasca Basin: Cable Cree Lake IR, Cree Lake IR, Barkwell Bay IR

### 2.1.1 Location

Region 1 is located in the Athabasca Basin. All three reserve areas are located on the shores of Cree Lake, Saskatchewan (Figure 1.1). The three reserve areas include:

- Cable Cree Lake IR: This reserve area covers 5.3 $km^2$ and is located on the west shore of the lake, north of Cable Bay and south of the Karras River which flows into Cree Lake.
- Cree Lake IR: This reserve area covers 16 $km^2$ and is also located on the west shore of the lake, beside Mackenzie Bay and north of the Karras River.
- Barkwell Bay IR: This reserve area covers 23.4 $km^2$ and is located on the northeast shore of the lake, on the east side of Barkwell Bay.

### 2.1.2 Topography

All three reserve areas occur on the Athabasca Plain ecoregion within the Athabasca Basin. Satellite imagery is presented on Figure 2.1. Cree Lake is surrounded by morainal and glaciofluvial landscape with numerous drumlins and drumlinoid ridges oriented in a northeast-southwest direction, reflecting the direction of glacial ice advance. Cable Cree Lake IR is located on a glaciofluvial plain while the Cree Lake IR area is classified as drumlinoid moraine, which is evident on topographic maps. The Barkwell Bay IR area is classified as a glaciofluvial outwash plain and has a few distinct drumlins, set back from the lake (Schreiner, 1984b).

Topographic features for Region 1 in the Athabasca Basin are visible in the Digital Elevation Model (DEM) shown on Figure 2.2. The Athabasca Plain regional surface slopes gradually to the northwest and southeast from a central highland around and west of Cree Lake (Schreiner, 1984a). Cree Lake is the fourth largest lake in Saskatchewan with a surface area of 1,434 $km^2$ (NRC, 2009). While Cable Cree Lake IR near the airfield location is a relatively flat area with low relief, the other two reserve areas have drumlins and drumlinoid ridges with elevations as high as 40 to 50 m above the lake.

### 2.1.3 Drainage

In the Athabasca Basin, water generally flows northward towards Lake Athabasca and Slave Lake through the Mackenzie River system that eventually flows into the Arctic Ocean. All three reserves in Region 1 are on the shores of Cree Lake (Figure 2.3) which outflows through the Cree River, which flows north across northern Saskatchewan into Black Lake and the Fond du Lac River, which in turn flows west into Lake Athabasca.

### 2.1.4 Protected Areas

#### Parks and Reserves

Region 1 was screened for national, provincial and municipal parks, conservation areas, nature reserves and national wildlife areas using available data from the Saskatchewan Ministry of Environment (MOE), and Environment Canada (EC). There are no parks, wildlife areas, or conservation reserves within or adjacent to the English River First Nation reserve areas within Region 1.

### Heritage Sites

The database for previously recorded heritage resources, maintained by the Saskatchewan Ministry of Tourism, Parks, Culture and Sport (TPCS, 2010), was consulted to identify previously recorded heritage resources found within the English River First Nation reserve areas in Region 1. Heritage resources include all of Saskatchewan's Historic and Precontact archaeological sites, architecturally significant structures, and palaeontological resources.

The results of the database search indicate that 25 archaeological sites have been recorded in Region 1 (Figure 2.4; Table 2.1). Precontact artifact find and scatter sites are the most common (n=19); followed by multiple features (n=2); recurrent features (n=2); artifact/feature combination (n=1); and one burial site which is a Site of Special Nature. These sites are all located along the north eastern shores of Cree Lake near the Barkwell Bay IR. Historic accounts also indicate that early fur trade posts were recorded on Cree Lake (Russell and Meyer, 1999). This includes the Northwest Company's Cree Lake I post and the independent trader Mowatt's House, both dating to 1803. A Hudson's Bay Company post was later operating on Cree Lake between 1925 and 1930.

The presence of heritage sites in Region 1 would need to be further discussed with the community and Aboriginal peoples in the area, if the community remains interested in continuing with the site selection process.

**Table 2.1: Heritage Resources Recorded near the Proposed Locations in Region 1**

| Site Type | Definition | No. of Sites |
|---|---|---|
| Artifact find | Archaeological sites consisting of 5 or fewer artifacts. An artifact is any object used or modified by people (e.g., projectile point, pottery sherds, lithic flakes). | 8 |
| Artifact scatter | Archaeological sites consisting of 6 or more artifacts. | 11 |
| Artifact/Feature combination | Archaeological sites consisting of both artifacts and features. | 1 |
| Multiple feature | Archaeological sites consisting of several features of a different kind. | 2 |
| Recurrent feature | Archaeological sites consisting of several features of the same kind. | 2 |
| Site of Special Nature | Sites that have more spiritual or cultural significance and are offered additional protection under Section 64 of *The Heritage Property Act* (i.e., burials or medicine wheels). | 1 |
| | **Total** | **25** |

## 2.2 Region 2 – Canadian Shield: Haultain Lake IR, Flatstone Lake IR, Porter Lake Island IR, Dipper Rapids IR, Primeau Lake IR, Knee Lake IR, Elak Dase IR

### 2.2.1 Location

Region 2 occurs within the Canadian Shield and includes the following seven reserve areas (Figure 1.1):

- Haultain Lake IR: This reserve area covers 2 $km^2$ and is located on the east shore of Haultain Lake, approximately 9 km west of Provincial road 914.
- Flatstone Lake IR: This reserve area covers 2.3 $km^2$ and is another remote site located 37 km north of the community of Patuanak.

- Porter Lake Island IR: This reserve area covers 0.425 $km^2$ and is a remote site located north of the Churchill River, near the winter road route leading to Cree Lake.
- Dipper Rapids IR: This reserve area covers 8.4 $km^2$ and is located 22 km east of Patuanak along the Churchill River system.
- Primeau Lake IR: This reserve area covers 17 $km^2$ and is located 29 km east of Patuanak along the Churchill River system.
- Knee Lake IR: This reserve area covers 5 $km^2$ and is located 40 km east of Patuanak along the Churchill River system.
- Elak Dase IR: This reserve area covers 14 $km^2$ and is located 51 km east of Patuanak along the Churchill River system.

### 2.2.2 Topography

Physiography for the reserve areas in Region 2 is typical for the Canadian Shield, with extensive areas of bedrock that form broad, smooth uplands and lowlands (Schreiner, 1984a). Satellite imagery is presented on Figures 2.5, 2.6, and 2.7. Lakes and ridges in the Canadian Shield region are often aligned in a northeast-southwest direction, reflecting the direction of glacial ice advance.

In the Canadian Shield, bedrock and thin moraine veneer (thin deposit of glacial material over bedrock) are typical. The Flatstone Lake IR and Porter Lake Island IR are located on terrain classified as moraine veneer (Simpson, 1997), with some rock exposed at the Flatstone Lake IR area but concealed by vegetation at the Porter Lake Island IR (Schreiner, 1984c). The Haultain Lake IR area was classified as glaciofluvial hummocky terrain; the east shoreline of the lake has sandy beaches and an esker was mapped near the area (Schreiner, 1984c).

The Dipper Rapids IR area, adjacent to Dipper Lake, is on a glaciofluvial plain and the portion along White Inlet was a historical glacial meltwater channel that exhibits erosional features (Schreiner, 1984d). The Primeau Lake IR area is characterized by bedrock and hummocky moraine landscape (Schreiner, 1984d). The terrain on the Knee Lake IR and Elak Dase IR reserve areas is classified as having moraine veneer with some bedrock ridges (Schreiner, 1984d).

In Region 2, elevations are lowest along the Churchill River (Figure 2.2). The topographic high in this region is at the drainage divide between the Churchill River basin and the Athabasca Basin south of Cree Lake; this area contains the headwaters of the Mudjatik, Haultain, and Foster rivers. Localized relief is complex due to the variations in rock type and erosion. Some of the bedrock is masked by overburden in the areas with thick drift (Schreiner, 1984c).

Local relief in the area of the Flagstone Lake IR roughly follows the shoreline and uplands that are about 10 to 20 m above the lake. The Porter Lake Island IR, beside Porter Lake, is located on steep terrain with a peak elevation of over 50 m above the lake. The relief of the uplands at the Haultain Lake IR is only about 10 m above the lake surface. The Dipper Rapids IR is mainly low-lying terrain adjacent to the lake, with the highest relief about 10 m above the lake. The Primeau Lake IR is a peninsula on the south side of Primeau Lake and its relief ranges from less than 10 m up to over 30 m above the lake where bedrock is exposed. The Knee Lake IR has steep bedrock terrain rising up to 40 m above the lake. The Elak Dase IR has 20 to 30 m of relief in the

uplands between the Churchill River and the adjacent eroded glaciofluvial plain through which the Haultain River flows.

### 2.2.3 Drainage

All of the reserve areas in Region 2 are within the Churchill River basin (Figure 2.3), which drains to Hudson Bay. The Churchill River begins at the outlet of Churchill Lake near the community of Buffalo Narrows and flows from west to east through Saskatchewan and Manitoba. Its tributaries entering from the north flow through exposed Canadian Shield terrain, while many of its tributaries entering from the south flow through the Boreal Plain.

Haultain Lake drains into the Haultain River, which flows south and joins the Churchill River downstream of Knee Lake. The Porter Lake Island IR is located beside Porter Lake, which drains into Porter Creek and the southward-flowing Mudjatik River that in turn enters the Churchill River upstream of Dipper Lake. The Flatstone Lake IR is on the shores of Flatstone Lake, which drains into the Mudjatik River just before it enters the Churchill River. The Dipper Rapids IR is located adjacent to White Inlet on the west shores of Dipper Lake on the Churchill River. The Primeau Lake IR is on the south shores of Primeau Lake on the Churchill River. The Knee Lake IR is on the north shores of Knee Lake on the Churchill River, and the Elak Dase IR is north of the Churchill River near the Haultain River inflow.

### 2.2.4 Protected Areas

#### Parks and Reserves

Region 2 was screened for national, provincial and municipal parks, conservation areas, nature reserves and national wildlife areas using available data from the MOE and EC. The Gordon Lake Recreation Site is located approximately 10 km east of the Elak Dase IR along Provincial road 914 (Figure 2.8). There are no parks, wildlife areas, or conservation reserves within or adjacent to the proposed English River First Nation reserve areas within Region 2.

#### Heritage Sites

The results of the heritage resources database search indicate that 19 archaeological sites have been recorded on the same NTS map sheets as the English River First Nation reserves in Region 2 (Figure 2.4; Table 2.2). Eighteen sites are present east of the Elak Dase IR. These sites were recorded as part of the original Key Lake Road assessment (Meyer 1979). Precontact artifact scatter sites dominate (n=13); followed by artifact finds (n=2); and one artifact/feature combination site. Two unknown sites have insufficient information to categorize. The remaining recurrent feature site occurs near the Dipper Rapids IR. This site has been identified as independent fur trader Louis Primeau's house, which was established in 1775. It is located along the Churchill River on Dipper Lake.

The Churchill River was a significant waterway during both Precontact and Historic times. Archaeological evidence indicates that people were occupying the Churchill River area as early as 10,000 years ago (Meyer, 1995). During the early fur trade period, explorers and traders began travelling the Churchill River in the 1770's. This was soon followed by the establishment of fur trade posts by both the English and French beginning in 1775 and continuing through to the 1930's (Russell and Meyer, 1999). In Region 2 at least two other fur trade posts have been documented. This includes the Hudson's Bay Company Dipper and Elbow (Knee) Lake Posts established in 1905 and 1921, respectively. The presence of heritage sites in Region 2 would need to be further discussed with Aboriginal peoples in the area, if the community remains interested in continuing with the site selection process.

**Table 2.2: Heritage Resources Recorded near the Proposed Locations in Region 2**

| Site Type | Definition | No. of Sites |
|---|---|---|
| Artifact find | Archaeological sites consisting of 5 or fewer artifacts. An artifact is any object used or modified by people (e.g., projectile point, pottery sherds, lithic flakes). | 2 |
| Artifact scatter | Archaeological sites consisting of 6 or more artifacts. | 13 |
| Recurrent feature | Archaeological sites consisting of two or more features of the same kind. Features are the remains of any non-portable human activity that can not be removed from a site without disturbing it (e.g. cabin remains, hearth, cellar depression). | 1 |
| Artifact/Feature combination | Archaeological sites consisting of both artifacts and features. | 1 |
| Unknown | Archaeological sites where insufficient information was recorded to classify to type. | 2 |
| | **Total** | **19** |

## 2.3 Region 3 – Western Canada Sedimentary Basin: Wapachewunak IR, Ile-a-la-Crosse IR, La Plonge IR

### 2.3.1 Location

Region 3 occurs within the Western Canada Sedimentary Basin (Figure 1.1), and includes:

- Wapachewunak IR: This reserve area covers 20 $km^2$ and is located at the north end of Lac Ile-a-la-Crosse near the community of Patuanak, at the end of Provincial road 918.
- Ile-a-la-Crosse IR: This reserve area covers 0.06 $km^2$ and is located on the east shore of Lac Ile-a-la-Crosse, north of the Beaver River inflow, and about 6 km west of Provincial road 918.
- La Plonge IR: This reserve area covers 96 $km^2$ and overlaps the junction of Provincial road 918 and Provincial road 165 at the community of Beauval.

### 2.3.2 Topography

The Boreal Plain landscape in this region contains uplands comprised of moraine plain with steeply-sloping eroded escarpments, hilly glacial till plains, and level plateau-like tops (Fung, 1999) that are intermixed with abundant peatland terrain. Satellite imagery is presented on Figure 2.9. The Wapachewunak IR spans part of a glaciofluvial outwash plain and an adjacent glaciofluvial lake plain (Schreiner, 1984d). The Ile-a-la-Crosse IR is in a region of moraine plain (Simpson, 1997) with numerous elongated peatlands in the area that are oriented in a northwest to southeast direction. The La Plonge IR contains the path of a historical glaciofluvial meltwater channel that currently contains the Beaver River, and a moraine plain makes up the adjacent upland east of the river (Simpson, 1997).

The topography of Region 3 is shown on Figure 2.2. The Wapachewunak IR is on a relatively flat and low-lying area near Lac Ile-a-la-Crosse. The Ile-a-la-Crosse IR is an area of low relief on the east shore of Lac Ile-a-la-Crosse. The Beaver River valley is a prominent feature at the La Plonge IR near Beauval; the east side of the valley is characterized by a steep escarpment, with relatively level moraine plain at the top.

### 2.3.3 Drainage

All of the reserve areas in Region 3 are within the Churchill River basin which drains eastward to Hudson Bay (Figure 2.3). The Wapachewunak IR is located near the community of Patuanak and the main segment of the Churchill River system at the north end of Lac Ile-a-la-Crosse. The Ile-a-la-Crosse IR is also located on Lac Ile-a-la-Crosse, just north of the Beaver River inflow. The La Plonge IR is on the banks of the Beaver River, which flows northward into Lac Ile-a-la-Crosse.

### 2.3.4 Protected Areas

#### Parks and Reserves

Region 3 was screened for provincial and municipal parks, conservation areas, nature reserves and national wildlife areas using available data from the MOE and EC. Fort Black, a provincially protected area is located south of the Ile-a-la-Crosse IR (Figure 2.8). Lac La Plonge Recreation site is located approximately 1.6 km east of the La Plonge IR along Provincial road 165, and Little Amyot Lake Recreation site is located approximately 20 km from the La Plonge IR along Provincial road 165 and 155. There are no parks, wildlife areas, or conservation reserves within the English River First Nation reserve areas within Region 3; however, there is a Migratory Bird Concentration Site located south of Beauval approximately 7.5 km southeast of the La Plonge IR.

#### Heritage Sites

The results of the heritage resources database search indicate that 22 archaeological sites have been recorded near the three English River First Nation reserve areas in Region 3 (Figure 2.4; Table 2.3). Precontact artifact find and scatter sites are the most common (n=11); followed by artifact/feature combination (n=7); and multiple feature sites (n=1). Three heritage resources have insufficient information to be given a site type designation. According to the site database, known heritage resources were recorded between 1961 and 2002 as part of various research and assessment projects. The majority of the sites are located near the south end of Lac Ile-a-la-Crosse, which is located along the Churchill River system.

The presence of heritage sites in Region 3 would need to be further discussed with the community and Aboriginal peoples in the area, if the community remains interested in continuing with the site selection process.

**Table 2.3: Heritage Resources Recorded near the proposed Locations in Region 3**

| Site Type | Definition | No. of Sites |
|---|---|---|
| Artifact find | Archaeological sites consisting of 5 or fewer artifacts. An artifact is any object used or modified by people (e.g., projectile point, pottery sherds, lithic flakes). | 3 |
| Artifact scatter | Archaeological sites consisting of 6 or more artifacts. | 8 |
| Artifact/Feature combination | Archaeological sites consisting of both artifacts and features. | 7 |
| Multiple feature | Archaeological sites consisting of several features of a different kind. | 1 |
| Unknown | Insufficient information to classify. | 3 |
| | **Total** | **22** |

The Churchill River and its associated tributaries and lakes, were a significant waterway during both Precontact and Historic times. In addition to the Precontact archaeological sites, at least seven fur trade posts were located in Region 3. This includes early posts established by the Northwest and Hudson's Bay Company near the community of Ile-a-la-Crosse beginning in 1776, as well as posts near Fort Black established in the early 1800's. Later, Hudson's Bay Posts were built near Beauval and Patuanak in the 1920's.

# 3.0 GEOLOGY AND SEISMICITY

The thirteen reserves of the English River First Nation can be grouped into three distinct geological regions: the Athabasca Basin, the Canadian Shield, and the Western Canada Sedimentary Basin. The English River First Nation reserves, located within each geological region, are outlined in Table 1.1. The discussion of regional geology will provide a general overview of the three geological regions, while the local geology discussion will focus on geological conditions of each English River First Nation reserve and its periphery (referred to as "reserve area").

## 3.1 Regional Bedrock Geology

The English River First Nation reserve areas are located within or underlain by the Hearne Province of the Canadian Shield, as shown on Figure 3.1. The Hearne Province comprises the eastern portion of the Churchill Structural Province of the Precambrian Canadian Shield (SGS, 2003). The Precambrian rocks of the Hearne Province are overlain by sedimentary rocks of the Athabasca Group within the Athabasca Basin, and Phanerozoic sedimentary rocks within the Western Canada Sedimentary Basin. Rocks of the Canadian Shield continue southward, deepening beneath the sedimentary rocks of the Western Canada Sedimentary Basin and northward, outcropping again along the northern margin of the Athabasca Basin.

### Canadian Shield

The Canadian Shield is a collage of Archean cratons and accreted juvenile terranes and sedimentary basins of Proterozoic age. It was originally an area of very large mountains and intense volcanic activity, and was the first part of North America to be permanently elevated above sea level.

The Hearne Province is bounded to the west by the Rae Province along the Virgin River Shear Zone (Snowbird Tectonic Zone), and is bounded to the east by the Reindeer Zone along the Needle Falls and Parker Lake Shear Zone, as shown on Figure 3.1. These shear zones are oriented in a northeast-southwest direction, which is the predominant alignment of major structural features and lithologies within the Precambrian in Northern Saskatchewan. The Hearne Province consists, from west to east, of the Virgin River, Mudjatik, Wollaston and Peter Lake Domains, which are primarily distinguished by changes in structural style (SGS, 2003). The Hearne Province is generally composed of 2.7 to 1.8 billion year old high grade metamorphic Archean to Paleoproterozoic rocks, such as gneissic granitoid rocks, metasedimentary rocks and granite (SGS, 2003).

All of the English River First Nation reserve areas occurring within the Canadian Shield are located within the Mudjatik Domain of the Hearne Province, with the exception of the Elak Dase IR, which is located within the Wollaston Domain, as shown on Figure 3.2. The Mudjatik Domain is separated from the Virgin River Domain to the west by the Cable Bay Shear Zone (Card and Bosman, 2007), while the eastern boundary of the Mudjatik Domain with the Wollaston Domain is transitional and primarily marked by a change in structural style (SGS, 2003; Delaney, 1993; Yeo and Delaney, 2007). The Mudjatik Domain is characterized by a dome and basin fold pattern (Card et al., 2008), which distinguishes it from the Virgin River Domain to the west and the Wollaston Domain to the east. The dome and basin fold pattern is characterized by nearly upright, orthogonal fold sets that are elongated along a northeast trending axis (Card et al., 2008). The majority of the Mudjatik Domain consists of extensive granitic to granodioritic felsic gneiss with interspersed metasedimentary gneiss (Thomas and Slimmon, 1985). The metasedimentary rocks are dominated by psammopelitic to pelitic rocks and amphibolite that are unconformably deposited on top of the Archean felsic gneiss (Card and Bosman, 2007). The metasedimentary rocks range from Archean to Paleoproterozoic in age, and they may correlate to the basal groups of the Wollaston Supergroup (Card et al., 2008). The metasedimentary rocks occur in narrow, arc shaped bands throughout the Archean felsic gneiss, defining the dome and basin pattern (SGS, 2003).

The Wollaston Domain is characterized as a northeast trending, tightly folded belt of Archean granitoid rocks and derived orthogneiss and Archean to Paleoproterozoic metasedimentary rocks with minor metavolcanic rocks (SGS, 2003; Delaney, 1993). Metasedimentary rocks form the Wollaston Supergroup (as defined by Yeo and Delaney, 2007), which was deposited along the eastern edge of the Hearne Craton first in a rift/passive margin setting, and later in a foreland basin setting, during which most of the preserved rocks were deposited, due to destruction of the Manikewan Ocean between the Hearne and Superior Cratons. The predominance of metasedimentary gneisses of the Wollaston Supergroup in the north and central parts of the Wollaston Domain declines towards the south, where they become discontinuous in bands intercalated with Archean felsic (ortho) gneiss and lesser younger granitoid rocks. The Wollaston Domain is separated to the east from the Wathaman Batholith Domain of the Reindeer Zone by the Needle Falls Shear Zone, whereas the western boundary with the Mudjatik Domain is marked by a transition in structural style from a linear fold belt to dome-basin fold interference (SGS, 2003; Delaney, 1993; Yeo and Delaney, 2007). The contact with the Needle Falls Shear Zone is sharp and distinct, whereas the transition with the Mudjatik zone is generally inferred (Munday, 1978), based on the degree of deformation.

The Virgin River Domain is very similar in composition to the Mudjatik Domain, especially at the boundary of the two domains, which is marked by the Cable Bay Shear Zone (Card and Bosman, 2007). The Virgin River Domain is dominated by extensive granitic to granodioritic felsic gneiss. Towards the west, the felsic gneiss is replaced by a narrow belt of middle amphibolitic rocks called the Virgin Schist Group, which are mainly mafic and pelitic schists of probable volcanic origin (Card and Bosman, 2007). The absolute age of the Virgin Schist Group is unknown, but is younger than 2.3 billion years, and it has been suggested that these rocks are spatially related to the Virgin River Shear Zone (part of the Snowbird Tectonic Zone), which bounds the Virgin River Domain to the west (Card and Bosman, 2007).

Generally, the Virgin River, Mudjatik and Wollaston Domains are characterized by upper amphibolite to granulite facies conditions (Card and Bosman, 2007) and complex deformation. Four phases of ductile deformation have been identified within the Virgin River, Mudjatik and Wollaston Domains, although the second phase of deformation is not as strongly represented within the Wollaston Domain as compared to the Mudjatik Domain. The first phase defines the main regional foliation, which was followed by tight to isoclinal folding striking northwest in the second phase (Yeo and Delaney, 2007; Card and Bosman, 2007). The third phase comprises open to tight, northeast-trending folds. The fourth phase consists of a series of open, upright shears, northwest-trending folds and late sinistral north to northwest-trending brittle faults (SGS, 2003).

Geophysics is an important tool in mapping the major geologic structures in Northern Saskatchewan (Hajnal et al., 2005; White et al., 2005). Regional geophysical data available include airborne magnetic, gravity, airborne radiometric, audio magnetotelluric and deep seismic surveys conducted as part of Lithoprobe (Lewry et al., 1994). Residual total magnetic field, Bouguer gravity, and radiometric (equivalent uranium) survey data sets are contoured and presented on Figures 3.3 to 3.5, respectively for all three study regions.

The geophysical trends of the major Precambrian structures within Region 2 (i.e., Lloyd, Virgin River, Mudjatik, Wollaston and Wathaman Batholith Domains) can be traced to the south beneath Region 3, the Western Canada Sedimentary Basin (White et al., 2005), particularly the magnetic high of the Wollaston Domain (Figure 3.3), which is one of the most prominent magnetic features in the Canadian Shield. These geophysical trends are traceable to some degree to the north, beneath Region 1, the Athabasca Basin (Figure 3.3). These trends reflect the fact that the rocks of Region 2 are the oldest, forming the stable continental craton beneath the entire study area, which is then overlain by the younger rocks of Regions 1 and 3.

The variations in magnetic and radiometric responses (Figures 3.3 and 3.5) are largely due to variations in mineral composition in the rocks (White et al., 2005), while the variation in gravity response (Figure 3.4) is in part a result of the density differences between rock types, but is also in part related to variations in deeper structures, including crustal roots (White et al., 2005).

Coupled geophysical modelling by White et al., (2005) along a west-east geophysical transect, located approximately 50 km south of the boundary between Region 2 and Region 3, estimates the rocks of the Mudjatik Domain to range in thickness from approximately 3 km to 8 km, and the rocks of the Wollaston Domain to range in thickness from approximately 6 km to 10 km. These estimates provide some insight with respect to the approximate thickness and continuity of major rock units proximal to the English River First Nation reserve areas situated along the southern margin of Region 2 and the northern margin of Region 3.

## Athabasca Basin

The Athabasca Basin is an elliptical bowl-shaped basin that covers approximately 100,000 $km^2$ in Northern Saskatchewan and Northwestern Alberta (SGS, 2003). Although the thicknesses of rocks within the Athabasca Basin diminish at the edges of the basin, they thicken rapidly towards the centre where rocks of the Athabasca Group are approximately 1,500 m thick at the deepest known point within the Athabasca Basin. However, many of the original rock materials have been eroded and it is estimated that the original thickness of the sediments deposited within the Athabasca Basin was 3,800 m (Ramaekers et al., 2007). The Athabasca Basin consists of sedimentary rocks of the Athabasca Group, which are primarily composed of quartz arenite, although minor conglomerate, mudstone and dolomite components are also present within the basin. Rocks of the Athabasca Group unconformably overlie Precambrian basement, in which the remnants of the paleoweathering profile can be up to 50 m thick. The Athabasca Basin is characterized by a series of sub-basins, which formed through a series of subsidence, uplift and erosion, involving movement along faults and shears within the basement rock (Ramaekers, 1990; Ramaekers et al., 2007; Jefferson et al., 2007). Sedimentary rocks within the Athabasca Basin are almost undeformed, with the exception of faults, local folding due to thrusting, soft sediment deformation, and the Carswell Structure (SGS, 2003).

Sedimentation within the Athabasca Basin post-dates the Trans-Hudson Orogeny (SGS, 2003) and occurred between approximately 1.76 billion years and 1.5 billion years before present (Ramaekers et al., 2007). Sedimentary rocks consist of four unconformity bounded quartzose fluvial sequences, each deposited within a distinct subbasin within the Athabasca Basin, and with different grain size distributions and paleocurrent directions. In ascending order (from oldest to youngest), these sequences include the Fair Point Formation, which infilled the Jackfish Subbasin, the Read, Smart and Manitou Falls Formations, which infilled the Cree Subbasin; the Lazenby Lake and Wolverine Point Formations, which infilled the Mirror Subbasin; and the Locker Lake, Otherside, Douglas, and Carswell Formations, which infilled a broader basinal area in the general areas of the Jackfish and Mirror Subbasins (Ramaekers et al., 2007). The English River First Nation reserve areas that occur within the Athabasca Basin are located along the southern edge (Figure 3.2), within the Cree Subbasin.

## Western Canada Sedimentary Basin

The Western Canada Sedimentary Basin is a north thinning sedimentary basin which forms part of an extensive Phanerozoic sedimentary basin that covers much of the Canadian and American prairies and stretches from the Gulf of Mexico to the Arctic Ocean. Sedimentary rocks within the Western Canada Sedimentary Basin range in age from Cambrian to Neogene, and unconformably overlie the Canadian Shield. In Saskatchewan, the Western Canada Sedimentary Basin dips to the southwest at approximately 4 m/km, has a maximum thickness of approximately 3,200 m, which occurs in the in southeastern portion of the province (SGS, 2003) and a

minimum thickness along its northern contact with the Canadian Shield. The Western Canada Sedimentary Basin is comprised of interlayered marine and terrestrial sequences that resulted from sedimentation in marine transgressive and regressive cycles.

Two major tectonic phases have been recognized in the deposition of the Western Canada Sedimentary Basin. Generally, the initial phase reflects a passive continental margin which consists of basal clastic units and thick sequences of carbonates and evaporites (SGS, 2003). The second phase reflects a convergent margin phase resulting in a foreland basin consisting of thick clastic sedimentary rocks associated with the Cordilleran Mountain Belt (SGS, 2003). Stratigraphy within the Western Canada Sedimentary Basin was also strongly influenced by the downwarping, reactivation of basement structures, and sea level changes.

The lithostratigraphy of the Western Canada Sedimentary Basin can be simplified into three main parts. The lowermost section is composed of a Paleozoic basal clastic succession of sandstone, conglomerate and shale. The second section consists of interlayered Paleozoic and minor Mesozoic age carbonates and evaporites. The third section is represented by a series of Mesozoic sandstones and shales, overlain by Cenozoic sandstone, shale units, and conglomeratic material which are generally limited to the southern portion of the basin. The English River First Nation reserve areas that occur within the Western Canada Sedimentary Basin are located near the northern margin, as shown on Figure 3.2.

## 3.2 Local Bedrock Geology

The discussion of the local bedrock geology for each of the English River First Nation reserve areas has been grouped based on the general geological region where each of the reserve areas is situated (Table 1.1).

### 3.2.1 Region 1 – Athabasca Basin: Cable Cree Lake IR, Cree Lake IR, Barkwell Bay IR

The English River First Nation reserve areas in Region 1 are located along the southern margin of the Precambrian Athabasca Basin, with the Cable Cree Lake IR and Cree Lake IR situated near the boundary of the basin with the Precambrian Canadian Shield. The geology in the Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR areas consists of sedimentary rocks of the Manitou Falls Formation within the Cree Subbasin that overlie the crystalline rocks of the Canadian Shield (Figure 3.6).

#### Lithologies

The Manitou Falls Formation is an upward fining sequence of quartz-pebble conglomerate, quartz arenite and fine sandstone to mudstone (Ramaekers et al., 2007). It consists of five separate members, including (in ascending order): Bird, Raibl, Warnes, Collins and Dunlop. Historically, the Raibl and Warnes Members were referred to as Manitou Falls “a” (Ramaekers et al., 2007). These members are not distinguished on Figure 3.6, primarily due to scale.

The Manitou Falls Formation comprises the majority of the rocks within the Cree Subbasin, and about half of the total volume of the Athabasca Group. In the Cree Lake area, where Cable Cree Lake IR, Cree Lake IR, and Barkwell Bay IR are located, the Manitou Falls Formation unconformably overlies Archean gneissic basement rock of the Canadian Shield (Ramaekers et al., 2007).

The Manitou Falls Formation is approximately 1.72 billion to 1.64 billion years in age. In the area of the Barkwell Bay IR, the thickness of the Manitou Falls Formation may be as great as 800 m (interpreted from Ramaekers et al., 2007). Near the Cable Cree Lake IR and the Cree Lake IR, the Manitou Falls Formation may become

thinner due to its proximity to the edge of the Athabasca Basin, however, it is estimated that the thickness could range between 100 to 200 m (interpreted from Saskatchewan Energy and Resources, 2010).

The basement rocks underlying the sedimentary rocks of the Athabasca Group in the Cree Lake area are expected to be continuations of the rocks of the Mudjatik and Virgin River Domains, including high grade granitoid rocks, monzogranite and leucotonalite (Card and Bosman, 2007).

### Metamorphism and Deformation

Paleoweathering and hydrothermal alteration has formed a regolith underneath the unconformity between the crystalline rocks of the Canadian Shield and the sedimentary rocks of the Athabasca Group. In addition to this, two types of regional scale alteration have occurred within the sedimentary rocks of the Athabasca Group. The first is cementation of the Athabasca Group sediments that caused them to become sandstones. This alteration is characterized by a quartz overgrowth that includes hematite-coated detrital quartz grains (Jefferson et al., 2007). Following this, a diagenetic sequence occurred that altered the kaolinitic matrix within the sedimentary rocks of the Athabasca Group to a clay mixture dominated by dickite (Jefferson et al., 2007). The exception to this is an area located approximately 40 km to the east of the western edge of Cree Lake, where clay alteration to illite occurred. This illite altered area starts from the Key Lake region and extends to the northeast. The sedimentary rocks within the Athabasca Group are generally unmetamorphosed (SGS, 2003).

Sedimentary rocks of the Athabasca Group are largely undeformed. Faulting and folding have been found only at local scale, and most folding within the Athabasca Group rocks is thought to be due to soft sediment deformation instead of tectonic events. The Athabasca Basin was formed through a series of subsidence and uplift events. These were created by block movements along fault zones rooted in older shear zones within the Canadian Shield rocks, which created sedimentary subbasins between fault systems (Ramaekers et al., 2007). This faulting occurs throughout the sedimentary rocks of the Athabasca Group, and it offsets generally subhorizontal formations along the fault traces. Thrusting along these fault systems induced local scale folding within the sedimentary rocks of the Athabasca Group. Faulting within the Athabasca Group is generally nearly vertical, trending northeast-southwest, northwest-southeast, north-south and east-west. The displacements along these faults vary, but based on cross-sections presented in Ramaekers et al. (2007), vertical movement along major faults is estimated to range from approximately 20 m to 100 m. Inferred fault traces shown on Figure 3.6 are based on the Geological Atlas of Saskatchewan data set. It is unknown if these faults occur within the underlying Canadian Shield rocks or if they continue through the total thickness of the rocks of the Athabasca Group. The Cable Bay Shear Zone has been interpreted, based on a distinct aeromagnetic low, to continue through the Athabasca Basin along the northwestern shoreline of Cree Lake, just east of the Cable Cree Lake IR and the Cree Lake IR. It is unknown to what extent this shear zone projects through the sedimentary rocks of the Athabasca Group.

In summary, English River First Nation reserve areas of Region 1 rest on a thick sequence of 1.64 billion year old undeformed sandstone, conglomerate and mudstone, with thicknesses raging from 100 m to greater than 800 m.

## 3.2.2 Region 2 – Canadian Shield: Haultain Lake IR, Porter Lake Island IR, Flatstone Lake IR, Dipper Rapids IR, Primeau Lake IR, Knee Lake IR, Elak Dase IR

The English River First Nation reserve areas that occur within the Precambrian Canadian Shield are primarily within the Mudjatik Domain, with the exception of the Elak Dase IR, which is situated within the Wollaston Domain (Figure 3.2). The reserve areas of Region 2 have been further categorized and evaluated based on

three areas: i) Haultain Lake area (Figure 3.7); (ii) Flatstone and Porter Lakes areas (Figure 3.8); and (iii) Dipper, Primeau and Knee Lakes areas (Figure 3.9). The English River First Nation reserve areas within each area and corresponding lithologies in each reserve area are summarized in Table 3.1. The rock types are discussed in more detail below.

**Table 3.1: Summary of Rock Types near English River First Nation Reserve Areas Located within the Canadian Shield (Region 2)**

| Geographical Area | English River First Nation Reserve Area | Rock Types Present |
|---|---|---|
| Haultain Lake Area (Figure 3.7) | Haultain Lake IR | Felsic Gneiss |
| Flatstone and Porter Lakes Area (Figure 3.8) | Flatstone Lake IR | Felsic Gneiss |
| | Porter Lake Island IR | Felsic Gneiss, minor Metasedimentary Rocks (Pelitic/Psammopelitic Gneiss) and Amphibolite |
| Dipper, Primeau and Knee Lakes Area (Figure 3.9) | Dipper Rapids IR | Felsic Gneiss |
| | Primeau Lake IR | Alaskite (alkali feldspar granite), minor Felsic Gneiss and Metasedimentary Rocks (Pelitic/Psammopelitic Gneiss) |
| | Knee Lake IR | Felsic Gneiss and Metasedimentary Rocks (Pelitic/Psammopelitic Gneiss) |
| | Elak Dase IR | Felsic Gneiss and Metasedimentary Rocks (Pelitic/Psammopelitic Gneiss, and minor Psammitic to Meta-arkosic Gneiss) |

## Lithologies

The main rock type found within the Canadian Shield at the English River First Nation reserve areas is a felsic gneiss unit, which is in some places overlain by arc shaped bands of metasedimentary rock (Munday, 1977; Pearson, 1977). The metasedimentary rocks are more predominant in the Wollaston Domain than in the Mudjatik Domain, and comprise psammitic to meta-arkosic gneiss, pelitic to psammopelitic gneiss and calc-silicate rocks of the Wollaston Supergroup.

### *Archean Felsic Gneiss*

Felsic gneiss of the Mudjatik Domain is the primary rock type found at the Haultain Lake IR (Figure 3.7), Flatstone Lake IR and Porter Lake Island IR (Figure 3.8), Dipper Rapids IR, and Knee Lake IR (Figure 3.9). Felsic gneiss of the Mudjatik Domain can also be found in the area of Primeau Lake (Figure 3.9), although its presence in this area is limited. The felsic gneiss is of Archean age and is similar in composition within both the Mudjatik and Wollaston Domains. Gneissic rock types within the Mudjatik Domain include granite gneiss, hypersthene-bearing granitic gneiss, amphibolite (Pearson, 1977; Munday, 1977), and charnockitic rock (Scott, 1977). Although several assemblages have been identified within the felsic gneiss unit, they are difficult to differentiate during regional mapping (Card, pers. comm., 2010), and therefore are shown as a single felsic

gneiss unit on the figures. This felsic gneiss of the Mudjatik Domain has an approximate crystallization age of 3.0 billion years (Orrell et al., 1999).

Felsic gneiss of the Wollaston Domain is interpreted to be formed by the metamorphism of granitic plutonic rocks and lesser amounts of sedimentary rocks. They are Late Archean in age and range between 2.65 billion years to 2.5 billion years in age (Yeo and Delaney, 2007). These rocks are laterally widespread and underlie metasedimentary rocks of the Wollaston Supergroup. Five assemblages of Archean felsic gneiss within the Wollaston Domain can be identified, although these assemblages are difficult to differentiate (Card, pers. comm., 2010), and therefore are shown as a single felsic gneiss unit on the figures. Gneissic rocks include quartz monzocharnockite, a monzonite-granite-granodiorite suite, a granodiorite-tonalite suite, amphibolite, and a heterogeneous assemblage of intrusive and metasedimentary rocks (Yeo and Delaney, 2007). In the area of the Elak Dase IR, metasedimentary rocks of the Wollaston Supergroup are predominant, except to the southwest where felsic gneiss of the Wollaston Domain can be found in a limited extent (Figure 3.9).

Felsic gneiss within both the Mudjatik and Wollaston Domains can be described as fine to coarse grained, and mostly granitic to granodioritic in composition (Thomas and Slimmon, 1985). Within the Mudjatik Domain, the felsic gneiss is foliated to banded, while in the Wollaston Domain, the felsic gneiss is described as equigranular and massive to well foliated (Thomas and Slimmon, 1985). Mineral associations can include biotite, horneblende, hypersthene, diopside, garnet, and magnetite. Although the exact thickness of these rocks in Region 2 is unknown, they are expected to be 3 km to 8 km thick in the reserve areas located in the Mudjatik Domain and 6 km to 10 km in the reserve area located in the Wollaston Domain, as interpreted from regional geophysical studies (White et al., 2005; Hajnal et al., 2005).

### *Metasedimentary and Metavolcanic Rocks and their Derivatives*

Metasedimentary rocks are formed by the metamorphism of precursor sedimentary rocks. While the metasedimentary rocks of the Mudjatik and Wollaston Domains are similar in composition, the metasedimentary rocks of the Mudjatik Domain may only be related to the basal units of the Wollaston Supergroup (Card et al., 2008). The rocks occurring within the Mudjatik Domain were deposited unconformably on top of felsic gneiss rocks, but their origin and exact age are unknown (Card and Bosman, 2007), although it has been estimated that they are of Archean to Paleoproterozoic age (Munday, 1977). Supracrustal rocks of the Mudjatik Domain are metasedimentary and metavolcanic in nature, and are composed of pelitic, psammopelitic and psammitic gneisses, calc-silicate rocks, marble, amphibolites (Munday, 1977; Pearson, 1977). Derivative rocks, formed by local to extensive melting of either of the metasedimentary or metavolcanic rocks, such as layered felsic gneiss, alaskite (alkali feldspar granite) and granitic pegmatites, also cover portions of the Mudjatik Domain. Metasedimentary and metavolcanic rocks of the Mudjatik Domain are found in the area of the Primeau Lake IR and Knee Lake IR (Figure 3.9). In the area of the Knee Lake IR, metasedimentary pelitic to psammopelitic gneiss occurs as a thin band on the northeast corner of the reserve (Figure 3.9). In the area of Primeau Lake IR (Figure 3.9), the main rock type consists of alaskite, formed from the felsic gneiss and intrusive rocks around 1.83 billion years ago (Scott, 1977).

Metasedimentary and metavolcanic rocks of the Wollaston Domain consist of the Wollaston Supergroup, which overlie Archean felsic gneiss, and is seen on geologic maps as linear northeast-southwest trending bands (Figure 3.2). These 2.1 to 1.8 billion year old rocks are characterized by four unconformity-bounded Paleoproterozoic siliciclastic metasedimentary rock formations (Yeo and Delaney, 2007) that were deposited in rift, passive margin and foreland basin settings. These sequences consist mainly of arkose, quartzite, pelite, orthoquartzite, psammopelite, calc-silicate rocks, and psammite (Yeo and Delaney, 2007). Mainly pelitic to

psammopelitic rocks of the Wollaston Supergroup comprise the major rock type found in the area of the Elak Dase IR (Figure 3.9).

Pelitic to psammopelitic gneiss found in the English River First Nation reserve areas in Region 2, shown on Figures 3.7 to 3.9, are fine to coarse grained, generally well foliated to gneissic in texture, commonly porphyroblastic and biotite rich. These gneisses can include cordierite, garnet, silimanite, graphite and magnetite (Thomas and Slimmon, 1985). Metasedimentary psammitic to meta-arkosic gneiss occurring in the area of the Elak Dase IR (Figure 3.9) consist of fine to medium grained, massive to foliated rocks, which can be locally colour banded. This unit can include quartz, feldspar, biotite, muscovite, sillimanite, cordierite, garnet, diopside, epidote, andalusite, interbanded calc-silicates, and pelitic gneiss (Thomas and Slimmon, 1985). These rocks occur in sparse pods less than 1 $km^2$ to the north and south of Elak Dase IR (Figure 3.9).

The alaskite adjacent to the Primeau Lake IR (Figure 3.9) is pink, fine to medium grained, and massive to foliated in texture. It can include biotite, hornblende, and garnet (Thomas and Slimmon, 1985; Scott, 1977). It can also have inclusions of felsic gneiss, pelitic gneiss and amphibolites (Thomas and Slimmon, 1985), and the contact of the alaskite with the surrounding felsic gneiss is generally sharp (Scott, 1977). The alaskite is limited to the Primeau Lake region, but in this area is extensive, with a width of approximately 8 km, and a north-south dimension of approximately 25 km.

There is no information regarding the thickness of metasedimentary rocks within the English River First Nation reserve areas within Region 2 but the combined thickness of the felsic gneiss and metasedimentary gneiss is expected to be 3 to 8 km thick in the Mudjadik Domain (White et al., 2005; Hajnal et al., 2005). Metasedimentary rocks within the Mudjatik and Wollaston Domains generally occur in thin, longitudinal bands that range from a few metres to approximately 3 km in width (Pearson, 1977).

## Metamorphism and Deformation

All Canadian Shield rocks near the English River First Nation reserve areas show evidence of metamorphism, regardless of domain. Metamorphism appears to have reached upper-amphibolite to lower-granulite facies conditions (Yeo and Delaney, 2007). Hypersthene is common in mafic rocks and felsic gneiss. Corderite, sillimanite, biotite, K-feldspar, magnetite and garnet are common in pelitic facies (Munday, 1978; Yeo and Delaney, 2007). Calc-silicate rocks contain hornblende, diopside, tremolite/actinolite, biotite, and calcite or dolomite (Yeo and Delaney, 2007).

Across all domains in Region 2, several deformational events occurred. Although the age of these deformations is hard to determine, within the Mudjatik and Wollaston Domains, four phases of deformation can be identified that post-date the 2.1 to 1.8 billion year old Wollaston Supergroup rocks (Yeo and Delaney, 2007). An early isoclinal deformation (D1) formed a prominent mineral foliation (Yeo and Delaney, 2007) characterized by rootless isoclinal hinges, metamorphic fabric parallel to the compositional layering and rare boudins. A second deformation (D2) is prominent within the Mudjatik Domain, but not as evident in the Wollaston Domain (Delaney, 1993). D2 is characterized by upright folds (Yeo and Delaney, 2007). A third deformational event (D3) reoriented the D1 foliation into a series of doubly plunging but generally northeasterly trending structures. The combination of the D2 and D3 events give the Mudjatik Domain its dome and basin structural style (Card and Bosman, 2007). The fourth deformation event (D4) consisted of gentle northwest striking folds (Card and Bosman, 2007).

Northeast trending shear zones are common. These shear zones developed after the D3 event, evidenced by displacement along D3 fold limbs, but before the D4 event. An example of these shear zones is the Cable Bay

Shear Zone (Figure 3.2) (Card and Bosman, 2007). In addition to these shear zones, several northwest-southeast trending faults have been inferred from reconnaissance mapping and geophysical surveys (Figure 3.2). Information regarding the age and description of these features is not readily available.

The Cable Bay Shear Zone designates the boundary of the Mudjatik Domain with the Virgin River Domain to the west (Figure 3.2). It has a width of 200 m to 300 m (Gilboy, 1985), and a length of more than 200 km, extending from just north of the Western Canada Sedimentary Basin to the middle of the eastern portion of the Athabasca Basin (Card and Bosman, 2007), and is represented by a significant aeromagnetic lineament. The Cable Bay Shear Zone does not occur within the English River First Nation reserve areas in Region 2, but it is interpreted to continue under the Athabasca Basin in the Cree Lake area of Region 1 (Figure 3.6). The Cable Bay Shear Zone does not appear to be a major lithologic boundary (Card and Bosman, 2007).

In summary, the Haultain Lake, Flatstone Lake, Porter Lake Island and Dipper Rapids reserve areas lie on 2.65 to 2.5 billion year old felsic gneiss that was formed by metamorphism of precursor plutonic rocks and is mostly granitic in composition. The Primeau Lake reserve area lies on alaskite which is mostly granitic in composition. The Knee Lake and Elak Dase reserve areas contain both felsic gneiss and metasedimentary rocks.

### 3.2.3 Region 3 – Western Canada Sedimentary Basin: Wapachewunak IR, Ile-a-la-Crosse IR, La Plonge IR

Three English River First Nation reserve areas occur within the Western Canada Sedimentary Basin. These include the Wapachewunak IR, Ile-a-la-Crosse IR, and La Plonge IR, as shown on Figure 3.10. The Western Canada Sedimentary Basin consists of Phanerozoic sedimentary rock ranging in age from Cambrian to Lower Cretaceous.

#### Lithologies

The English River First Nation reserve areas within the Western Canada Sedimentary Basin occur near the contact of Phanerozoic rocks with Canadian Shield rocks. Within this area, three bedrock lithostratigraphic units, ranging from Cambrian to Lower Cretaceous in age, are known to occur, and outcrop at several locations to the east along the Phanerozoic-Precambrian contact. These units are generally mappable across the entire Western Canada Sedimentary Basin within Saskatchewan. A conceptual lithostratigraphic column of the interpreted Phanerozoic rock sequences in the area of the English River First Nation reserve areas in Region 3 is developed from Fuzesy (1977), and is shown in Table 3.2. The Western Canada Sedimentary Basin is underlain by rocks of the Canadian Shield. Although no information regarding these crystalline rocks is available for this area, they would be expected to be similar to those found to the north in Region 2.

**Table 3.2: Conceptual Lithostratigraphic Column of the Phanerozoic Deposits**

| Phanerozoic Deposits | Age[(a)] | Approximate Regional Thickness[(b)] (m) |
|---|---|---|
| Morainal Plain | Quaternary | 48 |
| Mannville Group | Lower Cretaceous | 47 |
| Elk Point Group | Middle to Lower Devonian | 43 |
| Deadwood Formation | Upper Cambrian - Lower Ordovician | 23 |

Wavy line indicates unconformable contact

(a) From SIR, 1999; (b) From Fuzesy, 1977

In the area of the Wapachewunak IR, Ile-a-la-Crosse IR and La Plonge IR, the Mannville Group is mapped at the top of the Phanerozoic sequence, and it has been assumed that it is underlain by the Elk Point Group and, in places, the Deadwood Formation. Limited information exists regarding the depth to the individual stratigraphic units in these English River First Nation reserve areas in Region 3. No specific borehole data was found in the area of the Ile-a-la-Crosse IR, but depths have been extrapolated based on the borehole information present to the north and south of the site. Based on the borehole information from the Petroleum Technology Research Centre (PTRC) (2010), Saskatchewan Watershed Authority (SWA) Water Well Record (WWR) database and the regional data presented by Fuzesy (1977), the thickness of the Phanerozoic rocks above the Canadian Shield ranges from approximately 340 m near the La Plonge IR to approximately 150 m near the Wapachewunak IR. The Phanerozoic material thins to the north near the margin of the Canadian Shield.

The Deadwood Formation is Late Cambrian to Early Ordovician in age (SIR, 1999) and consists of granular sandstones, quartz arenites, siltstone-shales, argillaceous limestones and shales, and flat-pebble conglomerates (Greggs and Hein, 2000). Within the southern portion of the Western Canada Sedimentary Basin, the Deadwood Formation can reach thicknesses of 500 m, with localized thinning and thickening reflective of the Canadian Shield topography or local uplift prior to deposition. This is reflected by the presence of the Deadwood Formation near the Wapachewunak IR, but its absence near the La Plonge IR (PTRC, 2010).

The Middle Devonian (SIR, 1999) Elk Point Group consists of Upper and Lower Members of the Meadow Lake Formation, as well as the Winnipegosis Formation in the English River First Nation reserve areas near the northern margin of the Western Canada Sedimentary Basin. In the area of the La Plonge IR, the Ashern Formation is also present between the Upper Member of the Meadow Lake Formation and the Winnipegosis Formation. In Southern Saskatchewan, the Elk Point Group also includes the Prairie Evaporite Formation (SIR, 1999). The Lower Member of the Meadow Lake Formation consists of light grey to brown, commonly argillaceous and silty dolomite with local interbedded mudstone, sandstone and limestone. The Upper Member of the Meadow Lake Formation consists of a lower white to grey, laminated limestone with interbedded dolomite and mudstone, a middle argillaceous dolomite with minor mudstone and dolomitic limestone, and an upper mudstone that is mottled, dolomitic and pyritic. This upper portion can contain quartz, anhydrite, gypsum and plagioclase (Thomas and Slimmon, 1985). The Ashern Formation is a reddish brown to greenish grey argillaceous dolomite to dolomitic shale (SIR, 1999). The Winnipegosis Formation is mainly dolomite and limestone. The lower part of this formation consists of mottled, highly argillaceous, nodular carbonate and calcareous shale, whereas the upper part of this formation consists of laminated and massive carbonate (Thomas and Slimmon, 1985).

The Lower Cretaceous Mannville Group consists of grey to brown, variably argillaceous and carbonaceous quartzose sands and poorly consolidated sandstones. These rocks can be locally interbedded with mudstone and lignite (Thomas and Slimmon, 1985). In Southern Saskatchewan, the Mannville Group consists of the Pense and Cantuar Formations (SIR, 1999), however, these are undifferentiated along the northern margin of the Western Canada Sedimentary Basin.

## Metamorphism and Deformation

Within the Western Canada Sedimentary Basin, there are no known deformational features present in the English River First Nation reserve areas.

In summary, the Wapachewunak, Ile-a-la-Crosse, and La Plonge reserve areas rest on an undeformed, nearly flat sedimentary rock sequence that is predominantly sandstone and carbonate in composition. Although the exact thickness of this sedimentary rock sequence is unknown, it is estimated to be up to 340 m.

## 3.3 Quaternary Geology

Figure 3.11 illustrates the Quaternary geology of the English River First Nation reserve areas. Regionally, the main Quaternary deposits include morainal plains, and glaciofluvial plains, with sparse occurrences of glaciolacustrine plains. Areas dominated by rock outcrop are present to the north of Primeau Lake and marshy organic areas also occur throughout low lying areas in the region. Morainal deposits were formed through lodgement and ablation processes, and vary from flat to hummocky. Glaciofluvial plains mainly consist of outwash plains that were incised through the morainal deposits as the glacier receded and meltwaters drained. Both types of glacial deposits are primarily sandy, with varying amounts of silt and clay fractions (Schreiner, 1984a). The descriptions of the Quaternary deposits are based on surface mapping, and little to no information is available on the variation of the deposit types and compositions at depth.

The regional Quaternary geology originates from the Wisconsinan glaciation. Most of the hard Canadian Shield rocks were resistant to glacial erosion. Glacial evidence includes scouring, roche moutonnées, drumlinoids, wind flutings and striae (Schreiner, 1984a; Gilboy, 1985). Rugged local relief was enhanced as glaciers eroded low lying areas and polished resistant bedrock knobs (Schreiner, 1984a). Sandstone deposits from the Athabasca Group were extensively eroded by glaciations.

In the area of Cable Cree Lake IR, Cree Lake IR, and Barkwell Bay IR within the Athabasca Basin region, glaciofluvial and morainal deposits comprise the Quaternary deposits. Glaciofluvial deposits in this area consist of well sorted sand with minor silt, to matrix supported gravel to gravel and boulders (Campbell, 2007), and were primarily deposited in eskers, kames, ice-walled channels and outwash plains. Channel deposits within the Key Lake area, approximately 40 km to the southeast of Barkwell Bay IR are approximately 60 m deep, and cover areas approximately 1 km wide by several kilometres long (Campbell, 2007). Morainal deposits are primarily composed of till, which varies from very sandy to silty sand composition. Thickness of the Quaternary deposits within the Athabasca Basin can range from 0 to 100 m. While no specific information on the Quaternary thicknesses are available for Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR, Quaternary thicknesses generally increase from east to west, and 90 m of glacial cover was reported in the Key Lake area, approximately 40 km to the southeast (Campbell, 2007). The main glacial features present, predominantly to the north of Cree Lake, include drumlins and eskers.

Thickness of the Quaternary strata over the Canadian Shield is variable and is generally thicker down ice (southwest) of the Athabasca Basin. Landforms can vary from veneer to drumlinoid (Schreiner, 1984a). Thicknesses for the Quaternary geology in the areas of the Haultain Lake IR, Flatstone IR, Porter Lake Island IR, Dipper Rapids IR, Primeau Lake IR, Knee Lake IR and Elak Dase IR are unknown. In the area of Haultain Lake IR, the main Quaternary deposits are glaciofluvial and morainal. Quaternary deposits in the area of Flatstone IR, and Porter Lake Island IR are morainal in nature. In the area of Dipper Rapids IR, Quaternary deposits consist of ridged moraine and morainal plains, with minor glaciofluvial sediments, and rock outcrop along the northeast shore of Dipper Lake. The north side of the Primeau IR is adjacent to bedrock outcrop, while ridged moraine and morainal plain occur adjacent to the west, south and east sides. The Knee Lake IR is located within ridged moraine and morainal plain deposits. Rock outcrops in the area southeast of the Elak Dase IR, while glaciofluvial and morainal deposits occur to the south, west and north, respectively.

Quaternary materials cover the entire English River First Nation reserve areas within the Western Canada Sedimentary Basin. The glacial cover was deposited in mainly thick till plains on top of the Phanerozoic rocks. This till becomes less sandy in composition than the till found to the north over the Canadian Shield rocks (Schreiner, 1984a). This change in composition is due to the changing bedrock composition in the Western Canada Sedimentary Basin and reflects the sandstone, siltstone, mudstone, limestone and dolomite that make

up the Phanerozoic material. The thickness of the Quaternary deposits in the areas of Wapachewunak IR, Ile-a-la-Crosse IR, and La Plonge IR is unknown, although regionally along the northern margin of the Western Canada Sedimentary Basin the Quaternary thickness averages 48 m, as shown in Table 3.2 (Fuzesy, 1977). In the area of the Wapachewunak IR, the major Quaternary deposits consist of glaciofluvial plain to the west and east, and hummocky moraine to the south. Glaciolacusterine deposits are present to a limited extent to the north. North-south trending eskers are also found to the north of Wapachewunak IR. In the area of the Ile-a-la-Crosse IR, morainal plain deposits are present. Near the La Plonge IR, morainal plain deposits are present to the north and east, hummocky moraine and eolian deposits are found to the west, while organic materials are present to the west and south.

In summary, all English River First Nation reserve areas are covered by Quaternary deposits. While there is no information on the thickness of Quaternary deposits in each reserve area, there is some limited thickness information on a regional basis. In the Athabasca Basin, the regional thickness of Quaternary deposits ranges from 0 m to 100 m. In the Canadian Shield, regional thickness of Quaternary deposits is unknown. In the Western Canada Sedimentary Basin, regional thicknesses of Quaternary deposits range from approximately 20 m to 55 m and averages approximately 48 m (Fuzesy, 1977).

## 3.4 Neotectonic Activity

Neotectonics refers to recent stresses and strains in the earth's crust, some of which are still occurring.

The most significant neotectonic events within the thirteen English River First Nation reserve areas are numerous glacial cycles during the last million years (Shackleton et al., 1990; Peltier, 2002). During the last glaciation (Wisconsinan), most of Saskatchewan was covered by the Laurentide ice sheet that flowed southwest from Hudson Bay. The thickness of the Laurentide ice sheet across Saskatchewan is unknown, although it likely thinned to the southwest at the edges of the ice flow. The thickness of ice that covered the English River First Nation reserve areas is unknown.

The area where the English River First Nation reserve areas are located has been ice free for approximately 8,200 years (Campbell, 2007), and since the regression of the Laurentide ice sheet, isostatic rebound has been occurring. The amount of depression of the earth's crust in these areas, and the rate of rebound are unknown due to lack of data from the continental interior, but generally both are thought to diminish with distance from Hudson Bay (Lambert et al., 1998). Crustal uplift models suggest that the rate of rebound across the Prairie Provinces may be as much as 5 mm/year (Lambert et al., 1998). As a result of the glacial unloading, horizontal stresses are created locally in shallow bedrock. Natural stress release features include elongated compressional ridges or pop-ups such as those described in White et al. (1973) and McFall (1993).

Based on readily available information, no neotectonic structural features are known to occur within the English River First Nation reserve areas, although the same stress history and glacial unloading that occurs throughout Saskatchewan also applies to these areas.

## 3.5 Seismicity

Saskatchewan is one of the most seismically stable regions in North America (NRC, 2010). Historically, very few earthquakes of magnitude greater than 3 on the Richter scale have been recorded within Saskatchewan and none in the English River First Nation reserve areas, as shown on Figure 3.12. The largest earthquake ever recorded in Saskatchewan occurred in 1909 in the southern portion of the province near the USA border, and measured a magnitude of 5.5 (NRC, 2010).

Generally, a significant portion of the seismicity measured in Saskatchewan is due to mining activities near Wollaston Lake, Esterhazy, and Saskatoon (Gendzwill and Unrau, 1996). Of the 43 seismic events with a magnitude greater than 1.8 in the period between 1985 and 2008 in Saskatchewan, 30 of those are identified as anthropogenic (man-made). The remaining 13 have been documented by Natural Resources Canada as natural earthquakes (NRC, 2010). A query of the Geological Survey of Canada's Nation Earthquake Database found no earthquakes in the areas where the thirteen English River First Nation reserves are located for their period of active monitoring, 1985 through present.

In summary, the available literature and recorded seismic events indicate that Saskatchewan is located within an area of very low seismicity. Specifically, there were no earthquakes recorded near the English River First Nation reserve areas from 1985 through 2010 and no evidence of historical earthquakes prior 1985 from available sources.

# 4.0 HYDROGEOLOGY

## 4.1 Region 1 – Athabasca Basin: Cable Cree Lake IR, Cree Lake IR, Barkwell Bay IR

The Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR have no population registered with Statistics Canada (2010). There is no record of groundwater use in the area. The Saskatchewan Watershed Authority Water Well Records database (SWA, 2009) contained eight water well records approximately 50 km to the southeast of the Barkwell Bay IR. All of these records date back to year 1986 and indicate Key Lake Mining as their owner. The purpose of these wells is listed as withdrawal; there is no depth to groundwater or well yield information recorded in the database. The thickness of the sand overburden recorded in these wells ranges from 0 m to approximately 20 m and the underlying sandstone thickness is recorded as 68 m to 84 m.

### 4.1.1 Quaternary Aquifers

There is limited information regarding the Quaternary aquifers in the Athabasca Basin (Region 1) in the English River First Nation reserve areas. The surface geology of the region is characterized by unconsolidated glacial and periglacial Quaternary-aged deposits of varying thickness, as outlined in Section 3.5. These deposits are composed primarily of morainal and glaciofluvial sediments, including eskers. The glacial overburden is underlain by sedimentary rocks of the Athabasca Group. At the Cable Cree Lake IR, Cree Lake IR, and Barkwell Bay IR the permeable glacial drift aquifer is in direct hydraulic connection with the underlying Athabasca Group bedrock aquifer (AREVA, 2009).

### 4.1.2 Bedrock Aquifers

No site specific information on bedrock aquifers can be found for the Cable Cree Lake IR, Cree Lake IR, and Barkwell Bay IR. However, as discussed in above, this area can be considered one deep aquifer (100 to 800 m thick) due to the high permeability of both the glacial drift and underlying Athabasca Group bedrock. Experience from other areas in the Athabasca Basin indicates that three flow regimes can be distinguished within the Athabasca Basin at certain locations (Smellie and Karlsson, 1996). The first is a superficial regime with predominant flow in the overburden and the upper part of the weathered sedimentary rocks of the Athabasca Group. The second is an intermediate flow regime with water recharging from the upstream end in the highlands, and partly discharging into the nearby lakes in the lowlands. The lower regime can be thought of as a semi-regional regime that is in part being fed by water percolating through the overlying strata mostly via discrete fracture zones. The likely discharge points for these regimes, if they exist within the area of the Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR may be Cree Lake. The Athabasca Group is capable of producing large quantities of water; inflows in excess of 1,000 $m^3$/hr are reported in uranium mine workings in the Athabasca Group rocks at depths ranging from approximately 420 m to 510 m (Bashir and Hatley, 2010), therefore, high groundwater flow rates could possibly be expected at Barkwell Bay IR at typical repository depth (approximately 500 m).

In contrast to the rocks of the Athabasca Group, the underlying Canadian Shield basement rocks are only permeable along fractures and faults and for the most part serve as an impermeable barrier at the base of Athabasca Group. Based on evidence from other parts in the Athabasca Basin, basement rocks are not expected to be a significant groundwater source.

### 4.1.3 Hydrogeochemistry

No information on hydrogeochemistry was found for groundwater in the Cable Cree Lake IR, Cree Lake IR, and Barkwell Bay IR, However, in general, shallow groundwater in the Athabasca Basin contains low concentrations

of total dissolved solids (TDS) (Cameco, 2009a; AREVA, 2007). It has been hypothesized that the low TDS in groundwater is due to the fact that the rocks of the Athabasca Group are largely devoid of reactive mineral constituents. Consequently, the groundwater at greater depths in the Athabasca Group is also expected to be of similar good quality. This is consistent with experience at the McArthur River uranium mine, where groundwater pumped at depth has been approved for discharge to the environment without treatment (Cameco, 2009b).

## 4.2 Region 2 – Canadian Shield: Haultain Lake IR, Porter Lake Island IR, Flatstone Lake IR, Dipper Rapids IR, Primeau Lake IR, Knee Lake IR, Elak Dase IR

The Haultain Lake IR, Porter Lake Island IR, Flatstone Lake IR, Dipper Rapids IR, Primeau Lake IR, Knee Lake IR, and Elak Dase IR have no population registered with Statistics Canada (2010). There is no groundwater use information available for the area. A search of the SWA WWR database (SWA, 2009) indicated that there are seven wells recorded within the Western Canada Sedimentary Basin approximately 25 km west of the Dipper Rapids IR. However, it should be noted that these wells are located within the village of Patuanak, which is not included as part of this study area (Region 2) and are in closer proximity to the Wapachewunak IR than the Dipper Rapids IR (Figure 4.1). The wells are recorded as withdrawal wells and are completed in the overburden.

### 4.2.1 Quaternary Aquifers

There is no available information on the presence, extent or other characteristics of Quaternary aquifers in Region 2. In general the main Quaternary deposits of this region include morainal, glaciofluvial, and glaciolacustrine plains, although the thickness of these deposits is unknown. The groundwater table is expected to be shallow in low-lying areas, and it is expected that shallow unconfined groundwater flow generally parallels surface water drainage patterns.

### 4.2.2 Bedrock Aquifers

No information is available on deep bedrock groundwater conditions in this region. In general, crystalline bedrock formations in Saskatchewan do not readily permit groundwater flow, except as fracture flow. Experience from other areas in the Canadian Shield has shown that active groundwater flow is generally confined to shallow fractured localized systems. In Ontario, Singer and Cheng (2002) studied the groundwater movement in shallow bedrock of the Canadian Shield and reported that it is controlled by the secondary permeability created by fractures. Everitt, (1999) reported that in Manitoba's Lac du Bonnet Batholith, groundwater movement is largely controlled by a fractured zone down to about 200 m depth. It is expected that groundwater flow within Canadian Shield rocks in Saskatchewan will be similar to those found in other locations within the Canadian Shield.

### 4.2.3 Hydrogeochemistry

No information on hydrogeochemistry was found for this region. However, groundwater quality in the Canadian Shield formations of Saskatchewan would likely be similar to groundwater quality in Canadian Shield formations found elsewhere. Gascoyne et al., (1987) investigated saline brines within Precambrian plutons and identified a chemical transition at around 300 m depth marked by a uniform and rapid rise in total dissolved solids and chloride. This was attributed to advective mixing occurring above 300 m, with a shift to diffusion-controlled flow below that depth. 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 Atomic Energy Canada Limited's (AECL) Whiteshell Underground Rock Laboratory (URL) in Manitoba found that crystalline rocks from depths of 300 m to 1,000 m have TDS values ranging from 3 g/L to 90 g/L (Gascoyne et al., 1987; Gascoyne, 2000 and 2004). However, TDS exceeding 250 g/L have been reported in some regions of the Canadian Shield at depths below 500 m (Frape et al., 1984).

## 4.3 Region 3 – Western Canada Sedimentary Basin: Wapachewunak IR, Ile-a-la-Crosse IR, La Plonge IR

Region 3 encompasses the Wapachewunak IR, Ile-a-la-Crosse IR, and La Plonge IR. According to Statistics Canada (2010), La Plonge and Wapachewunak have populations of 139 and 526 individuals, respectively. There is no population registered for the Ile-a-la-Crosse IR. There are 71 wells recorded in the English River First Nation reserve areas considered in this region. Locations of the wells are shown on Figure 4.1.

The Wapachewunak IR obtains its drinking water from the Churchill River while the La Plonge IR obtains its drinking water from groundwater sources. It should be noted that the community of Beauval (which is not included as part of this study area) also relies on the groundwater supply and is located adjacent to the La Plonge IR.

A summary of the wells in this region is provided below. According to the information recorded in the database most of the wells appear to be completed in the overburden with no definitive information if any were completed in bedrock.

**Table 4.1: Water Well Summary for the area of Wapachewunak IR, Ile-a-la-Crosse IR, and La Plonge IR**

| Water Well Type | Number of Wells | Depth (m) | Static Level (m below surface) | Tested Yield (L/min) | Depth to Bedrock (m) |
|---|---|---|---|---|---|
| **Wapachewunak IR** | | | | | |
| Water Test Hole | 2 | 36 to 90 | N/A | N/A | 36 to 90 |
| Withdrawal | 5 | 36 to 59 | 0 to 5 | 45 to 114 | 36 to 59 |
| **Ile-a-la-Crosse IR** | | | | | |
| Water Test Hole | 5 | 15 to 113 | N/A | N/A | N/A |
| Withdrawal | 15 | 13 to 43 | 1.5 to 12 | 14 to 205 | N/A |
| **La Plonge IR** | | | | | |
| Observation | 4 | 11 to 68 | 4.3 to 4.6 | N/A | N/A |
| Water Test Hole | 4 | 16 to 172 | 13.4 | N/A | N/A |
| Withdrawal | 36 | 7 to 67 | 1.5 to 27 | 9 to 450 | N/A |

N/A = Not available

### 4.3.1 Quaternary Aquifers

Water well records indicate that most of the water wells in this region draw water from sand and gravel seams in the overlying glacial till. The groundwater table is reported to be within a few metres of the ground surface ranging to a depth of 27 m. Reported well yields are variable with well records recording values ranging from 9 L/min to 450 L/min. These values reflect the purpose of the wells (residential supply/industrial/municipal) and do not necessarily reflect the maximum sustained yield that might be available from the aquifer. The limited

number of well records and their concentration near the La Plonge IR limits the available information regarding the extent and characteristics of the overburden aquifer over the whole region.

### 4.3.2 Bedrock Aquifers

The well records available for the Phanerozoic region near the English River First Nation reserve areas in Region 3 do not provide any evidence of either the existence or use of a shallow bedrock aquifer. The Lower Cretaceous Mannville Group is present throughout the subsurface of Saskatchewan at depths of greater than 1,200 m in the south of the Province, which shallows towards the north. It consists of siliciclastic sandstones and siltstones, from which sandstones make up the aquifer portion of the unit, known as the Mannville Aquifer (Maathuis and Thorleifson, 2000). The Mannville Aquifer has saline water over much of its extent, except for where it outcrops south of the Canadian Shield contact, where groundwater from this unit may be potable (Maathuis and Thorleifson, 2000). The thickness of the Mannville Group in the region of the Wapachewunak IR, Ile-a-la-Crosse IR and La Plonge IR is approximately 47 m on average (Fuzesy, 1977). Owing to its salinity with depth in other parts of the province, the Mannville Aquifer potential, if it exists in this region, would likely be at depths within the Phanerozoic cover much shallower than at repository level. The other formations identified in the Phanerozoic cover are less likely to have aquifer potential.

No information is readily available on deep crystalline bedrock groundwater conditions at typical repository depth (approximately 500 m) in this region. It is, however, expected that the bedrock would have hydraulic properties that are similar to those described for Region 2.

### 4.3.3 Hydrogeochemistry

No information on groundwater hydrogeochemistry was found for this region. The overburden aquifer groundwater quality can be interpreted as potable owing to groundwater use in southern part of the region. There is no readily available hydrochemistry information for the bedrock aquifers in Region 3. Although the Mannville Group contains saline water over much of its extent, there is a possibility that the Mannville Group aquifer may yield potable water where it outcrops south of the Canadian Shield contact.

# 5.0 ECONOMIC GEOLOGY

Mineral occurrences and dispositions in the English River First Nation reserve areas in Regions 1, 2 and 3 are shown on Figure 5.1. The potential economic interest of these occurrences is discussed below.

## 5.1 Petroleum Resources

Rocks of the Canadian Shield are crystalline and represent a geological setting where the potential for petroleum resources is negligible, and with no current and past exploitation or exploration. Although the sandy nature of the sedimentary rocks of the Athabasca Group within the Athabasca Basin have the potential to act as petroleum reservoir rocks, no potential for petroleum resources within the Athabasca Basin is currently known, and no current and past exploitation or exploration activities have occurred.

Although in Southern Saskatchewan petroleum resources can be associated with various formations within the Western Canada Sedimentary Basin, none of these are known to exist near the three English River First Nation reserve areas within the Western Canada Sedimentary Basin. However, in the area investigated between Beauval and La Loche, gas odour was noticed from the limestone rock of the Upper Meadow Lake Formation of the Elk Point Group (Fuzesy, 1977). This formation may provide the basis for reservoir development within structural highs in this area although no known reservoirs have been identified to date. It is unknown if methane or shale gas may be associated with this formation. Oil and natural gas have been produced from the Mannville Group in West-Central Saskatchewan, and tar sands have been associated with the sedimentary rocks of the Mannville Group in Northern Alberta and Saskatchewan (north of La Loche). However, there are no known economic hydrocarbon deposits in the English River First Nation reserve areas (Thomas and Slimmon, 1985).

Within the Mannville Group, lignite seams near the northern margin of the Western Canada Sedimentary Basin can be up to 2 m thick in places (Fuzesy, 1977). Several coal dispositions are present adjacent to the La Plonge IR and the Wapachewunak IR, within the Western Canada Sedimentary Basin. Limited information is available on these dispositions; however, these lignite seams are located within the lower Mannville Group, are relatively continuous, and can be used as stratigraphic markers (SGS, 2003).

Based on the available information, the potential for petroleum resources at repository depth within the English River First Nation reserve areas is negligible.

## 5.2 Metallic Mineral Resources

There is no record of metallic mineral production near the English River First Nation reserve areas, with the exception of uranium from the Athabasca Basin. Past exploration has occurred in the areas of Dipper and Porter Lakes, but on a reconnaissance level. Figure 5.1 shows areas of active exploration and mining dispositions in the English River First Nation region, as well as the known mineral index reported in the Geological Atlas of Saskatchewan (Saskatchewan Energy and Resources Atlas 2010).

### Gold, Precious Metals, Iron and Base Metals

All gold, iron and base metal occurrences within the Canadian Shield rocks near the English River First Nation reserve areas occur within metasedimentary rocks.

Gold occurrences have been associated with mafic granulites and ultramafic metasedimentary rocks in the Porter Lake area, in the area of the Porter Lake Island IR. In this area, gold mineralization is also associated with silver and metal sulphides like copper, nickel, minor zinc, and lead (Harper, 1988). Approximately 40 km to the north of the Porter Lake Island IR near Ithingo Lake, there is a mineral disposition with developed gold

mineral prospects hosted within the metasedimentary rock; however, there are no occurrences within the area of Porter Lake Island IR that are currently economically proven.

Iron occurrences are found within a metasedimentary banded iron formation within the western extent of the Mudjatik Domain, and can be found in the area of the Porter Lake Island IR. No occurrences appear to be economically viable (Pearson, 1977; Gilboy, 1985).

Molybdenum occurrences have been found on an island in May Bay of Primeau Lake near the Primeau Lake IR, occurring in the alaskite rock (Scott, 1977). An iron occurrence has also been found in alaskite to the north of the Primeau Lake IR, and a copper occurrence associated with amphibolite is located along the eastern edge of the Primeau Lake IR. Based on a rock chip sampling program, copper concentrations range from 4 parts per million (ppm) to 92 ppm while molybdenum concentrations range from 0 ppm to 40 ppm (Scott, 1977). Neither occurrence is currently economically relevant.

Other base metal occurrences in the English River First Nation reserve areas include pyrrhotite, and nickel, although there is no information available to indicate whether these occurrences have been recently explored or have any economic potential.

## Uranium

Unconformity type deposits in the Athabasca Basin are some of the world's largest high grade uranium resources and represent the only uranium currently produced within Canada (Jefferson et al., 2007). The transition zone between the Mudjatik and Wollaston Domains underlies the most economic producing areas within the Athabasca Basin, and has been a target of exploration activities. The best sedimentary rocks for uranium appear to include the Manitou Falls Formation, found in the eastern half, south and north edges of the Cree Subbasin (Ramaekers, 1980). This is the general rock type in the location of the Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR.

Although no known economical uranium deposits have been discovered in the immediate Cree Lake area, which includes Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR, the entire Cree Lake area adjacent to the English River First Nation reserves is covered by active mineral disposition blocks that are undergoing active exploration activities. The Key Lake Operation is located approximately 50 km to the southeast of the Barkwell Bay IR, and during its operation has produced approximately 70,000 tonnes of uranium at an approximate grade of 2% (Jefferson et al., 2007). Based on their proximity to the Key Lake Operation, and their location within the Athabasca Basin, there is potential for an economically viable uranium resource to be discovered in the area of Cable Cree Lake IR, Cree Lake IR and Barkwell Bay IR in the future.

Within the rocks of the Canadian Shield, uranium occurrences have been found within granitoids, leucogranitoids and granitic pegmatites (Harper, 1988). These are generally associated with metasedimentary rocks throughout the Mudjatik and Wollaston Domains. The main focus of exploration for uranium within Canadian Shield rocks has been along the transition zone between the Mudjatik and Wollaston Domains, in the area of the Haultain Lake IR. An extensive portion of this area is covered by active dispositions; although no economically viable source of uranium has currently been discovered within this area.

## Rare Metals

There are no known rare earth metal occurrences within the English River First Nation reserve areas. The only known rare earth metal showing occurs approximately 20 km to the north of the Elak Dase IR near Cup Lake. This occurrence is not economically relevant at this time.

## 5.3 Non-Metallic Mineral Resources

Known non-metallic mineral resources within the English River First Nation reserve areas include limestone, sand and gravel, and peat. The majority of these occur within the Phanerozoic rocks of the Western Canada Sedimentary Basin, or within the Quaternary cover.

### Limestone

Limestone exploration has been undertaken at a limestone occurrence in the Pinehouse Lake region, approximately 50 km to the northeast of the La Plonge IR. Although no limestone occurrences have been identified in the areas adjacent to the La Plonge IR, Ile-a-la-Crosse IR and Wapachewunak IR, the limestone occurrence near Pinehouse Lake occurs within the Elk Point Group, which also is expected to underlie the English River First Nation reserve areas. At this time, there is no known economic potential for limestone in the English River First Nation reserve areas.

### Sand, Stone, and Gravel

Sand and gravel deposits consist of deposits related to the most recent glaciations. These resources occur in abundance, and are important sources of aggregate for infrastructure projects. There is approximately one small sand and gravel prospect per 26 $km^2$ and one large prospect for every 2,600 $km^2$ throughout Saskatchewan (SGS, 2003).

### Peat

The major peatlands of Saskatchewan occur on the northern margin of the Western Canada Sedimentary Basin. Peatlands west of La Ronge, including within the English River First Nation reserve areas contain a large quantity of well-humidified sedge fuel peat, generally with a sphagnum cover (SGS, 2003).

Only one peat moss producer operates within Saskatchewan, near Carrot River, which is approximately 340 km to the southeast of the La Plonge IR (SGS, 2003). Although unknown at this time, there may be potential for expanding this industry in the future.

### Diamonds

Diamond-bearing kimberlites have been identified and are currently under development east of Prince Albert, approximately 250 km southeast of the La Plonge IR (SGS, 2003). Currently, kimberlites are not known to occur in the English River First Nation reserve areas.

### Building Stone

Building stone is not currently exploited as a resource throughout Saskatchewan. However, there is potential for economic resources, especially in marble, granite, dolomite, amphibolites, and gabbro-diorite rock types. The majority of this potential occurs in the La Ronge region, but given the characteristics of the crystalline rocks in the English River First Nation reserve areas, this resource cannot be completely disregarded in this region.

# 6.0 INITIAL SCREENING EVALUATION

This section provides an evaluation of each of the five initial screening criteria (NWMO, 2010) for the English River First Nation reserve areas, based on the readily available information presented in Sections 2 to 5. 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).

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 English River First Nation from the site evaluation process. 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 participating in the siting process.

Given the large geographic extent covered by the thirteen English River First Nation reserves, the screening was first conducted on a regional basis to assess whether there are any unsuitable conditions that would exclude any of the three geological regions considered in Section 3.2. The thirteen reserves were grouped into three distinct regions based on the similarity of their geology: the three reserves within the sedimentary rocks of the Athabasca Basin (Region 1); the seven reserves within the Canadian Shield (Region 2); and the three reserves within the sedimentary rocks of the Western Canada Sedimentary Basin (Region 3).

## 6.1 Reserve Areas Not Meeting Screening Criteria

As described in Tables 6.1 and 6.2, the reserve areas located within the Athabasca Basin (Region 1) and the Western Canada Sedimentary Basin (Region 3) do not meet all the screening criteria and have, therefore, been excluded from further consideration.

The reserve areas within the Athabasca Basin include the Cable Cree Lake, the Cree Lake and the Barkwell Bay Indian Reserves (Table 6.1). All three reserves do not meet the screening criteria related to the presence of known groundwater resources at repository depth (Criterion 3); the presence of known economically exploitable resources (Criterion 4); and the presence of known unfavourable geological and hydrogeological characteristics that make the reserve areas unsuitable for hosting a deep geological repository (Criterion 5).

The reserves areas located within the Western Canada Sedimentary Basin include the Wapachewunak, the Ile-a-la-Crosse and the La Plonge Indian Reserves (Table 6.2). They all fail to meet the screening criteria related

the presence of known unfavourable geological and hydrogeological characteristics that make them unsuitable for hosting a deep geological repository (Criterion 5).

**Table 6.1: Screening of Reserve Areas within the Athabasca Basin (Region 1) – Cable Cree Lake IR, Cree Lake IR, Barkwell Bay IR**

| Screening Criteria Not Met | Reasoning for Unsuitable Condition |
|---|---|
| Criterion 3<br><br>Must not contain known groundwater resources at repository depth | As mentioned in Section 3.2.1, the depth of the sedimentary rocks of the Athabasca basin within Region 1 ranges from 100 m to 800 m. As discussed in Section 4.1, the Athabasca Group rocks act as a deep bedrock aquifer, with inflows that could exceed 1,000 $m^3$/hr. These rocks would unlikely meet the criterion related to the absence of known groundwater resources at repository depth (approximately 500 m). In cases where the thickness of the sedimentary rocks is relatively thin (i.e., less than 500 m) and the repository is developed within the underlying crystalline rocks, the sites would not be amenable to characterization and site data interpretation as discussed below (see Criterion 5). |
| Criterion 4<br><br>Must not contain known economically exploitable resources | The Athabasca Basin region of Saskatchewan contains some of the largest high grade uranium deposits in the world. A historically producing uranium property is located approximately 50 km to the southeast of the Barkwell Bay reserve area. Although these reserves areas cannot be definitively excluded based on this criterion because there are no known uranium deposits in their areas, the entire area surrounding the sites is covered by active mineral dispositions, which may lead to the discovery of an economically viable uranium deposit. |
| Criterion 5<br><br>Must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe | This criterion requires that the site not be located in a known area of geological or hydrogeological features that would make the site unsafe, as per the detailed geoscientific safety-related factors identified in the site selection process (NWMO, 2010). These are: safe containment and isolation of used nuclear fuel; long-term resilience to future geological processes and climate change; safe construction, operation and closure of the repository; isolation of used fuel from future human activities; and amenability to site characterization and data interpretation. The reserve areas within the Athabasca Basin (Region 1) do not meet the following geoscientific safely-related factors:<br>***Safe containment and isolation**:* The sedimentary rocks of the Athabasca Group are considered to have good aquifer properties at depth with a likely hydraulic connection to the surface. Given the potential for high groundwater flow at repository depth, it may not be possible to achieve the long-term isolation and containment of used nuclear fuel and prevent the migration of radionuclides away from the repository.<br>**Safe construction, operation and closure of the repository:** Based on experience from mining operations within the Athabasca Basin, the Athabasca Group sedimentary rocks can commonly have high groundwater inflows, unconsolidated sand seams, zones of highly altered weak material, and highly fractured areas that could make the construction, operation and closure of a facility difficult.<br>***Isolation from future human activities**:* With the potential for groundwater and economically viable mineral resources (Criteria 3 and 4), it may be difficult to maintain the facility's isolation from future human activities.<br>***Amenability to site characterization and data interpretation**:* The depth of the sedimentary rocks of the Athabasca basin within Region 1 ranges from 100 m to 800 m. In cases where the depth of the sedimentary rocks is lower than typical repository depth (approximately 500m), the repository would be developed within the underlying crystalline rocks. One of the key criteria in assessing the suitability of a site is related to having a host rock that is amenable to site characterization and site data interpretation 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 crystalline rock (e.g., fractures geometry and frequency), the presence of a thick sedimentary cover would greatly reduce the ability to characterize the crystalline rock at repository depth. |

**Table 6.2: Screening of Reserve Areas Western Canada Sedimentary Basin (Region 3) – Wapachewunak IR, Ile-a-la-Crosse IR, La Plonge IR**

| Screening Criteria Not Met | Reasoning for Unsuitable Condition |
|---|---|
| Criterion 5<br><br>Must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe | ***Amenability to site characterization and data interpretation***: As mentioned in Section 3.2.3, the three reserve areas within Region 3 are covered by up to 340 m of sedimentary rocks of the Western Canada Sedimentary Basin (Figure 3.10). Therefore, a deep geological repository in that area would have to be developed within the crystalline rock of the Canadian Shield underlying the sedimentary sequence. Similarly to the discussion for the Athabasca Basin (Region 1), the presence of a sedimentary cover would greatly reduce the ability to adequately characterize and understand the crystalline host rock at repository depth. Therefore, the three reserve areas within Region 3 are excluded from further consideration. |

## 6.2 Reserve Areas Meeting Screening Criteria

This section focuses on the screening evaluation of the seven reserves located within the Canadian Shield (Region 2). The surface area within the boundaries of some of these reserves would not be sufficient to accommodate the repository surface facilities. Therefore, as per discussions between NWMO and the Band Council, the initial screening was conducted to also assess whether there are areas at the periphery of the reserves that would meet the initial screening criteria. The lands within the English River First Nation reserves and their periphery are also referred to as the “the reserve area”.

### 6.2.1 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. Available land should be accessible to allow 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 in the English River First Nation reserve areas in Region 2 where surface facilities are unlikely to be built due to 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.

Because of their small size and/or narrow shape, four of the English River First Nation reserves within Region 2 would not be able to accommodate the repository surface facilities within their boundaries. These include the Porter Lake, the Flatstone Lake, Haultain Lake and Dipper Rapids reserves (Figures 3.7 to 3.9). However, the review of available mapping and satellite imagery (Figures 1.1, and 2.6) shows that despite the presence of major lakes and permanent water bodies, the areas at the periphery of all the English River First Nation reserves within Region 2 have no obvious constraints that would prevent the development of the repository surface facilities. As discussed in Section 2, topography is moderately variable with the most relief occurring as bedrock ridges covered by a thin veneer of glacial moraine (Figure 2.2), and low lands with marshy areas. While topographic relief is variable across the English River First Nation reserve areas, no obvious topographic

features that would prevent construction and characterization have been identified, although access to the marshy lowlands will need further investigation.

The English River First Nation reserve areas are largely undeveloped, with no major infrastructure present. The closest infrastructure is Provincial road 914, located approximately 9 km west of the Haultain Lake IR. None of the English River First Nation reserve areas within Region 2 are directly accessible by all season roads, although seasonal access to some sites may be available via Provincial roads 914 and 918.

As discussed further in Section 6.2.5, the English River First Nation reserve areas in Region 2 have the potential of containing sufficient volumes of appropriate host rock to accommodate the underground facilities associated with a deep geological repository. This would have to be confirmed in subsequent site evaluation stages.

*Based on the review of readily available information, it is concluded that the English River First Nation reserve areas within the Canadian Shield (Region 2) contain sufficient land to accommodate the repository surface and underground facilities.*

### 6.2.2 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 confirm that the remaining available land, after excluding protected areas, is of sufficient size to allow for the construction of the repository facilities. Protected areas are considered to be ecologically sensitive or significant areas, as defined by Provincial or Federal authorities. The English River First Nation reserve areas were screened for federal, provincial and municipal parks, conservation areas, nature reserves and national wildlife areas, and heritage sites using available data from federal and provincial databases.

As determined in Section 2.2.4, there are no federal, provincial or municipal parks in the reserve areas in Region 2. The nearest protected area is the Gordon Lake Recreation Site which is located approximately 10 km east of the Elak Dase IR (Figures 1.1 and 2.4). This recreational site is small and covers less that 4 $km^2$. Several heritage sites were identified near the Elak Dase IR. These sites are also small and generally concentrated along the Churchill River and along Provincial road 914 to the east of Elak Dase IR. There are no known wildlife or nature reserves in the area. Apart from the areas identified above, the English River First Nation reserve areas contain large parcels of land that are outside of protected areas, provincial parks and national parks.

The absence of locally protected areas would need to be confirmed in discussion with the community and Aboriginal peoples in the area during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

*Based on the review of readily available information, the English River First Nation reserve areas within the Canadian Shield (Region 2) contain sufficient land outside of protected areas, heritage sites, provincial parks and national parks to accommodate the repository's facilities.*

### 6.2.3 Screening Criterion 3: Known Groundwater Resources at Depth

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

In order to reduce 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 (approximately 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 in the areas covered by the English River First Nation reserve areas in the Canadian Shield. As discussed in Section 4.0, the Saskatchewan Watershed Authority Water Well Records database has no records of any water wells within the reserve areas.

The geology in the English River First Nation reserve areas at typical repository depth (approximately 500m) within Region 2 is dominated by the crystalline bedrock from 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 interconnected (Stevenson et al., 1996; McMurry et al., 2003).

The Saskatchewan Watershed Authority Water Well Records database indicates that no potable water supply wells are known to exploit aquifers at repository depths at the English River First Nation reserve areas. 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 absence of groundwater resources at repository depth in the English River First Nation reserve areas would, however, need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

*The review of available information did not identify any groundwater resources at repository depth in the English River First Nation reserve areas within the Canadian Shield (Region 2). Experience in similar geological settings suggests that the potential for deep groundwater resources at repository depths is low. The absence of groundwater resources at repository depth would, however, need to be confirmed during subsequent site evaluation stages, if the community remains interested in the site selection process.*

### 6.2.4 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 reduce 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 the past and potential future occurrence of natural resources such as oil and gas, 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 or coal resources at or near English River First Nation reserve areas within the Canadian Shield (Region 2). There are no currently operating or past producing mines within the area of the English River First Nation reserve areas in Region 2. There are several metallic mineral occurrences within the area such as gold, copper and iron (as detailed in section 5.2). However, none of these are known to be economically exploitable. Mineral occurrences in the area appear to be primarily associated with inferred fault traces, and metasedimentary rocks (Figure 5.1). Uranium dispositions are present less than 1 km to the east of the Haultain Lake IR. To date, no economically viable uranium deposits have been discovered in this area.

The review of known mineral deposits, exploration activity, and mineral potential indicates that the English River First Nation reserve areas within Region 2 have a generally low economic mineral potential. There are no known deposits of economically exploitable natural resources within the English River First Nation reserve areas within Region 2.

*Based on the review of readily available information, the English River First Nation reserve areas within Region 2 contain sufficient areas, free of known economically exploitable natural resources, to accommodate the required repository facilities. The absence of natural resources would need to be confirmed during subsequent site evaluation stages, if the community remains interested in the site selection process.*

### 6.2.5 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 safety factors outlined in Section 6 of the site selection document (NWMO, 2010).***

This criterion requires that the site not be located in a known area of 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 English River First Nation reserve areas within Region 2 from further consideration. These factors would be gradually assessed in more detail as the site evaluation process progresses and more site specific data is collected during subsequent site evaluation phases, provided the community remains interested in the site selection process.

## Safe Isolation and Containment Function

The geological and hydrogeological conditions of a suitable site should promote long-term isolation and containment 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, 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 English River First Nation reserve areas within Region 2 is generally dominated by felsic gneiss, with the presence of narrow, arc shaped bands of metasedimentary rocks. The felsic gneiss predominantly formed by metamorphism of precursor plutonic rocks and is mostly granitic in composition. The metasedimentary rocks are gneissic in nature and formed by high grade metamorphism of sedimentary rocks that were originally deposited on the felsic gneiss. Folding and thrusting may have locally buried these narrow metasedimentary rock bands to substantial depth. The thickness of the metasedimentary rock is not known, but the combined thickness of these two geological units is expected to be 3 km to 8 km thick in this area.

The geology in the area of four of the reserve areas, Haultain Lake IR, Flatstone Lake IR, Porter Lake Island IR and Dipper Rapids IR, is composed of felsic gneiss with the metasedimentary rock bands located between 2.7 km to 6.3 km from the reserves boundaries (Figures 3.8 to 3.9). Very few faults have been mapped around these reserve areas with distances ranging between 9 km and 33 km from the reserve boundaries.

The rock type in the Primeau Lake reserve area consists of mainly granite (alaskite), with areas composed of felsic gneiss and metasedimentary rock nearby (Figure 3.9). The nearest inferred fracture is located approximately 18 km to the northeast. The thickness of the alaskite is not known, but the combined thickness of the felsic gneiss and the alaskite is expected to be 3 km to 8 km thick in this area.

The rock in the Knee Lake and the Elak Dase reserve areas is composed of both felsic gneiss and metasedimentary rocks (Figure 3.9). The nearest inferred faults are located approximately 3.2 km to the east of the Elak Dase reserve and 14 km to the north of the Knee Lake reserve.

The lateral extent and depth of the various geological formations, particularly the felsic gneiss, in the area of the seven reserves within geological Region 2 are potentially sufficient for hosting a deep geological repository. While the metasedimentary rock in the Knee Lake and Elak Dase reserve areas may fulfil the safe isolation and containment function, it is uncertain whether they have sufficient volume to host a deep geological repository.

As discussed above, very few faults have been mapped in the seven reserve areas. This is consistent with the general faulting pattern mapped at the regional scale where faulting has been inferred on a frequency of 10 km to 20 km in a predominantly northwest (and secondary northeast) direction (Figure 3.2). There is no readily

available information regarding faulting between the inferred faults shown on Figure 3.2 or fracturing of the rock at depth. This would need to be further assessed in subsequent site evaluation stages.

From a hydrogeologic perspective, the review of readily available information did not reveal the existence of known deep fracture systems or deep aquifers in the crystalline rock within the English River First Nation reserve areas in Region 2. Crystalline rocks, such as those found in the area, generally have hydraulic properties that would limit groundwater flow except where extensive fracturing is present. Experience from other areas in the Canadian Shield indicate that active groundwater flow tends to be generally limited to shallow fractured systems, typically less than 300 m depth. In deeper rock, fractures are less common and less likely to be interconnected, leading to very slow groundwater movement with residence times that could reach a million years or more (McMurray et al., 2003; Gascoyne, 2000, 2004).

Based on the above information, there are geological units within the seven English River First Nation reserve areas in Region 2 that are expected to have geological and hydrogeological conditions that can potentially meet the containment and isolation requirements. Given their granitic composition, and their lateral extent and depth, the extensive felsic gneiss rocks might be considered as potential host rock for a deep geological repository. While the metasedimentary rock bands may fulfill the safe isolation and containment function, it is uncertain whether they have sufficient volume to host a deep geological repository.

Other geoscientific characteristics that may have an impact on the containment and isolation functions of a deep geological repository such as the mineralogy of the rock, the geochemical composition of the groundwater and rock porewater and the thermal and geomechanical properties of the rock would also need to be assessed during subsequent site evaluation stages.

## Long-term Stability

A suitable site for hosting a repository is a site that would remain stable over the very long term in a manner that will ensure that the performance of the repository will not be substantially altered by geological and climate change processes, such as earthquakes or glaciation. A full assessment of this geoscientific factor requires detailed site specific data that would be typically collected and analyzed through detailed field investigations. The assessment would include understanding how the site has responded to past glaciations and geological processes and would entail a wide range of studies involving disciplines such as seismology, hydrogeology, hydrogeochemistry, paleohydrogeology and climate change.

At this early stage of the site evaluation process, the long-term stability factor is evaluated by assessing whether there is any evidence that would raise concerns about the hydrogeological and geological long-term stability of the English River First Nation reserve areas within Region 2. The review of readily available information did not reveal any obvious characteristics that would suggest this.

English River First Nation reserve areas in Region 2 are located in the Hearne Province of the Canadian Shield, where large portions of land have remained tectonically stable for the last 1.8 billion years (SGS, 2003). No earthquakes have been recorded near any of the English River First Nation reserve areas from 1985 through 2010 and there is no evidence of historical earthquakes prior 1985. There is no evidence that the smaller scale northwest and northeast trending faults have been significantly active in the last 1.8 billion years.

The geology of the English River First Nation reserve areas within Region 2 is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years. This is a significant past perturbation that will likely occur in the future. However, findings from studies conducted in the Canadian Shield suggest that deep crystalline formations, particularly plutonic intrusions, have remained largely

unaffected by past perturbations such as glaciations. For example, findings of a comprehensive paleohydrogeological study of the fractured crystalline rock at the Whiteshell Research Area, located within the Manitoba portion of the Canadian Shield (Gascoyne, 2004), indicated that the evolution of the groundwater flow system was characterized by periods of long-term hydrogeological and hydrogeochemical stability. Furthermore, there was evidence that only the upper 300 m appeared to have been altered within the last million years. Several studies conducted in a number of plutons in the Canadian Shield and in the crystalline basement rocks in Western Ontario (McMurry et al., 2003) show that fractures below a depth of several hundred metres in the plutonic rock were ancient features. Additionally, subsequent geological processes such as plate movement and continental glaciation have caused reactivation of existing zones of weakness rather than the formation of large new zones of fractures. In Northern Saskatchewan, studies suggest that the Canadian Shield formations were resistant to erosion by the glaciers (Schreiner, 1984a).

In summary, the review did not identify any obvious geological or hydrogeological conditions that would clearly not satisfy the long term stability function of a potential repository within the English River First Nation reserve areas in Region 2. As mentioned above, the long-term stability function would need to be further assessed through detailed multidisciplinary geoscientific site investigations.

## Potential for Human Intrusion

The site should not be located in areas where the containment and isolation functions of the repository are likely to be disrupted by future human activities such as exploration or mining. Therefore, the repository should not be located within rock formations containing exploitable groundwater resources (aquifers) at repository depth and economically exploitable natural resources such as gas/oil, coal, minerals and other valuable commodities as known today.

This factor has already been addressed in Sections 6.3 and 6.4 which concluded that the potential for deep groundwater resources at repository depths and known economically exploitable natural resources is low throughout the English River First Nation reserve areas in Region 2. The potential for economically exploitable mineralization would require further assessment in subsequent stages of the site selection process.

## Amenability to Construction and Site Characterization

The characteristics of a suitable site should be favourable for the safe construction, operation, closure and long-term performance of the repository. Beside the requirement for space discussed in Section 6.1, this requires that the strength of the host rock and in-situ stress at repository depth are such that the repository could be safely excavated, operated and closed without unacceptable rock instabilities; and that the soil cover depth over the host rock should not adversely impact repository construction and site investigation activities. Similarly, the host rock geometry and structure should be predictable and amenable to site characterization and interpretation activities. The review of readily available information did not reveal any obvious conditions that would exclude the extensive felsic gneiss in the English River First Nation reserve areas in Region 2 from further consideration.

From a constructability perspective, limited site specific information is available on the local rock strength characteristics and in-situ stresses for the English River First Nation reserve areas in Region 2. However, there is abundant information at other locations of the Canadian Shield that could provide insight into what should be expected for the English River First Nation reserve areas in Region 2 in general. Available information suggests that crystalline rock formations within the Shield such as the felsic gneiss generally possess geomechanical characteristics that are good to very good and amenable to the type of excavation activities involved in the

development of a deep geological repository for used nuclear fuel (Chandler et al., 2004; McMurry et al., 2003; Everitt, 1999; Arjang and Herget, 1997).

In terms of predictability of the geological formations and amenability to site characterization activities, the review of readily available information on the bedrock geology and Quaternary geology for the surrounding English River First Nation reserve areas in Region 2 (Sections 3.2 and 3.5) indicate that conditions which could make the rock mass more difficult to characterize and predict may be present in localized areas. For example, there is no readily available information on the thickness of Quaternary deposits. Low lying areas in the English River First Nation reserve areas can be covered with muskeg. The degree to which these factors might affect the characterization and data interpretation activities would require further assessment during subsequent stages of the site selection process.

*Based on the review of readily available geological and hydrogeological information, the English River First Nation reserve areas within the Canadian Shield (Region 2) comprise areas of land that do not contain obvious known geological and hydrogeological conditions that would make the reserve areas unsuitable for hosting a deep geological repository. These areas include the Canadian Shield felsic gneiss rocks that dominate the geology of English River First Nation reserve areas in Region 2.*

# 7.0 INITIAL SCREENING FINDINGS

This report presents the results of an initial screening to assess the potential suitability of the thirteen English River First Nation reserve areas against five initial screening criteria using readily available information. The purpose of the initial screening is to identify any obvious conditions that would exclude the English River First Nation from further consideration in the site selection process. As outlined in the NWMO 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 features, 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 surface area within the boundaries of some of the English River reserves would not be sufficient to accommodate the repository surface facilities. Therefore, as per discussions between NWMO and the Band Council, the initial screening was conducted to also assess whether there are areas at the periphery of the reserves that would satisfy the initial screening criteria. The lands within the English River First Nation reserves and their periphery are referred to as the “the reserve areas”. For the purpose of the screening, the thirteen reserves of the English River First Nation were grouped into three distinct geological regions (Figure 3.2): the Athabasca Basin (Region 1), the Canadian Shield (Region 2), and the Western Canada Sedimentary Basin (Region 3).

The review of readily available information and the application of the five initial screening criteria did not identify any obvious conditions that would exclude the English River First Nation from being further considered in the NWMO site selection process. There are a number of English River First Nation reserve areas that are potentially suitable for hosting a deep geological repository. These include the seven reserve areas located on the Canadian Shield (Region 2). The English River First Nation reserves areas located within the sedimentary rocks of the Athabasca Basin (Region 1) and the Western Canada Sedimentary Basin (Region 3) were excluded from further consideration as they do not meet some of the screening criteria.

It is important to note that at this early stage of the site evaluation process, the intent of the initial screening was not to confirm the suitability of the reserve areas, but rather to identify whether there are any obvious conditions that would exclude the English River First Nation from further consideration in the site selection process. Should the English River First Nation remain interested in continuing with the site selection process, more detailed studies would be required to confirm and demonstrate whether the English River First Nation reserve areas contain sites that can safely contain and isolate used nuclear fuel. 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.

## Reserve Areas Not Meeting Screening Criteria

The reserve areas within the Athabasca Basin (Region 1) include the Cable Cree Lake, the Cree Lake and the Barkwell Bay Indian Reserves. All three reserves do not meet the screening criteria related to the presence of groundwater resources at repository depth; the presence of known economically exploitable resources; and the presence of known unfavourable geological and hydrogeological characteristics that make the reserve areas unsuitable for hosting a deep geological repository.

The reserves areas located within the Western Canada Sedimentary Basin (Region 3) include the Wapachewunak, the Ile-a-la-Crosse and the La Plonge Indian Reserves. They all fail to meet the screening

criteria related the presence of known unfavourable geological and hydrogeological characteristics that make them unsuitable for hosting a deep geological repository.

## Reserve Areas Meeting Screening Criteria

All seven reserve areas located within the crystalline rocks of the Canadian Shield (Region 2) contain areas that are potentially suitable for hosting a deep geological repository. They include the Haultain Lake, the Flatstone Lake, the Porter Lake Island, the Dipper Rapids, the Primeau Lake, the Knee Lake, and the Elak Dase Indian Reserves.

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# FIGURES

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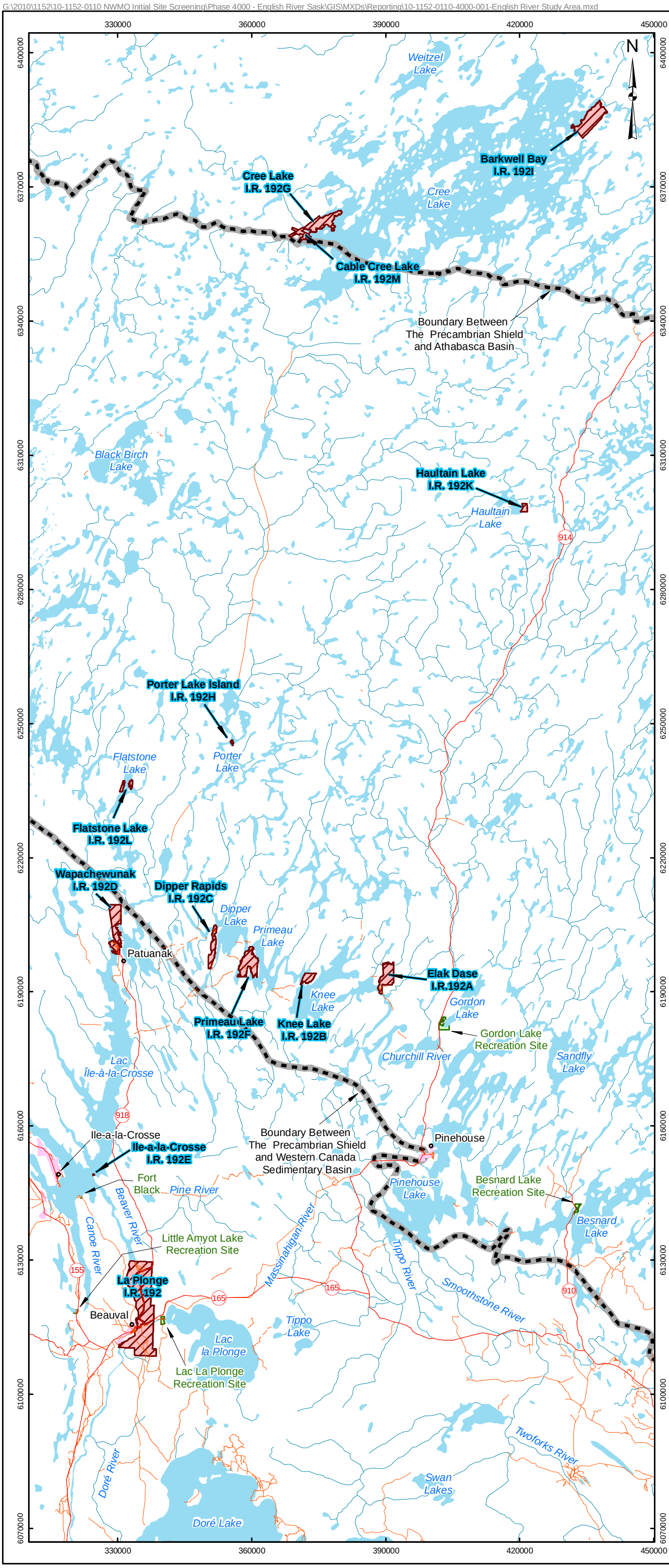
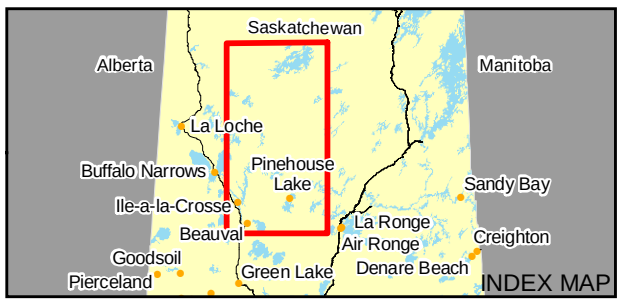



## LEGEND

- Community
- Highway
- Road
- Watercourse, Permanent
- Water Area, Permanent
- Urban Municipality
- Park and Recreation Area
- Indian Reserve
- Athabasca Basin Boundary
- Precambrian Shield Boundary
- Western Canada Sedimentary Basin Boundary




## REFERENCE

DMTI Highways and Roads
Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Waterbody and Watercourse data courtesy of Information Services Corp. Saskatchewan
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

15 7.5 0 15 30 45
SCALE 1:850,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
English River First Nation Reserve Areas

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 1.1 | |
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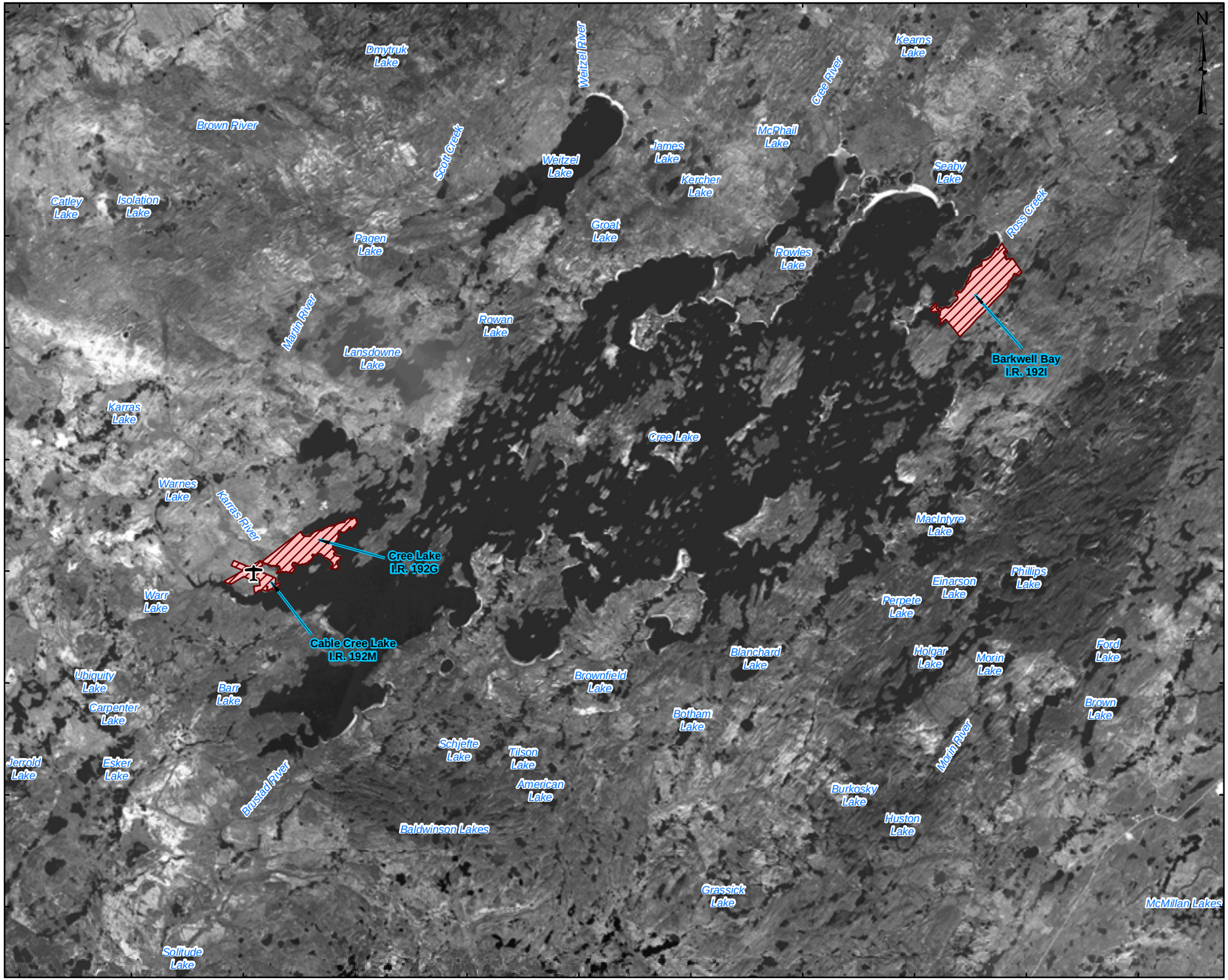
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |




## LEGEND

- Community
- Cable Cree Lake Airstrip
- Indian Reserve

## REFERENCE

SPOT Imagery courtesy of GeoBase
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

5 2.5 0 5 10 15
SCALE 1:350,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River, Saskatchewan

TITLE
Satellite Imagery of the English River First Nation Reserve Areas - Athabasca Basin

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 2.1 | |
| GIS | MGD | 11 Nov. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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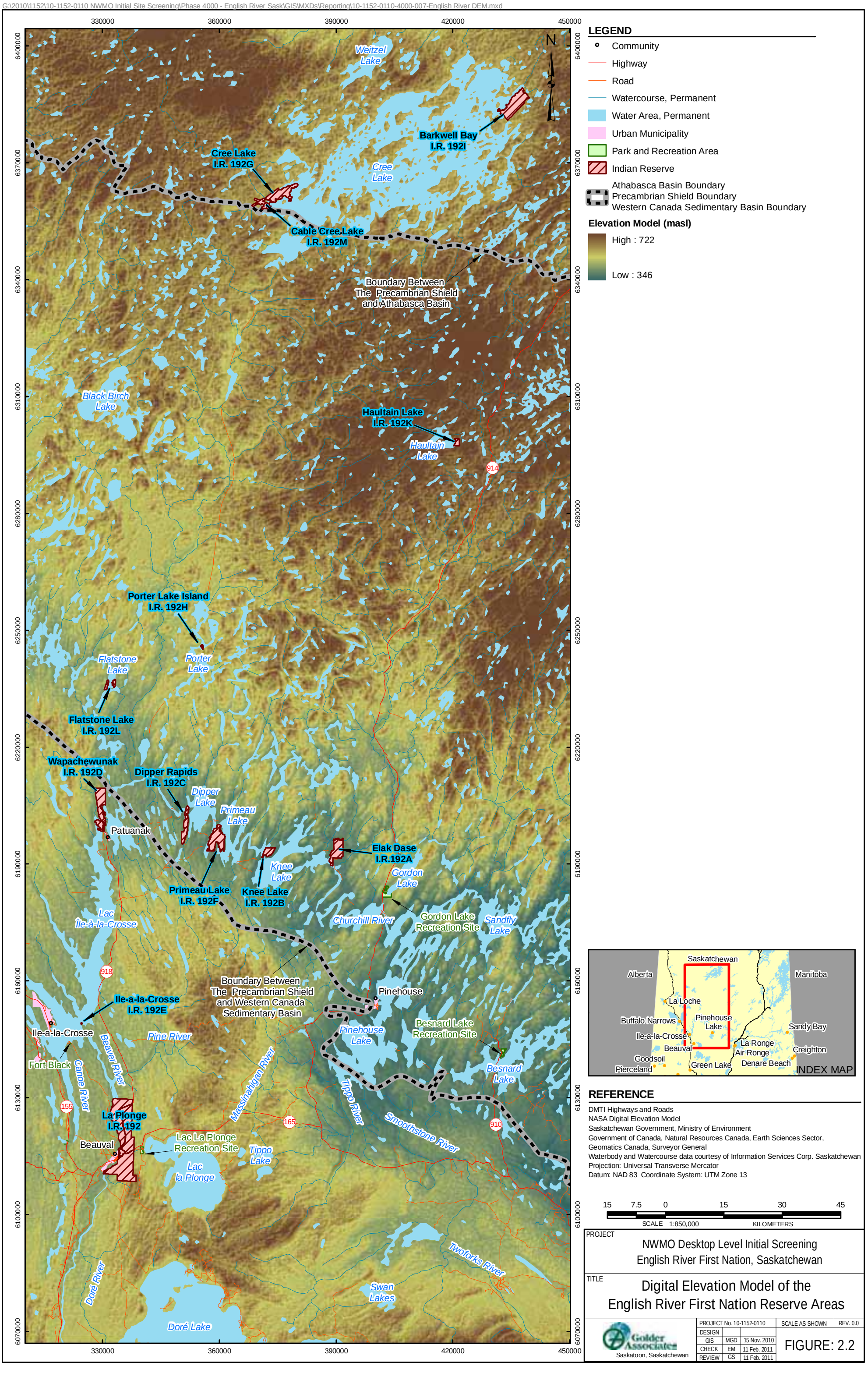

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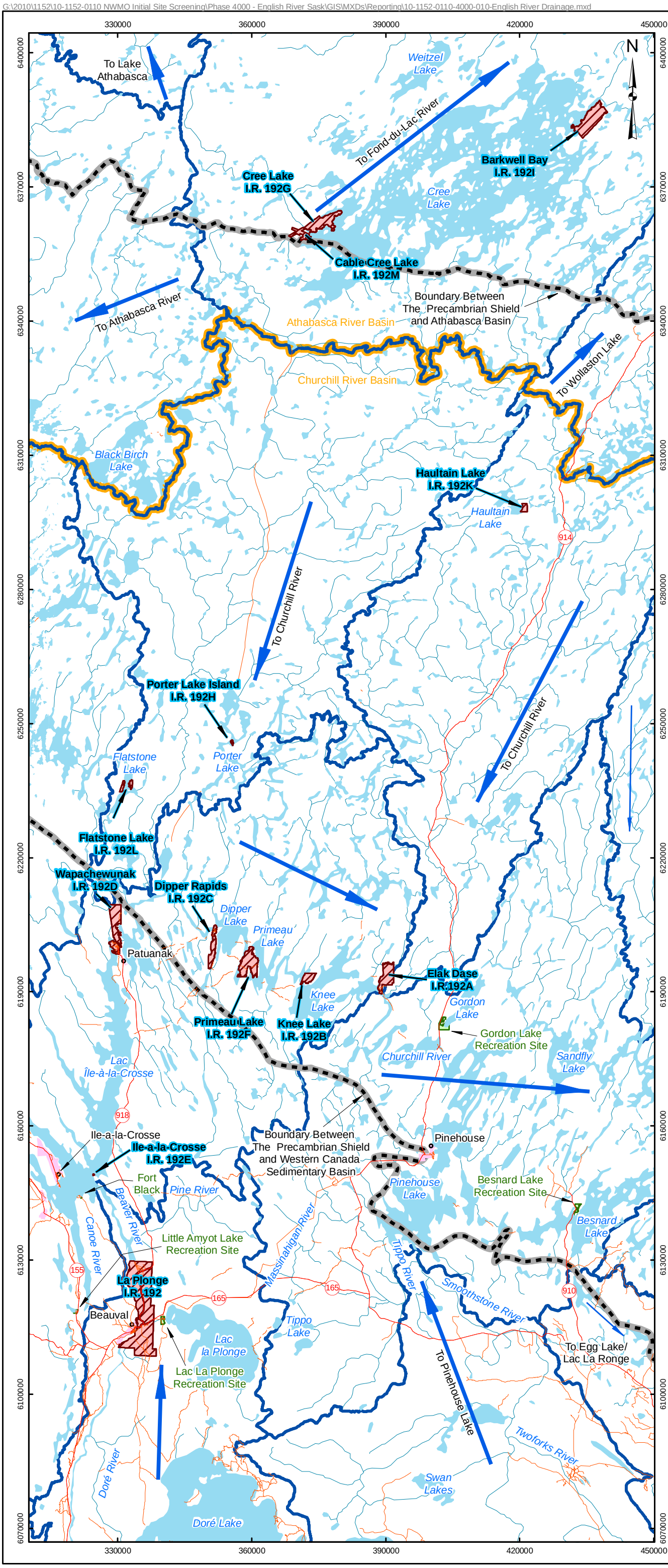
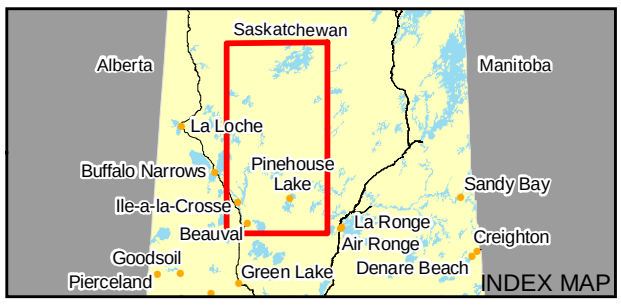



## LEGEND

- Community
- Highway
- Road
- Watercourse, Permanent
- Water Area, Permanent
- Urban Municipality
- Park and Recreation Area
- Indian Reserve
- Watershed Boundary
- Major Watershed Basin Boundary
- Athabasca Basin Boundary
  Precambrian Shield Boundary
  Western Canada Sedimentary Basin Boundary
- Flow Direction




## REFERENCE

DMTI Highways and Roads
PFRA, Agriculture Canada Watersheds
Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Waterbody and Watercourse data courtesy of Information Services Corp. Saskatchewan
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

15 7.5 0 15 30 45
SCALE 1:850,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Drainage Features of the
English River First Nation Reserve Areas

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 2.3 | |
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| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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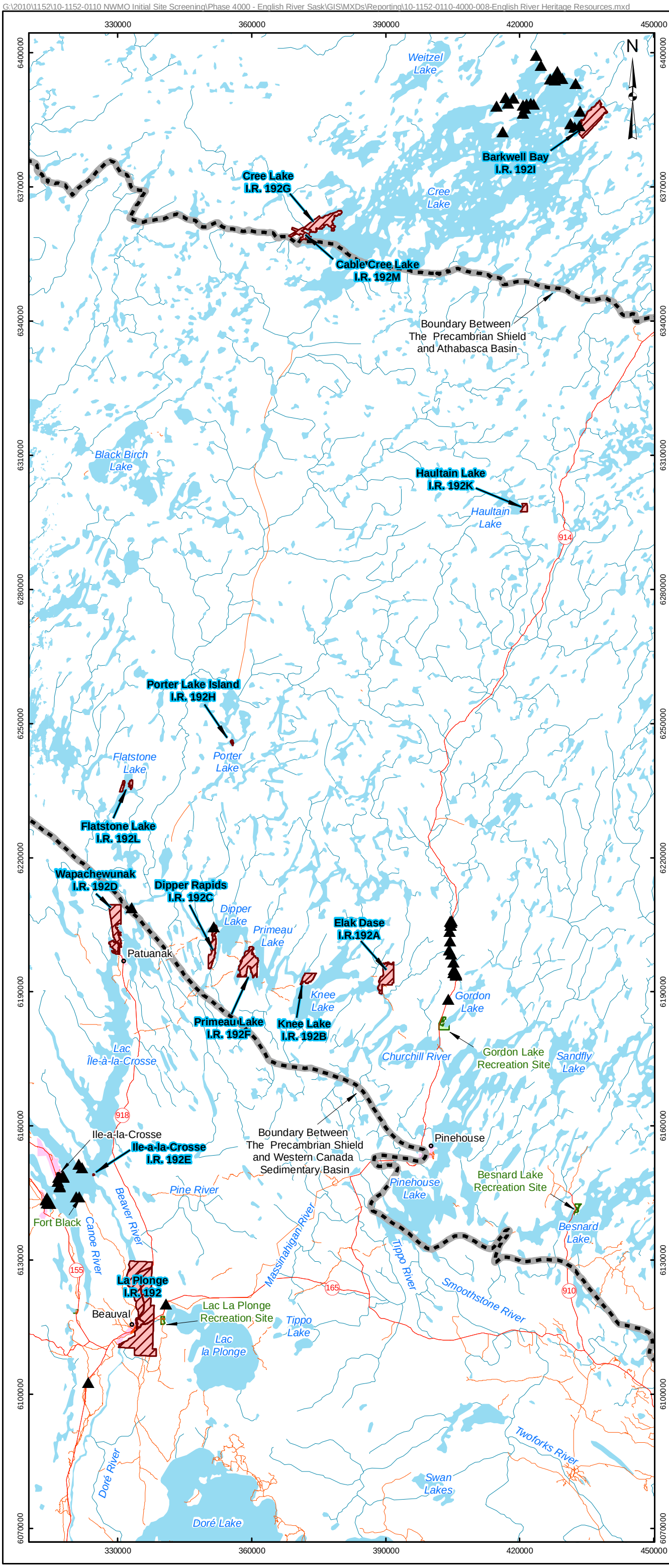
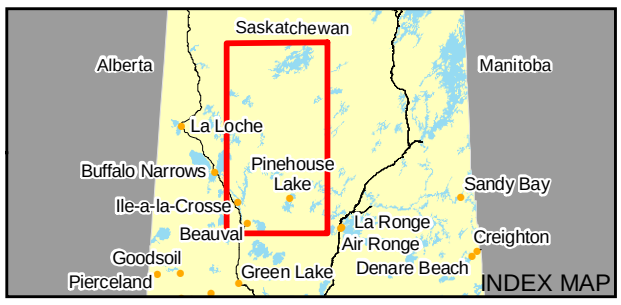



## LEGEND

- Community
- Highway
- Road
- Watercourse, Permanent
- Water Area, Permanent
- Urban Municipality
- Park and Recreation Area
- Indian Reserve
- Athabasca Basin Boundary
- Precambrian Shield Boundary
- Western Canada Sedimentary Basin Boundary
- Known Heritage Resource




## REFERENCE

DMTI Highways and Roads
Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Waterbody and Watercourse data courtesy of Information Services Corp. Saskatchewan Heritage Branch, Ministry of Tourism, Culture, Parks and Sport, 2010
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

15 7.5 0 15 30 45
SCALE 1:850,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Known Heritage Resources in the
English River First Nation Reserve Areas

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
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| DESIGN | | | FIGURE: 2.4 | |
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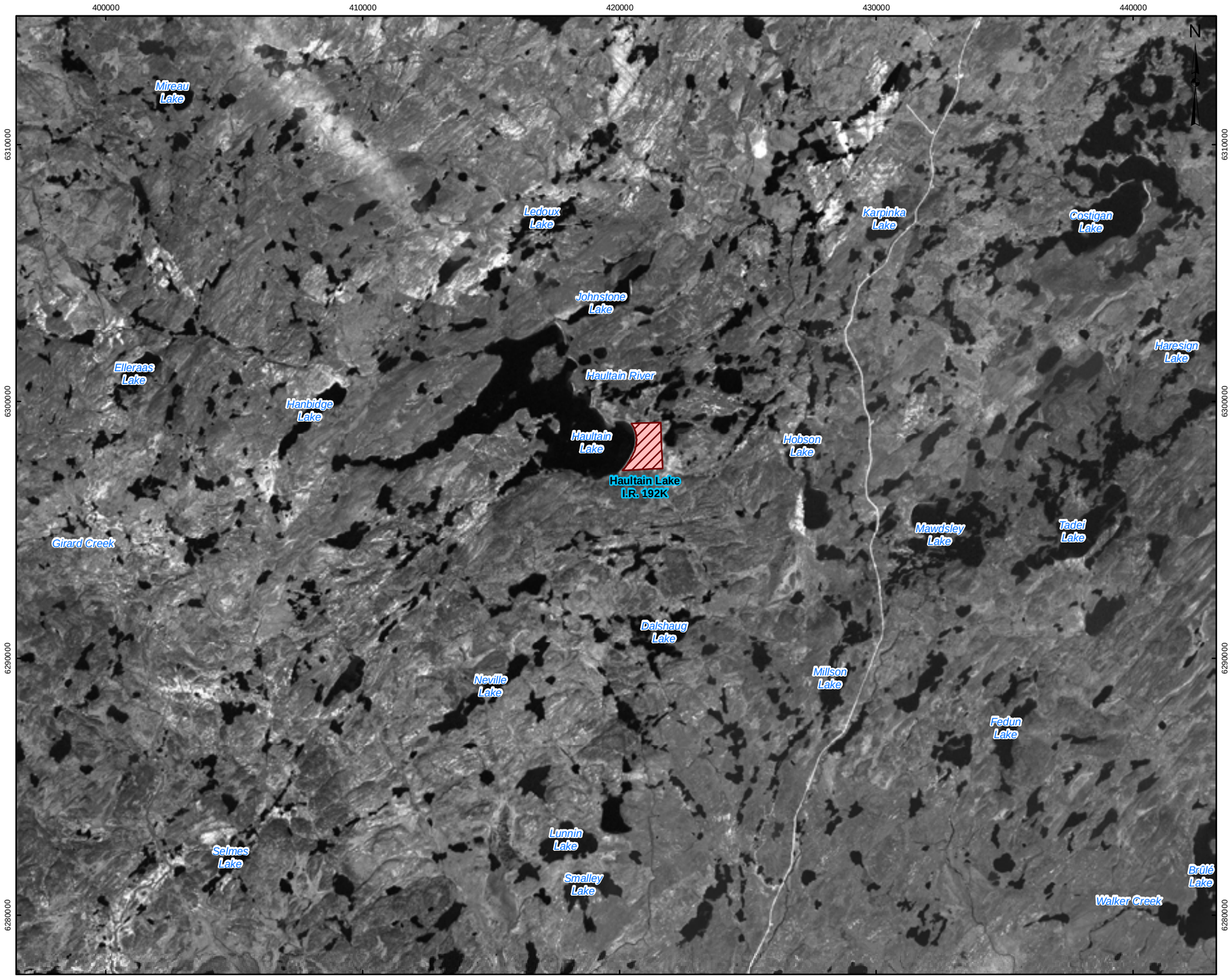


## LEGEND

- Community
- Indian Reserve

## REFERENCE

SPOT Imagery courtesy of GeoBase
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

3 1.5 0 3 6 9
SCALE 1:150,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River, Saskatchewan

TITLE
Satellite Imagery of the English River First Nation Reserve Areas - Canadian Shield (Haultain Lake Area)

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 2.5 | |
| GIS | MGD | 18 Nov. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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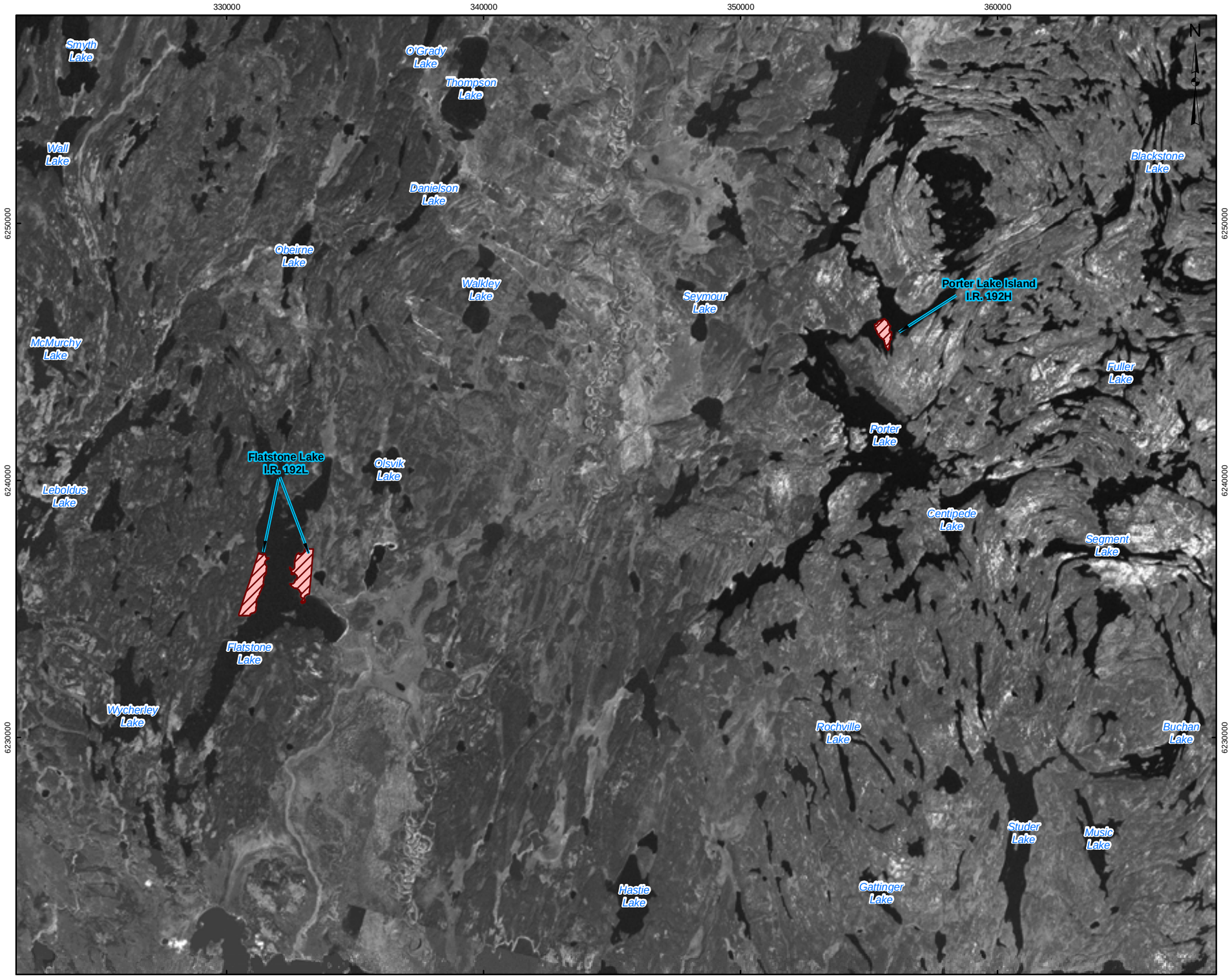


## LEGEND

- Community
- Indian Reserve

## REFERENCE

SPOT Imagery courtesy of GeoBase
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

3 1.5 0 3 6 9
SCALE 1:150,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River, Saskatchewan

TITLE
Satellite Imagery of the English River First Nation Reserve Areas - Canadian Shield (Flatstone and Porter Lakes Area)

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 2.6 | |
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| REVIEW | GS | 11 Feb. 2011 | | |

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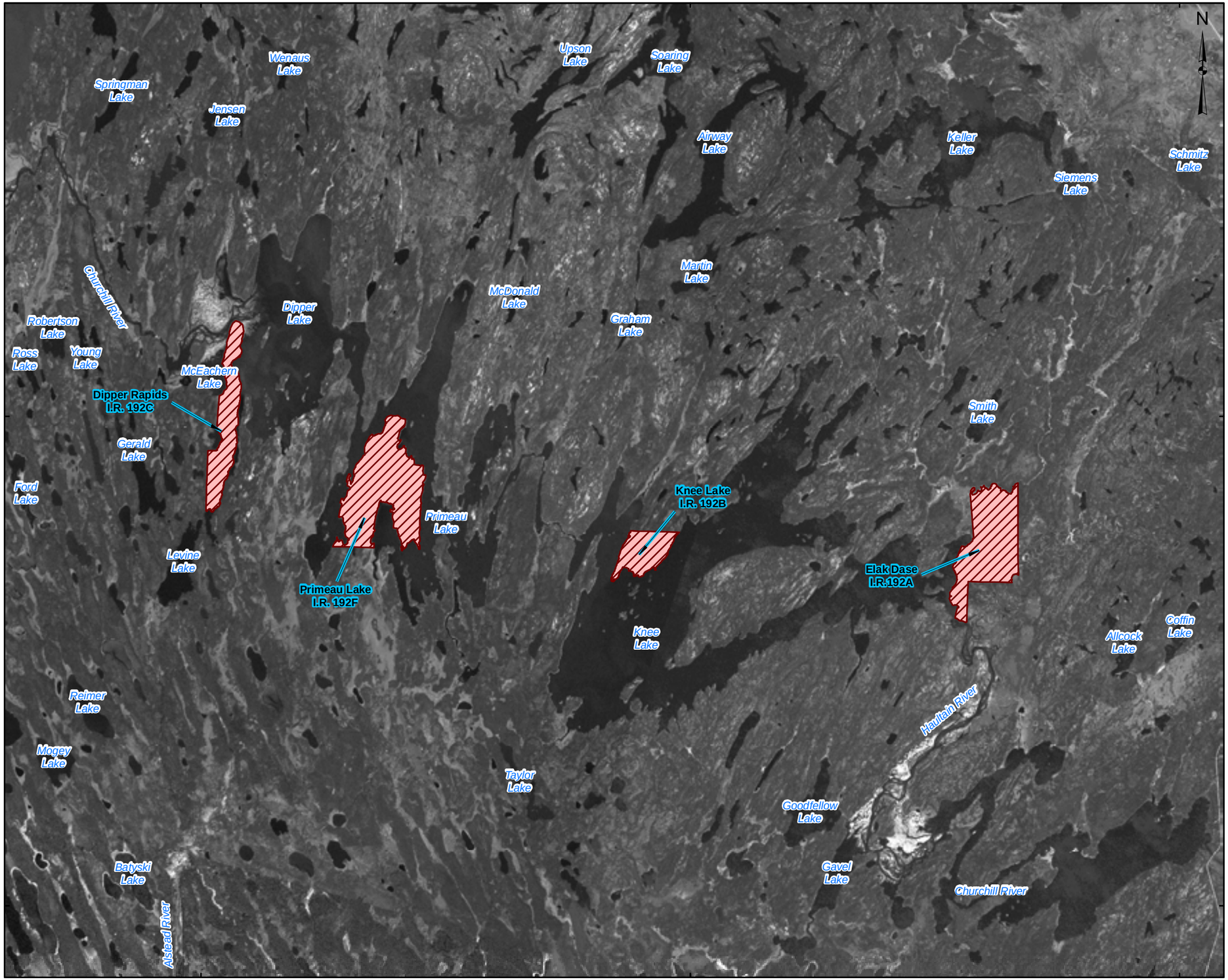


## LEGEND

- Community
- Indian Reserve

## REFERENCE

SPOT Imagery courtesy of GeoBase
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

4 2 0 4 8 12
SCALE 1:200,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River, Saskatchewan

TITLE
Satellite Imagery of the English River First Nation Reserve Areas - Canadian Shield (Dipper, Primeau and Knee Lakes Area)

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 2.7 | |
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| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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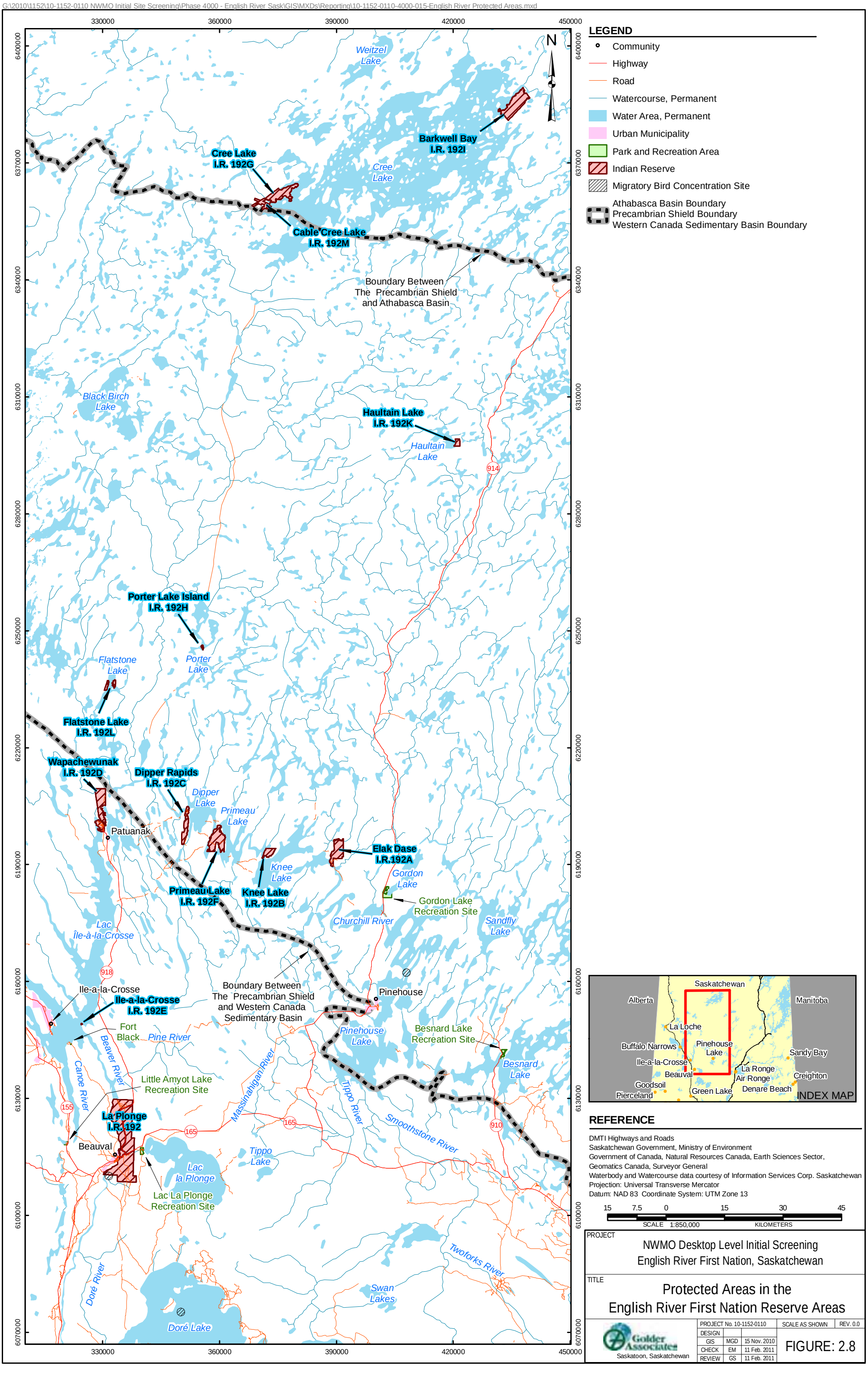

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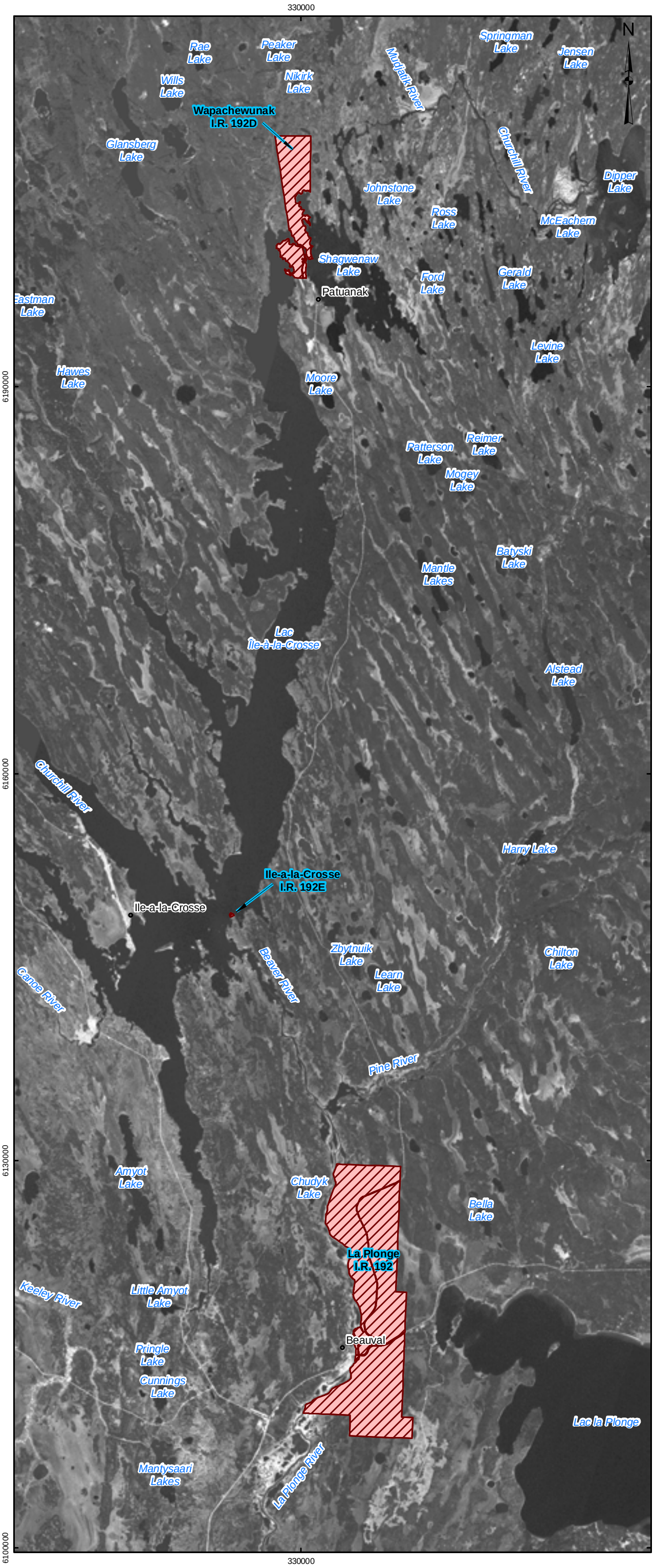
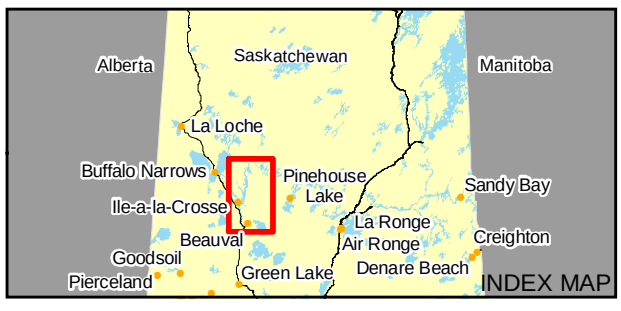



## LEGEND

- Community
- Indian Reserve




## REFERENCE

SPOT Imagery courtesy of GeoBase
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

5 2.5 0 5 10 15
SCALE 1:300,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Satellite Imagery of the English River First Nation Reserve Areas - Western Canada Sedimentary Basin

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
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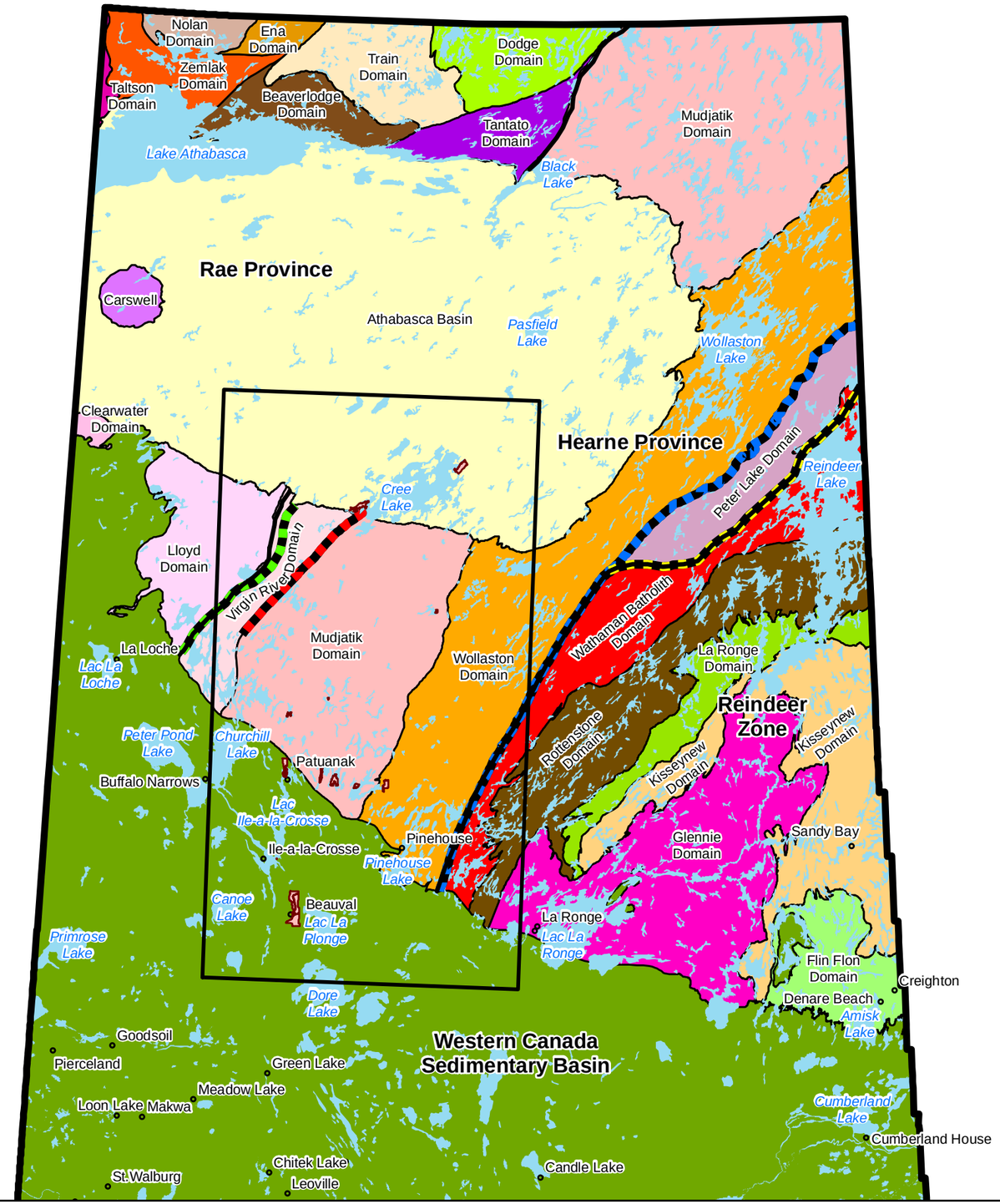


N

## LEGEND

- Community
- Precambrian Geological Province
- Needle Falls Shear Zone
- Virgin River Shear Zone (Snowbird Tectonic Zone)
- Parker Lake Shear Zone
- Cable Bay Shear Zone
- Water Area, Permanent
- Regional Area of Interest
- Indian Reserve
- Western Canada Sedimentary Basin

**Lithotectonic Domain**

- Athabasca Basin
- Beaverlodge Domain
- Carswell Domain
- Clearwater Domain
- Dodge Domain
- Ena Domain
- Flin Flon Domain
- Glennie Domain
- Kisseynew Domain
- La Ronge Domain
- Lloyd Domain
- Mudjatik Domain
- Nolan Domain
- Peter Lake Domain
- Rottenstone Domain
- Taltson Domain
- Tantato Domain
- Train Domain
- Virgin River Domain
- Wathaman Batholith Domain
- Wollaston Domain
- Zemlak Domain

## REFERENCE

Geological Atlas of Saskatchewan,
Saskatchewan Energy and Resources
Government of Canada, Natural Resources Canada, Centre for Topographic Information, 2001
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

50 25 0 50 100 150
SCALE 1:3,000,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Geology of Northern Saskatchewan

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
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| DESIGN | | | FIGURE: 3.1 | |
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| REVIEW | GS | 11 Feb. 2011 | | |

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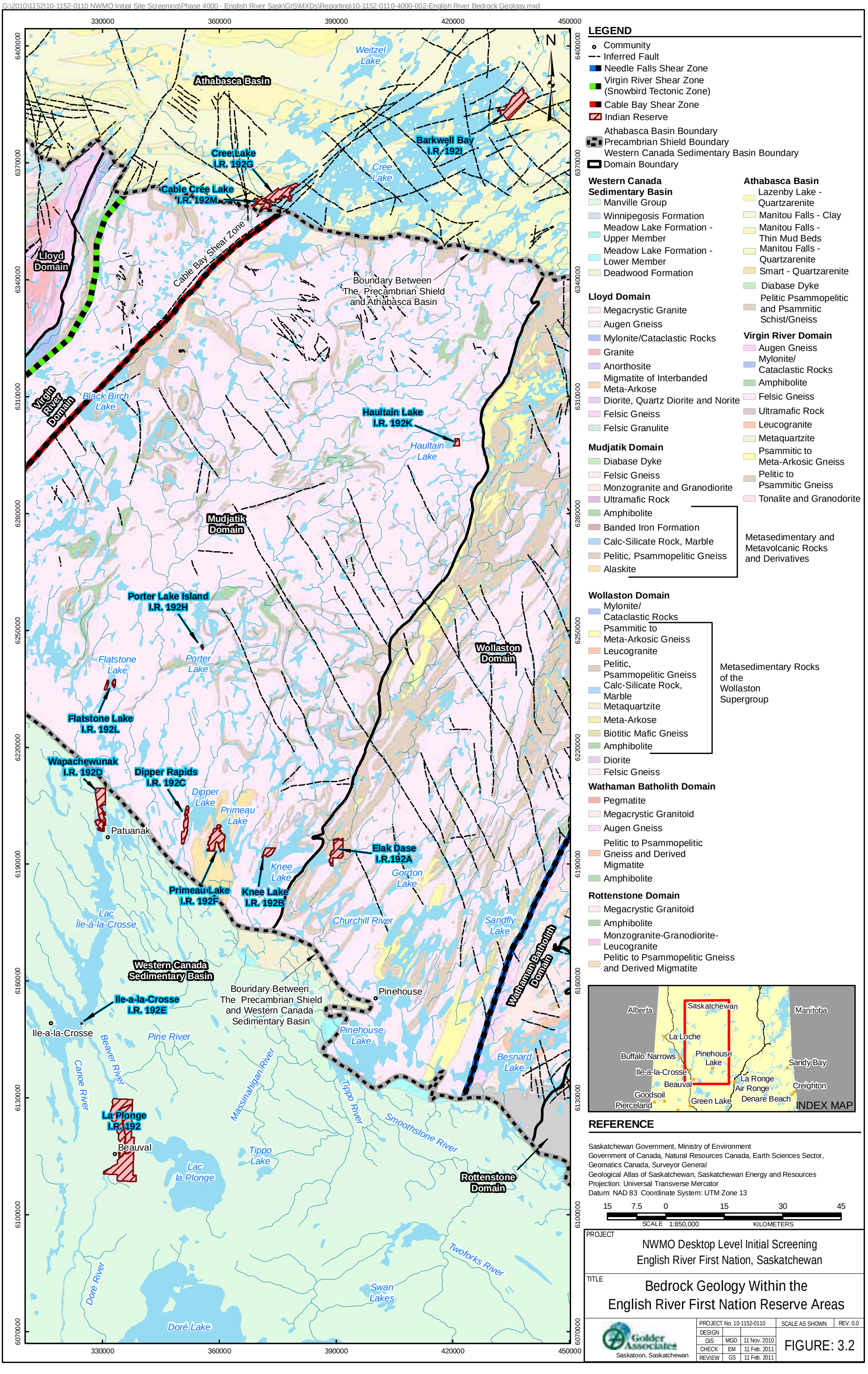

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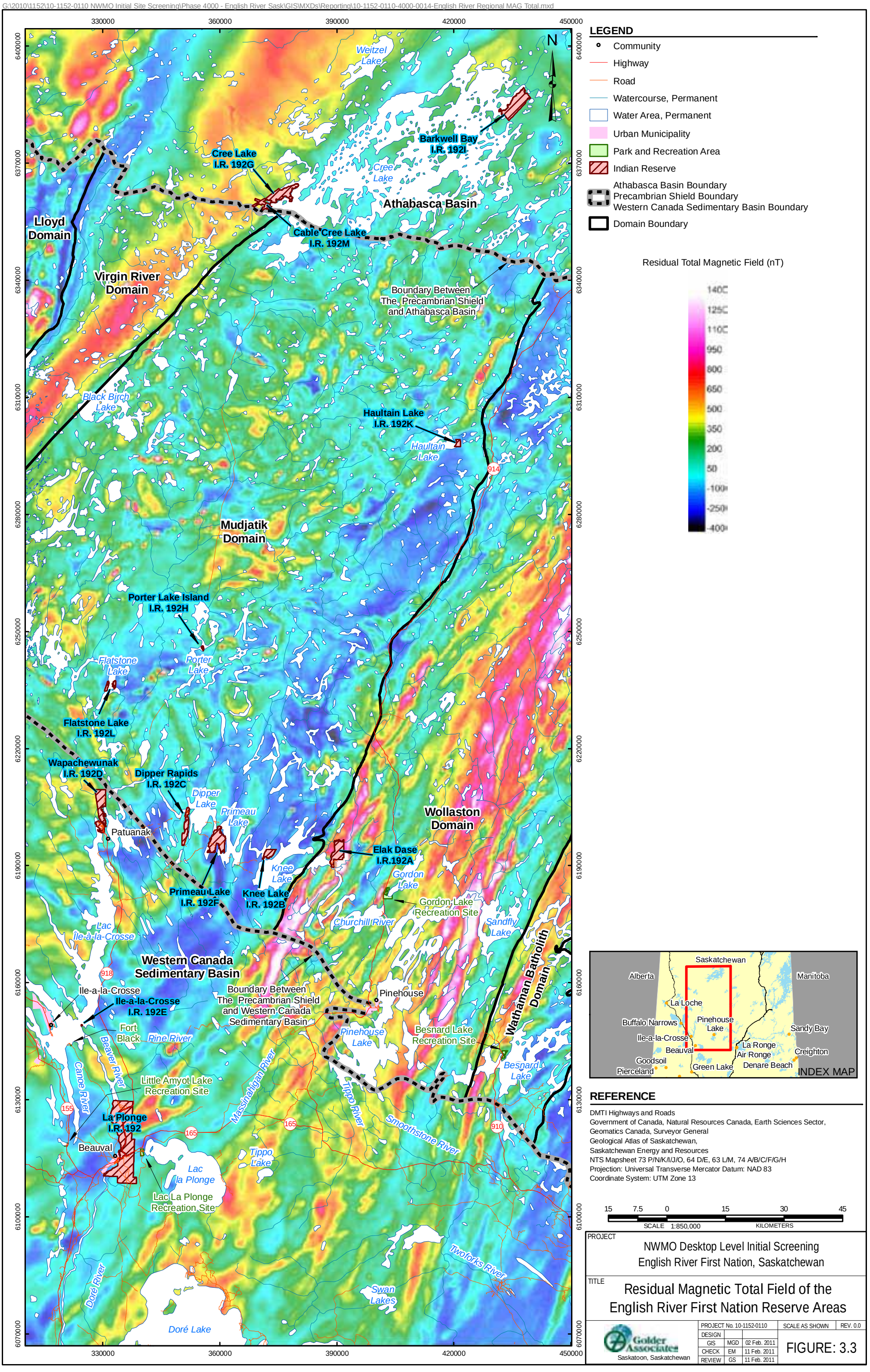

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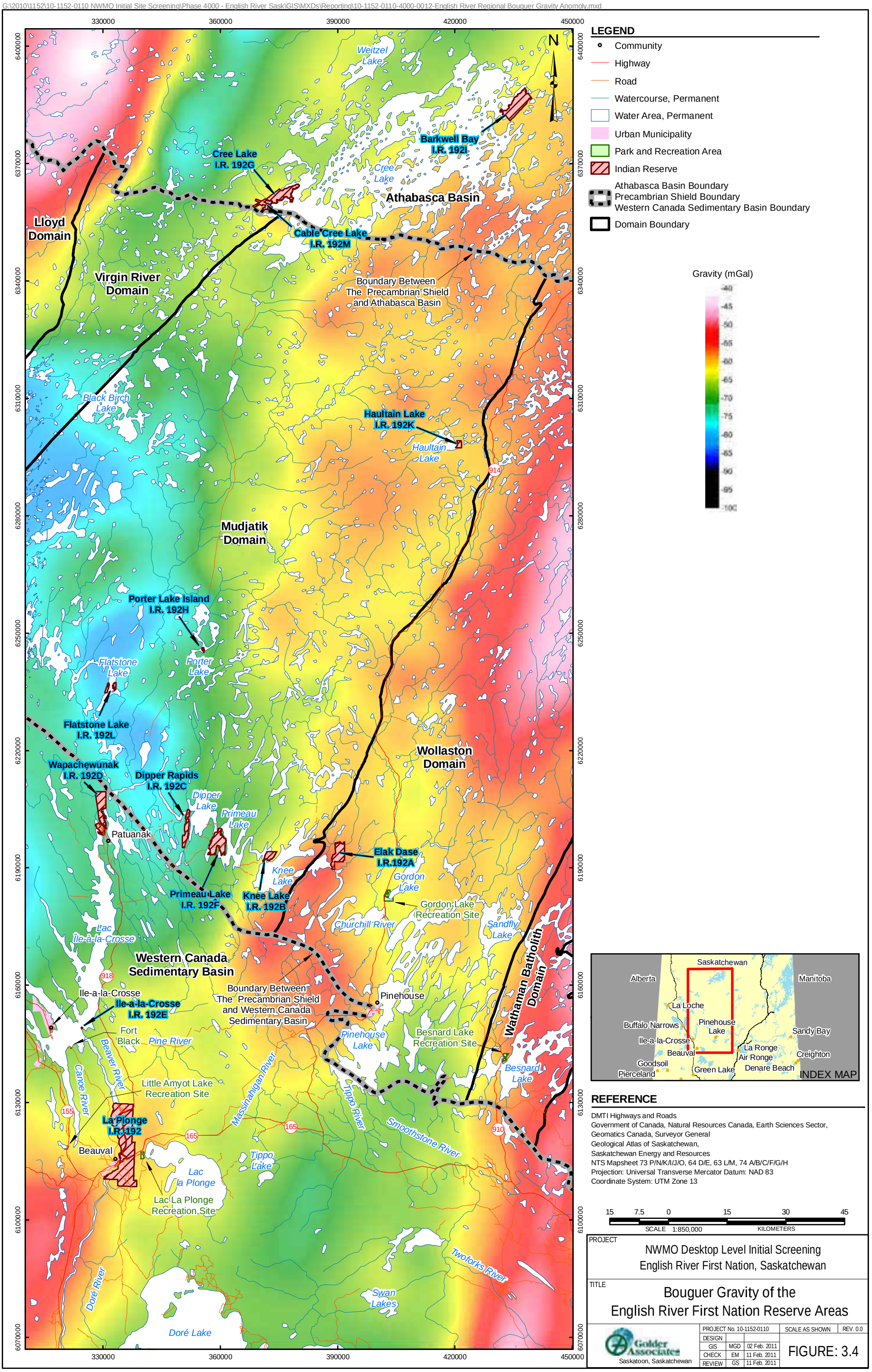

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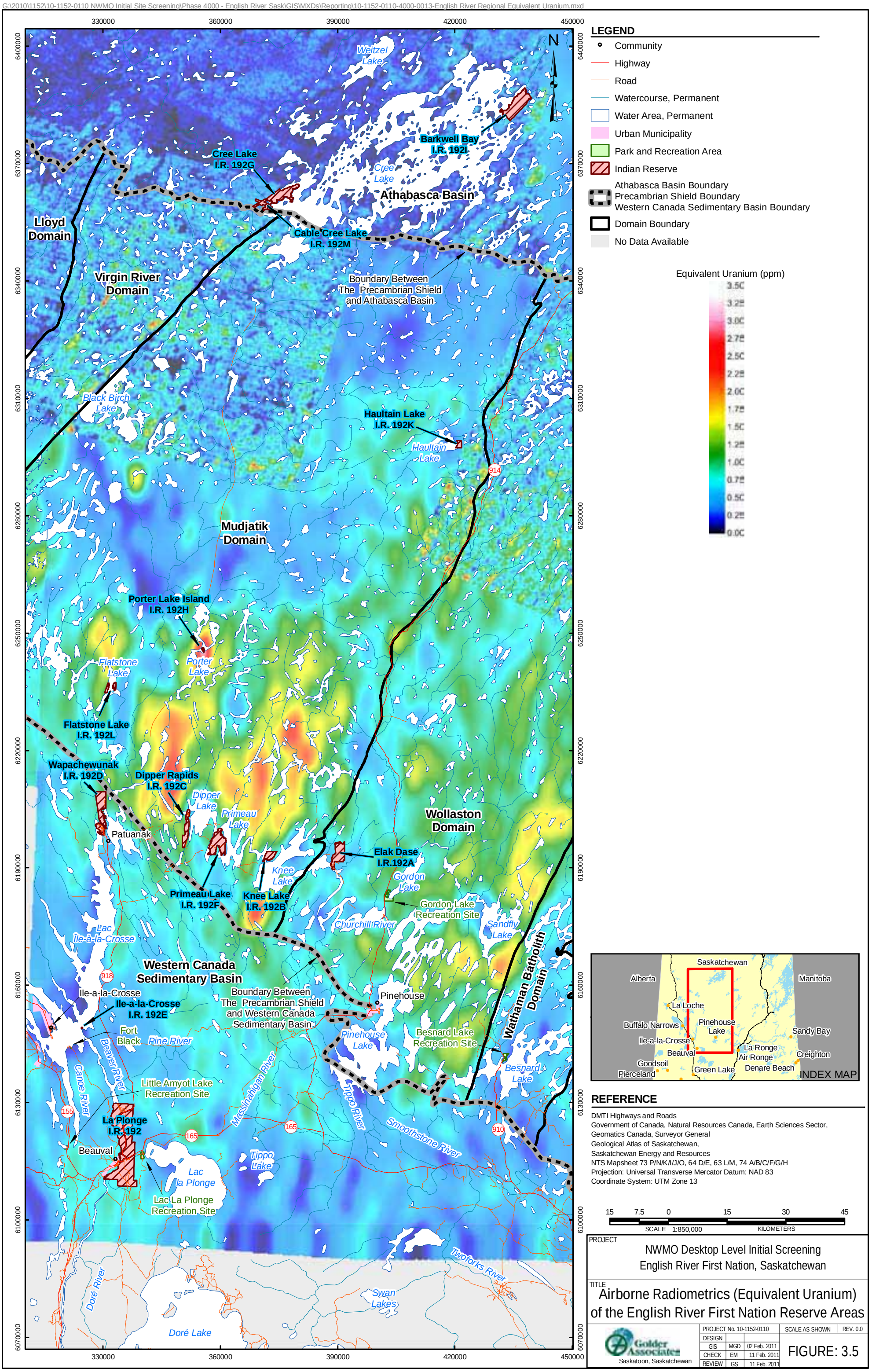

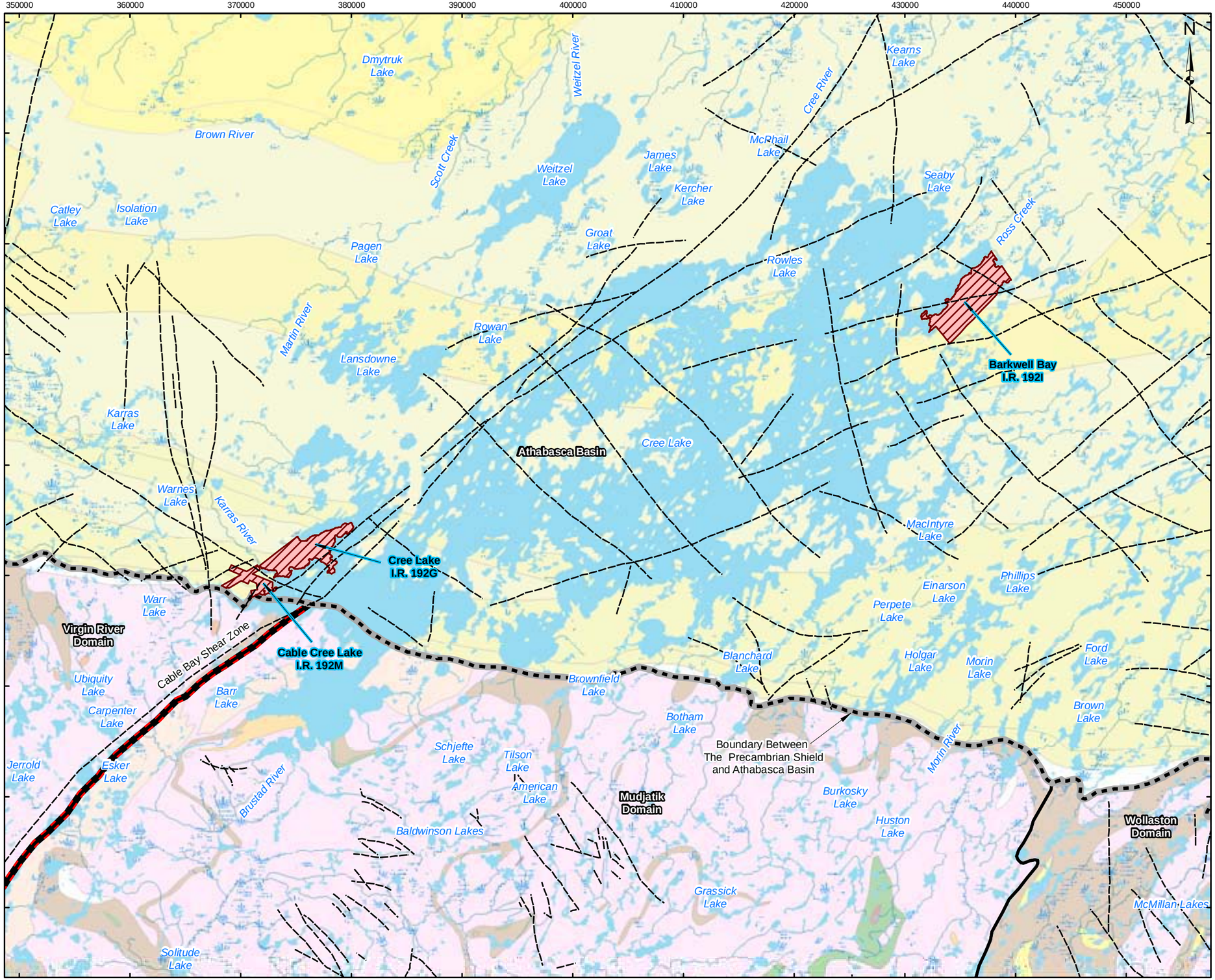


## LEGEND

- Community
- Inferred Fault
- Cable Bay Shear Zone
- Watercourse, Permanent
- Water Area, Permanent
- Wetland, Permanent
- Indian Reserve
- Athabasca Basin Boundary
- Precambrian Shield Boundary
- Western Canada Sedimentary Basin Boundary
- Domain Boundary

**Athabasca Basin**

- Lazenby Lake - Quartzarenite
- Manitou Falls - Clay
- Manitou Falls - Thin Mud Beds
- Manitou Falls - Quartzarenite

**Virgin River Domain**

- Felsic Gneiss
- Leucogranite
- Metaquartzite
- Pelitic to Psammitic Gneiss
- Tonalite and Granodorite

**Mudjatik Domain**

- Diabase Dyke
- Felsic Gneiss
- Monzogranite and Granodiorite
- Amphibolite
- Banded Iron Formation
- Pelitic, Psammopelitic Gneiss
- Alaskite

Metasedimentary and Metavolcanic Rocks and Derivatives

**Wollaston Domain**

- Psammitic to Meta-Arkosic Gneiss
- Pelitic, Psammopelitic Gneiss
- Calc-Silicate Rock, Marble
- Felsic Gneiss

Metasedimentary Rocks of the Wollaston Supergroup

## REFERENCE

Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Geological Atlas of Saskatchewan, Saskatchewan Energy and Resources
NTS Mapsheet 73 P/N/K/I/J/O, 64 D/E, 63 L/M, 74 A/B/C/F/G/H
Projection: Universal Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 13

5 2.5 0 5 10 15
SCALE 1:350,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
# English River First Nation Reserve Areas Athabasca Basin - Local Geology

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 3.6 | |
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| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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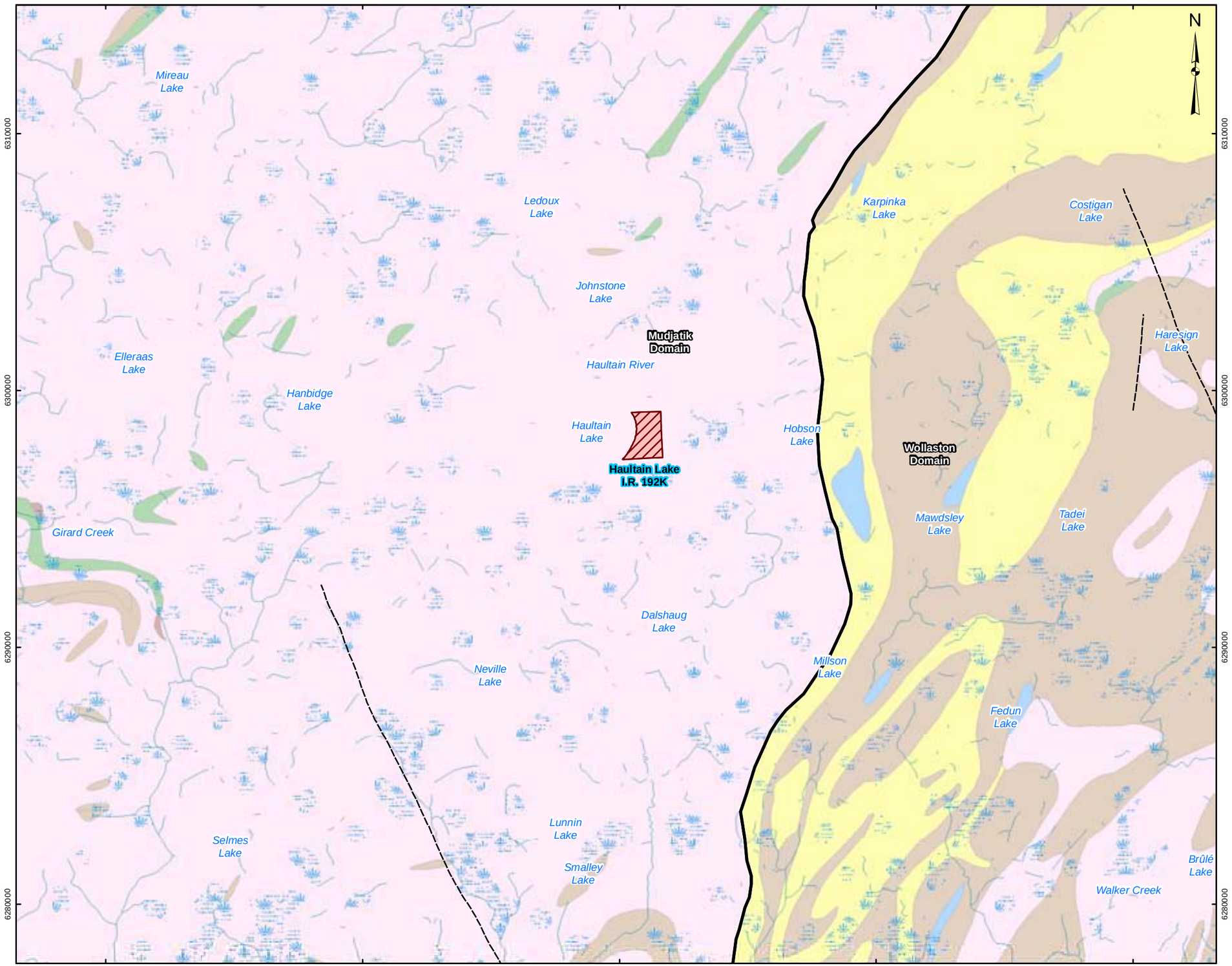


## LEGEND

- Community
- Inferred Fault
- Watercourse, Permanent
- Water Area, Permanent
- Wetland, Permanent
- Indian Reserve
- Domain Boundary

**Mudjatik Domain**

- Felsic Gneiss
- Amphibolite
- Banded Iron Formation
- Pelitic, Psammopelitic Gneiss

Metasedimentary and Metavolcanic Rocks and Derivatives

**Wollaston Domain**

- Psammitic to Meta-Arkosic Gneiss
- Pelitic, Psammopelitic Gneiss
- Calc-Silicate Rock, Marble
- Amphibolite
- Felsic Gneiss

Metasedimientary Rocks of the Wollaston Supergroup

## REFERENCE

Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Geological Atlas of Saskatchewan, Saskatchewan Energy and Resources
NTS Mapsheet 73 P/N/K/I/J/O, 64 D/E, 63 L/M, 74 A/B/C/F/G/H
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

3 1.5 0 3 6 9
SCALE 1:150,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
English River First Nation Reserve Areas - Canadian Shield - Local Geology (Haultain Lake Area)

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 3.7 | |
| GIS | MGD | 11 Nov. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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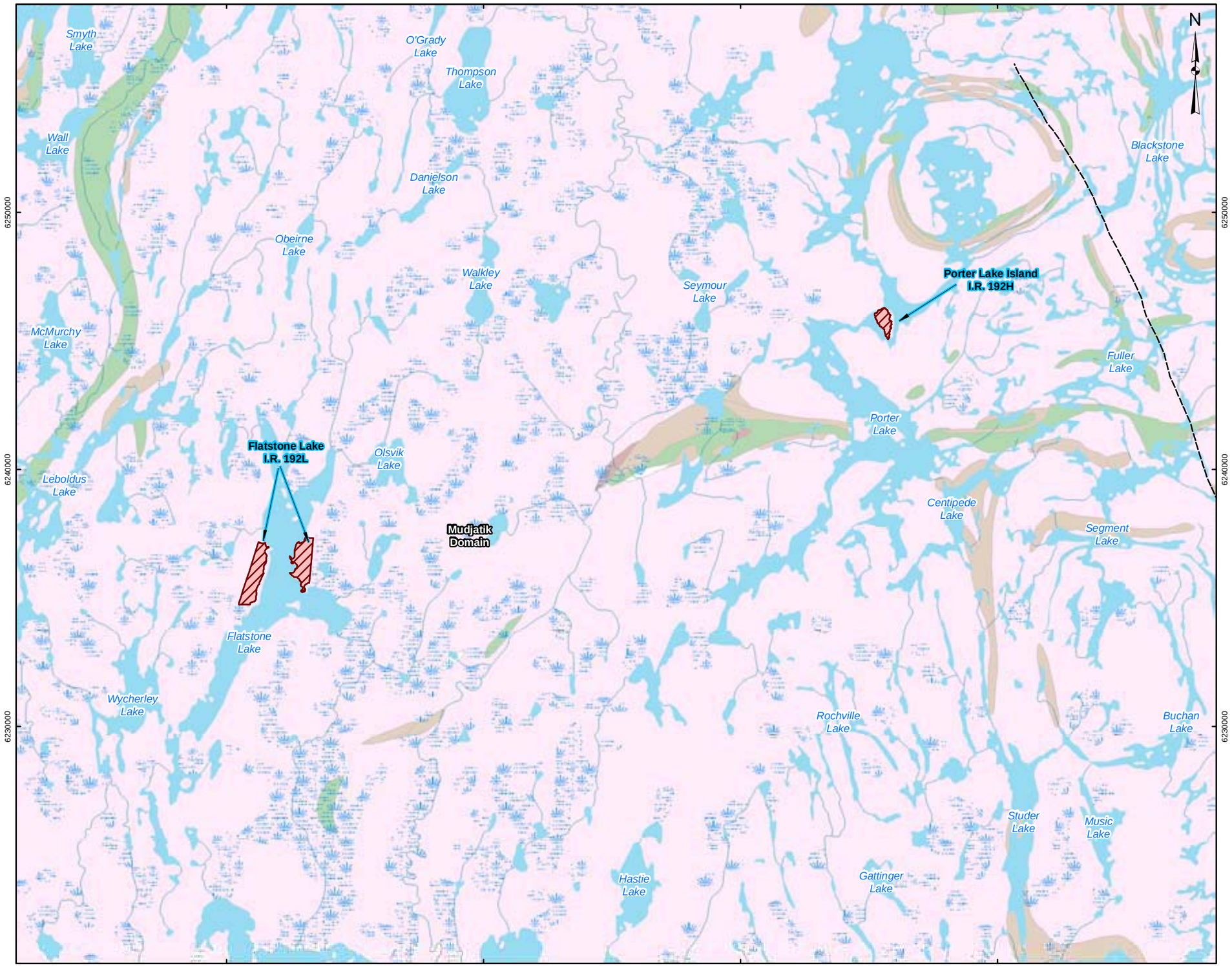



## LEGEND

- Community
- Inferred Fault
- Watercourse, Permanent
- Water Area, Permanent
- Wetland, Permanent
- Indian Reserve

**Mudjatik Domain**

- Felsic Gneiss
- Amphibolite
- Banded Iron Formation
- Pelitic, Psammopelitic Gneiss

Metasedimentary and Metavolcanic Rocks and Derivatives

## REFERENCE

Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Saskatchewan Energy and Resources
NTS Mapsheet 73 P/N/K/I/J/O, 64 D/E, 63 L/M, 74 A/B/C/F/G/H
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

3 1.5 0 3 6 9

SCALE 1:150,000 KILOMETERS

PROJECT

NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

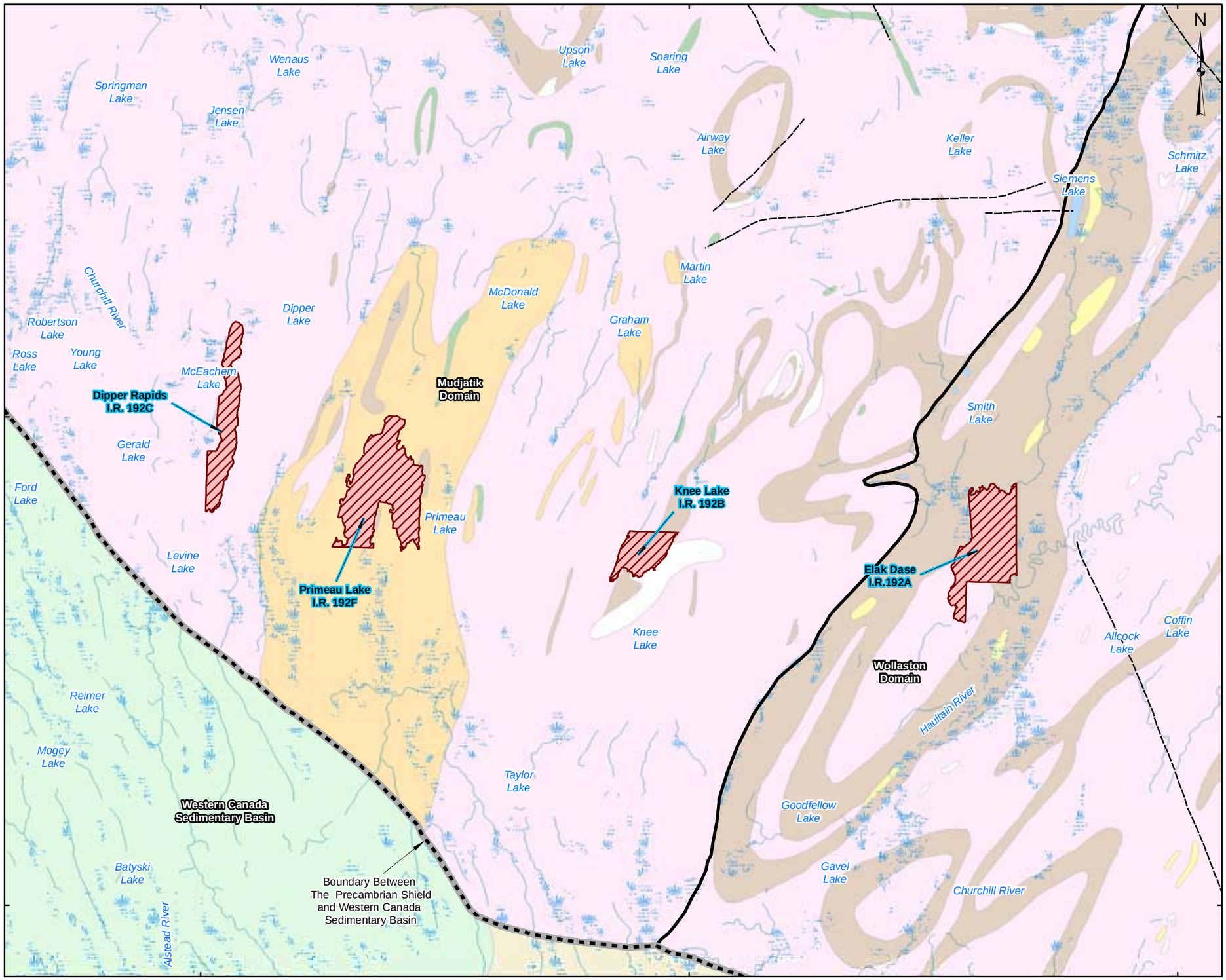
TITLE

English River First Nation Reserve Areas
- Canadian Shield -
Local Geology (Flatstone and Porter Lake Areas)

Golder Associates
Saskatoon, Saskatchewan

| | | | |
|---|---|---|---|
| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
| DESIGN | | | FIGURE: 3.8 |
| GIS | MGD | 11 Nov. 2010 | |
| CHECK | EM | 11 Feb. 2011 | |
| REVIEW | GS | 11 Feb. 2011 | |

G:\2010\1152\10-1152-0110 NWMO Initial Site Screening\Phase 4000 - English River Sask\GIS\MXDs\Reporting\10-1152-0110-4000- REGION 3 - English River Bedrock Geology.mxd




## LEGEND

- Community
- Inferred Fault
- Watercourse, Permanent
- Water Area, Permanent
- Wetland, Permanent
- Indian Reserve
- Athabasca Basin Boundary
- Precambrian Shield Boundary
- Western Canada Sedimentary Basin Boundary
- Domain Boundary

**Western Canada Sedimentary Basin**

- Manville Group
- Deadwood Formation

**Mudjatik Domain**

- Felsic Gneiss
- Amphibolite
- Pelitic, Psammopelitic Gneiss
- Alaskite

Metasedimentary and Metavolcanic Rocks and Derivatives

**Wollaston Domain**

- Psammitic to Meta-Arkosic Gneiss
- Pelitic, Psammopelitic Gneiss
- Calc-Silicate Rock, Marble

Metasedimentary Rocks of the Wollaston Supergroup

- Felsic Gneiss

## REFERENCE

Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Geological Atlas of Saskatchewan, Saskatchewan Energy and Resources
NTS Mapsheet 73 P/N/K/I/J/O, 64 D/E, 63 L/M, 74 A/B/C/F/G/H
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

4 2 0 4 8 12
SCALE 1:200,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
English River First Nation Reserve Areas
- Canadian Shield -
Local Geology (Dipper, Primeau, Knee Lakes Area)

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 3.9 | |
| GIS | MGD | 11 Nov. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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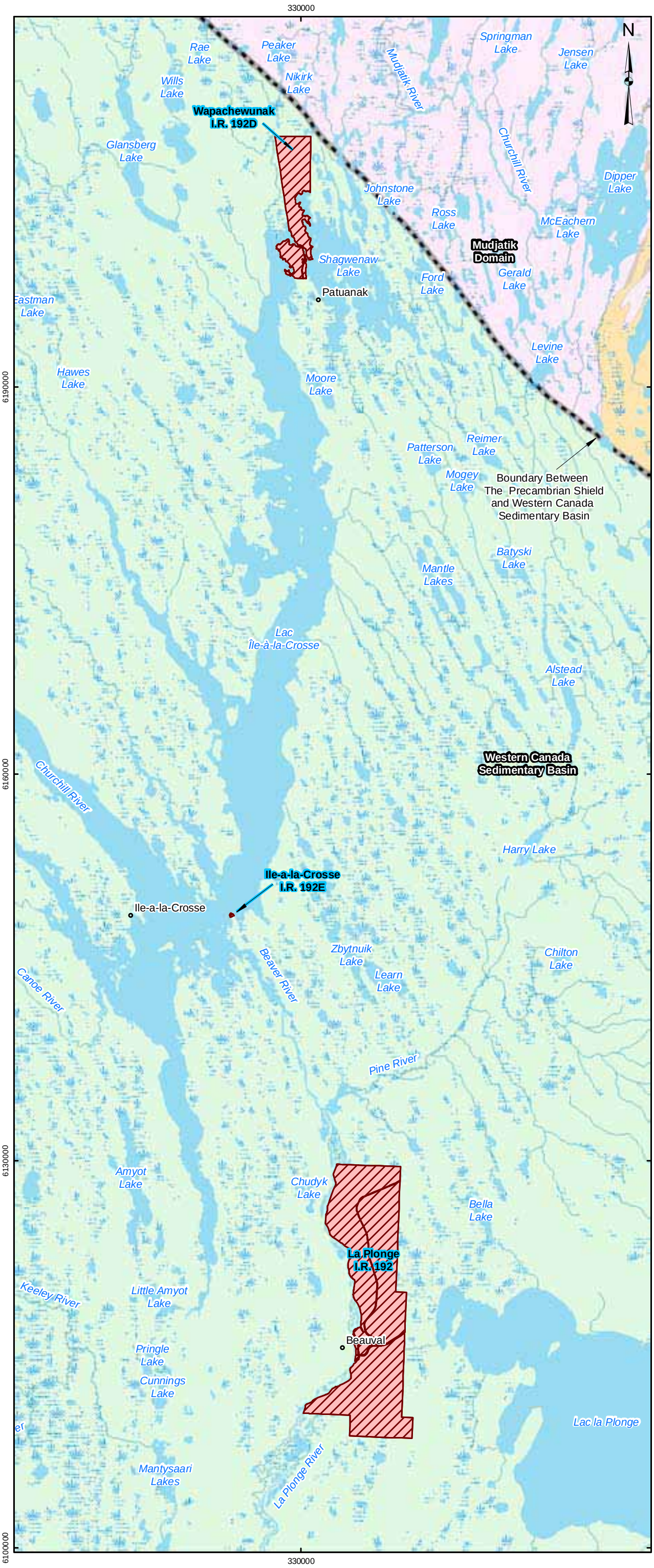



## LEGEND

- Community
- Watercourse, Permanent
- Water Area, Permanent
- Wetland, Permanent
- Indian Reserve
- Athabasca Basin Boundary
- Precambrian Shield Boundary
- Western Canada Sedimentary Basin Boundary
- Domain Boundary

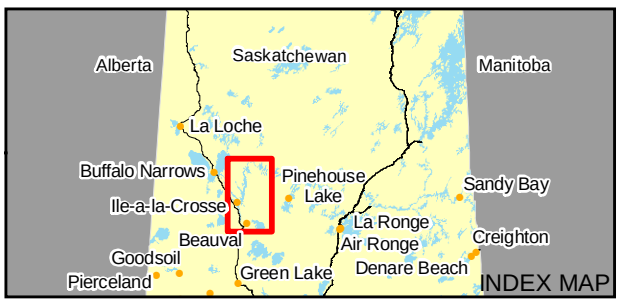
**Western Canada Sedimentary Basin**

- Manville Group

**Mudjatik Domain**

- Felsic Gneiss
- Pelitic, Psammopelitic Gneiss
- Alaskite

Metasedimentary and Metavolcanic Rocks and Derivatives




## REFERENCE

Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Geological Atlas of Saskatchewan, Saskatchewan Energy and Resources
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

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SCALE 1:300,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
English River First Nation Reserve Areas - Western Canada Sedimentary Basin - Local Geology

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 3.10 | |
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| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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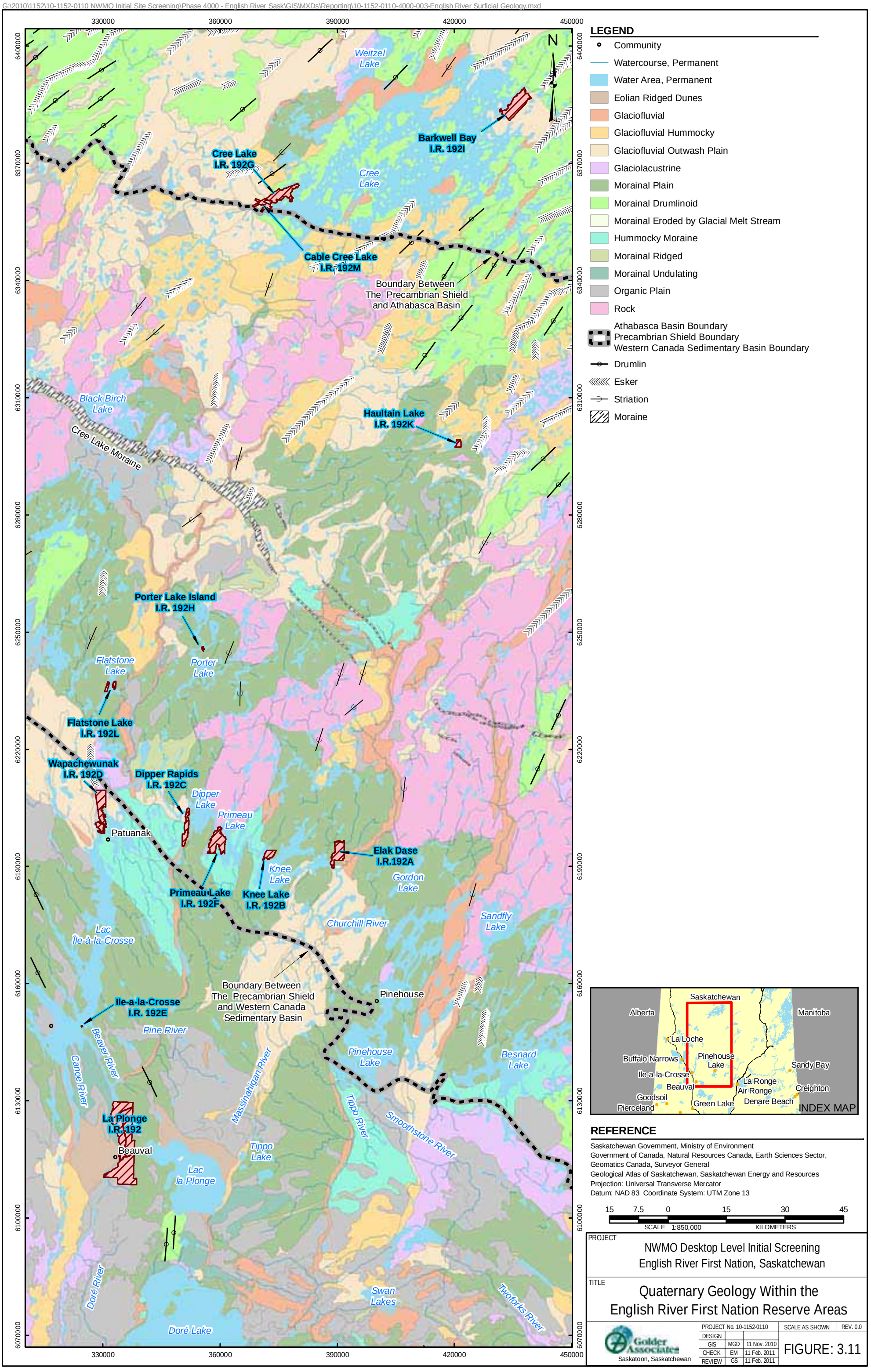

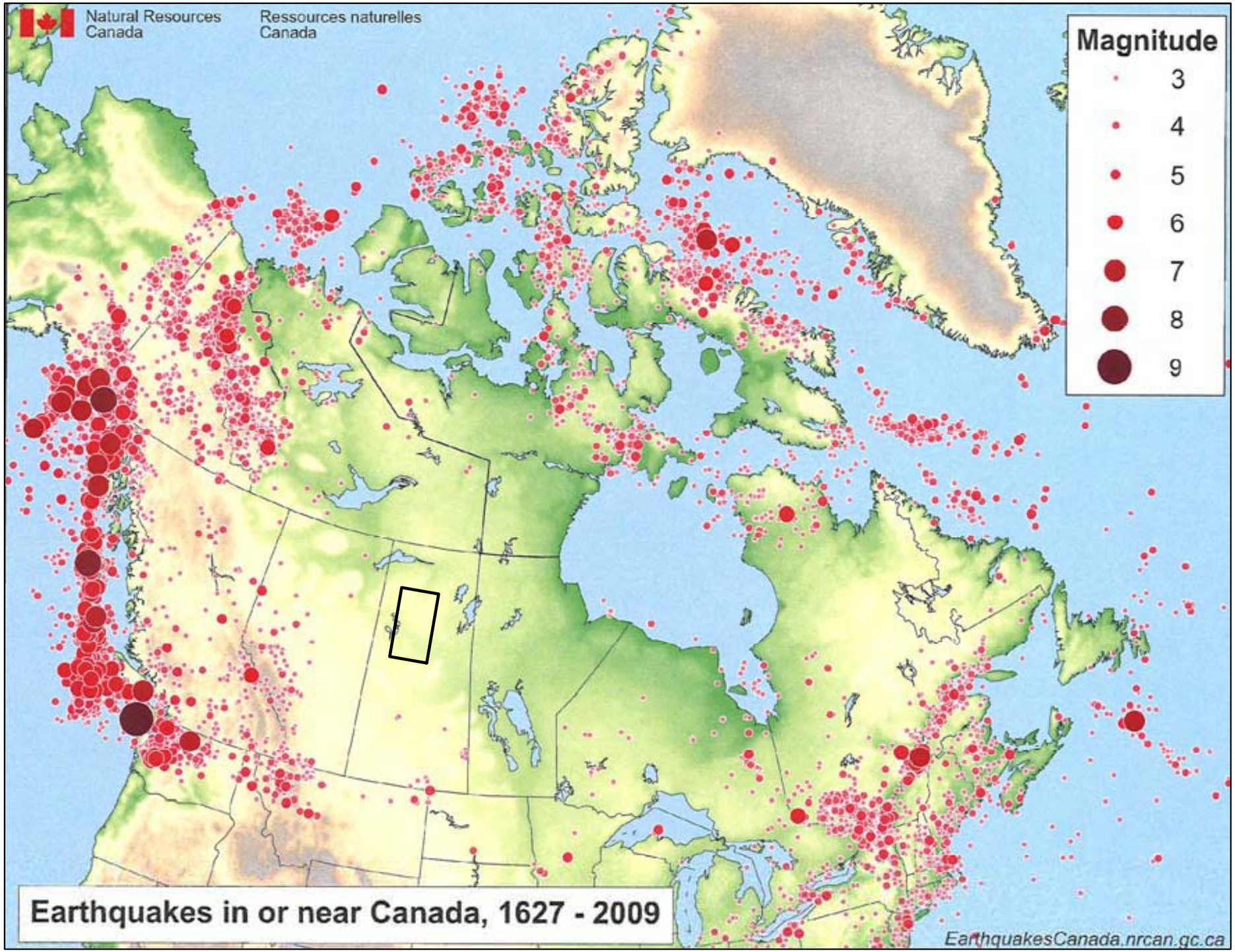


**LEGEND**

Area Encompassing English River First Nation Reserves

**REFERENCE**

EarthquakesCanada.nrcan.gc.ca
Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 13

250 125 0 250 500 750
SCALE 1:20,000,000 KILOMETRES

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Earthquakes in or Near Canada
1627 - 2009

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 3.12 | |
| GIS | MGD | 18 Oct. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |

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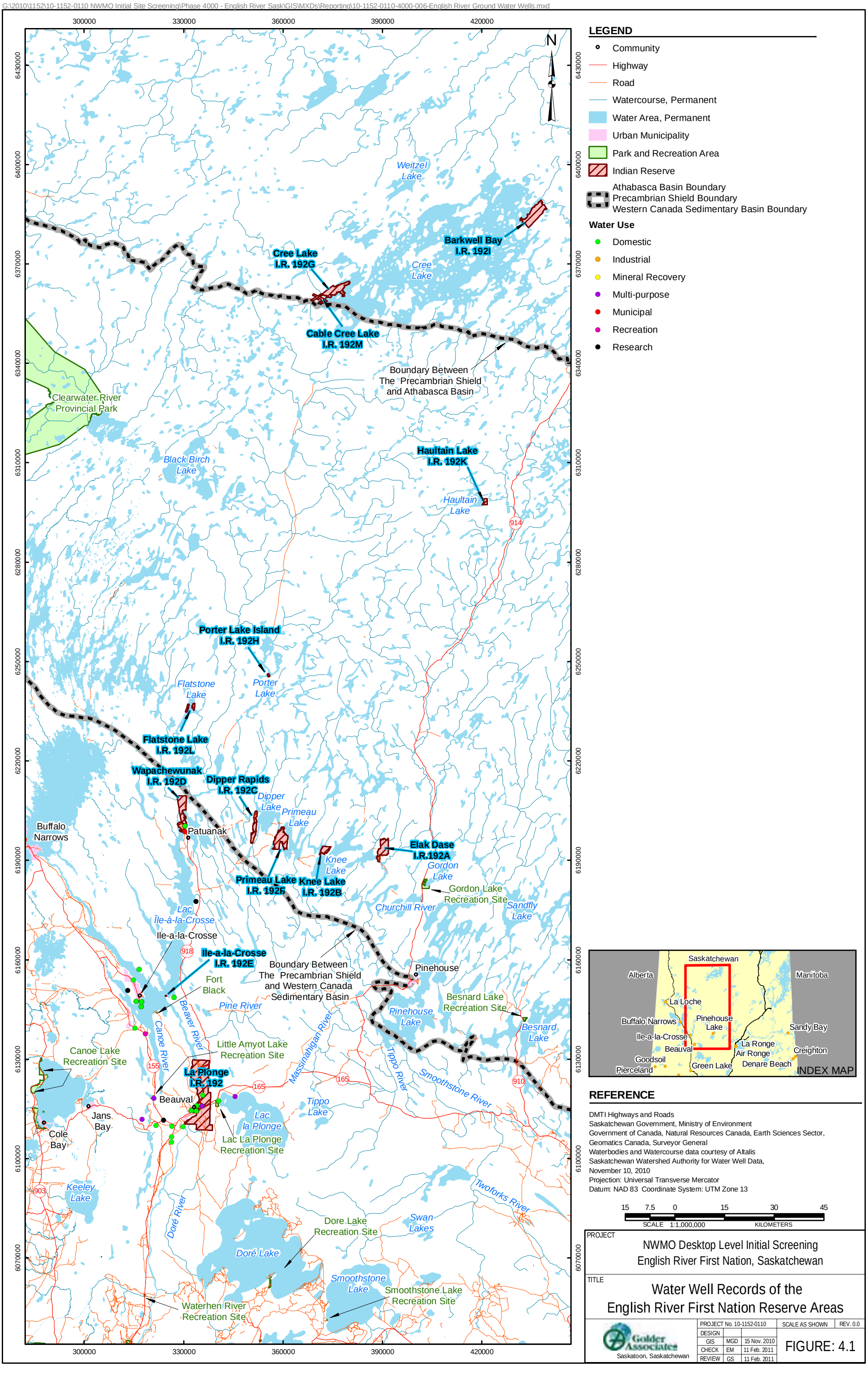

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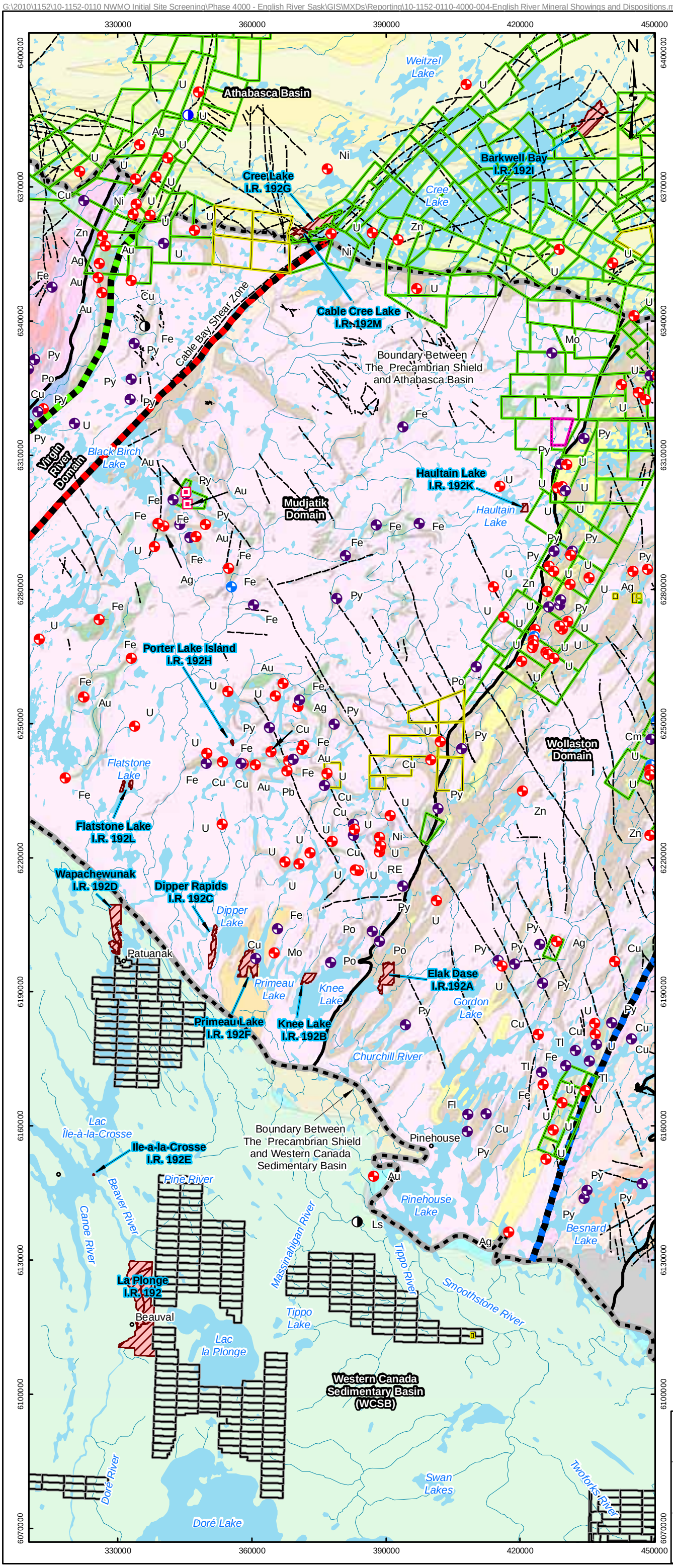



## LEGEND

- Community
- Watercourse, Permanent
- Water Area, Permanent
- Inferred Fault
- Needle Falls Shear Zone
- Virgin River Shear Zone (Snowbird Tectonic Zone)
- Cable Bay Shear Zone
- Indian Reserve
- Athabasca Basin Boundary
  Precambrian Shield Boundary
  Western Canada Sedimentary Basin Boundary
- Domain Boundary

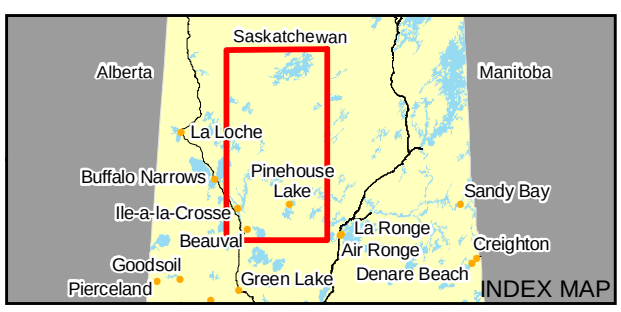
**Mineral Status**

- Mineral Deposit
- Mineral Deposit - Reserve
- Developed Mineral Prospect
- Showing Mineral Potential
- Showing Mineral Potential - Reserve
- Showing Mineral Potential - No Assays

**Mineral Disposition Status**

- Active
- Lapsed - Not Open
- Pending
- Active Coal Disposition

Ag - Silver
Au - Gold
Fe - Iron
Ls - Limestone
Mo - Molybdenum
Ne - Nepheline
Ni - Nickel
Pb - Lead
Po - Pyrrhotite
Py - Pyrite
RE - Rare Earth
Tl - Tourmaline
U - Uranium
Zn - Zinc




## REFERENCE

Saskatchewan Government, Ministry of Environment
Government of Canada, Natural Resources Canada, Earth Sciences Sector, Geomatics Canada, Surveyor General
Geological Atlas of Saskatchewan, Saskatchewan Energy and Resources
Projection: Universal Transverse Mercator
Datum: NAD 83
Coordinate System: UTM Zone 13

15 7.5 0 15 30 45
SCALE 1:850,000 KILOMETERS

PROJECT
NWMO Desktop Level Initial Screening
English River First Nation, Saskatchewan

TITLE
Mineral Showings and Dispositions Within the English River First Nation Reserve Areas

Golder Associates
Saskatoon, Saskatchewan

| PROJECT No. 10-1152-0110 | | | SCALE AS SHOWN | REV. 0.0 |
|---|---|---|---|---|
| DESIGN | | | FIGURE: 5.1 | |
| GIS | MGD | 11 Nov. 2010 | | |
| CHECK | EM | 11 Feb. 2011 | | |
| REVIEW | GS | 11 Feb. 2011 | | |