



NUCLEAR WASTE MANAGEMENT ORGANIZATION  
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

August 9, 2012

The Corporation of the Township of Huron-Kinloss  
P.O. Box 130, 21 Queen St.  
Ripley, ON N0G 2R0

Attn: Ms. Mary Rose Walden, CAO

**Re: Adaptive Phased Management Initial Screening – The Township of Huron-Kinloss**

Dear Ms. Walden,

Further to the Township of Huron-Kinloss' request to Learn More about the Adaptive Phased Management program and request for an initial screening, I am pleased to attach a report outlining the findings from the initial screening, as described in the Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel (May, 2010). As you know, the purpose of the initial screening in Step 2 of the process is to determine whether, based on readily-available information and five screening criteria, there are any obvious conditions that would exclude the Township of Huron-Kinloss 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 the Township of Huron-Kinloss from further consideration in the NWMO site selection process. The initial screening suggests that the Township comprises geological formations that are potentially suitable for hosting a deep geological repository for Canada's used nuclear fuel. It is important to note that this initial screening has not confirmed the suitability of your community. 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. 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 the Township of Huron-Kinloss 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, Huron-Kinloss as a whole community would need to clearly demonstrate that it is willing to host the repository in order for this project to proceed.

The next evaluation step would be to conduct a feasibility study as described in Step 3 of the site selection process. This feasibility study would focus on areas selected in collaboration with the community. As your community considers whether it is interested in advancing to the feasibility study phase, the NWMO encourages you to continue community discussion and further learning about the project. Support programs are available to assist your community to reflect on its long-term vision and whether this project is consistent with achieving that vision. Programs and resources are also available to engage your community residents in learning more about this project and becoming involved. We would be very pleased to provide further information about these programs.

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

Sincerely,



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

c. Mayor Mitch Twolan



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

**The Corporation of the Township of Huron-Kinloss**

Report



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

# **The Corporation of the Township of Huron-Kinloss**

**Prepared by:**

AECOM

300 – 300 Town Centre Boulevard  
Markham, ON, Canada L3R 5Z6  
[www.aecom.com](http://www.aecom.com)

905 477 8400 tel  
905 477 1456 fax

**Project Number:**

60247068-3

**Date:**

August, 2012



## AECOM Signatures

Report Prepared By:



---

Robin Frizzell, M.Sc., P.Geo  
Senior Geoscientist

Report Reviewed By:



---

Robert E.J. Leech, P.Geo.  
Practice Lead, Environment



## Executive Summary

On April 16, 2012, the Corporation of the Township of Huron-Kinloss 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 AECOM, to evaluate the potential suitability of the Township of Huron-Kinloss 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 Township of Huron-Kinloss from further consideration in the site selection process. The initial screening focused on the areas within the boundaries of the Township of Huron-Kinloss. At the request of the Township of Huron-Kinloss Council, the area west of Highway 21 was not included in the initial screening. The Council expects future development will likely occur along the lakeshore and wishes to provide future councils with the full range of development options for this area. Areas within neighbouring municipalities were also not included in the initial screening.

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 Township of Huron-Kinloss from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Township that are potentially suitable for safely hosting a deep geological repository. Potentially suitable host formations include the Upper Ordovician shale and limestone units that comprise the geology of the Township at typical repository depths.

It is important to note that the intent of this initial screening is not to confirm the suitability of the Township of Huron-Kinloss to host a deep geological repository, but rather to provide early feedback on whether there are known reasons to exclude it from further consideration. Should the community of Huron-Kinloss remain interested in continuing with the site selection process, more detailed studies would be required to confirm and demonstrate whether the Township of Huron-Kinloss contains 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.

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.

A brief summary of the assessment against each of the initial screening criterion is provided below.

### Availability of Land

Review of available mapping and satellite imagery indicates that the Township of Huron-Kinloss contains limited constraints that would prevent the development of the repository's surface facilities. The Township contains sufficient land to accommodate the surface and underground facilities associated with the repository and could be accessible for construction and field investigation activities.

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

The Township of Huron-Kinloss contains sufficient land outside of protected areas, provincial parks and national parks to accommodate the repository's facilities. There are no provincial or national parks within the Township of

Huron-Kinloss. One conservation area, the Lucknow Waterworks Conservation Area, exists in the community of Lucknow, along the southern boundary of the Township. There are seven provincially designated protected areas within or partly within the Township of Huron-Kinloss including the Greenock Swamp, the Kinloss Creek Wetland, Dickies Creek Wetland, Anderson's Creek Wetland Complex, Wingham Wetland Complex, Teeswater Wetland Complex and the Lothian-Lake Warren Shorelines. These areas cover approximately 6% of the Township and are classified as Provincially Significant Wetlands and Earth Science Area of Natural Scientific Interest (ANSI). The Point Clark Lighthouse National Historic Site is located along the shore of Lake Huron. There are only three known archeological sites within the boundaries of the Township of Huron-Kinloss. These three sites are localized and occupy a very small area.

The absence of other designated or protected areas and cultural heritage sites 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 (approximately 500 m) for the Township of Huron-Kinloss. The Ontario Ministry of Environment Water Well Records indicates that no potable water supply wells are known to exploit aquifers at typical repository depths in the Township of Huron-Kinloss or anywhere else in southern Ontario. Water wells in the Township obtain water from overburden or shallow bedrock aquifers at depths ranging from 3 to 111 m. Experience in similar geological settings across southern Ontario suggests that the potential for deep groundwater resources at repository depths is low throughout the Township of Huron-Kinloss. The absence of groundwater resources at repository depth would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

### **Absence of Economically Exploitable Natural Resources as Known Today**

Based on the review of readily available information, the Township of Huron-Kinloss contains land, free of known economically exploitable natural resources. Seven historic exploration wells that were drilled within the Township of Huron-Kinloss resulted in one recorded oil show, no oil or gas production, and all wells have been abandoned. The potential for existing and new conceptual hydrocarbon plays would have to be examined during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process. There is no record of metallic mineral production in the past, and no exploration potential for metallic minerals has been identified within the Township of Huron-Kinloss. Known non-metallic mineral resources in the Township of Huron-Kinloss include bedrock-derived crushed stone, natural surficial sand and gravel resources, salt and building stone. Current licensed non-metallic mineral extraction in the Township of Huron-Kinloss is limited to shallow sand and gravel resources.

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

Based on the review of available geological and hydrogeological information, the Township of Huron-Kinloss comprises large areas of land that do not contain obvious known geological and hydrogeological conditions that would make the area unsuitable for hosting a deep geological repository. The initial screening indicates that the sedimentary rock sequence beneath the Township of Huron-Kinloss is potentially suitable for hosting a deep geological repository. Potentially suitable host formations include the deep Upper Ordovician shale and limestone units that are laterally extensive and thick enough beneath the entire Township.



# Table of Contents

	page
<b>1. Introduction.....</b>	<b>1</b>
1.1 Background.....	1
1.2 Objectives and Approach for Conducting Initial Screenings .....	1
<b>2. Physical Geography.....</b>	<b>3</b>
2.1 Location .....	3
2.2 Topography.....	3
2.3 Drainage .....	3
2.4 Protected Areas .....	3
2.4.1 Parks and Reserves .....	3
2.4.2 Heritage Sites .....	4
<b>3. Geology and Seismicity.....</b>	<b>5</b>
3.1 Regional Geology .....	5
3.1.1 Regional Geological Setting .....	5
3.1.2 Precambrian Crystalline Basement Geology.....	5
3.1.3 Regional Sedimentary Bedrock Stratigraphy .....	6
3.2 Local Sedimentary Bedrock Geology of the Township of Huron-Kinloss.....	9
3.2.1 Stratigraphy .....	9
3.3 Deformation and Metamorphism .....	11
3.3.1 Tectonic History .....	11
3.3.2 Fault History.....	13
3.3.3 Diagenesis .....	13
3.3.4 Karst .....	14
3.4 Geomechanical Properties .....	15
3.5 Quaternary Geology .....	15
3.5.1 Quaternary Overburden Thickness .....	16
3.5.2 Glacial Erosion.....	16
3.6 Neotectonic Activity .....	16
3.7 Seismicity.....	17
<b>4. Hydrogeology.....</b>	<b>18</b>
4.1 Groundwater Wells .....	18
4.2 Deep Groundwater System .....	18
4.3 Hydrogeochemistry.....	19
<b>5. Economic Geology.....</b>	<b>20</b>
5.1 Hydrocarbon Resources .....	20
5.2 Metallic Mineral Resources.....	20
5.3 Non-Metallic Mineral Resources.....	21
5.3.1 Sand and Gravel.....	21
5.3.2 Bedrock Resources .....	21
<b>6. Initial Screening Evaluation .....</b>	<b>22</b>
6.1 Screening Criterion 1: Land Availability.....	22
6.2 Screening Criterion 2: Protected Areas .....	23

6.3	Screening Criterion 3: Known Groundwater Resources at Repository Depth.....	24
6.4	Screening Criterion 4: Known Natural Resources .....	25
6.5	Screening Criterion 5: Unsafe Geological or Hydrogeological Features .....	26
6.5.1	Safe Containment and Isolation .....	26
6.5.2	Long-Term Stability.....	28
6.5.3	Potential for Human Intrusion .....	28
6.5.4	Amenability to Construction and Site Characterization .....	29
<b>7.</b>	<b>Initial Screening Findings.....</b>	<b>30</b>
<b>8.</b>	<b>References .....</b>	<b>31</b>

## List of Figures

Figure 2.1	Township of Huron-Kinloss and Surrounding Area
Figure 2.2	Satellite Imagery of the Township of Huron-Kinloss
Figure 2.3	Physiographic Regions of the Township of Huron-Kinloss and the Surrounding Area
Figure 2.4	Digital Elevation Model (DEM) of the Township of Huron-Kinloss and the Surrounding Area
Figure 2.5	Drainage Features of the Township of Huron-Kinloss
Figure 3.1	Geological Features of Southern Ontario
Figure 3.2	Geology of Southern Ontario
Figure 3.3	Geological Cross-Section
Figure 3.4	Gravity map of Southern Ontario
Figure 3.5	Residual Total Magnetic Field of Southern Ontario
Figure 3.6	Bedrock Geology and Oil and Gas Wells of the Township of Huron-Kinloss and the Surrounding Area
Figure 3.7	Karst Mapping of Southern Ontario
Figure 3.8	Quaternary Geology of the Township of Huron-Kinloss and the Surrounding Area
Figure 3.9	Overburden Thickness of the Township of Huron-Kinloss and the Surrounding Area
Figure 3.10	Earthquake Map of Canada 1627-2010
Figure 3.11	Earthquake Map of Southern Ontario 1985-2012
Figure 4.1	Water Well Records of the Township of Huron-Kinloss
Figure 5.1	Non-Metallic Bedrock Resources of the Township of Huron-Kinloss and the Surrounding Area

## List of Tables

Table 3.1	Stratigraphy of Southern Ontario (Armstrong and Carter, 2010) .....	7
Table 3.2	Subcrop Geological Unit and Final Well Completion Unit for Oil and Gas Wells within the Township of Huron-Kinloss .....	10
Table 3.3	Stratigraphy Derived from Oil and Gas Exploration Well OGSRL #F012061 (1956) in the Township of Huron-Kinloss (Itasca Canada and AECOM, 2011, after OGSRL, 2006) .....	11
Table 3.4	Timetable of Major Tectonic Events in Southern Ontario .....	12
Table 4.1	MOE Water Well Record Details.....	18

# 1. Introduction

On April 16, 2012 the Corporation of the Township of Huron-Kinloss 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 AECOM, as part of Step 2 in the site selection process to evaluate the potential suitability of the Township of Huron-Kinloss against five screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Township of Huron-Kinloss. At the request of the Township of Huron-Kinloss Council, the area west of Highway 21 was not included in the initial screening. The Council expects future development will likely occur along the lakeshore and wishes to provide future councils with the full range of development options for this area. Areas within neighbouring municipalities were also not included in the initial screening.

## 1.1 Background

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

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

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

## 1.2 Objectives and Approach for Conducting Initial Screenings

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

1. The site must have enough available land of sufficient size to accommodate the surface and underground facilities.
2. This available land must be outside of protected areas, heritage sites, provincial parks and national parks.

3. This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.
4. This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.
5. This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the safety factors outlined in Section 6 of the Site Selection Document (NWMO, 2010).

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

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

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

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

## 2. Physical Geography

### 2.1 Location

The Township of Huron-Kinloss is situated within Bruce County in southern Ontario, between Owen Sound and Goderich, along the Lake Huron shoreline (see index map of Figure 2.1). Satellite imagery for the Township of Huron-Kinloss (Spot 5, taken in 2006) is presented on Figure 2.2. The Township is approximately 442 km<sup>2</sup> in size and includes the towns of Ripley and Lucknow. The largest community in the Township of Huron-Kinloss is the Town of Ripley, which is located in the central part of the township, and hosts the Municipal offices for the Township (Figure 2.2).

### 2.2 Topography

The Township of Huron-Kinloss is located in the Western St. Lawrence Lowlands physiographic region, a low-relief, gently undulating land surface (see index map of Figure 2.3). Figure 2.3 shows the detailed physiographic regions of the Township of Huron-Kinloss and surrounding areas.

The western part of the Township of Huron-Kinloss lies in the Huron Slope physiographic region, while the eastern part of the Township lies in the Horseshoe Moraines physiographic region. The Huron Fringe physiographic region occupies a small strip of land on the westernmost side of the Township, along the Lake Huron shoreline, and a small area of the Teeswater Drumlin field is present in the southeast corner. The Township is covered primarily with Quaternary glacial deposits, and numerous small lakes, streams, and wetlands areas are found throughout.

The Digital Elevation Model (DEM) for the Township of Huron-Kinloss is presented on Figure 2.4. The terrain in the Township is dominantly low-relief and slopes steadily downwards towards Lake Huron from a maximum of 336 metres above sea level (mASL) in the southeast corner to a minimum of 176 mASL along the western shoreline (Figure 2.4). Slightly higher relief is observed in the Horseshoe Moraines Physiographic region in the eastern side of the Township.

### 2.3 Drainage

Surface water drainage for the Township of Huron-Kinloss is shown in Figure 2.5. Drainage is generally westward into Lake Huron (Figure 2.4). The Township of Huron-Kinloss is located primarily within the Penetangore sub-watershed of the Western Georgian Bay and Eastern Lake Huron sub-basins. The far eastern and southeastern portion of the Township is part of the Saugeen sub-watershed and the Maitland sub-watershed, respectively.

The most prominent drainage features in the Township of Huron-Kinloss are the South Pine River and the Eighteen Mile River. These rivers, and the tributaries that feed them, flow east to west across the Township and discharge into Lake Huron. The eastern quarter of the Township is occupied by numerous wetlands and wetland complexes, and the western extent of the Greenock Swamp crosses into the Township in the northeast corner (Figure 2.5).

### 2.4 Protected Areas

#### 2.4.1 Parks and Reserves

There are no provincial or national parks within the Township of Huron-Kinloss (Figure 2.1). The nearest park is Inverhuron Provincial Park, located approximately 16 km north the Township along Lake Huron. One conservation area, the Lucknow Waterworks Conservation Area (0.6 ha), exists within the Township of Huron-Kinloss and is located in the community of Lucknow, along the southern boundary of the Township (Figure 2.1).

There are 7 provincially designated protected areas within the Township of Huron-Kinloss comprising the Greenock Swamp, the Kinloss Creek Wetland, the Dickies Creek Wetland, Anderson's Creek Wetland Complex, the Lothian-Lake Warren Shorelines and parts of the Teeswater and Wingham wetland complexes (Figure 2.1). The Teeswater Wetland Complex and the Wingham Wetland Complex encroach into the east and southeast portions of the Township. These designated protected areas cover approximately 5% of the area of the Township and are classified as Provincially Significant Wetlands and an Area of Natural Scientific Interest (ANSI), as shown on Figure 2.1 (Provincial Policy Statement, 2005). The Lothian-Lake Warren Shorelines Earth Science ANSI is a glacial lake feature located along the southern boundary of the Township and is approximately 3 km<sup>2</sup> in size. The Greenock Swamp is one of the largest wetland areas in southern Ontario with an area of about 90 km<sup>2</sup> and is primarily outside of the eastern boundary of the Township of Huron-Kinloss. Four (4) small locally significant wetlands are also found within the Township, as shown in Figures 2.1 and 2.5. These include the West Kinlough, Hayes Lake, Westford and Stewart Swamp complexes.

The presence and function of other natural features and areas, such as significant woodlands, significant valleylands or significant wildlife habitats (Provincial Policy Statement, 2005; Bruce County Official Plan, 2011) will be addressed during subsequent site evaluation stages, if the community remains interested in continuing to participate in the site selection process.

#### 2.4.2 Heritage Sites

The cultural heritage screening examined known archaeological and historic sites in the Township of Huron-Kinloss and surrounding areas, using the Ontario Archaeological Sites Database maintained by the Ontario Ministry of Tourism, Culture and Sport (Ontario Ministry of Tourism and Culture, undated). There are about one hundred and thirty two (132) registered archaeological within a radius of 40 km around the Township of Huron-Kinloss; the majority lie near the shores of Lake Huron. Three (3) of these sites are found within the Township of Huron-Kinloss. These three sites are localized and occupy a very small area. They are of Euro-Canadian cultural affiliation: two are undetermined functions and the third is a building. Locations of known archaeological sites are not shown in maps within this report to comply with Ministry of Tourism and Culture publication guidelines.

Of the other 128 archaeological sites outside of the Township of Huron-Kinloss, 91 of the sites are of Aboriginal cultural affiliation such as a lodge, chipping station, burials or possible burials, fishing camps, and campsites and isolated find spots or undetermined. Thirty-seven of the archaeological sites in the areas outside of the Township of Huron-Kinloss are of Euro-Canadian affiliation such as domestic, residential or homestead sites, cabins or undetermined.

The potential for archaeological sites within the Township of Huron-Kinloss is high. Archaeological potential is established by determining the likelihood that archaeological resources may be present on a subject property. In archaeological potential modelling, a distance to water criterion of 300 m is generally employed for primary water courses, including lakeshores, rivers and large creeks, while a criterion of 200 m is applied to secondary water sources, including swamps and small creeks (Government of Ontario, 1997). A distance criterion of 100 m is placed on historic transportation routes.

Other cultural heritage constraints include the Point Clark Lighthouse National Historic Site, which is located along the shore of Lake Huron, and the Lucknow Townhall Heritage Site, which is a building located within the Town of Lucknow (Figure 2.1).

The absence of other protected areas and heritage sites 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.

## 3. Geology and Seismicity

This section provides a general overview of the geology and seismicity of southern Ontario, including the Township of Huron-Kinloss and surrounding areas, focusing on information that is most relevant to this initial screening.

### 3.1 Regional Geology

#### 3.1.1 Regional Geological Setting

The bedrock geology of southern Ontario consists of a thick Paleozoic sedimentary sequence from Cambrian to Mississippian in age, deposited approximately 542 million to 318 million years ago (Johnson et al., 1992; Walker and Geissman, 2009). This sedimentary sequence unconformably overlies the Precambrian crystalline basement of the Grenville Province, the south-easternmost subdivision of the Canadian Shield (Figure 3.1; Figure 3.2). The Grenville Province comprises 2690 million to 990 million year old rocks deformed during orogenic events 1100 to 970 million years ago (Percival and Easton, 2007; Carr et al., 2000; White et al., 2000). The Precambrian Grenville Province, which extends from Labrador to Mexico, is generally considered to have been relatively tectonically stable since approximately 970 million years ago (Percival and Easton, 2007, see Section 3.3).

Southern Ontario is underlain by two main paleo-depositional centres, the Appalachian and Michigan Basins, which are separated by a Precambrian crystalline basement high referred to as the Algonquin Arch (Figure 3.1). The Paleozoic succession underlying the Township of Huron-Kinloss and surrounding area was deposited in the Michigan Basin, a broadly circular intracratonic basin centred in Michigan. The Paleozoic succession thins from a maximum of approximately 4,800 m at the centre of the Michigan Basin to approximately 850 m on the flank of the Algonquin Arch east of the Township of Huron-Kinloss (Figure 3.1). The Paleozoic strata dip gently (3.5 to 12 m/km) to the west or southwest throughout the Ontario portion of the Michigan Basin (Figure 3.1; Armstrong and Carter, 2010).

Figure 3.2 presents the bedrock geology of southern Ontario. Figure 3.3 shows a geological cross-section approximately 25 km north of the Township (location shown in Figure 3.2), which highlights the west-southwesterly dip of the Paleozoic succession from the Niagara Escarpment in the east to Lake Huron in the west (note approximately 45x vertical exaggeration). Also note that on Figure 3.3, due to differences in outcrop versus subsurface stratigraphic nomenclature, the colour-shaded bedrock units in the cross-section do not correspond directly to the colour shades shown in the bedrock map and accompanying legend on Figure 3.2.

#### 3.1.2 Precambrian Crystalline Basement Geology

The Precambrian crystalline basement beneath much of southern Ontario is characterized by gneisses and metamorphic rocks of the Grenville Province of the Canadian Shield (Figure 3.1; Carter and Easton, 1990). Geophysical investigations provide useful information regarding the character of these basement rocks. Seismic profiles of the crystalline basement have been interpreted as representing the penetrative ductile Grenville-aged deformation fabric beneath the undeformed Paleozoic sedimentary rocks (e.g., Milkereit et al., 1992). Similarly, the gravity and residual total magnetic field maps of the Township of Huron-Kinloss and surrounding areas, shown in Figures 3.4 and 3.5, reflect the distribution of rock units within the Precambrian crystalline basement, rather than features of the overlying Paleozoic sedimentary rock succession.

The south-central portion of the Township of Huron-Kinloss is underlain by a moderately high gravity signal. This is the northern extent of an area of high values that run south, along the western edge of the province, down to Lake Erie. The remainder of the Township is characterized by a moderate gravity signal, with the lowest values occurring



along the Lake Huron shoreline (Figure 3.4). An aeromagnetic low situated beneath the eastern half of the Township of Huron-Kinloss is part of a series of irregularly shaped lows, which extend in a roughly southwest-northeast direction from Goderich to Owen Sound (Figure 3.5). The observed variations of both gravity and magnetic intensity in southern Ontario may be in part the result of mineralogical and structural variation within and between recognized lithotectonic terranes of the Precambrian crystalline basement (Easton, 1992; Boyce and Morris, 2002).

### 3.1.3 Regional Sedimentary Bedrock Stratigraphy

Table 3.1 illustrates the Paleozoic bedrock stratigraphy for three different geographic regions in southern Ontario (Armstrong and Carter, 2010). The Township of Huron-Kinloss and surrounding area are within the region described by the centre column of Table 3.1. The Paleozoic sedimentary stratigraphy includes shale, carbonate and evaporite units formed predominantly from marine sediments that were deposited when this portion of eastern North America was located at tropical latitudes and intermittently covered by shallow seas (Johnson et al., 1992; Armstrong and Carter, 2010).

The sedimentary bedrock stratigraphy shown in Table 3.1 and Figure 3.3 adopts a subsurface nomenclature while geological mapping as shown in Figure 3.2 and 3.6 uses an outcrop nomenclature (e.g., Armstrong and Carter, 2010). This distinction primarily applies to the Trenton and Black River groups where the Bobcaygeon Formation (outcrop) is equivalent to the Coboconk and Kirkfield formations (subsurface), and the Verulam and Lindsay formations (outcrop) are approximately equivalent to the Sherman Fall and Cobourg formations (subsurface), respectively.

The geological cross-section shown in Figure 3.3 illustrates the high degree of lateral continuity of individual units within the Paleozoic sedimentary bedrock succession of southern Ontario. This cross-section also shows the uniformity of thicknesses and bedding dip magnitudes for the deep Upper Ordovician shale and limestone sedimentary rocks across the area.

The following descriptions of the Paleozoic bedrock stratigraphy in southern Ontario utilize the subsurface nomenclature as defined in Table 3.1. The descriptions are primarily adapted from Johnson et al. (1992) and Armstrong and Carter (2010), the latter of which is an update of the stratigraphy presented by Armstrong and Carter (2006). The Paleozoic bedrock stratigraphy is described according to the main sedimentary sequences presented in the central column of Table 3.1.

#### Cambrian

The Cambrian bedrock geology in southern Ontario is dominated by white to grey quartzose sandstone with regional lithological variations that include fine to medium crystalline dolostone, sandy dolostone, and argillaceous dolostone to fine to coarse quartzose sandstone (Hamblin, 1999). Cambrian deposits are generally characterized as a succession of clastic and carbonate rocks resulting from transgressive Cambrian seas that flooded across the broad platform of the Algonquin Arch and into the subsiding Michigan and Appalachian basins (Hamblin, 1999). The Cambrian units are largely absent over the Algonquin Arch as the result of a pre-Ordovician regional-scale unconformity (Bailey Geological Services and Cochrane, 1984). Based on the regional stratigraphic framework, the Cambrian unit is expected to be thin to absent beneath most of Township of Huron-Kinloss because it is interpreted to pinch out from west to east across the Township (Itasca Canada and AECOM, 2011). This relationship is confirmed by deep drilling within the Township, as discussed later in Section 3.2.1. There are no surface exposures of the Cambrian unit in southwestern Ontario.



**Table 3.1 Stratigraphy of Southern Ontario (Armstrong and Carter, 2010)**

Standard Reference	Elgin, Essex, Huron, Kent, Lambton, Middlesex, Perth Counties and Western Lake Erie	Manitoulin Island, Bruce, Grey, Durham, Halton, Waterloo, and Wellington Counties	Brant, Haldimand, Lincoln, Norfolk, Oxford, Welland, Wentworth Counties and Eastern and Central Lake Erie
Mississippian	Upper		
	Middle		
	Lower		
Devonian	Upper		
	Middle		
	Lower		
Silurian	Upper		
	Middle		
	Lower		
Ordovician	Upper		
	Middle		
	Lower		
Cambrian	Upper		
Precambrian		crystalline basement	

### Upper Ordovician

Unconformably overlying the Cambrian unit is a thick sequence of Ordovician sedimentary units with a distinctly bimodal composition; a carbonate-rich lower unit and a shale-rich upper unit. The lower unit was deposited during a major marine transgression (Coniglio et al., 1990) prior to the westward inundation of the carbonate platform by the upper unit shale-dominated sediments (Hamblin, 1999). The Upper Ordovician carbonates subcrop in the northeastern part of southern Ontario around the Lake Ontario and Lake Simcoe regions and the Upper Ordovician shales subcrop east of the Niagara Escarpment between Owen Sound and Niagara Falls (Figure 3.2).

The lower carbonate unit of the Upper Ordovician succession is a thick sequence of predominantly limestone formations (carbonate and argillaceous carbonate sedimentary rocks), which include, from bottom to top, the Shadow Lake, Gull River and Coboconk formations of the Black River Group, and the Kirkfield, Sherman Fall and Cobourg formations of the Trenton Group (Table 3.1). These rocks range in character from coarse-grained bioclastic carbonates to carbonate mudstone with interbedded calcareous and non-calcareous shales. The Shadow Lake Formation, at the base of the Black River Group, is characterized by poorly sorted, red and green sandy shales, argillaceous and arkosic sandstones, minor sandy argillaceous dolostones and rare basal arkosic conglomerate. The lower part of the overlying Gull River Formation consists mainly of light grey to dark brown limestones and the upper part of the formation is very fine grained with thin shale beds and partings. The Coboconk Formation, at the top of the Black River Group, is composed of light grey-tan to brown-grey, medium to very thick bedded, fine to medium grained bioclastic limestones.

The lowest interval of the Trenton Group is the Kirkfield Formation which is characterized by fossiliferous limestones with shaley partings and locally significant thin shale interbeds. The overlying Sherman Fall Formation ranges in lithology from dark grey argillaceous limestones interbedded with calcareous shales, found lower in the formation, to grey to tan bioclastic, fossiliferous limestones that characterize the upper portions of the unit. The overlying Cobourg Formation is described regionally as a grey, fine-grained limestone to argillaceous limestone with coarse-grained fossiliferous beds and a nodular texture. The Cobourg Formation is also subdivided to include an upper Collingwood Member that consists of dark grey to black, calcareous shales with increased organic content and distinctive fossiliferous limestone interbeds (Hamblin, 2003; Armstrong and Carter, 2010).

The upper unit of the Upper Ordovician succession is characterized by a thick sequence of predominantly shale sedimentary rocks, which comprise the Blue Mountain, Georgian Bay and Queenston formations. The Blue Mountain Formation is characterized by uniform soft and laminated grey non-calcareous shale with minor siltstone and minor impure carbonate (Johnson et al., 1992; Hamblin, 1999). The overlying Georgian Bay Formation is composed of blue-grey shale with intermittent centimetre-scale siltstone and limestone interbeds. The Queenston Formation is characterized by maroon, with lesser green, shale and siltstone with varying amounts of carbonate. The top of the Queenston Formation is marked by a regional erosional unconformity (Table 3.1; Armstrong and Carter, 2010).

### Lower Silurian

The Lower Silurian units, including the Cataract and Clinton groups and the Amabel and Guelph formations, unconformably overlie the Upper Ordovician shale (Table 3.1). A major marine transgression at the boundary of the Clinton and Cataract groups, and isolation of the Michigan Basin from the Appalachian Basin as a result of tectonic activity, was responsible for deposition of the extensive carbonate-dominated Amabel and Guelph formations. These Lower Silurian units form the cap-rock of the Niagara Escarpment in outcrop. The Lower to Upper Silurian boundary occurs within the Guelph Formation (Table 3.1; Brunton and Dodge, 2008).

The Cataract Group unconformably overlies the Upper Ordovician Queenston Formation and includes a lower unit of grey argillaceous dolostone and minor grey-green shale, and an upper clastic unit which consists of grey to green to

maroon noncalcareous shales with minor sandstone and carbonate interbeds. The Clinton Group is composed of thin- to medium-bedded, very fine- to coarse-grained fossiliferous dolostone. The Amabel Formation includes a lower unit of light grey to grey-brown, finely crystalline, thin- to medium-bedded, sparingly fossiliferous dolostone with minor chert nodules. It also includes an upper unit of blue-grey, fine- to coarse-grained, thick bedded to massive dolostone, which locally contains minor dolomitic limestone. The upper unit is lithologically very similar to the lower unit but is more argillaceous and locally contains vugs filled with gypsum, calcite, halite, or fluorite. The Guelph Formation lithology varies from reefal to inter-reefal dolostones and dolo-mudstones (Armstrong and Goodman, 1990).

### Upper Silurian

The Upper Silurian units include the evaporite and evaporite-related Salina Group and overlying dolostones and minor evaporites of the Bass Islands Formation (Table 3.1). The Upper Silurian units subcrop in a northwest trending belt that extends from south of Niagara Falls to west of Owen Sound (Figure 3.2). The Salina Group is characterized by repeated, cyclical deposition of carbonate, evaporite and argillaceous sedimentary rocks. A change to normal marine carbonate conditions away from the cyclic carbonate and evaporite setting was responsible for deposition of the Bass Islands Formation, which is a microcrystalline commonly bituminous dolostone containing evaporite mineral clasts. The contact with the overlying Devonian carbonates marks a major unconformity characterized by subaerial exposure (Uyeno et al., 1982).

### Lower and Middle Devonian

The Lower and Middle Devonian units unconformably overlie the Upper Silurian Bass Islands Formation and are dominated by carbonate sedimentary rocks of the Bois Blanc Formation and the Detroit River Group (Table 3.1). The Bois Blanc Formation is primarily a cherty dolostone unit overlain by mixed limestones and dolostones of the Detroit River Group (Amherstburg and Lucas formations). The Amherstburg Formation is a grey-brown to dark brown, fine- to coarse-grained, bituminous, bioclastic, fossiliferous, commonly cherty limestone and dolostone. Local reef development within the Amherstburg Formation is commonly also known as the Formosa Limestone. The Lucas Formation consists of brownish-grey, brown and cream, thin- to thick-bedded, fine crystalline dolostone. The Devonian carbonates crop out along the shoreline of Lake Huron and north shoreline of Lake Erie (Figure 3.2).

## **3.2 Local Sedimentary Bedrock Geology of the Township of Huron-Kinloss**

### **3.2.1 Stratigraphy**

The bedrock geology of the Township of Huron-Kinloss and surrounding area is shown in Figure 3.6. The figure also shows the location of oil and gas boreholes within the Township of South Bruce and surrounding areas from the Oil, Gas and Salt Resources Library Petroleum Wells Subsurface Database (OGSRL, 2006). Review of readily available information indicates that the subsurface Paleozoic bedrock geology of the Township of Huron-Kinloss is consistent with the regional geological framework described in Section 3.1.3. The Township is underlain by an Ordovician to Devonian Paleozoic sedimentary sequence that was deposited approximately 488 to 359 million years ago (Walker and Geissman, 2009; Armstrong and Carter, 2010). Additional detailed information on the regional sedimentary bedrock geology is available from the recently completed site characterization program at the Bruce nuclear site for OPG's proposed DGR for low and intermediate level radioactive waste (OPG-DGR) described in detail by NWMO (2011) and Intera (2011), which is located 20 km north of the Township. Key available borehole data includes:

- Seven oil and gas wells within the Township of Huron-Kinloss (Table 3.2), including one borehole (Well #F012061), drilled in 1956, that extends through the entire Paleozoic sedimentary sequence to the top of the Precambrian crystalline basement at a depth of approximately 1,017 metres below ground surface (mBGS) (Figure 3.6; Table 3.3).

- Oil and Gas Exploration Well #T004854 located just outside the northeast boundary of the Township (Figure 3.6) intersects the Precambrian crystalline basement at a depth of 890 mBGS (OGSRL, 2006).
- Six boreholes (DGR-1 to DGR-6) at the Bruce nuclear site with depths ranging from 463 to 869 mBGS (Figure 3.6), including one borehole (DGR-2), which intersects the top of the Precambrian crystalline basement at a depth of 861 mBGS (Intera, 2011). These boreholes provide unique and detailed information on hydrogeological and hydrogeochemical conditions at depth within the regional Paleozoic rocks.

**Table 3.2 Subcrop Geological Unit and Final Well Completion Unit for Oil and Gas Wells within the Township of Huron-Kinloss**

Well License #	Total Depth (mBGS)	Top Geological Unit (Subcrop)	Bottom Geological Unit
F012078	507.5	Lucas Formation	Guelph Formation
F012061	1017.1	Lucas Formation	Precambrian
F012066	566.9	Lucas Formation	Cabot Head Formation
F012063	568.8	Lucas Formation	Cabot Head Formation
T0026633	608.7	Lucas Formation	Cabot Head Formation
T003535	583.7	Lucas Formation	Cabot Head Formation
T003553	511.5	Lucas Formation	Cabot Head Formation

The wells in the OGSRL database, including DGR-1 and DGR-2 at the Bruce nuclear site, were used to develop a geological framework model for the OPG-DGR project (Itasca Canada and AECOM, 2011). The model allows for interpretation and simple 2-D and 3-D visualization of the stratigraphy over a portion of southern Ontario such as the cross-section shown in Figure 3.3.

The stratigraphy beneath the southwestern half of the Township of Huron-Kinloss, as interpreted from OGSRL Well #F012061, is shown in Table 3.3. The type and number of individual stratigraphic units identified in this well are consistent with the regional stratigraphic framework summarized in Section 3.1.3 and Table 3.1 (Armstrong and Carter, 2010). The same Paleozoic succession was also encountered in the boreholes beneath the Bruce nuclear site (Intera, 2011), with the exception of the Cambrian unit which pinches out midway across the Township of Huron-Kinloss (Bailey Geological Services and Cochrane, 1984).

Based on the information from OGSRL Well #F012061 (Table 3.3), the total thickness of the Paleozoic strata near the southern boundary of the Township of Huron-Kinloss is approximately 970 m. The stratigraphy at typical repository depths is comprised of Lower Silurian dolostones of the Guelph, Reynales, and Fossil Hill formations, the shaley Cabot head Formation and the dolostone Manitoulin Formation which extend from approximately 517 mBGS to 581 mBGS. These formations were described by Mazurek (2004) as not suitable for a deep geological repository because of their high hydraulic conductivities and/or limited thickness. Underlying these Silurian rocks are Upper Ordovician shales and limestones. The upper Ordovician shales have a cumulative thickness of about 200 m between 581 BGS and 805 mBGS and include the Queenston, Georgian Bay/Blue Mountain and Collingwood formations. Upper Ordovician limestones, including the Cobourg, Sherman Fall, Kirkfield and Gull River formations have a thickness of about 200 m, extending from 805 mBGS to a depth of 1,010 mBGS in Well #F012061. Well #T004854 located just outside the northeast boundary of the Township (Figure 3.6) encountered Upper Ordovician shale and limestone units at 463 mBGS (Queenston Formation) and 679 mBGS (Cobourg Formation) respectively. The Upper Ordovician formation thicknesses are expected to remain relatively uniform across the Township of Huron-Kinloss (Section 3.1.3).

**Table 3.3 Stratigraphy Derived from Oil and Gas Exploration Well OGSRL #F012061 (1956) in the Township of Huron-Kinloss (Itasca Canada and AECOM, 2011, after OGSRL, 2006)**

Standard Reference		Geological Unit*	#F012061	
			Unit Top (mBGS)	Unit Thickness (m)
Quaternary		Drift	0.6	47.3
Devonian	Middle	Lucas/Amherstburg Formation	47.9	92.4
	Lower	Bois Blanc Formation	140.2	60.4
Silurian	Upper	Bass Islands	200.6	50.9
		Salina G Unit	251.5	54.9
		Salina E Unit	306.3	13.7
		Salina C Unit	320.0	50.3
		Salina B Unit	370.3	51.8
		Salina A-2 Unit	422.2	56.4
		Salina A-1 Unit	478.5	38.1
		Guelph Formation	516.6	27.4
	Lower	Reynales / Fossil Hill Formation	541.3	9.8
		Cabot Head Formation	551.1	20.4
		Manitoulin Formation	571.5	9.1
Ordovician	Upper	Queenston Formation	580.6	77.7
		Georgian Bay / Blue Mountain Formation	658.4	115.8
		Collingwood Formation	774.2	30.5
		Cobourg Formation	804.7	36.6
		Sherman Fall Formation	841.3	50.3
		Kirkfield Formation	891.5	41.2
		Gull River Formation	932.7	77.7
		Shadow Lake Formation	1010.4	6.7
Precambrian		Precambrian	1017.1	

Note: \* Nomenclature at the Formation level in this table is slightly different than the recently updated nomenclature used in Table 3.1 (Armstrong and Carter, 2010).

There is limited readily available information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Township of Huron-Kinloss. However, it is expected that they are very similar to the characteristics of the Upper Ordovician units beneath the nearby Bruce nuclear site, which are described as comprising relatively undeformed, near horizontally layered, low porosity and low hydraulic conductivity sequences that are correlative over large lateral extents as a result of their simple geometry and uniform thicknesses (NWMO, 2011). The consistency of the stratigraphy between Well #F012061 located within Township of Huron-Kinloss and the deep boreholes at the Bruce nuclear site suggests a high degree of lateral continuity and predictability of the Ordovician stratigraphic units across this part of southern Ontario. This interpretation would have to be confirmed during subsequent stages of site evaluation, if the community remains interested in continuing with the site selection process.

## 3.3 Deformation and Metamorphism

### 3.3.1 Tectonic History

The geologic evolution of southern Ontario is characterized by a series of tectonic events, structural uplift, erosion, burial and faulting, which have occurred over the past 1,210 million years. Readily available information indicates that the Paleozoic sedimentary sequence in southern Ontario has not undergone regional-scale metamorphism (Armstrong and Carter, 2010). Table 3.4 summarizes the timing of major tectonic events that have influenced the Precambrian and Paleozoic rocks beneath southern Ontario.

**Table 3.4 Timetable of Major Tectonic Events in Southern Ontario**

Time Interval Before Present (millions of years)	Tectonic Activity	Reference
1210 – 1180	Regional metamorphism (proto-Grenville)	Lumbers et al., 1990; Easton, 1992; Hanmer and McEachern, 1992
1109 – 1087	Magmatism and formation of Midcontinent Rift	Van Schmus, 1992
1030 – 970	Main phase of Grenville Orogeny	Carr et al., 2000; White et al., 2000
970 – 530	Extensional rifting and opening of the Iapetus Ocean	Thomas, 2006
530 – 320	Subsidence of Michigan Basin and Uplift of southern Ontario basement arches (episodic)	Sanford et al., 1985; Howell and van der Pluijm, 1999; Kesler and Carrigan, 2002
470 – 440	Taconic Orogeny <ul style="list-style-type: none"> <li>E-W to NW-SE compression, uplift (southern Ontario arches)</li> </ul>	Sloss, 1982; Quinlan and Beaumont, 1984; McWilliams et al., 2007
410 – 320	Caledonian/Acadian Orogeny <ul style="list-style-type: none"> <li>E-W to NW-SE compression, uplift (southern Ontario arches)</li> </ul>	Sutter et al., 1985; Marshak and Tabor, 1989; Gross et al., 1992; Kesler and Carrigan, 2002
300 – 250	Alleghenian Orogeny <ul style="list-style-type: none"> <li>E-W to NW-SE compression</li> </ul>	Engelder and Geiser, 1980; Gross et al., 1992
200 – 50	<ul style="list-style-type: none"> <li>Opening of the Atlantic Ocean</li> <li>St. Lawrence rift system created</li> <li>reactivated Ottawa-Bonnechere Graben</li> <li>NE-SW extension</li> <li>uplift</li> </ul>	Kumarapeli, 1976; Kumarapeli, 1985
50 – Present	<ul style="list-style-type: none"> <li>NE-SW compression (from ridge push)</li> <li>post-glacial uplift</li> </ul>	Barnett, 1992

### Precambrian Tectonic History

After a phase of regional metamorphism of the Precambrian crystalline basement rocks during the Grenville Orogeny, a continent-scale rifting event occurred, which generated magmatism in the form of intrusive mafic dykes and sills and extrusive basaltic flows (Easton, 1992; Van Schmus, 1992). This phase was followed by crustal shortening and the main phase of the Grenville Orogeny (Carr et al., 2000; White et al., 2000).

The end of the Grenville Orogeny is marked by the transition to a passive tectonic phase of extension and rifting during the opening of the Iapetus Ocean (Table 3.4; Thomas, 2006).

### Paleozoic Tectonic History

Deposition of the Paleozoic rocks in southern Ontario began with a large rifting event and subsequent subsidence and deposition within the Michigan Basin (Sanford et al., 1985). The Middle Ordovician to Devonian-Mississippian sedimentary rocks reflects the complex interaction between regional-scale tectonic forces, sedimentation, and eustatic sea level fluctuations associated with the Taconic, Caledonian/Acadian, and Alleghenian orogenic events (Table 3.4). Uplift of the Precambrian crystalline basement arches in southern Ontario, and episodic subsidence within the Michigan Basin during these three main tectonic events are largely responsible for the regional variations in depositional setting and rock types.

### Mesozoic-Cenozoic Tectonic History

The Atlantic Ocean began to open approximately 200 million years ago during the Triassic Period and associated tectonic activity was focused at the margin of the continent. A transition from northwesterly to west-southwesterly North American plate motion and initiation of spreading in the North Atlantic approximately 50 million years ago controls the current east-northeast-oriented compressional stress field of eastern North America that characterizes the most recent tectonic phase (Barnett, 1992).



### 3.3.2 Fault History

Documented basement-seated faults that displace the Paleozoic strata in southern Ontario are shown on Figure 3.2 (compiled by Armstrong and Carter, 2010). The faults are organized into three categories based on the youngest geological unit that is offset: i) Shadow Lake/Precambrian, ii) the Trenton Group (Ordovician-aged) and iii) the Rochester Formation (Silurian-aged). These faults have been interpreted using borehole data obtained from oil and gas wells (structural contour maps) and geophysical analysis (e.g., Brigham, 1971). The faulting is interpreted to be caused by re-activation of pre-existing faults in the Precambrian crystalline basement during the evolution of the Paleozoic Michigan and Appalachian Basins (Sanford et al., 1985; Marshak and Paulsen, 1996).

Mapped faults within southern Ontario are shown as segments measuring from a few metres to about 40 km in length, with one exception that is almost 100 km in length (Figure 3.2). The faults are generally interpreted to be nearly vertical in dip, exhibit normal and/or strike-slip motion, and cluster into two main orientations; east-northeast to southeast and north to north-northeast (Figure 3.2). Displacements on all faults range from a few metres up to a maximum of 100 m (Brigham, 1971; Carter et al., 1996). Where faults strike easterly, the predominant offset is south-side-down. This fault orientation is most common near the Chatham Sag in southwestern Ontario where a marked concentration of faults occur along, and southeast of the trace of the Algonquin Arch (Figures 3.1 and 3.2).

Sanford et al. (1985) introduced a conceptual fracture framework for southern Ontario, based on hand contouring of isopachs of selected Silurian units and structure contours on the top of the Silurian Rochester Formation (outcrop nomenclature, equivalent to the Fossil Hill Formation). Some similarity exists between this conceptual fault model and the distribution of known faults located southeast of the Algonquin Arch and in particular proximal to the Chatham Sag. However, such a systematic fault pattern is not observed in structural contours on the top of the Precambrian basement surface to the northwest of the Algonquin Arch in the southern Ontario portion of the Michigan Basin, nor is it consistent with known or interpreted mapped faults in this area (Bailey Geological Services and Cochrane, 1984; Carter et al., 1996; Armstrong and Carter, 2010). Johnson et al. (1992) also noted that although fractures may exist, the extensive fracture framework conceptualized by Sanford et al. (1985), which includes an ordered and approximately 10 km-spaced set of faults offsetting Silurian strata, is not recognized.

A small portion of a mapped Paleozoic fault crosses over the eastern boundary of the Township of Huron-Kinloss (Figure 3.6). It strikes east-northeast and has a documented length of approximately 10 km. This fault is interpreted to postdate the deposition of the Ordovician Trenton Group carbonates that occurred approximately 450 million years ago (e.g., Sutter et al., 1985), but predate the deposition of the overlying Upper Ordovician shales. One other fault mapped immediately to the north of the Township of Huron-Kinloss strikes in the same orientation and is interpreted to predate the deposition of the Ordovician Trenton Group carbonates. No other faults have been reported within approximately 30 km of the area surrounding the Township of Huron-Kinloss.

In summary, two basement-seated faults are recognized within approximately 30 km of the Township of Huron-Kinloss (Figure 3.6). There is no evidence from the regional stratigraphic framework that anomalous structural complexity due to tectonic faulting occurs within the Paleozoic sedimentary succession beneath the Township of Huron-Kinloss. This would have to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

### 3.3.3 Diagenesis

Diagenesis includes changes (chemical, physical, biological) undergone by sediments after their initial deposition, not including metamorphism or surface weathering. The Paleozoic rocks of southern Ontario have been altered through their depositional and post-depositional lifecycle by diagenetic processes. The primary diagenetic process in the Michigan Basin is dolomitization of limestone, which is interpreted to have occurred in response to tectonically

driven fluid migration associated with Paleozoic orogenic events (e.g., Coniglio and Williams-Jones, 1992). Other diagenetic processes that have occurred in the Paleozoic sedimentary sequence in southern Ontario include clay alteration (Ziegler and Longstaffe, 2000), and hydrocarbon formation, migration and emplacement (e.g., Armstrong and Carter, 2010).

Diagenesis through salt dissolution in the Salina Formation and creation of subsequent collapse features (Upper Silurian and Devonian stratigraphy) has also altered the Paleozoic rocks. The process of salt dissolution and the creation of collapse features in the rock occurred in response to tectonic events that pushed large volumes of fluid through the stratigraphy dissolving the salt. This process occurred more than 300 million years ago during the Silurian to Devonian Caledonian Orogeny and the Devonian to Mississippian Acadian Orogeny (Sanford et al., 1985).

In summary, significant diagenetic events affecting the Paleozoic rocks of southern Ontario correspond to major tectonic events, which have not been active since approximately 200 million years ago (Table 3.4). There is limited readily available information regarding the diagenetic character of the Paleozoic sedimentary rocks beneath the Township of Huron-Kinloss. This information would need to be assessed further during subsequent stages of site evaluation, if the community remains interested in continuing with the site selection process.

#### **3.3.4 Karst**

Karst is created by the dissolution of carbonate and evaporite rocks as groundwater infiltrates through the sedimentary strata. Karst processes are most active in the shallow subsurface (less than 200 mBGS) while deeply buried rocks beneath southern Ontario are unlikely or not affected by modern karst processes (Worthington, 2011). These deeper formations could have been affected by karst processes during or after their deposition, referred to as paleokarst. In southern Ontario, these paleokarst zones are most likely to be observed at large breaks in the sedimentary record marked by regional unconformities (Table 3.1).

A map showing the distribution of areas with known, inferred or potential karst in southern Ontario is presented in Figure 3.7 (Brunton and Dodge, 2008). There is a small area of known karst mapped along the southern boundary of the Township of Huron-Kinloss. The Township lies entirely within an area of inferred karst identified in the Detroit River Group and Dundee Formation (Figure 3.7; Brunton and Dodge, 2008).

Figure 3.7 shows that in southern Ontario, mapped karst is found in the Ordovician carbonates that outcrop along the boundary with the Canadian Shield between Georgian Bay and eastern Ontario, Silurian Formation carbonates exposed along the escarpment (Lockport, Amabel, and Guelph formations, and the Bass Islands and Bertie formations) and Devonian carbonates in southern Ontario (Dundee Formation and Detroit River Group). Inferred and potential karst incorporates the outcrop and subcrop areas of the known karst geological units as outlined above. Brunton and Dodge (2008) noted that large-scale karstification is found both proximal to significant escarpments or cuesta margins and/or laterally within a few hundred metres of incised river systems. Modern karstification of carbonates is likely to occur almost exclusively in shallow freshwater zones.

In summary, karst features in southern Ontario are unlikely to affect the deep subsurface geological or hydrogeological conditions at typical repository depth (approximately 500 m). The influence that paleokarst may have on the deeper carbonate rock formations beneath the Township of Huron-Kinloss would need to be assessed further during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.



### 3.4 Geomechanical Properties

No readily available information on rock geomechanical properties at typical repository depth was found for the Township of Huron-Kinloss. The nearest detailed assessment of the geomechanical properties of the Paleozoic sequence was at the nearby Bruce nuclear site, and was conducted as part of detailed site characterization for the OPG-DGR project (Golder, 2003; NWMO, 2011; NWMO and AECOM, 2011). The assessment was based on the understanding of the regional geomechanics of southern Ontario, as well as on a suite of field and laboratory observations and measurements conducted at the Bruce nuclear site. A wide range of geomechanical properties of the sedimentary sequence was assessed, including short- and long-term behaviour of underground openings at typical repository depths. A brief summary of the relevant properties is given below, focusing on the Upper Ordovician shale and limestone units, which are found at typical repository depths beneath some sectors of the Township of Huron-Kinloss.

Previous construction experience with the excavation of underground openings in southern Ontario indicates that excavated openings in either the Upper Ordovician shale or limestone units are likely to be dry and stable (Golder, 2003). These include the 925 m long Darlington cooling water intake tunnel and the 470 m long storage cavern access tunnel at the Wesleyville Generating Station. The Darlington tunnel was completed within the Cobourg Formation beneath Lake Ontario. The Wesleyville tunnel intersects both the Cobourg Formation and the underlying Sherman Fall Formation.

Available information on strength and in situ stresses suggest that the Upper Ordovician shale and limestone units have a high strength and favourable geomechanical characteristics, which makes them amenable to the excavation of stable underground openings. For example, estimated mean uniaxial compressive strengths for Upper Ordovician limestone (Cobourg Formation) and shale (Georgian Bay Formation) units were 113 MPa and 32 MPa, respectively at the Bruce nuclear site (Intera, 2011). These values compare favourably with other sedimentary formations considered internationally for the long-term management of radioactive waste (NWMO, 2011).

Numerical simulations of the behaviour of underground openings in the limestone of the Cobourg Formation for the OPG-DGR project suggest that the openings will remain stable during construction and operation, requiring only standard support. The simulations also suggest that, in the long-term, the barrier integrity of the enclosing Ordovician bedrock formations will not be affected under various loading scenarios associated with glacial ice sheet, seismic ground motions and repository gas pressure (NWMO, 2011).

In summary, available information on geomechanical properties of the Upper Ordovician shale and limestone units in southern Ontario suggests the units have a high strength, and favourable geomechanical characteristics, which makes them amenable to the excavation of stable underground openings.

### 3.5 Quaternary Geology

The extent and type of Quaternary deposits in the Township of Huron-Kinloss and surrounding areas is illustrated in Figure 3.8. The Quaternary cover in the area mostly comprises glacial deposits including tills, glaciofluvial and glaciolacustrine sediments deposited during the late Pleistocene Wisconsinan glaciations, as well as more recent fluvial, lacustrine and organic deposits. The Quaternary sediments were deposited during fluctuations of the Huron and Georgian Bay Lobes of the Laurentide Ice Sheet that occurred between approximately 23,000 and 10,000 years ago during the Wisconsinan glaciation, prior to final retreat of glacial ice (Karrow, 1974).

Mapping of the Quaternary deposits in the Township of Huron-Kinloss shows that glaciolacustrine-derived St. Joseph till is found in the western two thirds of the Township, along with patches of elongated glaciolacustrine beach deposits associated with Glacial Lake Algonquin, that extend north to south through the Township. Northeast-

southwest oriented moraine ridges of the Wyoming Moraine are present at the eastern mapped extent of the till. The eastern third of the Township of Huron-Kinloss is characterized by glaciofluvial ice-contact and outwash sediments associated with the retreat of glacial ice (Figure 3.8). Eskers are mapped in the southeastern corner. Localized glaciolacustrine deposits are also present in the southeastern corner of the Township (Figure 3.8).

### 3.5.1 Quaternary Overburden Thickness

The thickness of the Quaternary deposits in the Township of Huron-Kinloss and surrounding areas is shown in Figure 3.9 (Gao et al., 2006). The Township of Huron-Kinloss is covered by Quaternary deposits with overburden thicknesses typically ranging from 6 m to 82 m, with the majority of the Township covered by greater than 8 m. The thickest areas of overburden are found in the northeast-southwest trending ridge of the Wyoming Moraine, located in the eastern third of the Township, and at the western edge of the Township, along the Lake Huron shoreline, where modern lacustrine sediments and thicker till deposits are present (Figure 3.9). The thinnest overburden deposits in the Township of Huron-Kinloss are associated with the glaciofluvial and ice-contact deposits occupying the spillway in the eastern third of the Township. Locally thinner areas are also found along the South Pine and Eighteen Mile Rivers and their tributaries which have cut narrow valleys through the till plain as they flow towards Lake Huron (Figure 3.9).

### 3.5.2 Glacial Erosion

Southern Ontario is expected to be affected by major glaciations recurring approximately every 100,000 years (Peltier, 2011). Hallet (2011) studied glacial erosion of the Bruce Peninsula caused by the Laurentide Ice Sheet, and concluded that significant glacial erosion likely did not occur, based on observations of striated surfaces with multiple episodes preserved, the relative absence of friction cracks, and the pervasive low relief of striated surfaces. Hallet (2011) also concluded that although uncertainties remain in ice sheet reconstructions and estimates of erosion by ice and melt water, all lines of study indicate that, at the nearby Bruce nuclear site, glacial erosion would conservatively be 100 m per 1 million years.

## 3.6 Neotectonic Activity

Neotectonics refers to deformations, stresses and displacements in the earth's crust of recent age or which are still occurring. The Late Pleistocene Laurentide Ice Sheet that advanced over most of Canada into the United States began approximately 120,000 years ago (Peltier, 2011). At last glacial maximum 25,000 years ago the Laurentide Ice Sheet surpassed 2,800 m in thickness over the most glaciated regions of the continent (Peltier, 2002). The weight of the ice sheet depressed the surface of the earth by approximately 600 m (Peltier, 2011). After the ice retreated some 14,000 years ago, the earth's surface has rebounded through a process known as glacio-isostatic adjustment which continues today. In southern Ontario and the Great Lakes region, the magnitude of glacio-isostatic adjustment is about 1.5 mm/year (Peltier, 2011). This glacial unloading creates horizontal stresses in shallow bedrock areas. These natural stress release features include elongated compressional ridges or pop-ups that are documented in southern Ontario (McFall, 1993).

A neotectonic study was conducted as part of detailed site characterization for OPG's proposed DGR at the Bruce nuclear site to analyse Quaternary landforms for the presence of seismically-induced soft-sediment deformation (Slattery, 2011). The study was conducted within a radius of up to 50 km from the Bruce nuclear site, which includes the Township of Huron-Kinloss. The study found no evidence for neotectonic activity associated with the most recent glacial cycle approximately 25,000 years ago (Slattery, 2011).

In summary, no neotectonic structural features are known to occur in the Township of Huron-Kinloss.

### **3.7 Seismicity**

The Township of Huron-Kinloss is located in the Grenville Province of the Canadian Shield, where much of southern Ontario has remained tectonically stable since approximately 970 million years ago (Percival and Easton, 2007; Table 3.4). All recorded earthquakes in southern Ontario have a magnitude of less than 5 (Figure 3.10; Natural Resources Canada, 2012). Figure 3.10 shows the location of all earthquakes with a magnitude greater than 3 that are known to have occurred in Canada from 1627 until 2010 (Natural Resources Canada, 2012) and Figure 3.11 shows the locations and magnitudes of all earthquakes recorded in southern Ontario between 1985 and 2012 (Natural Resources Canada, 2012). Most of the earthquakes in the broader region around the Township of Huron-Kinloss are concentrated in the area located southeast of the Algonquin Arch and, to a lesser extent, offshore in Lake Huron and Georgian Bay (Figure 3.11).

In summary, available literature and recorded seismic events indicate that the Township of Huron-Kinloss is located within a region of low seismic hazard.

## 4. Hydrogeology

### 4.1 Groundwater Wells

Information on groundwater in the Township of Huron-Kinloss was obtained from the Ontario Ministry of the Environment (MOE) Water Well Record Database. The location of known water wells are shown on Figure 4.1. The Township of Huron-Kinloss relies on shallow overburden and bedrock aquifers for its domestic, industrial and municipal water supply. In addition to being used for potable supply, shallow groundwater also supports baseflow to numerous streams and wetlands within the study area. There are four active municipal water supply systems in the Township of Huron-Kinloss. These include the Lakeshore Area Water Works and the Village of Ripley Well Supply, which are located within the Saugeen Valley Source Protection Area (SPA), and the Lucknow Water and Whitechurch Water Supply Systems, located within the Maitland Valley Source Protection Area. The Lakeshore Area Water Works consists of six bedrock wells (five of which are in service) that have a combined wellhead protection area of 8.46 km<sup>2</sup>. The wellhead protection area for the Ripley System is 0.87 km<sup>2</sup> (Saugeen, Grey, Sauble, North Bruce Peninsula, 2011). The wellhead protection areas for both the Lucknow Water Supply System and the Whitechurch Water Supply System are not documented. Well head protection areas would need to be considered during subsequent site evaluation stages, if the community decides to continue in the site selection process.

The MOE Water Well Record Database contains a total of 631 water well records for the Township of Huron-Kinloss (Figure 4.1). Of these 631 well records, 14 records contained information only on location and provided no data on well type, depth, or hydrogeological conditions. A summary of the 617 wells with hydrogeological data is provided in Table 4.1.

**Table 4.1 MOE Water Well Record Details**

Well Type	Number of Well records	Depth Range (m)		Static Level Range (mBGS)		Well Yield (L/min)		
		Min	Max	Min	Max	Min	Max	Mean
Overburden	35	3.4	80.8	0.6	27.4	1.5	77.4	13.2
Bedrock	582	15.2	111.3	-6.1	45.1	1.2	153.6	5.8

The MOE Water Well Records indicate that no potable water supply wells are known to exploit aquifers at typical repository depths (approximately 500 m) within the Township of Huron-Kinloss. Of the 617 well records found for the Township of Huron-Kinloss, 35 wells were completed in overburden aquifers and 582 wells were completed in bedrock aquifers (Table 4.1). Wells completed within overburden range in depths from approximately 3 to 81 m. Overburden well yields range from 2 to 77 L/min, with mean values of 13.2 L/min. Wells completed in the bedrock range in depth from approximately 15 to 111 m. Bedrock wells yield range from 1 to 154 L/min, with mean values of 5.8 L/min. These yields reflect the purpose of the wells, and do not necessarily reflect the maximum sustained yield that might be available from the aquifer. Note that a negative value in Table 4.1 for Static Level Range indicates an artesian well with the estimated head above the ground surface.

### 4.2 Deep Groundwater System

There is no direct hydrogeological information available on the deep groundwater system beneath the Township of Huron-Kinloss. However, as described in Section 3.2.1., there is a high degree of lateral continuity and predictability of the Upper Ordovician shale and limestone units across this part of southern Ontario. This suggests that the hydrogeological setting at depth beneath the Township of Huron-Kinloss is likely to be similar to that interpreted from regional hydrogeological information and the detailed site characterization work completed at the nearby Bruce nuclear site for OPG's proposed DGR project (Hobbs et al., 2011; Intera, 2011; NWMO, 2011).

These studies indicate that the active groundwater system is shallow, and limited to the upper approximately 200 mBGS. Below this depth, an intermediate to deep groundwater system has been recognized, both regionally and at the Bruce nuclear site (Intera, 2011; NWMO, 2011). Field data from the Bruce nuclear site indicates that the deep groundwater system has low groundwater yields due to the very low hydraulic conductivities of the Upper Ordovician shale and limestone units (approximately  $10^{-15}$  to  $10^{-10}$  m/s). The deep groundwater system at typical repository depth within the Upper Ordovician formations beneath the Bruce nuclear site is interpreted as diffusion-dominated and isolated from the shallow groundwater system by multiple near horizontally layered, laterally extensive, low permeability shale, dolostone and anhydrite formations (NWMO, 2011).

In summary, there are no known exploitable groundwater resources in the Upper Ordovician units at typical repository depths in the Township of Huron-Kinloss, due to the very low hydraulic conductivities of the Upper Ordovician shale and limestone units. Also, as discussed in Section 4.3, available regional information indicates a transition from fresh to non-potable, saline groundwater below approximately 200 mBGS (Hobbs et al., 2011; NWMO, 2011).

### 4.3 Hydrogeochemistry

There is no direct readily available information on groundwater hydrogeochemistry at typical repository depth for the Township of Huron-Kinloss. However, the regional hydrogeochemistry for southern Ontario has been described as part of site characterization activities for OPG's proposed DGR at the Bruce nuclear site (Hobbs et al., 2011; NWMO, 2011).

Two geochemical systems are recognized at the regional scale in southern Ontario: 1) a shallow system (less than 200 mBGS) containing fresh through brackish waters. Waters in this system have stable isotopic compositions ( $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ ) consistent with mixing of dilute meteoric or cold-climate (glacial) waters with more saline waters; and 2) an intermediate to deep system (more than 200 mBGS) containing predominately brines associated with hydrocarbons in reservoirs, which have elevated total dissolved solids (TDS) values (200,000 to 400,000 mg/L) and distinct stable oxygen and hydrogen isotopic signatures (Hobbs et al., 2011; NWMO, 2011).

Within the regional geochemical database, the maximum depth at which glacial waters are observed is 130 mBGS (Hobbs et al., 2011). The major ion composition of waters from the intermediate to deep system, in particular Cl and Br concentrations, support the interpretation that these waters evolved from seawater by evaporation past halite saturation, with limited evidence for recent dilution by meteoric or glacial waters. The redox conditions are believed to be reducing, due to the presence of methane gas in hydrocarbon reservoirs (Hobbs et al., 2011). The chemistries of the deep brines indicate that they were formed by evaporation of seawater, which was subsequently modified by fluid-rock interaction processes. The nature of the brines, in particular the high salinities and enriched  $\delta^{18}\text{O}$  values of the porewaters, indicate that the deep system is isolated from the shallow groundwater system and that the porewaters have resided in the system for a very long time (Hobbs et al., 2011; NWMO, 2011).

## 5. Economic Geology

### 5.1 Hydrocarbon Resources

The Paleozoic rocks of southern Ontario are known to include regions of commercial hydrocarbon accumulation; however there are no known oil and gas pools within the Township of Huron-Kinloss. Oil and gas exploration wells, known pools and mapped oil and gas pipelines are shown in Figure 3.6. There are eight known oil and gas pools in the approximately 40 km area outside of the Township of Huron-Kinloss, which are hosted within Silurian aged formations. The Ashfield 5-IX WD, Dungannon, Ashfield 7-1-III ED, and West Wawanosh 26-X Pools are located between approximately 8 and 19 km south of the Township. The Tipperary, Tipperary South, Bayfield, and Tuckersmith 30-III SHR Pools are all located more than 20 km from the Township of Huron-Kinloss (Figure 3.6).

Historic exploration in southwestern Ontario focused on Upper Ordovician (hydrothermal dolomite) and Upper Silurian (reef-type) units as potential hydrocarbon plays (e.g., Sanford, 1993; Hamblin, 2008; Lazorek and Carter, 2008). Seven exploration wells are documented within the Township of Huron-Kinloss in the Oil, Gas and Salt Resources Library (OGSRL) Petroleum Wells Subsurface Database (OGSRL, 2006). These wells primarily targeted Silurian (reef-type) hydrocarbon plays, but no economical oil or gas volumes or production was reported and all have been abandoned. Well #F012078 has a recorded oil show, with no production and was also abandoned. The presence or absence of oil and gas plays including hydrothermal dolomite in the Township of Huron-Kinloss would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

New conceptual hydrocarbon plays are identified for southern Ontario by Hamblin (2008). Potential plays include Cambrian gas deposits at the eastern edge of the Michigan Basin, Upper Ordovician Shadow Lake Formation where it overlies the Cambrian, and Upper Ordovician shale gas. With respect to potential Cambrian and Shadow Lake gas plays, Well #F012061 within the Township of Huron-Kinloss did not contain Cambrian deposits (Table 3.3); however, Cambrian deposits are likely found in the western portion the Township and the presence or absence of such types of hydrocarbon plays would need to be confirmed during subsequent site evaluation stages. An analysis of the Upper Ordovician shale gas potential for the Bruce nuclear site, located 25 km to the north of the Township of Huron-Kinloss, found that insufficient total organic content of the Ordovician shales, as well as insufficient thermal maturity, would preclude any likelihood of commercial gas accumulations (Engelder, 2011).

In summary, no hydrocarbon pools have been identified within the Township of Huron-Kinloss and previous oil and exploration wells were dry. The potential for existing and new conceptual hydrocarbon plays would have to be examined during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

### 5.2 Metallic Mineral Resources

There is no record of current or past metallic mineral production, and no exploration potential for metallic minerals has been identified within the Township of Huron-Kinloss. The sole documented metallic mineral occurrence in southern Ontario is sphalerite associated with Mississippi Valley Type (MVT) lead/zinc deposits within Silurian dolomite on the Bruce Peninsula (e.g., Sangster and Liberty, 1971). No commercial MVT deposits or other metallic resources have been found within southern Ontario.

## 5.3 Non-Metallic Mineral Resources

Known non-metallic mineral resources in the region include bedrock-derived crushed stone, natural surficial sand and gravel resources, salt and building stone. Current licensed non-metallic mineral extraction in the Township of Huron-Kinloss is limited to sand and gravel resources (Figure 5.1).

### 5.3.1 Sand and Gravel

Sand and gravel pits in the Township of Huron-Kinloss generally correspond to glaciofluvial outwash or ice-contact deposits found at surface (Figures 3.8 and 5.1). Several pits are also found on the glaciolacustrine beach deposits in the western portion of the Township. The Ontario Geological Survey Aggregate Resources Inventory for Bruce County (Rowell, 2012) indicates that 2010 aggregate production from the Township of Huron-Kinloss was 420,752 tonnes or approximately 19% of Bruce County's total sand and gravel resource extraction. Rowell (2012) designated primary, secondary and tertiary significance for sand and gravel resources based on quality and potential volume. One area within the Township of Huron-Kinloss was assigned a primary significance; this comprises the currently operating pit that is located in the southern area of the Township, surrounding the community of Lucknow (Figure 5.1). Rowell (2012) estimates that 58.2 million tonnes of aggregate may still be available for extraction in this area. Numerous areas of secondary significance are identified within the Township of Huron Kinloss and correspond to the glaciolacustrine beach deposits that stretch from northeast to southwest through the western half of the Township, a southeast-trending ice-contact deposit in the north-central portion of the Township, a combination of ice-contact and glaciofluvial outwash deposits located to the southeast, the esker deposit located in the southeast corner of the Township, and an additional area of glaciofluvial outwash in the southeastern corner that extends into the Township of Huron-Kinloss.

### 5.3.2 Bedrock Resources

There are no known licensed bedrock quarries or commercial mining operations within the Township of Huron-Kinloss or in the surrounding area (Figure 5.1). Economic bedrock resources are typically close to the surface, covered by less than 8 m of overburden, and must be of mineable thickness. Most bedrock extraction operations are located in areas where the overburden thickness is 8 m or less. The majority of the Township of Huron-Kinloss is covered by greater than 8 m of Quaternary sediments (Figure 3.9). Those areas with thin overburden or outcrop contain no unique bedrock resources with respect to aggregate, cement or building stone.

There are no known commercial salt resources located in the Township of Huron-Kinloss. Economic deposits of salt are mined south of the Township in Goderich Ontario. The presence or absence of salt resources would have to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.



## 6. Initial Screening Evaluation

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

Initial screening criteria (NWMO, 2010) require that:

1. The site must have enough available land of sufficient size to accommodate the surface and underground facilities.
2. This available land must be outside of protected areas, heritage sites, provincial parks and national parks.
3. This available land must not contain known groundwater resources at the repository depth, so that the repository site is unlikely to be disturbed by future generations.
4. This available land must not contain economically exploitable natural resources as known today, so that the repository site is unlikely to be disturbed by future generations.
5. This available land must not be located in areas with known geological and hydrogeological characteristics that would prevent the site from being safe, considering the outlined safety factors in Section 6 of the site selection document (NWMO, 2010).

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

### 6.1 Screening Criterion 1: Land Availability

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

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

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

Availability of land was assessed by identifying areas 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 (developed areas, infrastructure), accessibility and construction challenges, based on the information presented in Section 2. At the request of the Township of Huron-Kinloss Council, the area west of Highway 21 was not included in the initial screening. The Council expects future development will likely occur along the lakeshore and wishes to



provide future councils with the full range of development options for this area. Review of available mapping and satellite imagery shows that the Township of Huron-Kinloss contains limited constraints east of Highway 21 that would prevent the development of the repository's surface facilities (Figures 2.1, 2.2 and 2.5). These would mainly include Provincially Significant Wetlands, which account for approximately 5% of the area of the Township of Huron-Kinloss. The Earth Science ANSI of Lothian-Lake Warren is found along the southern boundary of the Township and occupies less than 1% of the Township area. In addition, a small Conservation Area is found within the Town of Lucknow.

A minor portion of the Township is also covered by residential and industrial/commercial infrastructure, largely in the west-central portion of the Township and along its southern boundary in proximity to the towns of Ripley and Lucknow, and along the shore of Lake Huron near Point Clark (Figure 2.1). The remainder of the Township of Huron-Kinloss east of Highway 21 is largely agricultural land with development limited primarily to roadways and settlement areas. Therefore, the Township of Huron-Kinloss contains sufficient land to potentially accommodate the repository's surface facilities.

As discussed in Section 2, topography is variable across the Township of Huron-Kinloss. However, no obvious topographic features have been identified that would prevent construction and characterization activities over most of the Township. The majority of the Township of Huron-Kinloss could be accessed from Highway 21 and the numerous subsidiary county and rural roads which cross the area (Figure 2.1).

As discussed in Section 6.5, readily available information suggests that the Township of Huron-Kinloss has the potential of containing sufficient volumes of host rock at depth to accommodate underground facilities associated with a deep geological repository. This would have to be confirmed in subsequent site evaluation stages, if the community remains interested in continuing to participate in the site selection process.

*Based on the review of readily available information, the Township of Huron-Kinloss contains sufficient land to accommodate the repository's surface and underground facilities.*

## 6.2 Screening Criterion 2: Protected Areas

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

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

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

There are no provincial or national parks within the Township of Huron-Kinloss (Figure 2.1). One conservation area, an Earth Science ANSI and seven (7) Provincially Designated Wetlands occupy approximately 6% of the area of the Township of Huron-Kinloss. There are also four very small locally significant wetlands within the Township (Section 2.4.1).

As discussed in Section 2.4, other cultural heritage constraints include the Point Clark Lighthouse National Historic Site located along the shore of Lake Huron and the Lucknow Town Hall Heritage building in the town of Lucknow. Three known localized archeological sites within the Township are documented and concentrated around settlement areas.

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

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

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

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

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

The review of available hydrogeological information did not identify any known groundwater resources at repository depth beneath the Township of Huron-Kinloss. The Ministry of the Environment Water Well Records indicates that no potable water supply wells are known to exploit aquifers at typical repository depths (approximately 500 m) within the Township of Huron-Kinloss or the surrounding areas (Section 4.1). All water wells known in the Township of Huron-Kinloss obtain water from overburden or shallow bedrock sources at depths ranging from 3 to 111 m.

As discussed in section 4.2, the potential for groundwater resources within the Upper Ordovician units at typical repository depth beneath the Township of Huron-Kinloss is extremely low. Experience from other areas in southern Ontario and the detailed site characterization work recently completed at the nearby Bruce nuclear site for OPG's proposed DGR for low and intermediate level radioactive waste has shown that there is no active deep groundwater system at typical repository depths due to the very low hydraulic conductivities of the Upper Ordovician shale and limestone units (approximately  $10^{-15}$  to  $10^{-10}$  m/s). The active groundwater system is shallow and limited to the upper approximately 200 m. Available hydrogeological data from OPG's proposed DGR project indicates that the deep groundwater regime within the Upper Ordovician units at typical repository depth is diffusion-dominated and isolated from the shallow groundwater system. In addition, as discussed in Section 4.3, a transition from fresh to non-potable and highly saline groundwater has been recognized below approximately 200 mBGS.

*The review of available information did not identify any known groundwater resources at repository depth beneath the Township of Huron-Kinloss. Experience in similar geological settings in the region suggests that the potential for deep groundwater resources at repository depths is extremely low beneath the Township of Huron-Kinloss. This would, however, need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.*

## 6.4 Screening Criterion 4: Known Natural Resources

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

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

The review of available information indicates that there are no known oil and gas pools within the Township of Huron-Kinloss. Seven historic exploration wells that were drilled primarily targeting Silurian reef-type hydrocarbon plays within the Township of Huron-Kinloss resulted in one recorded oil show, no oil and gas production, and all wells have been abandoned. New conceptual hydrocarbon plays are identified for southern Ontario by Hamblin (2008), including Upper Ordovician shale gas. An assessment of the shale gas potential at the Bruce nuclear site (25 km north of the Township) found that the likelihood of commercial gas accumulation in the Ordovician shale is low because of their low organic content and insufficient thermal maturity. This finding suggests that commercial gas accumulation in the Ordovician shales beneath the Township of Huron-Kinloss is also unlikely due to the proximity to the Bruce nuclear site and the consistency of the regional geological setting. The presence or absence of historical or new conceptual oil and gas plays would need to be confirmed during subsequent site evaluation stages, if the community remains interested in continuing with the site selection process.

There are currently no operating mines within the Township of Huron-Kinloss and there is no record of metallic mineral production in the past. No exploration potential for metallic minerals has been identified within the Township.

Known non-metallic mineral resources in the region include bedrock-derived crushed stone, natural surficial sand and gravel resources, salt and building stone. There are no known commercial salt resources located in the Township of Huron-Kinloss. Current licensed non-metallic mineral extraction in the Township of Huron-Kinloss is limited to sand and gravel resources (Section 5.3). The risk that these resources pose for future human intrusion is negligible, as quarrying operations would be limited to very shallow depths.

*Based on the review of readily available information, the Township of Huron-Kinloss contains sufficient land, 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 continuing with the site selection process.*

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

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

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

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

At this early stage of the site evaluation process, where limited geoscientific data at repository depth exist for the Township of Huron-Kinloss, the five safety-related geoscientific factors are assessed using readily available information, with the objective of identifying any obvious unfavourable hydrogeological and geological conditions that would exclude the Township from further consideration. These factors would be gradually assessed in more detail as the site evaluation process progresses and more site specific data are collected during subsequent site evaluation phases, provided the community remains interested in continuing with the site selection process.

As discussed below, the review of readily available geoscientific information did not identify any obvious geological or hydrogeological conditions that would exclude the Township of Huron-Kinloss from further consideration in the site selection process at this stage.

### 6.5.1 Safe Containment and Isolation

The geological and hydrogeological conditions of a suitable site should promote long-term containment and isolation of used nuclear fuel and retard the movement of any potentially released radioactive material. This requires that the repository be located at a sufficient depth, typically around 500 m, in a sufficient rock volume with characteristics that limit groundwater movement. Readily available information on the local and regional geology and hydrogeology was reviewed in Sections 3 and 4.

As discussed in Section 3.2.1, the geology of the Township of Huron-Kinloss is consistent with the regional geological framework. The Township is entirely underlain by a predictable and laterally extensive Ordovician to Devonian Paleozoic sedimentary sequence that was deposited approximately 488 to 359 million years ago.

Based on information from a historic oil and gas deep exploration well (Well #F012061, Table 3.3), the total thickness of the Paleozoic strata near the southwestern boundary of the Township of Huron-Kinloss is approximately 970 m. As discussed in section 3.2.1, the geology at typical repository depth beneath the Township of Huron Kinloss is dominated by the Upper Ordovician shales and limestones with a depth ranging from about 600 m mBGS in the southwestern area to about 500 mBGS in the northeastern area of the Township. The Upper Ordovician shale units are expected to be cumulatively more than 200 m thick and overlay more than 200 m of Ordovician limestone units beneath the entire Township. In the southwestern area of the Township, the Lower Silurian dolostones and shales are also present at around 500 mBGS depth. These formations were described as not suitable for a deep geological repository by Mazurek (2004) because of their relatively high hydraulic conductivity and/or their limited thickness.

While there is limited information on the geoscientific characteristics of the Upper Ordovician shale and limestone units beneath the Township of Huron-Kinloss, it is expected that they are relatively similar to the Upper Ordovician units beneath the nearby Bruce nuclear site (Section 3.2.1). The latter are described as comprising relatively undeformed, low porosity and low hydraulic conductivity sequences that are correlative over large lateral extents as a result of their simple near horizontal geometry and uniform thicknesses. Given their thickness and lateral extent, the Upper Ordovician shale and limestone units would potentially provide a sufficient volume of rock to physically contain and isolate a deep geological repository for used nuclear fuel.

Given the regional predictability of the geological setting, the hydrogeological and hydrogeochemical conditions at typical repository depth beneath the Township of Huron-Kinloss are expected to be relatively similar to those beneath the Bruce nuclear site (Section 4.2). The deep groundwater regime within the Upper Ordovician shale and limestone units beneath the Bruce nuclear site is described as diffusion dominated and isolated from the shallow groundwater system which is limited to the upper 200 mBGS. One mapped fault is recognized beneath the Township of Huron-Kinloss (Figure 3.2). This fault is interpreted to postdate the deposition of the Upper Ordovician Trenton Group carbonates, but predate the deposition of the overlying Upper Ordovician shales.

The isolated nature of the deep groundwater system is further supported by the regional hydrogeochemical setting (Section 4.3). Regional chemistries of the deep brines indicate that they were formed by evaporation of seawater, which was subsequently modified by fluid-rock interaction processes. Limited evidence for recent dilution by meteoric or glacial waters was found within the regional geochemical database. The nature of the deep brines, in particular their high salinities and distinct isotopic signatures, suggests long residence times and indicates that the deep system has remained isolated from the shallow groundwater system.

In summary, the review of available information did not identify any obvious geological or hydrogeological conditions that would fail the containment and isolation requirements. The Upper Ordovician shale and limestone beneath the Township of Huron-Kinloss are potentially suitable for hosting a deep geological repository for used nuclear fuel. These formations exist at a sufficient depth and in sufficient volumes to host a deep geological repository. They are also expected to have hydrogeological characteristics that would limit groundwater movement. Similar conclusions were previously reached by Mazurek (2004) in a regional analysis of the sedimentary formations within southern Ontario, which identified the Upper Ordovician shale and limestone units as potentially suitable environments to host a deep geological repository for used nuclear fuel. Additional geoscientific characteristics that may have an impact on the containment and isolation functions of a deep geological repository for used nuclear fuel beneath the Township of Huron-Kinloss, 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 need to be further assessed during subsequent site evaluation stages, provided the community remains interested in continuing with the site selection process.

### 6.5.2 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 future geological and climate change processes, such as earthquakes or glaciation. A full assessment of this geoscientific factor requires 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 long-term hydrogeological and geological stability of the Township of Huron-Kinloss. As discussed below, the review of readily available information did not reveal any obvious characteristics that would raise such concerns.

The Township of Huron-Kinloss is underlain by Precambrian crystalline basement of the Grenville Province, the southeasternmost subdivision of the Canadian Shield. The Precambrian Grenville Province, which extends from Labrador to Mexico, is generally considered to have been relatively tectonically stable since approximately 970 million years ago (Section 3). Only one mapped fault has been identified in the Township of Huron-Kinloss. There is no evidence suggesting that this fault has been tectonically active within the past approximately 444 million years.

The geology of the Township of Huron-Kinloss is typical of many areas of southern Ontario, which has been subjected to numerous glacial cycles during the last million years. Glaciation is a significant past perturbation that could occur in the future. However, findings from studies conducted in other areas of southern Ontario suggest that the deep subsurface Paleozoic sedimentary formations have remained largely unaffected by past perturbations such as glaciations (Sections 3 and 4).

A neotectonic study was conducted as part of detailed site characterization for OPG's proposed DGR at the Bruce nuclear site to analyse Quaternary landforms for the presence of seismically-induced soft-sediment deformation. The study was conducted within a radius of up to 50 km from the Bruce nuclear site, which includes the Township of Huron-Kinloss. The study concluded that the area has not likely experienced any post-glacial neotectonic activity. A study of the glacial erosion of the Bruce Peninsula caused by the Laurentide Ice Sheet concluded that significant glacial erosion likely did not occur, based on observations of striated surfaces with multiple episodes preserved, the relative absence of friction cracks, and the pervasive low relief of striated surfaces (Section 3.6). The study also concluded that potential future glacial erosion in the area would be limited with a conservative site-specific estimate of erosion of 100 m per 1 million years, which is much less than the typical depth of a used nuclear fuel repository (approximately 500 m).

In summary, the review did not identify any obvious geological or hydrogeological conditions that would fail to meet the long-term stability requirement for a potential repository within the Township of Huron-Kinloss. The long-term stability factor would need to be further assessed through detailed multi-disciplinary geoscientific and climate change site investigations, if the community remains interested in continuing with the site selection process.

### 6.5.3 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 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 is very low. Exploration drilling for oil and natural gas suggests that there are areas free of economic hydrocarbon resources within the Township of Huron-Kinloss.

#### 6.5.4 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. Besides 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.

From a constructability perspective, although no readily available site specific information on rock strength characteristics and in-situ stresses was found for the Township of Huron-Kinloss, there is abundant information at other locations of southern Ontario that could provide insight into what would be expected for the Township of Huron-Kinloss. Available information on strength and in-situ stresses suggests that the Upper Ordovician shale and limestone units have favorable geomechanical characteristics and are amenable to the excavation of stable underground openings. For example, estimated mean uniaxial compressive strengths for Upper Ordovician limestone (Cobourg Formation) and shale (Georgian Bay Formation) units were 113 MPa and 32 MPa, respectively at the Bruce nuclear site. These values compare favourably with other sedimentary formations considered internationally for the long-term management of radioactive waste (Section 3.4). Numerical simulation of the behaviour of underground openings in the limestone Cobourg Formation for the OPG-DGR project indicated that the openings will remain stable during construction and operation, requiring only standard support. The simulations also show that, in the long-term, the barrier integrity of the enclosing Ordovician bedrock formations will not be affected under various loading scenarios associated with glacial ice sheet, seismic ground motions and repository gas pressure (Section 3.5).

In terms of predictability of the geologic formations and amenability to site characterization activities, the review of available information on the bedrock geology for the Township of Huron-Kinloss did not reveal any conditions that would make the rock mass difficult to characterize. As discussed in Section 3, the sedimentary sequences beneath the Township of Huron-Kinloss are consistent with the regional geological framework for southern Ontario. The Paleozoic bedrock stratigraphy is characterized by minimal structural complexity and a simple geometry, providing a basis for the subsurface predictability of stratigraphic formations.

The Paleozoic sedimentary sequence beneath the Township of Huron-Kinloss is covered by Quaternary overburden deposits. As described in Section 3, overburden thickness in the Township ranges from 6 m to 82 m. The regional geological framework, the simple geometry and the predictability of the subsurface stratigraphic formations indicates that the thickness of the overburden cover is not likely to affect the ability to characterize the subsurface bedrock formations beneath the Township of Huron-Kinloss.

In summary, the review of readily available geological and geomechanical information for the Township of Huron-Kinloss (Section 3) did not indicate any obvious conditions which would make the rock mass unusually difficult to characterize or construct upon.

*Based on the review of available geological and hydrogeological information, the Township of Huron-Kinloss comprises land that does not contain obvious known geological and hydrogeological conditions that would make the area unsuitable for hosting a deep geological repository.*

## 7. Initial Screening Findings

This report presents the results of an initial screening to assess the potential suitability of the Township of Huron-Kinloss against five initial screening criteria using readily available information. The initial screening focused on the areas within the boundaries of the Township of Huron-Kinloss. At the request of the Township, the area west of Highway 21 was not included in the initial screening. Areas within neighbouring municipalities were also not included in the initial screening.

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

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 Township of Huron-Kinloss from being further considered in the NWMO site selection process. The initial screening indicates that there are geological formations within the boundaries of the Township that are potentially suitable for safely hosting a deep geological repository. Potentially suitable host formations include the Upper Ordovician shales and limestone units that comprise the geology of the Township at typical repository depths.

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 Township of Huron-Kinloss, but rather to identify whether there are any obvious conditions that would exclude it from the site selection process. Should the community of Huron-Kinloss remain interested in continuing with the site selection process, several years of progressively more detailed studies would be required to confirm and demonstrate whether the Township of Huron-Kinloss contains 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.



## 8. References

- Armstrong, D.K. and T.R. Carter, 2006:  
An Updated Guide to the Subsurface Paleozoic Stratigraphy of Southern Ontario. Ontario Geological Survey, Open File Report 6191.
- Armstrong, D.K. and T.R. Carter, 2010:  
The Subsurface Paleozoic Stratigraphy of Southern Ontario. Ontario Geological Survey, Special Volume 7.
- Armstrong, D.K. and W.R. Goodman, 1990:  
Stratigraphy and depositional environments of Niagaran carbonates, Bruce Peninsula, Ontario. Field Trip No. 4 Guidebook. American Association of Petroleum Geologists, 1990 Eastern Section Meeting, hosted by the Ontario Petroleum Institute. London, Ontario.
- Bailey Geological Services Ltd. and R.O. Cochrane, 1984:  
Evaluation of the conventional and potential oil and gas reserves of the Cambrian of Ontario. Ontario Geological Survey, Open File Report 5499.
- Barnett, P.J., 1992:  
Quaternary geology of Ontario. In: Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 1008-1088.
- Boyce, J.J. and W.A. Morris, 2002:  
Basement-controlled faulting of Paleozoic strata in southern Ontario, Canada. New evidence from geophysical lineament mapping. Tectonophysics, 353, 151-171.
- Brigham, R.J., 1971:  
Structural geology of southwestern Ontario and southeastern Michigan. Ontario Department of Mines and Northern Affairs Paper 71-2.
- Bruce County Official Plan, 2011:  
County of Bruce Official Plan. Printed August 26, 2011.  
[http://www.brucecounty.on.ca/assets/departments/planning/files/County%20Documents/County%20Plan\\_Consolidated\\_Public\\_Aug%202011.pdf](http://www.brucecounty.on.ca/assets/departments/planning/files/County%20Documents/County%20Plan_Consolidated_Public_Aug%202011.pdf).
- Brunton, F.R. and J.E.P. Dodge, 2008:  
Karst of southern Ontario and Manitoulin Island. Ontario Geological Survey, Groundwater Resources Study 5.
- Canadian Aeromagnetic Data Base, 2011:  
Aeromagnetic Data Base, Airborne Geophysics Section, GSC – Central Canada Division, Geological Survey of Canada, Earth Sciences Sector, Natural Resources Canada.  
([http://gdcinfo.agg.nrcan.gc.ca/contact\\_e.html#DataCentre](http://gdcinfo.agg.nrcan.gc.ca/contact_e.html#DataCentre))
- Canadian Geodetic Information System, 2011:  
Gravity and Geodetic Networks Section, Geodetic Survey Division, Geomatics Canada, Earth Sciences Sector, Natural Resources Canada. ([http://gdcinfo.agg.nrcan.gc.ca/contact\\_e.html#DataCentre](http://gdcinfo.agg.nrcan.gc.ca/contact_e.html#DataCentre))
- Carr, S.D., R.M. Easton, R.A. Jamieson and N.G. Culshaw, 2000:  
Geologic transect across the Grenville Orogen of Ontario and New York. Canadian Journal of Earth Sciences 37(2-3), 193–216.

- Carter, T.R. and R.M. Easton, 1990:  
Extension of Grenville basement beneath southwestern Ontario: lithology and tectonic subdivisions. In: Carter, T.R. (ed.), *Subsurface Geology of Southwestern, a Core Workshop*, American Association of Petroleum Geologists, 1990 Eastern Section Meeting. Ontario Petroleum Institute, London, Ontario.
- Carter T.R., R.A. Treveil and R.M. Easton, 1996:  
Basement controls on some hydrocarbon traps in southern Ontario, Canada. In: B.A. van der Pluijm and P.A. Catacosinos (eds.), *Basement and Basins of Eastern North America*. Geological Society of America Special Paper 308, 95-107.
- Chapman, L.J. and D.F. Putnam, 1984 (Digitized 2007):  
The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 270 pp. Accompanied by Map P.2715 (coloured), scale 1:600 000.
- Coniglio M. and A.E. William-Jones, 1992:  
Diagenesis of Ordovician carbonates from the north-east Michigan Basin, Manitoulin Island area, Ontario: Evidence from petrography, stable isotopes and fluid inclusions. *Sedimentology* 39, 813-836.
- Coniglio, M., M.J. Melchin and M.E. Brookfield, 1990:  
Stratigraphy, sedimentology and biostratigraphy of Ordovician rocks of the Peterborough–Lake Simcoe area of southern Ontario; American Association of Petroleum Geologists, 1990 Eastern Section Meeting, hosted by Ontario Petroleum Institute, Field Trip Guidebook no.3. London, Canada.
- Easton, R.M., 1992:  
The Grenville Province and the Proterozoic history of central and southern Ontario. In: *The Geology of Ontario*, Ontario Geological Survey, Special Volume 4, Part 2, 714-904.
- Earthquakes Canada, 2012:  
GSC, Earthquake Search (On-line Bulletin), <http://earthquakescanada.nrcan.gc.ca/stndon/NEDB-BNDS/bull-eng.php>, Nat. Res. Can., Feb. 2012.
- Engelder, T. and P. Geiser, 1980:  
On the use of regional joint sets as trajectories of paleostress fields during the development of the Appalachian plateau, New York. *Journal of Geophysical Research* 85(B11), 6319-6341.
- Engelder, T., 2011:  
Analogue Study of Shale Cap Rock Barrier Integrity. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-23 R000. Toronto, Canada.
- Gao, C., J. Shiota, R.I. Kelly, F.R. Brunton and S. van Haaften, 2006:  
Project Unit 05-013; bedrock topography and overburden thickness mapping, southern Ontario. Ontario Geological Survey, Miscellaneous Release—Data 207. ISBN 1-4249-2550-9.
- Golder, 2003:  
LLW Geotechnical Feasibility Study, Western Waste Management Facility, Bruce Site, Tiverton, Ontario. Report to Municipality of Kincardine and Ontario Power Generation. Golder Associates Ltd, Technical Report 021-1570.
- Gross, M.R., T. Engelder and S.R. Poulson, 1992:  
Veins in the Lockport dolostone: evidence for an Acadian fluid circulation system. *Geology* 20, 971-974.

- Hallet, B., 2011:  
Glacial Erosion Assessment. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-18 R000. Toronto, Canada.
- Hamblin, A., 1999:  
Upper Ordovician strata of southwestern Ontario: Synthesis of literature and concepts. Geological Survey of Canada, Open File 3729.
- Hamblin, A., 2003:  
Detailed outcrop and core measured sections of the Upper Ordovician/Lower Silurian succession of southern Ontario. Geological Survey of Canada, Open File 1525.
- Hamblin, A., 2008:  
Hydrocarbon potential of the Paleozoic succession of southwestern Ontario. Preliminary conceptual synthesis of background data. Geological Survey of Canada, Open File 5730.
- Hanmer, S. and S.J. McEachern, 1992:  
Kinematical and rheological evolution of a crustal-scale ductile thrust zone, Central Metasedimentary Belt, Grenville Orogen, Ontario. Canadian Journal of Earth Sciences 29, 1779-1790.
- Hobbs, M.Y., A. deHaller, M. Koroleva, M. Mazurek, J. Spangenberg, U. Mäder and D. Meier, 2011:  
Regional Hydrogeochemistry – Southern Ontario. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-12 R000. Toronto, Canada.
- Howell, P.D. and B.A. van der Pluijm, 1999:  
Structural sequences and styles of subsidence in the Michigan basin. Geological Society of America Bulletin 111, 974-991
- Intera, 2011:  
Descriptive Geosphere Site Model. Intera Engineering Ltd. report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-24 R000. Toronto, Canada.
- Itasca Canada and AECOM, 2011:  
Three-Dimensional Geological Framework Model. Itasca Consulting Canada, Inc. and AECOM Canada Ltd. report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-42 R000. Toronto, Canada.
- Johnson, M.D., D.K. Armstrong, B.V. Sanford, P.G. Telford and M.A. Rutka, 1992:  
Paleozoic and Mesozoic geology of Ontario. In: The Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 907-1008.
- Karrow, P.F., 1974:  
Till Stratigraphy in parts of Southwestern Ontario. Geological Society of America Bulletin 85, 761-768.
- Kesler, S.E. and C.W. Carrigan, 2002:  
Discussion on "Mississippi Valley-type lead-zinc deposits through geological time: implications from recent age-dating research" by D.L. Leach, D. Bradley, M.T. Lewchuk, D.T.A. Symons, G. de Marsily, and J. Brannon (2001). Mineralium Deposita 36, 711-740.
- Kumarapeli, P.S., 1976:  
The St. Lawrence rift system, related metallogeny, and plate tectonic models of Appalachian evolution, 301 - 320. In D.F. Strong (Ed.), Metallogeny and Plate Tectonics. Geological Association of Canada, Special Paper 14.

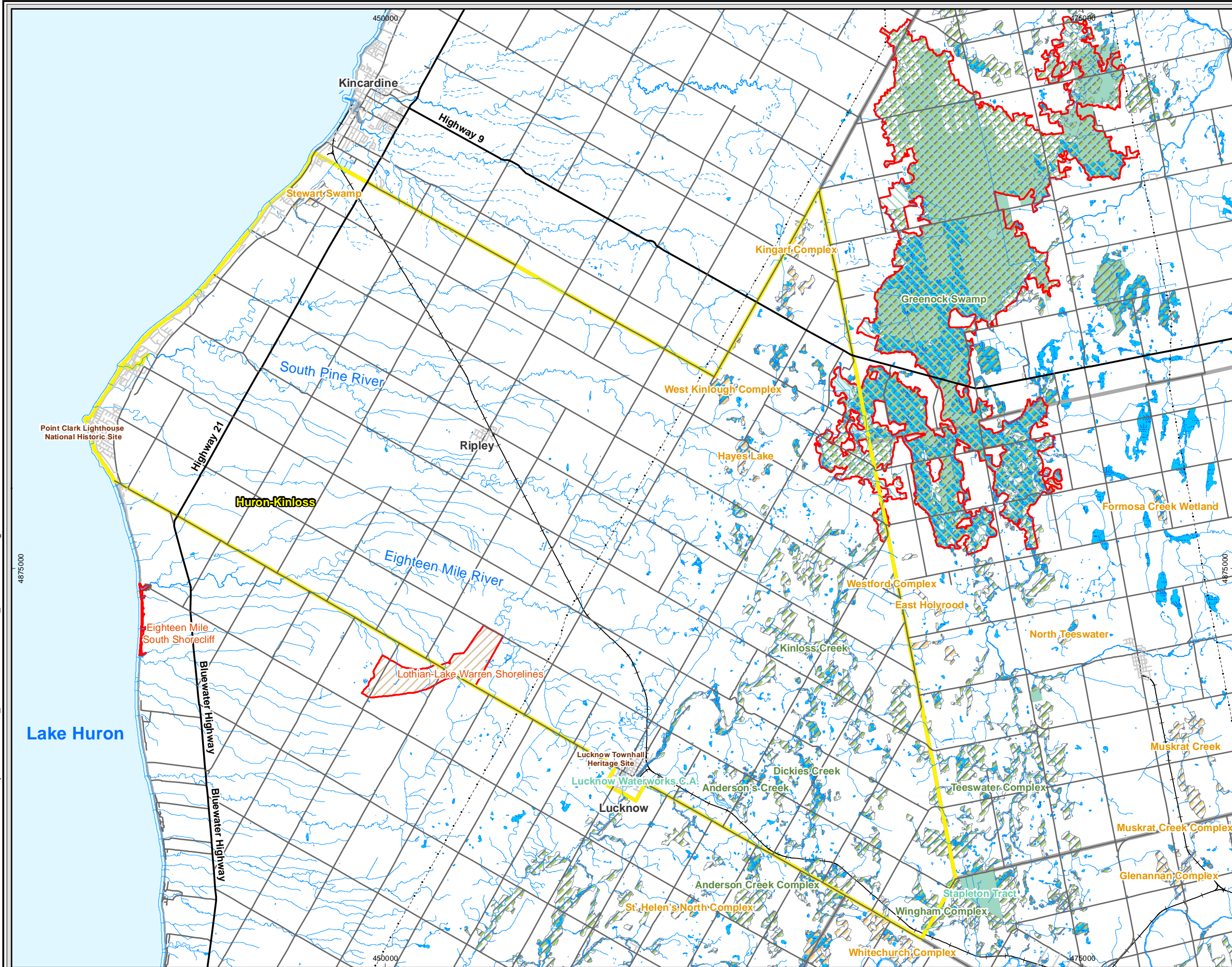
- Kumarapeli, P.S., 1985:  
Vestiges of Iapetan Rifting in the Craton West of the Northern Appalachians Geoscience Canada, 12, Number 2.
- Lazorek, M. and T. Carter, 2008:  
The Oil and Gas Plays of Ontario. Ontario Oil and Gas 2008 Edition. Ontario Petroleum Institute. London, Canada.
- Lumbers, S.B., L.M. Heaman, V.M. Vertolli and T.W. Wu, 1990:  
Nature and timing of middle Proterozoic magmatism in the Central Metasedimentary Belt, Grenville Province, Ontario. Special Paper- Geological Association of Canada 38, 243-276.
- Marshak, S. and J.R. Tabor, 1989:  
Structure of the Kingston Orocline in the Appalachian fold-thrust belt, New York, Geological Society of America Bulletin 101, 683-701.
- Marshak, S. and T. Paulsen, 1996:  
Mid-continent U.S. fault and fold zones: A legacy of Proterozoic intracratonic extensional tectonism? Geology 24, 151–154.
- Mazurek, M., 2004:  
Long-term Used Nuclear Fuel Waste Management - Geoscientific Review of the Sedimentary Sequence in Southern Ontario. Institute of Geological Sciences University of Bern Technical Report TR 04-01, Switzerland.
- McFall, G.H., 1993:  
Structural Elements and Neotectonics of Prince Edward County, Southern Ontario. Géographie physique et Quaternaire 47, 303-312.
- McWilliams, C.K., R.P. Wintsch and M.J. Kunk, 2007:  
Scales of equilibrium and disequilibrium during cleavage formation in chlorite and biotite-grade phyllites, SE Vermont. Journal of Metamorphic Geology 25, 895-913.
- Milkereit B., D.A. Forsyth, A.G. Green, A. Davidson, S. Hanmer, D.R. Hutchinson, W. Hinze and R.F. Mereu, 1992:  
Seismic images of a Grenvillian terrane boundary. Geology 20, 1027-1030
- Natural Resources Canada, 2012:  
Earthquake Map of Canada, 1627-2010. <http://www.earthquakescanada.nrcan.gc.ca/historic-historique/canegmap-eng.php>
- Natural Resources Canada:  
Centre for Topographic Information – Sherbrooke (CTI-S). Geobase Orthoimage 2005-2010. Spot 5, Obtained from Geobase (2006, 10 m resolution).
- NWMO, 2005:  
Choosing a way forward: The future management of Canada's used nuclear fuel. Nuclear Waste Management Organization. (Available at [www.nwmo.ca](http://www.nwmo.ca))
- NWMO, 2010:  
Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel, Nuclear Waste Management Organization, May 2010. (Available at [www.nwmo.ca](http://www.nwmo.ca))

- NWMO, 2011:  
OPG's Deep Geological Repository for Low and Intermediate Level Waste: Geosynthesis. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-11 R000. Toronto, Canada.
- NWMO and AECOM, 2011:  
Regional Geomechanics – Southern Ontario. AECOM Canada Ltd. and Nuclear Waste Management Organization Report NWMO DGR-TR-2011-13 R000. Toronto, Canada.
- Ontario Geological Survey, 1993:  
Bedrock geology, seamless coverage of the province of Ontario; Ontario Geological Survey, Data Set 6.
- Ontario Geological Survey, 1997:  
Quaternary geology, seamless coverage of the province of Ontario: Ontario Geological Survey, Data Set 14.
- Ontario Ministry of the Environment, 2012:  
Water Well Records. [http://www.ene.gov.on.ca/environment/en/subject/wells/STDPROD\\_075977.html](http://www.ene.gov.on.ca/environment/en/subject/wells/STDPROD_075977.html). 2012.
- Ontario Ministry of Natural Resources, 2009:  
Land Information Ontario Data Warehouse (LIO). Available from: <http://www.mnr.gov.on.ca/en/Business/LIO>. June 2009.
- Ontario Ministry of Tourism and Culture, undated:  
Ministry Cultural Services Unit, Ontario Archaeological Sites Database, Accessed: March 2012.
- Ontario Oil, Gas and Salt Resources Library (OGSRL), 2006:  
Oil and Gas Pools and Pipelines of Southern Ontario, revised October 2006. Petroleum Resources Centre, Ministry of Natural Resources Oil, Gas & Salt Resources Library UTM NAD83. Ontario Digital Base Data.
- Peltier, W.R., 2002:  
A design basis glacier scenario. Ontario Power Generation Report 06819-REP-01200-10069-R00. Toronto, Canada.
- Peltier, W.R., 2011:  
Long-Term Climate Change. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-14 R000. Toronto, Canada.
- Percival, J.A. and R.M. Easton, 2007:  
Geology of the Canadian Shield in Ontario. An Update. OPG Report No. 06819-REP-01200-10158-R00, OGS Open File Report 6196, GSC Open File Report 5511.
- Provincial Policy Statement, 2005:  
Provincial Policy Statement. Approved by the Lieutenant Governor in Council, Order in Council No. 140/2005. Issued under Section 3 of the *Planning Act*.  
<http://www.brucecounty.on.ca/assets/departments/planning/files/County%20Documents/PPS-2005.pdf>.
- Quinlan, G. and C. Beaumont, 1984:  
Appalachian thrusting, lithospheric flexure and the Paleozoic stratigraphy of the Eastern Interior of North America. Canadian Journal of Earth Sciences 21, 973-996.
- Rowell, D.J., 2012:  
Aggregate Resources Inventory of the County of Bruce, Southern Ontario. Ontario Geological Survey Aggregate Resources Inventory Paper 190, 112 pages.

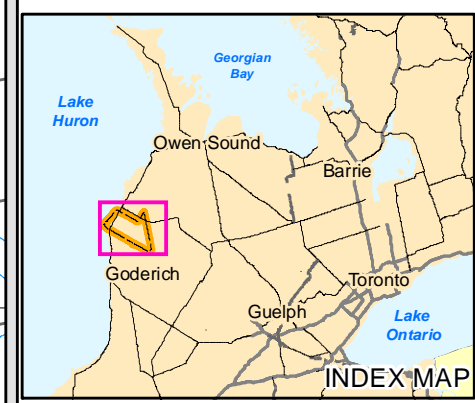
- Sanford, B.V., 1993:  
St. Lawrence Platform: economic geology. In: Stott, D.F. and J.D. Aitken (Eds.), *Sedimentary Cover of the Craton in Canada*, Geological Survey of Canada, *Geology of Canada Series*, no.5, 787-798.
- Sanford, B.V., F.J. Thompson and G.H. McFall, 1985:  
Plate tectonics – A possible controlling mechanism in the development of hydrocarbon traps in southwestern Ontario. *Bulletin of Canadian Petroleum Geology* 33, 52-71.
- Sangster, D.F. and B.A. Liberty, 1971:  
Sphalerite concretions from Bruce Peninsula, Southern Ontario, Canada. *Economic Geology* 66, 1145-1152.
- Saugeen, Grey Sauble, Northern Bruce Peninsula, 2011:  
Assessment Report - Saugeen Valley Source Protection Area. Approved November 28, 2011.  
[http://www.waterprotection.ca/AR/SVSPA/SVSPA\\_Approved\\_AR\\_Complete\\_Text.pdf](http://www.waterprotection.ca/AR/SVSPA/SVSPA_Approved_AR_Complete_Text.pdf).
- Slattery, S., 2011:  
Neotectonic Features and Landforms Assessment. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-19 R000. Toronto, Canada.
- Sloss, L.L., 1982:  
The Michigan Basin: Selected structural basins of the Midcontinent, USA. *UMR Journal* 3, 25-29.
- Sutter, J.F., N.M. Ratcliffe and S.B. Mukasa, 1985:  
40Ar/39Ar and K-Ar data bearing on the metamorphic and tectonic history of western New England. *Geological Society of America Bulletin* 96, 123-136.
- Thomas, W.A., 2006:  
Tectonic inheritance at a continental margin. *GSA Today* 16(2), 4-11.
- Uyeno, T.T., P.G. Telford and B.V. Sanford, 1982:  
Devonian conodonts and stratigraphy of southwestern Ontario. *Geological Survey of Canada, Bulletin* 332.
- Van Schmus, W.R., 1992:  
Tectonic setting of the Midcontinent Rift system. *Tectonophysics* 213, 1-15.
- Walker, J.D. and J.W. Geissman, compilers, 2009:  
Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C.
- White, D.J., D.A. Forsyth, I. Asudeh, S.D. Carr, H. Wu, R.M. Easton and R.F. Mereu, 2000:  
A seismic-based cross-section of the Grenville Orogen in southern Ontario and western Quebec. *Canadian Journal of Earth Sciences* 37, 183–192.
- Worthington, 2011:  
Karst Assessment. Worthington Groundwater report for the Nuclear Waste Management Organization NWMO DGR-TR-2011-22 R000. Toronto, Canada.
- Ziegler, K. and F.J. Longstaffe, 2000:  
Clay mineral authigenesis along a mid-continent scale fluid conduit in Palaeozoic sedimentary rocks from southern Ontario, Canada. *Clay Minerals* 35, 239-260.



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\SurroundingAreas100k.mxd



- Legend**
- Township of Huron-Kinloss
  - Municipal Division
  - Highway
  - Major Road
  - Local Road
  - Railway
  - Intermittent Stream
  - Permanent Stream
  - Waterbody
  - Cartographic Wetland
  - Conservation Areas
  - NGO Nature Reserve
  - Regulated Provincial Park
  - Provincially Significant Life Science ANSI
  - Provincially Significant Earth Science ANSI
  - Provincially Significant Wetland
  - Locally Significant Wetland



Basemapping, ANSIs and Conservation Areas from Ontario Ministry of Natural Resources  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068	Date
GIS	RM 8 Aug 2012
Approved	RF 8 Aug 2012

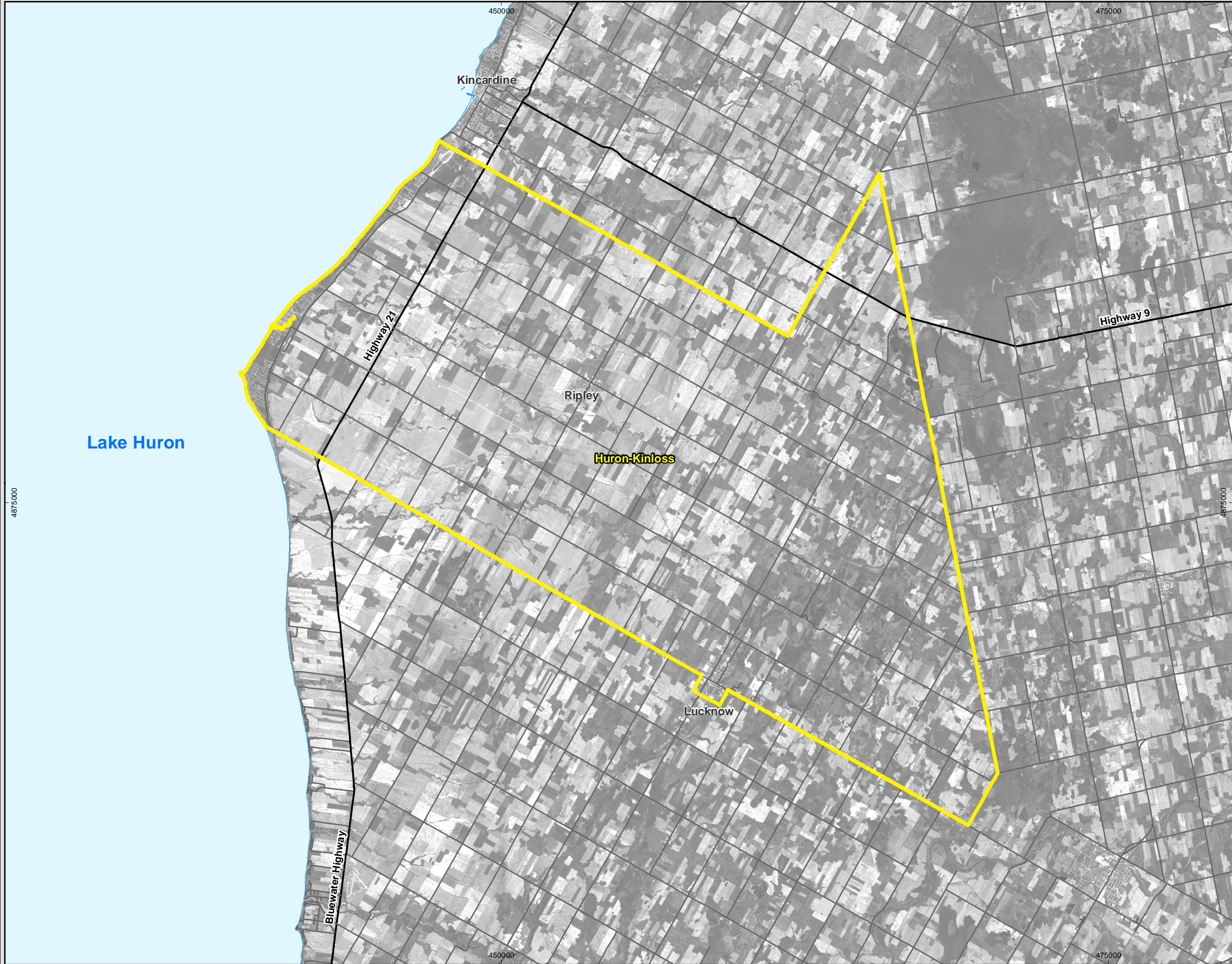
Kilometers  
0 0.5 1 2 3 4  
1:130,000

NWMO Desktop Level Initial Screening

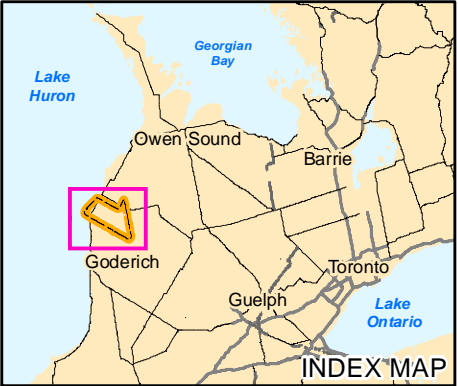
**Township of Huron-Kinloss and Surrounding Area**

August 2012  
Project 60247068



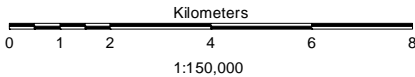
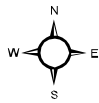


- Legend**
- Township of Huron-Kinloss
  - Highway
  - Major Road
  - Waterbody



Basemapping from Ontario Ministry of Natural Resources  
Imagery: Spot 5, Obtained from Geobase (2006, 10 m resolution)  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	8 Aug 2012
Approved	RF	8 Aug 2012



NWMO Desktop Level Initial Screening

**Satellite Imagery of the  
Township of Huron-Kinloss**

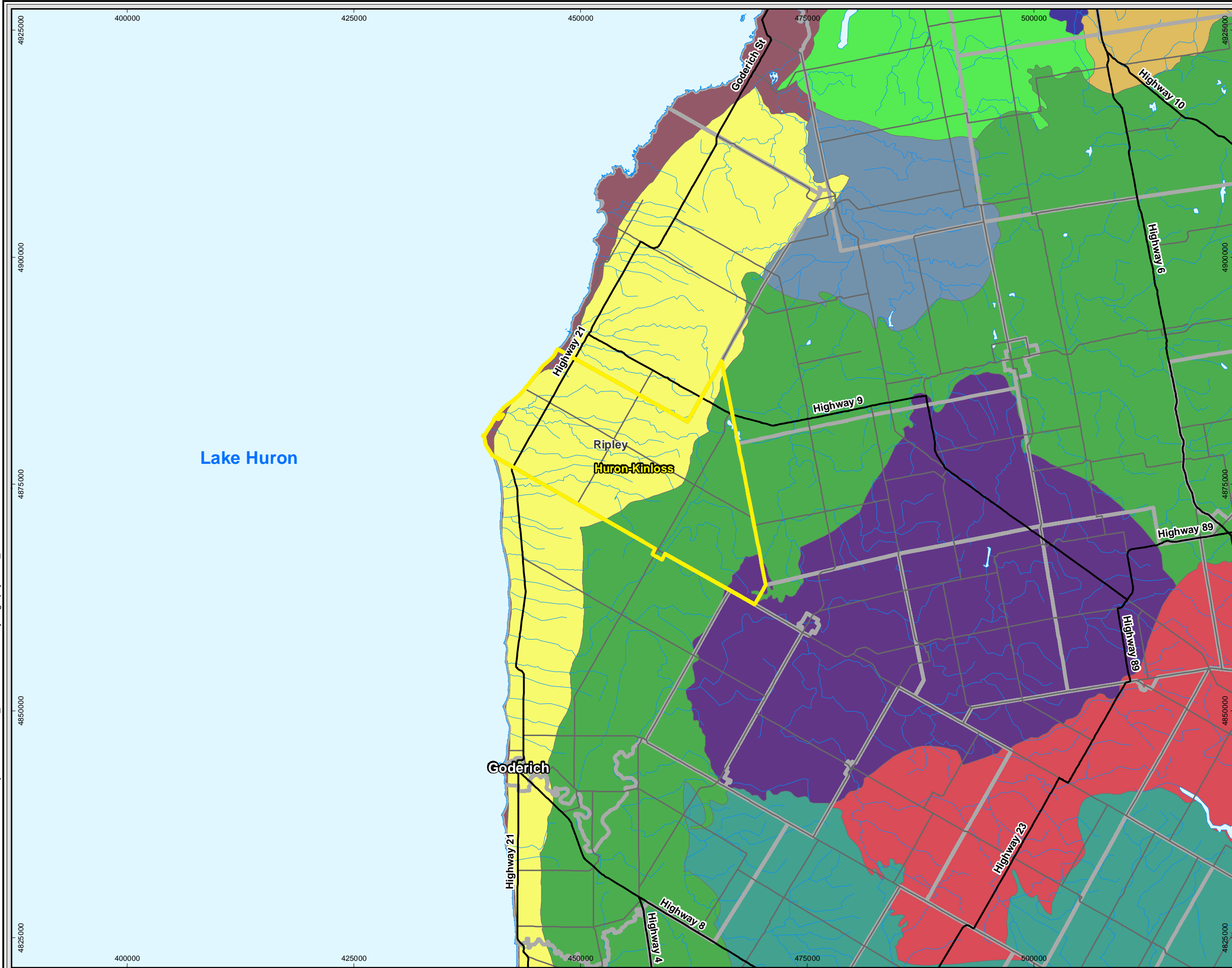
August 2012  
Project 60247068

**AECOM**

Figure 2.2



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068\Physiography\Huron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Municipal Division
- Highway
- Secondary Highway
- Waterbody

**Physiographic Regions**

- Bighead Valley
- Horseshoe Moraines
- Dundalk Till Plain
- Stratford Till Plain
- Teeswater Drumlin Field
- Arran Drumlin Field
- Saugeen Clay Plain
- Huron Slope
- Huron Fringe
- Bruce Peninsula

Physiography: Chapman, L.J. and Putnam, D.F. 2007.  
Physiography of Southern Ontario; Ontario Geological Survey  
Basemapping from Ontario Ministry of Natural Resources  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	15 Jun 2012
Approved	RF	15 Jun 2012

Kilometers  
0 2.5 5 10 15 20  
1:400,000

N  
W E  
S

NWMO Desktop Level Initial Screening

**Physiographic Regions of  
the Township of Huron-Kinloss  
and the Surrounding Area**

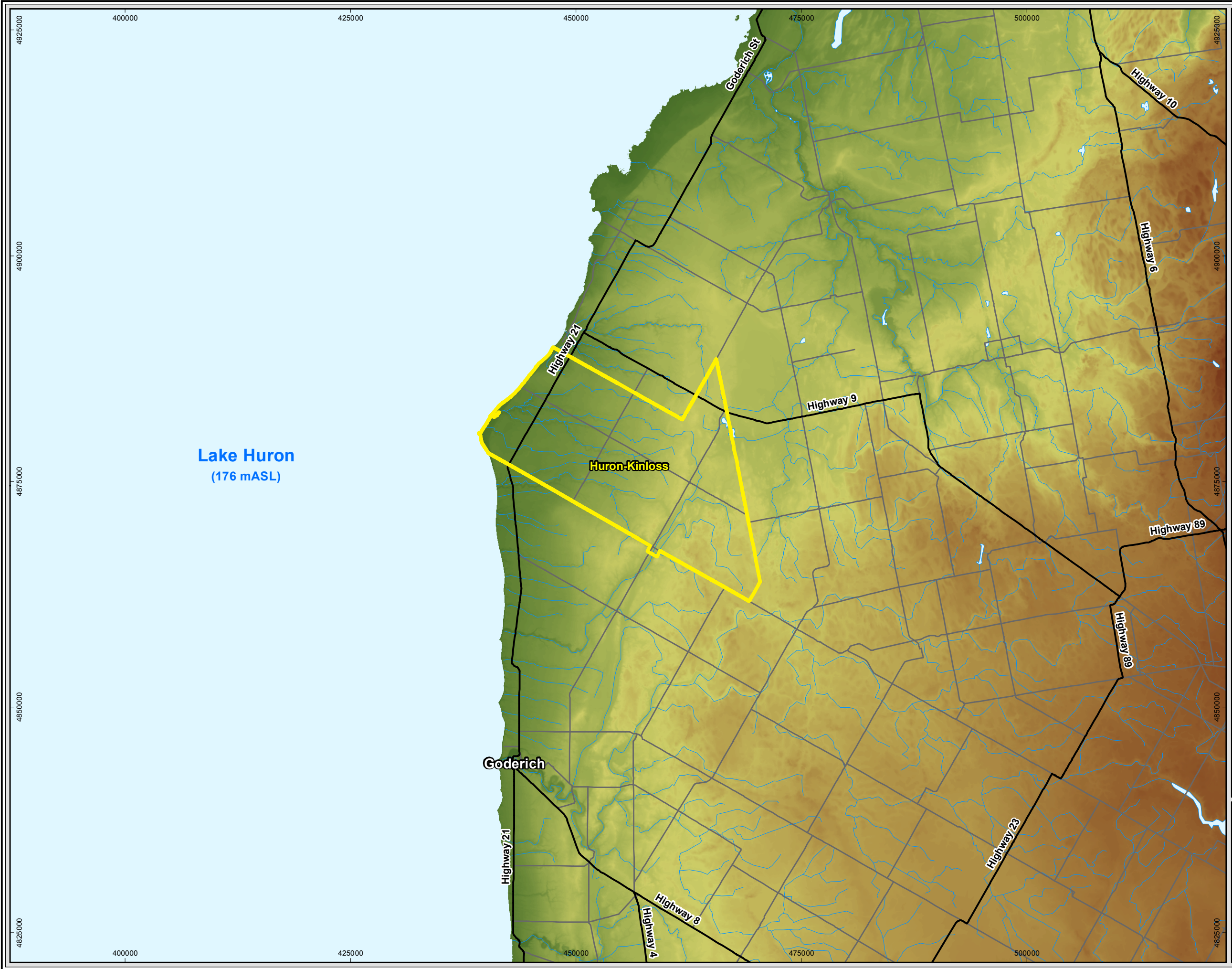
August 2012  
Project 60247068

**AECOM**

Figure 2.3



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068DEM\Huron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Highway
- Secondary Highway
- Watercourse
- Waterbody

**Elevation (mASL)**

522

350

176

INDEX MAP

Basemapping from Ontario Ministry of Natural Resources  
DEM: Land Information Ontario  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	8 Aug 2012
Approved	RF	8 Aug 2012

Kilometers

0 2.5 5 10 15 20

1:400,000

N  
W E  
S

NWMO Desktop Level Initial Screening

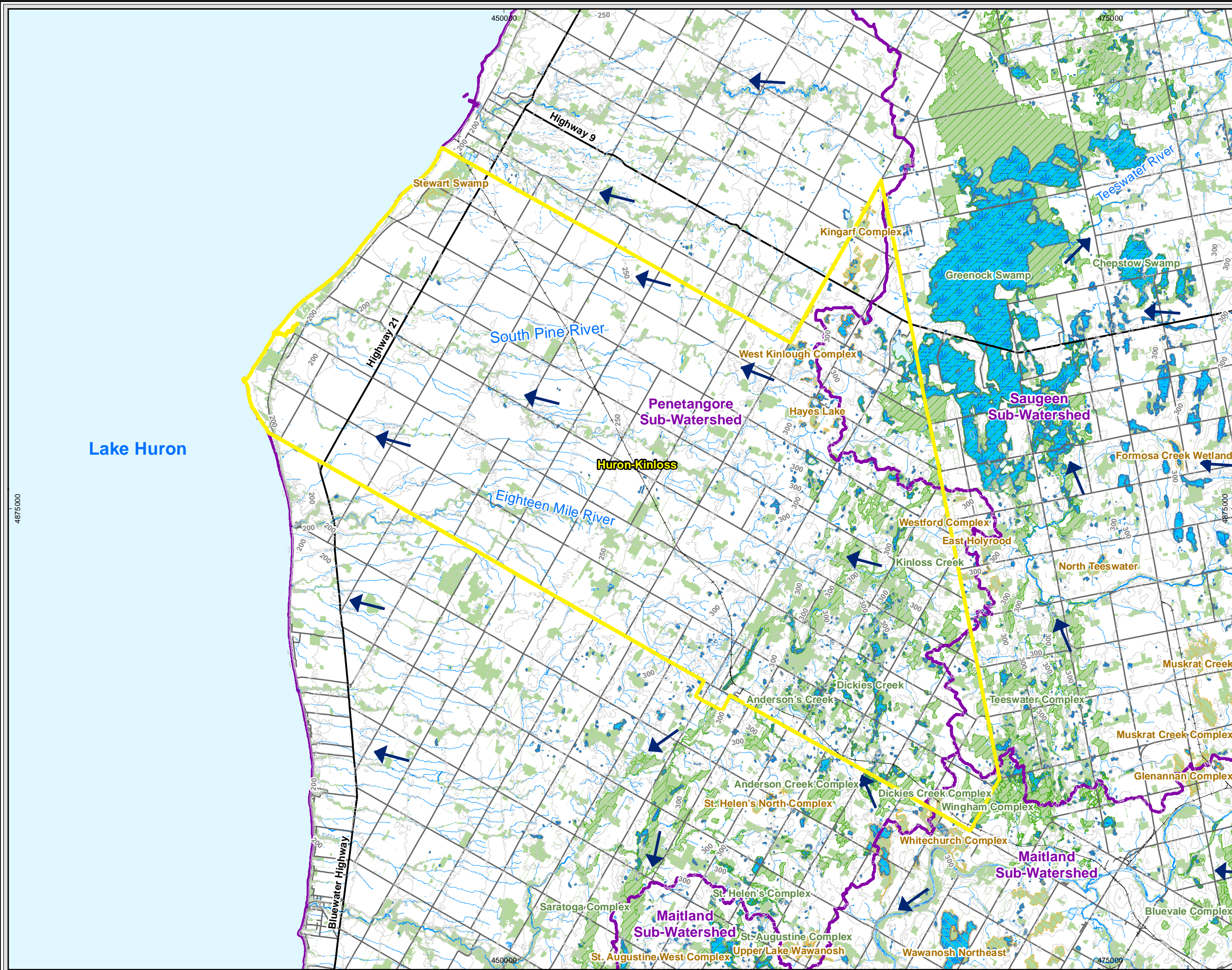
**Digital Elevation Model (DEM)**  
**of the Township of Huron-Kinloss**  
**and the Surrounding Area**

August 2012  
Project 60247068

**AECOM**

Figure 2.4





**Legend**

- Township of Huron-Kinloss
- Topographic Contour (10 m)
- Highway
- Major Road
- Railway
- Intermittent Stream
- Permanent Stream
- Waterbody
- Cartographic Wetland
- Provincially Significant Wetland
- Locally Significant Wetland
- Wooded Area
- Subwatershed Boundary
- Direction of Surface Water Flow

INDEX MAP

Basemapping and ANSIs from Ontario Ministry of Natural Resources  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068	Date
GIS	RM 8 Aug 2012
Approved	RF 8 Aug 2012

Kilometers

0 1 2 4 6 8

1:150,000

N  
W E  
S

NWMO Desktop Level Initial Screening

**Drainage Features of the Township of Huron-Kinloss**

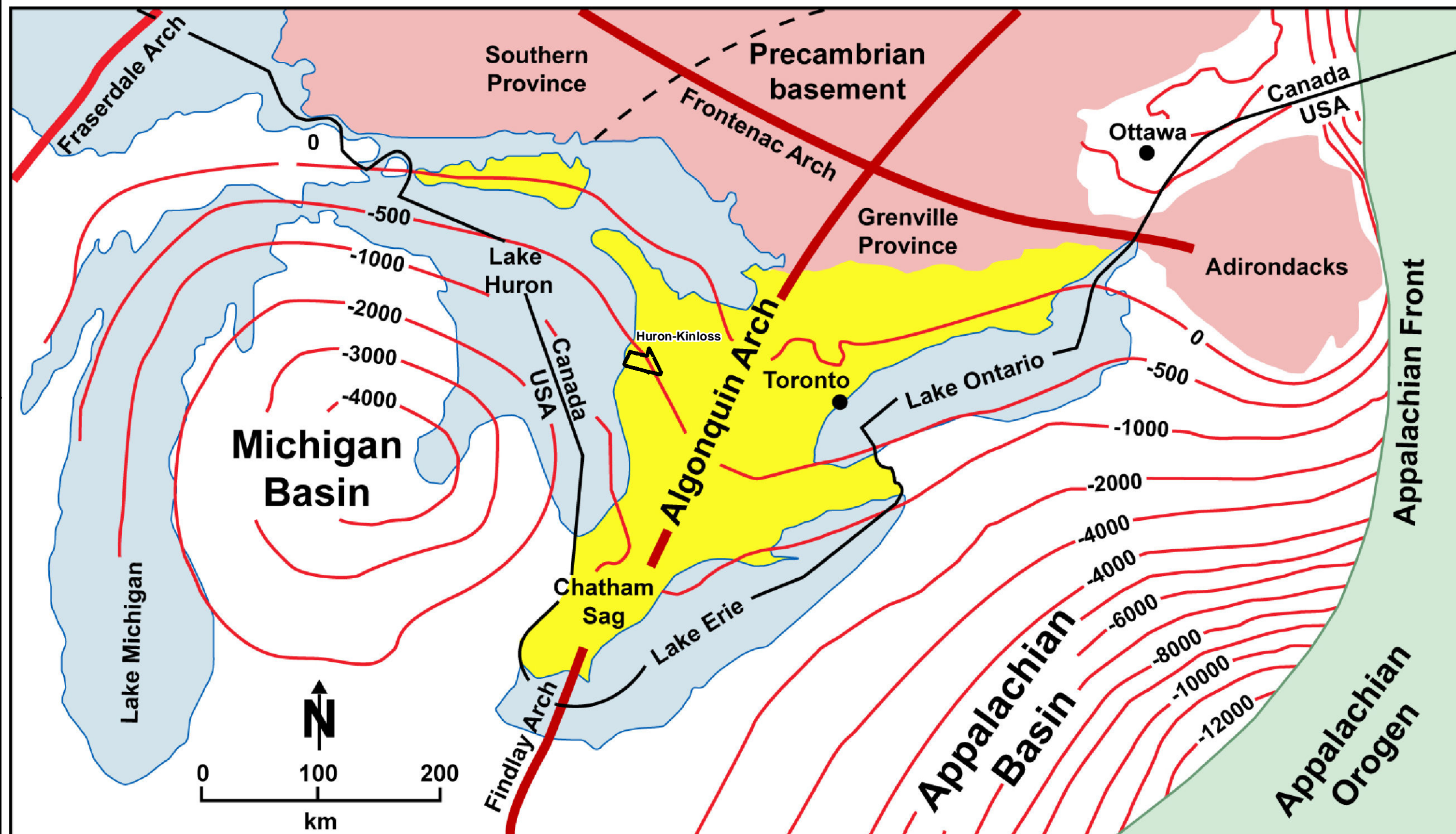
August 2012  
Project 60247068

**AECOM**

Figure 2.5



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068GeologicFeaturesofSouthernOntHuron\_Kinloss.mxd



- Legend**
- Township of Huron-Kinloss
  - Precambrian Basement
  - Appalachian Orogen
  - Paleozoic Sedimentary Rock of Southern Ontario
  - Contours of Precambrian Basement (mASL)
  - Axes of Arches
  - Precambrian Basement Boundary

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

Modified after Johnson et al., 1992

NWMO Desktop Level Initial Screening

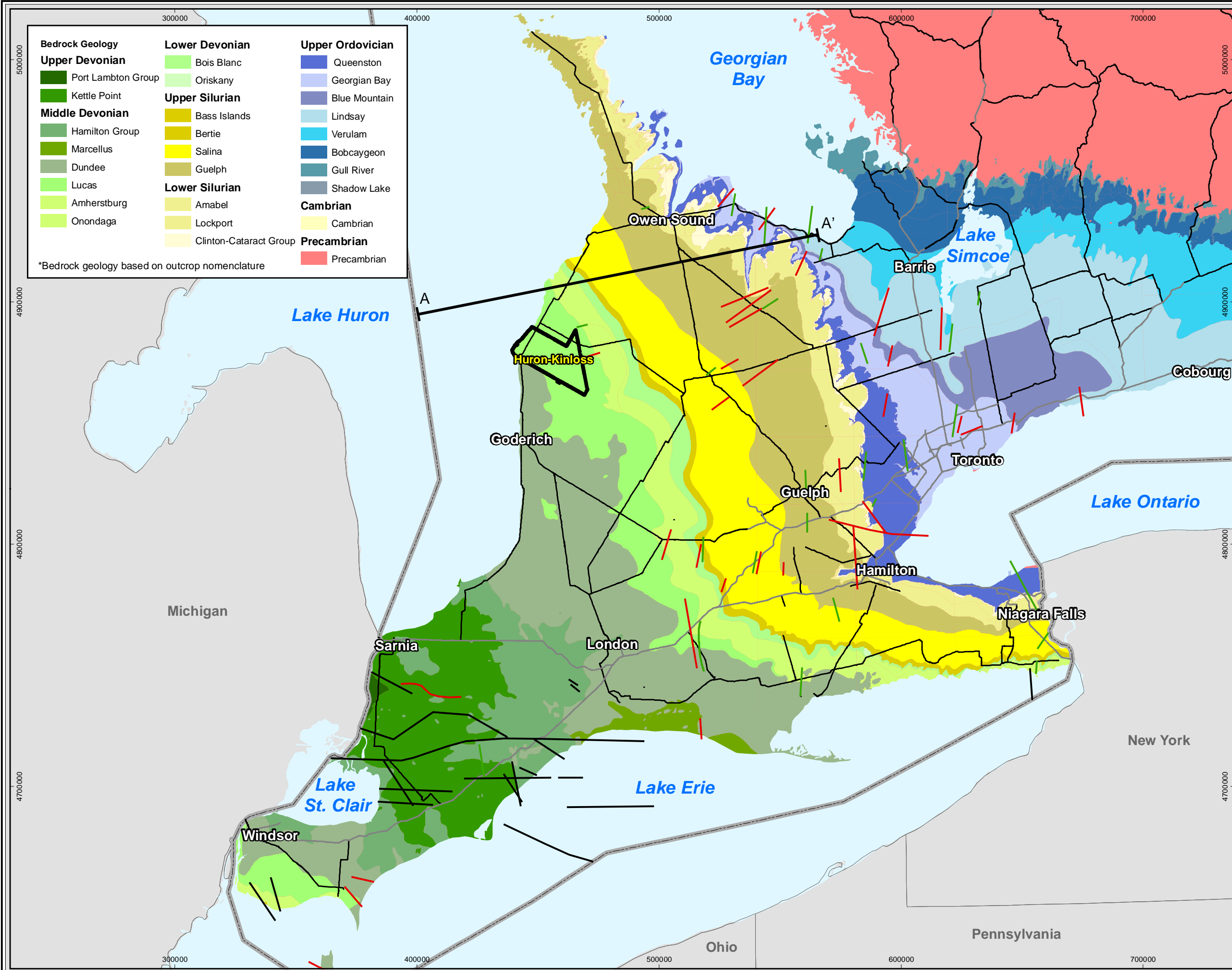
### Geological Features of Southern Ontario

August 2012  
Project 60247068

**AECOM**

Figure 3.1

Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068\BedrockGeology\SouthernOntarioHuron\_Kinloss.mxd



**Bedrock Geology**  
**Upper Devonian**  
Port Lambton Group  
Kettle Point  
**Middle Devonian**  
Hamilton Group  
Marcellus  
Dundee  
Lucas  
Amherstburg  
Onondaga

**Lower Devonian**  
Bois Blanc  
Oriskany  
**Upper Silurian**  
Bass Islands  
Bertie  
Salina  
Guelph  
**Lower Silurian**  
Amabel  
Lockport  
Clinton-Cataract Group

**Upper Ordovician**  
Queenston  
Georgian Bay  
Blue Mountain  
Lindsay  
Verulam  
Bobcaygeon  
Gull River  
Shadow Lake  
**Cambrian**  
Cambrian  
**Precambrian**  
Precambrian

\*Bedrock geology based on outcrop nomenclature

**Legend**  
Township of Huron-Kinloss  
Expressway  
Highway  
Canada - USA Boundary  
Waterbody  
Geological Cross Section Line  
**Faulted Units**  
Rochester (Silurian)  
Trenton (Ordovician)  
Shadow Lake/Precambrian

Basemapping from Ontario Ministry of Natural Resources  
Bedrock Geology: Ontario Geological Survey, 1993.  
Bedrock geology, seamless coverage of the province of Ontario: Ontario Geological Survey, Data Set 6.  
Fault Mapping: Armstrong and Carter, 2010.  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

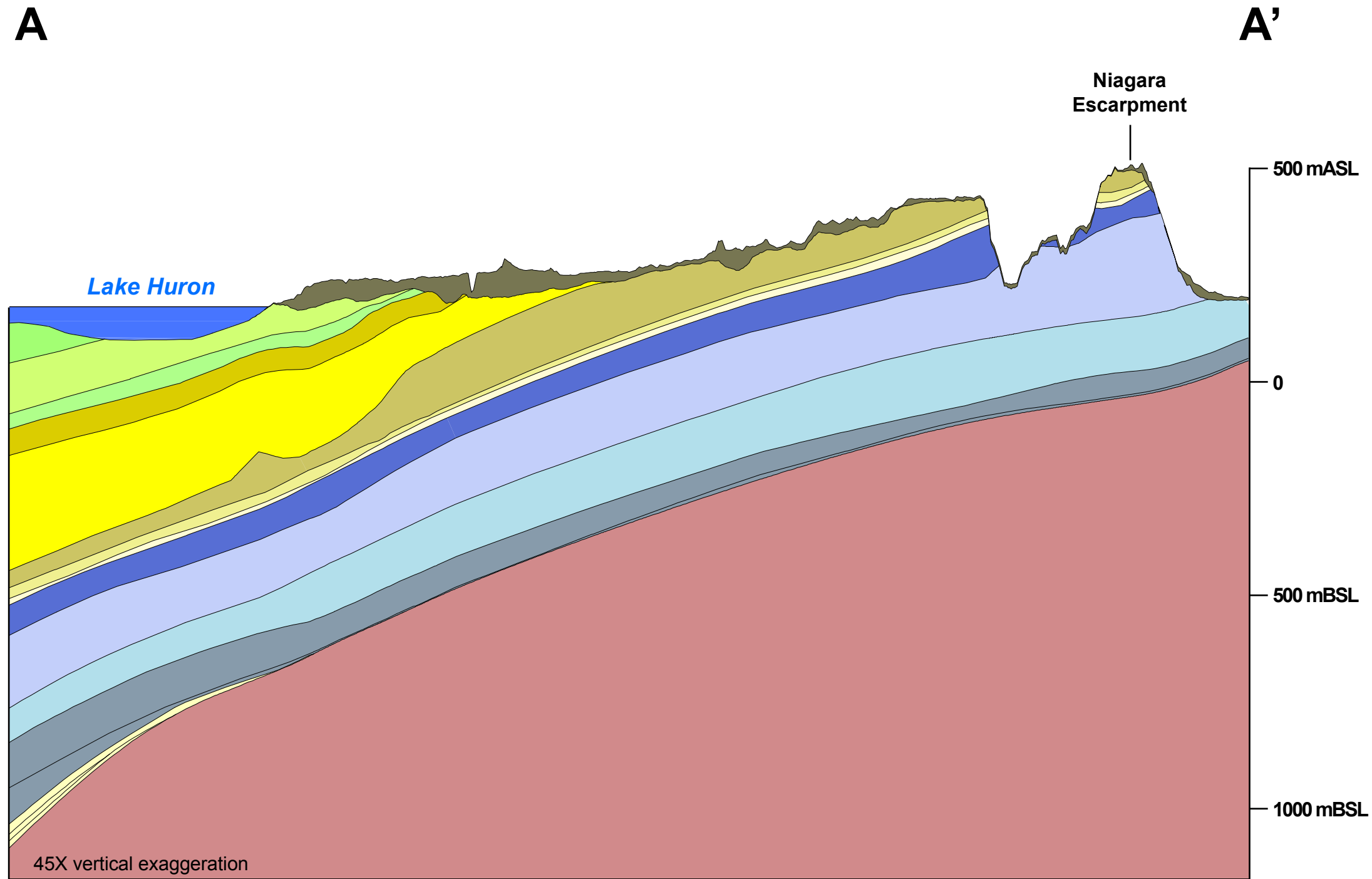
60247068	Date
GIS	RM 18 Jul 2012
Approved	RF 18 Jul 2012

Kilometers  
0 10 20 40 60 80  
1:1,500,000

NWMO Desktop Level Initial Screening

**Geology of Southern Ontario**  
August 2012  
Project 60247068

Figure 3.2



## Legend

Overburden

### Bedrock Geology

#### Middle Devonian

Lucas

Amherstburg

#### Lower Devonian

Bois Blanc

#### Upper Silurian

Bass Islands

Salina

Guelph

#### Lower Silurian

Lockport (Goat Island, Gasport)

Clinton-Cataract Group (Fossil Hill, Cabit Head, Manitoulin)

#### Upper Ordovician

Queenston

Georgian Bay/Blue Mountain

Trenton (Cobourg, Sherman Fall, Kirkfield)

Black River (Cobocok, Gull River, Shadow Lake)

#### Cambrian

Cambrian

#### Precambrian

Precambrian

modified after NWMO (2011)

60247068		Date
	SB	08 Aug 2012
Approved	RF	08 Aug 2012

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

NWMO Desktop Level Initial Screening

### Geological Cross-Section (Location Shown in Figure 3.2)

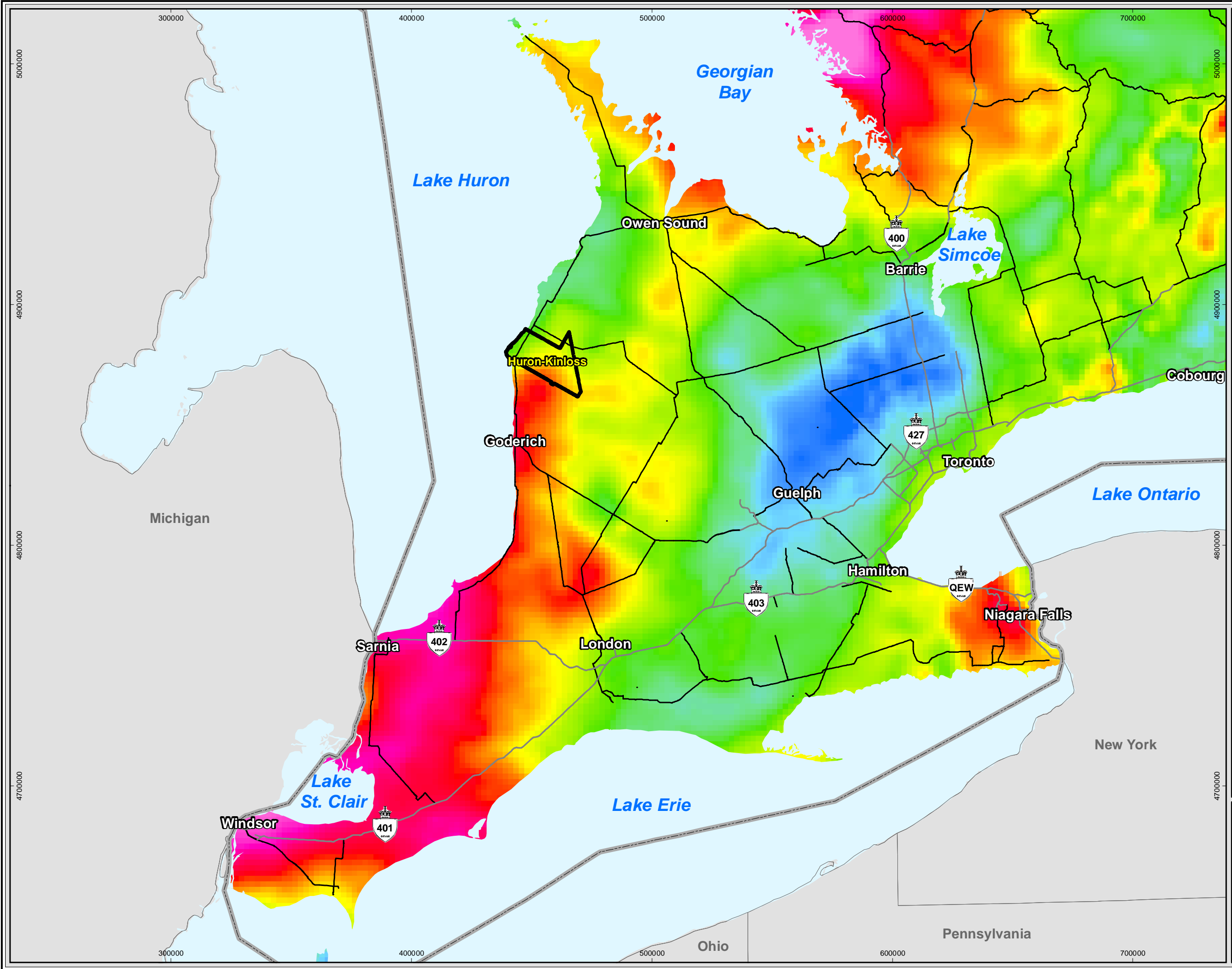
August 2012  
Project 60247068

**AECOM**

Figure 3.3



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068GravityAnomaliesHuron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Expressway
- Highway
- Canada - USA Boundary
- Waterbody

Gravity Anomaly (mGal)

-2.84  
-71.46



Basemapping from Ontario Ministry of Natural Resources  
Gravity: Canadian Geodetic Information System, Gravity & Geodetic Networks Section, Geodetic Survey Division, Geomatics Canada, Earth Sciences Sector, Natural Resources Canada  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068	Date
GIS	RM 18 Jul 2012
Approved	RF 18 Jul 2012

Kilometers  
0 10 20 40 60 80  
1:1,500,000

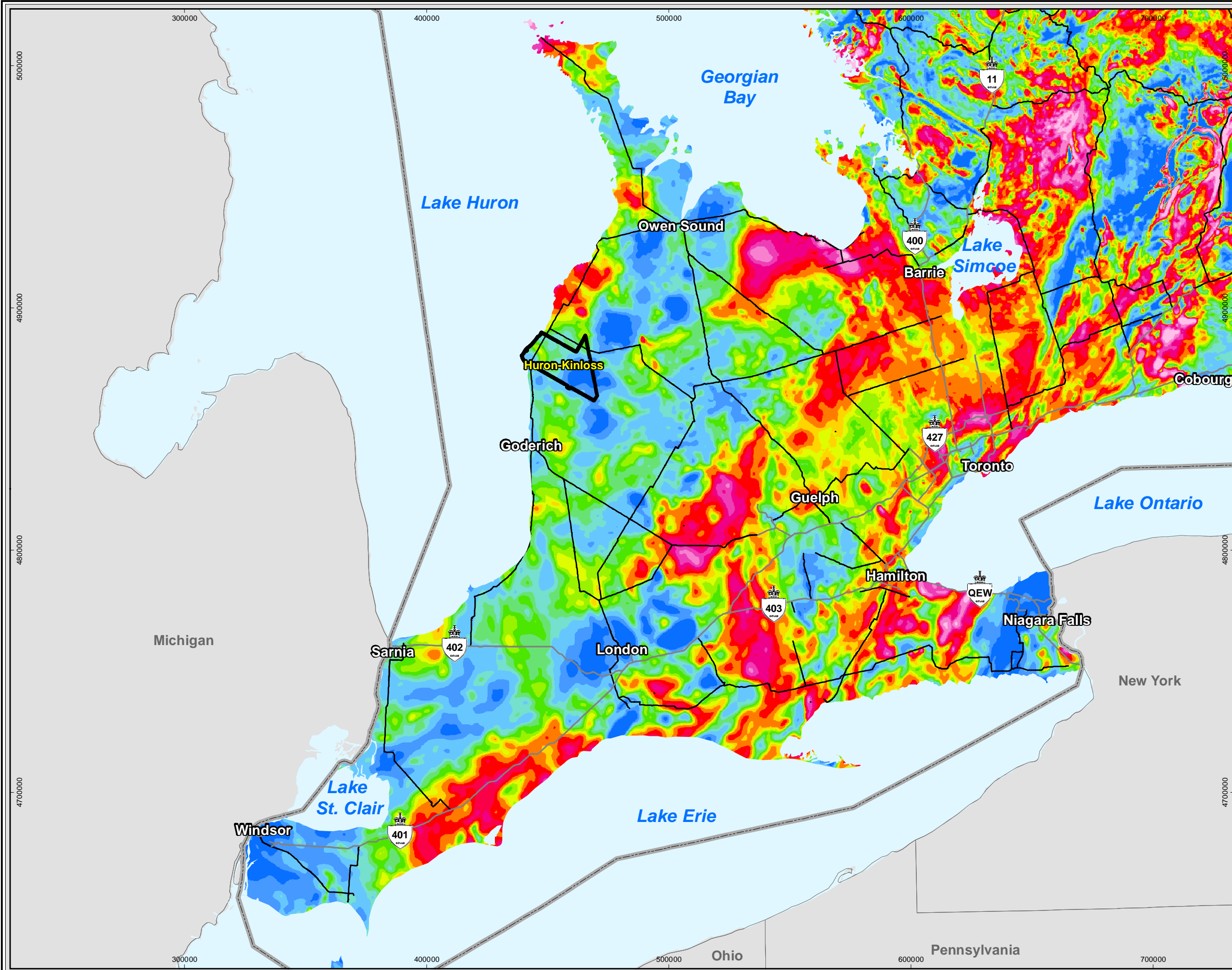
NWMO Desktop Level Initial Screening

**Gravity Map of Southern Ontario**

August 2012  
Project 60247068

Figure 3.4

Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068ResidualTotalMagneticFieldHuron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Expressway
- Highway
- Canada - USA Boundary
- Waterbody

Residual Total Magnetic Field (nT)

1235  
-250  
-543



Basemapping from Ontario Ministry of Natural Resources  
Aeromagnetic Data: 2011 Canadian Aeromagnetic Data Base,  
Airborne Geophysics Section, GSC - Central Canada Division,  
Geological Survey of Canada, Earth Sciences Sector, Natural  
Resources Canada, 2011  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068	Date
GIS	RM 18 Jul 2012
Approved	RF 18 Jul 2012

Kilometers  
0 10 20 40 60 80  
1:1,500,000

NWMO Desktop Level Initial Screening

**Residual Total Magnetic Field  
of Southern Ontario**

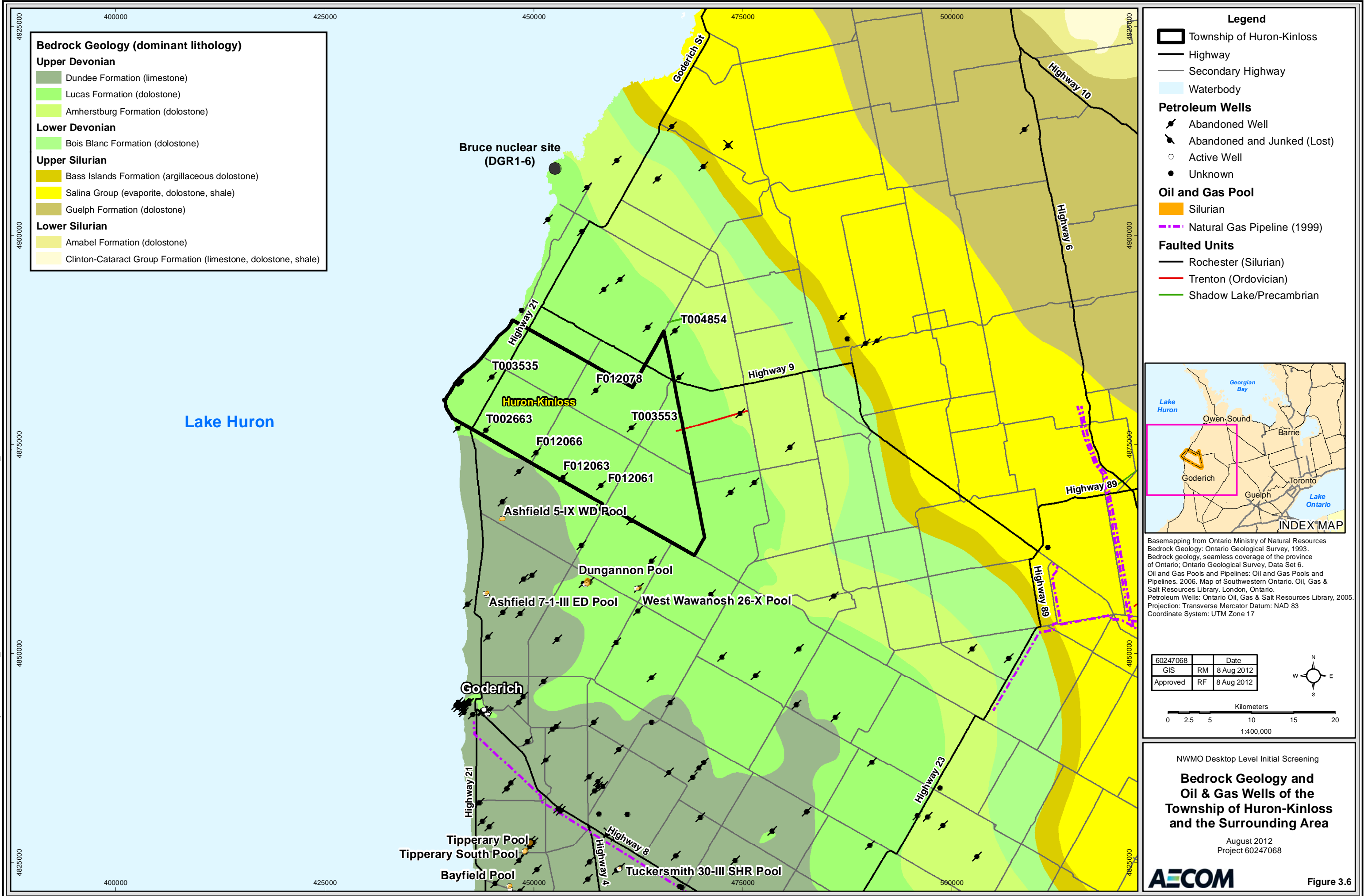
August 2012  
Project 60247068

**AECOM**

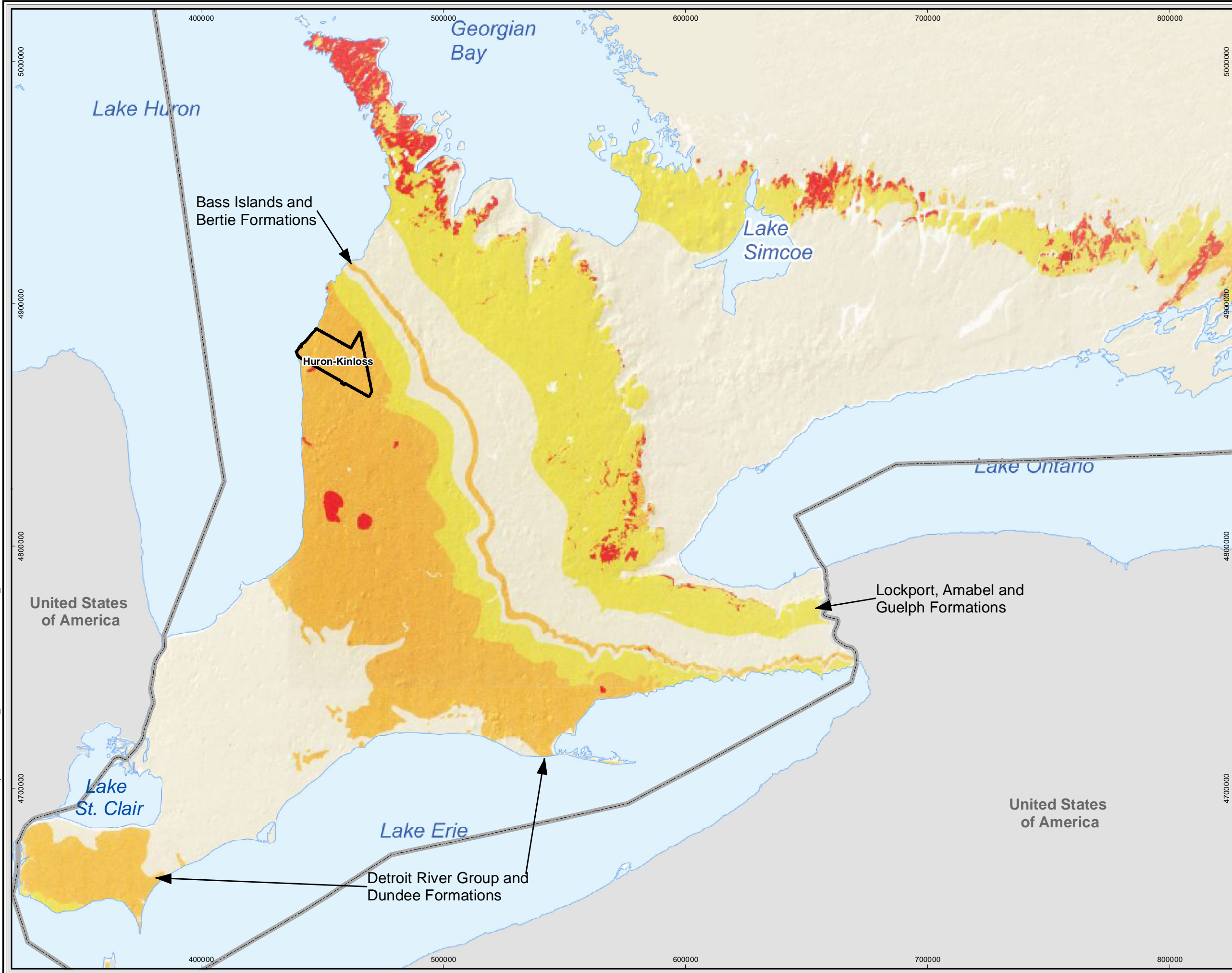
Figure 3.5



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\Huron\_Kinloss.mxd



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068KarstHuron\_Kinloss.mxd

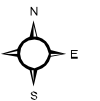


- Legend**
- Township of Huron-Kinloss
  - Canada - USA Boundary
  - Major Waterbody
  - Known Karst
  - Inferred Karst
  - Potential Karst



Basemapping from Ontario Ministry of Natural Resources  
Karst: Modified from Brunton and Dodge (2008)  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012



Kilometers  
0 10 20 40 60 80  
1:1,500,000

NWMO Desktop Level Initial Screening

## Karst Mapping of Southern Ontario

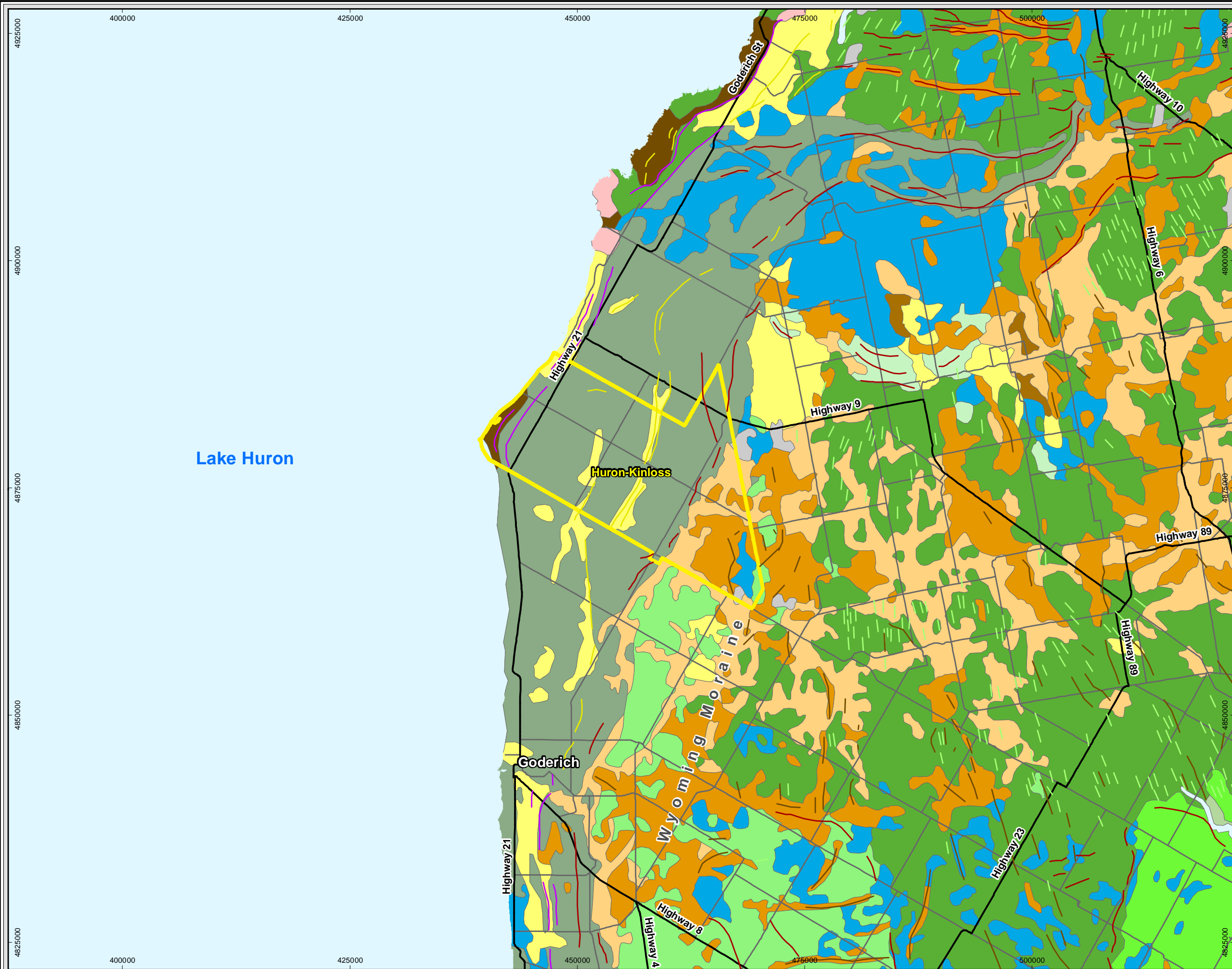
August 2012  
Project 60247068

**AECOM**

Figure 3.7



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068QuaternaryGeologyHuron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Highway
- Secondary Highway
- Waterbody
- beach, bar or spit
- drumlin or area of drumlins
- esker or area of eskers
- terrace escarpment (abandoned shore bluff)
- trend of end moraine crest

**Quaternary Geology**

- Bedrock
- Tavistock Till
- Mornington Till
- Elma Till
- Rannoch Till
- Dunkeld Till
- St. Joseph Till
- Glaciofluvial ice-contact deposits
- Glaciofluvial outwash deposits
- Glaciolacustrine deposits
- Glaciolacustrine beach deposits
- Fluvial deposits
- Lacustrine deposits
- Organic deposits

Basemapping from Ontario Ministry of Natural Resources  
Quaternary Geology: Quaternary Geology of Ontario Seamless Coverage-Data Set 14  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	8 Aug 2012
Approved	RF	8 Aug 2012

Kilometers

0 2.5 5 10 15 20

1:400,000

**INDEX MAP**

Georgian Bay  
Lake Huron  
Owen Sound  
Barrie  
Goderich  
Guelph  
Toronto  
Lake Ontario

**NWMO Desktop Level Initial Screening**

**Quaternary Geology of the Township of Huron-Kinloss and the Surrounding Area**

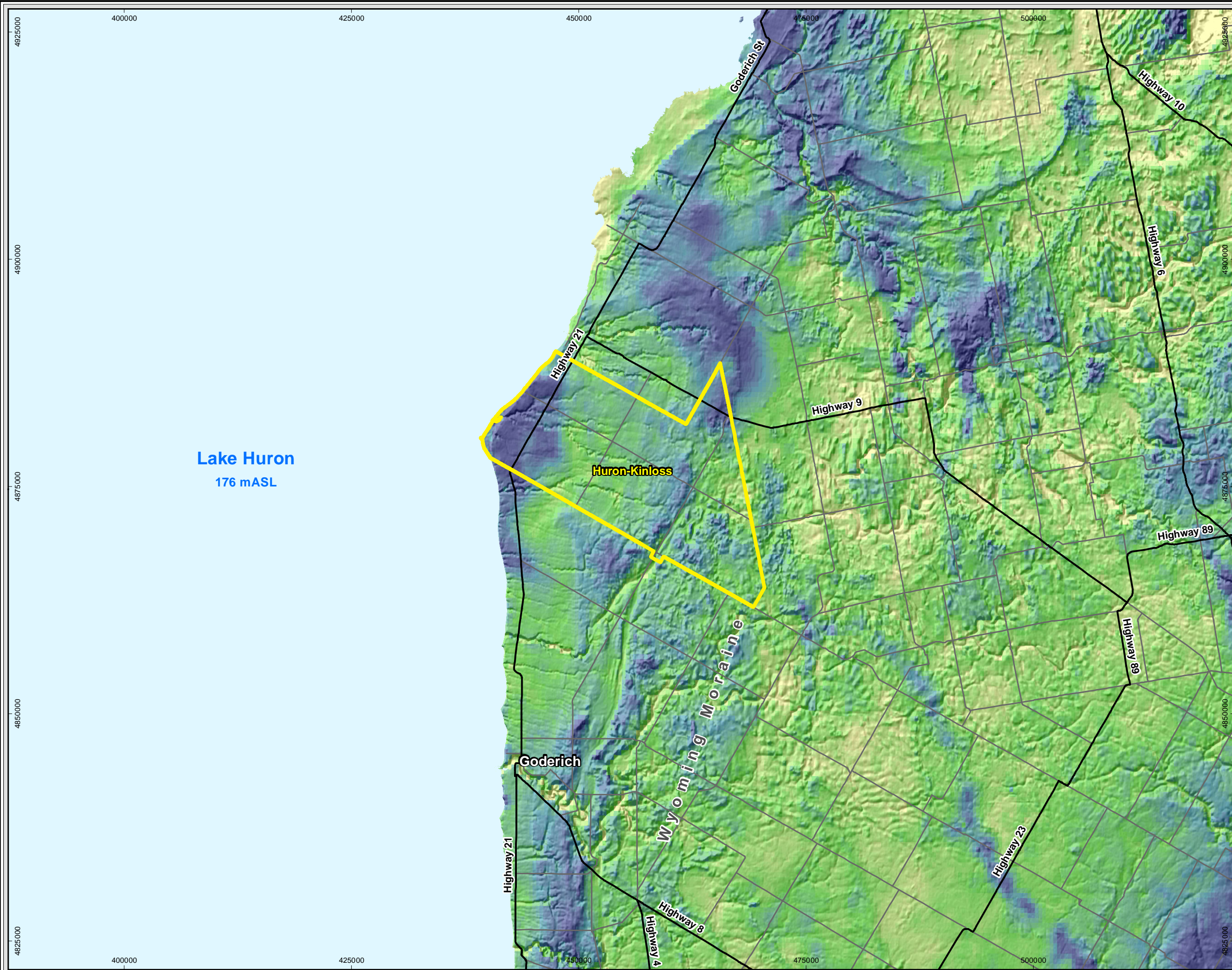
August 2012  
Project 60247068

**AECOM**

Figure 3.8



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068\OverburdenThicknessHuron\_Kinloss.mxd



**Legend**

- Township of Huron-Kinloss
- Highway
- Secondary Highway
- Waterbody

**Overburden Thickness (m)**

120  
60  
0

**INDEX MAP**

Basemapping from Ontario Ministry of Natural Resources  
Overburden Thickness: Gao, C., Shirota, J., Kelly, R. I.,  
Brunton, F.R., van Haften, S. 2006. Bedrock topography  
and overburden thickness mapping, southern Ontario;  
Ontario Geological Survey, Miscellaneous Release--Data 207.  
ISBN 1-4249-2550-9  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	8 Aug 2012
Approved	RF	8 Aug 2012

Kilometers  
0 2.5 5 10 15 20  
1:400,000

NWMO Desktop Level Initial Screening

**Overburden Thickness in  
the Township of Huron-Kinloss  
and the Surrounding Area**

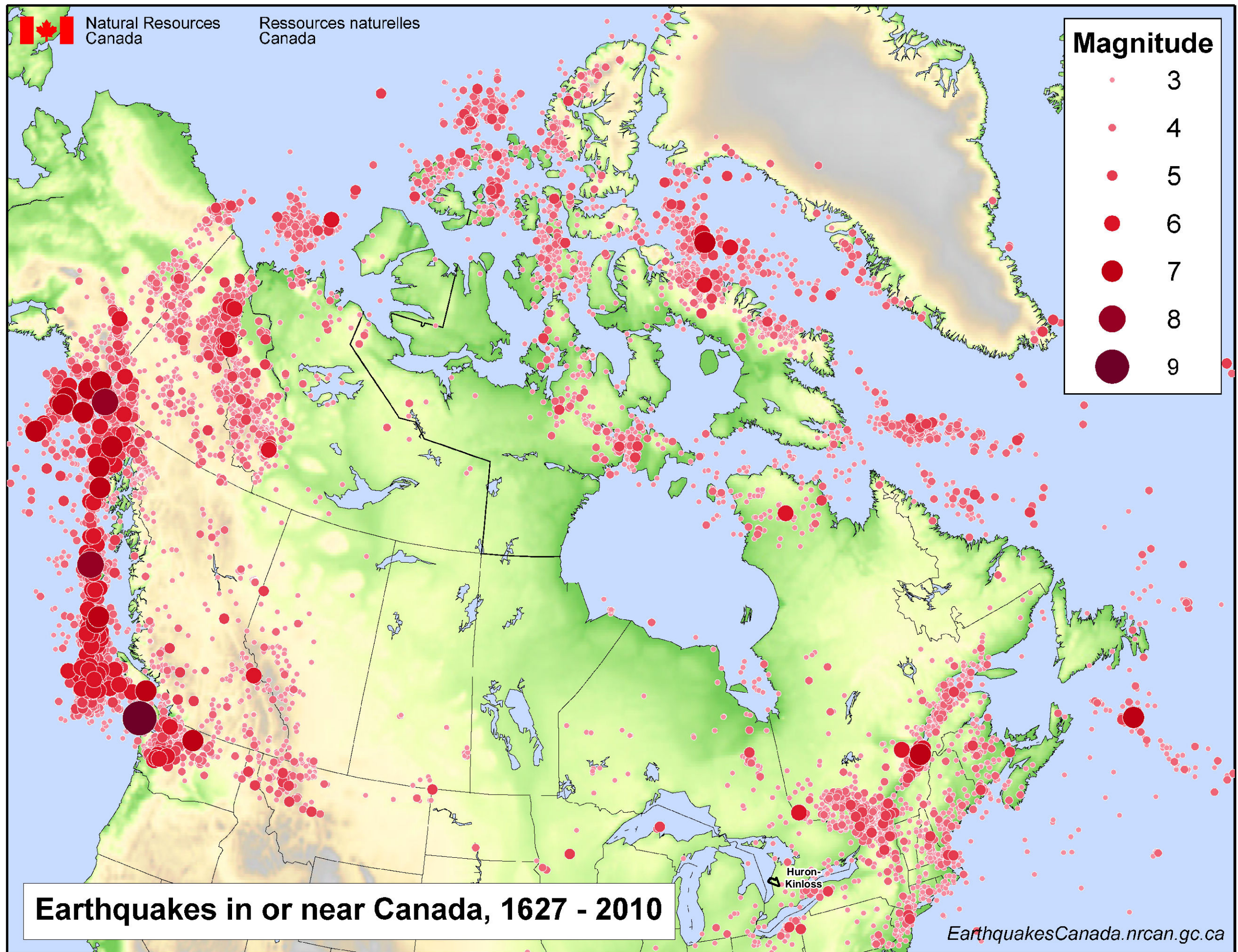
August 2012  
Project 60247068

**AECOM**

Figure 3.9



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068\HistoricalEarthquakesCanadaHuron\_Kinloss.mxd



**Legend**

□ Township of Huron-Kinloss

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

Basemapping from Ontario Ministry of Natural Resources  
Seismic: NRCAN. Earthquake Map of Canada 1627 -2010  
Projection: NA

NWMO Desktop Level Initial Screening

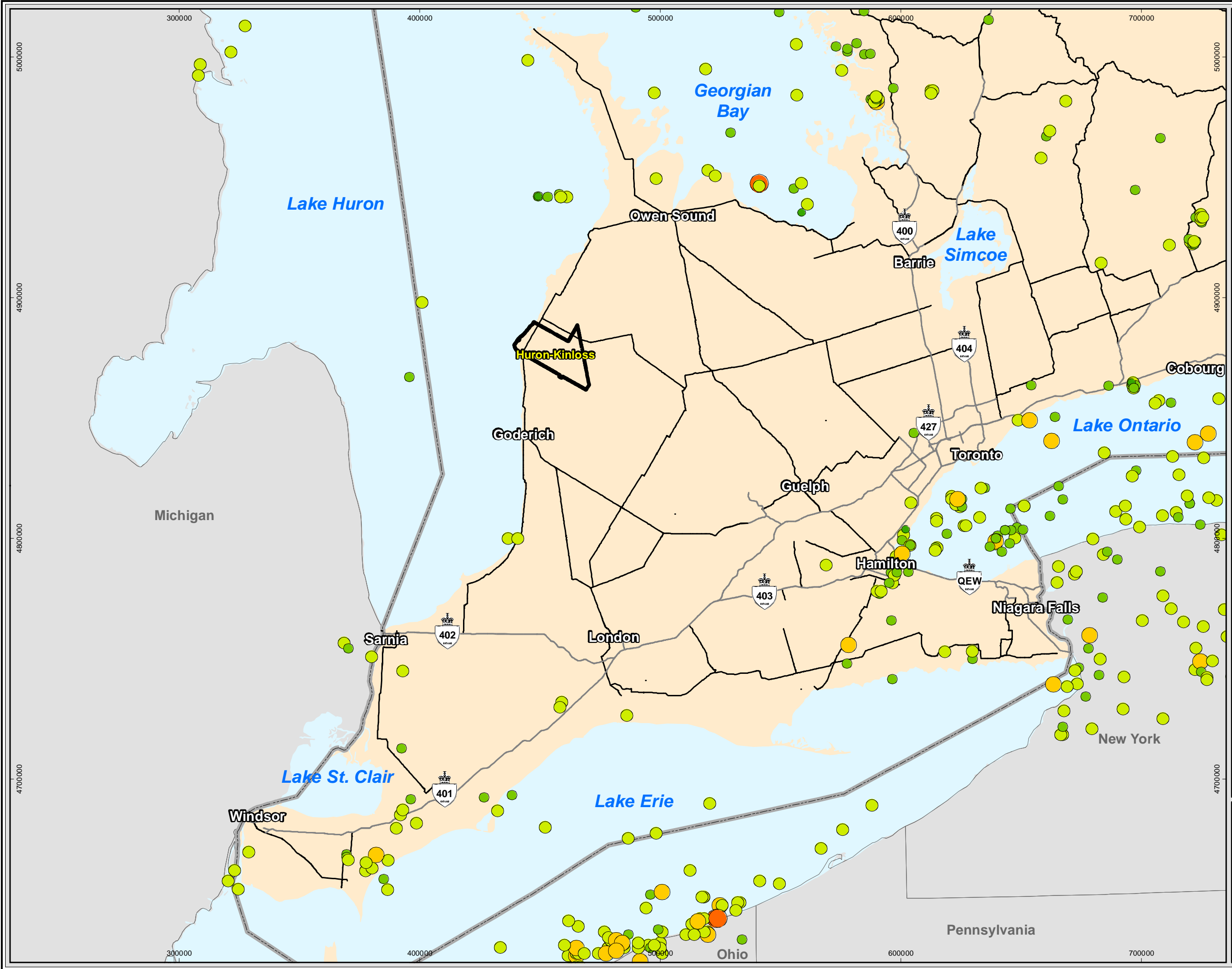
**Earthquake Map of Canada  
1627 - 2010**

August 2012  
Project 60247068

**AECOM**



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068\HistoricalEarthquakesSW\_OnHuron\_Kinloss.mxd



### Legend

- Township of Huron-Kinloss
- Canada - USA Boundary
- Expressway
- Highway
- Waterbody

### Seismic Events (Magnitude)

- <1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0

INDEX MAP

Basemapping from Ontario Ministry of Natural Resources  
Seismic: Earthquakes Canada, GSC, Earthquake Search (On-line Bulletin) Feb. 2012.  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	18 Jul 2012
Approved	RF	18 Jul 2012

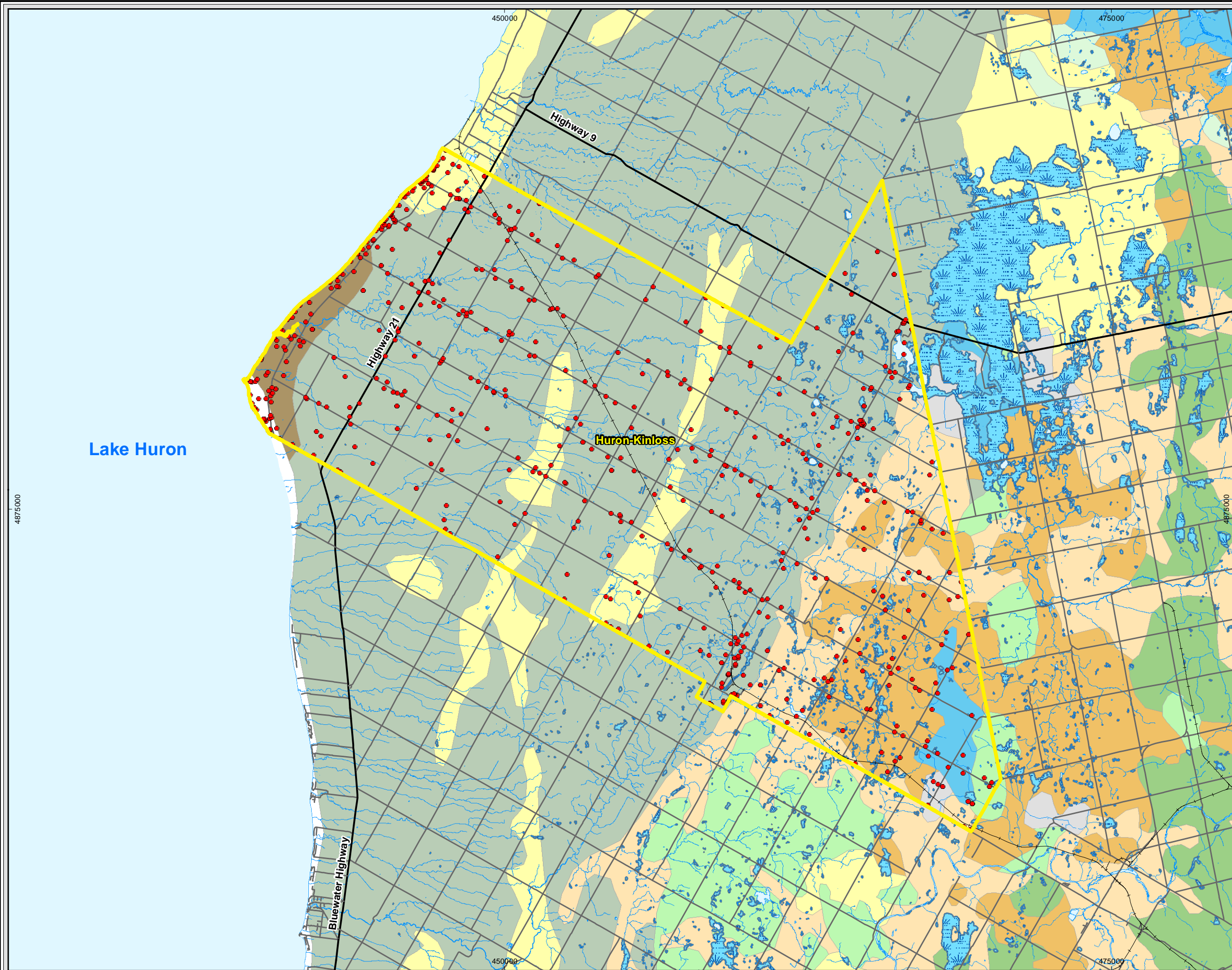
Kilometers  
0 10 20 40 60 80  
1:1,500,000

NWMO Desktop Level Initial Screening

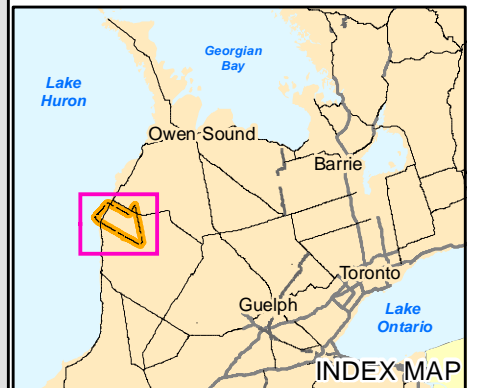
## Earthquake Map of Southern Ontario 1985 - 2012

August 2012  
Project 60247068

Figure 3.11

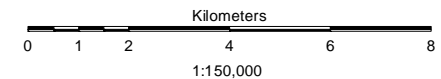
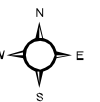


- Legend**
- Township of Huron-Kinloss
  - MOE Water Well Record
  - Highway
  - Major Road
  - Railway
  - Intermittent Stream
  - Permanent Stream
  - Waterbody
  - Wetland
- Quaternary Overburden**
- Elma Till
  - Rannoch Till
  - Dunkeld Till
  - St. Joseph Till
  - Glaciofluvial ice-contact deposits
  - Glaciofluvial outwash deposits
  - Glaciolacustrine deposits
  - Glaciolacustrine beach deposits
  - Lacustrine deposits
  - Organic deposits



Basemapping from Ontario Ministry of Natural Resources  
Quaternary Geology: Quaternary Geology of Ontario Seamless Coverage-Data Set 14  
Wells: Ministry of Environment, 2012  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	15 Jun 2012
Approved	RF	15 Jun 2012



NWMO Desktop Level Initial Screening

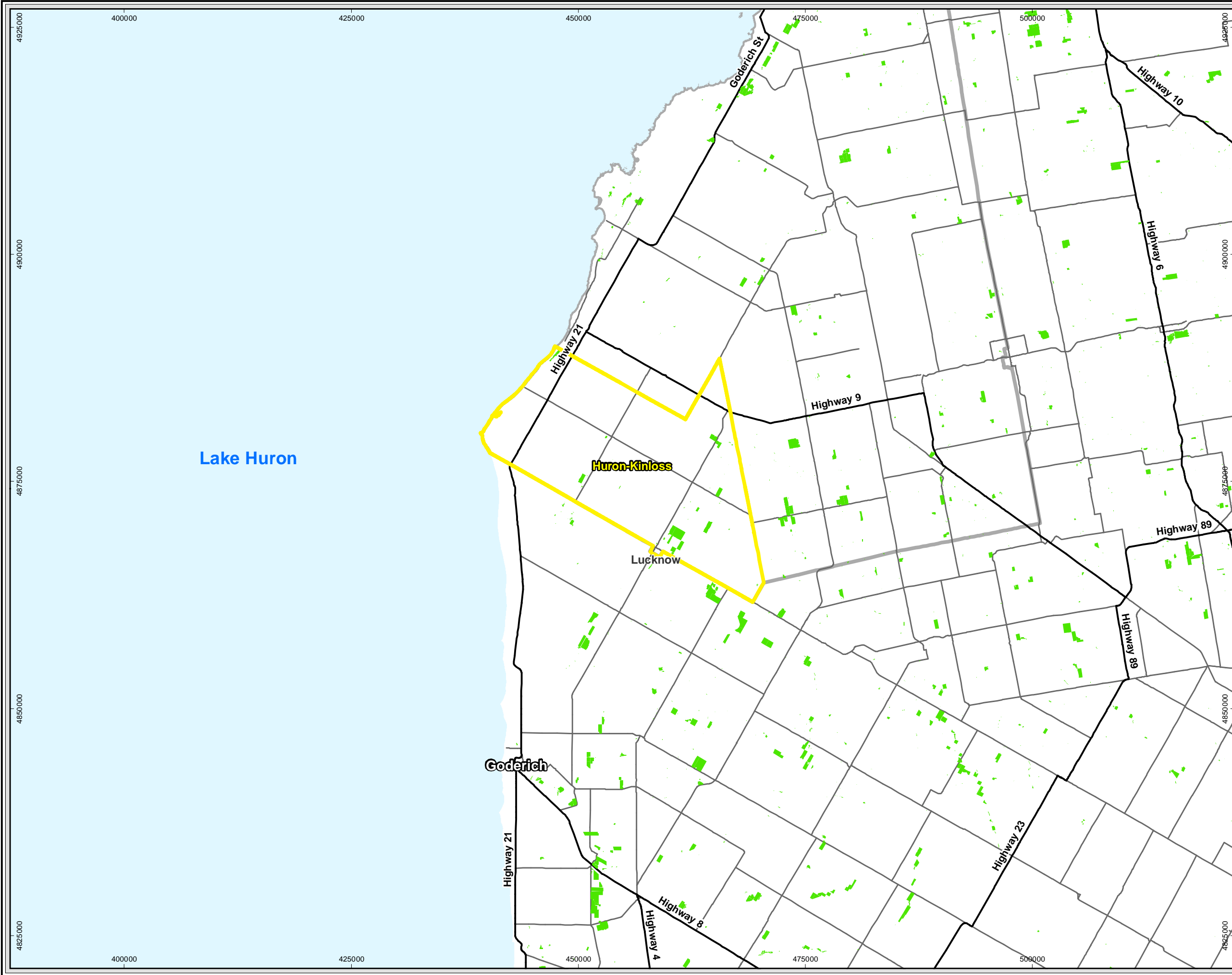
## Water Well Records of the Township of Huron-Kinloss

August 2012  
Project 60247068

**AECOM**



Path: P:\60247068\000-CADD\040-GIS\MXDs\Report\MXDs\Huron\_Kinloss\60247068EconomicBedrockResourcesHuron\_Kinloss.mxd



### Legend

- Township of Huron-Kinloss
- Highway
- Secondary Highway
- Waterbody
- Bruce County
- Sand, Gravel & Limestone Extraction
- Pit

Basemapping from Ontario Ministry of Natural Resources  
Sand, Gravel & Limestone Extraction: Ontario Ministry of Natural Resources  
Projection: Transverse Mercator Datum: NAD 83  
Coordinate System: UTM Zone 17

60247068		Date
GIS	RM	8 Aug 2012
Approved	RF	8 Aug 2012

0 2.5 5 10 15 20

Kilometers

1:400,000

N  
W E  
S

NWMO Desktop Level Initial Screening

**Non-metallic Bedrock  
Resources of the  
Township of Huron-Kinloss  
and the Surrounding Area**

August 2012  
Project 60247068

**AECOM**

Figure 5.1