OPG's DEEP GEOLOGIC

# REPOSITORY

FOR LOW & INTERMEDIATE LEVEL WASTE

# Description of Alternate Locations

December 2016

OPG CD# 00216-REP-07701-00014-R000

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**Document History**

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## EXECUTIVE SUMMARY

Ontario Power Generation Inc. (OPG) is currently seeking a licence to prepare the site and construct a Deep Geologic Repository (DGR) for its low and intermediate level radioactive waste (L&ILW) at the Bruce Nuclear site in the Municipality of Kincardine (the DGR Project at the Bruce Nuclear site).

This document presents a description of two alternate locations for a L&ILW DGR that meet OPG's criteria for technical and economic feasibility. OPG's technical feasibility criteria are (i) whether the depth and thickness of the rock is sufficient and (ii) whether the rock is geologically stable. OPG's economic feasibility criteria is OPG's ability to finance the cost fo a DGR at the alternate location.

OPG has identified two alternate locations that meet its technical and economic feasibility criteria: (a) one in crystalline rock of the Canadian Shield in central to northern Ontario, and (b) one in a sedimentary rock formation in southern Ontario. While these crystalline and sedimentary alternate locations meet these feasibility criteria, further steps would be necessary before a site is selected. Those steps would include implementing a site selection process, which would impose additional criteria beyond the feasibility criteria described above.

This document provides representative environmental features of the alternate locations, including land use; surface topography; hydrology; aquatic, terrestrial, and atmospheric conditions. The description also identifies the main differences in DGR facilities and activities that would be necessary at these alternate locations, due to their particular characteristics.

These descriptions are provided at a level of detail sufficient for an alternative means analysis of the environmental effects of a DGR Project at such alternate locations.

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# 1. INTRODUCTION

Ontario Power Generation Inc. (OPG) is currently seeking a licence to prepare the site and construct a Deep Geologic Repository (DGR) for its low and intermediate level radioactive waste (L&ILW) at the Bruce Nuclear site in the Municipality of Kincardine (the DGR Project at the Bruce Nuclear site).

In 2015 a Joint Review Panel (Panel) issued the Environmental Assessment Report on the DGR Project at the Bruce Nuclear site, which concluded that provided certain mitigation measures were implemented "*the project is not likely to cause significant adverse environmental effects*". The Panel also concluded that "*the DGR is the preferred solution for the management of L&ILW*" and "*the sooner the waste is isolated from the surface environment the better*."

In February 2016 the federal Minister of Environment and Climate Change requested that OPG provide additional information prior to making a decision on the environmental assessment (EA) of the DGR Project at the Bruce Nuclear site. In particular the Minister requested:

*"A study that details the environmental effects of technically and economically feasible alternate locations for the Project, with specific reference to actual locations that would meet OPG's criteria for technical and economic feasibility. In conducting this study, OPG is to detail the thresholds for what is considered to be technically and economically feasible. In addition, OPG is to indicate what the incremental costs and risks would be for additional off-site transportation of the nuclear waste."*

In response to OPG's letter dated April 15, 2016 describing OPG's proposed approach to responding to the Minister request, the Canadian Environmental Assessment Agency (Agency) provided clarification as follows:

"*[OPG] has indicated that it intends to provide an assessment of the environmental effects of two technically and economically feasible geologic regions in Ontario, specifically in a sedimentary rock formation in southern Ontario and in a granite rock formation located in central to northern Ontario, without providing specific reference to actual locations. …*

*.... the Agency requests that the analysis of the environmental effects of the alternate locations to be provided by OPG provide a narrative assessment that does not assume that alternate sites in the geologic formation would have the same geographical and hydrological characteristics of the preferred site."*

OPG's response to the information requested is documented in four reports, a main submission and three technical documents. The main submission provides context, describes the project for study purposes, summarizes the studies, and presents the overall findings. The technical documents, of which this is one, present detailed information on different elements of the information requested. The technical documents are:

- Description of Alternate Locations
- Environmental Effects of Alternate Locations
- Cost and Risk Estimate for Packaging and Transporting Waste to Alternate Locations.

The technical documents and the main submission rely to some degree, on content in the others. Cross-references are provided where appropriate. These four documents in total constitute the response to the Minister on her request for a study of alternate locations.

The purpose of this document is to present a description of two alternate locations for a L&ILW DGR that meet OPG's technical and economic feasibility criteria: (a) one in crystalline rock of the Canadian Shield in central to northern Ontario, and (b) one in a sedimentary rock formation in southern Ontario.

This document describes environmental characteristics, and the DGR facilities and activities, at these alternate locations in order to support the assessment of the potential environmental effects related to a DGR at either of these alternate locations.

For clarity, OPG is providing in this document and the main submission, specific references to actual locations. Further, OPG has not assumed that the alternate locations would have the same geographical and hydrological characteristics as the Bruce Nuclear site.

The topics are presented in the following order:

- Discussion of the technical and economic feasibility criteria and thresholds;
- Description of alternate location in crystalline rock; and
- Description of alternate location in sedimentary rock.

## 2. CRITERIA FOR TECHNICALLY AND ECONOMICALLY FEASIBLE ALTERNATE LOCATIONS

In this study of alternate locations – which is distinct from a siting process – technically and economically feasible alternate locations are to be identified based on criteria and thresholds. As this assessment is in support of an alternative means analysis for an alternate location, the criteria and thresholds applied are consistent with those of alternative means analysis. These criteria and thresholds are consistent with those in an early screening phase of a site selection process; these are basic necessary conditions for a DGR. Simply put, if a location does not meet these criteria and thresholds, it is not a feasible location for a DGR.

### 2.1 TECHNICAL FEASIBILITY

The ultimate technical objective for a DGR is that any selected location must support the safe construction, operation and postclosure performance of the DGR without harm to the public, workers or the environment. This safety is achieved by a combination of the physical features of the site, the design and the wastes, and by how the facility is constructed, operated and monitored.

OPG's has therefore identified the following technical feasibility criteria for a DGR:

1. Is the host rock geologically stable and resistant to expected geological and climate change processes?

2. Is the depth and thickness of competent rock sufficient to host and enclose a DGR?

These criteria reflect the basic requirement of a DGR to provide long-term containment and isolation of the wastes.

OPG has further considered thresholds for these criteria.

With respect to geological stability, the requirement should be that the rock has been stable for times that are long compared to the lifetime of the main hazard in the L&ILW, and that have been resilient to past glacial and seismic events. While much of the radioactivity in the L&ILW will decay within about 100,000 years, the OPG DGR safety assessment considered time frames of 1 million years. Therefore for demonstrated geologic stability, the bedrock should be much older than this. For context, in Ontario, the crystalline rock of the Canadian Shield at more than 1 billion years old, and the sedimentary rock formations of southern Ontario at 354 to 543 million years old, readily satisfy this criterion.

With respect to depth and volume, the thresholds adopted in the present study are a minimum of 200-m depth and 300-m bedrock thickness. These consider the nature of the hazard of the L&ILW, and in particular that it contains long-lived ILW. Therefore, consistent with international practice, such wastes are planned for disposal in deeper rock formations. The minimum depth of 200-m is consistent with remaining below the extent of shallow groundwater regimes. A minimum rock thickness of 300-m allows for at least a 100-m layer of competent bedrock to lie above and below the repository to ensure that it is fully enclosed.

In subsequent sections, two alternate locations in Ontario are identified that satisfy the above technical feasibility thresholds, one in crystalline rock and one in sedimentary rock.

## 2.2 ECONOMIC FEASIBILITY

OPG's has therefore identified the following economic feasibility criterion for a DGR :

1. OPG's ability to finance the cost of a DGR at the alternate location.

The threshold for the economic feasibility criterion is whether OPG reasonably expects to be able to finance the cost from internal resources, or through debt financing, or a combination of the two.

## 2.3 CRYSTALLINE ROCK ALTERNATE LOCATION

Within Ontario, crystalline rock is associated with the Canadian Shield, which extends through central to northern Ontario. The Ontario portion of the Shield is composed of parts of four main geological "provinces" – Superior, Southern, Keewatin and Grenville. Superior is the largest and oldest in Ontario (about 3 billion years old); Grenville is the youngest in Ontario (1 to 1.8 billion years old). The Canadian Shield consists of a variety of igneous and metamorphic rock types, including granite.

The crystalline rocks of the Canadian Shield are attractive because they are geologically stable and have demonstrated resilience (they are at least 1 billion years old), and have sufficient thickness at depth to meet the technical feasibility thresholds described above. Furthermore, these rocks can include low permeability volumes, and are generally mechanically strong.

The economic feasibility criterion and threshold are satisfied because OPG reasonably expects to be able to finance the cost of a DGR at the crystalline alternate location through one of the mechanisms, if required.

The crystalline alternate location is as defined in Figure 2-1. This crystalline alternate location can be identified by the GPS (Global Positioning System) co-ordinates listed in Table 2-1. The nearest edge of the Canadian Shield is about 200 km by road from the Bruce Nuclear site, while the farthest edge of the Canadian Shield in Ontario is at the Manitoba/Ontario border about 2000 km distant from Bruce Nuclear site.

All the lands and rivers in Ontario lie within one of two main watersheds: the Great Lakes basin / watershed which ultimately drains towards the Atlantic Ocean, or the Hudson Bay basin/ watershed which ultimately drains to Hudson Bay (Figure 2-2). A DGR at any location in Ontario would be in one of these watersheds.

Depending on the DGR location, it could be adjacent to the Great Lakes or be away from them. However, from a technical perspective, the key factor is the nature of the geology and the site-specific repository design. With an appropriate geology and design, the proximity of a water body to the DGR is not relevant because the movement of water or gas, even if it was released from the DGR, would not reach the water body until the radioactivity of such water or gas had diminished to the levels generally found naturally occurring throughout Ontario.

**Figure 2-1: Crystalline Alternate Location (brown shading)**

**Table 2-1: GPS Co-ordinates of the Crystalline Alternate Location**

| Latitude, Longitude |
|---|
| 44.9, -79.8 |
| 46.0, -81.2 |
| 46.6, -84.5 |
| 48.8, -86.6 |
| 48.0, -89.6 |
| 49.2, -95.1 |
| 52.8, -95.1 |
| 55.1, -91.6 |
| 53.5, -87.4 |
| 50.4, -85.4 |
| 50.8, -79.5 |
| 47.2, -79.6 |
| 45.3, -76.4 |
| 44.6, -76.6 |

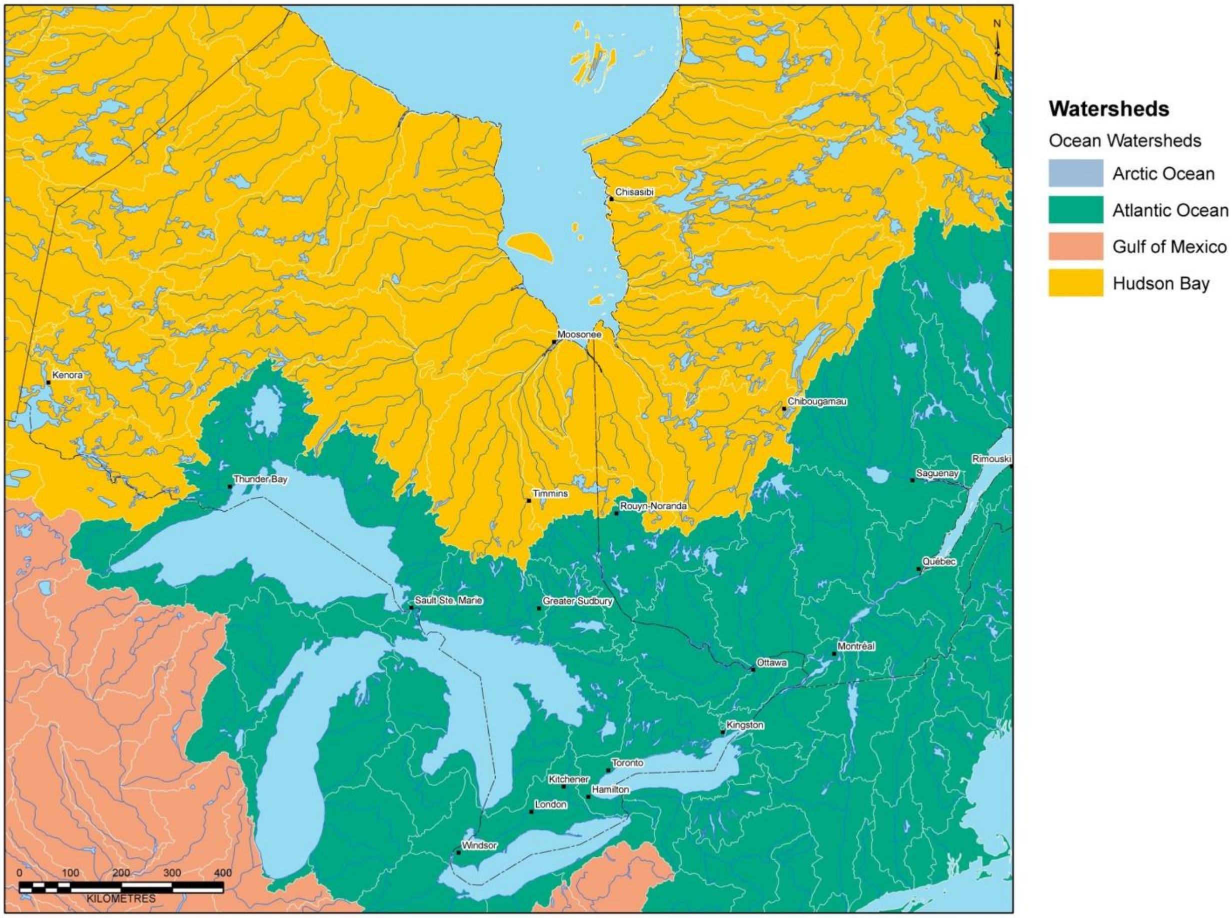



**Figure 2-2: Major Watersheds of Ontario [NRCan 2006]**

## 2.4 SEDIMENTARY ROCK ALTERNATE LOCATION

The Michigan and Appalachian Sedimentary Basins in southern Ontario are accessible and reasonably well characterized.

The features of sedimentary rock in southern Ontario are described in Mazurek [2004]. Southern Ontario is underlain by a sedimentary ‘layer cake’ comprised of rock formations that vary in age from Cambrian, Ordovician, Silurian to Devonian (354-543 million years old). Beneath this sedimentary rock is Precambrian crystalline rock. The near horizontally bedded sedimentary rock consists of shales, limestones, dolomites, sandstones and evaporites (salt, gypsum/anhydrite). Within the central part of the area, a southwest-to-northeast trending feature known as the Algonquin Arch occurs in the crystalline basement rock. This Algonquin Arch separates the Michigan Basin in southwestern Ontario and the Appalachian Basin to the south and east. Southern Ontario includes only the outer parts of both basins; the maximum sedimentary rock thickness in southern Ontario is about 1500 m.

The thickness of these sedimentary rocks is well defined because of this geological uniformity. Within these sedimentary rocks, the Ordovician sediments (shales and carbonates) are particularly attractive. They extend across much of southern Ontario and are generally thick, deep, and geologically stable.

Applying the technical feasibility threshold that these sediments must be at least 300-m thick, and allow the DGR to be positioned 200 m or deeper under ground surface, then the technically feasible sedimentary alternate location that meets these thresholds is as shown in Figure 2-3.

Applying the economic feasibility threshold of OPG’s ability to finance a DGR at the alternate location (which OPG reasonably expects to be able to do), then the economically feasible sedimentary alternate locations that meets that threshold is as shown in Figure 2-3.

This sedimentary alternate location can be identified by the GPS co-ordinates listed in Table 2-2. The sedimentary alternate location excludes the Bruce Nuclear site, and extends out to about 300 km from the Bruce Nuclear site.

All the lands and rivers in Ontario lie within one of two main watersheds: the Great Lakes basin / watershed which ultimately drains towards the Atlantic Ocean, or the Hudson Bay basin/ watershed which ultimately drains to Hudson Bay. There is no location in Ontario that does not lie within or drain towards a major water body (Figure 2-1). A DGR at any location in Ontario would be in one of these watersheds.

Depending on the DGR location, it could be adjacent to the Great Lakes or be away from them. However, from a technical perspective, the key factor is the nature of the geology and the site-specific repository design. With an appropriate location and design, the proximity of a water body to the DGR is not relevant because the movement of water or gas, even if it was released from the DGR, would not reach the water body until the radioactivity of such water or gas had diminished to the levels generally found naturally occurring throughout Ontario.

**Figure 2-3: Sedimentary Rock Alternate Location (green shading). Bruce Nuclear site (point) is not included.**

**Table 2-2: GPS Co-ordinates of the Sedimentary Alternate Location**

| Latitude, Longitude |
|---|
| 44.5, -80.2 |
| 43.7, -79.4 |
| 43.3, -79.8 |
| 43.2, -79.1 |
| 42.9, -79.0 |
| 42.0, -83.1 |
| 44.6, -81.3 |

## 3. DESCRIPTION OF CRYSTALLINE ALTERNATE LOCATION

This section provides a description of the crystalline alternate location, including its general geological and environmental features, and key aspects of the DGR facilities and activities at this location. This description is provided at a level of detail sufficient for an alternative means analysis of environmental effects related to an alternate location.

### 3.1 SURFACE GEOGRAPHY AND HYDROLOGY

The surface geography and hydrology describes the physical features of the land and the surface water bodies. Consideration of surface geography and hydrology was part of OPG's alternate location analysis. A representative surface area within the crystalline alternate location is shown in Figure 3-1. This area, approximately 11 km × 16 km, was developed as a reference area for a Canadian Shield setting for a used fuel DGR [NWMO 2012].

The physical topography is low relief as is typical of Canadian Shield, reflecting erosion over millions of years. The boundary for the area shown in Figure 3-1 corresponds to surface and groundwater divides, which represent vertical planes across which groundwater flow is not expected.

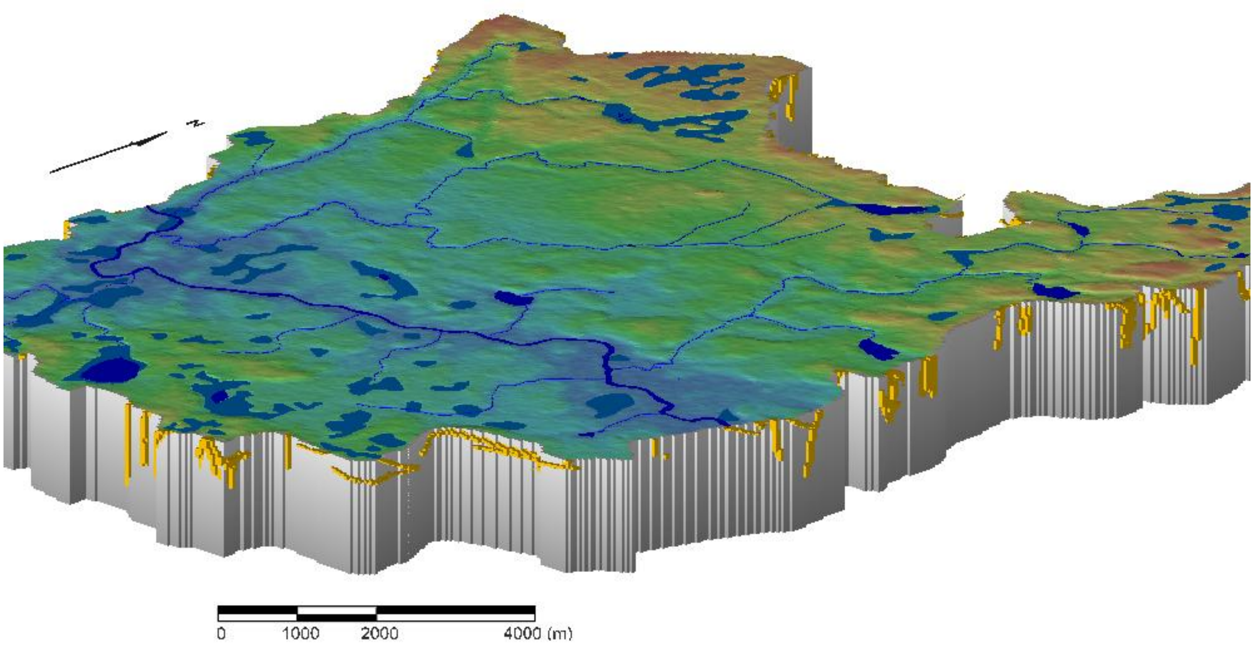



**Figure 3-1: Surface features for a representative area within the crystalline alternate location.**

Part of this crystalline alternate location borders on the Great Lakes or contains other water bodies. With appropriate rock characteristics and design, the proximity of a water body to the DGR is not relevant because the movement of any fluid or gas, even if it was released from the DGR, would not reach the water body until the radioactivity of such fluid or gas had diminished to the levels generally found naturally occurring throughout Ontario.

However, as requested by the Agency (and described in Section 1 above), the crystalline alternate location as considered in this assessment has different geographical and hydrological characteristics from the Bruce Nuclear site, as can be seen from Figure 3-1.

There are numerous small water bodies in this representative area as is typical of the Canadian Shield. Defined wetlands cover a small percentage of the surface area. Other areas may be transiently wet in the spring. The small lakes and wetlands feed streams that flow into the main river near the bottom of the area. This river corresponds with a topographic low. The presence of lakes, streams and rivers is consistent with typical Canadian Shield conditions. They act as discharge points for surface and groundwater flow.

The annual water flow through these various water features depends in large part on the climate, surficial geology and drainage around the area. In this representative area, the small water bodies near the DGR would have catchment areas of a few square kilometres, while the river would have a catchment area that depends on the upstream extent of the river and could be a few thousand square kilometres.

## 3.2 GEOLOGY

The characteristics of the rock are based on information on the geology of the Canadian Shield developed by Atomic Energy of Canada Limited (AECL) and subsequently by NWMO in its studies in support of a DGR for used fuel in crystalline rock [NWMO 2012].

The geology of the crystalline alternate location is defined by a layer of glacial drift, and lake and river sediments (i.e., clay, silt and sand), overlying the crystalline rock of the Canadian Shield. The Canadian Shield consists of a variety of igneous and metamorphic rock types, including granite.

For context and greater clarity, based on the performance needed for safety, the DGR would be designed at a depth that ensured isolation from natural and human activities, and in a sufficiently large volume of competent rock. As crystalline rock is typically fractured, so the DGR position within the rock would be dependent on the nature of the fractures. The site selection process would consider the permeability of the rock, the detailed fracture characterization, and DGR optimization.

## 3.3 STABILITY

The crystalline alternate location is in the Canadian Shield in the central to northern portion of the Ontario. This is within the North America interior cratonic region; which in general has a low seismic hazard.

The strength and geomechanical properties of many Canadian Shield granites and other crystalline rocks can be favourable for construction and operation of underground facilities.

## 3.4 LAND USE

Boreal forests covers a large part of the crystalline alternate location. Much of the crystalline alternate location is currently Crown land.

The crystalline alternate location covers the traditional territory of multiple indigenous communities. Siting would need the support of indigenous communities whose traditional territory contained where the DGR could be located. It is assumed that the DGR could be located to avoid culturally sensitive areas, and to avoid or minimize impacts on areas currently used for harvesting, trapping or hunting.

Given the limited industry in the crystalline alternate location, there would generally be low background levels of industrial noise or air emissions. Parts of the crystalline alternate location have been logged in recent history.

## 3.5 ENVIRONMENT

The environment of the crystalline alternate location is essentially that of the boreal forest of central to northern Ontario. The crystalline alternate location is within the Boreal Shield ecozone.

Typically background air quality in central to northern Ontario is non-industrial, and likely to have lower concentrations of pollutants than in southern Ontario.

Central to northern Ontario is generally well drained with an abundance of wetlands, lakes and rivers. Surface water quality in the area is generally good with limited anthropogenic influence. It is assumed that the DGR surface facilities are placed at least 120 m from any provincially significant wetland, consistent with the provincial guidelines.

In central to northern Ontario, land cover is dominated by boreal forest, except where the bedrock naturally outcrops.

## 3.6 PHYSICAL FACILITIES AND ACTIVITIES

The DGR at the crystalline alternate location would need to meet the same general project requirements as the DGR Project at the Bruce Nuclear site. Consequently, the general repository physical design is assumed to be similar to that of the DGR Project at the Bruce Nuclear site. However, some changes to the physical facilities and activities would be required as a result of being independent (distant) from the Bruce Nuclear site and due to the differences in the nature of crystalline rock compared to the rock at the Bruce Nuclear site. These differences are noted in this section.

A greater level of site characterization activity would be needed in crystalline rock than in sedimentary rock in order to characterize the nature of the fractures, to define the performance targets for engineered barriers, and to assess the characteristics of the rock in detail for the design and the safety case.

New infrastructure would be required to provide key services to the site, as its location in the Canadian Shield would likely be remote from main roads and power lines. For assessing environmental effects of the crystalline alternate location, it is assumed that additional road access of 0-20 km, and an additional high-voltage power corridor of 0-50 km, may be needed to connect to the site.

At the crystalline alternate location, additional facilities would be required to receive and temporarily store waste before transfer underground to the DGR, in order to allow for delays in shipping to it. It is estimated that two storage buildings would be required at the alternate location in order to receive and store the waste packages. The repackaging of the wastes, and their transport to the DGR at the alternate location, is discussed in the *Cost and Risk Estimate for Packaging and Transporting Waste to Alternate Locations* technical document [ENERGY SOLUTIONS 2016].

The crystalline alternate location would also require facilities and supporting services (e.g., security, surface fueling station, transportation receiving area, shop/maintenance facilities) that exist at the Bruce Nuclear site. There may also be a requirement to establish on-site emergency response capabilities depending on the proximity of the DGR to established services.

Including these facilities, it is estimated that the crystalline alternate location would occupy a surface facilities area of about 40 hectares, including the main waste handling facility, shaft headframes, offices, waste storage buildings, stormwater management system and waste rock management area. The area of the underground footprint is also coincidentally about 40 hectares. It is further assumed that the DGR site would be selected with capacity to allow for doubling of the underground repository in the future to accommodate decommissioning wastes (about 80 hectares total area).

The total amount of surface area required would depend on the size of the DGR footprint. Some controlled land area outside the footprint may be required to ensure no future drilling or mining at depth in the immediate vicinity of the DGR.

The DGR Project surface facilities at the Bruce Nuclear site are located about 1 km from the Bruce Nuclear site boundaries. For direct comparison with the Bruce Nuclear site, it could be assumed that the controlled site area for the alternate crystalline location also extends one kilometre from the project surface facilities and the underground footprint. This gives a total site area of about 700 hectares (1700 acres) if the controlled area is just around the 40 ha surface facilities, or about 900 hectares (2200 acres) if the controlled area is around the expanded underground footprint. This is for direct comparison; it is possible that a buffer outside of the underground footprint for surface land use may not be required for safety reasons.

At the crystalline alternate location, the precise depth of the DGR would be determined based on the characteristics of the site to best achieve a strong safety case. In general, greater depths are favored since the fracture spacing increases and rock mass hydraulic conductivity decreases, which is favourable for containment and isolation. However with greater depth, the in situ rock stress and temperature will increase which is less favourable.

In the DGR, the waste packages would be placed in rooms located underground at the repository depth. The general layout of the underground repository is assumed to be similar to the DGR Project at the Bruce Nuclear site, with emplacement rooms excavated from access tunnels driven from two islanded shafts that are purposefully designed and laid out to ensure long-term emplacement room stability given principal stress and rock strength conditions. Excavation would be done using controlled drill and blast.

For the crystalline alternate location, depending on the specific site characteristics, additional engineered barrier(s) would likely be provided to ensure safe containment and isolation, because of the fractured, more permeable nature typical of crystalline rock compared to the sedimentary rock at the Bruce Nuclear site. This could include additional grouting to control water inflow from fractures, and backfilling of some emplacement rooms to limit the free water movement in the vicinity of the waste packages.

An important topic that would require further evaluation for the crystalline alternate location is the engineered barrier requirements to ensure sufficient retention of Carbon-14 (C-14). This radionuclide has a long half-life (5700 years), and is relatively mobile in groundwater and as a gas (e.g., methane). In CANDU wastes, there is a significant amount of C-14 sorbed on the ion exchange resins that are used to maintain the purity of the CANDU moderator heavy water. This is a particular issue for CANDU intermediate level wastes that is different from used fuel.

In crystalline rock, it is likely that groundwater will contact the ion exchange resins sooner, and leading to the release of C-14 sooner than expected in sedimentary rock. Ideally, the rooms containing these resins would be in very low permeability and unfractured volume of crystalline rock to both delay inflow of water contacting the resins, and subsequently the release of C-14. Otherwise, it is likely that additional barriers would be required including (a) surface processing of the resins to make the C-14 less releasable than on as-packaged spent resins, and (b) backfilling the space within or around the packages with cement. These additional barriers would minimize contact with groundwater and mitigate C-14 waste from being released.

As a base assumption, it is assumed that the crystalline alternate location would require that all the ion exchange resins are pre-processed at surface at an off-site, licensed facility, and that the rooms for the processed resin wastes are stabilized with cement. Furthermore, an additional two underground rooms are assumed to accommodate the increased packaged waste volume from waste processing and cementing.

A somewhat larger volume of excavated rock may be needed if waste processing and grouting leads to a larger volume of the as-packaged wastes, if additional spacing is needed to avoid major fractures, and/or if additional concrete structure is needed as support for the rooms or waste packages due to the stress conditions in the host rock.

As a consequence of the nature of crystalline rock, there would be greater use of other engineered barriers at the crystalline alternate location. The net result would be that a specific DGR design would be developed that, through a combination of engineered and natural barriers, would ensure regulatory criteria were met with an appropriate margin of safety. However, it is likely that the crystalline alternate location margin of safety would be less than that of a DGR at the Bruce Nuclear site, reflecting the likely more permeable nature of the crystalline alternate location. This would need to be assessed further if a DGR in a crystalline alternate location was pursued.

Figure 3-2 illustrates how the DGR might be sited within the larger area shown in Figure 3-1. In particular, Figure 3-2 focuses in on a smaller 5 km $\times$ 6 km area towards the center of the larger area in Figure 3-1. Figure 3-2(a) shows an underground cross-section at an illustrative depth of several hundred meters, showing the major fractures at this depth. This figure illustrates how the DGR might be positioned to avoid the main permeable fractures, while also including an allowance for future expansion for L&ILW decommissioning wastes.

Figure 3.2(b) shows how the nominal surface footprint of the DGR might look, including surface structures and waste rock management area. Most surface facilities would be near the main shaft, although the waste rock management area could be positioned separately. This figure also shows how the site boundary including an illustrative 1-kilometre controlled zone might look (similar to the controlled zone at the Bruce Nuclear site). As in this example, the surface facilities can be placed to avoid significant surface water features, but the larger site itself would likely contain or intercept some surface water feature for a typical location on the Canadian Shield.

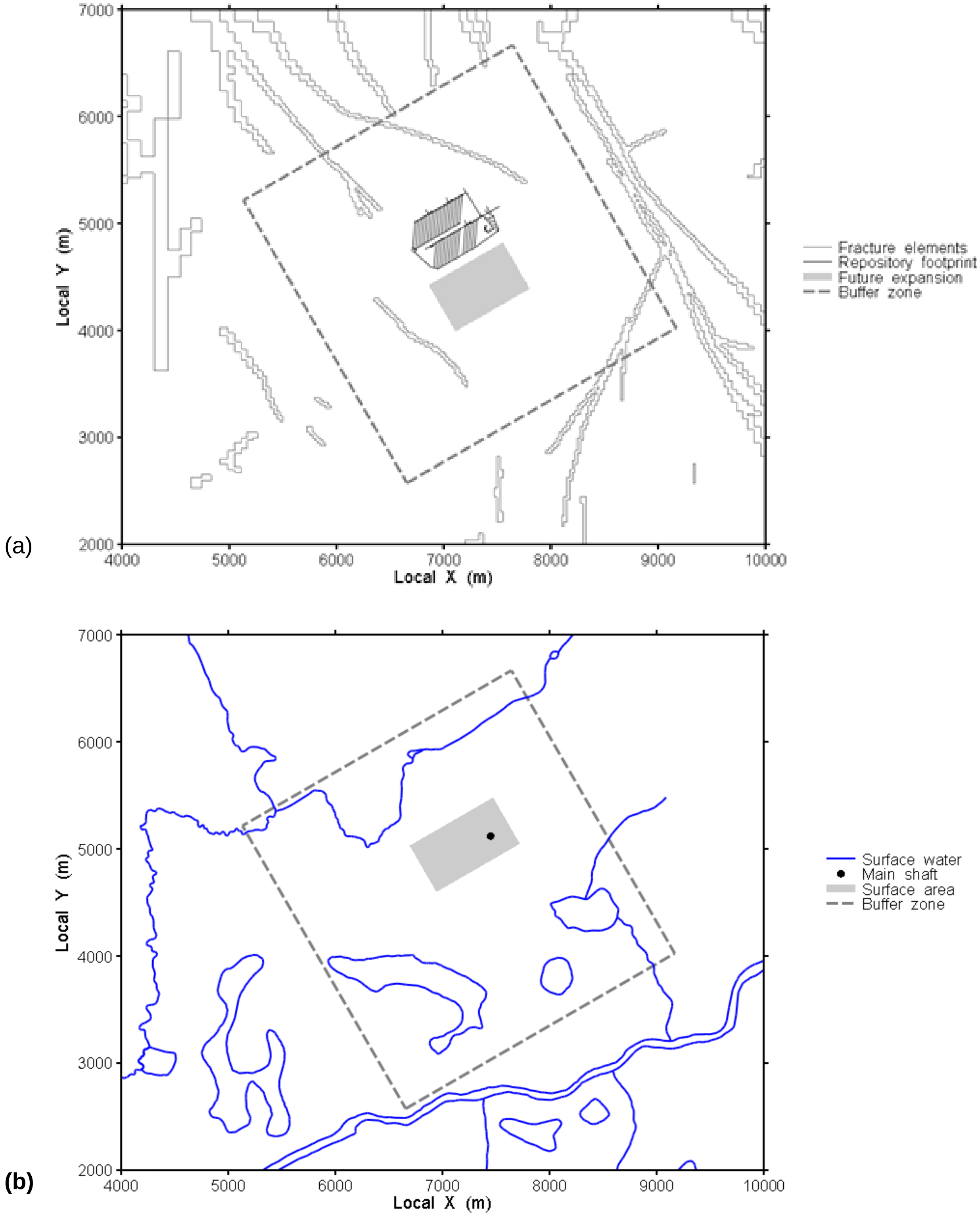



**Figure 3-2: Illustrative DGR Placement in Crystalline Alternate Location. (a) Underground area, including expansion capacity, relative to main fractures; (b) Surface facilities area.**

# 4. DESCRIPTION OF SEDIMENTARY ALTERNATE LOCATION

This section provides a description of the sedimentary alternate location, including the location, its general geological and environmental features, and key aspects of the DGR facilities and activities in this location. This description is provided at a level of detail sufficient for an alternative means analysis of environmental effects at alternate locations.

## 4.1 SURFACE GEOGRAPHY AND HYDROLOGY

A representative surface area within the sedimentary alternate location is shown in Figure 4-1. This area, approximately 15 km $\times$ 15 km area, is roughly similar in scale to that considered in the crystalline rock case, Figure 3-1.

The physical topography is low relief, as is typical of southern Ontario.

This sedimentary alternate location borders on the Great Lakes and contains other water bodies. With appropriate rock characteristics and design, the proximity of a water body to the DGR is not relevant because the movement of any fluid or gas, even if it was released from the DGR, would not reach the water body until the radioactivity of such fluid or gas had diminished to the levels generally found naturally occurring throughout Ontario.

However, as requested by the Agency (as described in Section 1 above), the sedimentary alternate location area as considered in this assessment has different geographical and hydrological characteristics from the Bruce Nuclear site, as can be seen from Figure 4-1.

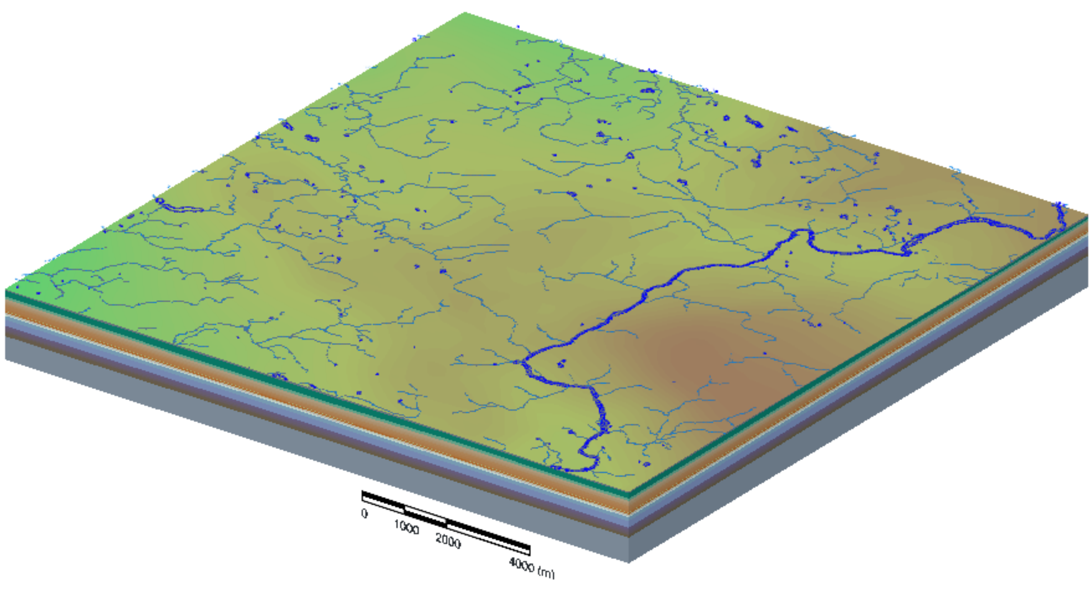



**Figure 4-1: Surface features for representative area in sedimentary alternate location**

There are numerous small rivers or streams in the vicinity. Defined wetlands cover a small percentage of the surface area. Other areas may be transiently wet in the spring. The streams and rivers drain towards a main river that runs through this area. The river corresponds with a topographic low. The presence of lakes, streams and rivers is consistent with typical southern Ontario conditions. They act as discharge points for surface and groundwater flow.

The annual water flow through these various water features depends in large part on the climate, surficial geology and drainage around the area.

## 4.2 GEOLOGY

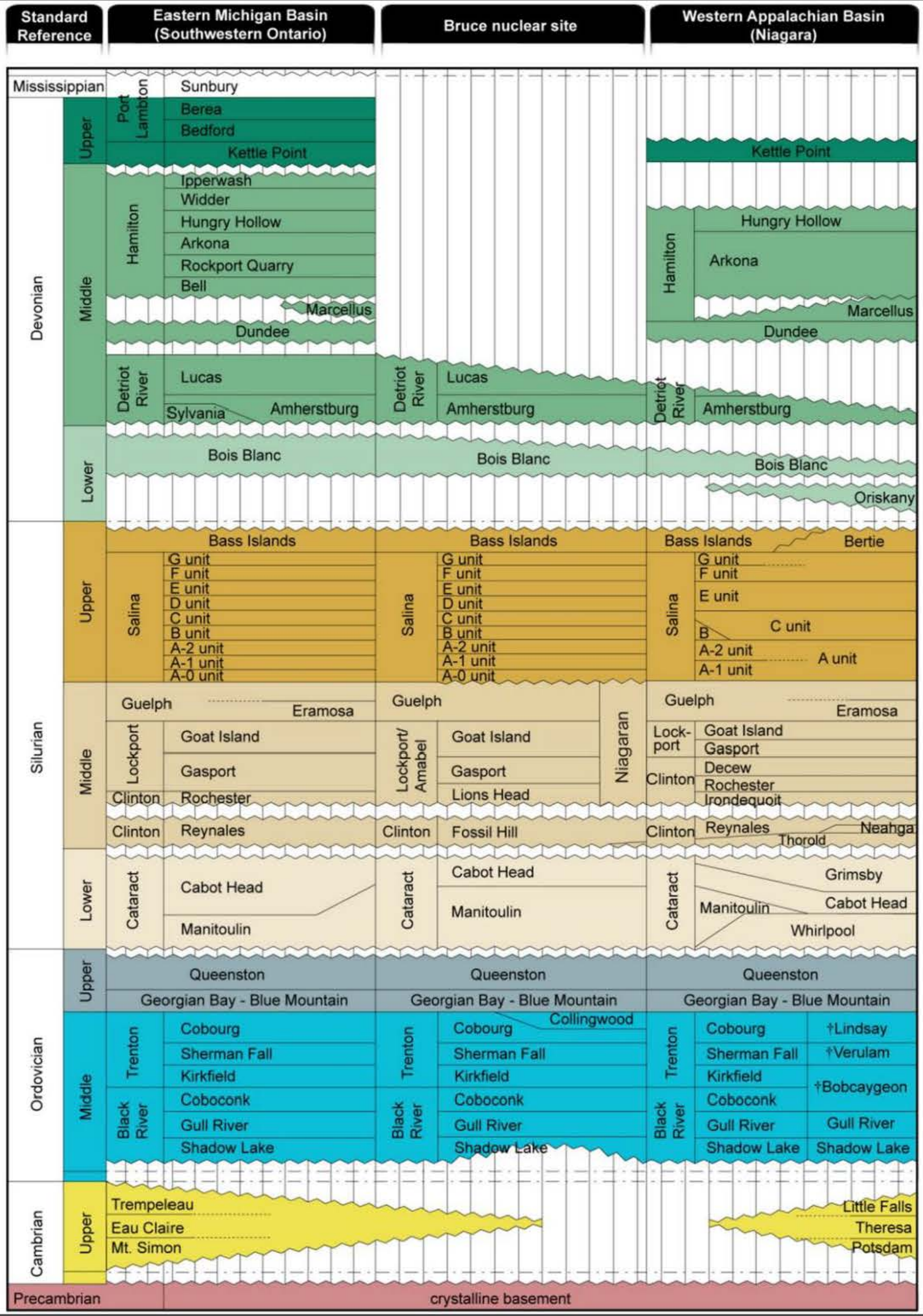
The characteristics of the rock are based on information on the geology of sedimentary rocks developed by OPG in support of the OPG DGR Project [NWMO 2011], and on the work by NWMO in its studies of a DGR for used fuel in sedimentary rock [NWMO 2013].

The geology of the alternate location is comprised of a layer of glacial drift, overlying thick sequences of sedimentary rock, which sit upon crystalline basement bedrock.

Figure 4-2 shows a more detailed list of the Paleozoic sedimentary rock stratigraphy of southwestern Ontario. This figures shows that the thick low-permeability Ordovician sedimentary rock formations that define the sedimentary alternate location are traceable over a large regional area in southwestern Ontario, from the Michigan Basin and over the Algonquin Arch into the Appalachian Basin.

For context and greater clarity, based on the performance needed for safety, the DGR would be designed at a depth that ensured isolation from natural and human activities, and in a volume of reasonably homogenous and competent rock. In the sedimentary alternate location, the Ordovician carbonates and shales are a suitable rock, and in particular the mechanically competent and very low permeability Cobourg limestone Formation is a suitable rock.

Fractures within the alternate location are generally sparse and infrequent, and generally do not penetrate sedimentary rocks younger than Ordovician in age [NWMO 2011].




Notes: Includes nomenclature from locations in the Michigan Basin (left), Bruce nuclear site (centre), and Appalachian Basin. † indicates outcrop nomenclature for southern and eastern Ontario. Modified from Armstrong and Carter (ARMSTRONG06).

**Figure 4-2: Stratigraphic Outline of Rock Formations in Southwestern Ontario [Armstrong and Carter 2006]**

## 4.3 STABILITY

The sedimentary alternate location is in southwestern Ontario, and is within an area of low seismic hazard.

The Cobourg Formation limestone is a generally mechanically competent rock formation.

## 4.4 LAND USE

Most of the sedimentary alternate location is rural, non-urban area and is currently land that is privately owned.

The sedimentary alternate location is within the traditional territory of multiple indigenous communities. Siting would need the support of indigenous communities whose traditional territory could contain the DGR. It is assumed that the DGR could be located to avoid culturally sensitive areas, and to avoid or minimize impacts on areas currently used for harvesting, trapping or hunting.

Much of the sedimentary alternate location contains former agricultural land, there would be no immediately nearby industry as a source of noise or air emissions.

## 4.5 ENVIRONMENT

The sedimentary alternate location is within southwestern Ontario. The sedimentary alternate location is within the Mixedwood Plains ecozone.

The background air quality in the sedimentary alternate location would be typical of southern Ontario. It may be noted that the air quality in the Regional Study Area for the Bruce Nuclear site was considered representative of air quality in southern Ontario, and therefore similar conditions could be assumed at this sedimentary alternate location [OPG 2011a, Section 6.7.5.1].

In southern Ontario, there are extensive networks of streams and small rivers that collect precipitation and carry the water to one of the Great Lakes. While the nearby presence of a Great Lake is generally not a technical feasibility factor, per the Agency's clarification, this assessment considers a location that is not the same as the Bruce Nuclear site.

Consistent with this, as illustrated in Figure 4-1, there are expected to be identifiable streams in the vicinity of the DGR in the sedimentary alternate location. However the DGR surface facilities would likely not to be located on a floodplain, therefore the nearby water courses are not large. Surface water quality in the area, and certainly where these streams merge with other watersheds, are assumed to be influenced by agriculture.

The southern Ontario region is generally well drained. Most watercourses are cool to cold water, and this would be generally applicable at the sedimentary alternate location. It is expected, in particular, that the DGR surface facilities would be at least 120 m from any provincially significant wetland per the provincial guideline. Therefore it is expected that there would be little encroachment on wetlands or streams, however some supporting habitat for aquatic species like crayfish may be removed as part of the surface facilities area (which includes waste rock management area, stormwater pond, surface buildings).

In southern Ontario, the climate is generally mild and moist. Land cover is dominated by cropland, pasture and abandoned fields, with woodland cover at about 16%. The vegetation is diverse. Whether the site was previously brownfield or marginal agricultural, in either case, the land is not expected to have significant existing tree cover.

## 4.6 PHYSICAL FACILITIES AND ACTIVITIES

The DGR at the sedimentary alternate location would need to meet the same general project requirements as the DGR Project at the Bruce Nuclear site. Consequently, the general repository physical design is assumed to be similar to that of the DGR Project at the Bruce Nuclear site. However, some changes to the physical facilities and activities would be required as a result of being independent (distant) from the Bruce Nuclear site. These differences are noted in this section.

As the DGR would be within southern Ontario, it is unlikely that there would be a need to construct extensive new road and power access to the site. For the purpose of assessing environmental impacts of the sedimentary alternate location, a range of 0-5 km has been assumed for the establishment of road access, and 0–5 km to establish a high-voltage power corridor to the site.

In other respects the DGR facilities at this sedimentary alternate location would be similar to the crystalline alternate location, as described in Section 3.6. The following key features are repeated below for completeness.

- At the DGR, additional surface facilities would be required to receive and temporarily store waste before transfer underground, in order to allow for delays in shipping to the DGR.

- The DGR would require facilities and supporting services that exist at the Bruce Nuclear site.

- The DGR would occupy a direct surface facilities footprint of about 40 hectares, with capacity to allow for doubling of the underground facility in the future to accommodate decommissioning wastes.

- The total controlled area around the DGR would include the underground and surface footprint of 40 ha, and any further area needed for postclosure institutional control, for example, or up to about 900 hectares.

- The general layout of the underground facilities would be similar to the DGR Project at the Bruce Nuclear site, with 31 rooms excavated off from two shafts, and aligned with the principal stresses.

- Given the same rock formation and waste packages, a similar volume of excavated rock is expected.

- Excavation would use controlled drill and blast.

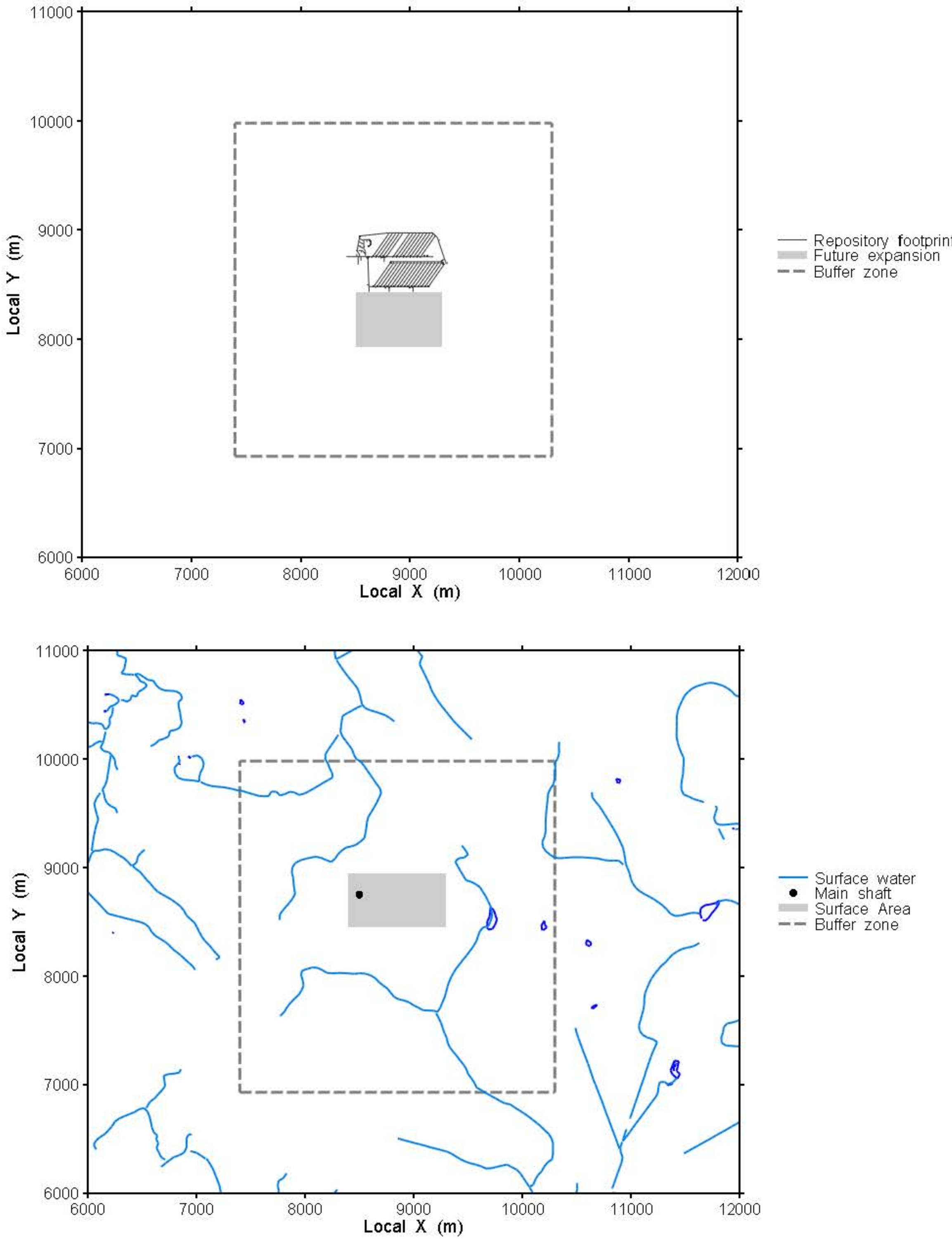
At this sedimentary alternate location, it is expected that the waste processing and engineered barriers as in the DGR Project at the Bruce Nuclear site would be sufficient. These would need to be assessed in the context of the DGR depth at the sedimentary alternate location; in particular if it is at much shallower depth than 680 m (the proposed depth of the DGR Project at the Bruce Nuclear site).

After closure, the radionuclides should be retained within the DGR as they decay. Any releases of radionuclides would have to occur by migration through the enclosing rock or shaft seals as dissolved species or gaseous species. These processes are very slow in the low permeability rock surrounding the DGR in the sedimentary alternate location.

Figure 4-3 illustrates how the DGR might be sited within the larger area shown in Figure 4-1.

Figure 4-3(a) shows an underground cross-section at an illustrative depth. Unlike the crystalline alternate location, there are no fractures at this depth on this scale. This figure includes an allowance for future expansion for decommissioning wastes.

Figure 4-3(b) shows the nominal surface footprint of the DGR, including surface structures and waste rock management area. Most surface facilities would be near the main shaft, although the waste rock management area could be positioned separately. This figure also shows the site boundary including an illustrative 1-km controlled zone (similar to the controlled zone at the Bruce Nuclear site). As in this example, the surface facilities can be placed to avoid surface water streams and wetlands, but the larger site itself likely contains or intercepts some surface water streams that would be expected in any area in southern Ontario.




(a)

**(b)**

**Figure 4-3: Illustrative DGR Placement in Sedimentary Alternate Location. (a) Underground area, including expansion capacity; (b) Surface facilities area.**

## 5. SUMMARY

In this document, the technical and economic feasibility criteria have been described for an alternate location for a DGR for OPG's L&ILW. Consistent with these criteria, two technically and economically feasible alternate locations have been described: an alternate location in crystalline rock in central to northern Ontario, and an alternate location in sedimentary rock of southern Ontario.

These alternate locations have been described, including in terms of typical or representative environmental features. The description also identifies the key differences in DGR facilities and activities at these alternate locations.

An important difference is that any DGR at an alternate location would be a new independent facility. As a result, there would be a need for a new nuclear licensed facility and for additional infrastructure at the alternate location. A location on the Canadian Shield in central to northern Ontario is also more likely to be forested and greenfield than a southern Ontario location. Finally the generally fractured nature and higher permeability of most crystalline rock would lead to constraints on siting, as well as more engineered barriers in the design and more waste pre-processing at surface.

These descriptions are provided to enable the environmental effects to be assessed for a DGR Project at these alternate locations. This analysis is provided in a companion document, Environmental Effects of Alternate Locations [GOLDER 2016].

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## 7. ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AECL | Atomic Energy of Canada Ltd. |
| C-14 | Carbon-14 |
| CANDU | CANada Deuterium Uranium |
| CEAA | Canadian Environmental Assessment Agency |
| CNSC | Canadian Nuclear Safety Commission |
| DGR | Deep Geologic Repository |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| GPS | Global Positioning System |
| IAEA | International Atomic Energy Agency |
| ILW | Intermediate Level Waste |
| JRP | Joint Review Panel |
| L&ILW | Low and Intermediate Level Waste |
| NWMO | Nuclear Waste Management Organization |
| OPG | Ontario Power Generation |