OPG's DEEP GEOLOGIC

REPOSITORY

FOR LOW & INTERMEDIATE LEVEL WASTE

Malfunctions, Accidents and Malevolent Acts Technical Support Document

March 2011

Prepared by: AMEC NSS Ltd.

NWMO DGR-TR-2011-07

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION

Ontario Power Generation (OPG) is undergoing a multi-year planning and regulatory approval process for a deep geologic repository (DGR) for the long-term management of low and intermediate level waste (L&ILW). Currently, the L&ILW produced as a result of the operation of OPG's nuclear reactors is stored centrally at OPG's Western Waste Management Facility (WWMF) located on the Bruce nuclear site. Although current storage practices are safe and could be continued safely for many decades, OPG's long-term plan is to manage these wastes in a long-term management facility. Throughout this report, OPG's proposal is referred to as the "DGR Project".

The DGR Project includes the site preparation and construction, operations, decommissioning, and abandonment and long-term performance of the DGR. The DGR would be constructed in competent sedimentary bedrock beneath the Bruce nuclear site near the existing WWMF. The underground facilities will include access-ways (shafts and tunnels), emplacement rooms and various underground service areas and installations. The surface facilities include the underground access and ventilation buildings, Waste Package Receiving Building (WPRB) and related infrastructure.

An environmental assessment (EA) of the proposed project is required under the provisions of the *Canadian Environmental Assessment Act* (CEAA) because the proponent (OPG) will be required to obtain a licence from the Canadian Nuclear Safety Commission (CNSC) to allow the project to proceed. The findings of the EA are presented in the Environmental Impact Statement (EIS) and Technical Support Documents (TSDs).

ES.2 METHODS

The effects of normal operations of the project are assessed in a series of Technical Support Documents (TSDs). This TSD assesses the effects of possible malfunctions, accidents and malevolent acts associated with the DGR Project. For the purpose of the EA of the DGR Project, malfunctions and accidents are grouped into two categories, namely:

- radiological malfunctions and accidents (i.e., those that could result in the acute release of radioactivity as well as non-radiological substances); and
- non-radiological malfunctions and accidents (i.e., those that involve only non-radiological substances).

Malevolent acts are defined as those events for which the initiating event of a malfunction or accident was an intentional attempt to cause damage to the facility.

The overall method used to assess the radiological and conventional malfunctions and accidents associated with the DGR Project involved the following steps:

1. Identification of events, features, or processes which could initiate the malfunctions and accidents;
2. Identification and screening of malfunctions and accidents; and
3. Detailed assessment.

ES.3 RESULTS

The major findings for radiological malfunctions and accidents during the site preparation and construction, operations, and decommissioning phases are:

- radiological doses to humans (including workers or members of the public) and non-human biota do not exceed established dose limits for credible accident scenarios; and
- non-radiological species released from various scenarios do not exceed the criteria established for humans (including workers and members of the public) and the environment (specifically ‘non-human’ biota, i.e., terrestrial and aquatic flora and fauna).

The major findings for radiological malfunctions and accidents during the abandonment and long-term performance phase are:

- While radiological doses to humans are significantly less than the dose criterion for some scenarios, doses to humans resulting from other scenarios could be about 1 mSv/a. However, all scenarios considered are very unlikely and therefore the risk to humans is low.
- While most contaminants are likely to remain well below their respective screening criteria, there could be exceedances of screening criteria for some radioactive species relating to certain scenarios. However, as these exceedances are local, the screening criteria are conservative, and the scenarios are very unlikely, the risk to non-human biota is low.

For conventional malfunctions and accidents that may occur during the site preparation and construction, operations, and decommissioning phases:

- there will be no likely adverse effects on the environment (including non-human biota);
- there will be no likely adverse effects on members of the public; and
- there will be no likely adverse effects on workers.

As there will be no works and activities during the abandonment and long-term performance phase, there is no potential for the occurrence of conventional malfunctions and accidents.

For malevolent acts:

- radiological consequences are expected to be bounded by those of malfunctions and accidents;
- non-radiological consequences are expected to be bounded by those of malfunctions and accidents, particularly in terms of affecting members of the public; and
- populations of non-human biota are expected to be unaffected.

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1. INTRODUCTION

Ontario Power Generation (OPG) is undergoing a multi-year planning and regulatory approvals process for a deep geologic repository (DGR) for the long-term management of low and intermediate level waste (L&ILW). Currently, the L&ILW that is produced as a result of the operation of OPG's reactors is stored centrally at OPG's Western Waste Management Facility (WWMF) located on the Bruce nuclear site. Although current storage practices are safe and could be continued safely for many decades, OPG's long-term plan is to manage these wastes in a long-term management facility.

A key element of the regulatory approvals process is an environmental assessment (EA), the findings of which are presented in an Environmental Impact Statement (EIS). The EA considers the long-term management of L&ILW currently in interim storage at the WWMF, as well as that produced by the operation of OPG-owned or operated nuclear generating stations, in a DGR at the Bruce nuclear site in the Municipality of Kincardine, Ontario. The project location is shown on Figure 1-1. Throughout this report, OPG's proposal is referred to as the "DGR Project". The DGR Project includes the site preparation and construction, operations, decommissioning, and abandonment and long-term performance of the DGR.

The DGR Project will be constructed in competent sedimentary bedrock beneath the Bruce nuclear site near the existing WWMF. The underground facilities include access-ways (shafts and tunnels), emplacement rooms and various underground service areas and installations. The surface facilities include the underground access and ventilation buildings, Waste Package Receiving Building (WPRB) and related infrastructure. All surface and underground facilities will be located within the boundaries of the OPG-retained lands near the WWMF at the Bruce nuclear site.

OPG is the proponent for the DGR Project. OPG will own, operate and be the licensee for the DGR Project. The regulatory approvals phase of the project, including the EA process and the site preparation and construction licensing, has been contracted to the Nuclear Waste Management Organization (NWMO). The NWMO is responsible, with support from OPG, for completing the EIS and obtaining the site preparation and construction licences.

1.1 EA PROCESS AND REGULATORY CONTEXT

The EA process was initiated by OPG's submission of a Project Description for the DGR Project to the Canadian Nuclear Safety Commission (CNSC) on December 2, 2005. The site preparation and construction licence application for the DGR Project was submitted by OPG to CNSC on August 13, 2007. An EA of the proposed DGR Project is required under the provisions of the *Canadian Environmental Assessment Act* (CEAA) because the proponent (OPG) requires a licence from the CNSC to allow the project to proceed. Under the CEAA, the CNSC is identified as the Responsible Authority (RA); however, the Canadian Environmental Assessment Agency also has statutory responsibilities.

Under the CEAA, this type of project is identified in the Comprehensive Study List Regulations. The CNSC issued draft guidelines for a comprehensive study EA of the DGR Project, which were the subject of a public hearing held in Kincardine on October 23, 2006. Following the hearing, the CNSC recommended to the Minister of the Environment that the DGR Project be referred to a review panel given the public concerns, possibility of adverse environmental effects and concerns regarding the comprehensive study's ability to address all the questions raised [1].

The Minister of the Environment referred the EA of the DGR Project to a joint review panel on June 29, 2007. Draft guidelines for the preparation of the EIS for the joint review panel were issued by the Canadian Environmental Assessment Agency and the CNSC for public review on April 4, 2008. The guidelines, a copy of which is appended to the EIS, were finalized on January 26, 2009. The scope of the EA for the DGR Project includes the site preparation, construction, operations and decommissioning of the above- and below-ground facilities for the long-term management of L&ILW. The EA also addresses the abandonment and long-term performance of the DGR Project.

An EA is a tool to provide an effective means of integrating environmental factors into the planning and decision-making processes in a manner that promotes sustainable development and minimizes the overall effect of a project. The methods used in the EA and presented in the EIS are consistent with the final guidelines, and are based on systematic and detailed consideration of the systems, works, activities and events comprising the DGR Project.

1.2 EA REPORTING STRUCTURE

The EA for the DGR Project is documented in an EIS, which is based on the guidelines and work detailed in a series of technical support documents (TSDs). In addition, there are parallel technical studies, information from which is also used in preparing the EIS and TSDs. Finally, the findings are summarized in the EIS Summary. Figure 1.2-1 illustrates the relationships between the EIS and summary report, its supporting documents, and the independent technical studies for the DGR Project.

The EIS comprises the following volumes:

- **Volume 1** consolidates and summarizes all aspects of the EIS studies. It includes a description of the EA methods, a description of the DGR Project, a description of the existing environment, an assessment of likely environmental effects, including cumulative effects, a discussion of the plan for a follow-up program, and a discussion of the communication and consultation program.
- **Volume 2** contains a series of appendices that support the material in Volume 1, including a copy of the guidelines and human health assessment. It also contains a summary of the community engagement and consultation program along with copies of supporting materials.

The TSDs present information on the existing environment and the detailed results of the studies and investigations conducted to assess the direct and indirect effects of the DGR Project on the environment. The TSDs on which the EIS is based are as follows:

- Atmospheric Environment;
- Hydrology and Surface Water Quality;
- Geology;
- Aquatic Environment;
- Terrestrial Environment;

- Socio-economic Environment;
- Aboriginal Interests;
- Radiation and Radioactivity; and
- Malfunctions, Accidents and Malevolent Acts.

These TSDs are interconnected with one another. Each respective report focuses on the effects of the DGR Project on that particular environment, through a direct interaction with the DGR Project or through a change identified in another TSD (i.e. indirect interaction). Cross-references are provided throughout the TSD where it relies on information predicted in another report.

It is important to note that the assessment of potential radiation and radioactivity effects of normal operations of the DGR Project are documented in the Radiation and Radioactivity TSD, regardless of the physical media through which they are transported (e.g., air or water). This was done because of the special importance placed on radiation and radioactivity, and the combined effects to the receiving environment regardless of the path of exposure.

The TSDs assess the direct and indirect effects of the DGR Project as a result of normal operations, with the exception of this Malfunctions, Accidents and Malevolent Acts TSD. The EIS Guidelines require identification of credible malfunctions, accidents and malevolent acts, and an evaluation of the effects of the DGR Project in the event that these accidents, malfunctions or malevolent acts occur. All of these effects are assessed and discussed in the Malfunctions, Accidents and Malevolent Acts TSD (this report) regardless of the element of the environment that is affected. The reasoning for this is that a single accident has the potential to affect multiple elements of the environment.

The independent parallel technical study reports used in preparing the EIS include:

- Postclosure Safety Assessment [2];
- Geosynthesis [3]; and
- Preliminary Safety Report [4].

1.3 CONTENTS OF THIS REPORT

Malfunctions and accidents could take place throughout all phases of the DGR Project as internally-initiated events (such as equipment failures) and externally-initiated events (including human activity such as traffic accidents and natural hazards such as tornados or earthquakes). For the purpose of the DGR Project EIS, malfunctions and accidents associated with the DGR Project are grouped into two categories:

- radiological malfunctions and accidents; and
- non-radiological malfunctions and accidents.

Radiological accidents refer to those that could result in the acute release of radioactivity to the environment and potentially affect the environment. Radiological accidents can also result in the release of non-radiological compounds in the wastes. For continuity, the assessment of effects from radiological accidents considers both the radiological and non-radiological releases from the wastes. These scenarios are evaluated in Section 4.

Non-radiological accidents refer to those that involve only non-radiological substances and will not have any adverse radiological effects on the environment and humans. These include things such as the spill of chemicals, lubricants and oils, fires, traffic accidents, and explosions. These scenarios are assessed in Section 5 as non-radiological accidents.

In addition, a third category, malevolent acts are considered. Malevolent acts are defined as those events where the initiating event for a malfunction or accident was an intentional attempt to cause damage to the facility. These scenarios are evaluated in Section 6 as malevolent acts.

Prompt criticality accidents have been considered as the fourth category. The amount of fissile radionuclides in the waste in the DGR is small, and is dispersed over the DGR Project volume. In addition, used fuel and recognizable fuel fragments are not accepted by the DGR Project. Therefore, criticality is not credible for the DGR Project and further assessment of criticality accidents is not conducted in this report. Additional information on the waste to be emplaced in the DGR Project is included in Section 4.5 of the EIS.

External events, such as lightning strike and earthquake have the potential to affect the DGR Project. Although such events are not initiated by the project, for the purposes of this assessment, they are included as malfunctions and accidents. In other situations, especially in the case of radiological malfunctions and accidents, initiating events are represented by the postulated failure of the systems and procedures associated with the operation of the DGR Project. Therefore, it is necessary to give full consideration of the likelihood of initiating events and the consequential effects of such events.

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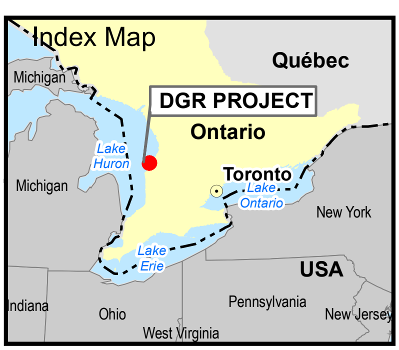
Kilometres



LEGEND

- City
- Highway
- Provincial Highway
- Secondary Highway

REFERENCE

Base Data - MNR NRVIS, obtained 2004, CANMAP v7.3 2003
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2005
Datum: NAD 83 Projection: UTM Zone 17N

PROJECT

MALFUNCTIONS, ACCIDENTS, AND MALEVOLENT ACTS TECHNICAL SUPPORT DOCUMENT

TITLE

LOCATION OF THE DGR PROJECT

Golder Associates
Mississauga, Ontario

PROJECT NO. 06-1112-037			SCALE: AS SHOWN	R000
DESIGN	ASB	17 Oct. 2007	FIGURE 1-1	
GIS	BC	14 Apr. 2010		
CHECK	BC	14 Apr. 2010		
REVIEW	MAR	14 Apr. 2010		

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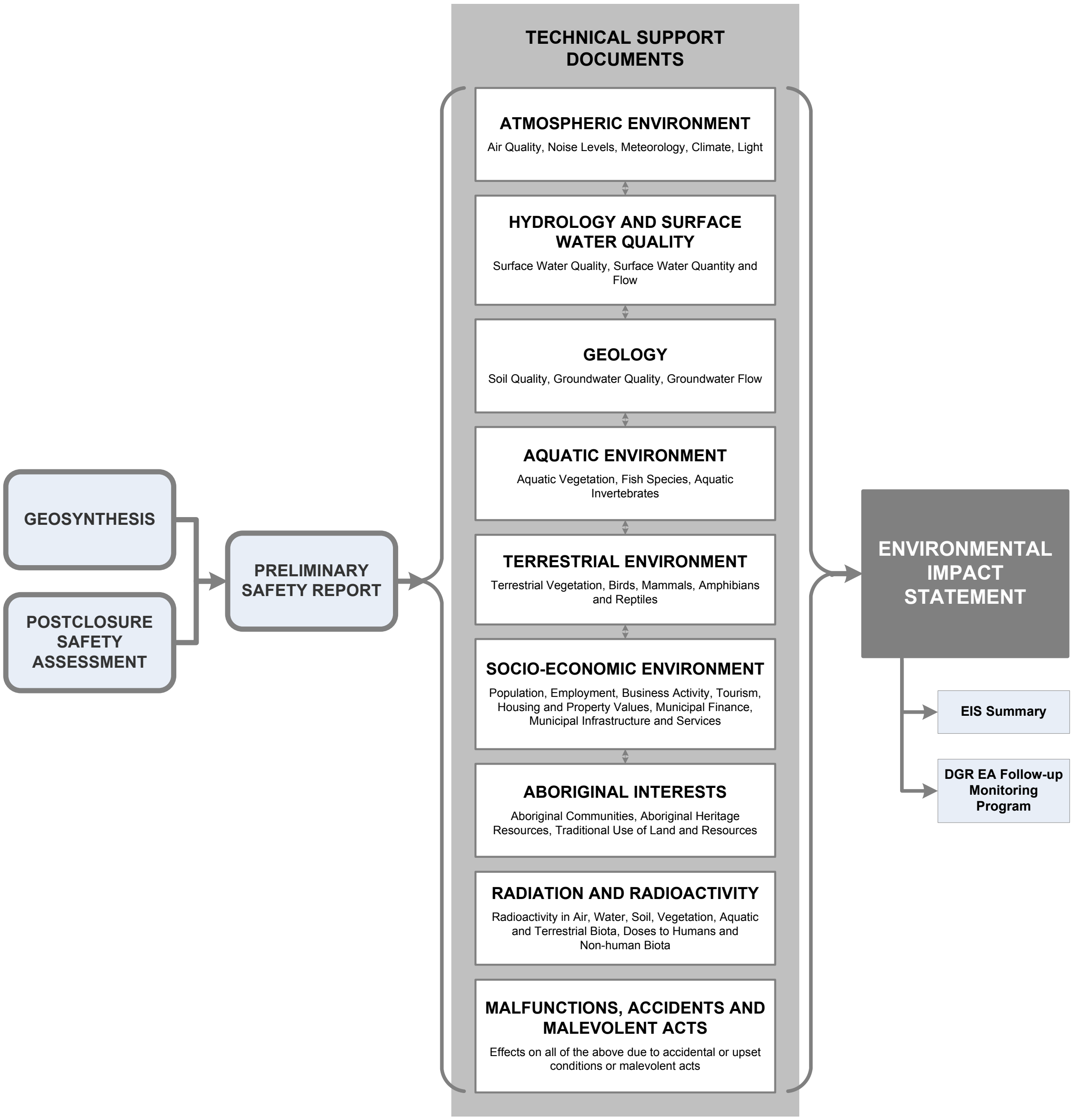

Figure 1.2-1: Organization of EA Documentation

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2. APPROACH

The approach used for assessing the DGR Project, and documented in this TSD, supports the philosophy of EA as a planning and decision-making process. The assessment characterizes and assesses the effects of the DGR Project in a thorough, traceable, step-wise manner. The overall methods used to assess malfunctions and accidents associated with the DGR Project are described below. Methods specific to each of the steps are provided at the start of their respective sections.

2.1 SITE PREPARATION AND CONSTRUCTION, OPERATIONS, AND DECOMMISSIONING PHASES

During the site preparation and construction, operations, and decommissioning phases, the assessment follows the steps described below:

1. **Identification of credible initiating events:** A list of operations, geotechnical and external initiating events is identified. Credible initiating events are then defined for these phases based on the annual frequency estimated. The list of initiating events applies to both radiological and non-radiological events.
2. **Identification and screening of credible accidents:** The potential malfunctions and accidents that could occur as a result of credible initiating events are identified. A list of bounding accident scenarios is then developed for further assessment. Credible non-radiological events are also identified, which are defined as those which occur from credible initiating events (i.e., if the initiating event is credible, it is conservatively assumed that the accident is also credible).
3. **Assessment:** For those bounding malfunctions and accidents, detailed assessment is carried out to determine the significance of adverse effects, if any, on the environment, taking into account the DGR Project design, safety procedures and plans and past experience and records. Mitigation measures are identified to control or minimize the adverse effects on the environment, feasibility and economic factors being taken into account.

2.2 ABANDONMENT AND LONG-TERM PERFORMANCE PHASE

Timing of the abandonment of the DGR facility will be based on discussions with the regulator. CNSC guidance on assessing the long-term safety of radioactive waste management defines scenarios as “a postulated or assumed set of conditions or events. They are most commonly used in analysis or assessment to represent possible future conditions or events to be modelled, such as the possible future evolution of a repository and its surroundings” [5]. The purpose of scenario identification and development is not to predict the future; rather, it is to use scientifically-informed judgement to develop a range of possible future evolutions of the DGR Project against which the performance of the system can be assessed.

The guidelines for the preparation of the EIS for the DGR Project identify the need for the postclosure safety assessment to include a scenario of the normal (or expected) evolution of the site and facility with time based on reasonable extrapolations of present-day site features and receptors’ lifestyles (the Normal Evolution Scenario), and including its expected degradation (loss of barrier functions) with time. These considerations are addressed in Section 9 of the EIS.

In accordance with Regulatory guidance [5], additional scenarios are considered to examine the effects of unlikely disruptive events that lead to possible penetration of barriers and abnormal degradation and loss of containment (Disruptive Scenarios). Thus, the Disruptive Scenarios consider unlikely “what if” cases that are designed to test the robustness of the DGR Project system to scenarios that result in the breaching or extreme degradation of geosphere and/or engineered barriers. These Disruptive Scenarios are considered in this TSD and are summarized in Section 8 of the EIS. The uncertainties associated with the future evolution of the DGR Project system are assessed in part through these scenarios, and in part through sensitivity cases considered within each scenario.

These steps, as they apply to assessment of radiological and non-radiological accidents, are described further in Sections 4 and 5.

3. PROJECT OVERVIEW AND IDENTIFICATION OF INITIATING EVENTS

Initiating events are identified for each phase of the DGR Project, which is described in Section 3.1. Section 3.2 identifies the initiating events considered for the site preparation and construction, operations, and decommissioning phases of the DGR Project. Section 3.3 provides a description of the initiating events considered for the abandonment and long-term performance phase. To provide context, an overview description of the project is provided, including a description of the above- and below-ground facilities.

3.1 OVERVIEW DESCRIPTION OF THE PROJECT

The assessment of effects requires a detailed description of the DGR Project. The individual works and activities are the physical structures, buildings, systems, components, activities and events comprising the DGR Project. The specific works and activities required for the DGR Project are summarized in the Basis for the EA in Appendix B. Further details on the DGR Project design can be found in Section 4 of the EIS and in Chapter 6 of the Preliminary Safety Report [4].

The DGR Project will receive L&ILW currently stored in interim facilities at the WWMF, as well as that produced from OPG-owned or operated nuclear generating stations. Low level waste (LLW) consists of industrial items and materials such as clothing, tools, equipment, and occasional large objects such as heat exchangers, which have become contaminated with low levels of radioactivity. Intermediate level waste (ILW) consists primarily of used reactor components and resins used to clean the reactor water circuits. The capacity of the DGR is a nominal 200,000 m^3 of “as-disposed” waste.

The DGR Project comprises two shafts, a number of emplacement rooms, and support facilities for the long-term management of L&ILW (Figure 3.1-1). The DGR will be constructed over a period of five to seven years. The DGR Project design is the result of a thorough comparison and evaluation of different alternative methods of implementing the DGR Project. This includes considerations such as the layout of the DGR and construction methods. The evaluation compared each of the alternative means using technical, safety, environmental and economic factors to identify the preferred alternative. This evaluation is presented in Section 3 of the EIS. This TSD assesses the effects of the preferred alternative means (i.e., the DGR Project) on the environment.

3.1.1 Surface Facilities

The surface DGR facilities will be located on vacant OPG-retained land to the north of the existing WWMF. A new crossing will be constructed over the abandoned rail bed to provide access to the proposed DGR Project site from the WWMF (Figure 3.1.1-1). Throughout the EA documentation, these ditches are referred to as the South Railway Ditch and the North Railway Ditch. The surface structures will be grouped in relatively close proximity to facilitate operations and maintenance activities, and provide a compact footprint.

The Waste Package Receiving Building (WPRB) will receive all radioactive waste packages and transfer them to the main shaft cage for transfer underground. A maintenance workshop and stores for essential shaft-related spares and materials will be attached to the WPRB. An office, main control room and amenities building will also form part of the main shaft complex for administrative purposes, control and monitoring of the DGR, and receiving visitors to the DGR. An electrical sub-station will provide power to the entire facility, both surface and underground, and an emergency power supply system will maintain critical equipment in the event of an outage.

Waste rock piles for the complete excavated volume of rock will be accommodated to the north-east of the two shafts. A stormwater management system of ditches and a pond will be provided to control the outflow of surface runoff and sump discharge water from the site before release into an existing drainage ditch at the Bruce nuclear site, and ultimately Lake Huron (Figure 3.1.1-1). The discharge will also be monitored to confirm it meets certificate of approval water quality requirements.

3.1.2 Underground Facilities

The underground DGR facilities will be constructed in limestone bedrock (Cobourg Formation) at a nominal depth of 680 m beneath the OPG-retained lands in the centre of the Bruce nuclear site (Figure 3.1-1). The overall underground arrangement enables infrastructure to be kept in close proximity to the main shaft, while keeping the L&ILW emplacement areas away from normally occupied and high use areas.

The DGR will have two vertical shafts (main and ventilation shafts) in an islanded arrangement with a services area in which offices, a workshop, wash bay, refuge stations, lunch room and geotechnical laboratory will be provided. From this centralized area, the two panels of emplacement rooms are connected via access tunnels. A main access tunnel will be driven from the main shaft station to the east, passing the ventilation shaft and then proceeding towards the emplacement room panels. The main access tunnel will continue straight into the Panel 1 access tunnel, while a branch tunnel to the south will lead to the Panel 2 access tunnel. The length of the rooms is approximately 250 m. End walls may be erected once the rooms are filled.

The emplacement rooms will all be aligned with the assumed direction (east-north-east) of the major principal horizontal stresses of the rock mass to minimize the risks of any rock fall in the emplacement rooms.

A ventilation system will supply air at a controlled range of temperatures to ensure that freezing does not occur in the main shaft and the atmosphere is kept in a reasonably steady and dry state that is suitable for workers and limits corrosion of structures and waste packages.

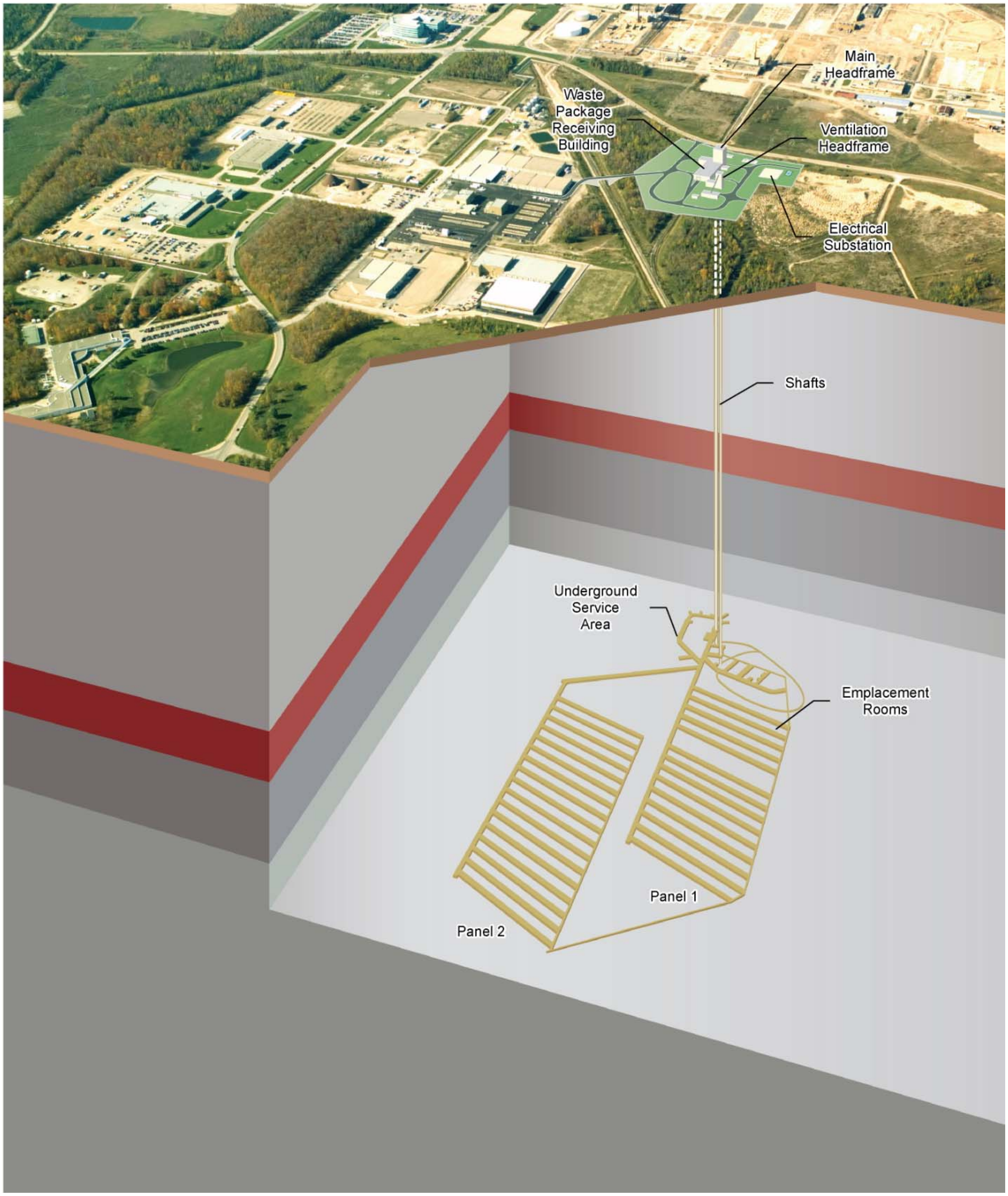

Figure 3.1-1: Schematic of DGR Project

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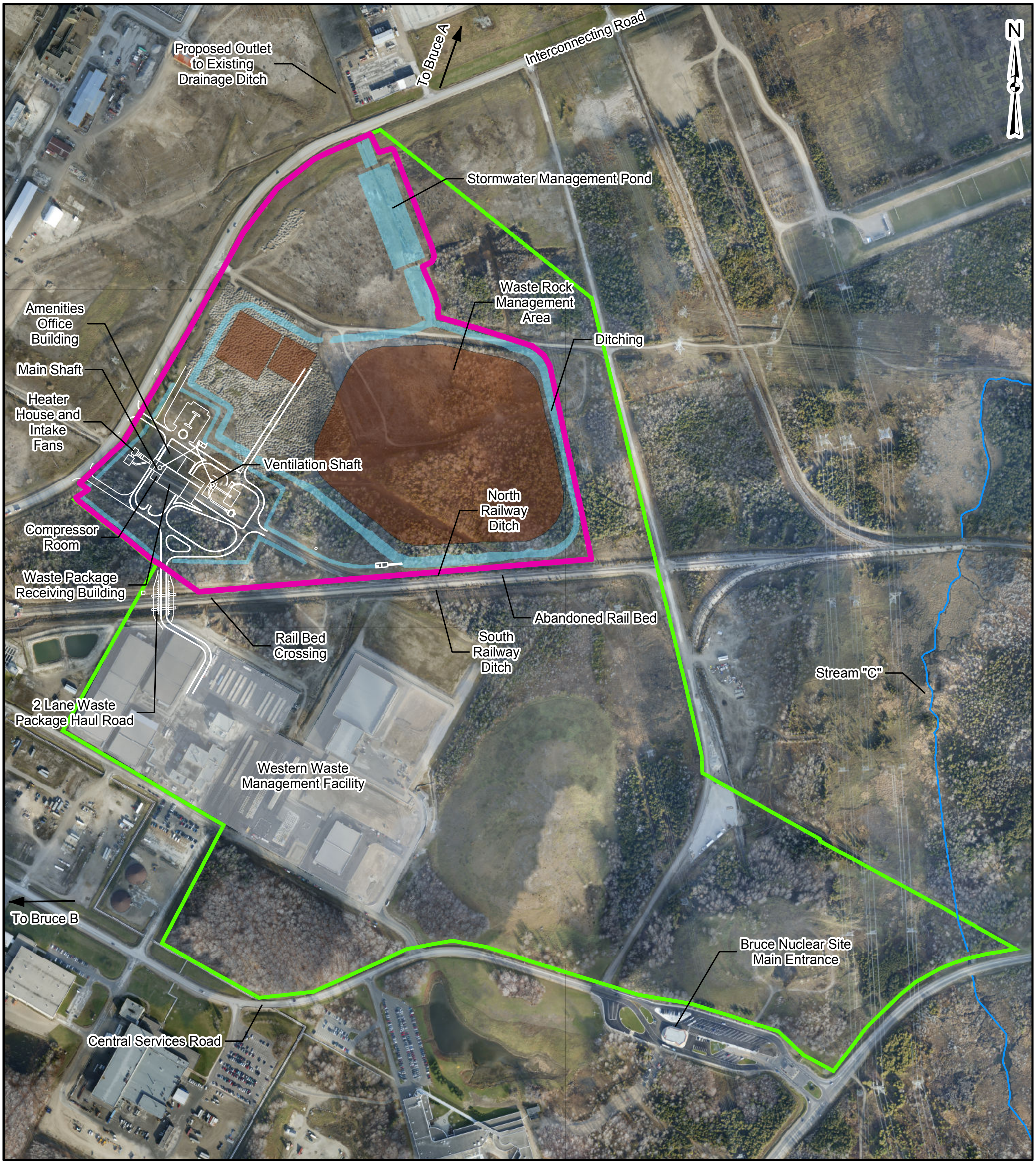

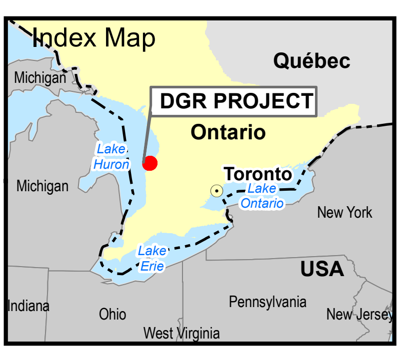

LEGEND

- DGR Project Site
- Project Area (OPG-retained lands that encompass the DGR Project)
- Soils and Rock Stockpile
- Stormwater Management System

0 125 250 500

Metres

REFERENCE

Base Data Provided by 4DM, Nov 2007.
Imagery and Topo Collected and Processed by Terrapoint Canada Inc., Acquisition Date: Nov. 12, 14, and 15, 2006, Ground Resolution: 0.25m, Datum: NAD 83 Projection: UTM Zone 17N

PROJECT

MALFUNCTIONS, ACCIDENTS, AND MALEVOLENT ACTS TECHNICAL SUPPORT DOCUMENT

TITLE

LAYOUT OF DGR SURFACE INFRASTRUCTURE

Golder Associates
Mississauga, Ontario

PROJECT NO. 06-1112-037			SCALE: AS SHOWN	R000
DESIGN	AB	16 Mar. 2010	**FIGURE 3.1.1-1**	
GIS	BC	25 Nov. 2010		
CHECK	KC	25 Nov. 2010		
REVIEW	AB	25 Nov. 2010		

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3.2 INITIATING EVENTS – SITE PREPARATION AND CONSTRUCTION, OPERATIONS, AND DECOMMISSIONING PHASES

Malfunctions and accidents could be initiated by a variety of events[1]. These initiating events are categorized into three groups:

- operations initiating events: power failure (grid and emergency power supply), mechanical/equipment failure (such as truck, forklift, crane, ventilation fan, hoisting system), stacked package fall due to corrosion, cage fall, utility pipe failure and human error;
- geotechnical initiating events: major earthquake and local rock fall within emplacement room; and
- external initiating events: severe weather conditions, flood, forest fire affecting the DGR Project, aircraft crash and meteor impact.

Table 3.2-1 summarizes the initiating events considered for the DGR Project and their potential frequency of occurring at the DGR Project. Frequency is grouped into three classes:

- Possible Events: annual frequency $>10^{-2}$;
- Unlikely Events: annual frequency between 10^{-2} and 10^{-7}; and
- Non-credible Events: an annual frequency of $\leq 10^{-7}$.

Accident scenarios with an annual frequency of 10^{-6} or less are generally considered to be not credible. However, to accommodate the uncertainty in frequency estimates in this range, hazardous events with a frequency of 10^{-7} or less were considered non-credible. The risk from such accident scenarios was deemed to be acceptable, and they were screened out from further consideration. Therefore, the following initiating events are deemed non-credible and are not considered further in this report:

- criticality;
- explosion;
- tornado;
- external fire affecting the DGR Project;
- aircraft crash[2]; and
- meteor impact.

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1 The equivalent initiating event for abandonment and long-term performance phases are those FEPs discussed in Section 3.3

2 The potential consequences of a deliberate aircraft crash (i.e., a malevolent act) are considered in Section 6.2.2.1

Table 3.2-1: Summary of the Initiating Events Considered

Type	Initiating Events	Frequency [a]
Operations Initiating Events	Mechanical/equipment failure	Possible
	Human error causing: • LLW package drop/hit • ILW package drop/hit [b] • Indoor fire • Inadequate package shielding	 Possible Unlikely Unlikely Unlikely
	Major vehicle accident	Unlikely
	Container failure	Unlikely
	Power failure (both grid and backup)	Unlikely
	Cage fall	Unlikely
	Criticality	Non-credible
	Explosion	Non-credible
Geotechnical Initiating Events	Major earthquake	Unlikely
	Rock fall/rock burst	Unlikely
External Initiating Events	Severe weather conditions: • Severe rainfall • Severe snow/ice • Severe wind • Lightning strike • Tornado	 Unlikely Unlikely Unlikely Unlikely (Headframe) Non-credible (Waste Package) Non-credible
	Flooding (above ground)	Unlikely
	Flooding (underground)	Unlikely
	External fire	Non-credible
	Aircraft crash	Non-credible
	Meteor impact	Non-credible

Notes:
a Possible events were assessed to have an annual frequency of $>10^{-2}$ of occurring at the DGR; Unlikely events have an annual frequency of between 10^{-2} and 10^{-7}; Non-credible events have an annual frequency $\leq 10^{-7}$.
b Less likely than LLW package due to the much fewer ILW packages handled at DGR.
Source: [4]

3.3 INITIATING EVENTS – ABANDONMENT AND LONG-TERM PERFORMANCE PHASE

The DGR Project system and its evolution are affected by various external, internal and contaminant factors. These factors may be further categorized as features, events or processes (FEPs). For example, an earthquake is an external event, carbon steel waste package is an internal feature, and sorption is a contaminant process.

The internal and contaminant factors are situated within the spatial boundaries of the DGR Project system, whereas the external factors originate outside these boundaries. The external FEPs provide the system with both its boundary conditions and with factors that might cause change in the system. If these external factors can significantly affect the system within the assessment timescale, they can be considered to be scenario-generating FEPs in the sense that whether they occur or not (or the extent to which they occur) could define a particular future scenario that should be considered within the postclosure safety assessment [2].

A list of greater than 50 external potential FEPs and almost 200 internal potential FEPs relevant to the DGR Project system has been developed in the postclosure safety assessment. These include:

- repository factors (e.g., repository design, waste allocation, construction and operation);
- geological processes and effects (e.g., seismicity, deformation);
- climate processes and effects (e.g., local/regional/global climate change, glacial effects, human/ecological/hydrological responses to these changes); and
- future human actions (e.g., social and institutional developments on-site, drilling activities).

A comprehensive list of FEPs is available in the postclosure safety assessment [2].

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4. RADIOLOGICAL MALFUNCTIONS AND ACCIDENTS

In this section, radiological malfunctions and accidents that result from credible initiating events and FEPs are identified and assessed for each DGR Project phase, that is, site preparation and construction, operations, decommissioning, and abandonment and long-term performance. Specifically, radiological accidents refer to those accidents that could result in the acute release of radioactivity to the environment. Radiological accidents can also result in the release of non-radiological hazardous material from the wastes. For continuity, the assessment of effects from radiological accidents considers both the radiological and non-radiological releases.

4.1 METHODS FOR ASSESSMENT OF RADIOLOGICAL MALFUNCTIONS AND ACCIDENTS

4.1.1 Site Preparation and Construction, Operations, and Decommissioning Phases

4.1.1.1 Identification and Screening of Radiological Accidents

Potential radiological accidents, resulting from the credible initiating events discussed in Section 3, were identified for these phases. Based on the frequency of the initiating events and the likelihood of the events/consequence, the accidents scenarios that have a frequency of occurrence of less than 10^{-7}/a are screened out as non-credible accidents. In addition, the bounding scenarios are identified, based on the qualitative estimation of the magnitude of the consequences, which is a function of the waste category, the number of waste packages affected and the location of the hazardous event. The detailed identification and screening processes are documented in Chapter 7 of the Preliminary Safety Report [4].

It should be noted that as there will be no waste movement during the site preparation and construction phase, there is no potential for radiological accidents during this phase.

4.1.1.2 Assessment of Bounding Radiological Accidents

The bounding radiological accidents are then assessed to investigate the effects on workers, members of the public and non-human biota (Section 4.1.1.3). The basis of the assessment of bounding accidents, for example, the assumptions and models for the calculation of doses to humans, can be found in Chapter 7 of the Preliminary Safety Report [4]. For the calculation of doses to non-human biota, the method is the same as that described in the Radiation and Radioactivity TSD. The radiological dose criteria are provided Section 4.1.1.4.

4.1.1.3 Non-human Biota

Non-human biota are represented by eleven valued ecosystem components (VECs) (Table 4.1.1-1), which are the same as those identified in the Radiation and Radioactivity TSD.

Table 4.1.1-1: Non-human VECs Selected for the Assessment of Radiological Accidents

VEC	Indicators
Benthic Invertebrates	• Burrowing crayfish
Aquatic Vegetation	• Variable leaf pondweed
Benthic Fish	• Lake whitefish • Redbelly dace • Creek chub
Pelagic Fish	• Spottail shiner • Smallmouth bass • Brook trout
Aquatic Birds	• Double-crested cormorant • Mallard
Aquatic Mammals	• Muskrat
Terrestrial Invertebrates	• Earthworm
Terrestrial Vegetation	• Eastern white cedar • Common cattail • Heal-all
Terrestrial Birds	• Bald eagle • Yellow warbler • Wild turkey • Red-eyed vireo
Terrestrial Mammals	• White-tailed deer • Northern short-tailed shrew • Red fox
Amphibians and Reptiles	• Midland painted turtle • Northern leopard frog

4.1.1.4 Radiological Dose Criteria

Dose Limits for Humans

The radiological doses from radionuclide releases and direct radiation must not exceed 50 mSv for the DGR Project workers and 1 mSv for members of the public (at the Bruce nuclear site boundary) to meet the CNSC regulatory dose limits. In this report, comparison with these criteria is used to assess the effects of the DGR Project on humans during malfunctions and accidents.

Dose Criteria for Non-human Biota

The following dose criteria (Table 4.1.1-2) are used to assess the effects of the project on non-human biota during malfunctions and accidents.

Table 4.1.1-2: Dose Criteria

VEC	Dose Criteria (Gy)
Benthic Invertebrates	1.8
Aquatic Vegetation	0.9
Pelagic Fish	0.2
Benthic Fish	0.2
Aquatic Birds	0.4
Aquatic Mammals	0.4
Terrestrial Invertebrates	0.6
Terrestrial Vegetation	0.6
Terrestrial Birds	0.4
Terrestrial Mammals	0.4
Amphibians and Reptiles	1.8

Source: [6]

4.1.1.5 Non-radiological Exposure Criteria

The L&ILW contain a variety of non-radiological species or chemicals. The following non-radiological species could potentially be released during radiological accidents in quantities sufficient to cause effects to health of workers and members of the public:

- antimony (Sb);
- arsenic (As);
- asbestos;
- barium (Ba);
- beryllium (Be);
- cadmium (Cd);
- chromium (Cr);
- cobalt (Co);
- copper (Cu);
- dioxins/furans.
- lead (Pb);
- manganese (Mn);
- mercury (Hg);
- nickel (Ni);
- selenium (Se);
- strontium (Sr);
- uranium (U);
- zinc (Zn); and
- zirconium (Zr).

The effect of these non-radiological species or chemicals is assessed against the values of Immediately Dangerous to Life and Health (IDLH), provided by the U.S. National Institute for Occupational Safety and Health (NIOSH) and the U.S. DOE Protective Action Criteria (PAC), which are applicable for workers and members of the public, respectively. The values of IDLH and PAC are presented in Table 4.1.1-3.

The effects of these substances on non-human biota are assessed against the Canadian environmental quality standards, presented in Section 4.1.2.6.

Table 4.1.1-3: Exposure Criteria for Short-term Inhalation of Non-radiological Species

Non-Radiological Species in Waste	Workers	Public
	IDLH (µg/m³)	PAC Criteria (µg/m³)
Antimony	50,000	500
Arsenic	5,000	300
Asbestos	N/D	50
Barium	50,000	1,220
Beryllium	4,000	3.5
Cadmium	9,000	30
Chromium	25,000	25 [i]
Cobalt	20,000	60
Copper	100,000	220
Lead	100,000 [a]	150
Manganese	500,000 [b]	3,000
Mercury	10,000 [c]	250 [j]
Nickel	10,000 [d]	600
Selenium	1,000	600
Strontium	N/D	125,000
Uranium	10,000 [e]	600 [f]
Zinc	500,000 [g]	3,000
Zirconium	25,000	10,000
Dioxin/Furan [h]	N/D	1.5

Notes:
a as lead monoxide
b as manganese tetroxide
c as mercurous oxide
d as nickel (II) oxide
e as uranium (soluble) and uranium (insoluble)
f as U, UO_2, U_3O_3
g as zinc oxide
h as 2,3,7,8-tetrachlorodibenzo-p-dioxin
i based on 20% CrO_3 (CrVI); PAC-1 values are 1,000 as Cr; 10,000 as Cr_2O_3(CrIII); 5 as CrO_3 (CrVI)
j as mercury vapour; Hg_2O is not stable
PAC values adopted are PAC-1. PAC-1 criteria based on lowest of element or oxide form; expressed in terms of element content. IDLH and PAC values from [4].
N/D Criteria for workers have not been developed by NIOSH.

4.1.2 Abandonment and Long-term Performance Phase

4.1.2.1 Identification of Disruptive Events

Disruptive events considered for this phase are identified in the postclosure safety assessment, in which they were defined as Disruptive Scenarios [2].

4.1.2.2 Screening of Disruptive Events

Through a systematic study of potential external features, events and processes (FEPs) that could drive the evolution of the repository system, the postclosure safety assessment [2] identified four disruptive scenarios, which consider events that could lead to possible penetration of barriers and abnormal degradation and loss of containment. These disruptive scenarios are unlikely or “what if” cases that test the robustness of the DGR Project.

4.1.2.3 Assessment of Representative Disruptive Events

The disruptive events were then assessed to investigate the effects on humans and non-human biota (Section 4.1.2.4). The basis of the assessment of the representative accidents, including the assumptions and models for the calculation of doses to humans and the effects on non-human biota, can be found in Chapter 8 of the Preliminary Safety Report [4]. The radiological dose criteria and non-radiological exposure criteria are provided in Sections 4.1.2.5 and 4.1.2.6, respectively.

4.1.2.4 Non-human biota

The non-human biota VECs are represented by indicator species relevant to the environment, and are representative of current conditions (northern forest of deciduous forest zone) and potential future conditions (inland tundra) at the DGR Project site.

4.1.2.5 Radiological Criteria

Dose Constraint for Humans

In this report, comparison with the following criteria is used to assess the effects of the project on humans during malfunctions and accidents for the abandonment and long term performance phase. These are defined in the postclosure safety assessment as Disruptive Scenarios [2].

- A dose criteria of 1.0 mSv/a is used for radiological exposure of humans under credible disruptive scenarios.
- If calculated doses exceed 1.0 mSv/a, the acceptability of results from that scenario is examined on a case-by-case basis, taking into account the likelihood and nature of the exposure, uncertainty in the assessment, and conservatism in the dose criterion. The risk is then calculated and compared with a reference risk value of 10^{-5}/a, which represents a serious health risk, such as fatal cancer.

Radiological Criteria for Non-human Biota

The screening-level acceptance criteria, expressed as No-Effect Concentrations (NECs), are used as radiological criteria for non-human biota for this phase. The criteria, listed in Table 4.1.2-1, have been accepted by the CNSC for postclosure safety assessment purposes.

Table 4.1.2-1: No-Effects Concentrations for Non-human Biota

Radionuclide	Media			
	Water (Bq/L)	**Soil (Bq/kg)**	**Sediment (Bq/kg)**	**Groundwater (Bq/L)**
Carbon-14	0.24	350	280,000	1,600,000
Chlorine-36	3.1	5	41,000	300,000
Zirconium-93	1.8	280,000	5,000,000	5,900,000
Niobium-94	0.016	130	26,000	36,000
Technetium-99	0.8	60	3,000,000	810,000
Iodine-129	3.2	19,000	1,200,000	900,000
Radium-226	0.00059	280	930	590
Neptunium-237	0.058	50	1,100	580
Uranium-238	0.023	49	66,000	560
Lead-210	5.0	3,700	6,300	180,000
Polonium-210	0.007	30	110,000	540

4.1.2.6 Non-radiological Exposure Criteria

The non-radiological exposure criteria, which have been reviewed and accepted by the CNSC, are consistent with the recommendations of the CNSC Regulatory Guide G-320 [5]. The benchmark concentrations are taken from federal and provincial environmental objectives and guidelines, in particular the Environmental Quality Guidelines published by the Canadian Council of Ministers of the Environment (CCME). These criteria, presented in Table 4.1.2-2, apply to humans and terrestrial and aquatic biota. These are based on the most conservative guideline concentration for surface water, groundwater, soil and sediment from CCME and Ministry of the Environment (MOE) guidelines [7;8;9]. For some elements of potential interest, no criteria are available from CCME or MOE. In these cases, the exposure is evaluated based on surface water criteria from other sources [10].

Table 4.1.2-2: Environmental Quality Standards for Non-radioactive Contaminants

Species	Groundwater (µg/L)	Soil (µg/g)	Surface Water (µg/L)	Sediment (µg/g)
Silver	0.3	0.5	0.1	0.5
Arsenic	13	11	5	6
Boron	1,700	36	200	—
Barium	610	210	—	—
Beryllium	0.5	2.5	11	—
Bromine	—	—	1,700	—
Cadmium	0.5	1	0.017	0.6
Chlorobenzene	0.01	0.01	0.0065	0.02
Chlorophenol	0.2	0.1	0.2	—
Cobalt	3.8	19	0.9	50
Chromium	11	67	1	26
Copper	5	62	1	16
Dioxins/Furans	1.5×10^{-5}	7×10^{-6}	0.3	—
Gadolinium	—	—	7.1	—
Hafnium	—	—	4	—
Mercury	0.1	0.16	0.004	0.2
Iodine	—	—	100	—
Lithium	—	—	2,500	—
Manganese	—	—	200	—
Molybdenum	23	2	40	—
Niobium	—	—	600	—
Nickel	14	37	25	16
PAH	0.1	0.05	0.0008	0.22
Lead	1.9	45	1	31
PCB	0.2	0.3	0.001	0.07
Antimony	1.5	1	20	—
Scandium	—	—	1.8	—
Selenium	5	1.2	1	—
Tin	—	—	73	—
Strontium	—	—	1,500	—
Tellurium	—	—	20	—

Table 4.1.2-2: Environmental Quality Standards for Non-radioactive Contaminants (continued)

Species	Groundwater (µg/L)	Soil (µg/g)	Surface Water (µg/L)	Sediment (µg/g)
Thallium	0.5	1.0	0.3	—
Uranium	8.9	1.9	5	—
Vanadium	3.9	86	6	—
Tungsten	—	—	30	—
Zinc	160	290	20	120
Zirconium	—	—	4	—

Note:
— No values available
Source: [2]

4.2 IDENTIFICATION AND SCREENING OF RADIOLOGICAL MALFUNCTIONS AND ACCIDENTS

In this section, radiological malfunctions and accidents are identified and screened for all project phases. On this basis, bounding scenarios are selected, which are subject to consequence assessment to determine the significance of adverse effects.

4.2.1 Site Preparation and Construction Phase

The site preparation and construction phase includes initial preparation of the site for future construction activities, construction of surface facilities and excavation and construction of underground facilities. All these activities will take place in the DGR Project site (see Figure 3.1.1-1) and there is no L&ILW involved during this phase. Therefore, the occurrence of radiological accidents during this phase has been screened out.

4.2.2 Operations Phase

The operations phase includes the receipt of waste from the WWMF, and emplacement of the transferred waste into the DGR Project. As L&ILW will be handled during the operations phase, radiological malfunctions and accidents may occur. They could be initiated by any of a variety of events as discussed in Section 3. The identification of the radiological accident scenarios considered for the operations phase is detailed in Chapter 7 of the Preliminary Safety Report [4].

Chapter 7 of the Preliminary Safety Report [4] documents the process followed to identify credible accident scenarios, taking into account the potential accident scenarios involving an initiating event, and potential consequences. Combinations of events were also considered, but most combinations were found to be not credible, unless they have a common cause. The resulting credible accident scenarios can be categorized into the following accident types:

- Fire: External fires may cause the contents of some waste packages to ignite and burn, mainly LLW and unshielded ILW packages. Shielded ILW packages are unlikely to ignite, but the heat from an external fire can cause release of steam and volatile species (e.g., carbon-14; tritium).
- Container Breach (Low Energy): Low-height or low-speed impacts resulting in some loss of containment. Waste packages are not crushed. This category includes low-speed transfer vehicle accidents, and drops from heights less than four metres.
- Container Breach (High Energy): Drops or impacts that result in significant package failure. This category includes drops from heights greater than four metres, cage fall, and roof collapse.
- Inadequate Shielding: Inadvertent exposure of workers to high dose rate conditions.
- Ventilation System Failure: Loss of ventilation underground due to loss of power.

The wastes are grouped into categories in terms of characteristics, and representative waste types are selected from each category for this assessment as follows in order to quantitatively assess the potential consequences of the identified accident scenarios:

- Ash LLW (spillable, not combustible, contains chemical hazard elements) – bottom ash (old) was selected as these have the highest radiological inventory of ash waste packages;
- Combustible LLW (combustible) – box compacted waste was selected since these have higher package radiological inventory;
- Non-Processible/Other LLW (not readily spillable or combustible, largest volume of waste) – non-processible boxed was selected as these are the largest volume of waste, and non-processible drummed as these have the highest LLW package radiological inventory;
- Resin/filter ILW (spillable, potentially combustible) – moderator resins were selected as these have the highest radiological inventory (especially carbon-14 and tritium); and
- Retube ILW (not spillable, not combustible, activated metal) – end fittings were selected as these have the highest radiological inventory.

Although retube waste packages are robust and designed not to fail under accident conditions, including drop from stacking height, they are considered in high energy breaches due to cage falls underground [4].

Based on the qualitative estimation of the magnitude of the consequences of credible radiological accidents, those accidental scenarios with the highest potential inventory at risk are identified as the bounding accidents [4]. The bounding accident scenarios developed for above-ground and underground accidents can be found in Chapter 7 of the Preliminary Safety Report [4].

4.2.3 Decommissioning Phase

Decommissioning of the DGR Project includes all activities required to close and seal the repository and remove the above-ground infrastructure. This includes dismantling the equipment, sealing the repository shafts and decontaminating and demolishing the surface facilities. Credible radiological malfunctions and accidents could occur during the decommissioning of the DGR Project. However, the L&ILW wastes of concern have been emplaced in the underground facilities and are isolated from the environment. It is considered that radiological malfunctions and accidents during decommissioning are bounded by those identified for the operations phase. Therefore, no further assessment of the radiological malfunctions and accidents for DGR Project decommissioning is warranted. Mitigation strategies and emergency procedures for operations will remain in place during decommissioning in case of the occurrence of potential accidents.

4.2.4 Abandonment and Long-term Performance Phase

Malfunctions and accidents could occur during the abandonment and long-term performance phase that could result in radiological and non-radiological consequences. Through a systematic study of a range of future scenarios, the postclosure safety assessment [2] identifies four disruptive scenarios[3] that consider events that could lead to possible penetration of barriers and abnormal degradation and loss of containment. These disruptive scenarios, as described in Table 4.2.4-1, are unlikely or "what if" cases that test the robustness of the DGR Project.

Table 4.2.4-1: Disruptive Scenarios during the Abandonment and Long-term Performance Phase (Postclosure)

Disruptive Scenarios	Brief Description
Human Intrusion	Inadvertent intrusion through the geosphere into the DGR Project by an exploration borehole at some time after control of the site is no longer effective. In this "what if" case, contaminants are assumed to be released and humans could be exposed via three pathways: • direct release to the surface of gas and slurry prior to sealing of the borehole; • retrieval and examination of core contaminated with waste; and • the long-term release of contaminated water from the repository into permeable geosphere horizons via the exploration borehole. These releases could result in the exposure of the drill crew or people who might occupy the DGR Project site subsequent to the intrusion event.
Severe Shaft Seal Failure	The shafts represent a potentially important pathway for contaminant release, and therefore the project design includes specific measures to provide a good shaft seal, taking into account the characteristics of the DGR Project system. This "what if" scenario represents very poor performance of the shaft seals and repository/shaft excavation damaged zone (EDZs).

[3] Note that other than Disruptive Scenarios, there is also the Normal Evolution Scenario (evaluated in Section 9 of the EIS). For information, a brief description of the Normal Evolution Scenario is provided, as follows:
The Normal Evolution Scenario is the expected long-term evolution of the repository and site following closure. Over the 1 Ma assessment timescale, the scenario includes waste and packaging degradation, gas generation and buildup, rockfall, earthquakes and, after about 60 ka, glacial cycles. Most of the radioactivity will be contained within or near the repository by the low permeability host rock, where they decay [4].

Table 4.2.4-1: Disruptive Scenarios during the Abandonment and Long-term Performance Phase (Postclosure) (continued)

Disruptive Scenarios	Brief Description
Poorly Sealed Borehole	Several site investigation/monitoring boreholes have been sunk in the vicinity of the DGR Project down to and beyond the depth of the DGR Project during site characterization. This scenario considers the consequences of one of the boreholes not being properly sealed. The poorly sealed borehole provides an enhanced permeability connection between the level of the repository, the overlying groundwater zones and the biosphere, thereby bypassing some of the natural geological barriers to contaminant migration from the DGR Project.
Vertical Fault	There is strong geological, hydrogeological, and geochemical evidence that transmissive vertical faults/fracture zones do not exist within the footprint or near vicinity of the DGR Project. Despite this evidence, the Vertical Fault Scenario considers 'what if' there is a transmissive vertical fault, either undetected or representing the displacement of an existing structural discontinuity, in close proximity to the repository. The fault extends from the Precambrian basement to the permeable Guelph formation, thereby bypassing part of the natural barrier to contaminants from the DGR.

Source: [2]

All disruptive scenarios identified in Section 4.2.4 are advanced for detailed assessment in Section 4.3.

4.3 ASSESSMENT OF BOUNDING ACCIDENT SCENARIOS

4.3.1 Operations Phase – Bounding Scenarios

The effects of malfunctions and accidents on humans (workers and members of the public) and non-human biota were calculated for the scenarios discussed in Chapter 7 of the Preliminary Safety Report [4]. Detailed calculation methods for doses to humans, including assumptions and models are presented in Chapter 7 of the Preliminary Safety Report [4] (effects on workers and members of the public) and the Radiation and Radioactivity TSD (effect on non-human biota). The results are summarized below.

4.3.1.1 Members of the Public

The predicted radiological dose, over a 1-hour exposure period, to a member of the public at the nearest Bruce nuclear site boundary for any accident scenario is much less than the 1 mSv limit. Although unlikely that a member of the public would be exposed at the Bruce nuclear site boundary for more than one hour, longer exposures would not exceed the criteria. In addition, non-radiological species released during credible accident scenarios are less than the PAC 1 criteria for the public. Detailed results can be found in Chapter 7 of the Preliminary Safety Report [4].

4.3.1.2 Workers

The predicted radiological doses to workers over a 5-minute exposure time for any accident scenario are much less than the 50 mSv limit. In addition, in the case of a ventilation system failure, workers exposed to tritium and carbon-14 would be subjected to air concentrations much less than the Derived Air Concentrations (DACs)[4]. Concentrations of non-radiological species released during credible accident scenarios are less than the IDLH criteria for workers. Detailed results can be found in Chapter 7 of the Preliminary Safety Report [4].

4.3.1.3 Non-Human Biota

Detailed calculation results of dose to non-human biota for the bounding scenario are summarized in Table 4.3.1-1. As shown in Table 4.3.1-1, doses to non-human biota resulting from the bounding scenario will be below the applicable criteria.

The effects of non-radiological contaminants on non-human biota are also assessed. The estimated concentrations of non-radiological contaminants released from the worst scenarios identified in Chapter 7 of the Preliminary Safety Report [4] are summarized in Table 4.3.1-2. These values are contaminant concentrations in soil resulting from the deposition of chemical species from the contaminated plume. They are derived from the concentration of contaminants in the plume estimated in Chapter 7 of the Preliminary Safety Report [4] using the deposition velocity for the Bruce nuclear site presented in CSA N288.1-08 [11]. The concentrations of non-radiological contaminants in soil are considerably below the criteria. The contaminants in water bodies (streams and Lake Huron) due to atmospheric deposition will be quickly diluted such that the incremental concentration in water is negligible. Therefore non-human biota will not be affected.

It should also be noted that in the unlikely event of a radiological accident involving the DGR Project, unplanned releases will be controlled. The consequences of an accidental release are limited because only a small number of packages and a small quantity of L&ILW are handled at any time. Also, the design includes measures to control accidental release. Therefore, the concentrations of radionuclides in environmental media would be greatly reduced. Accidents would be cleaned up as soon as possible. Thus, the effect would be localized and for a short period of time. Accordingly, only individual flora and fauna in the immediate vicinity would be affected. The overall populations of non-human biota would remain unaffected, in particular those populations spanning Bruce County.

Table 4.3.1-1: Dose to Non-human Biota for Bounding Accident – Operations Phase

VEC	Indicator	Dose (Gy)	Dose Criteria (Gy)	Dose (% of Dose Criteria)
Benthic Invertebrates	Burrowing crayfish	1.9×10^{-3}	1.8	0.1
Aquatic Vegetation	Variable leaf pondweed	2.2×10^{-3}	0.9	0.3

4 The concentration of a given radionuclide in air, which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in Annual Limit on Intake.

Table 4.3.1-1: Dose to Terrestrial and Aquatic Biota for Bounding Accident – Operations Phase (continued)

VEC	Indicator	Dose (Gy)	Dose Criteria (Gy)	Dose (% of Dose Criteria)
Benthic Fish	Lake whitefish	2.2×10^{-3}	0.2	1.0
	Redbelly dace			
	Creek chub			
Pelagic Fish	Spottail shiner	2.2×10^{-3}	0.2	1.0
	Smallmouth bass			
	Brook trout			
Aquatic Birds	Double-crested cormorant	2.9×10^{-3}	0.4	0.8
	Mallard	4.3×10^{-3}	0.4	1.2
Aquatic Mammals	Muskrat	8.2×10^{-3}	0.4	2.2
Terrestrial Invertebrates	Earthworm	6.3×10^{-5}	0.6	0.01
Terrestrial Vegetation	Eastern white cedar	5.6×10^{-2}	0.6	9.6
	Common cattail			
	Heal-all			
Terrestrial Birds	Bald eagle	2.7×10^{-2}	0.4	7.5
	Yellow warbler	6.3×10^{-4}		0.2
	Wild turkey	9.2×10^{-2}		25.1
	Red-eyed vireo	8.1×10^{-4}		0.2
Terrestrial Mammals	White-tailed deer	1.7×10^{-1}	0.4	46.2
	Northern short-tailed shrew	4.6×10^{-6}	0.4	0.001
	Red fox	2.1×10^{-1}	0.4	57.2
Amphibians & Reptiles	Midland painted turtle	2.0×10^{-3}	1.8	0.1
	Northern leopard frog			

Note:
Dose calculations assume that the species are exposed to the bounding scenarios identified in the Preliminary Safety Report [4] for a period of 24 hours.

Table 4.3.1-2: Estimated Non-radiological Contaminants in Soil – Operations Phase

Non-radiological contaminants [a]	Concentration in air (μg/m^3) [b]	Deposition velocity (m/s) [c]	Concentration in soil (μg/g) [d]	Criteria-soil (μg/g)
Chromium	12.5	1.56×10^{-2}	1.68×10^{-2}	67
Nickel	12.0	1.56×10^{-2}	1.62×10^{-2}	37

Notes:
a The contaminants with the highest ratio of air concentration to criterion are listed
b The concentration in air is derived based on the Preliminary Safety Report [4]
c The deposition velocity is taken from CSA N288.1-08 [11]
d Based on an assumption of 24-hour deposition

In summary, the assessment of potential exposure to humans (workers and members of the public) and non-human biota resulting from the malfunctions and accidents related to the operations phase of the DGR Project concludes:

- major DGR Project accidents are unlikely to occur;
- credible DGR Project accidents do not exceed radiological dose criteria for workers or members of the public;
- credible DGR Project accidents do not exceed the relevant non-radiological species criteria for workers or members of the public;
- credible DGR Project accidents do not exceed radiological dose criteria for non-human biota;
- credible DGR Project accidents do not exceed the relevant non-radiological species criteria for non-human biota; and
- in most cases, the safety criteria are met by large margins.

4.3.2 Abandonment and Long-term Performance Phase – Disruptive Scenarios

The evaluation of postulated radioactive accidents during the abandonment and long-term performance phase is assessed fully in the postclosure safety assessment [2]. The following sections provide a summary of the assessment.

4.3.2.1 Humans

The likelihood of the disruptive events that could initiate the Disruptive Scenarios identified in Table 4.2.4-1 is expected to be very low. In actuality, the likelihood of the scenarios that could occur is even lower since the Disruptive Scenarios assessed herein make additional conservative assumptions [4]. The key results for different scenarios are as described:

- For the Human Intrusion Scenario, if a borehole is drilled into the repository and gases and material from the repository are not appropriately contained, the calculated doses could be about 1 mSv for the drill crew or a future person living and farming on the contaminated site. The likelihood of drilling into the repository in any given year is very low due to the lack of mineral resources and the repository's small footprint and depth, and high contaminant releases are unlikely when following standard deep drilling practices. Thus the peak risk of serious health effects is low, and much less than the reference health risk value of 10^{-5}/a.

- For the Severe Shaft Seal Failure Scenario, the maximum calculated doses are about 1 mSv/a, based on immediate failure of 500 m of low-permeability shaft seals, reduced sorption in the shafts, increased degradation of shaft EDZs, and assuming a family is farming directly on top of the shafts (including a house located on the main shaft). The scenario is very unlikely. Therefore, the risk from the severe shaft seal failure scenario is low.
- Calculated peak annual doses for the Poorly Sealed Borehole Scenario and the Vertical Fault Scenario are several orders of magnitude less than the dose criterion.
- Additional cases were evaluated to determine what it would take to have a disruptive scenario with larger impacts. For the Human Intrusion Scenario, the borehole would have to be extended down to the Cambrian and then poorly sealed, so that there was water flowing up the borehole, through the repository and to the surface. For the Severe Shaft Seal Failure Scenario, the entire shaft would need to degrade by 4 to 5 orders of magnitude below design basis to a hydraulic conductivity of 10^{-7} m/s, about equivalent to fine silt and sand. In these cases, the peak doses to someone living on top of the repository site could be tens of milliSieverts.
- The primary risk in the disruptive scenarios is from release of carbon-14 containing gas from the repository. The potential impacts therefore decrease to well below the dose criterion after about 60,000 years due to carbon-14 decay. Since glaciation at the DGR site is not likely to occur prior to then, there is little risk from glaciation affecting these maximum peak doses from disruptive scenarios.
- Finally, it is noted that the effects of the disruptive scenarios are local. Even if the entire carbon-14 inventory were released as gas within a one year period, then doses to people living around the Bruce nuclear site would be around or below the public dose criterion.

4.3.2.2 Non-human Biota

For postclosure Disruptive Scenarios, the potential effects on non-human biota are low. Most contaminants (i.e., all non-radiological elements and most radionuclides) are likely to remain well below their respective screening criteria [2]. There could be local exceedance of screening criteria for some radioactive species relating to the Human Intrusion Scenario and the Severe Shaft Failure Scenario. In particular, carbon-14 and niobium-94 would locally exceed soil criteria by a factor of 20 if the drilling debris from the repository were to be dumped on the surface at the DGR Project site in the event the Human Intrusion Scenario were to occur. Carbon-14 would locally exceed the surface water screening criterion by a factor of 1.4 if the event of the Severe Shaft Failure Scenario occurs. Since these exceedances are local, the screening criteria are conservative, and the scenarios are very unlikely, the risk to non-human biota is determined to be low.

4.4 MITIGATION, CONTINGENCY PLANS AND EMERGENCY PREPAREDNESS

The effects on human and non-human biota from potential accidents at the DGR Project were found to be generally small. The effects can be minimized or controlled through implementation of the following mitigation measures:

- minimization of combustible materials and ignition sources, especially near waste packages;
- use of overpacking and shielding on higher activity packages;

- limited number of packages handled in any transfer;
- limited equipment speeds;
- fire detection and suppression equipment, such as automatic fire suppression systems on diesel transfer equipment;
- appropriate follow-up measures corresponding to the results of contamination and dose rate monitoring;
- access to refuge stations and safety equipment;
- appropriate worker training and operating procedures; and
- emergency communication systems.

These measures have already been considered within the design and can be further emphasized during detailed design and later during operation. Contingency plans will also be in place, and emergency response, including mine rescue, will be available to protect the workers.

4.4.1 Contingency Planning

For situations in which consequences of accident assessment are not negligible, mitigation will be achieved through one or more of the following:

- design mitigation;
- preventative measures to reduce further the likelihood of such accidents;
- controls installed on equipment to restrain their movement (e.g., limit switches);
- administrative controls (mainly through procedures); and
- worker training.

For accidents assessed to have larger consequences, contingency plans will be in place, and emergency response, including mine rescue, will be available to protect the workers.

4.4.2 Emergency Preparedness

The Bruce nuclear site is served by its own internal Emergency Response Team, medical and fire prevention facilities. In addition, a comprehensive on- and off-site emergency response plan is in place. Response teams have been trained and are equipped to respond to potential emergencies such as personal injury, fire or non-routine releases of radioactivity. The municipal fire department, the Regional Medical Officer of Health and Kincardine's health and safety service providers work cooperatively with Bruce Power, which coordinates site-wide fire protection and emergency response to ensure that additional support and response capability is in place.

5. CONVENTIONAL (NON-RADIOLOGICAL) MALFUNCTIONS AND ACCIDENTS

In this section, conventional (i.e., non-radiological) malfunctions and accidents that could result from credible initiating events are identified and assessed for the site preparation and construction, operations, and decommissioning phases. As there will be no works and activities during the abandonment and long-term performance phase, there is no potential for non-radiological accidents. Specifically, conventional accidents refer to those accidents that could result in only non-radiological effects. The assessment of effects of non-radiological malfunctions and accidents has been completed using information provided in the various TSDs, the Preliminary Conventional Safety Assessment [12] and the Preliminary Safety Report [4].

5.1 METHODS FOR ASSESSMENT OF NON-RADIOLOGICAL ACCIDENTS

5.1.1 Identification of Credible Non-radiological Accidents

Credible accidents are identified based on literature review and analysis of past and current practices in the mining and nuclear industries. It is conservatively assumed in this report that all conventional accidents that could occur as a result of credible initiating events are credible.

5.1.2 Screening of Credible Non-radiological Accidents

Consequences of effects of non-radiological accidents are considered separately for members of the public, workers and the environment. Therefore, the credible non-radiological accidents were screened taking into account the different receptor groups.

5.1.2.1 Environment (including Non-human Biota)

For potential effects on the environment (i.e., atmospheric, hydrology and surface water quality, geology, aquatic, terrestrial, socio-economic, Aboriginal interests), the credible non-radiological accidents are screened as to whether they could have an adverse consequence on the environment (including non-human biota on- and off-site), whether the scenario has been considered elsewhere in the assessment, and whether the potential effects are likely bounded by another scenario. The bounding scenario(s) are then advanced for assessment.

5.1.2.2 Members of the Public

Credible non-radiological accidents with potential for effects on members of the public (off-site) are assumed to be those that may have an effect on the environment outside of the Bruce nuclear site. Similar to the screening for effects on the environment (Section 5.1.2.1), bounding scenario(s) are identified.

5.1.2.3 Workers

For potential consequences to workers, occupational accidents identified in the Preliminary Conventional Safety Assessment [12] are considered collectively (i.e., no bounding case is identified).

5.1.3 Assessment of Bounding Non-radiological Accidents

5.1.3.1 Environment (including Non-human Biota)

The bounding non-radiological accidents are then assessed in the context of each of the environmental components (i.e., atmospheric, hydrology and surface water quality, geology, aquatic, terrestrial, socio-economic, Aboriginal interests) to determine their likelihood to result in adverse effects on the various components. The likelihood of an adverse effect occurring was determined by taking into account the description of the bounding scenario, the understanding of each particular environmental component (as defined in the other TSDs), and the control and mitigation measures available.

5.1.3.2 Members of the Public

Effects on members of the public are assessed to determine the likelihood of adverse effects of non-radiological accidents. The likelihood of adverse effects occurring is determined similarly to those methods described above for the other environmental components.

5.1.3.3 Workers

For workers, each of the accidents is assessed, taking into account the potential consequences and control and mitigation measures specified.

5.1.4 VEC Characteristics

5.1.4.1 Environment (including Non-human Biota)

The assessment of non-radiological accidents focuses on the VECs chosen for each of the other environmental components that have the potential to be affected by an accident. The VECs considered are:

- atmospheric environment – air quality and noise levels;
- hydrology and surface water quality – surface water quality;
- aquatic environment – redbelly dace, creek chub, brook trout, variable leaf pondweed, burrowing crayfish, lake whitefish, spottail shiner, smallmouth bass and benthic invertebrates;
- terrestrial environment – eastern white cedar, heal-all, common cattail, northern short-tailed shrew, muskrat, white-tailed deer, red-eyed vireo, wild turkey, yellow warbler, mallard, bald eagle, midland painted turtle and northern leopard frog;
- geology – groundwater quality (particularly in the overburden) and soil quality;
- socio-economic environment – community infrastructure and services and tourism; and
- Aboriginal interests – Aboriginal communities, Aboriginal heritage resources, and traditional use of land and resources.

These VECs are described fully in their respective TSDs. Some VECs identified for the EA of the DGR Project are not included in this list as there are no potential interactions with the accidents (e.g., population and economic base).

5.1.4.2 Members of the Public

The assessment considers the overall effect on the health of a member of the public living at the closest residences outside the Bruce nuclear site. The effects on more distant residents would be less than the closest receptors.

5.1.4.3 Effects on Workers

The assessment of conventional accidents on workers focuses on the health of workers.

5.2 IDENTIFICATION OF CONVENTIONAL MALFUNCTIONS AND ACCIDENTS

Conventional malfunctions and accidents for the DGR Project could be initiated by one of a variety of initiating events as discussed in Section 3. Based on the analysis of past and current practice in the mining and nuclear industries (for the nuclear industry, focusing on the construction and operation of nuclear waste management facilities), along with the review of the DGR Project Preliminary Conventional Safety Assessment [12], credible conventional malfunctions and accidents[5] that could occur during each DGR Project phase were identified, considering all project works and activities described in the Basis for the EA (Appendix B). These credible non-radiological malfunctions and accidents, including the description of malfunction and accident scenarios, are summarized in Table 5.2-1. Accidents that involve releases to the environment are considered in Section 5.3.1. Any accidents that involve members of the public are considered in Section 5.3.2 and any accidents that primarily involve workers (i.e., occupational accidents) are considered in Section 5.3.3.

Table 5.2-1: Credible Non-radiological Accidents Related to the DGR Project

Malfunctions and Accidents	Description of the Malfunctions and Accidents
Fire	The following fire accidents could occur during the site preparation and construction phase: • combustion of waste (grass and trees) generated during site clearing; • combustion of construction materials; • fire at a temporary facility or involving equipment; • fire during a vehicle accident; and • fire during welding and cutting. During the operations phase the following fire accidents could occur: • fire at a temporary facility or involving equipment; • fire during a vehicle accident arising within the DGR Project; and • electrical fault. During decommissioning, asphalt and other materials such as concrete, sand, and bentonite will be used for shaft sealing. Fire could occur as large volumes of asphalt are slip-lined to form part of the shaft seal.

5 It was conservatively assumed in this report that all conventional accidents that could occur as a result of credible initiating events, identified in Section 3, are credible.

Table 5.2-1: Credible Non-radiological Accidents Related to the DGR Project (continued)

Malfunctions and Accidents	Description of the Malfunctions and Accidents
Vehicle accident	Vehicle accidents could occur during the site preparation and construction, and decommissioning phases including: • collision with other vehicles, equipment, temporary buildings, or wildlife; and • turnover of transportation vehicles such as haulage trucks or front-end loaders. During operations, vehicle collisions also include: • turnover of above-ground transfer vehicle loaded with waste packages; and • collision with other vehicle when transferring waste.
Electrical accidents	Electrical accidents, such as an electrical short circuit or electrical shock, could occur in any phase and could result from: • misuse or poor maintenance of electrical equipment; • damage to electrical equipment (power distribution line, for example) as a result of other DGR Project activities; • staff access to live electrical equipment without authorization; and • severe weather conditions, such as lightning.
Structural instability	During the site preparation and construction phase, structural instability-related accidents include: • toppling of soil and waste rock piles; • collapse or rolling of stacked pipes; • caving/trench wall collapse; • collapse of scaffold, elevated plate form and ladder; • heavy equipment crashes; • fall involving roof, face, rib, side or highwall of underground facilities, including tunnel and emplacement rooms; • structural damage to or cave in of one or both shafts; and • collapse of buildings under construction. During the operations phase, waste packages stacked in open waste emplacement rooms could topple/collapse for the following reasons: • waste packages are stacked in unstable positions (heavy packages on top of light packages) or misaligned; • waste packages drop when unloaded from transfer vehicle, which roll/slide and strike the stack; and • earthquakes. During the decommissioning phase, structural instability-related accidents include: • collapse of surface buildings during dismantling as a result of improper dismantling procedure; and • collapse of surface buildings during dismantling as a result of natural hazards including earthquake and extreme weather conditions such as high wind.

Table 5.2-1: Credible Non-radiological Accidents Related to the DGR Project (continued)

Malfunctions and Accidents	Description of the Malfunctions and Accidents
Material handling accidents/ equipment failure	Material handling accidents/equipment failure that could occur during the site preparation and construction, and operations phases include: • material dropping from scaffold, elevated platform, or crane or other lifting equipment; • loss of control of mobile equipment/equipment collision; • uncontrolled loading impacting equipment or personnel; • material falling into the main or ventilation shafts; • material falling from scaffold or elevated platform; • material rolling or sliding above-ground, in the shaft, or underground; and • utility damage (for example, water line, communication system) due to unexpected ground disturbance. During the decommissioning phase, material handling accidents/equipment failure include the following scenarios: • materials dropping from crane or other lifting equipment during dismantling; • sealing items rolling or sliding above-ground or falling into the shafts as a result of human errors or mechanical failures; and • utility damage (for example, water line, communication system) due to unexpected ground disturbance.
Spill of fuel, chemicals, lubricants and oils	Spill of chemicals, lubricant and oils could take place during the site preparation and construction, operations and decommissioning phases. For the purpose of the assessment, the volume of a spill is assumed to be approximately 4,500 L diesel fuel, 200 L of a chemical or 100 L of a lubricant or oil. The scenarios include: • During a vehicle accident, tanker truck or gas tank of the vehicle is damaged and liquids (gasoline, diesel or liquid chemicals) in the tank spill. • The integrity of the on-site liquid storage equipment (tanks) is damaged as a result of extreme weather conditions or mechanical failure causing chemicals, lubricants and oil contained in the equipment to spill into the environment. • Leak of diesel fuel from a tanker truck could occur at the DGR as a result of operational errors while refuelling equipment or vehicles. Spills could occur as a result of operational errors. A typical accident is the leak of diesel fuel from a tanker truck or a storage tank while refuelling equipment or vehicles.

Table 5.2-1: Credible Non-radiological Accidents Related to the DGR Project (continued)

Malfunctions and Accidents	Description of the Malfunctions and Accidents
Occupational accidents	Occupational accidents could occur in any phase and include: • falls of workers from scaffold, ladder or elevated work location; • slips, trips or falls on uneven or slippery (wet or icy) surface; • injury during welding and cutting; • injury during material handling; • drowning; • frostbite; • heat exhaustion/stroke; • accidents related to moving/rotating machinery or other equipment/tools; • machinery-related accidents during the operation of drill, dozer or other equipment or accidents related to the use of hand tools; • injury due to falling objects, including from collapse of buildings; and • falls from buildings under construction, or falls into the main or ventilation shafts.
Explosion/ detonation	Explosions could occur during the site preparation and construction phase from: • inadvertent detonation of explosive used during construction; • explosion of gas or dust generated during underground excavation; and • explosion of a vessel under pressure (pressurized cylinder/tank).
Exposure to substances hazardous to health	Workers could be exposed to substances hazardous to health including toxic or controlled substances. Exposures considered are those that were beyond those exposures that occur under normal, controlled conditions associated with being a worker.
Entrapment	During construction, typical entrapment scenarios include workers entrapped in underground facilities, for example, due to rock fall, or workers may be entrapped in the main or ventilation shafts. The cause of entrapment in a shaft could be power failure, structural failure of the shaft, or winder failure of the shaft conveyer. During operations, personnel entrapment could occur when workers use the personnel hoist. Personnel could also be trapped in emplacement rooms, airlocks, equipment rooms or battery rooms.
Loss of ventilation	Ventilation system required during underground construction and operations could be partially or totally lost. The cause of such a failure could be loss of electrical power or mechanical fan failure.
Asphyxiation	The risk of asphyxiation could arise especially in confined spaces. Asphyxiation scenarios due to a severe reduction in air quality could occur as follows: • Inrush of toxic gas from outside sources (chemicals, fire from surrounding facilities), or internal sources (gas inrush from underground during excavation). • Smoke or fumes from underground fire accident, which overload the ventilation system by clogging filters. • Construction dust migration.

Table 5.2-1: Credible Non-radiological Accidents Related to the DGR Project (continued)

Malfunctions and Accidents	Description of the Malfunctions and Accidents
Shaft damage	The shaft could be damaged if the hoist is out of control as a result of mechanical failure or operator errors.

5.3 SCREENING OF CONVENTIONAL MALFUNCTIONS AND ACCIDENTS

5.3.1 Environment (including Non-human Biota)

Each credible malfunction and accident identified in Table 5.2.1-1 was reviewed to determine if it has the potential to interact with the environment. Those accidents associated primarily with worker hazards (i.e., occupational safety) are considered in Section 5.3.3. Table 5.3.1-1 summarizes accidents that could potentially result in an adverse environmental consequence, and warrant further analysis.

Table 5.3.1-1: Screening of Conventional Accidents on the Environment

Malfunctions and Accidents	Phase	Screening
Fire	• Site preparation and construction phase • Operations phase • Decommissioning phase	An above-ground fire was considered in Section 4. This evaluation considered non-radiological effects in addition to radiological effects. No adverse effects were identified, and effects would be limited to the Bruce nuclear site. Given the range of compounds associated with the fire considered in Section 4, this would likely bound the effects of a fire of brush or construction materials. No further consideration is required in this section.
Explosion/ detonation	• Site preparation and construction phase	An on-site explosion may occur during the site preparation and construction phase. Effects would likely be restricted to the Bruce nuclear site. However, this scenario is advanced for further consideration.

Table 5.3.1-1: Screening of Conventional Accidents on the Environment (continued)

Malfunctions and Accidents	Phase	Screening
Electrical accidents	• Site preparation and construction phase • Operations phase • Decommissioning phase	An electrical accident could occur within the DGR Project site and may lead to a fire. A fire is considered separately in this table. Potential effects of an electrical accident on workers (e.g., electrical shock) are considered in Section 5.3.3. Therefore, no further consideration is required in this section regarding potential effects on the environment.
Spill of fuel, chemicals, lubricants or oils	• Site preparation and construction phase • Operations phase • Decommissioning phase	A spill of chemicals, lubricants of oils could occur on the DGR Project site. This accident is advanced for further consideration.
Vehicle accident	• Site preparation and construction phase • Operations phase • Decommissioning phase	An on-site vehicle accident could result in a fire, spill or explosion. These possible outcomes of a vehicle accident are considered separately in this table. Potential effects of a vehicle accident on workers are considered in Section 5.3.3. Therefore, no further consideration of a vehicle accident is required.

5.3.2 Members of the Public

Similar to the screening of effects on the environment described above, each credible malfunction and accident identified in Table 5.2-1 was also screened to determine if it could reasonably be expected to result in an adverse consequence to members of the public that would warrant further analysis. Only accidents with potential off-site consequences could affect members of the public, and only a fire or a spill could potentially have off-site effects. As described in Table 5.3.1-1, a fire was considered in Section 4 and found to have no adverse effects on- or off-site. Therefore, the scenario advanced for assessment is a spill of fuel, chemicals, lubricants or oils during the site preparation and construction, operations, and decommissioning phases.

5.3.3 Workers

Occupational hazards to workers resulting from malfunctions and accidents are described in the Preliminary Conventional Safety Assessment [12]. The assessment was conducted systematically using a screening process hazard analysis method combined with a job hazard analysis approach [12]. Although the hazard assessment considered both occupational safety and accidents, only the latter are discussed in this TSD. Occupational safety is discussed in Appendix C of the EIS. The non-radiological hazards to workers are listed in Table 5.3.3-1, which provides a summary of the potential consequences and plausible outcomes for each hazard. The hazards and corresponding potential consequences during the decommissioning phase are considered to be similar to those identified for the site preparation and construction phase.

In addition to the mitigation and control measures listed in the table, a key in-design mitigation for the DGR Project is an emergency power supply system, to maintain critical systems in the event of a grid power failure. These generators would power-up critical components within 30 seconds of an unscheduled power outage. The loads that would be served by the emergency power system include shaft hoists, an air compressor and emergency lighting and communications. More information on the emergency power supply is provided in Section 4 of the EIS.

Table 5.3.3-1: Summary of Screening of Hazards to Workers

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Build-up of explosive gasses underground	• Operations	• Explosive atmosphere • Fire • Oxygen deficiency	• Personal injury	• Slow rates of gas generation expected • Contaminated dose monitoring • Good ventilation air flow rate, directed from clean side towards dirty side • End walls
Confined space entry	• Operations	• Hazardous atmosphere	• Occupational disease • Personal injury or death	• Confined space entry program
Cranes and shaft hoisting	• Site preparation and construction • Operations	• Dropped load • Crane failure • Structural collapse • Uncontrolled load impacting equipment or personnel • Shaft damage • Hoist failure	• Personal injury or death • Reportable dangerous occurrence • Potential loss of critical safety function	• Critical lift procedure • Lift planning • Qualified workers • Work permits • Worker awareness • Operator training • Hoisting log books/records • Equipment planned/preventative maintenance • Equipment design installation and operation to meet established crane and hoisting safety permits • Safe work code of practice

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Electrical	• Site preparation and construction • Operations	• Electric shock • Fire • Electrocution	• Reportable dangerous occurrence • Personal injury or death • Potential loss of critical safety function	• Live electrical line work procedures • Lock-out/tag-out procedure • Qualified workers • Work permits • Emergency response capability
Fire	• Site preparation and construction • Operations	• Brush fire • Construction material fire • Temporary facility or equipment fire • Hazardous atmosphere • Worker burns	• Personal Injury or death	• Emergency response capability • Minimization of combustible materials and ignition sources • Access to refuge stations, multiple exits and safety equipment • Emergency communication systems • Fire detection and suppression equipment • Fuel dispensing procedure • Housekeeping • Hot work permit • Safe work code of practice • Inspection and maintenance program • Emergency equipment in mobile equipment

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Ground Disturbance	• Site preparation and construction	• Contacting electrical conductor • Damaged communications cables • Damaged water line	• Personal injury or death • Potential loss of critical safety function	• Work permits • Ground disturbance permits • Worker awareness • Exposing utility lines by hand or other suitable means • Pre-excavation ground survey
Hand Tools	• Site preparation and construction • Operations	• Cuts, bruises and scrapes	• Personal injury • Reportable dangerous occurrence	• Safe work code of practice • Personal Protective Equipment (PPE) • Maintenance and inspection program
Hazardous Materials Handling	• Site preparation and construction • Operations	• Worker exposure to toxic, designated or controlled substance	• Occupational disease • Personal injury or death	• PPE • Worker awareness • WHMIS

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Hoisting using a shaft sinking bucket	• Site preparation and construction	• Hoisting equipment failure • Crush or amputation injury • Cuts, bruises and scrapes • Uncontrolled load impacting equipment or personnel	• Personal injury or death	• Planned/preventative equipment maintenance • Equipment design, installation and operation to meet shaft/hoist safety standards • Hoisting log books/records • Inspection protocol • PPE • Worker awareness • Operator training • Use only qualified workers • Shaft sinking safe work practices • Worker orientation
Loose ground/rock burst	• Site preparation and construction • Operations	• Rock falling from roof or walls (rock burst, fall of ground)	• Personal injury or death	• Worker awareness • Ground control standards • Loose rock scaling work instruction • Inspection protocol • Engineered ground support

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Moving/rotating machinery	• Site preparation and construction • Operations	• Crush or amputation injury	• Personal injury or death	• Machine guarding • Worker orientation and awareness • PPE • Safe work practices • Spotters for mobile equipment • Barricading off of work areas • Controlled access • Maintenance and inspection program
Mucking shaft bottom during sinking	• Site preparation and construction	• Falling from scaffold, ladder or elevated platform	• Personal injury or death	• Fall protection program • PPE • Operator training • Shaft sinking procedures
Power line relocation	• Site preparation and construction	• Electric shock • Falling from scaffold, ladder or elevated work location	• Personal injury or death	• Lock-out procedure • Live electrical line work procedures • Work permits • Use only qualified workers
Pressurized cylinder/tank leak	• Site preparation and construction	• Fire, explosion • Oxygen deficiency	• Personal injury or death	• Safe work code of practice • Worker awareness • Inspection protocol • Emergency response capability • Flash back arrestors

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Pressurized container	• Site preparation and construction	• Serious fire, explosion	• Personal injury or death	• Fire suppression system at container recharging locations • Worker awareness • Emergency response capability • Procedures • WHMIS
Scaffold, elevated platform and ladder	• Site preparation and construction • Operations	• Structural collapse • Falling from scaffold, ladder or elevated platform • Falling material from scaffold or elevated platform	• Personal injury or death • Reportable incident/dangerous occurrence	• Scaffolding, elevated work platform and ladder procedures • Fall protection program • Shaft sinking safe work practices • Safe work code of practice • PPE • Hoisting log boods/records inspection protocol • Worker awareness • Use only qualified workers • Work permits

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Shaft flooding from unexpected groundwater source	• Site preparation and construction	• Drowning • Flooded shaft	• Personal injury or death	• Probe-hole drilling and grout procedure • Worker awareness • Underground water management system • Hydrostatic shaft liner • Very tight rock – water ingress not expected • See Chapter 7 of the Preliminary Safety Report [4] for more information
Shaft inspection	• Site preparation and construction • Operations	• Hoisting equipment failure • Falling from height	• Personal injury or death	• Equipment planned/preventative maintenance • Hoisting log books/records • PPE • Worker awareness • Shaft inspection • Safe work practices • Worker orientation
Static electricity ignition source	• Site preparation and construction	• Fire	• Personal injury or death	• Fire suppression system • Static electricity grounding • Fuel dispensing procedure

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Traffic/excavation/ mobile/heavy equipment	• Site preparation and construction • Operations	• Traffic accident • Heavy equipment collision • Vehicle hitting personnel	• Personal injury or death • Reportable incident/dangerous occurrence	• Defensive driving practice • Worker awareness • Vehicular speed control standard • Operator training • Traffic plan • Use of spotters • Signage
Trenching	• Site preparation and construction	• Caving/trench wall collapse • Accumulation of hazardous aerosols	• Personal injury or death	• Trenching code of practice • Work Permits • Worker awareness • Excavation permits
Uneven walking surface/poor footing	• Site preparation and construction • Operations	• Slips trips and falls	• Personal injury	• Housekeeping • PPE • Worker awareness • Alternative routes • Barricades • Signage
Unstable stacking and storage of material	• Site preparation and construction	• Toppling of pile • Collapse or rolling of stacked pipes	• Personal injury or death	• Safe work code of practice • Worker awareness • Pipe handling work instruction • Housekeeping

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Underground ventilation failure	• Site preparation and construction • Operations	• Exposure to noxious fumes, dust and gasses	• Occupational disease • Personal injury	• Install visual and audible alarms on ventilation system • Inspect ventilation system prior to entering the underground workplace • Routine monitoring of ventilation flows • Refuge station • Evacuation procedure • Back-up power
Underground blasting	• Site preparation and construction	• Exposure to blasting dust and fumes • Unexpected detonation • Exposure to blast concussion and flying debris	• Occupational disease • Personal injury or death	• Central blasting control • Controlled re-entry • Adequate ventilation • Blasting procedures • Controlled blasting times • Use only qualified workers
Welding and cutting	• Site preparation and construction • Operations	• Burns • Fire • Worker exposure to welding flash • Worker exposure to toxic or designated substance	• Personal injury or death • Occupational disease	• Worker awareness • PPE • Hot work permit • Maintenance and inspection program

Table 5.3.3-1: Summary of Screening of Hazards to Workers (continued)

Hazardous Activity or Condition	DGR Project Phase [a]	Potential Consequences	Plausible Outcomes to Workers	Control/Mitigation Measures
Working on the shaft bottom	• Site preparation and construction	• Crush or amputation injury • Cuts, bruises and scrapes • Falling objects • Hazardous atmosphere • Slip trips and falls • Uncontrolled load impacting equipment or personnel	• Personal injury or death	• Worker awareness • PPE • Ground control standards • Safe work code of practice • Loose rock scaling work instruction • Controlled re-entry after blasting • Housekeeping • Operator training • Worker orientation
Working around water	• Operations	• Drowning	• Personal injury	• Procedures for working around water • Inspection and maintenance program • Anti-backflow devices in water lines

Note:

a The decommissioning phase was not explicitly considered in the Preliminary Conventional Safety Assessment [12]; however, hazards will likely be similar to those identified in the site preparation and construction phase.

Source: [12]

5.4 ASSESSMENT OF BOUNDING MALFUNCTIONS AND ACCIDENTS

The scenarios identified in Section 5.3 are assessed in the context of each of the environmental components, members of the public and workers. During this process, the following factors were taken into account:

- DGR Project design;
- safety procedures and plans (e.g., health and safety [13]);
- in-design mitigation (e.g., secondary containment for on-site storage); and
- past experience and records in the nuclear and mining industries.

5.4.1 Effects on the Environment

As described, two scenarios were advanced from Section 5.3.1: a spill that could occur during site preparation and construction, operations or decommissioning, and an explosion during site preparation and construction.

5.4.1.1 Spill of Fuels, Chemicals, Lubricants or Oils

As noted in Table 5.2-1, malfunctions and accidents scenarios involving a spill could include a vehicle accident, failure of on-site storage equipment (i.e., a storage tank) or operational errors. For the purpose of the assessment, the likely maximum volume of a spill is assumed to be approximately 4,500 L diesel fuel, 200 L of a chemical or 100 L of a lubricant or oil. The consequences of a spill would be the same, regardless of the project phase they occur in, therefore, the discussion below applies to each of the site preparation and construction, operations, and decommissioning phases.

Atmospheric Environment

In the event of a spill, equipment used to respond to the spill would result in tailpipe, dust and noise emissions that may interact with air quality and noise. However, emissions associated with the support and response equipment are similar to those identified for the existing operations at the WWMF, and are therefore not expected to result in measurable increases to air or noise emissions. Fuels represent the largest potential spill volume. Spilled fuel also has the potential to volatilize; however, the majority of fuel used is diesel, which is less likely to volatilize than gasoline. Therefore, the effects of such a spill are likely to be very localized and not measurable. Chemical spills would also be of a small volume (i.e., 200 L) and would represent a localized on-site issue even if they volatilize. Accordingly, no likely measurable changes to either air quality or noise are predicted to result from spills during the DGR Project and no further consideration is warranted.

Hydrology and Surface Water Quality

It is assumed these spills would occur in the boundaries of the DGR Project site and thus would be remote from any water bodies (e.g., Stream C, Lake Huron) with the exception of the site drainage and North and South Railway Ditches. A spill could potentially occur during the construction of the crossing from the WWMF to the DGR, which could potentially affect water quality in the North or South Railway Ditches. The likelihood of a fuel spill occurring in the immediate vicinity of the North and South Railway Ditches is very low as fuel storage areas are not located near these ditches. During operations, a spill could potentially occur during the on-site transfer of waste from the WWMF to the Waste Package Receiving Building, which could potentially affect water quality in the North and South Railway Ditch if the spill occurred while crossing the abandoned rail bed. A spill to one of the on-site ditches would be collected, and directed via the stormwater management system to the stormwater management pond where it can be held until it is determined to be suitable for discharge.

As described in the Hydrology and Surface Water Quality TSD, there was no observed flow in the North and South Railway Ditches during 2007 and 2009 field programs (i.e., it is typically stagnant and/or dry); therefore, a spill would likely be contained to the immediate environment and would not reach Lake Huron or Stream C.

To mitigate the effects of spills, appropriately equipped and trained on-site spills response teams will be available at all times as part of emergency response programs. For example, a spill of diesel fuel would be mitigated by quickly assessing the situation for any immediate health and safety risks to the spills response team, on-site workers and the public by controlling the source of the spill and notifying appropriate regulatory agencies, by deploying containment booms to surround and contain the spill, and finally, by implementing an effective cleanup plan that would likely involve the use of specialized equipment to pump the diesel fuel into secure containers. These measures would contain a spill within the Project Area.

Therefore, taking into account the above control measures, it is unlikely that there would be adverse effects on surface water quality.

Geology

Releases of fuels, chemicals, lubricants and oils can affect soil quality and groundwater quality through the introduction of contaminants into the sub-surface, including direct pathways to subsurface soils and/or bedrock groundwater (e.g., because of excavations, trenches).

Measurable changes to soil quality and/or groundwater quality can occur over the short-term to long-term as a result of a release of contaminants in an accident or malfunction. However, through the use of best management practices inherent in the DGR Project, through operating in compliance with current Ontario regulations, and through the implementation of protocols for the transportation, handling, storage and process systems (which are already in place at the Bruce nuclear site), it is expected that conventional spills can be mitigated such that any adverse effects to soil and groundwater quality are unlikely.

The majority of spills would be recognized and responded to immediately because of the inherent nature of construction activities (i.e., the malfunction/accident occurs while workers are present), and, therefore the likelihood of an accident or malfunction creating a persistent adverse effect to soil quality and/or groundwater quality is considered to be minimal. During operations, there will be an even lower likelihood of a spill affecting soil and groundwater quality as many of the surface facility areas will all be paved and there will be limited opportunity for interaction with the subsurface.

Therefore, taking into account the above discussion, it is unlikely that there would be adverse effects on geology.

Aquatic Environment

Accidental spills could affect the aquatic environment. Construction equipment is not expected to be near the North or South Railway Ditch, Stream C, wetland communities or Lake Huron for the majority of the DGR Project. However, equipment will be used in proximity to the railway ditches during construction of the crossing of the abandoned rail bed. The occurrence of a spill on or in the vicinity of the crossing is expected to be unlikely. Additionally, any spills would be responded to quickly and no adverse effects on surface water quality are likely, as described in Section 5.3.1. Therefore, it is unlikely that there will be an adverse effect on the aquatic environment VECs if a spill occurs.

Terrestrial Environment

Conventional malfunctions and accidents could affect plants or wildlife if they come in contact with the spilled contaminant. This could lead to changes in the health of individual plants and wildlife through toxic effects if chemicals are absorbed, inhaled or ingested.

Measures for spill containment, spill emergency response and environmental protection will be in place before any potentially hazardous materials are brought on-site. Additionally, the spill would be confined to within the DGR Project site as discussed in the previous sections. Vegetation will have been cleared in the very early stages of the site preparation and construction phase and animals will likely avoid the area once construction activities commence due to lack of habitat and the presence of workers. Therefore, there is no likely adverse effect on the terrestrial environment VECs as a result of a spill. As noted above, no adverse effects on other environmental components have been identified; therefore there are no pathways through which indirect effects on the terrestrial environment VECs could occur.

Socio-economic Environment

There is no likely direct interaction with the socio-economic environment VECs as a result of a spill. As noted above, no adverse effects on other environmental components have been identified that would cause an indirect effect on the socio-economic environment VECs.

Aboriginal Interests

There is no likely direct interaction with Aboriginal interests VECs as a result of a spill. As noted above, no adverse effects on other environmental components have been identified that would cause an indirect effect on Aboriginal interests VECs.

5.4.1.2 Explosion

In the event of an explosion, there would be a localized release of emissions that may interact with air quality and noise. However, these emissions would be similar to those predicted as part of normal blasting during construction. Emissions associated with the support and response equipment are similar to those identified for the existing operations at the WWMF, and are therefore not expected to result in measurable increases to air or noise emissions. No off-site effects are anticipated on air quality.

There are no likely interactions with hydrology, surface water, soil or groundwater quality. An explosion would not likely directly affect aquatic and terrestrial biota unless they were in the immediate vicinity of the accident, although some nearby individuals could be startled by the sudden loud noise associated with an explosion. The DGR Project site will be fenced and the site cleared very early in the project schedule, therefore, it is unlikely that there will be animals in the immediate area. In addition, an explosion associated with blasting is likely to be located below ground surface, away from the receiving environment.

An explosion on the Bruce nuclear site may have an effect on people's feelings of well-being and sense of safety and security. However, an explosion associated with the DGR Project would be limited to the DGR Project site, and will not result in the release of radioactivity. Therefore, an explosion would not likely cause a measurable change in people's feelings.

Therefore, based on the above discussion, no adverse effects on the environment are likely as a result of an explosion. Effects on workers are considered in Section 5.4.3.

5.4.2 Members of the Public

As described in Section 5.3.2, the only scenario with potential off-site effects advanced for discussion is a spill during the site preparation and construction, operations or decommissioning phases. As described in Section 5.4.1, no likely adverse effects are identified on air, surface water or groundwater quality. Only vegetation within the immediate vicinity of the spill could be contaminated, but the public cannot access the Bruce nuclear site so there is no potential that the public could come into direct contact with any potentially contaminated vegetation.

Therefore, a spill at the DGR Project site will not have an adverse effect on members of the public.

5.4.3 Effects on Workers

The assessment of hazards to workers was conducted systematically using a screening process hazard analysis method combined with a job hazard analysis approach [12], as described in Section 5.3.3. The assessment of hazards forms the basis for establishing priorities related to mitigation measures and recommendations for the DGR Project, and to assist in determining the safety significance of the hazards associated with certain activities.

The non-radiological hazards to workers identified for the DGR Project are listed in Table 5.3.3-1, which provides details on the potential consequences and plausible outcomes of each identified hazard.

Mitigation and control measures will be implemented as part of the DGR Project. The mitigation and control measures identified for non-radiological hazards to workers are provided in Table 5.3.3-1. The effects from the malfunctions and accidents scenarios originating from identified hazards can be minimized through implementing these measures as part of the DGR Project.

Provided these mitigation and control measures are used, it is anticipated that there will be no unacceptable risks to workers resulting from the DGR Project.

5.4.4 Summary

Based on the assessment presented above, there will be no likely adverse effects on the environment, members of the public or workers. Therefore, further assessment of the effects of conventional malfunctions and accidents associated with the DGR Project is not required.

5.5 CONTINGENCY PLANS AND EMERGENCY PROCEDURES

Based on the assessment, it is concluded that residual adverse effects of all malfunctions and accidents identified will be unlikely. However, in case of the occurrence of accidents such as fire or spills, NWMO (site preparation and construction) and OPG (operations) will establish contingency plans and emergency procedures to prevent incidents and minimize the effects. OPG's Nuclear Waste Management Policy states that activities involving the handling, processing, transportation and storage of radioactive materials be performed in a manner that protects the workers, the public and the environment, and ensures compliance with applicable regulatory and licence basis requirements [14].

OPG has a number of environmental programs and emergency response procedures for the operation of the WWMF established and implemented under OPG's Environmental Management System in accordance with the requirements of ISO 14001, OHSAS 18001, and industry best practices [15;16;17]. OPG will have programs in place for the DGR Project similar to those at the WWMF and that comply with the above standards and practices, as well as applicable Canadian standards, such as CSA Z16000-08 *Emergency Management and Business Continuity Programs* and CSA Z-731-03 *Emergency Preparedness and Response* [18;19].

In particular, the control and safe handling of hazardous materials are covered under various aspects of OPG's Nuclear Waste Management Division (NWMD) Environment Health and Safety Program [16] and OPG's Environmental Policy [20]. The handling of hazardous materials must meet provincial legislation, particularly the *Occupational Health and Safety Act* and the *Environmental Protection Act* for non-radiological hazards. Material Safety Data Sheets on all hazardous materials used on the DGR Project site will be available as required by the Workplace Hazardous Materials Information System (WHMIS). Spills management and response for the WWMF [21], or equivalent, will be extended to the DGR Project.

5.5.1 Fire Protection and Emergency Response

The Bruce nuclear site is served by its own internal Emergency Response Team, medical aid and fire prevention and response capabilities. In addition, a comprehensive on- and off-site emergency response plan is in place. Response teams have been trained and are equipped to respond to potential emergencies such as personal injury, fire or non-routine releases of radioactivity. The municipal fire department, the Regional Medical Officer of Health and Kincardine's health and safety service providers work co-operatively with OPG and Bruce Power to ensure that additional support and response capability is in place.

Trained and qualified mine rescue teams will be provided as required by the mining Regulations. If necessary, the mine rescue team will evacuate workers after a fresh air passage can be guaranteed to the surface. Back up will be provided by nearby mine rescue teams through mutual assistance agreements.

5.5.2 Spills Response

An environmental management plan will be in place for the site preparation and construction phase, as described in Section 4 of the EIS. The environmental management plan will include the site spills and release response plan. During the operations phase, environmental policies, programs and procedures will be implemented consistent with the requirements of OPG's existing Environment Policy (OPG-POL-0021) and Spills Management Policy (OPG-POL-0020). Procedures will likely be consistent with those outlined in the NWMD's Western Spill Management Procedure [21]. Decommissioning is planned many years in the future; however, it is assumed an environmental management plan, including policies and procedures to address potential spills will be in place. Further, an EA will be required prior to receipt of a decommissioning licence.

To mitigate the effect of spills, appropriately equipped and trained on-site spills response teams will be available at all times as part of emergency response procedures, as described in the EA Follow-up Monitoring Program. The malfunctions and accidents prevention follow-up monitoring program consists of a checklist of good industry management practice that will be verified in the field (see DGR EA Follow-up Monitoring Program [22] for more information).

OPG's NWMD's spill history is presented in Table 5.5.2-1. Categories of spills are as defined by the Ministry of the Environment (MOE) as follows:

- "A" Spill – very serious (widespread injury or damage);
- "B" Spill – serious (local injury or damage);
- "C" Spill – less serious (spills reportable to the MOE that are not classified as A or B); and
- "D" Spill – spills that are exempted (non-reportable) to the MOE.

As shown, there was one reportable spill (category "C") in 2009, and one in 2010. In 2010, there were three additional non-reportable spills (category "D") of less than 1 L. Spills were identified and responded to quickly. The reportable spills were as follows:

- 2009: A spill of dilute glycol and water mixture occurred on September 16, 2009 at the WWMF. Approximately 200 L of dilute glycol and water mixture was discharged to the asphalt pavement and then entered the storm sewer system and discharged to the South Railway Ditch.
- 2010: The lime silo overfilled causing lime to be discharged from the top of the silo to the natural environment.

Table 5.5.2-1: OPG NWMD Spill History

Spill Category	2005		2006		2007		2008		2009		Q2 2010	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
A	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0
C	≤1	0	≤1	0	≤1	0	≤1	0	≤1	1	≤1	1
D	— [a]	— [a]	— [b]	2	— [b]	1	— [a]	— [a]	— [a]	— [a]	12 [c]	3

Notes:
a Category D spills were not reported
b No target
c Category D spills target and actual for 2010 includes non reportable spills (exempted by regulation) and potential spills

6. MALEVOLENT ACTS

The EIS Guidelines require that the following be documented for the assessment of malevolent acts:

- information necessary to permit consideration of relevant environmental effects;
- potential environmental effects that could result from intentional malevolent acts; and
- comparison of environmental effects resulting from malevolent acts with the effects identified for accidents and malfunctions affecting the DGR Project.

The purpose of this section is to document the assessment of malevolent acts for the DGR Project.

6.1 METHOD FOR ASSESSMENT OF MALEVOLENT ACTS

Malevolent acts are assessed using methods different from those used for conventional malfunctions and accidents. As malevolent acts cannot be bounded by specified event scenarios, a high level, qualitative assessment of these events is provided below.

6.2 ASSESSMENT OF POTENTIAL MALEVOLENT ACTS

There are four broad categories of potential malevolent acts: threats of violence, sabotage, theft and attack. Threats and theft are not considered in this assessment.

The DGR Project is entirely contained within the Bruce nuclear site and will remain well protected by the Bruce nuclear site security forces from the start of site preparation and construction through to decommissioning of the facility.

Security measures at the Bruce nuclear site, within which the DGR Project is located, include:

- facility fences and controlled access to both the Bruce nuclear site and the DGR Project site;
- emergency response and preparedness planning; and
- security screening for all personnel working at the DGR Project facility will be required as this is a standard requirement for workers within the Bruce nuclear site.

Potential malevolent acts are considered for each DGR Project phase: site preparation and construction; operations; decommissioning; and abandonment and long-term performance.

6.2.1 Site Preparation and Construction Phase

6.2.1.1 Radiological Effects

The site preparation and construction phase includes initial preparation of the site for future construction activities, construction of surface facilities, and excavation and construction of underground facilities. Since there will be no radioactive waste on-site during this phase, malevolent acts with potential radiological effects can be screened out.

6.2.1.2 Non-radiological Effects

The site preparation and construction phase of the DGR Project will present a range of conventional (non-radiological) work-place hazards similar to those presented by comparable large construction and mining projects.

Sabotage may precipitate malfunctions and accidents considered within the conventional safety assessment [12], in which case the consequences are bounded by that assessment. Section 5.4.3 summarizes potential effects on the health of workers because of potential malfunctions and accidents.

All attack scenarios have the potential to produce significant consequences. Public consequences would be bounded by the accident scenarios considered within the conventional safety assessment, possibly by the estimated consequences of a large fire at the facility. For workers positioned at the periphery of an attack, consequences may be bounded by the accidents considered within the safety assessment. This assessment is documented in Section 5.4.3. In the immediate vicinity of an attack, worker fatalities are possible.

6.2.2 Operations Phase

6.2.2.1 Radiological Effects

The operations phase includes the receipt of radioactive waste from the WWMF and emplacement of radioactive waste in the DGR.

In general, DGR Project waste package integrity and worker safety do not depend on power, ventilation or control systems (or can tolerate extended outages). This helps to reduce the vulnerability of the project to sabotage. In addition, the DGR Project is within a fenced and monitored area within the overall Bruce nuclear site fence. It will be well protected by Bruce nuclear site security.

Likely, the most realistic scenario is sabotage or attack by an employee attempting to damage systems or waste packages directly. Potential malevolent acts include deliberately driving a forklift into a package or dropping a package during handling; pushing a package or vehicle into the shaft; and setting waste packages on fire. The immediate consequences of these threats are limited to breach of the packages directly affected. The aftermath of the event may involve an extended shutdown for repair of any damaged facilities. Mitigation measures include worker security clearance and access limiters on the shaft.

A person using an explosive or incendiary device would cause the most damage. As explosives used for construction would be accounted for and removed from the site before the DGR Project starts operation, this would require the worker to smuggle explosives on-site. In addition, underground rock and structures will be very durable. Shaft and underground excavation requires explosives to be placed in holes drilled in the rock at multiple locations and depths. An explosion within an excavated space is unlikely to cause rupture of the shaft walls or ceiling. Therefore, significant rockfall cannot be easily initiated.

Ignition would be limited by the general low combustibility of the wastes and use of non-combustible containers, as well as the heavy lids on packages. Most of the DGR Project systems that contain or handle radioactivity are inherently robust. Furthermore, wastes with higher radioactivity are in stronger packages: for example, higher dose resin liners will be in 0.25 to 0.35 m-thick concrete shields and 1-tonne steel liners. Damaging these systems or igniting substantive fires would require a large amount of explosive or incendiary material.

Filled rooms will be closed and monitored. Diesel fuel will be kept in limited quantities underground, in a dedicated area. Fuel will be moved underground in totes separate from waste package transfers. Also there will be full fire detection and mitigation equipment in place. All these mitigation measures will further minimize the radiological effects resulting from the occurrence of an underground fire.

Transfer of ILW from the WWMF to the DGR Project, including any staging at surface prior to emplacement, may present the greatest vulnerability to malevolent acts. This risk can be mitigated through procedures, such as controlling the total amount of radioactivity in transit or queued for emplacement, and use of indoor staging areas to make it more difficult to estimate the total amount of material in queue.

The DGR is about 1.1 km from the nearest Bruce nuclear site boundary, placing it within the range of a remote military-style attack from that boundary; an aircraft crash is also possible. Even so, the limited amount of radioactivity queued for emplacement on the surface at the DGR Project make significant radiological consequences for the public unlikely; also, as the wastes are emplaced underground, they become protected from attack by several hundred meters of rock.

6.2.2.2 Non-radiological Effects

The access to underground is through either the main shaft, which is centrally located and monitored, or the ventilation shaft. There will be multiple mechanisms available for communicating with underground staff. There will also be two exits and several refuge locations. These measures will minimize the risk of hostage taking or attack on personnel.

Explosives would not be on-site during operations. Some of the conventional work place hazards present during construction will persist into the operations phase as documented in Table 5.3.3-1. The potential non-radiological consequences of malevolent acts will remain largely unchanged. Bounding consequences of malevolent acts during construction of the DGR Project will continue to be bounding during operations.

6.2.3 Decommissioning Phase

6.2.3.1 Radiological Effects

Decommissioning of the DGR Project will include all activities required to close the repository, followed by removal of the above-ground infrastructure. This includes dismantling the equipment, sealing the repository and access-ways, and decontaminating and removing the surface facilities.

While reduced project activities will limit opportunities for malevolent acts and reduce the potential consequences, less worker presence could increase the potential for malevolent acts to occur. However, all radioactive wastes would have been emplaced in the repository and isolated from the environment by several hundred metres of rock. Therefore, the potential radiological effects of a malevolent act during decommissioning are considered bounded by those of the operations phase.

6.2.3.2 Non-radiological Effects

Opportunities for sabotage and attack during decommissioning will be similar to those of the site preparation and construction phase, which has been discussed in Section 6.2.1.

6.2.4 Abandonment and Long-term Performance Phase

6.2.4.1 Radiological Effects

Over the long term, deep geologic disposal of L&ILW provides the best possible security against malevolent acts. Placing the waste a nominal 680 m below the surface presents significant impediments to any attempt to disturb the emplaced materials.

6.2.4.2 Non-radiological Effects

In terms of conventional safety, the site will be largely indistinguishable from the surrounding lands. Therefore, conventional effects of malevolent acts can be screened out.

6.3 CONSEQUENCES OF MALEVOLENT ACTS

The Preliminary Safety Report [4] considers the consequences of container breach, cage fall, and fires. Therefore, the consequences of many credible malevolent acts are already represented or bounded within the scenarios described in Section 4 of this TSD, and in the Preliminary Safety Report [4].

6.3.1 Consequences for Non-human Biota

The malevolent acts considered in this assessment have the potential to affect non-human biota that use the Bruce nuclear site. This includes individual members of populations of terrestrial and aquatic biota identified in this EA as VECs. Since the greatest effect of a malevolent act would be limited to the near vicinity of the DGR and because small quantities of radioactive material are stored at surface at the DGR, the overall populations of terrestrial and aquatic biota would remain unaffected in the event a malevolent act against the DGR Project is carried out. In particular, those populations spanning Bruce County would be unaffected.

6.3.2 Consequences to Members of the Public

The public consequences of container breach, cage fall and fires, including exposure to radionuclides and non-radioactive species, have been shown to be small in the Preliminary Safety Report [4].

Less credible acts include use of explosives. Consequences would be limited by the amount of explosives that an employee could smuggle on-site and carry unobserved to the waste packages. Adjusting the accident parameters in the Preliminary Safety Report [4] to reflect an explosion, the consequent radiological dose to the public located at the nearest Bruce nuclear site boundary remains significantly below the acute accidental dose criterion of 1 mSv.

The radiological consequences of an airplane crash are similarly bounded. The aircraft could cause more damage than credible explosions plus initiate a fire, but the thermal plume would significantly increase dilution through dispersion.

6.3.3 Consequences to Workers

The effect of extreme malevolent acts can include worker fatalities, depending on their proximity to the location of the attack. Nonetheless, the effect of more credible malevolent acts (e.g., deliberately crashing a transfer vehicle) would be bounded by malfunctions and accidents caused by unintentional human activity, resulting in relatively low consequences for workers. These bounding scenarios are discussed in the Preliminary Safety Report [4].

6.4 COMPARISON OF EFFECTS WITH MALFUNCTIONS AND ACCIDENTS

In general, the radiological consequences of credible malevolent acts are expected to be similar to those of malfunctions and accidents. Scenarios including detonation of explosives have the potential to produce public consequences exceeding those of the bounding accident scenarios, but public consequences would remain significantly below the acute accidental dose criterion of 1 mSv.

Extreme malevolent acts, such as use of explosives, could cause worker fatalities in the vicinity. More credible malevolent acts, including sabotage of safety systems, are bounded by accident scenarios.

The potential non-radiological consequences of malevolent acts are expected to be similar to those of non-radiological malfunctions and accidents, particularly in terms of affecting the public.

While individual members of resident populations of non-human biota would be affected by malevolent acts, overall populations are expected to remain unaffected. This is true for both radiological and non-radiological consequences.

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7. CONCLUSIONS

In this report, malfunctions, accidents and malevolent acts that might occur during the DGR Project were identified based on the analysis of all project works and activities including site preparation, construction, operation, decommissioning, abandonment and long-term performance. The effect of the credible malfunctions and accidents identified, radiological or non-radiological, were then assessed, taking into account DGR Project design, safety procedures and plans, and past experience and records. The major findings are summarized below.

For radiological malfunctions and accidents determined to be credible for the site preparation and construction, operations, and decommissioning phases:

- radiological doses to humans (including workers or members of the public) and non-human biota do not exceed established dose limits for credible accident scenarios; and
- non-radiological species released from various scenarios do not exceed the criteria established for humans (including workers or members of the public) and non-human biota.

For malfunctions and accidents (Disruptive Scenarios) that might occur during the abandonment and long-term performance phase:

- While radiological doses to humans are significantly less than the dose criterion for some scenarios, doses to humans resulting from other scenarios could be about 1 mSv/a. However, all these scenarios are very unlikely and, therefore, the risk to humans is low.
- While most contaminants are likely to remain well below their respective screening criteria, there could be exceedances of screening criteria for some radioactive species relating to certain scenarios. However, these exceedances are local, the screening criteria are conservative, and the scenarios are very unlikely. Therefore, the risk to non-human biota is low.

For conventional malfunctions and accidents that might occur during the site preparation and construction, operations, and decommissioning phases:

- there will be no likely adverse effects on the environment (including non-human biota);
- there will be no likely adverse effects on members of the public; and
- there will be no likely adverse effects on workers.

For malevolent acts:

- radiological consequences are expected to be similar to those of malfunctions and accidents;
- non-radiological consequences are expected to be similar to those of malfunctions and accidents, particularly in terms of affecting the public; and
- populations of non-human biota are expected to remain unaffected.

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APPENDIX A: LIST OF ACRONYMS, UNITS AND TERMS

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List of Acronyms

Acronym	Descriptive Term
CCME	Canadian Council for Ministers of the Environment
CEAA	Canadian Environmental Assessment Act
CNSC	Canadian Nuclear Safety Commission
DAC	Derived Air Concentrations
DGR	Deep Geologic Repository
DOE	Department of Energy
EA	Environmental Assessment
EDZ	Excavation Damage Zone
ENEV	Estimated No Effects Values
EIS	Environmental Impact Statement
FEP	Features, Events or Processes
ILW	Intermediate Level Waste
IDLH	Immediately Dangerous to Life and Health
L&ILW	Low and Intermediate Level Radioactive Waste
LLW	Low Level Waste
MOE	Ministry of the Environment
NEC	No-Effect Concentration
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation Inc.
PAC	Protective Action Criteria
PPE	Personal Protective Equipment
RA	Responsible Authority
TSD	Technical Support Document
VEC	Valued Ecosystem Component
WHMIS	Workplace Hazardous Material Information System
WPRB	Waste Package Receipt Building
WWMF	Western Waste Management Facility

List of Units

Symbol	Units
Bq	Becquerel
Bq/kg	Becquerel per kilogram
Bq/L	Becquerel per litre
Gy	Gray
km	Kilometre
m	Metre
m^3	Cubic metre
mSv	MilliSievert
mSv/a	MilliSievert per year
$\mu g/m^3$	Microgram per cubic metre
µg/L	Microgram per litre
µg/g	Microgram per gram

Glossary of Terms

Bounding Scenario – An accident scenario with effects expected to be of a higher magnitude that the other scenarios examine. Effects from all other scenarios would likely be less than the bounding scenario.

Bruce nuclear site – The 932 hectare (9.32 km^2) parcel of land located within the administrative boundaries of the Municipality of Kincardine in Bruce County. Two operating nuclear stations are located on the site. The site is owned by OPG but has been leased to Bruce Power since May 2001. However, parts of the site, including land on which WWMF is located, have been retained by OPG. See also *OPG-retained lands*.

Bruce Power – The licensed operator of the Bruce A and Bruce B nuclear generating stations.

Cambrian – The earliest period of the Paleozoic era extending from 543 to 490 million years ago; also, refers to rocks formed, or sediments laid down, during this period (e.g., Cambrian sandstones).

Canadian Environmental Assessment Agency (CEAA) – The federal body accountable to the Minister of the Environment. The Agency works to provide Canadians with high-quality environmental assessments that contribute to informed decision making, in support of sustainable development.

Canadian Nuclear Safety Commission (CNSC) – The Canadian federal agency responsible for regulating nuclear facilities and materials, including management of all radioactive waste in Canada.

Closure – The administrative and technical actions directed at a repository at the end of its operating lifetime. For example covering the waste (for a near surface repository), backfilling and/or sealing of rooms, tunnels and/or shafts (for a geological repository), and termination or completion of activities in any associated structures.

Decommissioning – Those actions taken, in the interest of health, safety, security and protection of the environment, to retire a licensed activity/facility permanently from service and render it to a predetermined end-state condition.

Deep Geologic Repository (or DGR, or Repository) – The underground portion of the deep geologic repository facility for low- and intermediate-level waste. Initially, the repository includes the access-ways (shafts, ramps and/or tunnels), underground service areas and installations, and emplacement rooms. In the postclosure phase it also includes the engineered barrier systems. The repository includes the waste emplaced within the rooms and excludes the excavation damage zone.

Deep Geologic Repository Project Site (or DGR Project site) – The portion of the Project Area that will be affected by the site preparation and construction of the surface facilities (i.e., the surface footprint).

Direct Effect – A direct effect occurs when the VEC is affected by a change that results from a project work and activity.

Dispersion – A small scale, spreading and mixing process resulting from dissolved substances traveling at different velocities along and between flow paths through a porous or fractured medium. The spreading of the dissolved substance in the direction of bulk flow is known as longitudinal dispersion. Spreading in directions perpendicular to bulk flow is known as transverse dispersion.

Dose – A measure of the energy deposited by radiation in a tissue. Also referred to as absorbed dose, committed equivalent dose, committed effective dose, effective dose, equivalent dose or organ dose, depending on the context.

Earthquake – A shaking or trembling of the earth resulting from subterranean movement usually along faults.

Emplacement Room – A portion of the underground repository into which waste packages are permanently placed. Rooms are bounded by the host rock for floor, ceiling and walls on most sides, and by a wall or access tunnel on one side.

Geosynthesis – The assembly of all the geologically-based evidence relevant to the repository safety case; the integration of multi-disciplinary geoscientific data relevant to the development of a descriptive conceptual geosphere model; explanation of a site-specific descriptive conceptual geosphere model within a systematic and structured framework.

Human Intrusion – Human actions that modify the performance of engineered and/or natural barriers leading to the creation of a route by which humans (potentially both the intruder(s) and public) could be exposed to radionuclides derived from the repository.

Indirect Effect – An indirect effect occurs when the VEC is affected by a change in another VEC.

Intermediate-Level Waste (ILW) – Radioactive non-fuel waste, containing significant quantities of long-lived radionuclides (generally refers to half-lives greater than 30 years).

Low Level Storage Building (LLSB) - Refers to a series of buildings at OPG's Western Waste Management Facility for the interim storage of low-level waste.

Low-Level Waste (LLW) – Radioactive waste in which the concentration or quantity of radionuclides is above the clearance levels established by the regulatory body (CNSC), and which contains primarily short-lived radionuclides (half-lives shorter than or equal to 30-years).

OPG-retained Land – The parcels of land on the Bruce nuclear site for which control has been retained by OPG. This includes the WWMF, certain landfills, and the Heavy Water Plant Lands.

Radioactive Waste – Any material (liquid, gaseous or solid) that contains a radioactive "nuclear substance" as defined in Section 2 of Nuclear Safety and Control Act, and which the owner has declared to be waste. In addition to containing nuclear substances, radioactive waste may also contain non-radioactive "hazardous substances", as defined in Section 1 of the CNSC's General Nuclear Safety and Control Regulations.

Receptor – Any person or environmental entity that is exposed to radiation, or a hazardous substance, or both. A receptor is usually an organism or a population, but it could also be an abiotic entity such as surface water or sediment.

Risk – A multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual or potential exposures. It relates to quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences.

Safety Report – A key licensing document which provides an overview of the facility design and operations, summarizes the integrated results of individual safety assessments, and demonstrates that a facility can be constructed, operated, or continue to be operated, without undue risk to health and safety of the workers and the public, and the environment.

Preliminary Safety Report (PSR) is the Safety Report submitted to CNSC in support of an application for a Site Preparation/Construction Licence.

Final Safety Report (FSR) is the Safety Report submitted to CNSC in support of an application for a Licence to Operate.

Scenarios – A postulated or assumed set of conditions or events. They are most commonly used in analysis or assessment to represent possible future conditions or events to be modelled, such as the possible future evolution of a repository and its surroundings.

Shaft – A vertical or near-vertical excavated passageway that connects the surface with an underground workplace or connects two or more underground workplaces at different elevations.

Valued Ecosystem Component (VEC) – VECs are features of the environment selected to be a focus of the environmental assessment because of their ecological, social, or economic value, and their potential vulnerability to the effects of the DGR project.

Waste Package Receiving Building (WPRB) – The building at the DGR surface where waste packages arrive for transfer underground.

Western Waste Management Facility (WWMF) – The centralized processing and storage facility on the Bruce nuclear site for OPG's L&ILW and for the dry storage of used fuel from Bruce nuclear generating stations.

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APPENDIX B: BASIS FOR THE EA

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Table B-1: Basis for the EA

Project Works and Activities	Description
Site Preparation	Site preparation would begin after receipt of a Site Preparation Licence and would include clearing approximately 30 ha of the DGR Project site and preparing the construction laydown areas. Activities would include: • Removal of brush and trees and transfer by truck to on-site storage; • Excavation for removal and stockpiling of topsoil and truck transfer of soil to stockpile on-site; • Grading of sites, including roads, construction laydown areas, stormwater management area, ditches; • Receipt of materials including gravel, concrete, and steel; • Installation of construction roads and fencing; • Receipt and installation of construction trailers and associated temporary services; and • Install and operate fuel depot for construction equipment.
Construction of Surface Facilities	Construction of surface facilities will include the construction of the waste transfer, material handling, shaft headframes and all other temporary and permanent facilities at the site. Activities would include: • establish a concrete batch plant; • receipt of construction materials, including supplies for concrete, gravel, and steel by road transportation; • excavation for and construction of footings for permanent buildings, and for site services such as domestic water, sewage, electrical; • construction of permanent buildings, including headframe buildings associated with main and ventilation shafts; • receipt and set up of equipment for shaft sinking; • construction of abandoned rail bed crossing between WWMF and the DGR site; • fuelling of vehicles; and • construction of electrical substation and receipt and installation of standby generators.
Excavation and Construction of Underground Facilities	Excavation and construction of underground facilities will include excavation of the shafts, installation of the shaft and underground infrastructure (e.g., ventilation system) and the underground excavation of the emplacement and non-storage rooms. Activities will include: • drilling and blasting (use of explosives) for construction of main and ventilation shafts, and access tunnels and emplacement rooms; • receipt and placement of grout and concrete, steel and equipment; • dewatering of the shaft construction area by pumping and transfer to the above-ground stormwater management facility; • temporary storage of explosives underground for construction of emplacement rooms and tunnels; • receipt and installation of rock bolts and services; and • installation of shotcrete.

Table B-1: Basis for the EA (continued)

Project Works and Activities	Description
Above-ground Transfer and Receipt of Waste	Above-ground handling of wastes will occur during the operations phase of the DGR Project and will include receipt of L&ILW from the WWMF at the staging area in the DGR Waste Package Receiving Building (WPRB) and on-site transfer to shaft. Above-ground handling of wastes includes: • receipt of disposal-ready waste packages from the WWMF by forklift or truck • offloading of waste packages at the WPRB; • transfer of waste packages within the WPRB by forklift or rail cart; • temporary storage of waste packages inside the WPRB.
Underground Transfer of Waste	Underground handling of wastes will take place during the operations phase of the DGR Project and will include: • receipt of waste packages at the the main shaft station; • offloading from cage and transfer of waste packages by forklift to emplacement rooms; • rail cart transfer of some large packages (Heat Exchangers/Shield Plug Containers) to emplacement rooms; • installation of end walls on full emplacement rooms; • remedial rock bolting and rock wall scaling; • fuelling and maintenance of underground vehicles and equipment; • receipt and storage of fuel for underground vehicles. Emplacement activities will be followed by a period of monitoring to ensure that the DGR facility is performing as expected prior to decommissioning.
Decommissioning of the DGR Project	Decommissioning of the DGR Project will require a separate environmental assessment before any activities can begin. Decommissioning of the DGR Project will include all activities required to seal shafts and remove surface facilities including: • removal of fuels from underground equipment; • removal of surface buildings, including foundations and equipment; • receipt and placement of materials, including concrete, asphalt, sand, bentonite for sealing the shaft; • construction of concrete monolith at base of two shafts, removal of shaft infrastructure and concrete liners, and reaming of some rock from the shafts and shaft stations; • sealing the shaft; and • grading of the site. The waste rock pile (limestones) will be covered and remain on-site.
Abandonment of the DGR Facility	Timing of abandonment of the DGR facility will be based on discussion with the regulator. Activities may include removal of access controls.
Presence of the DGR Project	Presence of the DGR Project represents the meaning people may attach to the existence of the DGR Project in their community and the influence its operations may have on their sense of health, safety and personal security over the life cycle of the DGR Project. This includes the aesthetics and vista of the DGR facility.

Table B-1: Basis for the EA (continued)

Project Works and Activities	Description
Waste Management	Waste management represents all activities required to manage waste during the DGR Project. During construction waste management will include managing the waste rock along with conventional waste management. During operations, waste management would include managing conventional and radiological wastes from the underground and above-ground operations. Decommissioning waste management may include management of conventional and construction wastes. Activities include: • transfer of waste rock, by truck to the WRMA; • placement of waste rock on the storage pile; • collection and transfer of construction waste to on-site or licensed off-site facility; • collection and transfer of domestic waste to licensed facility; • collection, processing and management of any radioactive waste produced at the DGR facility; • collection, temporary storage and transfer of toxic/hazardous waste to licensed facility.
Support and Monitoring of DGR Life Cycle	Support and monitoring of DGR life cycle will include all activities to support the safe construction, operation, and decommissioning of the DGR Project. This includes: • operation and maintenance of the ventilation fans, heating system, electrical systems, fire protection system, communications services, sewage and potable water system and the standby generator; • collection, storage, and disposal of water from underground sumps, and of wastewater from above-and below ground facilities; • management of surface drainage in a stormwater management facility; • monitoring of air quality in the facility, exhaust from the facility, water quality of run-off from the developed area around the shafts and Waste Rock Management Area, water quality from underground shaft sumps and geotechnical monitoring of various underground openings; • maintenance and operation of fuel depots above-ground (construction only) and below-ground; and • administrative activities above- and below-ground involving office space, lunch room and amenities space.
Workers, Payroll and Purchasing	Workers, payroll and purchasing will include all workers required during each phase to implement the DGR Project. Activities include: • spending in commercial and industrial sectors; • transport of materials purchased to the site; and • workers travelling to and from site.

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