

PROPOSED DEEP GEOLOGIC REPOSITORY FOR LOW AND INTERMEDIATE-LEVEL RADIOACTIVE WASTE AT THE BRUCE SITE, TIVERTON, ONTARIO

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Abstract

A Deep Geologic Repository (DGR) for the long-term management of operational Low and Intermediate Level Radioactive Waste (L&ILW) is being proposed by Ontario Power Generation at the 932-ha Bruce site. The Bruce site is located approximately 225 kilometres northwest of Toronto near Tiverton, Ontario. The project is currently in the environmental assessment phase. This paper describes OPG's proposed DGR, a concept which is still under development. The underground repository concept is comprised of horizontally-excavated emplacement rooms arranged in two panels with access provided via two vertical concrete-lined shafts. The emplacement rooms would be constructed at a depth of about 680 m within limestone. This limestone formation is laterally extensive and is directly overlain by 200 m of low permeability shale. The low-permeability diffusion-controlled geosphere immediately surrounding and above the repository will assure long-term isolation of the L&ILW.

1. Introduction and Background

Low and intermediate-level radioactive waste that is produced during the operation of Ontario's reactors is stored centrally at Ontario Power Generation's (OPG's) Western Waste Management Facility. Although current storage practices are safe, OPG's long-term plan is to transfer these wastes to a long-term management facility because some of the wastes remain hazardous for thousands of years.

In 2002 the Municipality of Kincardine volunteered to assess options for long-term management of L&ILW at the existing storage site. In October 2004, Kincardine and Ontario Power Generation reached an agreement on the terms and conditions of a hosting agreement for a DGR facility, subject to achieving all regulatory approvals. The DGR concept was selected by Kincardine's Council members because it would have the largest margin of safety of all options considered and because this concept is consistent with best international practice. Through a polling process it was confirmed that the residents of the Municipality of Kincardine agree with Council's decision to support the establishment of a long-term management facility for L&ILW on the Bruce site. The proposed DGR will not be accepting OPG's used nuclear fuel /Squire and Barker, 2005/.

In December 2005, OPG initiated an Environmental Assessment in accordance with the Canadian Environmental Assessment Act. In June 2007, the federal Minister of the Environment referred the project to a Review panel. The next step in the process is the release of guidelines for preparation of the Environmental Impact Statement (EIS).

Documents describing the above processes and various other studies can be found on the DGR project web site at www.opg.com/dgr.

2. L&ILW from Reactor Operations and Refurbishment

OPG's L&ILW is generated primarily by the operation of 20 nuclear reactors at Pickering, Bruce and Darlington stations and the waste is sent to WWMF for interim storage (Figure 2-1). Approximately 5,000 m³ to 7,000 m³ of new waste is received at the WWMF each year, resulting in 2,000 m³ to 3,000

m³ of additional stored waste following volume reduction. If the fleet of 20 reactors operates a nominal 40 years, then about 160,000 m³ (as-stored volume) of operational and refurbishment L&ILW will be produced. In the future, about 135,000 m³ of L&ILW will also be generated during the decommissioning of the reactors and the associated nuclear waste storage facilities.

2.1. Operational Low Level Wastes

LLW consists of common industrial items that have become contaminated with low levels of radioactivity during routine clean-up and maintenance at the nuclear generating stations. It consists of mops, rags, paper towels, temporary floor coverings, floor sweepings, protective clothing, and hardware items such as tools. Where possible, the LLW is processed by either compaction or incineration to reduce volume and the space required for storage and disposal.



Figure 2-1. Aerial view of OPG's Western Waste Management Facility (October 2007); 1) Ten Low-Level Storage Buildings, 2) In-ground Containers for ILW, 3) Refurbishment Waste Storage Buildings, and 4) Western Used Fuel Dry Storage

Wastes that can neither be compacted nor incinerated are stored as-received without processing. The "non-processible" wastes constitute approximately 25 per cent of all wastes received but make up about 55 per cent of the waste stored at WWMF. LLW is stored in a variety of stackable carbon-steel containers and these containers are stored in warehouse-like structures, known as Low-Level Storage Buildings (LLSBs) (Figures 2-1 and 2-2). There are currently ten LLSBs at the WWMF containing approximately 65,000 m³ of waste. The wastes stored in LLSBs and in all other storage structures at WWMF are continually monitored and can be easily retrieved. All WWMF storage structures have minimum design life of 50 years.

2.2 Operational Intermediate Level Wastes

ILW, because of its physical condition and greater levels of radioactivity, is not processed for volume reduction. ILW consists of ion exchange resins, filters and irradiated reactor core components. These wastes are currently stored in concrete- and steel-lined structures constructed in augered boreholes, in concrete-lined and covered trenches, and in concrete above-ground structures (these latter structures are no longer receiving waste). There is 10,000 m³ of ILW in storage and approximately 300 m³ of ILW is received at the WWMF each year. About five per cent of all waste (excluding used nuclear fuel) received at WWMF is classified as ILW.

2.3 Refurbishment Waste

Ontario's reactors are either under-going refurbishment or there are future plans for reactor refurbishment. The refurbishment activities include replacement of motors, valves, instrumentation, fuel channels and steam generators. As a result of the refurbishment and improvements activities, it is expected the life of each of reactor unit will be extended for up to 30 additional years. About 26,000 m³ of radioactive waste will be generated from the planned refurbishment activities.

The irradiated fuel channel wastes are being stored in reinforced concrete containers with inner and outer steel shells. The loaded containers are disposal-ready and weigh about 30 Mg. Steam generators removed during refurbishment are being transferred intact to a storage building. The largest steam generator to be handled will weigh about 135 Mg and have an overall length of 16 m. Because of their weight and size, these steam generators will likely require the use of special handling and processing equipment in order to allow transfer into the DGR.



Figure 2-2. Containers stacked inside Low-Level Storage Building

2.4 Future Decommissioning Wastes

Following permanent shutdown, the reactors at Pickering, Bruce and Darlington will be decommissioned generating additional L&ILW. About 124,000 m³ of decommissioning LLW will be produced mainly as metals and concrete, and when sent to a repository would take the form of boxed wastes and various large objects. In addition, approximately 11,000 m³ of ILW will be generated as reactor components, filters and resins wastes. OPG is currently not seeking approval to dispose of these future decommissioning wastes in the DGR.

3. Geologic Setting and Reference Repository Depth

The geologic conditions beneath the Bruce site have been evaluated through a review of regional data in existing reports, and through an on-site drilling and testing program /Jensen et al, 2007/. The site is underlain by approximately 850 m of relatively undeformed, and nearly horizontal carbonates, shales and evaporates formations. It is proposed that the repository be constructed within this sedimentary sequence at a depth of 680 m in the low permeability argillaceous limestone Coburg formation.

The stratigraphic sequence is comprised of an upper 400 m of Devonian and Silurian age dolostones with some shale and evaporate layers. In the geologic past Silurian salt formations with combined thickness up to 100 m were solution-weathered from within this upper sequence of rocks which has contributed to enhanced permeability of the near-surface dolostone formations. The lower half of the

sequence is Ordovician in age and is comprised of an upper 200 m of shales and a lower 200 m of limestones. The entire sedimentary sequence rests on the crystalline Precambrian basement (Figure 3-1).

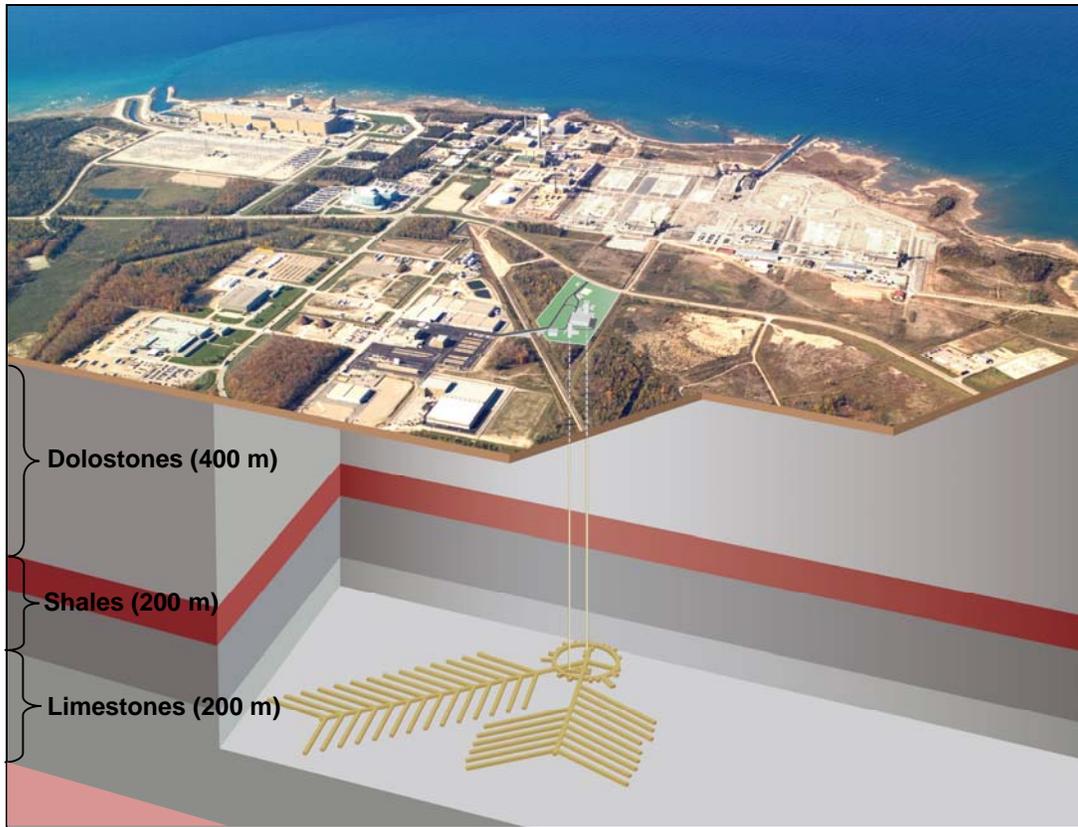


Figure 3-1: Proposed L&ILW Deep Geologic Repository at Bruce site

The key attributes of this geologic setting with respect to hosting a repository are /OPG, 2005/:

- Extremely low permeability of the 400-m-thick sequence of Ordovician sedimentary rock formations which are proposed for hosting the repository;
- Diffusion-dominated migration regime and the absence of cross-formational ground water flow in the Ordovician rock formations as indicated by distinct hydrogeochemical signatures within specific rock formations. These characteristics have existed over geologic timeframes despite repeated glacial perturbations during the Pleistocene period;
- Nearly stagnant deep-seated groundwater flow domains within the proposed host formations as indicated by the extremely high groundwater salinity (>100 mg/L). The extremely high salinity is the result of rock-water reaction times on the order of millions of years;
- Predictable “layer-cake” geometry and lateral continuity of the sedimentary rock formations over distances of 100s of kilometers; and
- Stability of the lower Ordovician rock formations; they have remained intact and relatively undeformed for hundreds of millions of years.

Results of a preliminary geotechnical assessment have indicated that the construction of an underground repository in either an Ordovician shale or Ordovician limestone formation would be feasible. However for the purposes of developing the repository concept, the deep Ordovician limestone was selected as the preferred host formation. The potential advantages of constructing a

repository in limestone versus shale are: a) the geotechnical properties of limestone allow construction of larger and more stable underground openings, b) the overlying 200-m-thick shale layer offers an ideal location to construct shaft seals; and c) mining limestone to create underground openings will likely produce a resource in the form of aggregate which, as a minimum, could be recycled for other construction purposes at no cost to OPG.

4. Layout and Construction

A conceptual layout has been developed for the proposed underground repository and the associated surface facilities for the DGR. The underground repository layout, as depicted in Figure 4-1, will provide sufficient capacity for 186,000 m³ of operational and refurbishment L&ILW (packaged volume for disposal and includes volume of sacrificial shielding materials). The proposed DGR layout is subject to change as the design of the facility progresses. The DGR facility would be centrally located on the 900-ha Bruce site. The underground repository design consists of a series of dead-ended emplacement rooms arranged in parallel rows on either side of central access tunnels. Access to the repository is assumed to be through two vertical concrete-lined shafts. The DGR surface facilities are comprised of the Main Shaft and Waste Receiving Building, Ventilation Shaft Headframe Building, and various ancillary facilities. Additional information about waste capacity and size of the proposed repository is presented in Table 4-1.

Table 4-1. Summary of key repository features and associated value or dimension

Repository Feature	Value/Dimension
Packaged volume of LLW in South Panel	141,000 m ³
Number of operational LLW packages	39,000
Number of LLW emplacement rooms	28
Packaged volume of operational ILW	45,000 m ³
Number of ILW packages in East Panel	11,000
Number of ILW emplacement rooms	15
Rock pillar width between rooms	16 m
Overall footprint of repository	~ 35 ha
Repository excavated volume	~ 450,000 m ³

4.1 Shafts

The Main Shaft and the Ventilation Shaft would be excavated using the drill and blast method to a depth of 400 m and then by roadheader to the proposed repository horizon at 680 m. The use of roadheader is proposed to minimize excavation damage to rock in which primary shaft sealing materials will be placed. The 6.5-m diameter Main Shaft provides primary access to the underground repository and services, including fresh air, for the underground repository are also provided via this shaft (Figure 4-2). The Ventilation Shaft has a 4.5-m finished inside diameter and its functions include providing emergency access for staff to and from the repository, routing for exhaust air from the repository, and removal of excavated rock materials.

The two DGR shafts will be excavated through 150 m of potential water-bearing dolostone formations near the top of sedimentary sequence. Excavation grouting will be used to condition rock formations to limit any water inflow during construction, and then the shafts will be concrete-lined to further limit potential water inflow. As successfully demonstrated at a nearby 530-m deep salt mine, the constructed features in each DGR shaft and the thick low permeability formations directly overlying and hosting the repository will result in negligible water inflows via the shafts /Mamen, 1959/.

4.2 Underground Tunnels and Ventilation System

Access to the emplacement rooms from the underground waste package receiving area near the Main Shaft will be via two tunnels. All tunnels and emplacement rooms will be excavated by roadheader.

Both access tunnels have a poured concrete floor and the East Panel tunnel has rails mounted flush to the floor surface to allow movement of rail cars loaded with large and heavy packages.

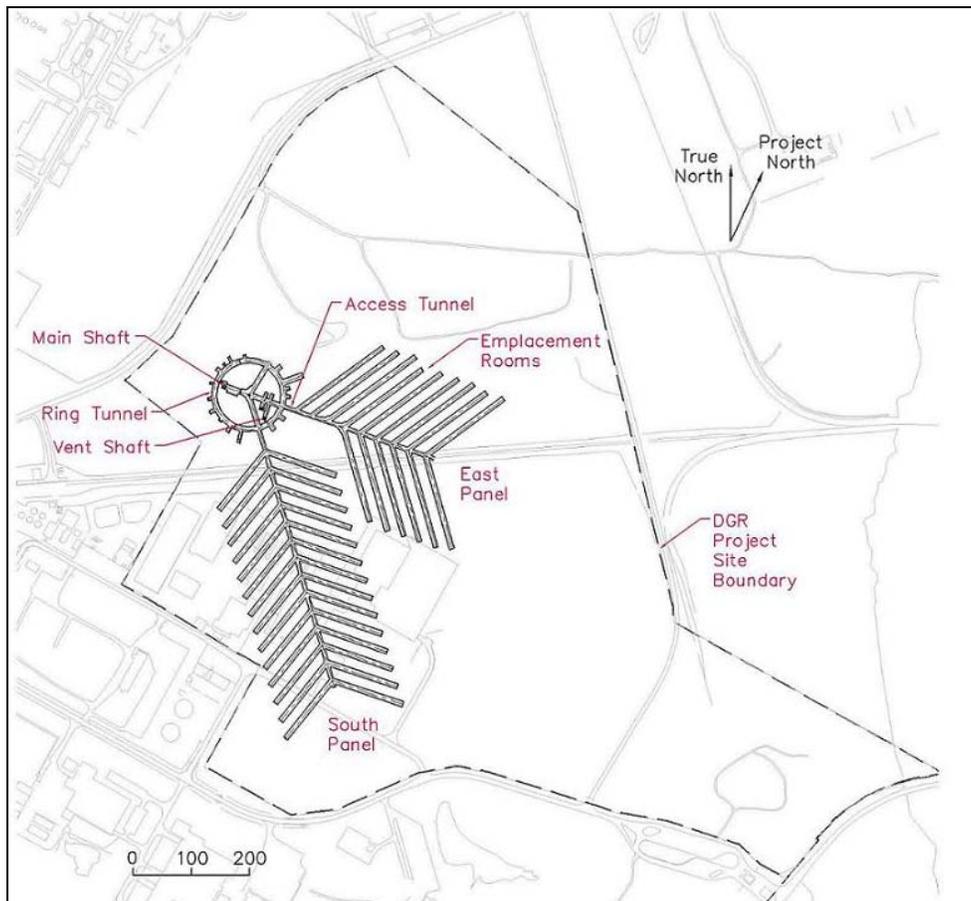


Figure 4-1. Conceptual layout of a repository to accommodate OPG's L&ILW

A ventilation system is required to support repository construction activities (i.e. flush gases and dust from rock excavation activities) and to deliver fresh air during waste emplacement operations. Ventilation of underground repository will be by a pull-system of surface fans with fresh air introduced via the Main Shaft and then exhausted by the Ventilation Shaft (note that airflow direction in shafts is currently under review and may change). Fresh air will be delivered to working areas within the repository via the access tunnels and in such a manner that underground workers are always in fresh air. The exhaust air will be directed to the vent shaft through a roof-mounted system of steel ducts. A Heating, Ventilation and Air Conditioning (HVAC) plant will condition fresh air prior to delivery to the underground repository.

4.3 Emplacement Rooms

All emplacement rooms will have exposed limestone rock walls and will have a poured concrete floor to allow access by rubber-tired forklifts. In three East Panel rooms, there will be rails embedded flush to the floor surface for access by the rail car carrying the heavy ILW packages. The entrance tunnels to all emplacement rooms will be designed to allow closure of the rooms once filled with waste.

Underground openings have been excavated in similar limestone formations and geologic settings elsewhere in Ontario and the United States /Byerly, 1975 & Raven et al, 1989/. Based on experience in these underground openings, it is expected that there will be no visible seepage into the proposed emplacement rooms and tunnels of the DGR.

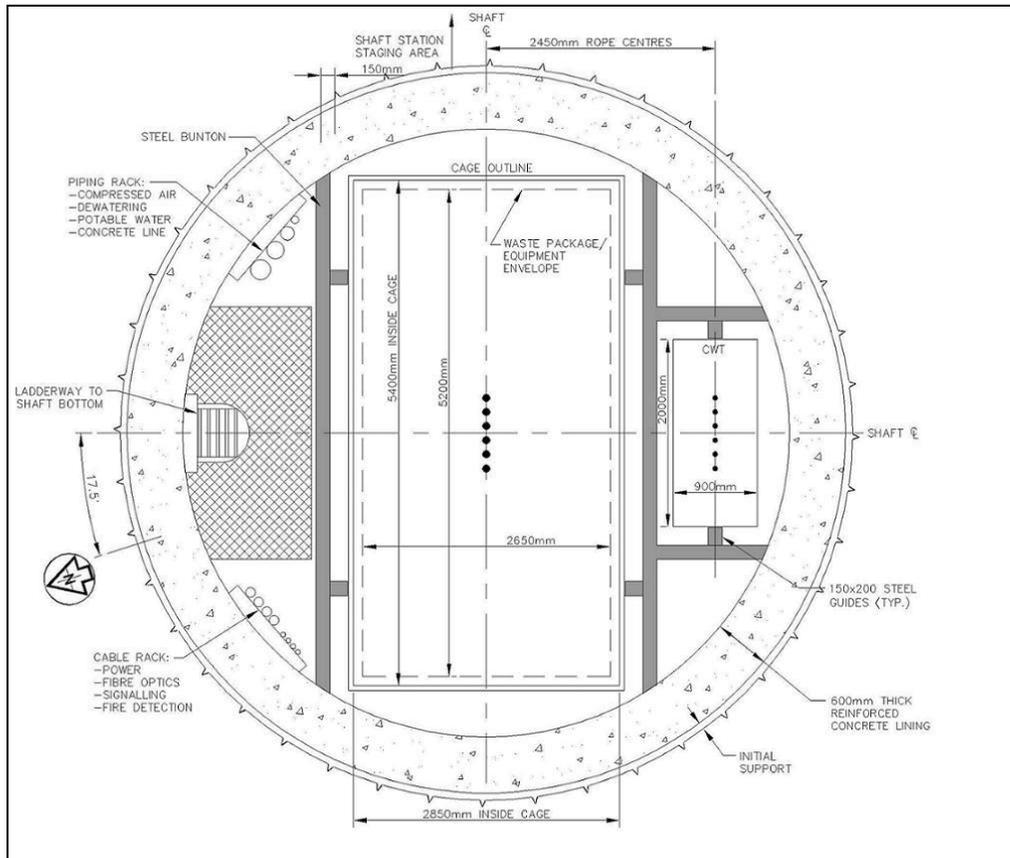


Figure 4.2. Conceptual layout of DGR Main Shaft

4.4 Underground Office, Amenities and Maintenance Areas

Adjacent to Main Shaft and Vent Shaft there will be a Ring Tunnel with excavations to house the underground office and amenities (Figure 4-1). Refuge areas will be located throughout the underground repository and will be equipped with emergency supplies of fresh water, compressed air, a fireproof door and sealing materials, and a communications link with surface. The maintenance area will be used for servicing of all underground equipment. It will also serve as the terminus and distribution point for services brought underground via the Main Shaft.

4.5 Surface Facilities

Two new surface buildings and other ancillary facilities will be constructed, and they will be integrated into the existing infrastructure at the WWMF (Figure 3-1). The Main Headframe and Waste Package Receiving Building will be used to house the Koepe hoisting system, waste receiving facilities, and offices. The Vent Shaft Headframe Building is located above the second smaller shaft, and houses exhaust fans and the access/emergency man-hoist equipment. Nearby will be buildings housing HVAC equipment, electrical substation, emergency generator, and other ancillary facilities.

It is currently assumed that all waste rock from underground excavation will be transferred to an disposal area located on the Bruce site and within the DGR Project Site boundaries. It is estimated that approximately 750,000 m³ (bulked) of waste rock will be produced during the 5-year construction program and placed in the 6-ha disposal area to a height of 15 m.

4.6 Future Design Modifications and Improvements

The proposed layout of the underground repository is based, by necessity, on assumptions about future waste quantities, form in which wastes will be received, nature of the deep rock conditions, and preferred methods to handle waste packages in access tunnels and emplacement rooms. As new information is gathered and assumptions are updated, the layout and design of the underground repository will be modified and improved. Future design studies will also define the final locations of various surface facilities taking into consideration factors such as potential construction impacts, traffic flow, material flows, interaction with current operations, and potential environmental impacts.

5. Repository Operation

L&ILW retrieved from various storage structures at the WWMF or shipped directly from the nuclear generating stations will be received at the DGR waste package receiving area and then transferred into the underground repository.

5.1 LLW Package Handling

It is expected that the majority of LLW packages will be transferred “as is” to the DGR. However all LLW packages will be inspected and if any are found damaged, have high radiation levels, or are otherwise unacceptable for emplacement in the underground repository, they will be placed into an overpack container. The waste packages will be delivered by forklift or truck to the DGR waste package receiving area and then loaded into the Main Shaft cage. The packages will be unloaded from the cage and then transported by forklift to the LLW emplacement rooms. The LLW packages will be stacked in the rooms in a manner similar to current practice within LLSBs (Figures 2-2).

5.2 ILW Package Handling

ILW is currently stored in structures that provide shielding against gamma radiation. In order to provide continuous shielding for workers during handling, it has been assumed that the various ILW containers will be placed directly into concrete shields after removal from storage structures. The shields remain in place during movement to the repository, as well as after emplacement. Depending on the type of ILW and the size of the storage container, the full weight of a shielded ILW package is expected to be in the range of 5 Mg to 35 Mg. A large number of the ILW packages will be in the form of two 3-m³ resin liners stacked inside a cylindrical concrete shield. This type of shield would have a 250-mm-thick wall with a nominal outside diameter of 2 m, an overall length of 5 m, and a full weight of 30 Mg.

At the repository level most ILW packages are transferred by heavy-duty forklift to the emplacement rooms. The large and heavy ILW packages will be transferred by rail car. Once in an emplacement room, a gantry crane is used to unload these ILW packages from the rail car and to place the packages into position within the room.

5.3 Repository Development and Expansion

The repository shown in Figure 4-1 has a modular design that would allow repository capacity to be expanded, as required, to match the L&ILW disposal needs of Ontario’s nuclear power program. It is expected that the geologic conditions at the Bruce site will allow lateral expansion of the repository, if required.

During initial repository construction and prior to start of waste emplacement operations, a sufficient number of emplacement rooms will be constructed to accommodate 186,000 m³ of waste (as-disposed volume). Should a future decision be made to expand beyond this capacity, waste receipt and emplacement operations would cease to allow the construction of additional rooms. During this construction campaign, the waste-filled rooms would be isolated to protect the construction workers. While excavating new emplacement rooms, the access tunnels and shafts will be converted to non-radiological working areas to facilitate construction activities. Any future expansions of the repository to increase capacity beyond the current proposed capacity would require regulatory approval.

5.4 Room Closure and Repository Shaft Sealing Systems

At the completion of room filling, walls will be erected to isolate waste-filled rooms from the active emplacement rooms, access tunnels and the ventilation exhaust tunnel. The walls will be designed to limit release of tritiated air, natural and waste-generated methane, and other off-gases from waste packages (e.g. H₂ and CO₂), as well as potentially contaminated water. Each wall will have provisions to allow venting should monitoring indicate contaminant concentrations in air exceed levels that would not allow safe reentry. Although there is no intention to reenter the emplacement room following sealing, provisions to allow venting and safe reentry are required.

A conceptual sequence of shaft sealing has been developed and includes the stripping of the concrete liners and any excavation-damaged rock on the shaft walls, followed by placement of the clay-based and concrete seal materials. The shaft seals will be designed so that the bulk permeability of the seals will be the same as or less than the permeability of the surrounding shale formations. The seals will be in full contact with the surrounding rock and constructed to limit preferential migration along pathways between the seals and the rock. The time-dependent deformation characteristics of the Ordovician shale may cause “squeezing” of the seals, further enhancing the effectiveness of the shaft sealing systems. It is expected that these clay-based sealing systems will maintain their integrity in perpetuity.

6. DGR Project Schedule

The DGR is currently in the regulatory approvals phase which is expected to last about five years. This process includes geoscientific site investigations, environmental baseline monitoring, safety assessment analyses, conceptual and preliminary engineering design, completion of an Environmental Assessment, and application for Site Preparation and Construction Licences.

It is currently assumed that the Environmental Impact Statement (EIS) will be submitted in 2011 and EA approval will be received in 2012. CNSC Site Preparation and Construction Licence approvals are assumed to be in 2012. L&ILW receipts at the DGR will start in late 2018, and span several decades depending on future developments in Ontario’s nuclear power program.

Acknowledgement

The conceptual design described in this paper is largely based on work completed by Hatch Limited (www.hatch.ca) under contract to Ontario Power Generation.

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