OPG's DEEP GEOLOGIC

REPOSITORY

FOR LOW & INTERMEDIATE LEVEL WASTE

Conceptual Design Report

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OPG's Deep Geologic Repository for Low and Intermediate Level Waste Conceptual Design Study

CONCEPTUAL DESIGN REPORT

February 2008

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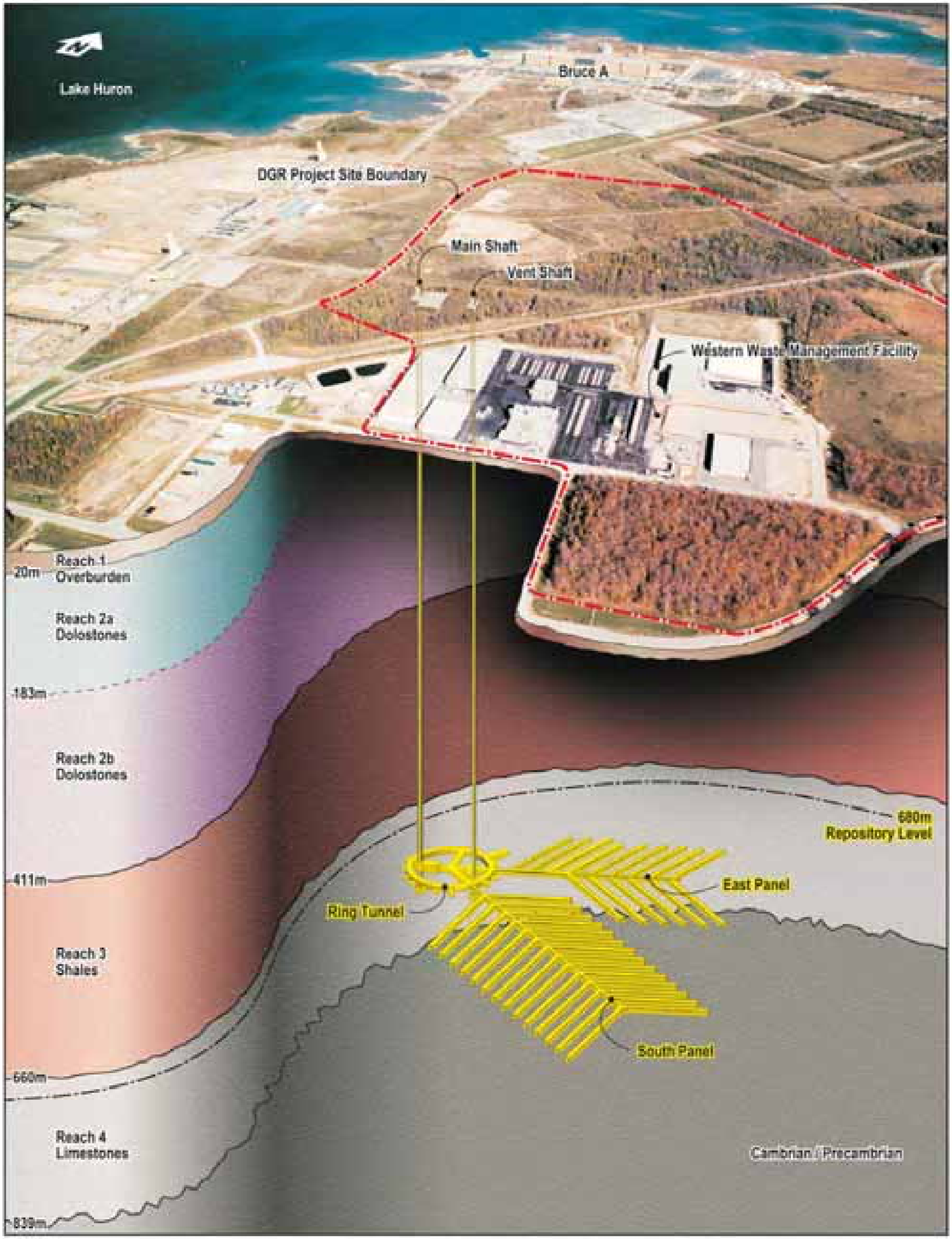
CONCEPTUAL DESIGN REPORT
EXECUTIVE SUMMARY



Executive Summary

Currently Ontario Power Generation manages about 5,000 to 7,000 m^3 of low level and intermediate level radioactive waste (L&ILW) each year from the nuclear power plants at Bruce, Darlington and Pickering in Ontario. LLW typically consists of industrial items and materials, such as clothing, tools and equipment, which have become contaminated with low levels of radioactivity. This waste is sent to the Western Waste Management Facility (WWMF) where it is processed and then placed into interim storage. There are also some large objects, such as heat exchangers and steam generators, which are and will be replaced during refurbishment work at the power plants, and fall into the category of LLW. ILW consists primarily of used reactor components, and resins used to clean the reactor water circuits, which are stored in in-ground containers at the WWMF site. This report describes the conceptual engineering design for OPG's proposed Deep Geologic Repository (DGR) and provides the basis for Preliminary Engineering.

A previous design study was performed in 2004, and this current study updates and advances aspects of that design. The scope of work described in this report involves consideration of all aspects of the DGR including its construction, the receipt of waste from the WWMF and nuclear power plants, and subsequent emplacement.

The DGR consists of surface infrastructure for the receipt of waste packages and transfer underground via a 6.5 metre finished diameter Main Shaft to the repository horizon at 680 metres below surface. The downcast Main Shaft will have a concrete Headframe equipped with a large Koepe multi-rope friction hoist to handle a payload in a large cage of up to 40 tonnes, made up of a maximum waste package mass of 35 tonnes and 5 tonnes allowance for transfer cars, pallets and rigging. An HVAC system, comprising heaters (for winter operations) and refrigeration plant and bulk air cooler (for summer conditions) will supply air at a controlled range of temperatures and humidity to ensure that underground conditions are suitable for workers and maintain the atmosphere in a reasonably steady and dry state to limit corrosion of structures and waste packages.

The 4.5 metre finished diameter Ventilation Shaft will be an upcast shaft with main exhaust fans on surface to pull the spent air out of the repository. Additionally, a second egress single drum hoist will be installed in this shaft. During repository construction, this hoist will also remove the excavated rock from underground using a combination cage and skip conveyance.

Shafts will be excavated by traditional drill and blast methods in the harder dolostones and using vertical road headers in the shales to limit EDZ development. Extensive pre-excavation grouting will be required to sink the shafts through the upper 160 metres of the dolostones and possibly through other layers lower down within the dolostone reach.

A roadheader is considered feasible for the rock mass conditions of the limestones at the repository horizon and is the preferred excavation method for emplacement rooms based on superior excavation control and reduced rock damage. Judicious use of drill and blast excavation methods will still need to be employed for some aspects of repository development, such as the smaller ancillary rooms.

Waste rock piles for the complete excavated volume of rock (893,000 m^3) will be accommodated to the north-east of the two shafts. Of this volume, approximately 26,000 m^3 has been identified as being re-usable for DGR surface and underground construction. The rock piles will be 15 metres high.

A stormwater run-off management system of ditches and a retention pond will be provided to control the outflow of discharge water from the site before release into Lake Huron. The water will also be monitored for contaminants to ensure that no harmful release can occur. Based on the chemical properties of the different rock type, it is not expected that either total dissolved solids or individual chemical concentrations will exceed any regulatory limits. Capping, berms and vegetation will be used to limit the aesthetic impact of the rock piles and control dust and suppress noise. Protection will also be provided to certain environmentally sensitive areas, which have been identified at the site.

Figure I provides an extract from the site base plan showing the key surface structures for the DGR.

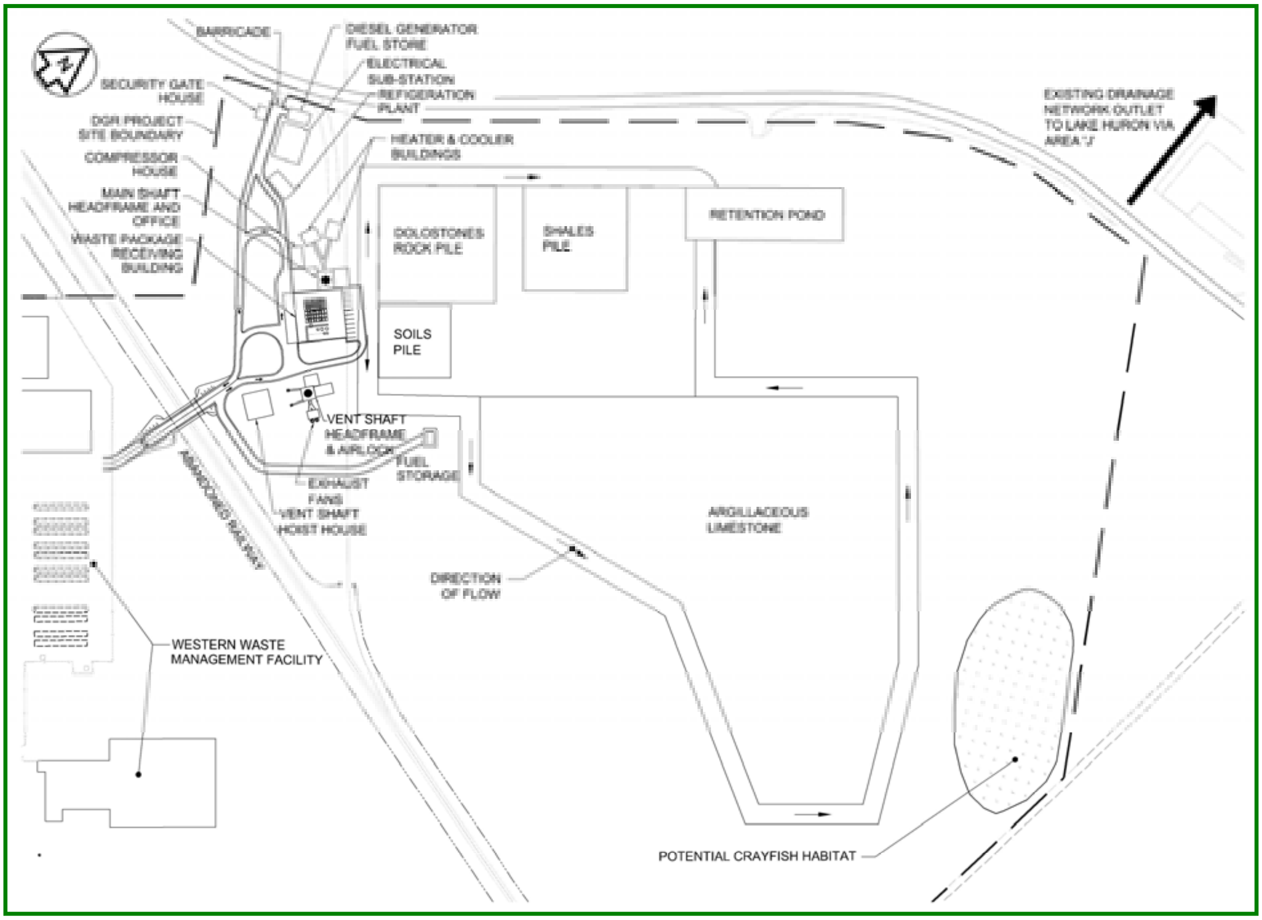


Figure I – DGR Surface Layout

The reference capacity of the repository is nominally 200,000 m^3 of "as-disposed" waste and will be fully developed during initial construction, so that once waste emplacement operations commence, no mining activities, other than inspection and maintenance of rock support, concrete linings and roadbeds, and ventilation systems, will need to occur.

The underground layout of the repository has two vertical shafts located on a central ring tunnel from which two emplacement room access tunnels radiate out to the south and east. This arrangement enables all underground infrastructure to be kept in close proximity to the shaft, while keeping the emplacement areas away from normally occupied and high activity areas. There will be two panels of access rooms, one ("South Panel") containing the majority of the bin and rack type LLW packages and the other ("East Panel") being designed to contain the ILW and certain large, heavy and irregularly shaped LLW packages, such as heat exchangers and steam generators (see Figure II overleaf).

Based on a review of OPG's reference waste inventory data and incorporation of modified shield designs for the resin liners and T-H-E (Tile Hole Equivalent) liners, the final computed "as-disposed" waste volume is estimated at close to 186,000 m^3. For these quantities of waste, packing efficiencies of 63% and 44% for the LLW South Panel and ILW/large LLW East Panel rooms respectively will be achieved.

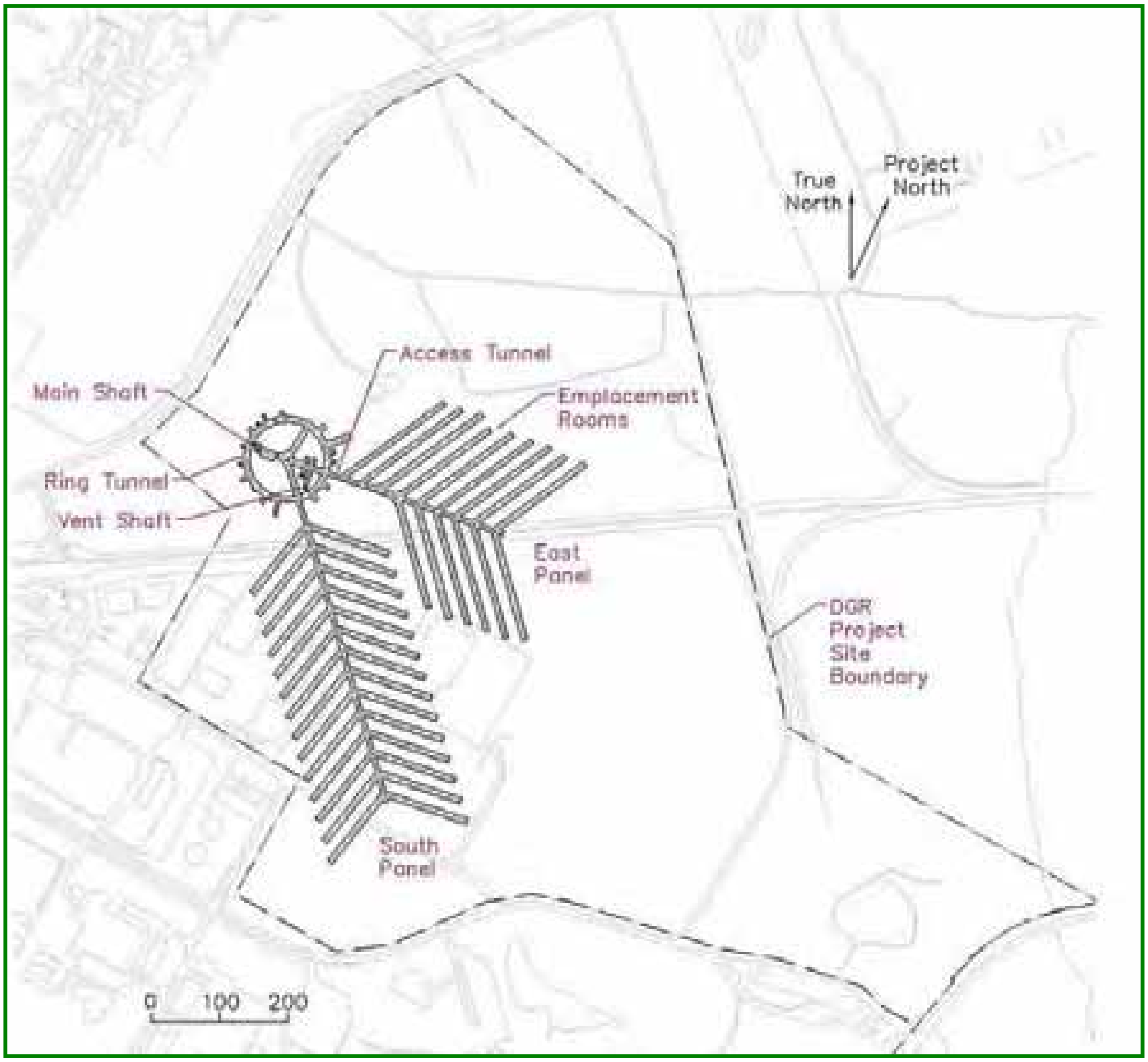


Figure II – DGR Underground Layout

All the emplacement rooms are "dead-ended" in that there is only one way in and out of them from the main access tunnels. To control ventilation air exhausting from the repository, all emplacement rooms and access tunnels will be equipped with solid ventilation ducts to contain air that has flowed over waste packages and duct it right up to discharge in the upcast Ventilation Shaft. In this manner, workers will be isolated from potentially contaminated air.

With the exception of the T-H-E liner waste packages, all waste packages will be 'contact-handleable'. The T-H-E liners will be transferred underground and to their emplacement rooms in a re-usable shield. These shielded wastes are heavy (at a mass of about 32 tonnes) and long (12 metres) and will be transferred on a custom designed rail car handling device, which will enable them to be supported in the shaft cage in a vertical orientation and then rotated to the horizontal after off-loading at the Repository Level Station for transfer into the emplacement room. In the room, an emplacement machine will hydraulically push the T-H-E liner out of its shield and into a mass concrete pipe array, which will provide the necessary permanent shielding. The two T-H-E emplacement rooms will be equipped with a gantry crane to enable the transfer of these long and awkward packages.

All other waste packages will be more simply handled within the shaft cage. They will be moved on and off of the Main Shaft cage on rail cars or by forklift and will be moved to the repository level at one per trip or in multiples, the number depending on their individual mass.

The majority of the waste packages will be transferred from the shaft cage to the emplacement rooms by diesel-powered forklifts. The T-H-E liners, heat exchangers and shield plug containers will be mounted on rail cars on surface and transferred all the way to their emplacement room on rail, where they will be off-loaded and stored using a gantry crane. The East Panel access tunnel and certain rooms will be equipped with rails embedded into the concrete floors of the repository for this purpose.

There will be a total of 43 emplacement rooms, of which 28 will be dedicated to the 'standard-type' LLW (bins and racks) and are identical in cross-section and length. These rooms are all located in the South Panel of the DGR. The East Panel will have 15 rooms of various sizes to most efficiently dispose the ILW and non-standard, large and heavy LLW packages. The rooms and their designed contents are summarised in the table below.

Number of rooms	Contents	Waste Package Codes	Length (m)	Width (m)	Height (m)
28	General 'standard' LLW	BINOPK, B25, BRACK, DRACK, DBIN, NPB47, RTK,	124	8.6	7.0
2	Shield Plug Containers, Heat Exchangers, T-H-Es, IC-2s & certain shielded Resin Liners	SPC, HX, THLIC18, THLIC2	165	8.1	7.2
1	Tile Hole Liners, Encapsulated Tile Holes and certain Steam Generator Segments	THLSTG3, ETH, SGSGMT	171	8.6	5.7
6	Resin Liners (unshielded/overpacked/shielded)	RL, RLOPK, RLSHLD	171	7.7	6.0
3	ILW Shields and certain Retube Waste (pressure tubes)	ILWSHLD, RWC(PT)	162	8.6	5.7
1	Steam Generator Segments	SGSGMT	186	8.4	6.7
2	Retube Waste (end fittings and pressure tubes)	RWC(PT), RWC(EF)	183	7.4	6.3

At the start of DGR operations, a large volume and quantity of waste packages, amounting to 69% and 53% of the total reference LLW and ILW volume respectively, will be in storage at the WWMF. The design will allow transfer of this stored waste to be achieved in approximately 6 years, after which transfer to the repository will likely be performed on a campaign rather than continuous basis.

In addition to the specific aspects of the conceptual design noted above, considerable geotechnical modelling has been undertaken to determine the optimal excavation sizes and define the necessary rock support measures that will be employed. Both shotcreting and rock bolts will be used.

The width of rock pillars between parallel emplacement rooms have been established to be twice the span of the emplacement rooms on the basis of an expected cost, reliability-based design approach for expected Cobourg rock mass conditions of 72 MPa Uniaxial Compressive Strength and Geologic Strength Index of 69.

Current indications from geomechanical tests on samples from DGR-2 borehole suggest that the expected rock mass conditions used are prudently conservative. The current results bode well for conditions at repository depth relative to those used in this design study. Refinement of the pillar width design criteria and the depth location of the repository should be possible as further geomechanical investgiations are undertaken.

Once filled, emplacement room will be closed with block walls having access panels for vantialtion connections. Monitoring of gas emissions and contaminant levels will be undertaken using instrumentation installed in the ducted return air lines and at the inlet to the Ventilation Shaft surface exhaust fans. Should levels show trending that may lead to safety limits being exceeded, pro-active measures can be taken to prevent such an occurrence. Such measures can include reducing or closing off ventilation from any room that is found to be the source of increased levels and retrieval of the offending waste packages.

Waste retrieval will be possible, if required, by simply reversing the process of emplacement to remove any packages that have been identified for retrieval. All the waste package handling equipment (forklifts, gantry cranes, emplacement machines and rail cars) will be able to perform such operations with no more difficulty than during the emplacement process, although it would be expected that some of the larger, heavier or more awkward packages, such as the T-H-E Liners, would take a considerable amount of time to retrieve.

A conceptual design has also been produced for the final repository shaft sealing system, which will provide the long-term post-closure isolation of the repository from the biosphere. This system will include a number of sections at the base of the shafts and within the shaft barrels, which involve stripping off the shaft lining and removal of the portions of the exposed rock to reduce the excavation damaged zone in the shale layers and allow for keying of the seal into the host rock. Concrete plugs will be used for structural support and to retain any internal gas pressure up to 14 MPa, while layers of bentonite clays mixed with sand and asphalt water-stops will provide the sealing mechanism to limit the overall effective hydraulic conductivity to not worse than 10^{-10} m/s.

All conceptual designs have been produced to meet specific Design Requirements and the OPG Waste Acceptance Criteria ([R77]), in particular the shielding designs to ensure that radiation dose rates are limited to 2 mSv/hr contact and the 0.1 mSv/hr at 1 metre, and the 100 year design life. To this end, structural items (steelwork, piping, platework etc.) will all have sacrificial thickness and have corrosion protection applications well in excess of what would normally be found in an industrial or mining plant.

The design has generally been based on using proven methods and equipment for both construction and operations. New technology, which could require an unknown level of development to produce a fully viable and safe product, has been avoided. There are, however, two aspects where equipment will be used in a somewhat unconventional manner; namely, vertical shaft excavation using roadheaders, and rail car-mounted device to rotate the T-H-E liners between the horizontal and vertical for transferring these waste packages in the shaft cage. For both cases, however, the equipment is well-proven in other applications.

The conceptual design has been reviewed to confirm that the repository can be expanded, if required, to accommodate an assumed additional volume of 200,000 m^3 of "as-disposed" waste. Such an expansion would require having a future development and construction campaign. For this the waste emplacement operations would be suspended and both shafts used to support the mining effort in as short a period as is reasonable. The underground infrastructure would already be in place and re-commissioning of explosives magazines and construction material stores and workshops would be easily accomplished. The skip would be re-installed in the Ventilation Shaft conveyance to remove the excavated rock. To achieve this expanded capacity, a new "North Panel", identical to the existing "South Panel" would be developed for the 'standard' LLW rooms, and the "East Panel" would be extended up to near the boundary line of the DGR Project Site to expand the capacity of that panel.

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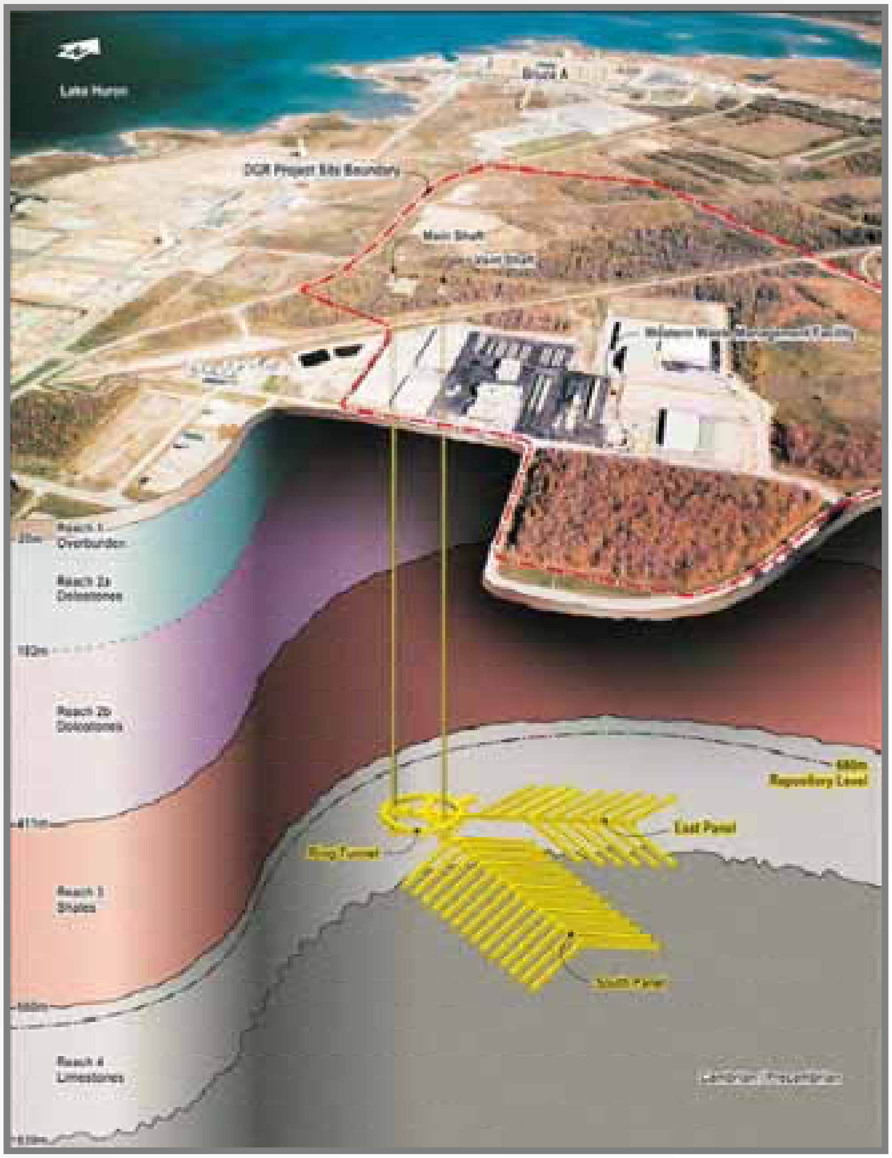

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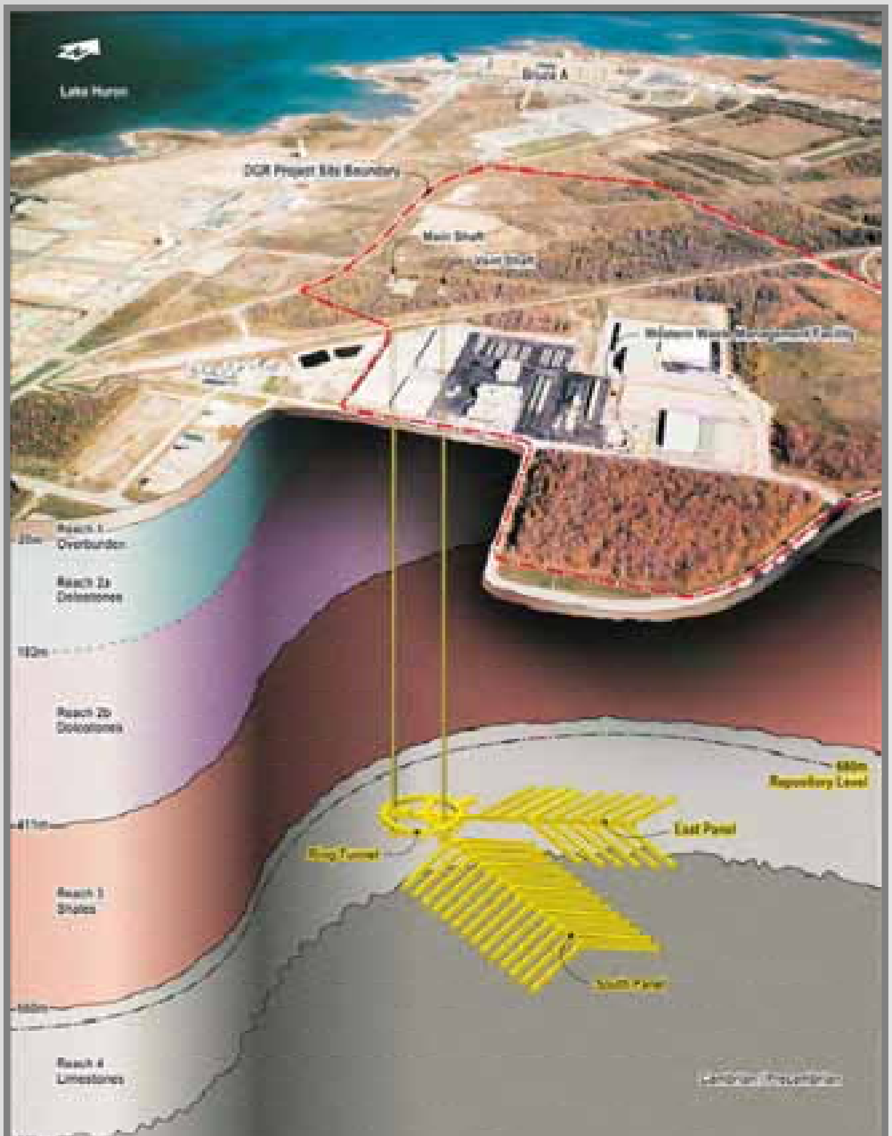
Conceptual Design Report

1. Introduction



1. Introduction

1.1 Background and Purpose

Ontario Power Generation (OPG) is conducting a study for a proposed Deep Geologic Repository (DGR), in which all operational Low and Intermediate Level Waste (L&ILW) generated by the OPG owned nuclear power generating stations will be disposed. This engineering conceptual design report will provide the basis for a future phase of Preliminary Engineering, which would support the application for a Site Preparation/Construction Licence.

L&ILW resulting from the operation and refurbishment of OPG-owned nuclear generating stations is primarily stored at interim facilities at the Western Waste Management Facility (WWMF), which is within OPG-retained lands on the Bruce Nuclear Site in the Municipality of Kincardine.

The Bruce Nuclear Site is owned by OPG, although with some exceptions, the land and generating stations are currently leased to Bruce Power. The WWMF is centrally located on the Bruce Nuclear Site, approximately 2 km from the Bruce A facility, 1.5 km from the Bruce B facility and 1.3 km from Lake Huron. The WWMF occupies approximately 19 hectares on land controlled by OPG.

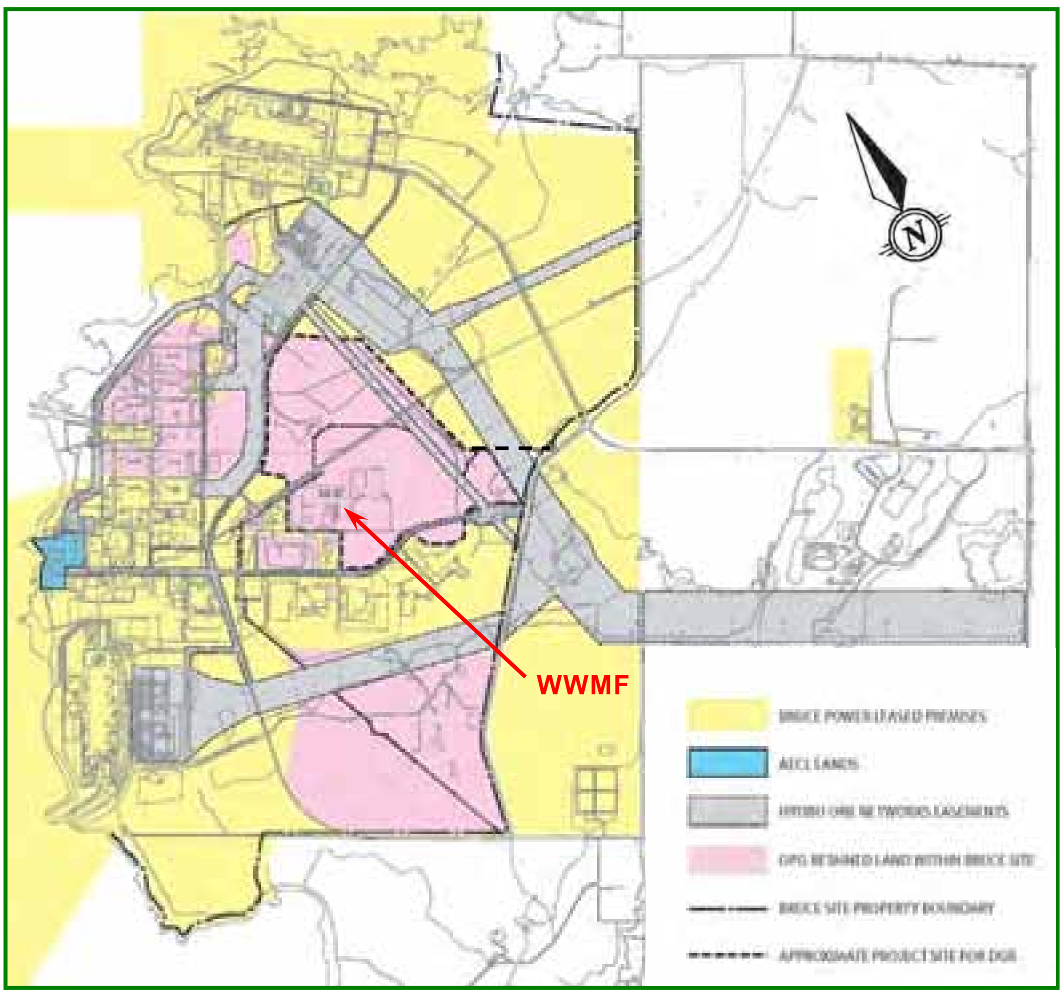


Figure 1-1 – Bruce Nuclear Site with WWMF and DGR Project Site Location

The geologic conditions beneath the Bruce Nuclear Site have previously been evaluated through a review of data in existing reports, and in drilling records maintained by OPG and provincial government agencies. These existing data indicate that the site is underlain by approximately 800 metres of relatively undeformed, horizontally-bedded carbonates and shales, which rest on the crystalline Precambrian basement. In general, the stratigraphic sequence is comprised of an upper 400 metres of Devonian and Silurian-age dolostones with some shale layers. In the geologic past Silurian salt formations with combined thickness up to 100 metres were solution-weathered from within this upper sequence of rocks which has contributed to enhanced permeability of the dolostone formations. The lower half of the sequence is Ordovician in age and is comprised of an upper 200 metres of shale and a lower 200 metres of argillaceous limestone.

The deep geologic conditions at the Bruce Nuclear Site are being confirmed through a comprehensive site characterization program, which commenced in 2006 with the drilling of two boreholes – one to the interface of the dolostones and shales, and the other through the shales and limestones to the Precambrian basement. The new data will be used to confirm the suitability of the proposed host rock formations, to further develop the repository layout and design, and to develop a safety case for the repository.

Annually, about 5,000 to 7,000 cubic metres of low and intermediate level operational waste is currently received at the WWMF. After receipt and processing, the waste is placed into storage. Approximately sixty percent of operational waste from existing reactors, which would be emplaced in the proposed DGR is already stored at the WWMF. This L&ILW will be retrieved from the various storage structures and, when required, processed and/or repackaged, then transferred to the DGR.

Low level waste (LLW), which consists of minimally contaminated materials such as mop heads, rags, paper towels, floor sweepings and protective clothing, is received at the Waste Volume Reduction Building (WVRB). It is then either moved directly into an LLSB, or processed by incineration or compaction to reduce its volume before transfer to an LLSB. Following volume reduction, the low level waste is placed in carbon steel bins that are stacked within above-ground concrete Low Level Storage Buildings (LLSB's).

Intermediate level waste (ILW) consists primarily of used reactor components, and resins and filters used to keep reactor water systems clean. The ILW is loaded into specially reinforced and shielded transfer packages and stored directly in shielded storage structures, quadricells, trenches, tile holes and in-ground containers (ICs). Some wastes may require additional processing and packaging before transfer to the DGR facility.

Large object wastes currently in storage at WWMF include heat exchangers, tanks and steam generators that were removed during various station refurbishment projects. The heaviest and largest objects will be the steam generators (300 tonnes and 100 m^3).

1.2 Overview of Previous Work

Previous conceptual studies for LLW and ILW repositories were conducted in 2003 and 2004, which had led to identification of the feasibility of disposing of this waste in a deep underground facility:

- 2003 – Geotechnical feasibility study of the feasibility of a covered above-ground concrete vault and a deep rock cavern vault in either shale or limestone formations. (Reference [R2])
- 2004 – Conceptual design for L&ILW disposal in a deep repository located 660 metres underground in the Cobourg Formation. (Reference [R3])

The previous DGR concept, which was developed in the [R3] study, comprised horizontally-excavated emplacement rooms arranged in parallel rows with access provided via two vertical concrete-lined shafts. The emplacement rooms would be constructed within a competent limestone formation at reference depth of 660 metres below ground level. The DGR's waste receipt and Headframe building would be used to receive waste packages and to house the Main Shaft hoisting system. This building would also house the Heating, Ventilation and Air Conditioning (HVAC) plant. The Ventilation Shaft would be located about 500 metres to the north-east of the Main Shaft and has buildings containing the access/emergency hoist and the exhaust fans. All underground construction and operational activities would be performed via the Main Shaft.

The previous [R3] study assumed that most waste packages would be retrieved from storage and transferred to the DGR "as is" with shielding added, as necessary, to provide radiological protection. After the start of DGR operations, L&ILW would continue to be shipped from the nuclear generating stations to the WWMF for processing, if required, and then transferred directly to the DGR Main Shaft Receipt Building, by-passing storage. The waste packages would then be lowered by hoist to the repository horizon and transferred by the underground waste handling system to emplacement rooms. Waste packages would be stacked within emplacement rooms by forklift and, when full, the rooms would be isolated from the access tunnel by a constructed wall. The repository could be open as long as 100 years to receive L&ILW from Ontario's nuclear reactors. When filled with waste and after receipt of all necessary regulatory approvals, the repository would be sealed by placing low permeability clay- and concrete-based plugs in each shaft.

1.3 Study Approach

This conceptual design study has updated and advanced the previous [R3] concept. Major aspects of the study included:

- Review of the waste inventory and design of shielding for ILW;
- Review of the underground repository access-way types;
- Geotechnical modelling of the rock mass and emplacement room and other underground opening to determine the optimal layouts and pillar sizes;
- Consideration of different underground layouts and shaft locations;
- Excavation and construction methods;
- Types and sizes of equipment for construction and waste emplacement operations;
- Arrangements of the surface infrastructure, including access from the WWMF and size and location of the waste rock piles;
- Repository sealing design at closure.

The approach for all the elements of the study was to review the previous concept, identify changes required as a result of new or updated information, and improve the level of detail of designs where limited work had been previously performed. In all cases, the philosophy was to determine if safer, more reliable and more cost-effective methods and designs could be used.

1.4 Scope of Report

This report describes the updated conceptual design for the Deep Geologic Repository and covers the following specific investigation and design areas:

- Location and layout of the DGR facility, including surface infrastructure and buildings for the Main and Ventilation Shaft areas, connection to the WWMF, and waste rock disposal on surface within the delineated DGR Project Site;
- Underground repository arrangement, including main access-ways, layout and sizes of emplacement rooms and support infrastructure;
- Construction methods and equipment for the shafts, underground tunnels and emplacement rooms;
- Repository ventilation modelling and conditioning of air throughout the year, including heating and cooling systems, and main fans;
- Geotechnical analysis of stratigraphy, modelling of the underground excavations to determine optimal pillar and room sizes, rock support and grouting requirements, and repository depth;
- Waste package handling & emplacement, including review and update of the inventory of "as-disposed" waste, taking account of revised shielding designs for resin liners and T-H-E liners, and revised reprocessing for large waste packages such as steam generators and heat exchangers; surface handling, transfer into, down and out of the shaft conveyance, underground transfer to the emplacement rooms and emplacement, and materials handling equipment to achieve all the steps in the transfer process;
- Support services, namely dewatering, potable water, compressed air, electrical, lighting, communications requirements, control and monitoring;
- Fire protection and detection, emergency response, zoning and site security requirements;
- Repository construction and development sequences and labour complements;
- Operations schedule and sequence of waste emplacement, labour complements and equipment requirements;
- Final sealing of Repository at Closure.

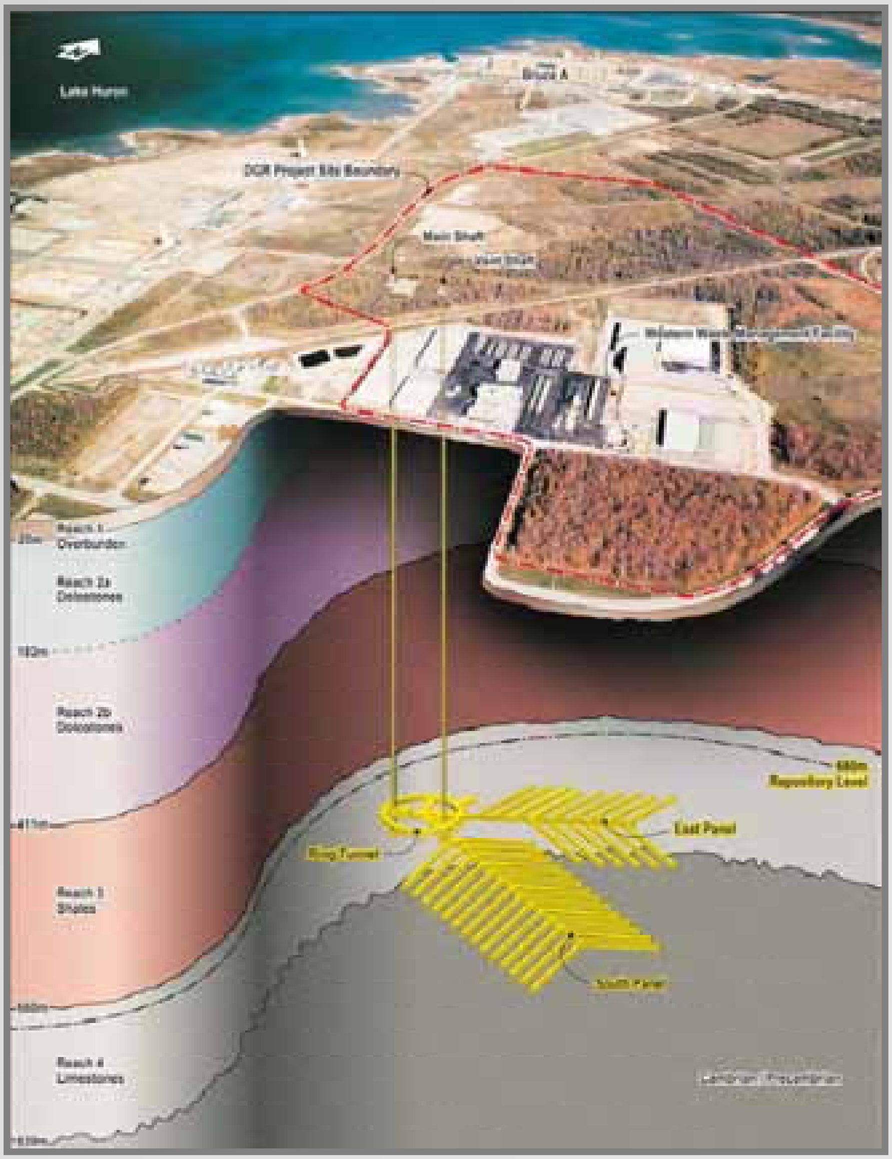
Each key aspect of the study is addressed within the report with reference as relevant to previous work and best practice. Sketches are used to illustrate layouts, equipment and methods proposed, with an appendix containing key dimensioned drawings of surface and underground layouts.

The study has been performed at a conceptual level and the report provides the appropriate level of detail in support of this work, rather than a preliminary or detailed engineering design document.

The study only covers disposal of Low and Intermediate Level Wastes.

Conceptual Design Report

2. Site Location and Characteristics



2. Site Location and Characteristics

The DGR will be located within a delineated DGR Project Site on the OPG retained lands at the Bruce Nuclear Site. The existing Western Waste Management Facility (WWMF) is situated within these lands, which will have a significant role in the life of the DGR Facility during the early years of operations. The waste packages, already in storage by the time the DGR commences underground disposal, will be transferred from the WWMF to the DGR with any re-packaging and shielding being undertaken at the WWMF. Once DGR operations commence, all waste packages will still be received at the WVRB (at the WWMF) and processed there before transfer to the DGR with the exception of resin liners, which will be delivered directly to the WPRB.

Once all the in-ground, large wastes and standard bins and racks have been transferred to the DGR, the WWMF will largely then provide only a support role for the DGR. Access to the surface structures of the DGR will be via a bridge crossing the railway ditch and all waste emplacement staff will have surface office, change house and canteen facilities at the WWMF.

Support services will be provided from the WWMF: i.e. electrical power, sewerage, potable and construction water. All goods and waste packages coming in from outside to the DGR will pass through existing security controls at the WWMF.

Within the DGR Project Site, there are certain restrictions on the positioning of the DGR surface facilities and accordingly the most appropriate area for the shaft infrastructure and waste rock piles are to the north of the existing WWMF. Of key note are the environmentally sensitive railway ditch, which traverses the property from east to west, just north of the WWMF, a low voltage power line running from near the wetlands to the north-west and then north-west towards the LLSB's at the WWMF, and the potential crayfish habitat identified on the eastern boundary. There is also an old construction landfill site south-east of the WWMF. Although this latter area could be used for the DGR surface infrastructure, considerable effort would be necessary in ground preparation for construction.

The salient features of the topography, water courses and existing structures, obstructions and environmentally sensitive aspects in the immediate vicinity of the DGR Project Site are shown in Figure 2-1 below. To provide context the location of the key elements of the proposed DGR surface infrastructure (Shaft positions and rock piles) are also included on this figure.

2.1 Topography and Drainage

2.1.1 Site Topography

A detailed topographic survey of the Bruce site was completed by 4DM Inc. for OPG. The Digital Elevation Model and Lidar files for the site were issued to OPG using the UTM NAD 83, Zone 17 base reference.

The Lidar data indicates that the extent of OPG-controlled lands associated with the Bruce site lies between 180 and 195 m.a.s.l., while Lake Huron is at 176 m.a.s.l. Within the extent of the lands required for the DGR, the surface elevation ranges from 187 m.a.s.l. in the southern portion of the site, to 181 m.a.s.l. in the northern extent.

The site is generally flat with open natural and anthropogenic landscapes, as well as both hardwood (in the uplands) and coniferous (in the lowlands) forested areas.

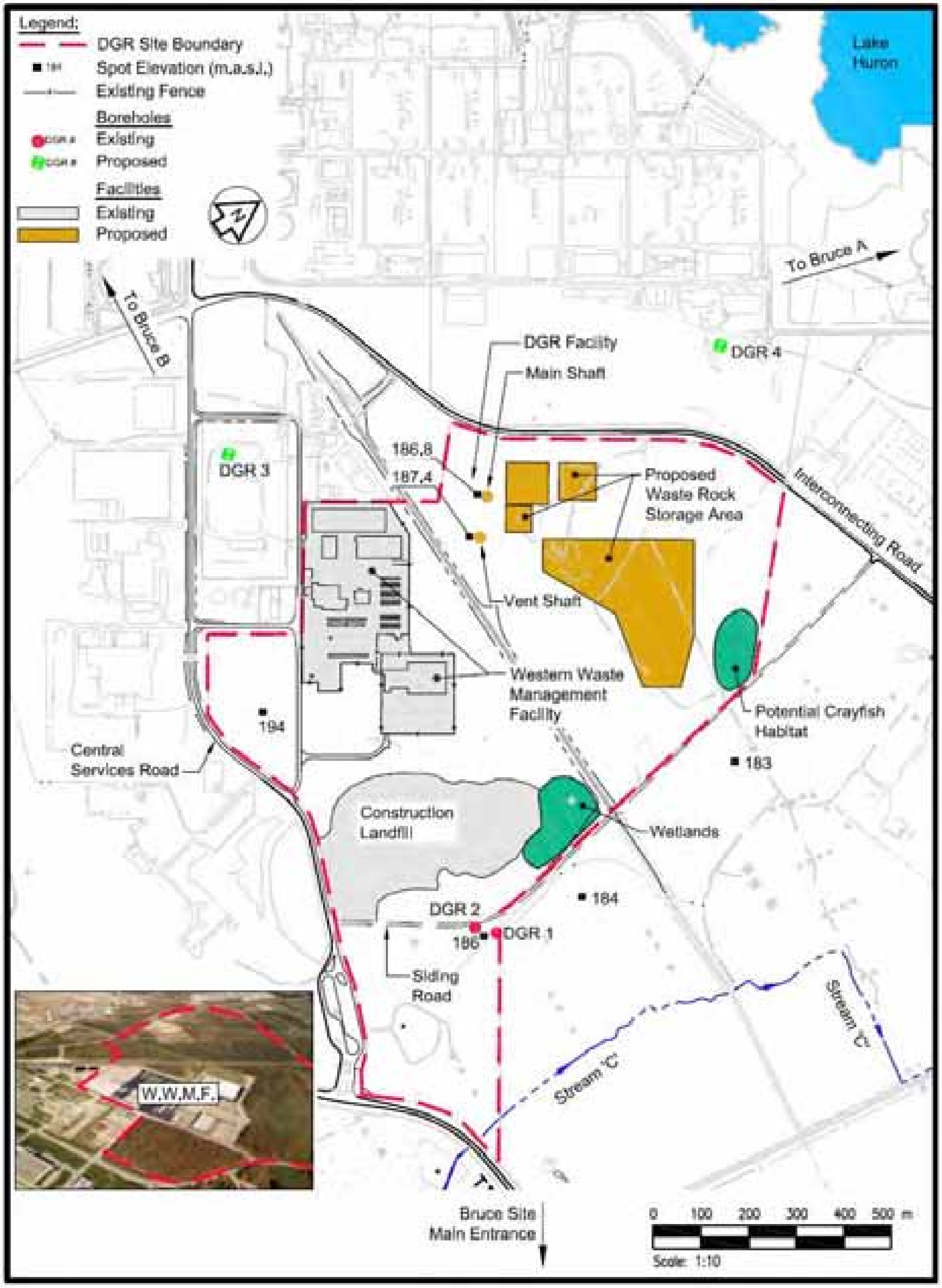


Figure 2-1 – DGR Project Site

2.1.2 Drainage

The watershed in the proposed location of the DGR drains towards the northwest through several existing drainage ditches across the proposed location of surface facilities and waste rock storage. Drainage generally flows in a northerly direction, discharging into Lake Huron through Area 'J'. A locally low portion of the DGR site has been identified as potential crayfish habitat (see Section 4.2.5.13 and Drawing 323874DGR-200-023 in Appendix E). The catchment for this feature primarily occurs to the east of the DGR site, while the outflow from the feature is to the north, where it connects with the aforementioned drainage ditches.

The nearest permanent watercourse to the site is Stream 'C', an important coldwater fish habitat, located approximately 600 m east of the proposed location of the DGR. Stream 'C' drains northeast into the Baie du Doré, Lake Huron.

2.2 Climatic Conditions

2.2.1 Stormwater Volumes

Rainfall volumes for the 100-year, 12 and 24-hour storm events are provided in Table 2-1.

Storm Duration (hours)	Average Rainfall Intensity (mm/hr)	Rainfall Volume (m^3)	Runoff Volume (m^3)**		
			(C = 0.5)	(C = 0.7)	(C = 0.9)
12	8	23,040	11,520	16,128	20,736
24	4.5	25,920	12,960	18.144	23,328

* As obtained from Ministry of Transportation Drainage Management Manual, Part 3, 1997
**Note: "C" refers to Runoff Co-efficient

Table 2-1 – Expected Runoff Volumes for the 100-year 12 and 24 hour storm events*

2.2.2 Temperatures and Precipitation

Climatic normals for nearby meteorological stations were obtained from Kincardine, Hanover and Wiarton, Ontario (Table 2-2, Table 2-3 and Table 2-4). In general, climatic characteristics at this site are expected to be influenced by the close proximity to Lake Huron.

Average temperature for the year is 7.8°C in Kincardine, 6.5°C in Hanover, and 6.1°C in Wiarton. Monthly average lows for both locations occur in January and February, with temperatures averaging around -7°C to -8°C, while average high occur in July with temperatures around 19°C. Monthly average precipitation in this region varies from 68 to 120 mm, with an average annual precipitation of 1030.1 mm in Kincardine, 1048.7 mm in Hanover and 1041.3 mm in Wiarton.

Wind data for the area is available from the Wiarton airport. Data from this station indicate that winds are primarily from the south to southwest, with the exception of April where winds were predominantly from the north (as shown in Table 2-4). Average wind speeds for the year are 13.5 km/h, with January having the highest monthly average (17.1 km/hr), and July having the lowest monthly average (10.2 km/h). The maximum gust speed for this site of 126 km/h was recorded on 30 April 1984.

	Month												Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Temperature													
Monthly Daily Average (°C)	-4.8	-3.9	-0.3	5.2	11.6	17.6	19.6	19.4	16.2	10.0	4.0	-1.5	7.8
Monthly Daily Maximum (°C)	-1.4	0.0	3.9	10.0	16.8	22.8	24.5	24.2	21.2	14.1	7.1	1.4	12.1
Monthly Daily Minimum(°C)	-8.1	-7.8	-4.5	0.4	6.4	12.4	14.6	14.5	11.1	5.9	0.8	-4.4	3.4
Precipitation													
Monthly Rainfall (mm)	27.2	24.7	42.3	64.8	78.3	80.4	76.5	95.6	104.8	84.1	69.1	39.3	740.5
Monthly Snowfall (cm)	89.9	41.1	34.5	8.3	0.0	0.0	0.0	0.0	0.0	1.3	30.5	84.0	289.7
Monthly Precipitation (mm)	119.7	72.9	68.6	63.3	91.1	70.3	62.5	68.1	104.0	84.1	108.4	117.2	1030.1

* Latitude: 44° 10.120'N / Longitude: 81° 37.120'W / Elevation: 203.00m.a.s.l. / Source: [R6].

Table 2-2 – Kincardine, Ontario Climate Normals (1995-2005)*

	Month												Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Temperature													
Monthly Daily Average (°C)	-7.1	-6.7	-1.7	5.4	12	16.9	19.5	18.5	14.3	8.3	2.4	-3.8	6.5
Monthly Daily Maximum (°C)	-3	-2	3.2	10.9	18.6	23.3	26	24.7	20.2	13.3	6	-0.2	11.8
Monthly Daily Minimum(°C)	-11.2	-11.4	-6.6	0	5.4	10.4	13	12.3	8.4	3.3	-1.3	-7.5	1.2
Precipitation													
Monthly Average Rainfall (mm)	27.2	24.7	42.3	64.8	78.3	80.4	76.5	95.6	104.8	84.1	69.1	39.3	787.1
Monthly Average Snowfall (cm)	83.2	46.9	30.1	9.5	0	0	0	0	0	1.2	28.5	62.2	261.6
Monthly Average Precipitation (mm)	110.4	71.6	72.4	74.3	78.3	80.4	76.5	95.6	104.8	85.3	97.6	101.5	1048.7
Extreme Daily Rainfall (mm)	34.9	51.2	35.8	44.5	78	60	56.2	95.8	68.8	36.8	44.6	50.3	
Extreme Daily Snowfall (cm)	33.6	30.5	36	25.9	0	0	0	0	0	17	39.5	40	
Extreme Daily Precipitation (mm)	34.9	53.3	36	44.5	78	60	56.2	95.8	68.8	36.8	44.6	50.3	

* Latitude: 44° 7.200'N / Longitude: 81° 0.600'W / Elevation: 270.00m.a.s.l. / Source: Environment Canada, 2004a. [R7].

Table 2-3 – Hanover, Ontario Climate Normals (1971-2000)*

	Month												Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Temperature													
Monthly Daily Average (°C)	-6.8	-6.9	-2.2	4.7	10.9	15.6	18.6	18.1	14	8.4	2.6	-3.3	6.1
Monthly Daily Maximum (°C)	-2.8	-2.4	2.4	9.5	16.6	21.3	24	23.2	19	12.8	6	0.2	10.8
Monthly Daily Minimum(°C)	-10.8	-11.3	-6.8	-0.1	5.1	9.8	13.1	12.8	9	4	-0.8	-6.8	1.4
Precipitation													
Monthly Average Rainfall (mm)	21.8	20.7	36.6	54.9	74.3	74.4	71.2	85.2	104.3	86.9	77.7	32.4	740.4
Monthly Average Snowfall (cm)	125.2	74.3	46.4	15.3	1.1	0	0	0	0	4.4	47.7	112.1	426.6
Monthly Average Precipitation (mm)	105.3	68	73.4	68.1	75.3	74.4	71.2	85.2	104.3	91	115.6	109.5	1041.3
Extreme Daily Rainfall (mm)	32	48	36.1	45.3	48.8	67.8	104.6	73.4	88.6	69.3	46	45.5	
Extreme Daily Snowfall (cm)	51.4	30.7	45.5	26.8	14.5	0	0	0	0.2	23.6	32.5	38.4	
Extreme Daily Precipitation (mm)	47.6	48.6	47.2	45.3	48.8	67.8	104.6	73.4	88.6	69.3	46	45.5	
Wind													
Speed (km/h)	17.1	14.7	14.6	14.4	11.8	10.5	10.2	10.3	11.9	14.5	15.9	16	13.5
Most Frequent Direction	S	S	S	N	SW	SW	SW	SW	S	S	S	S	S

* Latitude: 44° 45.000'N / Longitude: 81° 6.000'W / Elevation: 222.20m.a.s.l. / Source: Environment Canada, 2004b [R8] .

Table 2-4 – Wiarton, Ontario Climate Normals (1971-2000)*

Note: "Precipitation" in Table 2-2, Table 2-3 and Table 2-4 is the water equivalent of all types of precipitation. At most ordinary stations the water equivalent of snowfall is computed by dividing the measured amount by ten. At principal stations it is usually determined by melting the snow that falls into Nipher gauges. The amount of snow determined by this method normally provides a more accurate estimate of precipitation than using the 'ten-to-one' rule. Even at ordinary climate stations the normal precipitation values will not always be equal to rainfall plus one tenth of the snowfall. Missing observations is one cause of such discrepancies.

2.3 Generalised Area Geology

The main emplacement rooms, ancillary rooms and access tunnels of the DGR will be constructed in the Cobourg limestone formation that is located at a depth that is approximately between 660 m and 687 m below grade surface (bgs) at the Bruce Site. The planned repository depth would be at depth of 680 m (bgs). Access and ventilation to this level will be provided by two shafts that will be constructed through the interlying geology. An understanding of the geology beneath the Bruce Site used in this study has been developed over a number of studies and investigations.

In addition to the GSCP investigations, the results of other nearby investigations were also utilised. As part of a previous study relating to the DGR, an interpreted stratigraphic sequence at the Bruce Site was established through a review of local deep natural gas exploration wells by Golder in 2003 [R2]. The stratigraphic interpretation was based upon drill records primarily from the Texaco #6 exploration well, located 3 km southeast of the site and is considered representative of the full Palaeozoic sequence to depths of 880 m where the granitic Precambrian basement rocks were encountered. In addition to the Texaco #6 exploration well, the stratigraphic column was developed with consideration of the Union Gas Co. Kincardine #1 and Texaco #4 well records.

In 1986 through 1988, the bedrock stratigraphy directly underlying the DGR Project Site was investigated to an approximate depth of 100 metres over several geotechnical investigations carried out for Ontario Hydro. A total of six boreholes (US-1 to US-6) were drilled in the immediate vicinity of the WWMF and the proposed DGR shaft access area for part of previous waste management investigations [R13]. The investigations are referred to as the "US Boreholes".

As part of the Ontario Power Generation (OPG) Geoscientific Characterization Plan (GSCP) for the Bruce Site, Intera Engineering Limited recently completed Phase 1 investigations [R9] which included a deep bedrock drilling program of two vertical 152 mm diameter continuously cored boreholes (DGR-1 and DGR-2) to depths of approximately 462 and 862 meters below ground surface (m bgs). Both of these boreholes were drilled at the same location at the Bruce site. The results of this investigation improve upon the accuracy of the previous interpretative stratigraphic sequence and form the primary basis for the conceptual design of the DGR. The laboratory testing results associated with those investigations were summarised in a number of technical memoranda [R10], [R11] and [R12].

The relative location of the DGR-1 and DGR-2 boreholes, Texaco #6, Texaco #4, Union Gas Co. Kincardine #1 and US Boreholes relative to the DGR Project Site are shown in Figure 2-2 and the stratigraphic sequence and classification of the rock units encountered and developed stratigraphic column from these boreholes are shown in Figure 2-3.

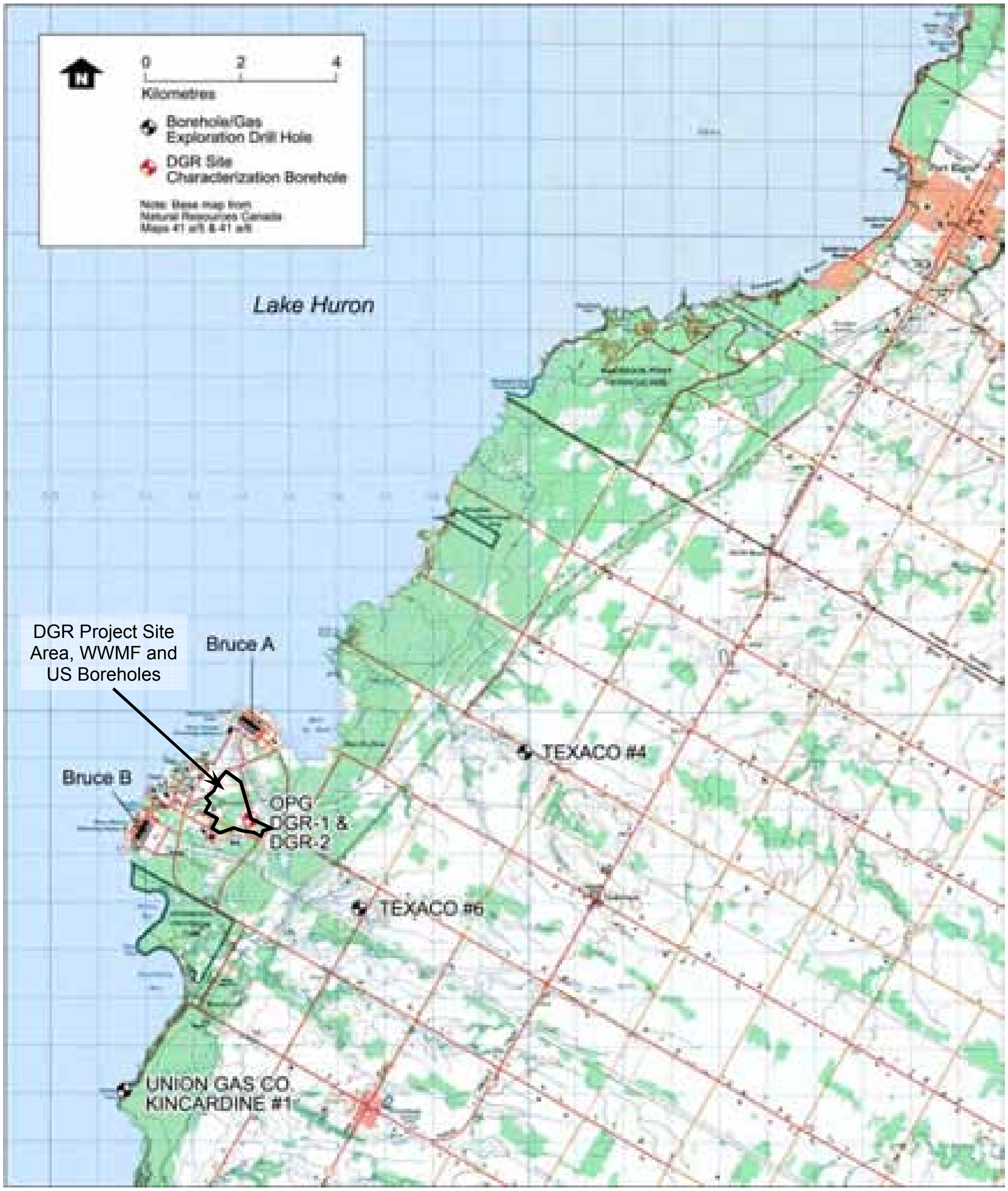


Figure 2-2 – DGR Project Site Showing Area Topography and Location of Geologic Investigations

2.3.1 Overburden Deposits

The total overburden thickness overlying the bedrock varies between 1.5 to 18 m over the Bruce Site but at the shaft site locations is expected to be between 15 to 20 metres on the basis of the DGR-1 and DGR-2 boreholes and US boreholes. The overburden is comprised of a comparatively complex sequence of surface sand and gravel from former beach deposits overlying clayey silt to sandy silt till with interbedded lenses and layers of sand of variable thickness and lateral extent. Near the present Lake Huron shoreline, sand, gravel and boulders left from beach deposits thinly overlie the bedrock.

At the Western Waste Management Facility and the DGR-1 boring locations of the Bruce Site, the area is underlain by up to 20 m of surficial deposits over bedrock. The sequence is subdivided in descending order into a surficial layer of sand and gravel, a weathered brown till horizon 2 to 4 m thick overlying fresh grey till comprised of dense silty sand to very hard clayey silt with sand and boulders. The till has been described as massive in character and although saturated, it appears 'dry' when excavated due to its well-graded fine-grained composition and low permeability. The till is split by a middle sand layer of quite variable thickness and lateral extent that is locally in direct contact with the bedrock. This 'Layered Till' contains thin laminations and lenses of wet silt and sand which result in this till appearing 'wet' when exposed. This layer overlies the middle sand layer.

2.3.2 Bedrock Geology

The overburden is underlain by near flat lying Palaeozoic age dolostone, shale and limestone sedimentary rock to an estimated depth of about 840 m (bgs) where Precambrian granite basement is encountered. These sub-horizontal bedding units dip approximately one percent to the WSW (i.e. beneath Lake Huron).

The entire Palaeozoic sedimentary sequence beneath the Bruce Site is in the order of 860 m thick and overlies the Precambrian basement. The sequence consists of approximately 375 m of Devonian and Silurian age dolostones extending downward through the Amherstburg, Bois Blanc, Bass Island, Salina, Guelph, Lockport and Reynales Formations. This sequence is underlain by an approximately 250 m thick section of predominately shale consisting of the Lower Silurian age Cabot Head Formation (~20 m), the Manitoulin Formation dolostone (~16 m), the Upper Ordovician age Queenston Formation (~70 m), the Georgian Bay Formation (~98 m), the Blue Mountain Formation (~36 m) and Collingwood Formations (~7 m). The shales overlie a 185 to 190 m thick sequence of Middle Ordovician limestone including the Cobourg, Sherman Fall, Bobcaygeon and Gull River Formations.

Correlations between the stratigraphic sequences encountered at the Bruce Site and to similar stratigraphic sequence and units on the south shore of Lake Huron north shore of Lakes Erie and Ontario confirm that the lateral continuity of strata within this sequence (including thickness variations) can be demonstrated over Southwestern Ontario. Along the north shore of Lake Ontario and east of Toronto, the Ordovician limestone formations come to surface and are exposed within rock quarries and tunnels which have been driven within the Cobourg Formation at the Darlington Nuclear Generating Station and the previously proposed Wesleyville Thermal Generating Station. These stratigraphic sections demonstrate the lateral continuity of the formations across Southern Ontario including into the Ottawa area, providing evidence that the rock properties established within the strata adjacent to Lake Ontario can be extrapolated to the Bruce Site where the strata occur at depth.

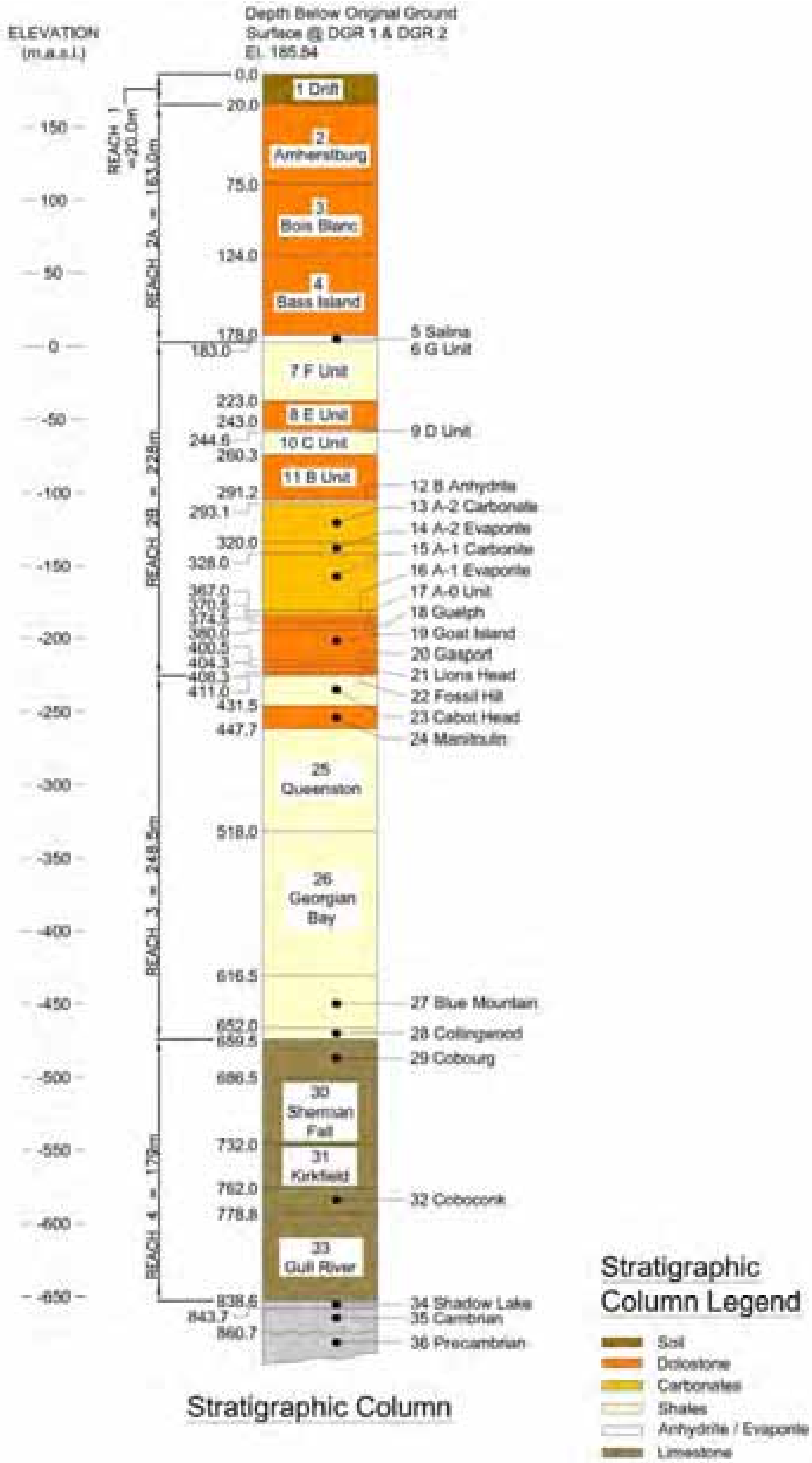


Figure 2-3 – Updated Bedrock Stratigraphic Column Based on Investigation Boreholes DGR-1 and DGR-2

2.4 Hydrogeologic Conditions

Information on hydrogeologic conditions at the proposed location of the DGR is based on the preliminary results of materials removed from the DGR-1 and -2 boreholes (Table 2-5) and the LLW Geotechnical Feasibility Study for the Western Waste Management Facility of the Bruce Site ([R2]).

Unit (Reach)	Physical Properties					Chemical Properties
	Rock Type	Thickness (m)	K_V/K_H	K_H (m/s)*	Porosity	Average TDS (g/l)**
1) Drift (1)	Overburden	20.0	1:5	1.00×10^{-04}	0.10	0.5 (11)
2) Amherstburg (2a)	Dolostone	55.0	1:10	1.00×10^{-05}	0.10	0.5 (1)
3) Bois Blanc (2a)	Cherty dolostone	49.0	1:10	1.00×10^{-05}	0.10	1.6 (2)
4) Bass islands (2a)	Dolostone	54.0	1:10	1.00×10^{-05} *	0.10	1.6 (2)
5) Salina (2a)						
6) G Unit (2a)	Shaley dolostone with anhydrite	5.0	1:10	1.00×10^{-05}	0.08	
7) F unit (2b)	Dolomitic shale with anhydrite	40.0	1:10	4.00×10^{-12} P	0.03	310 (3)
8) E Unit (2b)	Dolostone with dolomitic shale	20.0	1:10	4.00×10^{-12} P	0.08	
9) D Unit (2b)	Anhydritic dolostone	1.6	1:10	1.00×10^{-10}	0.08	
10) C Unit (2b)	Dolomitic shale and shale	15.7	1:10	6.00×10^{-12} P	0.03	
11) B Unit (2b)	Dolostone with anhydrite	30.9	1:10	2.00×10^{-12} P	0.08	
12) B Anhydrite (2b)	Anhydrite	1.9	1:1	1.00×10^{-13}	0.08	
13) A-2 Carbonate (2b)	Dolostone	26.9	1:10	1.00×10^{-10} D	0.08	
14) A-2 Evaporite (2b)	Anhydritic dolostone	8.0	1:1	2.00×10^{-07} *S	0.08	340 (2)
15) A-1 Carbonate (2b)	Dolostone	39.0	1:10	2.00×10^{-12} P	0.08	300 (2)
16) A-1 Evaporite (2b)	Anhydritic dolostone	3.5	1:1	1.00×10^{-13}	0.08	
17) A-0 Unit (2b)	Bituminous dolostone	4.0	1:10	1.00×10^{-08} S	0.08	
18) Guelph (2b)	Sucrosic dolostone	5.5	1:10	1.00×10^{-08} S	0.08	300 (12)
19) Goat Island (2b)	Dolostone	20.5	1:10	1.00×10^{-07}		
20) Gasport	Dolostone	3.75	1:10		0.08	
21) Lions Head	Dolostone	4.05	1:10	2.00×10^{-11} D		
22) Fossil Hill (2b)	Dolostone	2.7	1:10	2.00×10^{-11} D	0.08	
23) Cabot Head (3)	Shale	20.5	1:10	2.00×10^{-11} D & 2.00×10^{-12} P	0.03	240 (25)
24) Manitoulin (3)	Argillaceous dolostone	16.15	1:10	2.00×10^{-12} P & 1.00×10^{-12} P	0.01	
25) Queenston (3)	Red shale	70.35	1:10	1.30×10^{-11} (3) P	0.11	
26) Georgian Bay (3)	Grey shale and siltstone	98.5	1:10	1.20×10^{-11} (4) P	0.11	180-270
27) Blue Mountain (3)	Grey shale	35.5	1:10	1.00×10^{-11} P & 5.30×10^{-12} P	0.11	
28) Collingwood (3)	Grey shale	7.5	1:10	9.60×10^{-12} P	0.11	
29) Cobourg (4)	Argillaceous limestone	27.0	1:10	9.60×10^{-12} P	0.02	210 (38)
30) Sherman Fall (4)	Shaley and argillaceous limestones	45.5	1:10	7.90×10^{-12} P & 1.00×10^{-11} P	0.02	

* P= Pulse, D = DST, F = Flow, S = Slug
** Number of tests/analyses indicated in brackets with average value

Table 2-5 – Physical and Chemical Properties of DGR Rock Units

2.4.1 Hydraulic Conductivity

Hydraulic conductivity of the surficial deposits and bedrock below the Bruce Site extend over several orders of magnitude (Table 2-5). Highest permeabilities generally occur in the surficial deposits and shallow bedrocks close to the surface, and decrease with increasing depth below ground surface.

Reach 1, the surficial deposits, is characterized by horizontal permeabilities in the order $1x10^{-4}$ m/s.

Reach 2a is comprised of the shallow bedrock layers to a depth of 183 m below ground surface. Permeabilities in this reach are on the order of $1x10^{-5}$ m/s. Based on the loss of drilling fluid within DGR-1, there is a zone of extremely high permeability located in the Bass Islands formation, within this reach, at 140-143 m below ground surface.

Reach 2b includes shales and dolostones and cover a wide range of permeabilities. The highest permeabilities within this reach have been recorded in the Guelph Formation and Goat Island member of the Lockport Formation ($1x10^{-7}$/$1x10^{-8}$ m/s), while the lowest permeabilities are observed in the shales and upper dolostone unites ($4x10^{-12}$ m/s).

Reach 3, comprised primarily of shales and the dolostones of the Manitoulin Formation, is a reach of very low permeability, ranging from $1x10^{-11}$ m/s in the Blue Mountain Formation, to $9.6x10^{-12}$ m/s in the Collingwood Formation.

Much like Reach 3, Reach 4 represents a zone of very low permeability. The limestones of this unit range from $1x10^{-11}$ m/s in the Kirkfield Formation to $9.6x10^{-12}$ m/s in the Cobourg Formation (the location of the proposed DGR).

2.4.2 Groundwater Levels and Directions of Groundwater Flow

Based on water well records from the region surrounding the Bruce Site, groundwater in this area flows west towards Lake Huron. As a result, the Bruce site is down-gradient of any groundwater users. Groundwater levels within the Bruce Site are either slightly above or slightly below 176 m.a.s.l., the level of Lake Huron. In the vicinity of proposed location for the DGR, groundwater was found in the shallow bedrock at 9 to 12 m below ground surface, or approximately 180 to 184 m.a.s.l., and in the overburden 1 to 2 m below ground surface, or approximately 190 to 192 m.a.s.l.

These groundwater levels are indicative of a downward hydraulic gradient through the overburden towards the bedrock, then horizontally to Lake Huron.

2.4.3 Groundwater Quality

Groundwater quality within Reach 1 and the upper portion of Reach 2a (Amhertsburg, Bois Blanc, and Bass Islands Formations) is typical of that found within limestone and dolostone terrain. In these locations, groundwater has the following characteristics: fresh, hard, neutral to slightly alkaline pH, calcium, magnesium, bicarbonate and sulphate mineralised. Total dissolved solids in this area range from 0.5 to 1.6 g/l, generally increasing with depth. This fresh water within these bedrock formations is representative of water that has evolved from infiltration or precipitation over time and actively circulates within these areas.

At greater depths, groundwater becomes saline to brine water, with total dissolved solids ranging anywhere from 180 to 340 g/l. Dissolved constituents in this water can vary primarily from sodium chloride in the saline water to calcium chloride in the brine water. These waters are representative of ambient waters that have been present in these formations over geological timeframes.

2.5 Geotechnical Engineering Characterization

For the purposes of developing the conceptual design of the Deep Geologic Repository, a desk study was performed to characterise the anticipated engineering behaviour of the soil and rock units in response to shaft and emplacement room construction. This involved review of previous studies, available historical borehole logs and case study information of relevant works performed elsewhere but in the same geologic formations anticipated to be encountered during construction of the DGR. The assessments made during the desk study were modified as appropriate based upon the results of the recent DGR-1 and DGR-2 borehole investigations.

Unless stated explicitly otherwise, the geomechanical basis, assumptions and descriptions contained herein have been based upon information previously summarised in the following documents:

> "Conceptual Design of a Deep Repository for Low and Intermediate Level Waste at Ontario Power Generation's Western Waste Management Facility", Report prepared by Parsons MMM Joint Venture in association with Golder Associates for Ontario Power Generation, March 2004. [R3]

> "LLW Geotechnical Feasibility Study, Western Waste Management Facility, Bruce Site, Tiverton, Ontario", Report by Golder Associates for Municipality of Kincardine and Ontario Power Generation, January 2003. [R2]

> "Technical Report TR 04-01 - Long-Term Used Nuclear Fuel Waste Management - Geoscientific Review of the Sedimentary Sequence in Southern Ontario", Report prepared by Mazurek, M. 2004, Institute of Geological Sciences, University of Bern, Switzerland. [R14]

> "Characterising the Geomechanics Properties of Sedimentary Rocks for the DGR Excavations", Paper by Lam, T., Martin, D. and McCreath, D., Canadian Geotechnical Society 2007 Conference, Ottawa 2007. [R15]

Relevant excerpts from those works were utilised in the development of the following sections and in the engineering characterization and anticipated behaviour descriptions described in the Shaft Construction and Emplacement Room and Access Tunnel Construction Sections of this document.

2.5.1 Ground Categorisation by Reach

Based on the stratigraphic sequence and the anticipated hydraulic conductivity of the various rock units as shown in Figure 2-3, the ground units within the DGR Project Site Boundary were categorised into four different geologic units (denoted as "Reaches") on the basis of generalised anticipated engineering behaviour. A brief description of these reaches follows with all quoted elevations and depths made on the basis of the recent DGR-1 and DGR-2 borehole investigations.

- **Reach 1 – Overburden**
  - Nominally from EL. 186 to 166 metres above sea level ("masl") (Depth from 0 to 20 m depth below ground surface (bgs))

- **Reach 2 – Dolostones**
  - **Reach 2a – Highly Permeable Dolostones**
    - EL. 166 to –3 masl (Depth 20 to 183 m bgs)
    - 169 metres thick
  - **Reach 2b – Reduced Permeability Dolostones**
    - EL. -3 to –225 masl (Depth 183 to 411 m bgs)
    - 222 metres thick
- **Reach 3 – Shales**
    - EL. –225 to –474 masl (Depth 411 to 660 m bgs)
    - 249 metres thick
- **Reach 4 – Limestones**
    - EL. –474 to –653 masl (Depth 660 to 839 m bgs)
    - 179 metres thick
    - Cobourg (Lindsay) Formation, repository floor level at –494.2 masl (680 m bgs)

2.5.2 Engineering Works of Significance

To characterise the anticipated engineering behaviour, part of the geotechnical desk study included a review of relevant case studies in the literature consisting of geotechnical investigations of tunnel and shaft projects excavated within the Southern Ontario area and in geology identical or substantially similar to the Bruce DGR site. Review of the performance of similar works and the geomechanical behaviour of the ground mass in response to those works, assisted in the development of the conceptual designs used in this study.

The following projects and investigations have been organised to reflect projects of significance to each of the engineering characterizations or reaches described previously.

Works of Significance to Reach 2 – Dolostones

- Ontario Hydro US Boreholes - Bruce Site ([R13]).
- Bruce B Nuclear Generating Station Intake Tunnel - Bruce Site ([R16]] and [R36]).
- Goderich Mine Access Shaft - Goderich, Ontario ([R17], [R18], and [R19]).
- Drumbo Mine Access Shaft – Drumbo, Ontario ([R20]).
- Ojibway Mine Access Shaft – Windsor, Ontario. ([R2]).
- Detroit River International Crossing – Windsor, Ontario ([R21]).

- **Works of Significance to Reach 3 – Shales**
- Niagara River Hydroelectric Development – Niagara Falls, Ontario ([R22], [R23], [R24]).
- Burloak Water Intake Pipe – Oakville, Ontario ([R23]).
- Lakeview Generating Station Geotechnical Investigations – Mississauga, Ontario ([R27]) (also provides information with respect to Reach 4).
- Heart Lake Tunnel – Mississauga, Ontario ([R28], [R29]).
- Thorold Tunnel - Thorold, Ontario ([R30]).
- Multiple tunnels and foundation investigations in Southern Ontario and New York ([R31], [R32], [R33], [R34], [R35]).

Works of Significance to Reach 4 – Cobourg (Lindsay) Limestones

- Wesleyville Access Tunnel – Port Hope, Ontario ([R36]).
- Darlington Intake Tunnel - Bowmanville, Ontario ([R36] and [R37]).
- Multiple tunnels and foundation investigations in Southern Ontario and New York ([R34], [R35] and [R38]]).

2.5.3 Reach 1 – Overburden

The total overburden thickness overlying the bedrock is expected to range from approximately 15 to 20m over the DGR surface site. Other anticipated conditions regarding Reach 1 – Overburden include:

- Glacial & shoreline (lacustrine) deposits.
- Sand - dense to very dense, fine to medium sand, with coarse sand to medium gravel.
- Weathered Till - compact to very dense silt to fine sand, with some coarse sand to medium angular gravel and occasional cobbles.
- Unweathered Till - dense to very dense fine sand and silt, with some coarse sand to medium angular gravel and occasional angular cobbles.

The assumed geomechanical basis for Reach 1 – Overburden materials was made on the representative Till Composition and Standard Penetration Test (SPT) values, summarised in Table 2-6 and Table 2-7 respectively.

Material	Range (%)
Sand/gravel	30-50
Silt	38-52
Clay	11-18

Table 2-6 – Reach 1 - Overburden: Representative Till Composition

Material	N-Value Range (blows/ft)	N-Value Average (blows/ft)
Sand	15 to over 100	40
Weathered Till	20 to over 100	50-60
Unweathered Till	30 to over 100	60-70

Table 2-7 – Reach 1 - Overburden: Representative Standard Penetration Test (SPT)

2.5.4 Reach 2 – Dolostones

Reach 2 generally consists of dolostone and shaly dolostones from the rock formations shown in Table 2-8. In general, the dominant engineering behaviour for portions of the Reach 2 – Dolostones has been interpreted to be high permeability and storativity in the upper portion of the reach yielding high water inflows during mining, and requiring extensive pre-excavation grouting measures. Table 2-9 provides representative behaviour parameters for Reach 2 dolostones.

Formation	Rock Type	Age
Amherstburg	Limestone and Dolostone	Middle Devonian
Bois Blanc	Cherty Dolostone	Lower Devonian
Bass Island	Dolostone	Upper Silurian
Salina	Predominantly Dolostone and Shale, Anhydrite and Evaporites	Upper Silurian
Guelph, Goat Island and Gasport	Dolostone	Middle Silurian
Lions Head	Limestone/dolostone	Lower Silurian
Fossil Hill	Dolostone	Lower Silurian

Table 2-8 – Reach 2 - Dolostones: Dolostone and Shaly Dolostone Formations

2.5.4.1 Reach 2: Specific Rock Formations

The **Amherstburg Formation** is comprised of hard, fossilferous, finely laminated, lightly fractured dolostone. The dolostone is brown, fine grained to gray, very fine grained crystalline. Bedding is predominately horizontal at medium to massive thickness with some soft thin bituminous seams along bedding planes. The average vertical joint spacing is 0.6 to 1 m. The joints are typically tight with slight weathering. Localised highly fractured zones are present in the formation as leached zones and vuggy to very vuggy zones. Rock quality is classified as "Fair" with a Q rating of 4.75 (RMR rating of 58). Geomechanical properties for this formation are provided in Table 2-9. The values in the table are from [R2] and are based on laboratory testing from the Bruce Generating Station.

The **Bois Blanc Formation** is a gray to brown, fine grained limestone and dolostone. Bedding is massive and chert nodules are abundant throughout the formation. The chert material is known to spall when exposed. Joint are very rough with bituminous coatings.

Bass Island is a light brown, faintly porous, fine grained dolostone with occasional black shale partings. The dolostone is petroliferous with bedding of medium thickness and occasional stylolite beds.

The **Salina Formation** is over 200 m thick and is interbed with numerous dolostone to dolomitic limestone and shale layers. The dolostone within this formation is thinly to medium bedded, medium grained with vugs or infillings of gypsum. Bedding is medium to massive for the dolomitic limestone. Within the shale layers, thin anhydrite beds and occasional salt are present. The shale material tends to slake when exposed.

Discontinuities are smooth and planar in the mudstones and shales. In the massive dolostones, the discontinuities are rough and planar to wavy. Geomechanical properties for this formation are provided in Table 2-9. The values in the table are from [R2] and are based on laboratory testing from mining experience at Goderich, Ojibway, Caledonia No. 3, Hagersville, and Drumbo.

The **Guelph, Goat Island, Gasport, Lions Head and Fossil Hill Formations** consist of dolostone and shaly dolostone. The Guelph Formation is porous and therefore has gas and water-bearing potential.

Formation	Rock Type	Unit Weight (MN/ m^3)	Uniaxial Compressive Strength (MPa)	Elastic Modulus (GPa)	Poisson's Ratio	Tensile Strength (MPa)
Amherstburg	Dolostone	2.45 (2.35-2.60)	60 (12-136)	45 (9-117)	-	-
Salina	Dolostone	2.6	100 (85-120)	35 (30-40)	0.25 (0.25-0.30)	5 (4.0-7.5)
Salina	Shale	2.6	35	8 (8-10)	0.35	1.5 (1.0-2.6)
Salina	Gypsum	2.4	30 (25-35)	8	0.35	1.5 (1.1-2.7)

Table 2-9 – Reach 2 - Dolostones: Typical Geomechanical Properties (As reported in the literature at other project sites with similar geology)

2.5.4.2 Reach 2: Assumed Engineering Behaviour

The Bruce A and Bruce B cooling water intake tunnels, Goderich Mine shaft, Ojibway Mine shaft and the Detroit River Outfall No.2 tunnel were all constructed in the same (or very similar) rock units of Reach 2. The construction of each of these facilities experienced very high groundwater inflows that required extensive grouting, re-alignment, re-design during construction and even project termination.

Of significance to the DGR are the thick salt beds present beneath Goderich, Ontario which are mined by underground and solution methods. These beds were eroded from beneath the Bruce area in the geological past, resulting in collapse and differential subsidence of the overlying rocks (i.e. above a depth of about 185 m). This is believed to have resulted in significant fracturing of the rock mass and hence account for the higher permeabilities measured in the upper portions of Reach 2 (denoted Reach 2a). Below this depth, the Silurian age dolostones and Ordovician age (approximately 430 to 500 million years old) shale and limestone bedrock formations are expected to be highly predictable and of uniformly low permeability. Correspondingly, Reach 2 has been sub-divided into two sub-reaches on the basis of anticipated permeabilities and storativities.

On the basis of information obtained from other projects in these rock units, the dominant engineering behaviour characteristics for the Reach 2 – Dolostone and Shaly Dolostones have been interpreted to be:

- High permeability and storativity that will yield high water inflows during shaft sinking. This will require extensive pre-excavation grouting measures in Reach 2a. Grouting in Reach 2b will also likely be required but to a significantly lesser extent than in Reach 2a.
- Highly saline ground water/pore fluid (Reach 2b), which presents corrosion risks.
- Potential for hydrogen sulphide and methane; hydrogen sulphide more likely.
- High in-situ horizontal stresses (relative to rock strength) likely in Reach 2b, lesser so in Reach 2a.

2.5.5 Reach 3 – Shales

Reach 3 generally consists of shales from the rock formations shown in Table 2-9. In general, they are anticipated to be massive, tight formations of argillaceous rock. Table 2-11 provides representative geomechanical behaviour parameters for Reach 3 rock formations.

Formation	Rock Type	Age
Cabot Head	Shale and shaly dolostone	Upper Ordovician
Manitoulin	Argillaceous dolostone	Upper Ordovician
Queenston	Shale and siltstone	Upper Ordovician
Georgian Bay	Shale and siltstone	Middle Ordovician
Blue Mountain	Shale	Middle Ordovician
Collingwood	Shale	Middle Ordovician

Table 2-10 – Reach 3 - Shales: Formations

2.5.5.1 Reach 3: Specific Rock Formations

The **Cabot Head Formation** consists of fissile (i.e. capable of being split or divided in the direction of bedding planes) shale to shaly dolostone, which then transitions into the Manitoulin Formation. The **Manitoulin Formation** is a fine to coarse grained, thinly bedded dolostone with shale partings.

The **Queenston Formation** is a reddish brown shale and mudstone with occasional interbeds and nodules of green siltstone. The upper beds have less than 30% siltstone interbeds and the lower beds have frequent siltstone beds. At the Niagara Tunnel test adit, the formation is massive to blocky with some fissile (i.e. capable of being split or divided in the direction of bedding planes) sections and highly susceptible to slaking when exposed. Hydraulic conductivity for the Queenston Formation ranges from 2.5×10^{-13} to 1×10^{-9} m/s. Rock quality is classified as “Good” based on a Q rating of 10.75 (RMR rating of 65).

From the Burloak Water Intake Project ([R23]), the Queenston Formation was described as moderately weathered to fresh, dark red, fine to very fine grained shale with occasional to frequent fresh, green/gray, fine grained mudstone and siltstone layers. Rock coring from this project yielded core recovery typically between of 79 to 100% and rock quality designation (RQD) of 17 to 100% (77% average).

Geomechanical properties for this formation are provided in Table 2-11. The values in the table are from [R2] and are based on laboratory testing from the Sir Adam Beck Additional Diversion Project in Niagara Falls.

The time dependent deformation (swell/squeeze) behaviour under relief of high in-situ horizontal stresses of the Queenston formation has been well documented ([R22], [R31] and [R34]). Because of the prevalence for time-dependent deformation, numerous swell tests have been performed on the Queenston Formation. Briefly, the results of swelling tests have confirmed that swelling is orthotropic, strains in the vertical direction are higher than twice those in the horizontal direction, swelling potential increases with time and swelling deformation may last for a long time.

Recent swelling results from test performed on samples obtained from the DGR-2 borehole investigation [R12] indicate that isotropic swelling potential was measured on samples immersed in fresh water and no swelling was measured for samples immersed in synthetic formation (saline) water. The swelling potentials that were measured in fresh water are less than typical measurements made elsewhere – but only slightly so (0.19% versus 0.3% for Queenston shale). Since fresh water will condense during construction and may migrate during shaft sinking from the upper reaches of the shaft to the swelling shale levels, installation of yielding rock support elements that can accommodate time dependent deformation (swell/squeeze) behaviour under relief of high in-situ horizontal stresses measures construction are felt necessary.

Areas of the Queenston Formation have been known to be a source of natural gas. Near Fayette-Waterloo and West Auburn, New York, wells at 580 m are estimated to have reserves of 450 billion cubic feet ([R35]).

The **Georgian Bay Formation** is typically gray fissile (i.e. capable of being split or divided in the direction of bedding planes) shale with some limestone and siltstone beds. Bedding in this formation is thin to thick (13 to 600 mm). Hydraulic conductivity ranges from 1.0×10^{-13} to 4.0×10^{-12} m/s. Rock quality is classified as "Good" with an average Q rating of 7.5 (RMR rating of more than 15). Geomechanical properties for this formation are provided in Table 2-11. The values in the table are from [R2] and are based on laboratory testing from the Lakeview Generating Station.

From investigations performed for the Burloak Water Intake project ([R23]), the Georgian Bay Formation is described as moderately weathered to fresh, gray to occasionally dark gray, fine to very fine grained fissile (i.e. capable of being split or divided in the direction of bedding planes) shale with interbedded fresh, gray, fine grained calcareous sandstone, siltstone, and limestone layers. Rock core recovery from boreholes for the project was typically 100% and RQD of 77 to 100% (95% average).

The **Blue Mountain** and **Collingwood Formations** are interbedded black, petroliferous shale and gray mudstone. These formations are predominately shale.

Formation	Rock Type	Unit Weight (MN/ m^3)	Uniaxial Compressive Strength (MPa)	Elastic Modulus (GPa)	Poisson's Ratio	Tensile Strength (MPa)	Horiz. To ver. In-situ Stress Ratio (K_0)
Queenston	Shale	2.68	40 (33-46)	12 (6-23)	0.30 (0.10-0.44)	3 (2.0-4.6)	(2-4)
Georgian Bay	Shale	2.60	36 (11-97)	20 (11-41)	0.20 (0.10-0.20)	-	(2-20)

Table 2-11 – Reach 3 - Shales: Typical Geomechanical Properties (As reported in the literature at other project sites with similar geology)

2.5.5.2 Reach 3: Assumed Engineering Behaviour

The behaviour of the Reach 3 shales has been well documented in the literature but in works and investigations at significant distances from the Bruce Site. Based upon the experience at the Heart Lake Tunnel in Mississauga, Niagara River Hydroelectric Development and numerous works documented in the literature, it is evident that the shales of this reach exhibit similar engineering characteristics in response to excavation. Correspondingly, on the basis of information obtained from other projects in these rock units, the dominant engineering behaviour characteristics for the Reach 3 - Shales has been interpreted to be:

- Low permeability therefore significant water inflow during mining not likely.
- Potential for methane – particularly from the Georgian Bay shale.
- Time-dependent deformation (TDD) due to swelling, squeezing and creep effects may occur upon relief of initial stresses (excavation) and introduction of fresh water from upper rock layers (shunt flow along shaft extrados); highly stress dependent.
- High in-situ horizontal stresses (relative to rock strength) with K_o of 2 or greater.
- High susceptibility to slaking upon exposure.

- Highly saline pore fluid, which is a potential corrosion risk.
- Low tensile strength.
- Highly fissile (i.e. capable of being split or divided in the direction of bedding planes).

2.5.6 Reach 4 – Limestones

The DGR will be founded in the Reach 4, which generally consists of argillaceous limestone rock formations shown in Table 2-12 and Table 2-13, provides representative behaviour parameters for Reach 4 Cobourg limestone formation.

Formation	Rock Type	Age
Cobourg	Argillaceous limestone with shale interbeds	Middle Ordovician
Sherman Fall	Shaly limestone	Middle Ordovician
Kirkfield	Shaly and argillaceous limestone	Middle Ordovician
Coboconk	Shaly and crystalline limestone	Middle Ordovician
Gull River	Lithographic limestone	Middle Ordovician

Table 2-12 – Reach 4 - Limestone: Formations

2.5.6.1 Reach 4: Specific Rock Formation

Within Reach 4, the engineering behaviour of the Cobourg Formation (also referred to as the Lindsay formation in the literature) is of greatest significance to the DGR facility. This rock is a fine grained, thin to medium bedded argillaceous limestone. Joints are planar or stepped with smooth to rough walls with a large number of joints healed with calcite. The joint spacing is approximately 1 m at the Bowmanville Quarry. At that location, there is one major steeply dipping joint set striking east-west. Other rock behaviour information includes:

- Core recovery of 93 to 100% (97% average) from Darlington Intake Tunnel
- Hydraulic conductivity of 6.3×10^{-14} to 4.0×10^{-11} m/s

The rock quality is classified as "Good" with an average Q rating of 31.7 (RMR rating of 75). Geomechanical properties for this formation are provided in Table 2-13 . The values in the table are from [R2] and are based on laboratory testing from the Bowmanville Quarry and the Lakeview Generating Station.

A more detailed development of the geomechanical basis of design for the Cobourg formation (including geomechanical test results from DGR-2 investigation) is provided in Section 7.

Formation	Rock Type	Unit Weight (MN/ m^3)	Uniaxial Compressive Strength (MPa)	Elastic Modulus (GPa)	Poisson's Ratio	Tensile Strength (MPa)	Horiz. To ver. In-situ Stress Ratio (K_0)
Cobourg	Limestone	2.65 (2.60-2.65)	60 (25-140)	40 (16-66)	0.3	-	(2-10)

Table 2-13 – Reach 4 - Cobourg Formation: Typical Geomechanical Properties (As reported in the literature at other project sites with similar geology)

2.5.6.2 Reach 4 – Cobourg Limestone: Assumed Engineering Behaviour

The Darlington Intake tunnel, Wesleyville Tunnel, Lakeview Generating Station boreholes and Bowmanville Quarry have all investigated the same rock units of Reach 4 but at significant distances from the Bruce Site. Correspondingly, on the basis of information obtained from other projects in these rock units, the dominant engineering behaviour characteristics for the Reach 4 – Cobourg Formation Limestones have been interpreted to be:

- Low permeability therefore water inflow during mining not likely
- Corrosion concerns due to salinity of pore fluid
- Argillaceous/shaly therefore some potential for methane
- High in-situ horizontal stresses (relative to rock strength)

2.5.7 Results from Recent Investigations at Bruce Site

As stated previously, Phase I Investigations of the Ontario Power Generation (OPG) Geoscientific Characterization Plan (GSCP) for the Bruce Site have recently been completed. This includes a deep bedrock drilling program of two vertical 152 mm diameter continuously cored boreholes (DGR-1 and DGR-2) to depths of approximately 462 and 862 meters below ground surface (m bgs). As part of this program, a suite of geomechanical laboratory tests on rock samples from these boreholes has been performed and the results are summarised in the following documents:

Rock Strength Properties:

Gorski, B., Anderson, T. and Conlon B. (CANMET Mining and Mineral Sciences Laboratories, Natural Resources Canada), (2007). "DGR Site Characterization Document TM-07-03 - Laboratory Geomechanical Strength Testing of DGR-1 and DGR-2 Core – Revision 1", Intera Engineering Project 06-219 - Doc ID: TM-07-03. [R10]

Cerchar Abrasivity Index:

Maloney, S. (Mirarco/Geomechanics Research Centre, Laurentian University), (2007). "DGR Site Characterization Document TM-07-04 - CERCHAR Abrasivity Testing of Argillaceous Limestone of the Cobourg Formation", Intera Engineering Project 06-219 - Doc ID: TM-07-04. [R11]

Swelling Potential:

Micic, S. and Lo, K.Y. (K.Y. Lo Inc.), (2007). "DGR Site Characterization Document TM-07-16 - Laboratory Swell Testing of DGR-2 Core – Revision 0", Intera Engineering Project 06-219 - Doc ID: TM-07-16. [R12]

The preliminary geomechanical testing results from DGR-1 and DGR-2, which are reported in the listed reports, support the interpretive engineering characterisation assessments made from the literature search herein. Further, the results, while preliminary, indicate that the design basis developed from the literature search desk study is prudently conservative.

The optimistic results should be qualified on the basis that the values of geomechanical properties (UCS, Cerchar Abrasivity Index and Swelling Potential) values and their variation with depth have been obtained from a single borehole investigation. The variation in rock mass properties within bedding units and the variation of those bedding units over the lateral extents of the planned DGR are not yet established. Despite this, the current results bode well for geologic conditions at the repository depth to be better than those used herein. Ground conditions will continue to be assessed in future investigations and monitored during construction to permit refinement of the design to take advantage of the best rock mass conditions possible.

2.6 Regional Seismicity

The Bruce Site lies within the tectonically stable interior of the North American continent which is characterized by low rates of seismicity. As summarised by Golder ([R2]) and re-stated herein, the seismic zone map in the National Building Code, for example, places the site in Zone 0, corresponding to the least seismically active regions of the country.

The results of a site specific seismic hazard analyses ([R39]) carried out as part of Bruce Powers' Bruce A Units 3 & 4 Restart Environmental Assessment concluded that, within the "Regional Study Area" defined for that study (an area bounded by Latitudes 42° to 48° N; Longitudes 78° to 84°W), the historic rates of seismic activity were:

- 47 events of Magnitude M ≥ 3 in 100 years; and
- 8 events of Magnitude M≥ 4 in 100 years.

Further, within a 100 km radius of Bruce there have been no earthquakes of M≥4 in the period of historic record (which would extend back about 200 years for events of this magnitude).

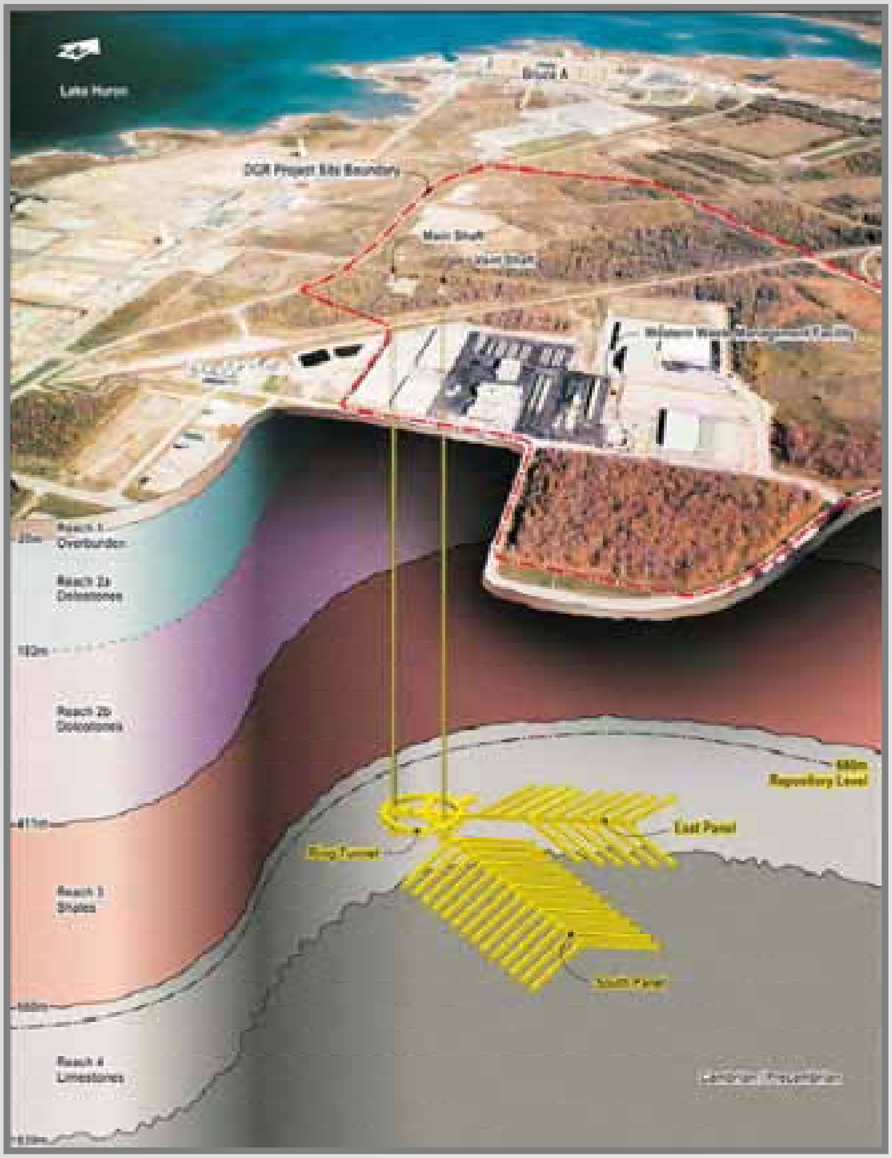
Based on this data, the study further concluded that, within the "Regional Study Area":

- The recurrence rate for a Magnitude M≥5 event would be 0.013 per annum (1 to 2 events every 100 years);
- The recurrence rate for a Magnitude M≥6 event would be about 0.002 per annum (one event every 500 years); and
- The maximum magnitude for the Region is M = 7.0.

For earthquakes with probabilities of occurrence of 1/2,500 per annum and 1/10,000 per annum, the peak particle ground velocities in hard rock at the Bruce Site were predicted to be 14 mm/s and 27 mm/s, respectively, and the corresponding peak ground accelerations were predicted to be 5% and 11% of the acceleration due to gravity (g, 9.81 m/s^2).

Peak ground velocities and accelerations of these magnitudes are not expected to adversely affect engineered surface structures such as those proposed for the generic shaft support and access structures, nor would they adversely affect the stability of underground openings proposed for the DGR shafts, access tunnels and emplacement rooms.

3. Conceptual Design Requirements



3. Conceptual Design Requirements

The DGR facility will consist of surface and underground structures. The key surface structures will be buildings that are used to receive waste packages, house equipment such as hoisting and ventilation equipment, and to provide space for various amenities. The key underground structures will be comprised of shaft access-ways, emplacement rooms and their access tunnels, support chambers for maintenance, diesel and lubrication, electrical sub-station, offices, geotechnical laboratory, lunch room and sanitary facilities, and any seals that are constructed in these underground openings. This section lists the design criteria, which have been used in producing the conceptual design of the DGR facility, and will guide the development of design requirements for use in the future phases of engineering and construction of the facility.

These requirements do not apply to the structures, systems and components that would be used to retrieve L&ILW from existing storage or then to transfer the waste packages to the surface receiving area of the DGR facility.

The preliminary waste acceptance criteria for the DGR facility are listed in "Preliminary Waste Acceptance Criteria for the Deep Geologic Repository", Procedure, W-PROC-WM-0085 R00 (hereafter referred to as "DGR WAC") ([R77]). The DGR WAC specifies the responsibilities of OPG management for determining suitable waste package configurations, acceptance criteria for receiving waste packages at the DGR, and ensuring safe practices are adopted and maintained. Liaison and planning with waste producing facilities to enable wastes to be successfully transferred to the DGR while complying with all criteria will be an important aspect of the process.

The procedures to be followed against each main criteria are also presented. Key criteria, which form inputs to the Conceptual Design Study include:

- Waste characterisation
- Documentation
- Acceptable waste package designs
- Condition of waste containers
- Mass and size limits
- Containment and venting
- Identification/labelling
- Handling
- Dose rate limits
- Radionuclide composition limits
- Contamination limits
- Heat load limits

The conceptual design described in this report is not based on detailed ALARA optimisation and human factors engineering. These matters will be fully addressed in subsequent stage of DGR design process.

This section of the report must be read in conjunction with "L&ILW DGR – Project Glossary", 00216-LIST-00120-00001 ([R40]), where many of the terms used in this section have been defined.

3.1 Functional Requirements

3.1.1 The repository facility will be capable of receiving, inspecting, handling and emplacing operational L&ILW from OPG-owned stations and L&ILW generated during refurbishment projects at OPG-owned nuclear stations.

3.1.2 During the pre-closure period, the repository facility will be capable of supporting all aspects of an underground geoscience characterisation program. Support would include providing office space for staff, laydown areas and building space for equipment and various rock and water samples. Support would also include access to the surface and to the repository with support services necessary to implement the sampling, testing and measurement activities.

3.1.3 During the pre-closure period and following the start of waste emplacement operations, the repository facility will be capable of supporting all aspects of operations to create additional emplacement rooms in the repository, as necessary (e.g. mining support facilities, excavated rock stockpiles, access to underground repository for excavation operations and explosives transfers, and rock mucking).

3.1.4 During the pre-closure period and following completion of waste emplacement operations, the repository facility will be capable of supporting all aspects of an extended monitoring program. The repository facility will be available for personnel access to all major underground service areas and access tunnels to carry out monitoring activities and to maintain the monitoring installations.

3.1.5 The closed repository, including shaft seals, and the surrounding geosphere shall contain and passively isolate the radioactive waste so as to protect the health and safety of persons and the environment.

3.2 Performance Requirements

3.2.1 The initial repository configuration will have sufficient capacity to accept a total waste disposal volume of about 200,000 m^3 (equivalent to about 160,000 m^3 as stored), with waste types specified in [R76].

3.2.2 The repository facility will be capable of receiving and handling boxed LLW (e.g. various containers currently in LLSB storage) at a throughput rate of no less than twenty-four (24) packages per 8-hour shift.

3.2.3 The repository facility will be capable of receiving and handling 3 m^3 resin liners at a throughput rate of no less than four (4) liners per 8-hour shift.

3.2.4 The repository facility will be designed, constructed and operated so that the release of potentially contaminated air, water (e.g. run-off from waste rock pile), and solids (e.g. waste rock) from the facility has radiological and chemical contaminant concentrations and amounts that are below allowable/regulatory limits.

3.2.5 The repository facility will be designed, constructed and operated so that the temperature of the rock at the repository horizon does not vary to an extent that would encourage condensation of water vapour in the airstream.

3.3 Interfacing Requirements

3.3.1 The surface waste receipt area of the repository facility will interface with equipment transferring waste packages originating at:

a) WWMF storage structures;

b) Waste Volume Reduction Building (WVRB) (and any other waste processing facility constructed at the WWMF); and

c) Nuclear stations (e.g. truck deliveries of resin liners in transportation packages)

3.3.2 The WWMF on-site waste retrieval and transfer systems are not part of the repository facility.

3.3.3 The repository facility will interface with the existing infrastructure on the Bruce Nuclear site and in particular at WWMF. To the degree that is practical, the repository facility will make use of existing infrastructure (e.g. for office space, amenities, roadways, material storage) and services (e.g. security, electrical, communications, water, sanitary, fire and emergency response) to support construction, operation, decommissioning and closure activities. The Headframe of the radioactive waste-handling shaft will be located as close as practical to WWMF.

3.3.4 Interface with Bruce Power/WWMF will need to be maintained to ensure services (water, power, security, etc) will be available when needed. Proposed physical location of interfaces between DGR and Bruce Power/WWMF-supplied services will be described in the conceptual design report.

3.3.5 The repository facility will interface with OPG's Nuclear Waste Management Division's (NWMD's) Integrated Waste Tracking System.

3.4 Design Limits

3.4.1 The repository facility will be capable of supporting waste emplacement operations for at least 100 years. This time period includes a period for extended monitoring.

3.4.2 The maximum payload to be handled by the main shaft hoisting system will be 35 tonnes plus the mass of the equipment used to transfer package(s) underground.

3.4.3 To allow for uncertainties in future waste volumes, the repository layout will be such that it is possible to increase waste capacity to a disposal volume up to 400,000 m^3 (equivalent to about 300,000 m^3 as stored) with little to no change to the repository facility infrastructure.

3.4.4 The pillar design of the repository shall be based upon reliability-based methods using expected rock strength properties (UCS and GSI) that examines the expected cost of unsatisfactory performance relative to the cost of advance mitigations but with a probability of failure of the pillar nominally 0.01% or less.

3.4.5 The repository facility will have a surface area(s) for the storage of waste rock and the area(s) will have the capacity to store all waste rock produced by the underground excavation of the repository.

3.5 Seismic and Anthropogenic Vibration Requirements

3.5.1 The occurrence of a seismic ground motion event, as specified in the National Building Code ([R81]), will not lead to a structural failure in any part of the repository facility during the operational life of the facility.

3.5.2 The use of explosives will not adversely impact adjacent emplacement rooms or any other aspect of waste emplacement operations. The use of explosives will not adversely impact the operations of any other facility on the Bruce Nuclear site, and the natural environment (e.g. fish populations in nearby waters).

3.5.3 The potential for and possible impacts of rock bursts will be assessed and, if necessary, provisions will be included in the repository design for remedial measures.

3.6 Design Constraints

3.6.1 The repository facility will be located within the defined DGR Project Site boundaries on OPG-retained land.

3.6.2 The underground repository will be constructed in a suitable limestone formation located beneath the Collinwood Shale Formation. Limestone and other predominantly calcareous formations will be considered suitable for hosting the underground repository if the formation is able to accommodate all categories and quantities of radioactive waste to be emplaced, whilst maintaining adequate containment and isolation of these wastes.

3.6.3 The repository design will complement and protect natural waste isolation attributes of the repository site. No aspect of the repository design will comprise or diminish the positive natural waste isolation attributes of the site.

3.6.4 There will be flexibility in the repository layout and design so that design changes can be implemented if adverse rock conditions are identified during site investigations or encountered during construction, or if other factors require that such changes be made.

3.6.5 To the degree that it is practical and necessary, underground openings will be oriented within the in-situ stress field so as minimise stress concentration around openings, to promote long-term stability, and to minimise rock support system maintenance requirements.

3.6.6 The horizontal distance between the surface expression of any part of the repository containing waste materials and the shore of Lake Huron will not be less than 750 m, and where practical this separation distance will be maximised. The Lake Huron shoreline position in the vicinity of Bruce Nuclear site means shoreline position as shown on Hatch Drawing No 323874DGR-602-001 ([R41]).

3.6.7 The ventilation discharge from the repository will be located at a sufficient distance from the ventilation inlet and other normally inhabited areas to ensure discharge fluids are neither re-introduced into the repository nor fall-out on surface in concentrations, which may be harmful to persons or the environment. Prevailing winds and their effect on the exhaust plume from the ventilation discharge will be taken into account in determining the location of the ventilation discharge.

3.6.8 No part of the repository facility can be constructed within 100 m of a transmission power line or the base of a transmission tower. In planning the location of the repository facility, possible future location(s) of new transmission line corridors will be considered. [Note: [R42] specifies safe approach distances when working in the vicinity of power lines.]

3.7 Room Closure and Package Retrievability

3.7.1 Emplacement rooms will be closed once filled with waste packages.

3.7.2 The functions of the closure wall are:

a) To limit release of potentially contaminated air (e.g. tritiated air) from waste-filled rooms;
b) To restrict airflow into waste-filled rooms so as to minimise ventilation requirements;
c) To provide shielding so as to limit occupational dose to workers outside waste-filled rooms; and
d) To restrict room entry once filled with waste.

3.7.3 Once closed and if deemed necessary based on analysis of monitoring data, it will be possible to flush potentially explosive gases from the room

3.7.4 Although there is no intention to retrieve waste following emplacement, it will be possible to easily retrieve[1] the emplaced waste packages at any time during the pre-closure period until such time when an emplacement room is closed.

3.8 Shaft Seal Systems

These requirements are related to sealing systems to be installed in repository shafts that have hydrogeological significance with respect to the postclosure safety of the repository.

3.8.1 The bulk hydraulic conductivity of the sealing materials (e.g. sand/bentonite mixture) will be equal to or less than 10^{-10} m/s.

3.8.2 The sealing systems will limit release of radioactivity from the repository.

3.8.3 The sealing systems will limit flow of groundwater into the repository.

3.8.4 The sealing system materials and design will be compatible with chemical and mechanical conditions within surrounding host rock (related to 3.9.4).

3.8.5 The sealing systems will maintain their structural integrity in perpetuity without need for maintenance or replacement.

3.8.6 The sealing systems will be designed so as to prevent subsidence and accidental entry into the repository.

[1] Easy retrieval means that the waste packages can be removed with the same equipment and procedures used to originally emplace the packages within a room but where the procedures are applied in reverse order. Easy retrieval does not mean that it should be possible to directly access any particular waste package within a waste-filled room for purpose of retrieval from the room.

3.8.7 Sealing systems will be designed so that they can be constructed by using existing construction technologies and materials.

3.8.8 Sealing systems will be designed to prevent flow of potentially poor quality groundwater present in a lower aquifer upward via a shaft or borehole into an upper freshwater aquifer (related to 3.18.11 (a)).

3.8.9 The shaft sealing systems will be capable of withstanding an internal gas pressure of 14 MPa without failure of the seal systems. The gases may be generated by degradation of organic wastes and corrosion of metals within the repository after closure, and natural gases that may seep into underground openings.

3.9 Environmental Requirements

3.9.1 The repository facility will be designed, constructed and operated in such a manner so as to create an environment that:

a) is safe and comfortable for workers and other persons entering the facility;
b) will help ensure various structures, systems and components in the repository maintain their integrity as per performance requirements;
c) will help ensure waste packages retain their integrity as required to meet requirements in Section 3.7; and
d) minimises amount of radiologically and chemically contaminated materials (air, water or solids) released into the underground and surface environments.

3.9.2 The heating, ventilation and air conditioning (HVAC) systems for both surface and underground facilities will be designed for local climatic conditions as specified in the National Building Code or as defined by Environment Canada databases, whichever is the more adverse. The HVAC system will deliver air to the repository horizon with a temperature and humidity which are within the limits for underground workers in accordance with ASHRAE ([R43]) and ACGIH ([R44]) principles.

3.9.3 The repository facility will be designed, constructed and operated in such a manner that there is minimal contact of water (i.e., precipitation, dripping or seeping groundwater, or condensate on waste packages) with the waste packages, and waste packages will not be exposed to standing water while emplacement rooms are open.

3.9.4 The repository and its engineered features will be designed taking into consideration the expected physical conditions (e.g. rock properties, in-situ stress, ground water pressures and ambient temperature) and chemical conditions (e.g., 100 to 300 g/L pore water salinity; high chloride concentrations) within the rock mass hosting the repository.

3.10 Operability Requirements

3.10.1 The repository will be capable of operating 365 days per year and 3 shifts per day with specific times reserved for shaft inspections and maintenance (Note that the facility is expected to operate on the order of 200 days per year, one shift per day).

3.10.2 Primary operational control of the repository facility will be executed from a central location at ground surface. A secondary operational control area will be located underground. Operational control includes the real-time and continuous monitoring of the safety, environmental and operational status of the repository facility.

3.10.3 The repository will be designed so that required working time spent in waste-filled emplacement rooms is minimised during emplacement operations.

3.10.4 During the operational phase, it will be possible to perform underground construction in a nuclear zoned environment. However, it will not be required that emplacement operations and underground mining/construction be performed concurrently.

3.10.5 The repository facility operations will support an on-going program to collect various types of data relevant to safety assessment including data on rock mass and rock support behaviour in response to excavation, groundwater flow and chemistry, gas generation, seismicity, surface biosphere, and releases into surface atmosphere.

3.10.6 Waste packages will be handled in a manner that minimises the possibility of accidentally being dropped and that maintains package integrity.

3.10.7 Waste packages will be emplaced in a manner that maintains package integrity, maximises use of available space, is consistent with any requirements in applicable mining and/or building codes, and does not unnecessarily impede waste package retrieval.

3.10.8 Repository's underground ventilation system will be operated so as to place workers in the fresh air supply side of each workplace, with potentially contaminated air being exhausted through excavations that are not routinely occupied or in sealed ducting. This will be achieved by causing the air to flow from areas of low potential contamination to areas of greater potential contamination.

3.10.9 Systems to collect water originating within the shaft and below the shaft collar will be arranged to flow by gravity to sumps that are located at the shaft bottoms.

3.10.10 Likely-contaminated water originating within the underground repository will be directed to a sump(s) dedicated to the collection of this water.

3.11 Reliability Requirements

3.11.1 The target availability of the repository facility for emplacement operations, excluding scheduled stoppages, will be 80%.

3.11.2 Adequate electrical power supply will be maintained to ensure the safety of the repository facility and its personnel under all circumstances.

3.11.3 There will be backup electrical power supply (above-ground and underground) to operate all key systems in the event of an interruption of the main electrical power supply.

3.11.4 The repository facility will be located, designed, constructed and operated so as to minimise the probability of flooding during the preclosure period and, should flooding occur, its impact on operations. The design flood level will be the 1:500 year probability flood level or the known maximum flood level since scientific recording began. The application of maximum flood level data will take into consideration the limited statistical database available for the proposed DGR facility location.

3.12 Maintainability Requirements

3.12.1 It will be possible to maintain and refurbish all structures, systems and components within the repository facility, as necessary, to ensure performance as per original design specifications during operating life of the repository facility.

3.12.2 The underground rock openings will be designed and constructed so as to require only routine maintenance (e.g. rock scaling, replacement/repair of rock supports, shotcrete replacement/repair, concrete liner replacement/repair) during the operating life of the repository.

3.12.3 The amount of installed equipment and associated maintenance requirements in waste-filled emplacement rooms will be minimised so as to avoid worker exposure to radiation.

3.12.4 Once filled with waste packages and closed, maintenance of any structures, systems or components within a closed emplacement room will no longer be required.

3.12.5 There will be facilities located underground for the routine ongoing maintenance of all underground equipment. It will be possible for any underground equipment to be removed to surface for replacement or major refurbishment using the same process as was used for installing it underground in reverse.

3.13 Periodic Inspection and Monitoring Requirements

3.13.1 Monitoring will be carried out during the preclosure period starting with the site characterisation program. Monitoring will continue during the preclosure period to gather information, as necessary:

a) to establish repository facility and environmental baseline conditions;
b) to assess performance of various structures, systems and components relative to design specifications and baseline conditions;
c) to monitor changes in underground rock/excavation conditions (e.g. rock movement, stress) over time;
d) to assess preclosure safety and environmental performance relative to predefined standards or limits, and baseline conditions; and
e) to provide data for analysis of postclosure performance and safety for the sealed repository.

3.13.2 All waste packages will be inspected upon receipt at the repository facility to verify that they meet the DGR WAC for the facility. If packages do not meet the DGR WAC, they will be returned to the originator.

3.13.3 Once waste packages are placed into their final position within an emplacement room, it will no longer be necessary to routinely inspect the waste packages.

3.13.4 It will be possible during the pre-closure period, to monitor air quality and gas pressure within a closed emplacement room. This monitoring capability is required to measure concentrations of potentially explosive gases (i.e. hydrogen and methane) and to allow safe re-entry into a closed room, if necessary

3.14 Occupational Safety Requirements

3.14.1 Activities associated with locating, constructing, operating, decommissioning and closing the repository facility will meet all applicable federal and provincial laws and regulations, and applicable OPG governing documents.

3.14.2 The repository facility will be designed, constructed, operated, decommissioned and closed such that the radiological risk to site workers is acceptably low and in keeping with the best practices in the international community.

3.14.3 Shielding of source will be the principal procedures used to minimise radiation doses to workers at the repository facility.

3.14.4 The occupational dose limit will be 20 mSv/a [as per 3.18.2(c)]. For design purposes, the occupational dose constraint will be 10 mSv/a.

3.14.5 The ventilation system for the underground repository will prevent the accumulation of toxic, asphyxiating, radioactive, flammable or explosive gases within all accessible areas of the repository by diluting them to safe concentrations and by removing them.

3.15 Fire Safety

3.15.1 The repository facility will be designed, constructed and operated so as to minimise the possibility of fire.

3.15.2 Fire protection systems will be installed in the repository facility, as required by applicable regulations and codes. Care will be taken in selection of these systems to ensure that they will not adversely influence other aspects of the repository facility safety (e.g., no water sprinkler in hoist room and in emplacement rooms).

3.16 Security Requirements

3.16.1 The repository facility will be securely fenced to prevent unauthorised access into the controlled area.

3.16.2 Access to the repository facility will be restricted to qualified and authorised personnel, and those escorted by qualified and authorised personnel.

3.16.3 To the degree that it is necessary, the security provisions for the repository facility will be integrated into existing collaborative arrangements between OPG and Bruce Power.

3.16.4 Explosives used for the construction of the repository will be securely stored in compliance with relevant regulations, and in a manner that will not compromise the security and safety of any CNSC-licensed facility on the Bruce Nuclear site.

3.17 Constructability Requirements

3.17.1 The repository will be constructed using conventional construction techniques. To the degree that it is possible, the design will not require the use of unique or special construction techniques or techniques that may require extensive development work before they can be used. Construction of repository seals may require construction techniques not normally used in the mining industry.

3.17.2 One suite of mining equipment should be capable of excavating all opening sizes and geometries of openings located at the level of the emplacement rooms. In other words it should be a major design goal to minimise different types of equipment required to excavate access tunnels and emplacement rooms.

3.17.3 During construction, all shafts, tunnels and rooms will be made accessible, as necessary, to allow personnel to periodically gather geoscience data.

3.17.4 The repository will be constructed in such a way as to preserve the postclosure safety functions of the repository and the geological barrier as shown to be important by the postclosure safety case.

3.17.5 Rock excavation techniques will be used that minimises the excavation damage zone in any rock forming the perimeter of excavations to be permanently sealed (related to shaft sealing).

3.18 Regulations, Standards and Codes

The repository facility falls under Federal Jurisdiction. Thus, with the exception of workplace health and safety, Canadian federal acts, regulations and codes will apply to all aspects of the repository facility. By Canadian Federal Regulation 98-180, responsibility for workplace health and safety at all OPG nuclear facilities (including OPG nuclear waste management facilities) has been delegated to the Province of Ontario. Thus workplace health and safety during the construction and operation of the DGR facility will be regulated under the Ontario *Occupational Health and Safety Act (OHSA)* and its associated regulations.

Under the *Nuclear Safety and Control Act* and regulations, the repository facility would be classified as a Class 1B nuclear facility and *Class 1 Nuclear Facilities Regulations* apply.

The design of the repository facility will meet the requirements of the regulations, codes and standards listed below, except when the document is identified as "guidance only". Guidance documents provide "best practice" information which may be useful in developing the conceptual design for the repository facility.

The latest version of all regulations, standards and codes listed in this section will be used. In the event of any conflict or inconsistency between any requirement of the *Nuclear Safety and Control Act* and its Regulations, and any requirement of the regulations, code or standards listed in this section, the conflict or inconsistency will be directed to the CNSC for resolution.

3.18.1 Ontario Power Generation

a) Radiation Protection Requirements – Nuclear facilities, N-RPP-03415.1-10001-R07, June 2001.

3.18.2 CNSC and ICRP

a) Radiation Protection Regulations, Registration SOR/2000-203, 31 May 2000, Canada Gazette Part II, Vol 134, No. 13, 21st June 2000.
b) International Commission on Radiological Protection (ICRP), Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste, ICRP Publication No. 81, Pergamon Press, 2000 (guidance only)
c) CNSC's G-224, "Environmental Monitoring Program at Class 1 Nuclear Facilities and Uranium Mines and Mills, July 2004

d) CNSC's G-129, Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)" (Rev 1), October 2004
e) Class I Nuclear Facilities Regulations, Registration SOR/2000-204, 31 May 2000, Canada Gazette Part II, Vol 134, No. 13, 21st June 2000
f) General Nuclear Safety and Control Regulations, Registration SOR/2000-202, 31 May 2000, Canada Gazette Part II, Vol 134, No. 13, 21st June 2000

3.18.3 Buildings and Structures

a) Surface facilities (except "mine-specific") - National Building Code (2005)
b) Surface facilities - Ontario Regulation 213/91, Construction Projects (applicable to construction work to a nominal depth of 50 m below ground surface)
c) Surface facilities and underground waste handling - Ontario Regulation 851/90, Industrial Establishments
d) Underground facilities - Ontario Regulation 854/90, Mines and Mining Plants [2]

3.18.4 Fire Protection System

a) Surface facilities (except "mine-specific") - *National Building Code (2005)*
b) Underground and surface "mine-specific" (e.g. Headframes, hoist rooms) facilities - *Ontario Regulation 854/90, Mines and Mine Plants*
c) National Fire Code (2005)
d) US National Fire Protection Association, Standard 801, *Fire Protection for Facilities Handling Radioactive Materials* (guidance only)

3.18.5 Pressurised Air System

a) National Building Code (2005)
b) Ontario Regulation 854/90, Mines and Mine Plants

3.18.6 Repository Ventilation System

a) Ontario Regulation 854/90, Mines and Mine Plants
b) American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2004
c) CAN/CSA-N285.0-95, General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants
d) CNSC's G-221, "A Guide to Ventilation Requirements for Uranium Mines and Mills", June 2003 (guidance only)

3.18.7 Piping & Pressure Vessels

a) American Society of Mechanical Engineers Code B31.3 – Process Piping, 2006
b) American Society of Mechanical Engineers Boiler and Pressure Vessel Code (BPV), 2007

3.18.8 Environmental

a) All aspects of locating, construction, operation, decommissioning and closure of the repository facility will comply with NWMD's Environmental Policy dated 6 June 2006 (approved by OPG Board of Directors, 10 May 2006; available NWMD intranet site).

[2] Although the underground portion of the repository facility is likely not a mine, as defined in OHSA, OPG has decided that O. Reg. 854/90, Mines and Mining Plants [R62], will be applied to the DGR project.

b) Activities associated with locating, construction, operation, decommissioning and closure of the repository facility will meet all applicable federal and provincial environmental protection laws and regulations.

3.18.9 Concrete

a) CAN/CSA-A23.1, Concrete Materials and Methods on Concrete Construction
b) ACI 201, American Concrete Institute's "*Guide to Durable Concrete*" (guidance only)

3.18.10 Rock Excavations

Ground support system selection and design will incorporate consideration of:

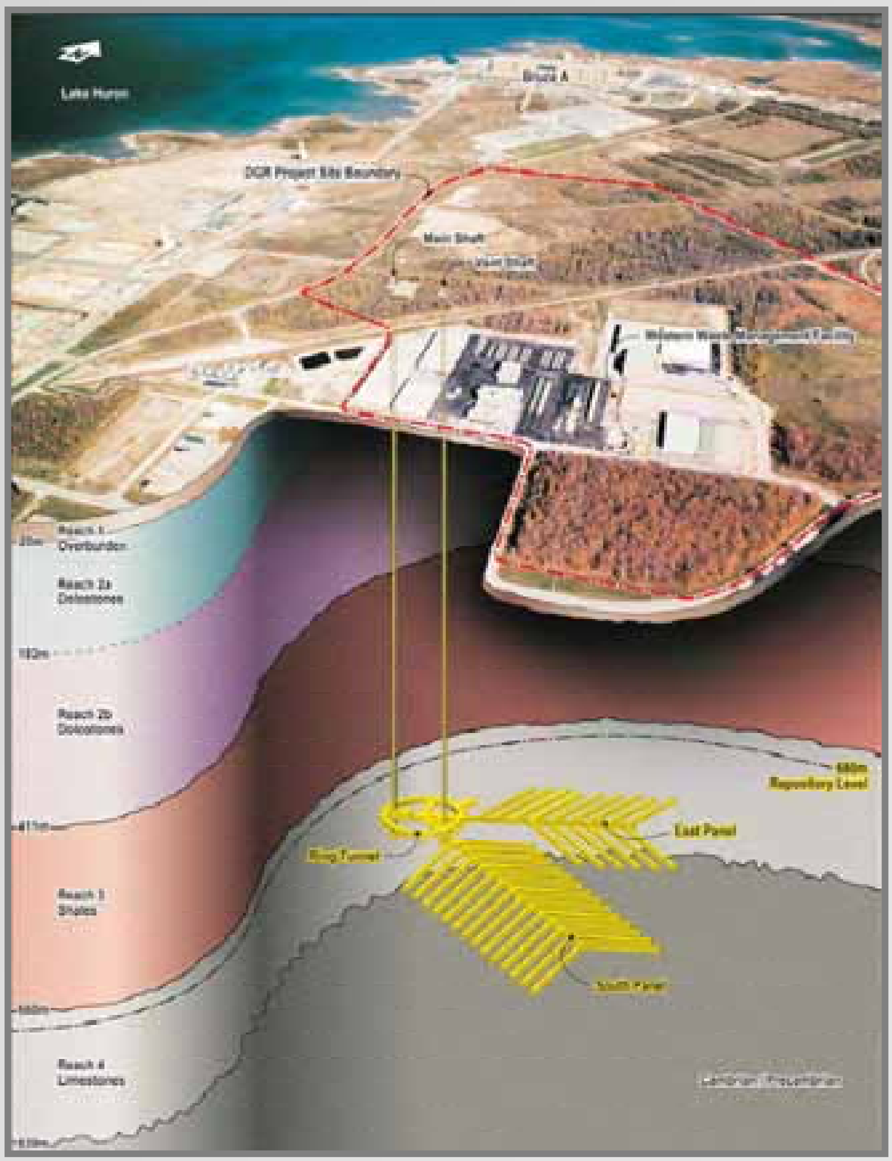
a) Rock mass quality using Bieniawski's "RMR" ([R45]).
b) Rock mass quality using Barton's "Q" ([R46]) (guidance only);
c) The Hoek-Brown rock mass failure criterion ([R47]); and
d) Traditional beam analyses for flat back mine roofs (guidance only)

3.18.11 Shaft Sealing

A shaft sealing system design will incorporate consideration of:

a) Ontario Ministry of Natural Resources, Provincial Operating Standard, "*Oil, Gas, Salt Resources of Ontario*", Version 2, Section 11 entitled Well Plugging ([R85])
b) Ontario Regulation 240/00, Mine Development and Closure Under Part VI of the Act, Schedule 1: Part 1, Protection of Mine Openings to Surface

4. Location and Layout of Facility



4. Location and Layout of Facility

4.1 Description of Facility

The surface features of the DGR infrastructure include

- the Main Shaft, which will provide access to the underground repository for transfer of waste packages, personnel, equipment and materials;
- the Ventilation Shaft, which will act as a second egress and convey the air discharged from the repository;
- The Waste Rock piles, where all the underground rock excavated during construction of the DGR will be stored.

Detailed descriptions of the structures and surface features of the DGR, together with their functions are given in Section 4.2. The repository access shafts and the underground layouts are described in Sections 4.3, 4.4 and 4.5.

The general layout of the surface facilities and the link to the WWMF are shown in Figure 4-8.

4.2 Surface Infrastructure & Buildings

The surface infrastructure for the DGR project site will generally be designed so that drainage is directed away from all structures with suitable gradients in order to manage stormwater flows in the facility ditches and stormwater management pond. In particular, the shaft collars will be established at suitable elevations to prevent any inflow in to the repository from storm or potential flooding events with account being taken of frozen ground, accumulated snow and spring thaws and wave run-ups from coastal flooding of Lake Huron. The required elevation will be determined during the future phases of engineering with consideration given to the appropriate regulatory storm event. "Regulatory storm events" are the approved standards to be used in particular watersheds to define the limits of the flood plain for regulatory purposes.

4.2.1 Main Shaft Area

The Main Shaft area will include the following key structures:

- Main Shaft Headframe and Hoist
- Waste Package Receiving Building (WPRB) and Staging Area
- Repository HVAC system, consisting of a Refrigeration Plant, Bulk Air Cooler, and Air Heating Plant
- Shaft Offices
- Shaft Maintenance Workshop, Materials and Equipment Store

4.2.1.1 Main Shaft Headframe

The Main Shaft Headframe will be a 50 metre high reinforced-concrete structure with a plan area of 12 x 14 metres, in which a tower-mounted Koepe friction hoist will be installed. The concrete structure provides the best method for providing the necessary structural support for this heavy hoist and additionally is also ideally suited to providing insulation of the equipment and personnel working within the Headframe during winter conditions. The Headframe design will ensure that, with a well-crafted planned maintenance system, the structure will not require any major refurbishment during the 100 year operation of the DGR.

In addition to the hoist, the Headframe will contain the deflection sheaves for the friction hoist tail (or balance) ropes, arresting gear for retarding the conveyance in the event of an overwind, ultimate crash beams and an electric overhead beam crane at the top of the Headframe for maintenance of the large and heavy hoist components.

Doors in the side of the Headframe and extension rails at the Hoist Level will be installed to enable any large hoist components to be lowered to the ground on the outside of the Headframe structure for replacement or major overhaul.

The Headframe schematic is shown in Figure 4-1, with the main conveyance (cage) shown at the shaft collar position.

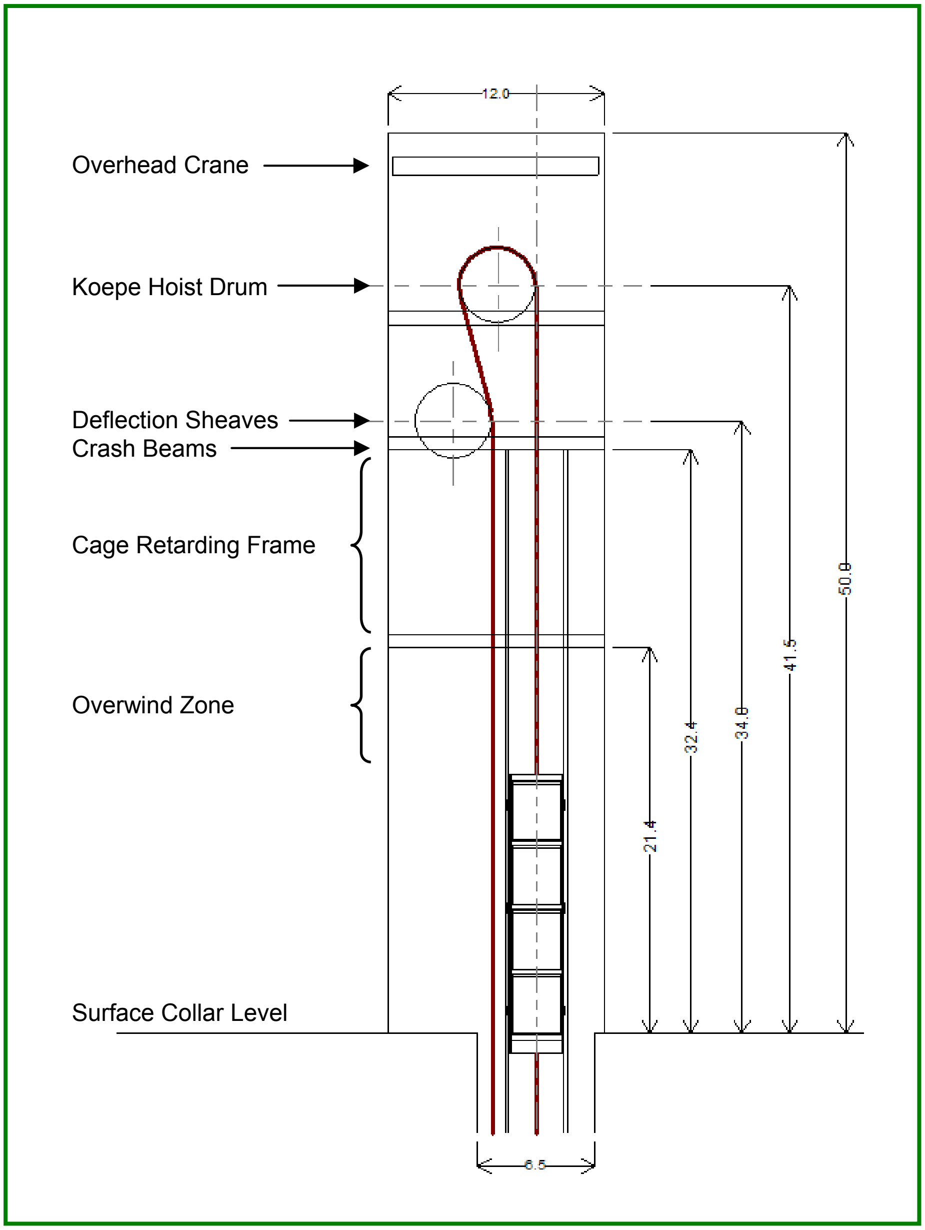


Figure 4-1 – Main Shaft Headframe Schematic

4.2.1.2 Hoist

A Koepe friction hoist will be used for lowering the waste packages to the repository level. This type of hoist consists of a fabricated steel drum with friction inserts mounted around the circumference of the drum, in which the wire ropes will run. The friction between the ropes and these inserts transfers the driving and retarding torque to operate the hoisting system. A set of ropes is attached to the top of the cage and run over the hoist drum to the counterweight on the other side.

In order to maintain a sensible internal shaft diameter, the ropes on the counterweight side are moved horizontally by a set of deflection sheaves 7.5 metres below the Koepe drum (see Figure 4-1). A set of tail ropes are connected to the bottom of the cage and run down to a loop below the lowest shaft station and thence back up to attach to the bottom of the counterweight.

This type of hoist has a high load capacity since multiple ropes are used to share the load. Because it is 'balanced' by winding the cage against the counterweight and balancing the head ropes against the tail ropes, motor power is reduced compared to an equivalent double-drum style hoist, which would have large out-of-balance loads at the extremities of the wind.

A simplified schematic of the Koepe hoisting system is shown in Figure 4-2, and a typical tower-mounted Koepe drum can be seen in Figure 4-3.

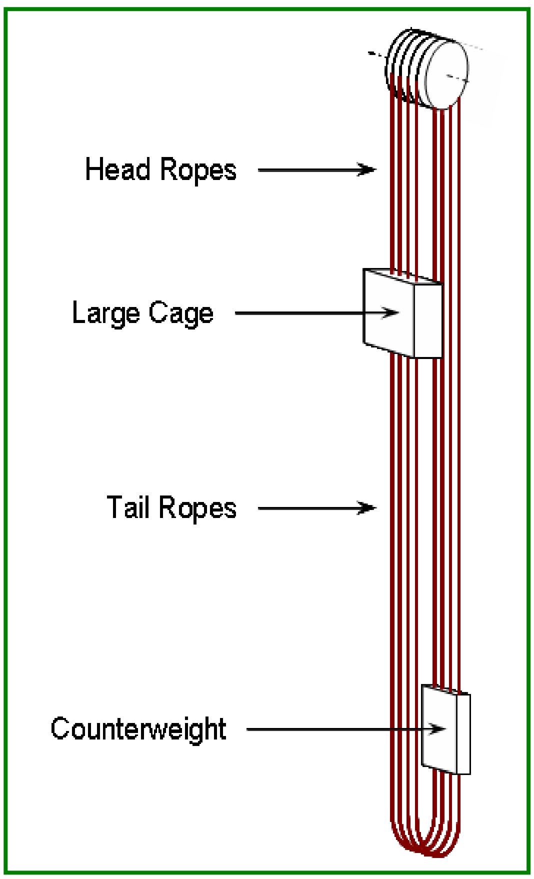


Figure 4-2 – Koepe Schematic

Figure 4-3 – Tower-mounted Koepe Hoist

The Koepe friction hoist for the DGR will consist of a 4.27 metre diameter drum directly driven by an A.C. motor. Six x 42 mm diameter head ropes and four x 54 mm tail ropes will be used for this hoist.

The duty cycle for the hoist when transferring waste packages to the repository horizon is shown in Table 4-1. The hoist will be restricted to half speed operation for very heavy and long T-H-E waste packages to ensure stability due to the nature of the package and method of placement in the cage.

A 14 metre tall cage with an internal floor plan of 5.4 metres long x 2.85 metre wide will be used. The cage plan dimensions are determined to accommodate the mining equipment that will be required for excavation of the underground repository. It is noted that certain of the larger pieces of machinery, such as the roadheader, will still require stripping down into components to transfer underground and the cage has been sized to suit those components. The height of the cage is determined by the longest waste package, being the IC-18 T-H-E liners, which are 11.8 metres in length and will be transported on a special rail car (of additional height), which is designed to provide them with the necessary support during transport in the cage.

The height of the cage enables four decks to be installed, which allows maximum hoisting efficiency to be achieved when standard low mass packages (LLW bins/racks, ILW shields) are being transferred.

When large and heavy payloads are loaded into or removed from the cage, there is a change in rope tensions, which leads to changes in rope stretch. Thus as a heavy load is loaded into the cage, the ropes will elastically extend and the cage will move downwards. Conversely, when the cage is unloaded, the ropes will contract and the cage will move upwards. Although this effect is much less with a multi-rope Koepe hoist, compared to a double drum, there will still be a small vertical motion of up to 0.4 metres. Because of the critical nature of the heavy ILW packages, it is important that such movements do not occur. In many Canadian mines, a system of "chairing" is used, especially for rock skips, where the conveyance is set down on steel beams in the shaft to prevent conveyance movement when the skip is loaded with rock. However, for the DGR cage hoist, neither upward nor downward motion during loading and unloading is acceptable, so a positive locking system is proposed. This is the "Levelok" system, which is proven in many deep South African mine shafts and is being introduced on deeper mines in Canada and USA.

The system consists of a set of locking clamps, which are mounted on the conveyance. A quick-coupled pneumatic connection is manually made when the cage is in the correct position, which then drives a small hydraulic power pack to apply the clamps to the shaft steelwork at the shaft collar and station, thereby preventing any movement while the cage is being loaded or unloaded. The system includes fail-safe features to ensure that the clamps cannot release unintentionally due to air or hydraulic pressure failure. Figure 4-4 shows a loose Levelok clamp, four of which will be mounted on or just under the top of the cage ([R48]).

Figure 4-4 – "Levelok" Cage Clamp

An additional safety feature, which is required in the Headframe and at shaft bottom comprises a method of retarding an overwound conveyance as previously noted in Section 4.2.1.1. Such a device is required under the Ontario Occupational Health and Safety Act ([R49]). Tapered guides are specified in that regulation. However, they do not provide a definable control of the deceleration rate. Modern devices such as the Siemag "Strain Energy Ductile Safety Arrestor" ([R50]) or the Horne Hydraulics "Technogrid Overwind Arrestor" ([R51]) provide a much more reliable and controlled method of stopping an overwound cage.

Both methods use the principle of deforming steel structures to absorb the kinetic energy of the conveyance as strain energy. The Siemag system uses a crash frame that is connected to steel strips running through fixed position roller boxes that bend and re-straighten the strips as the frame is raised or lowered by the moving conveyance (see Figure 4-5). The Horne system uses a steel lattice connected at one end to the shaft steelwork and at the other to the crash frame (see Figure 4-6).

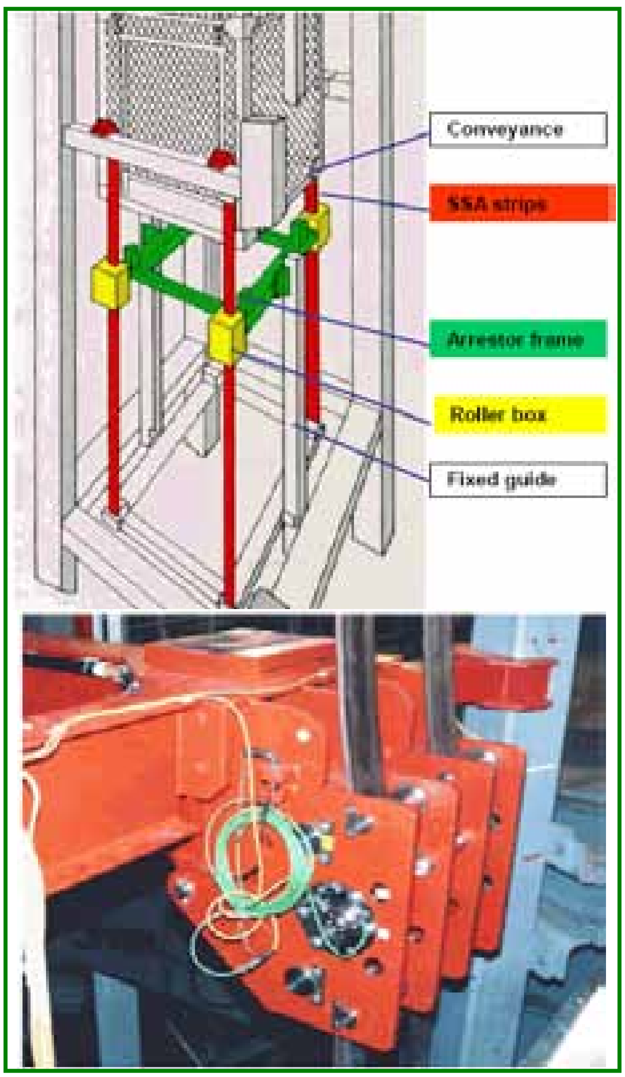


Figure 4-5 – Siemag Conveyance Arrestor

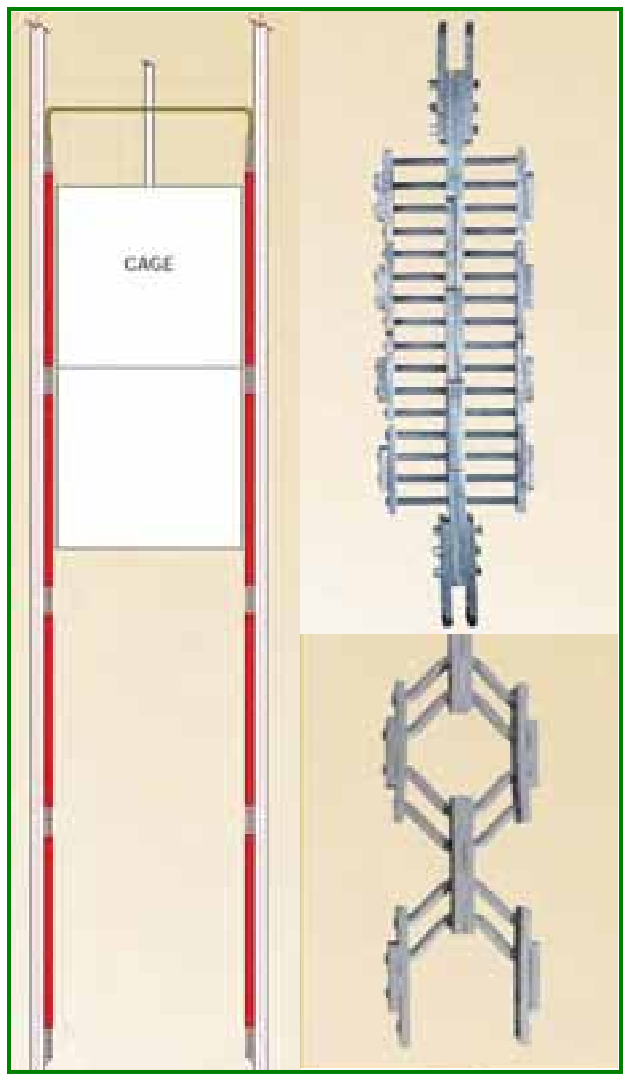


Figure 4-6 – Horne Conveyance Arrestor

Hoist Duty Cycle					
				Full Speed	***Half Speed***
Length of Wind			(m)	680	680
Maximum Speed			(m/s)	5	2.5
Acceleration/Deceleration			(m/s^2)	0.5	0.5
Creep:	Out		(s)	10	15
	In		(s)	10	15
Total Creep			(s)	20	30
Release Levelok		Lowering	(s)	10	15
		Raising	(s)	10	10
Apply Levelok		Lowering	(s)	15	10
		Raising	(s)	10	10
Cycle Time		Lowering	(s)	191	332
		Raising	(s)	186	186
Stopping Distance					
		- Normal	(m)	25.0	6.3
		- Emergency	(m)	8.3	2.1
Loads					
	Payload		kg	40,000	
	Cage Mass		kg	40,000	
	Attachments		kg	4,000	
Head Ropes					
	Number			6	
	Diameter		mm	42	
	Construction			34LR UHP Compact Strand	
	Density		kg/m	8.77	
	Tensility		MPa	1,800	
	Strength		kN	1,391	
	Suspended Length				
		Cage at Collar	m	25	
		Cage at 680 m	m	705	
	Factor of Safety				
		Cage at Collar		**6.90**	
		Cage at 680 m		**6.95**	
Tail Ropes					
	Number			4	
	Diameter		mm	54	
	Construction			14 Strand N-S	
	Density		kg/m	13.49	
	Tensility		MPa	1,600	
	Strength		kN	2,020	
	Suspended Length				
		Cage at Collar	m	705	
		Cage at 680 m	m	25	

Hoist Duty Cycle			
Factor of Safety			
	Cage at Collar		**21.65**
Drum	Minimum Diameter	mm	4,270
	Tread Pressure	MPa	1.13
	D/d ratio (Drum : Rope)		101.7
Tail Loop	Minimum Diameter	mm	2,430

Table 4-1 – Main Shaft Hoist Duty Cycle

Modern electronic control and safety systems utilising well-proven programmable logic controllers will be installed on the hoist. All safety systems will have multiple redundancy to ensure that the hoist will operate safely at all times, even in the event of failure of any one system.

The hoist drum will have two integral machined steel discs on the outside of the drum cheeks, against which multiple disc brake units are mounted. In a similar manner to the control and safety systems, these multiple units will also provide redundancy and ensure that one set of brake units on one disc only will be able to safely stop the hoist in the event of failure of the complete set of brake units on the other disc. The brake controls will be fully dynamic and will ensure that emergency braking will be achieved at controlled and ramped retardation rates to avoid any shock loads being applied to the shaft conveyances and remain in compliance with the mining regulations. In the event of any power failure, the braking system will act in a fail safe manner to bring the hoist to a smooth stop. The hydraulics are equipped with accumulators to ensure that hydraulic power remains available to achieve a controlled stop of the hoist under power failure conditions.

The main mechanical and structural components of the hoist (drumshaft, drums, bearings etc.) will be designed to provide a 100 year life using fatigue and finite element analysis as appropriate.

4.2.1.3 Waste Package Receiving Building and Staging Area

A DGR Waste Package Receiving Building (WPRB) will be connected to the shaft Headframe. Waste packages will be off-loaded from the transporters transferring them from the WWMF or from the OPG-owned nuclear power plants. An arrangement sketch of the layout of this building is shown in Figure 10-2.

This building, which will be approximately 38 metres square and 18 metres high, will be of insulated and clad steel-framed construction. It will have a drive-through off-loading bay on the south side with large doors at each end. This arrangement will enable the overhead beam crane or both size of forklift to off-load the waste packages and move them into either the staging area or into a 'reprocessing' section for those packages requiring overpacking or shielding before transfer underground for final disposal. Addtionally, a truck door in the south wall of the bay will enable container trucks to back up to the off-loading platform to enable standard LLW containers to be removed by drive-on forklifts.

The enclosed off-loading bay will also facilitate both operations throughout the inclement winter months and zone control by ensuring egress from the WPRB is via specific doors with monitor points (refer to Section 10.5).

During the initial years of operation of the DGR, all processing of existing wastes will be performed at the WWMF. But certain new waste packages will arrive at the WPRB direct from the power plants. The 40 tonne overhead beam crane installed in this building will assist with placement of the heavy and large wastes in their shields or overpacks, and will move them into position at the shaft collar for transfer into the shaft cage by forklift or on rail cars. The building will have a section for new resin liners being delivered direct from the power plants, which is separated from the rest of the building by a 4.5 m high x 0.5 m thick concrete wall to protect workers in the other areas around the shaft being exposed to radiation fields while the resin liners are being transferred into their shields, which are stored in this part of the staging area.

The storage capacity of this building has been sized to provide a buffer store of up to a full shift of the greatest volume/number of packages that would need to be transferred in a shift. The standard box-type LLW packages are the determining factor. Although packages could be moved across from the WWMF throughout the day, there will be times when some of the larger and heavier waste packages are being transferred underground. The more awkward of these items (e.g. T-H-E liners and heat exchangers) will tie up the hoist loading area for a considerable portion of the shift, and this buffer capacity would be necessary to allow for receipt of other waste packages during the shift.

In this way, it can be ensured that the surface receipt of packages will not become a bottleneck in the process and thereby cause the transfer operations to fall behind schedule.

The staging area has been laid out to temporarily store up to 35 standard LLW packages and a suite of the different types of resin liner shields (adequate to hold 4 resin liners – see Section 8.2.2.1) in the shielded Resin Liner section. These quantities are the highest number that are likely to be transferred in one day. While the number of standard LLW packages exceeds the requirements given in the Design Requirements (see Section 3 above), which only requires 24 items to be handled per shift, this is an average number and to make up for days where only a few heavy of large ILW or LLW packages are transferred, it will be necessary to move larger quantities of the standard LLW packages on many days during clearance of the backlog.

Adequate travelling ways between the staging area and the off-loading bay, and between the staging area and shaft cage entry have been allowed for rail car and forklift manoeuvring.

4.2.1.4 Repository HVAC system

The HVAC system, which will be constructed to the west of the Headframe, will provide both cooling of the air during the summer months and heating of the air during winter.

The cooling plant will consist of a steel-framed, insulated and cladded refrigeration plant building fitted with centrifugal water chillers using HFC-134a as the refrigerant, and a direct contact bulk air cooler in which the chilled water is sprayed into a polypropylene fill material against the incoming air flow.

The bulk air cooler will be made up of two cells in a single reinforced concrete shell to allow for reduced cooling when the maximum summer temperatures are not realised by isolating one cell, and to enable one cell to be taken off-line for maintenance or repairs if needed during the summer months.

From the bulk air cooler, the chilled air will then pass through a set of mist eliminators, which will remove all water droplets from the airflow before the air flows into an inlet plenum to the shaft. This plenum will be constructed below ground level with the air intake to the shaft approximately 10 metres below the collar. The air will be cooled to between 12 and 15°C, depending on ambient conditions.

During winter a set of natural gas heaters, installed in a reinforced-concrete heater building, will be used to heat the air to a minimum of 6°C. The air exiting the heating building will then be introduced into the same shaft-inlet plenum as used for the chilled air.

Sets of axial flow fans will be used to push the air through the bulk air cooler and heaters and into the shaft and will overcome the frictional losses in the shaft. Doors will be used to isolate the heating or cooling system, as appropriate to the function being performed.

Both the heating and cooling system will be fully controllable to optimise air temperatures, limit humidity and minimise power and natural gas consumption. To this end the outlet air temperatures would be controlled by operating the refrigeration machines and heaters at variable cooling and heating parameters.

The refrigeration plant will be approximately 13 x 11 metres in plan dimensions and 8 metres high. The bulk air cooler will be approximately 12 x 10 metres in plan dimensions and 10 metres high. The heater building will be approximately 14 x 10 metres in plan dimensions and 4 metres high.

A more detailed description of the heating and cooling systems is given in the Section 5 below, in which the full ventilation design is presented.

4.2.1.5 Shaft Offices

A shaft office section, constructed from brick, will be attached to the Headframe and receipt building for the shaft operations staff (engineer, shaft controller/planner, hoist driver, cage tender, mechanic, electrician, and instrumentation/controls technician). Other surface operations personnel may have offices in the vicinity of the WPRB or alternately at the existing WWMF.

4.2.1.6 Shaft Maintenance Workshop, Materials and Equipment Store

Maintenance materials and spares for the shaft system will be stored in an insulated and cladd steel-framed, building attached to the shaft Headframe. This building will also allow for minor repairs of standard shaft items, such as hoisting components, ropes, rope attachments, shaft cage and counterweight.

Any major overhaul of equipment would be undertaken off-site at specialist workshops.

4.2.1.7 Control room

A control room will be incorporated into the shaft offices. This room will be equipped with computing and control equipment to marshal all signals and data transmitted from underground and the hoisting system and display the status and production logs of all equipment, facilities and systems.

The shaft controller/planner would use this data acquisition and monitoring system to control the shaft operations and the flow of waste packages to the DGR and transfer into the DGR. All safety data would be relayed to the control room, such as ventilation flows, fan operations, HVAC system status, contamination levels in the air, water levels in underground sumps, compressed air pressures underground.

4.2.2 Ventilation Shaft Area

The Ventilation Shaft area will include the following key structures:

- Ventilation Shaft Headframe
- Collar House

- Hoist
- Hoist Room
- Waste Rock Bin and Airlock
- Exhaust Fan Building

The Ventilation Shaft will be used as a second egress and for hoisting rock during the construction phase.

4.2.2.1 Headframe

The Ventilation Shaft Headframe will be an insulated and clad steel structure. Without the need for a large tower-mounted Koepe hoist, this construction is more cost effective. The Headframe will be 40 metres in height and will include a tipping path and chutes for discharge of the waste rock that is excavated during construction of the repository. Should there be any need for expansion of the repository at a later stage, this arrangement would be used.

The Headframe steelwork will be constructed with heavier main members than would normally be used at mine shafts to ensure that the structure will not require any major refurbishment during the 100 year life of the repository.

4.2.2.2 Collar House

The insulated and clad, steel-framed collar house will be used for control of the shaft by the cage tender. Basic maintenance of the conveyance and ropes will also be carried out here, although all equipment and materials will normally be stored at the Main Shaft and offices for the maintenance personnel will also be located there.

4.2.2.3 Hoist and Hoist Room

A single drum hoist will be installed in a 20 x 20 metre building, which will be 12 metres high and constructed as an insulated and clad steel-framed structure. The building will contain all the hoist electrics and control cubicles.

The hoist will have a 3.66 metre diameter drum, and will hoist a combination cage and skip, which will ensure that the 2nd egress function of the shaft is always available. One 40 mm diameter triangular strand wire rope will be used to wind the conveyance. The design of the hoist's main mechanical and structural components will follow the same principle outlined in Section 4.2.1.2 above.

Control and safety systems, which are similar to those used in the Main Shaft, will be installed with redundancy for each of the critical systems. Multiple disc brakes units on two brake paths on the fabricated hoist drum will be employed.

The internal cage plan dimensions are 1.8 x 1.25 metres and the deck is 2.4 metres high, which will provide capacity for 14 persons. The skip, which will be positioned below the cage, will be a bottom discharge type with a capacity for 8.7 tonnes of broken rock.

During the development of the repository, this hoist will be used for both personnel transport and waste rock removal. After completion of development, it will only be used as a 2nd egress to enable personnel to be evacuated from the repository in the event of an emergency or if the Main Shaft cage is unavailable for any reason. At this time, the skip body will be removed from the bale to reduce overall mass and conserve power when the hoist is operated.

The combination cage and skip is shown in Figure 4-7.

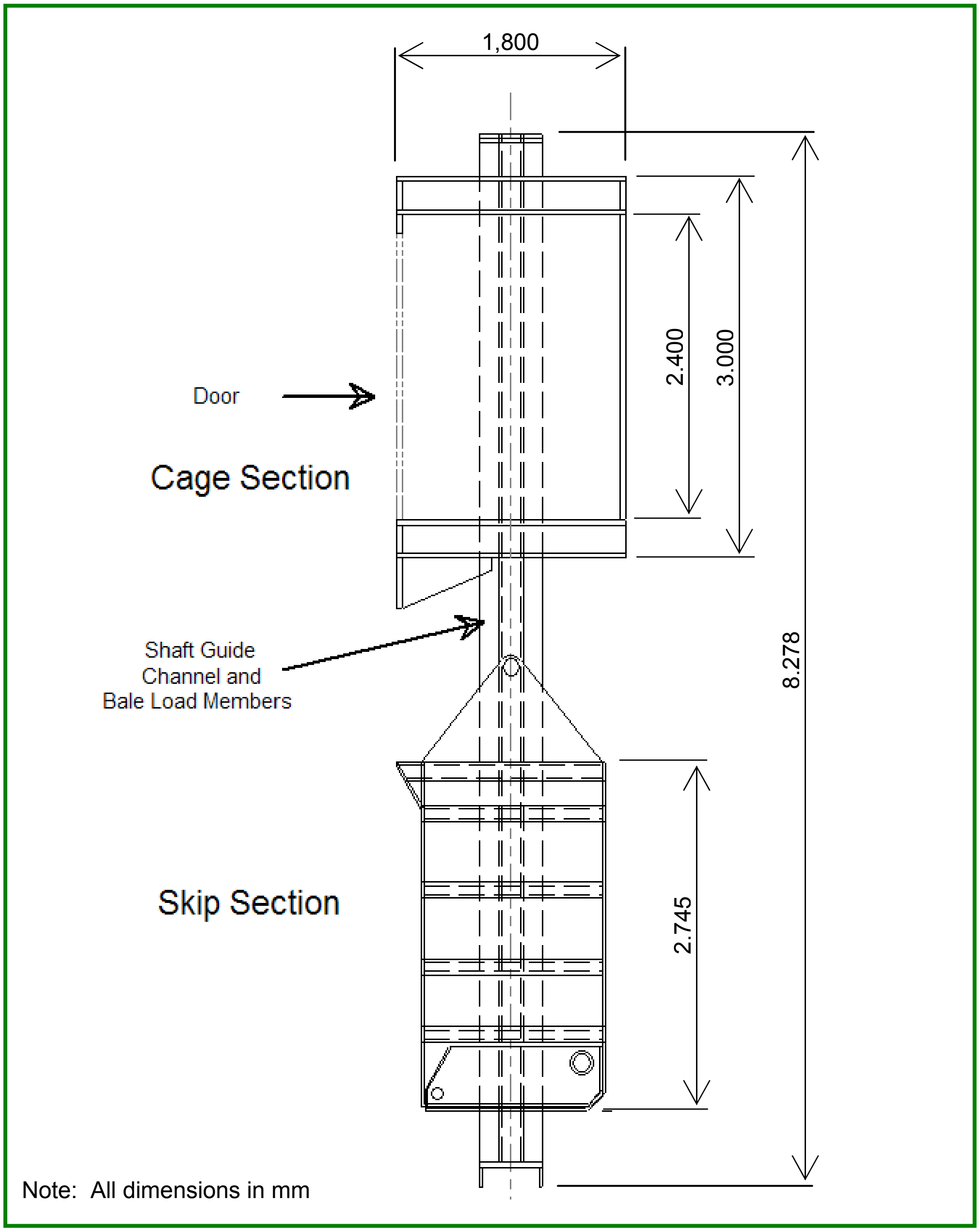


Figure 4-7 – Combination Cage and Skip for Ventilation Shaft

Unlike with the Main Shaft cage, there will be no need to install a "Levelok" system on this conveyance. When hoisting rock in the skip, the conveyance will be seated on "chairs" during loading to prevent rock spillage. During personnel winding, the change in mass between an empty and full cage will be minimal and will not pose any risk to staff.

4.2.2.4 Waste Rock Bin and Airlock

A waste bin will be attached to the Ventilation Shaft Headframe to hold rock discharged from the skip during the repository construction. As this is an upcast shaft, an airlock will be installed as part of the bin structure to ensure that the Headframe is under the same pressure as the shaft. This is necessary to prevent short-circuiting of the air circuit, which would otherwise occur as the exhaust fans would try to draw air from the outside rather than up the shaft.

4.2.2.5 Exhaust Fan Buildings

The main repository exhaust fans will be installed in a building, which is 8.7 metres wide x 6.7 metres long. Three fans are recommended, with two normally operating and one stand-by unit. The fans are described in more detail in Section 5.7. The fans will be arranged to run from a diesel-driven generator to cater for any interruptions in power supply to the DGR site. All structures will be steel with cladding and insulation as necessary. The exhaust drift from the shaft will be a reinforced concrete construction.

4.2.3 Shared Services

Certain surface infrastructure, such as power, compressed air, sanitation, water and natural gas will be shared by both shafts, the underground repository and other surface buildings. The services themselves are presented in Section 9. The site structures and plant are described hereunder:

4.2.3.1 Electrical Sub-Station

The main incoming electrical sub-station will be sited to the north-west of the shaft area and close to the interconnecting road and the adjacent Hydro One easement. The incoming power will be 44 kV, which will be fed via a set of main breakers into transformers, which will reduce the voltage to 13.8 kV. This voltage will be fed directly to the main power users (Main Shaft hoist and refrigeration machines and also to further breakers and transformers to produce lower voltages (600 V and 110 V) for surface low tension power users, and all associated power distribution switchgear and motor control centres within suitable brick buildings. The sub-station will be equipped with lightning protection equipment.

Additionally, an emergency diesel generator will be sited within the sub-station yard with switchgear to allow for automatic connection to the DGR power reticulation system to enable immediate supply of emergency power to key equipment and areas of the DGR. The diesel generator is further discussed in Section 9.5.

The area of the sub-station will be approximately 30 x 22 metres in plan.

4.2.3.2 Compressor Plant

A steel-framed, insulated and clad compressor plant building will be established close to the Main Shaft to provide compressed air for shaft sinking. Following completion of construction, the compressors will provide the facility with compressed air for underground refuge stations, sump agitation and general construction and maintenance requirements.

Three centrifugal compressors will likely be required during the construction period. One would act as a stand-by unit. Following completion of construction, only two compressors will be required, with one being operational and the other acting as a stand-by. The compressor plant will also include cooling towers for the water cooled compressors. The plant building will require an area of 16 metres x 10 metres.

4.2.3.3 Fuel Storage

A fuel and lubrication storage site with a capacity of 5,000 litres will be constructed close to the contractors' lay down area during construction. This facility will support all diesel and gasoline powered equipment on site during construction and facility operations, and is shown on Drawing 323874DGR-200-023. Additionally, a separate 8,000 litre diesel tank will be installed close to the emergency generator (see Section 9.5) for its exclusive use. Both fuel stores will be surrounded with berms to ensure that the full fuel volume can be retained in the event of tank failure or spills.

4.2.4 Connection to WWMF

A concrete bridge will be constructed to span the abandoned railway ditch as shown on the site plan in Figure 4-8. This bridge will be designed to support the maximum mass of any transporter and load (waste packages, hoist components, etc.) that will move these items to and from the DGR shaft areas.

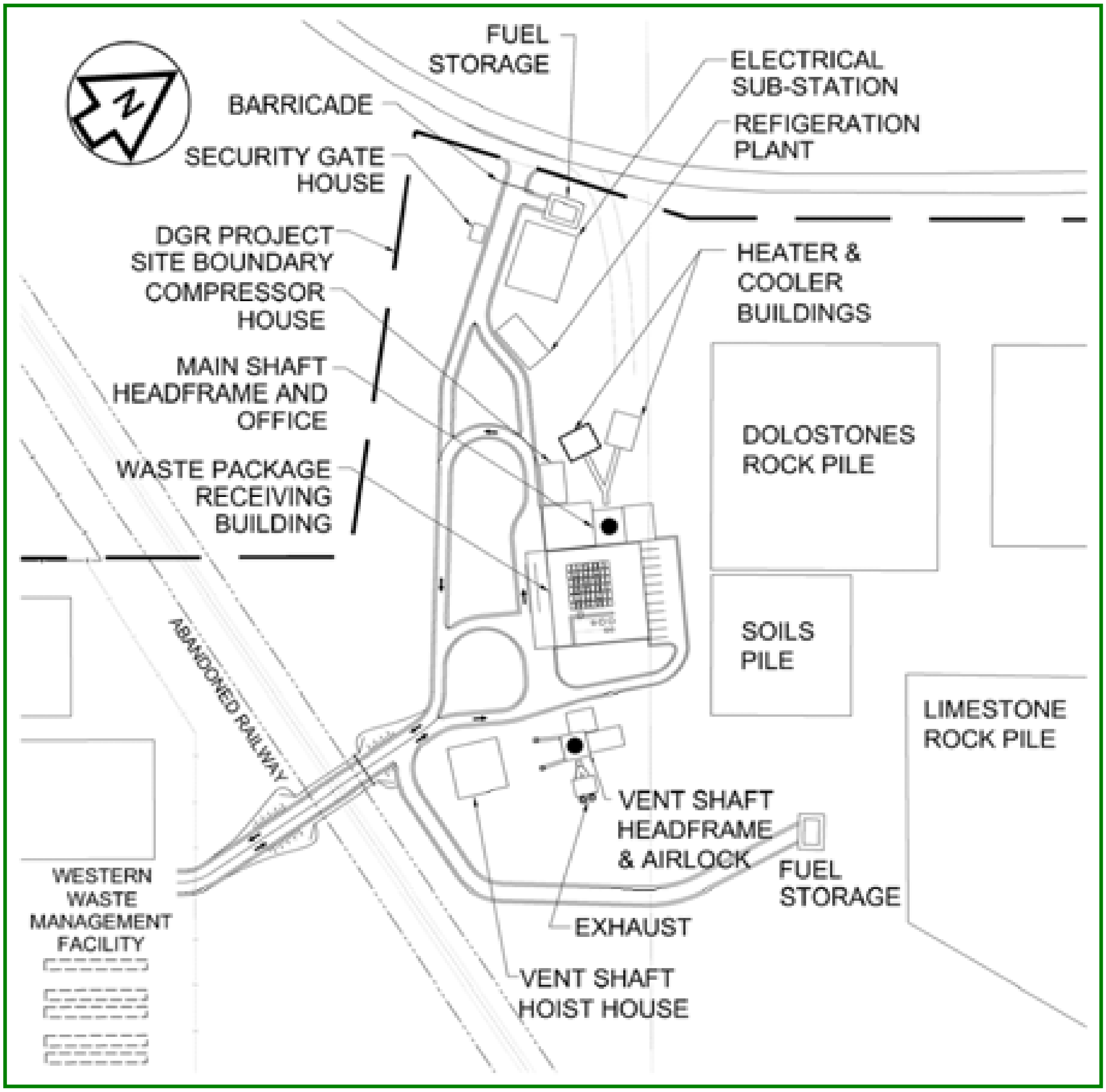


Figure 4-8 – Proposed Surface Layout of DGR and Connection to WWMF

4.2.5 Waste Rock Storage

4.2.5.1 Characteristics of Excavated Materials

4.2.5.1.1 Overburden

Borehole drilling from DGR-1 & DGR-2, which was carried out in 2007, found that surficial deposits overlying the bedrock within the study area reach a thickness of 20 metres. Based on borehole drilling conducted nearby, overburden sequences within the area consist of, in descending order, a surficial layer of sand and gravel, a weathered brown till horizon 2 to 4 metres thick overlying fresh grey till comprised of dense silty sand to very hard clayey silt with sand and boulders.

4.2.5.1.2 Bedrock

To date, two investigation boreholes, as noted above, have been drilled on behalf of OPG to characterise the sedimentary bedrock sequence near the DGR location. These boreholes show that the depth to the contact between the Ordivician shales (Reach 3) and Ordovician limestones (Reach 4) is 652 m below ground surface.

Details of each unit are provided in Table 2-5.

4.2.5.2 Chemical Characteristics

Based on the information provided in Table 2-5, total dissolved solids (TDS) from groundwater within the shallow bedrock typically fall within the range of 500 to 1,600 mg/L with a tendency to increase slightly with depth. Groundwater in the intermediate to deep bedrock zones are typically saline to brine and chloride levels are very high and can vary up to 300,000 mg/L. The principal dissolved constituents vary from sodium chloride in the saline water to calcium chloride in the brine water.

These chloride concentrations indicate that many of the rock formations themselves have characteristically high chloride levels. After excavation and disposal, there is the potential for chlorides to leach in the run-off. Chloride can have a negative effect on the environment, including soils, groundwater and surface water. While elevated chloride concentrations have been found in the run-off from storage piles of excavated rock materials from the Queenston Formation as part of the Niagara Tunnel Project, these concentrations are less than the regulatory requirements. Therefore, no supplemental environmental protection measures to manage and treat chlorides in the leachate from waste rock are currently proposed in the water management plan.

Similarly, no supplemental environmental protection measures are proposed with respect to leaching of benzene, toluene, ethylene, and xylene (BTEX). Excavations from the Test Adit and Niagara Tunnel have not found BTEX levels within leachate from excavated Queenston and Rochester Formation shales that would be sufficient to require special leachate treatment or disposal ([R23]). Similarly, gas content is expected within the shales, including the Queenston and Rochester Formations, borehole investigations conducted within the Niagara Region ([R24]) failed to detect significant amounts of gas, and none of the exploration wells identified in Section 2.3 contained gas levels determined to be suitable for commercial natural gas extraction.

4.2.5.3 Quantities of Excavated Materials

The quantities of rock materials to be excavated for (i) the shafts (both access and ventilation); (ii) the repository; and (iii) the ancillary rooms and access tunnels, are given by Reach and Type in Table 4-2 and Table 4-3. The general stratigraphic sequence and designated reaches is presented in Table 2-5.

The excavated quantities were calculated using:

(i) Volumes for the DGR level development (ring, tunnel, ancillary rooms, access tunnels and emplacement rooms;

(ii) Interior diameters of the Main and Ventilation Shafts of 6.5 and 4.5 metres respectively;

(iii) A bulking factor (volume increase during excavation) of 1.6. This bulking factor was selected as an average value for crushed limestone material.

Reach	**Volume (m^3)***	
	In-Situ	**Bulked (1.6)**
Overburden (Reach 1)	2,202	3,524
Dolostones and shales (Reach 2)	29,984	47,975
Shales (Reach 3)	19,874	31,797
Argillaceous Limestone (Reach 4)	420,381	672,609
Total (Rock Only, excludes Overburden)	***472,441***	***755,905***

NOTES: *Calculated volumes based on DGR-1 and 2 observed thickness

Table 4-2 – Estimated Quantities of Excavated Materials by Reach

Material Type	**Volume (m^3)***	
	In-Situ	**Bulked (1.6)**
Overburden	2,202	3,524
Dolostones	26,621	42,593
Shales	23,237	37,179
Argillaceous Limestone	420,381	672,609
Total (Rock Only, excludes Overburden)	***472,441***	***755,905***

NOTES: *Calculated volumes based on DGR-1 and 2 observed thickness

Table 4-3 – Estimated Quantities of Excavated Materials by Material Type

Production rates for the total volume of excavated materials were determined based on average excavation rates of approximately 1.5 metres advance per day during shaft sinking (including stations, sumps, loading pocket, and geological investigation) and a combined average rate of 533 m^3 (in-situ) per day on the DGR level (see Section 7.6.1.2). Roadheader cutting rates vary based on material properties. With the predicted strength of the argillaceous limestone, approximately 15 effective cutting hours would be required daily ([R75]) to achieve the design annual volumes. The production rates during the shaft and underground level development program are expected to be as follows:
(*Note*: the 'year' numbers correspond to those given in the Conceptual Schedule (Section 12.5))

- Year 2: 2,969 m^3 (2,202 m^3 of soils; 767 m^3 of dolostones).
- Year 3: 21,197 m^3 of dolostones.
- Year 4: 47,696 m^3 (4,658 m^3 dolostones; 23,237 m^3 shales; and 19,801 m^3 limestone).
- Year 5: 184,410 m^3 of argillaceous limestone.
- Year 6: 157,215 m^3 of argillaceous limestone.
- Year 7: 58,956 m^3 of argillaceous limestone.

The following sections describe the various issues, requirements and opportunities for the management of excavated rock.

4.2.5.4 Re-Use On-Site

During the construction of the DGR project, it is anticipated that aggregate will be needed for access roads, concrete and backfill material. It is estimated that approximately 1,500 m^3 of excavated dolostones will be used for access road preparation during repository construction and waste rock disposal area preparatory activities. Dolostone material would only become available after the initial construction of access roads to the permanent site structures and construction laydown areas. However, this material will be used for those roads required within the waste rock disposal area. It is estimated that 50 percent of the access roads will be constructed when the dolostones become available, resulting in 750 m^3 needed. An on-site crusher will be required to crush the rock to the specifications for road materials.

Approximately 20,000 m^3 of dolostones will be needed for concrete aggregate associated with concrete lining in the shafts. Aggregate quantities of approximately 5,400 m^3 will be needed for road bases in the repository. It is expected that the quality of the excavated dolostone material would be suitable for concrete aggregate, however, any shales from Reach 2 mixed with the dolostones would negate potential use. As a result, dolostones for concrete aggregate production will be used from thicker layers (such as the 158 metre of Amhertsburg through Bass Islands). Sampling and testing of the dolostones will be required in order to confirm that they can be used for concrete aggregate. In addition, crushing and screening may be required prior to use as an aggregate. Mixtures of shales and dolostones will also be used as aggregate for construction of access roads and berms, while shales from Reach 2 will be used in construction of berms.

If all of the dolostones meet the requirements for either aggregate for access roads or concrete, then approximately 17,700 m^3 will require temporary on-site storage to meet the total aggregate demand of approximately 26,150 m^3 as shown in Table 4-4. Should the dolostones not meet the specifications for aggregate use, they may be disposed permanently on-site, or re-used in construction of berms. At this time, it is uncertain how many berms will be required so the remaining 22,000 m^3 of materials from Reach 2 will be treated as if permanent disposal will be required on site.

Use of Aggregate	**Quantity (m^3)**
Access Roads	750
Concrete Shaft Liner	20,000
Repository	5,400
Total	**26,150**

Table 4-4 – Aggregate Quantity Required for Initial DGR Construction

Approximately 13,500 m^3 of rock materials (dolostones and/or limestones) will also eventually be needed as backfill above the composite sealing system in the shafts when the repository is closed. The rock will be disposed on-site, until needed, and will then be mined from the disposal area. As similar materials have been exposed to surface conditions for many years without significant degradation of dolostone and limestone materials, it is expected that these materials will still be usable after disposal for the 100 year design criterion for DGR operation.

Further it is expected that all materials excavated from the overburden layer during shaft sinking and creation of drainage ditches will be re-used on site during construction. Uses of overburden materials will include capping of the shale disposal pile and berms. Based on the amount of overburden available (see 4.2.5.5), all of these materials will be re-used on site in capping of the shale pile (approximately 7,500 m^3 required), grading of the site, or construction of berms such that there will be no requirement for permanent disposal of overburden materials. Additional soils may be available as a result of land grading/stripping within the disposal and construction areas. If insufficient materials are available on site, materials will have to be obtained externally.

4.2.5.5 Temporary Storage Requirements

Materials required for re-use, including overburden (soils), dolostones and shales from Reaches 1 and 2 will be temporarily stored on the site. Drawing 323874DGR-200-023 (See Appendix E) provides the location of temporary storage areas within the Waste Rock Disposal Area ("WRDA").

Overburden excavated for Main and Ventilation shafts (~3,500 m^3 bulked) and for drainage ditching and retention pond (~7,800 m^3 bulked) will require temporary storage immediately following excavations. Temporary storage of overburden will be needed for a period of up to 4 years.

Overburden will be stored in the southwest portion of the available lands, next to the construction work areas to facilitate material handling during construction and to maximise distance between loose soils and the potential crayfish habitat indicated in Figure 2-1. Soils will be piled to a height of 10 metres to minimise area requirements. At this height, the soil pile will be an approximately 59 x 59 metres square, covering an area of 0.3 hectares. As loose soils can be easily eroded, a silt fence barrier will be placed around the temporary soil pile to contain any silt laden runoff during storm events, thereby minimising soil loss. If soils are to be left in place for a period of greater than 1 year, they will be vegetated to minimise erosion. However, it is expected that most overburden materials will be re-used in less than 1 year.

Temporary storage of approximately 48,000 m^3 (bulked) of dolostones/shales excavated from Reach 2 during shaft sinking will be required for a period of approximately 10 years as it will eventually be used in construction of the DGR). Dolostone will be stored immediately adjacent to the overburden on the south-western boundary of the site. Dolostones and shales will be separated to the greatest extent possible. Due to the difficulty in separating the shales from some of the dolostones in Reach 2, some of these materials may be stored together with the shales in the WRDA. Shales separated from Reach 2 will be stored with shales excavated from Reach 3 and are addressed in Section 4.2.5.6 below. Dolostones will be piled to a height of 10 metres, to minimise area requirements. At this height and with all of the dolostones excavated and stored, the pile will be approximately 89 x 89 metres square, covering an area of 0.8 hectares. However, depending on when materials are required for re-use, the pile may never reach maximum capacity.

Both overburden and dolostones will be stored within the drainage ditch network (addressed further in Section 4.2.5.6). All piles of excavated materials will be stored with a 2:1 (horizontal : vertical) slope to ensure pile stability. It is anticipated that all of the soils and at least half of the dolostones will be re-used on-site during construction. As a result, there should be no permanent disposal of soils excavated during construction of the DGR.

4.2.5.6 Waste Rock Disposal Area (WRDA)

As the majority of excavated materials from Reaches 1 and 2 will be re-used on site, the approximate quantity of rock materials required for long-term on-site disposal is 730,000 m^3 (bulked; 755,900 m^3 of excavated materials minus the 26,150 m^3 required for re-use). The following sections discuss the details and requirements of disposing the rock on-site.

4.2.5.7 Location and Size

Drawing 323874DGR-200-023 in Appendix E provides the location and layout of the proposed waste rock disposal area. The disposal area has been divided into three sections, one for temporary and permanent storage of overburden and dolostones (as addressed in Section 4.2.5.5), one for limestones, and one for shales.

The size of the disposal location is based on a total rock volume for the initial repository development of approximately 730,000 m^3 (bulked). Three rock types will be disposed within the WRDA; dolostones, shales and limestone.

Based on anticipated re-use requirements of 26,150 m^3 of dolostones, approximately 16,450 m^3 (bulked) from Reaches 2 and 3 will require permanent disposal. These materials will remain in the same location as for temporary storage, along the south-western boundary of the site. The disposal pile will be approximately 10 metres high, in a 60 x 60 metre square, covering an area of 0.4 hectares.

Approximately 37,000 m^3 (bulked) of shales from Reaches 2 and 3 will be disposed in the south section of the disposal area. The disposal pile will be approximately 13 metre high, in a 79 x 79 metre square, covering an area of 0.6 hectares.

The amount of limestone (Reach 4) from repository development is approximately 672,600 m^3 (bulked) and will be located in the eastern portion of the disposal area in order to minimise impacts on the outflow from the potential crayfish habitat in the north-eastern corner. The height of the pile is estimated to be 15 metres, and will cover approximately 6.2 hectares at that height.

All rock disposal piles have been designed with 2:1 slopes to ensure stability.

It is proposed that the rock will be transported from the excavation to the disposal area via a trucks and a radial conveyor system. Initially, trucks would be used for the shaft sinking operation. Later when rock production rates are higher, a conveyor system will be used. Conveyors have been used in many quarry operations to move materials over both short and long distances. In addition to probable lower overall costs associated with a conveyor system, a covered conveyor system would reduce potential issues associated with rock spillage and dust along roadways. It is expected that a conveyor system would only be required during the excavation campaign period. If a conveyor is to be used, a dust suppressant system should be installed at the top of the conveyor to reduce dust emissions. A bulldozer will be required to move the rock and grade accordingly.

4.2.5.8 Stormwater Management

It is anticipated that run-off from the WRDA will contain fines from both exposed rock, during construction and operation of the DGR, and soil, during temporary storage on-site. As the excavated rock material is from a natural source and has not likely been impacted by contamination, the waste rock would likely be considered as 'inert fill' according to Ontario Regulation 347 ([R55]). This would require confirmation through Toxicity Characteristic Leaching Procedure (TCLP) testing. Following confirmation, stormwater runoff from the waste rock would be acceptable for discharge to the natural environment; however, stormwater management is still required within the WRDA to control Total Suspended Solids (TSS)/ turbidity as required by the MOE prior to discharge. Based on current experience with excavated materials from these stratigraphic layers in other locations, such as the Niagara Tunnel and the Test Adit, it is not anticipated that special treatment for chlorides or BTEX will be required.

Stormwater runoff from waste rock disposal piles will be collected in a network of 15 metre wide, 2 metre deep trapezoidal drainage ditches, which will be vegetated to minimise erosion, around the perimeter of the WRDA (see Drawing 323874DGR-200-023 in Appendix E). The drainage network will direct runoff to a retention pond, designed for removal of TSS. The retention pond will be located on the western boundary of the site, near the entrance off Interconnection Road (see Drawing 323874DGR-200-023). As the site drains to the north, some grading of the northern half of the site will be required to ensure that stormwater flow passes into the pond.

A preliminary assessment of the area required to manage the storm water runoff water quality associated with the 24 hectares of land available for the waste rock disposal area returned an estimate of 6,000 m^3 of required water quality storage volume. This equates to a retention pond surface area of approximately 0.48 hectare based on assumed dimensions of 40 m wide x 120 m long x 2 m deep with 4(H):1(V) side slopes.

In future phases of engineering, the final dimensions of the site drainage system including the stormwater quality retention pond, drainage ditches, etc., will be designed to be capable of controlling and conveying larger storms up to and including the 1:100 year, 24-hour storm event without spilling into sensitive areas. While it may not be possible to design the stormwater management ponds to be capable of retaining all potential storm flows, the control gates and structures would need to be designed to be capable of passing this storm event without structural failure. The suitability of the storm event data (as shown in Table 2-1) will be re-assessed as part of the determination of final dimensions for the site drainage system during future phases of engineering.

Water from the retention pond will then be discharged via a controlled output into the existing drainage ditch network along the Interconnecting Road, which drains north towards Lake Huron via Area "J". This will avoid impacting Stream C, which was previously identified as an area of concern by Golder Associates (see Section 4.2.5.13 and Drawing 323874DGR-200-023 in Appendix E). Areas within the WRDA that currently drain towards Stream C will be redirected via the proposed stormwater management system. Prior to discharging any effluent from the retention pond, testing (pH, temperature, TSS, benzene toluene ethylbenzene and xylene (BTEX) and petroleum hydrocarbons (PHC)) will be undertaken to confirm compliance with applicable discharge requirements.

In order to ensure that discharges from the retention pond do not exceed requirements for TSS, pH or chlorides (if required), a gate will be installed on the outlet. This gate can be controlled either manually or remotely. In either case there are two potential operating regimes for the gate:

- Gate is left in closed position and is opened as required following testing

- Gate is left in open position and water quality is monitored remotely (at the DGR Control Room or, out of normal DGR working hours, at the WVRF Control Room, which is manned 24 hours a day, 7 days a week) so that the gate can be closed should an excess of TSS occur.

Both options would be appropriate for the DGR. The second option is preferred as it is self-regulating and would require minimal on-site monitoring.

During construction of the DGR, existing drainage ditches along the abandoned railway bed within the DGR project site will be either incorporated or rerouted into the proposed drainage network. It is not expected that either of these ditches provide a significant wetted habitat. However, an assessment should be completed as part of the environmental studies for the DGR project. Should expansion of the DGR be required, it is likely that the drainage outlet from the potential crayfish habitat would also need to be rerouted or incorporated within the proposed drainage network. A detailed assessment of the potential impacts would be required at that time.

4.2.5.9 Visual Impact

A setback or buffer of 30 metres from the Interconnecting Road has been included in the design of the long-term rock disposal area. Visual screening (i.e., berm and/or trees) will be installed; however, since the disposal pile will be 15 m in height, it will not provide a complete visual screen of the pile. Trees are recommended around the waste rock disposal area due to the preferred aesthetics and reduced surface area requirements of trees as opposed to berms. It is anticipated that several of the buffer areas are likely already treed and these trees will also contribute to dust management (see Section 4.2.5.11). While a berm(s) may be a suitable alternative, a greater effort and cost during the initial design (i.e., to ensure slope stability), construction (i.e., availability of suitable materials when needed, effort required for construction) and maintenance phases would be required.

Berms could be constructed around the permanent site structures and temporary work areas to provide visual screening from the Interconnecting Road and surrounding area. The use of berms in this area would also create opportunities for re-use of excavated materials as identified in Section 4.2.5.4.

Due to the size of the limestone pile (6.2 ha), capping is not currently recommended as the cost and logistics of this undertaking may outweigh the aesthetic benefits. However, capping is recommended for shales and soils to be left for more than a year (see Section 4.2.5.10)

4.2.5.10 Capping

The shale pile will be capped to minimise the potential for erosion of these materials while also limiting infiltration into the pile. Capping of the shales will also reduce the visual impact of this pile. Shales will be capped using standardised capping procedures for landfills as identified in Ontario Regulation 232/98 ([R57]). This includes a minimum of 0.6 metre of cover materials, such as clays, as well as a minimum of 150 mm of topsoil or other material capable of sustaining plant growth. Topsoil would then be seeded using local vegetation species capable of providing abundant growth with limited care, such as quick-growing grasses. Overburden materials stripped/excavated from the project area are likely to be suitable for use in capping of the shale pile; however, testing would be required to confirm suitability.

4.2.5.11 Dust Generation

Dust will be generated during the placement of excavated rock in the WRDA. This will be of primary concern during the conveying of the rock from the vent shaft to the disposal site. Fugitive dust displacement could potentially impact local air quality as well as movement along the Interconnecting Road.

Trees planted along the Interconnecting Road will provide some filtration of fugitive dust. In addition to this natural buffer, a dust suppressant system such as a water spray bar should be installed at the top of the conveyor and drop heights from the conveyor to the rock piles should be minimised to reduce dust generation from falling rock. Additional dust suppressant materials, such as calcium chloride and lignin-based materials are not recommended for application to excavated materials if re-use of these materials remains a possibility. Best Management Practices will be employed to minimise fugitive dust creation during deposition of excavated materials within the DGR.

It is not anticipated that dust generation will occur from the waste rock piles in the long term (after completion of construction) as the majority of fugitive dust should have already been displaced during wind and rain events during construction.

4.2.5.12 Noise and Vibration

Noise and vibration associated with the movement of excavated rock materials may potentially impact nearby facilities. Sources of noise and vibration would include underground shaft excavation work and transport of excavated materials on the ground surface. Mitigation measures include the use of berms and buffer zones along the Interconnecting roadway and minimizing the amount of equipment use on the ground surface. Disposal piles may also shield the surrounding areas from noise impacts, and will be included in any noise analysis.

Best Management Practices will be used during construction to minimise the impacts of noise on the surrounding area.

4.2.5.13 Protection of Existing Sensitive Environmental Features

The design of the waste rock pile considered various environmental constraints, as generally depicted in Figure 2-1. Since a portion of the proposed DGR lands are located within the catchments for Stream C, an important coldwater fish habitat within the site that is protected under the *Fisheries* Act, an important constraint was to avoid discharges to this watershed. To avoid potential effects to Stream C, water from the stormwater management system will be directed into the existing drainage network that leads directly to Lake Huron. Surface water from areas of the site that currently drain to Stream C will be redirected into the proposed stormwater management system.

Potential habitat for two species of burrowing crayfish (*Fallicambarus fodiens* and *Orconectes immunis*) has been identified on the DGR site ([R50]). Neither species are identified under the federal *Species at Risk Act* or the provincial *Endangered Species Act, 2007*, and both are considered to have apparently secure populations within the province ([R53]). However, the occurrence of *F.* fodiens is considered as uncommon within the province by a specialist in the field ([R54]). Since burrowing crayfish habitat would be protected under the *Fisheries Act*, the waste rock pile has been designed to avoid the areas identified with the highest potential for use by burrowing crayfish. In addition, a 30 metre vegetated buffer has been placed around this potential crayfish habitat to enhance protection of this feature. If buffer areas are not currently vegetated, they will be planted using species native to Bruce County, and will use local genetic stock where practical. These actions should help lessen potential effects on crayfish habitat, which will be evaluated as part of the environmental studies for the DGR project. Should additional crayfish habitat be detected during these studies, additional 30 m buffers will be placed around these areas.

As part of the field studies for the environmental study of the proposed DGR project, Golder Associates completed vegetation and wildlife surveys at the DGR project area. With the exception of the items mentioned above, these studies did not identify any species, communities or habitats that would constrain the layout of associated surface facilities.

4.3 Main Shaft

The maximum mass for any waste package will be 35 tonnes, as per the Design Requirements (see Section 3 above) and the low and intermediate level waste inventory ([R76]), which is specified in Section 8.1. An additional 5 tonnes has been allowed for any rigging and attachments involved in the transfer process, giving a cage payload of 40 tonnes.

The cage internal dimensions of 5.4 metres long by 2.85 metres wide x 14 metres high have been set by both the mining equipment needed for repository development, and the height of the shielded IC-18 T-H-E liner waste packages.

These dimensions determine the internal diameter of the Main Shaft, which has been set at 6.5 metres. The shaft will be split into three parallel compartments:

- Cage compartment (in the centre of the shaft)
- Counterweight compartment (to the south of the cage compartment)
- Services compartment (to the north of the cage compartment)

The cage and counterweight compartments only contain those respective conveyances. The service compartment will accommodate electrical power cables and piping as listed below:

- Power feeders
- Fibre-optic cables
- Hoist signalling cables
- Fire detection cables
- 150 mm NB Compressed air line
- 100 mm NB Dewatering line
- 50 mm NB Potable water line
- 50 mm NB Slick line (concrete for construction only)

Additionally, this compartment will also contain a ladder way with landings from the surface collar to shaft bottom to enable rescue from the conveyance in the event of a hoist breakdown and provide access to the shaft bottom. With the Koepe hoist, the system can be close to "balance" during winding operations and, consequently, it cannot be guaranteed that the cage could be lowered to the station under gravity in the event of power or other drive failure.

The cross-section of the shaft is shown in Figure 4-9.

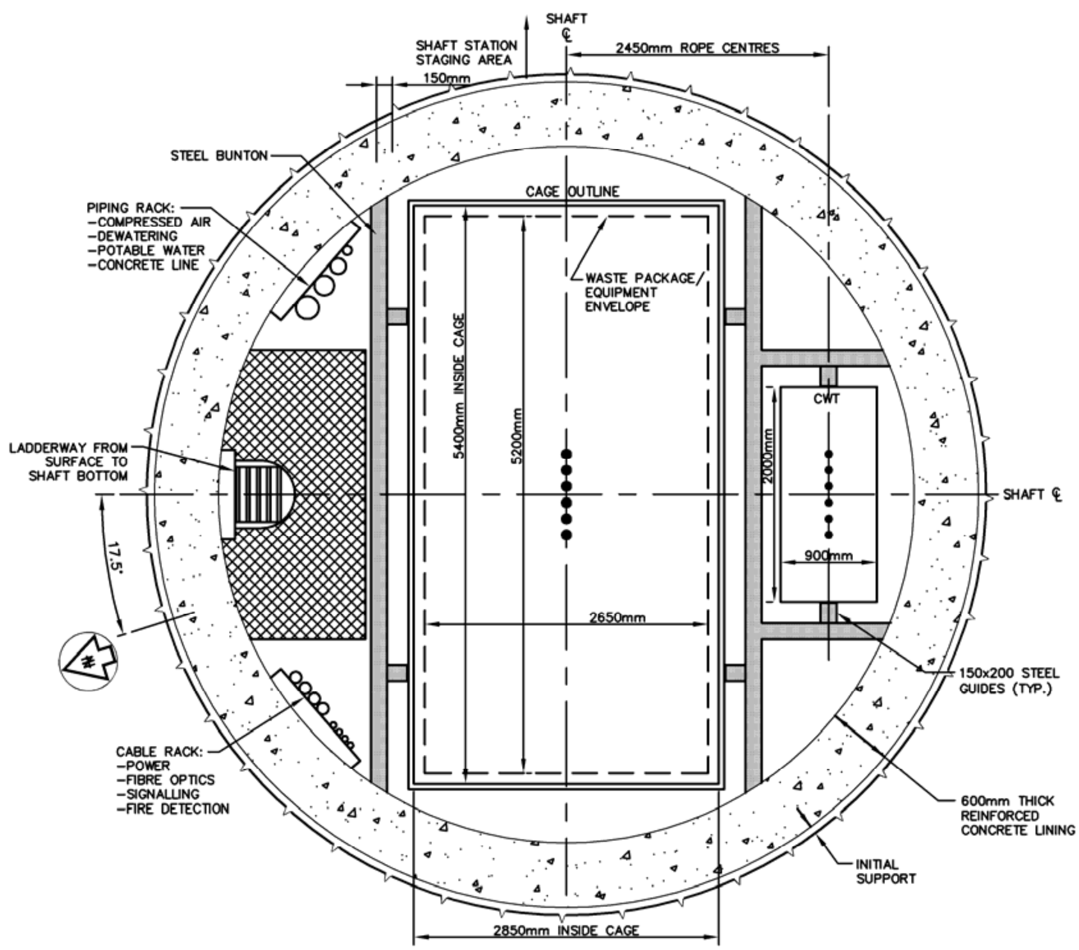


Figure 4-9 – Main Shaft Cross-Section (6.5 metre internal diameter)

The shaft will be equipped with steel buntons, which divide the shaft into compartments, and vertical steel guides, which are affixed to the shaft buntons. Buntons will be 100 mm wide tubular, and guides will be 150 mm wide x 200 mm deep hollow sections, fabricated from steel pipe that is drawn through a rectangular die. A total clearance of 12 mm is allowed between the guides and the slippers, which are mounted on the cage guides. This clearance allows for smooth riding in the shaft and will not become excessive as the brass slipper plates wear.

In Ontario, it is necessary to use wooden guides in man cage compartments to allow 'safety dog' devices to operate *unless* the cage is suspended by more than one rope. Safety dogs are devices that are automatically deployed in the event of failure of the cage rope connection, which dig into the guide to stop the cage free-falling to the bottom of the shaft. For the 6-rope Koepe hoist proposed for the Main Shaft, there would be no need to use dogs as the redundancy created by multiple ropes obviates this requirement.

Steel guides are more durable and suitable for the very heavy loads that will be hoisted. Additionally, wooden guides require wetting to remain in condition and water in the DGR Main Shaft should be avoided as this would have detrimental effect on waste packages.

4.4 Ventilation Shaft

The Ventilation Shaft diameter has been set by ventilation air flow requirements, which are described in Section 5.

The internal finished shaft diameter will be 4.5 metres. The shaft will be split into two compartments:

- Cage and Services compartment, with services and ladderway separated by dividers
- Empty compartment (upcast ventilation only)

Upcast air will flow in both compartments. However, it is important to maximise the open area for air flow to minimise friction as the air velocity will be higher than in the downcast Main Shaft.

As with the Main Shaft, the shaft will be equipped with steel buntons, which divide the shaft into compartments. But in this case, vertical timber guides will be used since the conveyance is supported by a single rope and will, therefore, have to be equipped with safety dogs.

The conveyance compartment will be split into three by steel dividers connected into the main bunton. The service section will accommodate electrical power cables and piping, which will be needed for shaft construction and will provide back-up of critical services from the Main Shaft, including power, fire detection, hoist signalling, compressed air and dewatering.

Additionally, this compartment will also contain a ladderway section down from the repository level with landings to access the loading pocket (for waste rock loading of the skip) and shaft bottom. As the hoist is a single drum arrangement, rescue of any personnel in the event of hoist breakdown can be achieved by using brake controls to lower the cage to the repository level, where they can disembark. Additionally, this hoist will be arranged to be able to run on power from the emergency diesel generator. Therefore, a ladderway is not required between the surface collar and the repository level.

The cross-section of the shaft from the DGR Level to Shaft Bottom is shown in Figure 4-10. There will be no ladderway above the DGR Level. Both cross-sections are illustrated on Drawing 323874DGR-200-018 in Appendix E.

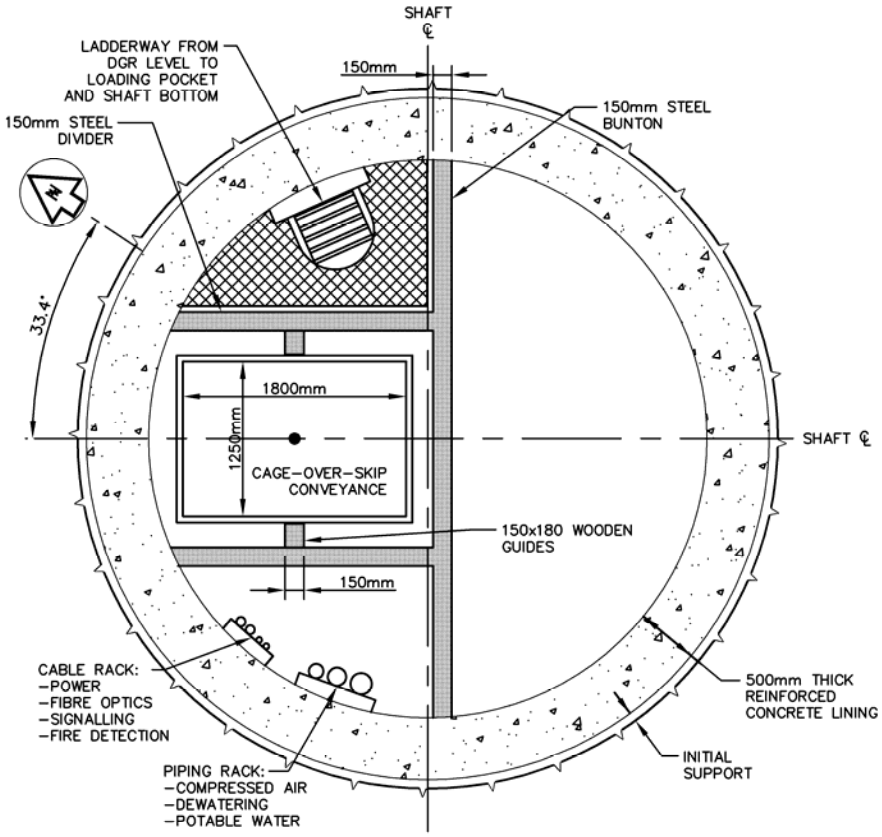


Figure 4-10 – Ventilation Shaft Cross-Section (4.5 metre internal diameter)

4.5 Underground Repository Arrangement

4.5.1 Main Access-ways

Two type of access-way were considered in the conceptual design:

- Vertical shafts *or*
- An inclined ramp with a second egress shaft and vertical ventilation raise

The vertical shaft option was selected as preferable having significant advantages over the ramp system. A ramp would have a much longer construction schedule, higher capital cost and greater risks of construction, which include the final sealing of the repository. These factors are significantly impacted by the geologic formations that the access-ways must go through to reach the required depth combined with the design requirement of a 100-year life. Although there is limited site-specific geologic information available, the rock formations underlying the Bruce site are predominant throughout a major portion of Southern Ontario where a number of tunnels and mine shafts have been developed.

The evidence from these projects indicates that there is a high probability of significant water inflows from the dolostone formations as well as time dependent deformations and degradation, particularly in the shales, which would require immediate support after excavation.

This led to the conclusion that a ramp access would have to be completely lined with concrete from top to bottom with significant grouting and additional rock reinforcement required through specific sections. The impact is a significant increase in construction costs, much slower advance rates and an increased risk of tunnel collapse or flooding.

Although these are also risks during shaft development, they are significantly less due to the shorter exposure of a vertical shaft through horizontal layers, the smaller, circular cross sectional area and the slip form concrete lining construction approach employed in shafts. Even without the exceptional geologic conditions, the schedule and capital cost of the ramp option are not enough to outweigh any perceived benefits of the ease of transportation in a ramp. The risks presented by the geology eliminated the ramp from further consideration.

4.5.2 Layout of Emplacement Rooms and Access Tunnels

To select the room configuration for the DGR, a number of geometric conceptual layouts were developed and compared. Considered layouts included a number of rib pillar arrangements with rooms connecting to a main access tunnel that ran between two shafts that were located at opposite ends of the DGR Project Site Boundary (700 metres) apart, room and pillar, large silos and a shaft island concept where the shafts were located in relatively close proximity to each other near the WWMF.

These alternatives were developed to a consistent level of detail and compared on the basis of worker safety, waste package handling reliability, ease of ventilation, capital costs, operating costs, ancillary space requirements, sensitivity to rock mass conditions, recoverability and retrievability, ease of closure, foot print size on the DGR site, ease of potential expansion and potential for concurrent construction and waste handling.

Based on this analysis, a number of alternatives were eliminated primarily on the basis of waste package handling reliability and cost (both capital and operating) leaving a reduced number of alternatives with similar cost, safety and reliability assessments. A more refined comparison using a reduced set of criteria (assuming other criteria, including cost to be equal) consisting of fire-life-safety, ease and reliability of waste package handling, ventilation control, length of emplacement rooms, reliability of sealing the repository, ease of construction, adaptability to different than expected ground conditions and surface infrastructure management.

On the basis of these criteria, the "Shaft Island Panel" was selected being considered comparable to other options in all criteria but superior to the others on the basis of ease and reliability of repository sealing, security and surface infrastructure management. By locating the emplacement rooms as branches remote from the central hub of the underground facilities, potential worker exposure to waste packages is minimised. Personnel would only require to approach or enter rooms for specific package transfer and emplacement operations, or for inspection and maintenance purposes.

The underground repository is arranged as a "Shaft Island Panel" layout where the two shafts are grouped close together, being 87 metres apart, on a central ring tunnel, on which the underground support infrastructure (offices, workshops, refuge bays etc.) is positioned. A full list of these facilities is given in Section 4.5.3.

The Ventilation Shaft is to the south-east of the Main Shaft. The access tunnels from the Main Shaft to the emplacement room panels will be optimally laid out with long radius bends and a minimum number of turns, which improves visibility, manoeuvrability, and thus safety for the forklifts and rail cars when moving the waste packages from the shaft staging area to the emplacement rooms.

These tunnels will commence from the Main Shaft station inside the "ring tunnel", and will be used for handling mining equipment and excavated waste rock during construction and providing the easiest and safest route for transferring waste packages from the Main Shaft station to the panel access tunnels and thence to each emplacement room.

Exhaust air will be ducted through the ring tunnel to the Ventilation Shaft.

The principle of the emplacement room and tunnel layout is shown in Figure 4-11 and is detailed with final room designations on Drawings 323874DGR-200-002 and 323874DGR-200-004 in Appendix E. The overall area of the repository footprint is approximately 282,000 m^2.

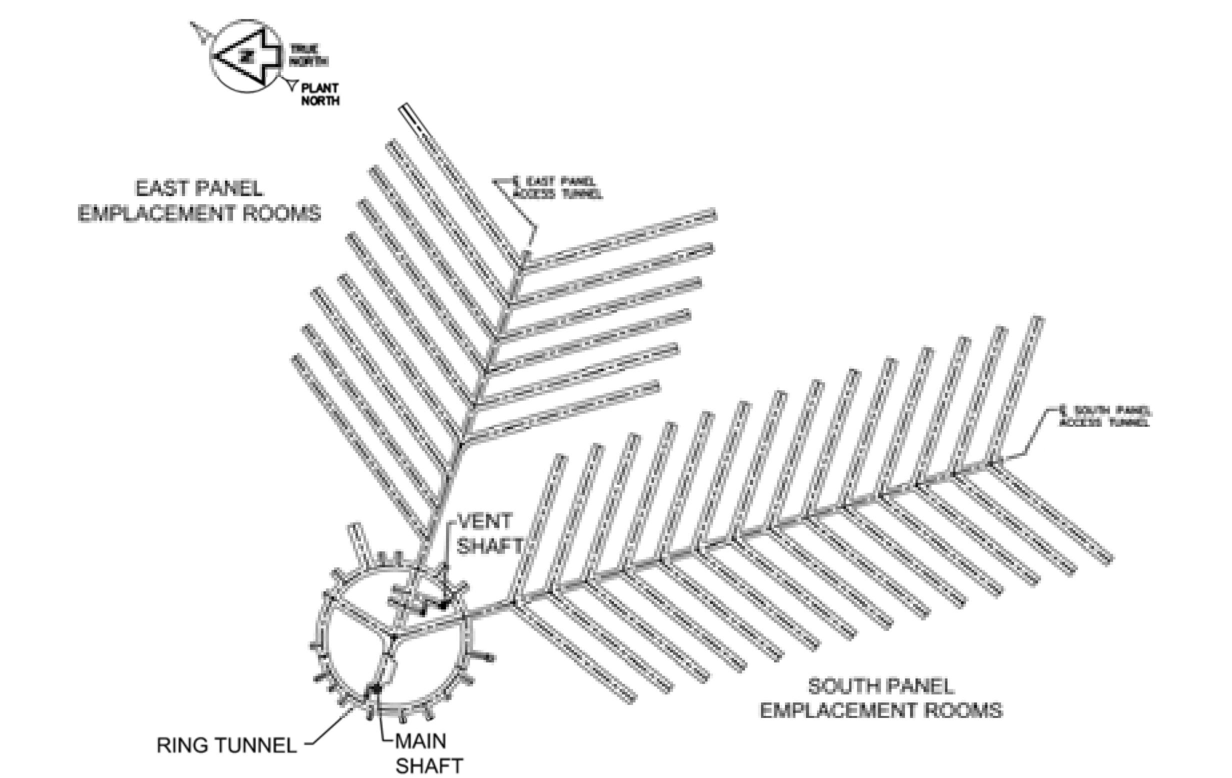


Figure 4-11 – Layout of Underground Repository

4.5.3 Emplacement Room Dimensions

The emplacement room layout and sizes were optimised using the following methodology:

1. Development of room sizing requirements relative to package sizes and waste package stacking envelopes for each waste package type and using recommended excavation room width to pillar width and waste handling methods developed in the course of the Conceptual Design Study.
2. Determination of the optimal nominal 8m wide room in consideration of all LLW package sizes only.
3. Assessment of the benefits achieved by considering other standard room widths

4. Using the optimal nominal room width as a basis for determining ILW package rooms
5. Consideration of custom room sizing for each package type
6. Optimisation by categorisation of custom room sizes into similar room sizes and combination of different ILW packages and large or irregularly-shaped LLW packages within the same rooms
7. Selection of a preferred room width categorisation strategy.

The distribution of how the current waste volumes are to be placed in the repository formed the basis of the room sizing optimisation exercise. The philosophy for optimisation emplacement room sizing was:

Minimise the total excavated volume of the DGR storage area (emplacement rooms plus access tunnels) in consideration of:

- *Waste volumes and types to be disposed*
- *Waste package construction and packing limitations (packing envelopes)*
- *Potential future expansion*
- *Limitations on room sizes – clearances and tolerances*
- *Room ventilation requirements*
- *Package handling methods*
- *Rock support requirements*
- *Access tunnel requirements*

The outcome of the optimisation was a standardisation of the LLW emplacement rooms in the South Panel, and a rationalisation of the ILW rooms to best use the footprint area and minimise the length of access tunnels.

4.5.3.1 Waste Package Inventory – Sizes and Numbers

All LLW and ILW to be handled are either currently or will be stored in discrete, defined packages of various sizes, shapes and dimensions. Some re-packing or shielding will be required for various packages in order to reliably and safely transport them to the repository. Using the OPG Inventory, a complete listing of the current understanding of the waste package inventory was prepared and a summary of the package sizes and inventory (including anticipated volumes) used as a design basis for the room optimisation process is contained in Section 8.1.

For the purposes of the emplacement stacking optimisation exercise, the Waste Package Inventory was categorised into specific groupings (Groups A to H), with some sub-sets for items such as resin liners and retube wastes. These Groups are defined in Section 8.1.

Based upon that inventory, the actual total volume of waste to be disposed is 185,906 m^3 ("as-disposed", based on package inventory numbers and package dimensions). This forms the base case DGR, which has a nominal capacity of 200,000 m^3 "as-disposed" waste as assumed by the Design Requirements (see Section 3 above).

4.5.3.2 Underground Location of Emplaced LLW and ILW Waste Packages

Due to differences in package sizing and stacking provisions, there are practical reasons for the nominal segregation of LLW and ILW packages into different rooms and different panels of the DGR.

In a general context, most LLW packages are standardised, rectangular or cylindrical, stackable elements and most ILW (and some LLW) packages are non-standard, non-stackable or irregularly shaped.

While there are exceptions to this generalisation, it is evident that emplacement room optimisation can be best accomplished by segregating the two waste types in different panels of the repository and optimising their respective emplacement room sizes. However, it would be possible to locate LLW and ILW rooms in the same panel.

4.5.3.3 Room Sizing Requirements and Waste Package Stacking Envelopes

To optimise the DGR, the emplacement room sizing must accommodate stacking arrangements for all package sizes in the most efficient stacking manner possible yet still provide sufficient room to assure reliable waste package handling. Both forklifts and gantry cranes will be used for underground waste package handling, and to accomplish these methods a number of tolerances and allowances were established on the basis of experience and previous studies.

These tolerances and clearances are presented in the following subsections and depicted in Figure 4-13, Figure 4-14, Figure 4-15, Figure 4-16 and Drawing 323874DGR-200-011.

4.5.3.3.1 Packing Envelopes

Package stacking envelopes have been determined for each standard package type using package dimensions, the number of packages wide and number of package high for various room sizes. The following assumptions have been made in determining packing envelopes:

- An allowance of 50 mm between each stacked column and row of packages has been assumed for the purpose of width calculation to account for variations in out-of-plumbness, placement tolerances and gaps. This (and lesser) spacing is already achieved in the LLSB's (low level storage buildings) at the WWMF (see Figure 4-12).
- For safety and package handling reliability reasons, forklifts will carry all packages with forks perpendicular to the greatest package dimension (i.e. no packages carried with their longest dimension parallel to the forks).
- Combined with the previous assumption and due to expected room widths relative to 'forklift back to fork-tip' length, back-up and turning radius requirements, no package will be placed by forklift with its longest dimension parallel to the room length. In other words, all packages will be emplaced so their longest dimension would be perpendicular to the room length. This assumption does not apply to handling by gantry crane.
- Forklift width will be smaller or comparable to the least width of the package size and be equipped with a lateral fine-adjustment of the fork position under supported loads to facilitate placement of packages to the specified tolerances.

Figure 4-12 – Typical Waste Package Stacking at WWMF Facilities

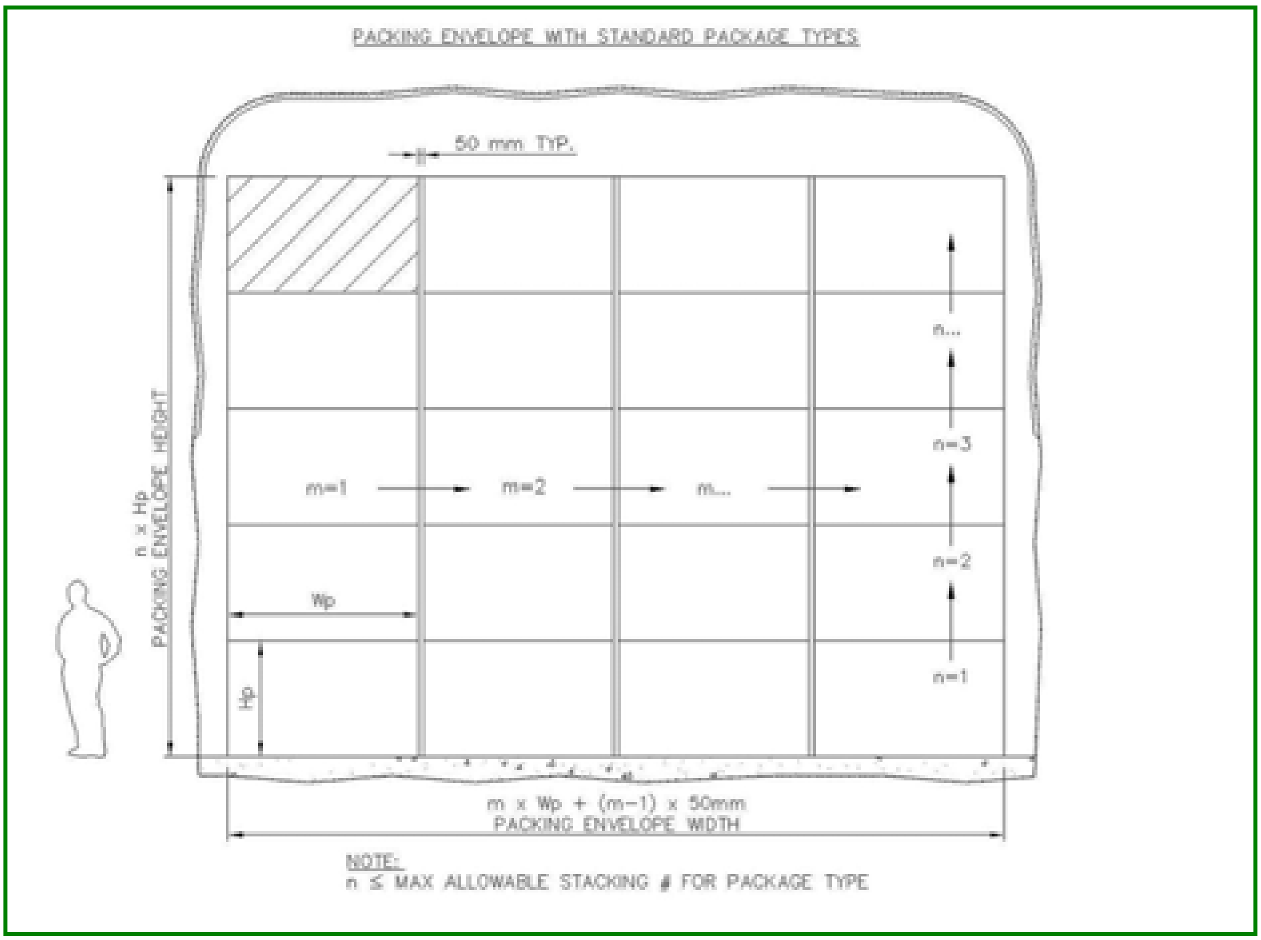


Figure 4-13 – DGR Packing Envelope Width and Height Sizing Basis

4.5.3.3.2 Excavation Tolerances

Use of a roadheader as the excavation method for the emplacement rooms will provide an accurate excavation profile that can be developed with minimal over-break and tight spots. The use of surveying with laser-profiling will permit in-process quality control of the excavated shape concurrent with excavation and hence permit corrections during the work and permit excavation to within tighter tolerances. Correspondingly, it is considered that actual excavated room dimensions can be achieved (relative to the specified room dimensions) on a plus 100 mm, minus zero basis. Depending upon bedding plane thicknesses, some excess excavation or fallout may occur in the roof of rooms prior to rock support installation resulting in a slightly larger than specified room heights.

4.5.3.3.3 Rock Support Allowance

Rock support requirements for the expected rock mass conditions (UCS = 72 MPa, GSI = 69 with sub-horizontal bedding planes and sub-vertical joints at 1 metre spacing) call for rock bolts to be installed in the roof (or back) of all rooms and 50 mm thick shotcrete layer to be applied to the roof and upper half of the room walls. In space critical applications, it is typical to cut-off the exposed rock dowel tails to leave no more than a 150 mm protrusion from the rock surface. Consequently, a 150 mm allowance for rock support beyond the specified excavated room dimensions has been assumed for design purposes.

4.5.3.3.4 Concrete Floor

A concrete floor nominally 200 mm thick will be poured to provide a level floor in the emplacement rooms with a flat and stable surface for stacking operations and plumb waste package stacks as discussed in more detail in Section 7.5.4. This will be cast directly upon the roadheader excavated emplacement room floor after removal of loose material using compressed air and rotating nylon brush cleaners. A screed rail or self-levelling concrete is specified for concrete placement to meet flatness tolerances appropriate for warehousing applications with forklifts. Results of survey and laser profiling will be used to mark concrete floors to assist in accurate placement of waste packages.

The concrete floor will be 600 mm thick along the edges of each gantry crane-equipped room to accommodate embedded gantry crane rails. In addition, for handling of large waste package items, embedded rails will be installed in gantry crane rooms.

4.5.3.3.5 Vertical Roof Clearances

A minimum room height clearance of 600 mm above the planned waste package stacked height to the roof support allowance will provide sufficient vertical clearance for forklift suspended waste packages and horizontal travel over the penultimate layer of previously stacked packages. This 600 mm combined with the 150 mm rock support allowance results in a minimum clearance of 750 mm from the stacked waste packages to the roof of the excavated emplacement room.

Placing of waste packages near the roof of the emplacement rooms will require a spotter in a scissor-style or boom manlift. The 750 mm clearance will provide adequate overhead tolerance for line-of-sight spotting and directional guidance from the spotter to the forklift operator. The presence of rock dowel tails will not adversely impede line-of-sight.

4.5.3.3.6 Gantry Crane Clearances

A gantry crane will be used to offload some packages from the rail car, on which they are transferred to the rooms, due to their large size and mass and awkward shapes. The requirement for travel of such a crane with an overhead beam required different room sizing criteria than for emplacement rooms using forklifts for waste package handling. To minimise the impact of overhead ventilation ducts, twin rectangular (600 mm high by 1000 mm wide) rather than circular ducts will be installed to reduce the overhead height requirements. Other clearances and allowances are:

- A 1,000 mm minimum horizontal clearance (on each side of the room) from the excavated wall to the waste packing envelope. This is inclusive of the rock support (150 mm for shotcrete and rock dowel tails), clearance between the gantry structure and the rock support (150 mm), gantry support columns (300 mm) and clearance between the gantry and the waste packing envelope (300 mm minimum).
- A 1,500 mm minimum vertical clearance between top of lifted packages and the underside of the gantry beam for lifting and rigging.
- A depth of 600 mm for the depth of the gantry crane beam.
- A vertical clearance above the gantry beam to excavated roof of the emplacement room of 900 mm, which includes 600 mm for the ventilation ducts plus 100 mm blocking, 50 mm shotcrete and 150 mm minimum clearance between gantry beam and the underside of the ducts.
- A 600 mm thick concrete rail haunch for gantry travel. This will also double as a placeholder for the heat exchangers, which will be stacked horizontally in a pyramid formation.

4.5.3.3.7 Horizontal Wall Clearances and Minimum Room Width

For rooms requiring packages to be placed using forklifts, a lateral package handling allowance of 150 mm from the package envelope to the 150 mm rock support allowance was used. These combined allowances result in a horizontal clearance on each side of the packing envelope of 300 mm or a minimum room width 600 mm wider than the package envelope. In addition to waste package handling tolerance, these clearances also provide allowance between the package envelope and walls for air-flow ventilation around the disposed waste packages.

The packing envelope horizontal width for each package type has been determined on an assumed horizontal clearance of 50 mm between vertical stacks.

Each stack row will be completed prior to commencing placement of the next row, thereby minimising the distance of travel to place packages within these horizontal and vertical wall clearances.

4.5.3.3.8 Ventilation Allowances

To provide room ventilation during waste storage and closure prior to full repository closure, ventilation ducts will be provided for the full length in the emplacement rooms. In all cases, ventilation ducts will be a steel pipe material with a design life of 100 years in DGR emplacement room conditions. Each duct will be hung tight to the room roof using stainless steel cables and hardware affixed to roof rock support (dowels) with 50 mm blocking placed between the duct and the 50 mm thick shotcrete layer.

The vertical clearance between the stacked waste packages and ventilation ducts can be relaxed due to the ability for the spotter to be situated higher than the waste package stacked height in this area. This clearance was set at 150 mm below the duct.

In rooms with waste packages to be placed by forklift, these ducts will consist of either a single 1,200 mm diameter duct or twin 900 mm diameter ducts depending upon the vertical clearance between the stacked waste package envelope and the emplacement room roof. For vertical clearances less than 1,150 mm, a single 1,200 mm diameter circular duct will be used but would require omission of a single waste package over the entire length of the room. If the vertical clearance is greater than 1,150 mm, the twin 900 mm diameter ducts will be used and no packages will then need to be omitted from the stacking envelope. In rooms with waste packages to be placed by gantry crane, these ducts will consist of twin rectangular ducts 1,000 mm wide and 600 mm high (nominally equivalent to a single 1200 mm diameter circular duct) located above the gantry crane.

4.5.3.3.9 Roadheader Construction Considerations

Roadheaders of the type necessary to excavate the emplacement rooms under the expected rock conditions are nominally 4.5 to 4.7 metres high. These heights, combined with a 1 metre practical overhead allowance for rock support installation, emplacement room concrete floor thickness and construction ventilation, require a minimum room height of 5.7m regardless of waste package handling and stacking methodology.

4.5.3.3.10 Utility Clearances

During construction and in ancillary areas certain utilities such as electrical power, lighting, compressed air and construction wash water will be required. These utilities will be progressively removed as waste is stored in each room and, therefore, will not impact room tolerances. Correspondingly, with the exception of the permanent ventilation ducts, no dedicated utility clearances were provided within the emplacement room excavation envelope.

4.5.3.4 Maximum and Minimum Room Sizes

Using these tolerances and allowances, the minimum room dimensions were determined for various arrangements of waste packages or packing envelopes. Room sizing criteria were developed for 3 different room conditions:

- LLW / ILW handling using a forklift with one ventilation duct
- LLW / ILW handling using a forklift with two ventilation ducts
- LLW / ILW using a gantry crane within the emplacement room

These room sizing criteria for each of these conditions relative to the waste package envelopes are shown in Figure 4-14, Figure 4-15 and Figure 4-16 respectively. Using these sizing criteria, the following minimum and maximum room sizing bases were developed:

- Minimum forklift horizontal room excavated width = Packing envelope width + 0.6 m
- Minimum gantry crane horizontal room excavated width = Packing envelope width + 2.0 m
- Minimum forklift vertical room excavated height = Packing envelope height + 0.95 m
- Minimum gantry room vertical excavated height = Packing envelope + 3.2 m
- Minimum vertical room excavated height = 5.7 metre (roadheader limitations)
- Maximum width controlled by optimisation process including consideration of practical rock span and support considerations.
- Maximum heights controlled by practical stacking limitations (maximum packing envelope) for each waste package type.

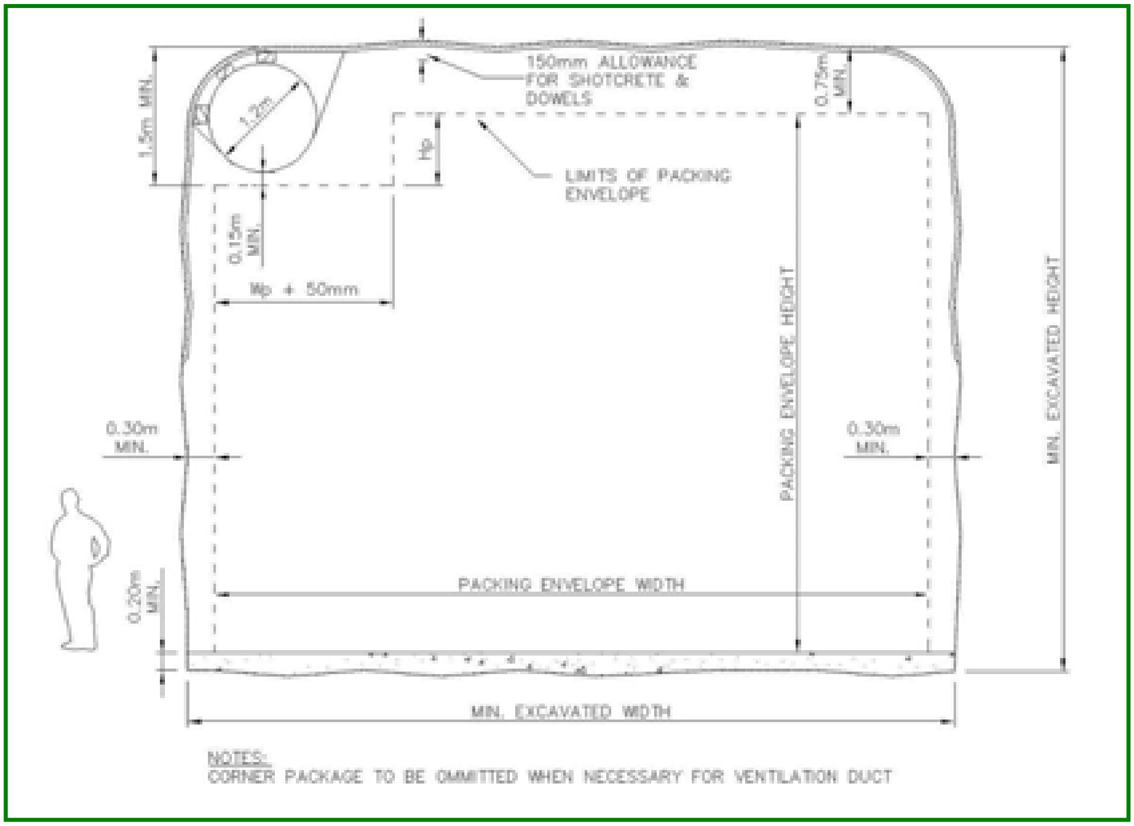


Figure 4-14 – DGR Room Sizing Basis relative to Packing Envelope using One Ventilation Duct

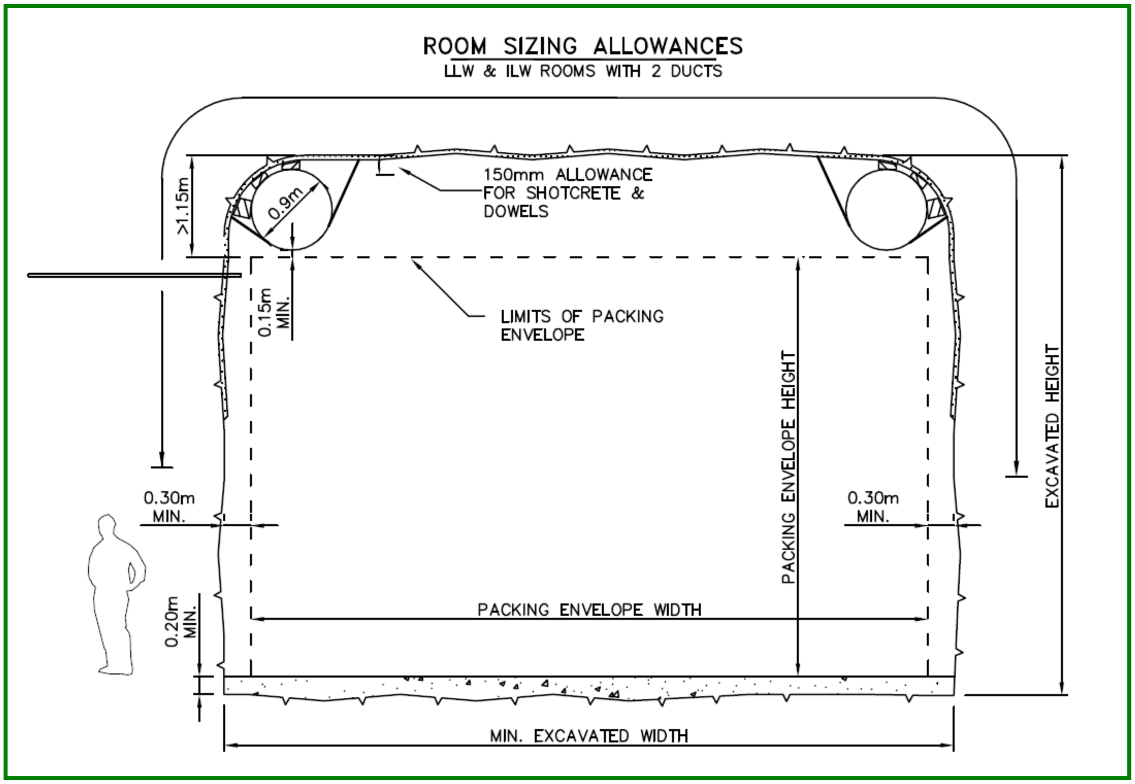


Figure 4-15 – DGR Room Sizing Basis relative to Packing Envelope using Two Ventilation Ducts

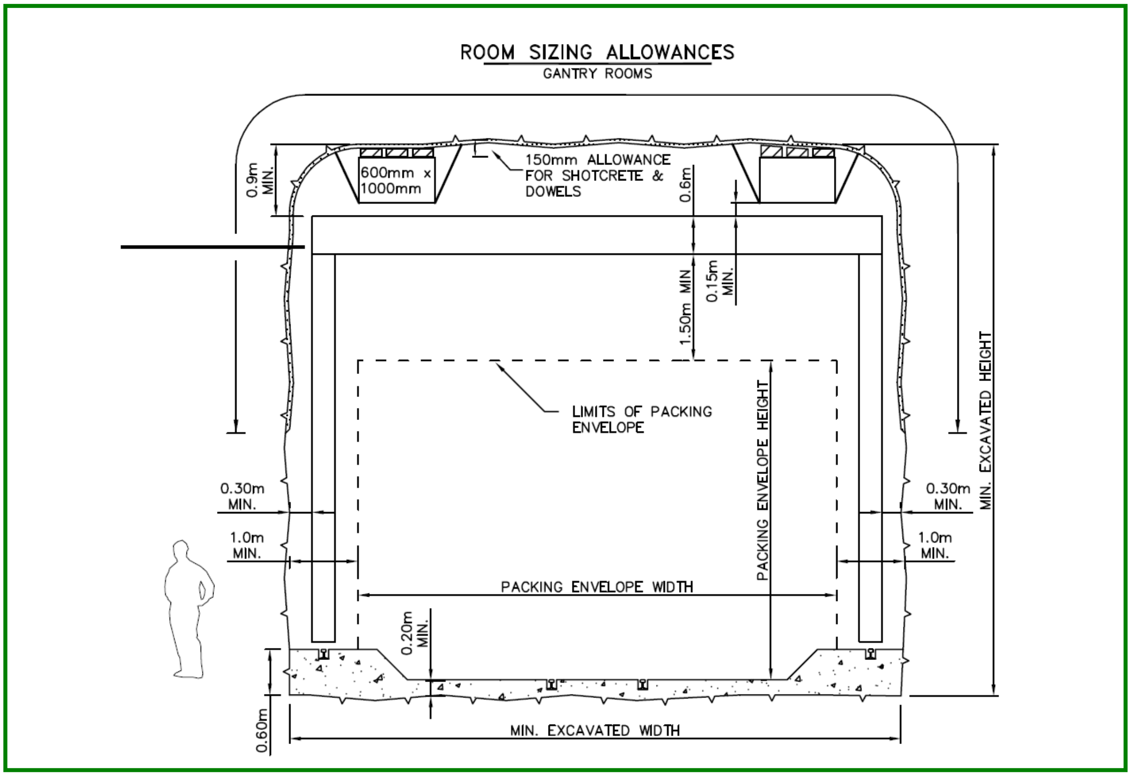


Figure 4-16 – DGR Room Sizing Basis relative to Packing Envelope and Gantry Crane

4.5.3.5 Emplacement Room Lengths

The shaft-island geometric layout will utilise emplacement room panels radiating outward from the central, circular ring tunnel. Two vertical shafts are located almost diametrically opposite each other within the ring tunnel and are designated as the "Main" (downcast) and "Ventilation" (upcast) Shafts. A key consideration in the selection of this geometric layout is its flexibility to utilise the footprint geometry of the DGR Project Site in an efficient manner.

This arrangement, combined with the desired location of the main shaft relative to the Western Waste Management Facility at the west end of the DGR Project Site and the geometry of the DGR Project Site results in two emplacement room panels for the reference DGR capacity case (200,000 $m^{3)}$ waste, and three in the potential expansion case. These panels are denoted the South, East and North Panels respectively.

The best footprint utilisation of the DGR Project Site in this arrangement for the reference and potential future expansion waste volumes was achieved using 120 metre long emplacement rooms in the North and South panels and 180 to 200 metre long emplacement rooms in the East panel. The size of these panels, expected room packing efficiencies for each type of waste package and the proportion of each type of waste volume (LLW and ILW) to be disposed provided a rationale to dispose standard sized LLW waste packages in the North and South Panel emplacement rooms and to dispose ILW and non-standard LLW waste packages in the East Panel emplacement rooms.

4.5.3.5.1 Unusable Room Length Allowance

The number of each package type and the number of packages in each stacked row determines the required total minimum length of emplacement rooms. For practical purposes, an additional length allowance is necessary in each discrete room to account for:

- Ventilation flow at dead-end of room
- Waste handling at "open-end" of room
- Geometric allowance to account for skew angle of 55 degrees between the access tunnel and emplacement rooms.
- Bulkhead construction allowance (inside entrance to emplacement room) and thickness at access tunnel intersection ("open-end")
- Allowance for ventilation connections inside of room at bulkhead
- Accumulated gap allowance on package placement over length of room beyond assumed gap dimensions

An unusable room length allowance of 8 metres was used to determine the length of each discrete emplacement room to take into account the accumulation of the above-listed effects.

4.5.3.5.2 Standard LLW Room Size

The "standard Group A" LLW packages (see Section 8.1 for the definition of the waste package groups) represent the majority of waste packages (75% by number and 70% by volume).

The design optimisation involved selection of the best packing arrangement and calculation of the combined two-dimensional packing efficiency assuming that all of the Type A waste packages were to be disposed in the same standard width room. By varying the dimensions of the standard (widths and heights), a maximum two-dimensional packing efficiency of 69.83% was achieved for room dimensions of 8.6 metre wide and 7.0 metre high. These dimensions represented an integer multiple of the width and height of the most common package size – Non-Pro Bin 47 (NPB47).

The minimum two-dimensional packing efficiency of all of the different package types for this standard width room is 61.5% indicating that the 8.6 metre width provides efficient waste disposal for all of the package types considered. During the optimisation, various other logical room widths were investigated from 7 to 13 metres. Although slightly improved packing efficiencies (0.6% to 2.1%) are achievable with rooms of 10.9 metres width or greater, the additional rock support requirements negate any overall advantage.

Application of room length calculation criteria for this standard width room determines that twenty-eight (28), 123.9 metre long rooms will be required in the South Panel. These rooms will contain 131,388 m^3 of Group A waste volume (as-disposed) and require a combined emplacement room and access tunnel excavated volume of 227,935 m^3. The three-dimensional efficiency of the excavated emplacement room volume will be 62.9%.

Room Type	Width (m)	Height (m)	Min. Length Req'd (m)	No. of Rooms	Unusable Length Allowance (m)	Specific Room Length (m)	Total Room Length (m)	Exc'd Volume (m^3)	Waste Volume (m^3)	3-D Packing Efficiency
S-A	8.60	7.00	3,245.1	28	8	123.9	3,469.1	208,839	131,387	62.91%
Access Tunnel (7m H x 6.5m W)			419.7					19,095		
		Combined volume - emplacement room & access tunnel						**227,935**		

Note: The Room Type "S-A" refers to the Panel designation (S = South) and the Room size identifier (A = All Standard LLW)

Table 4-5 – Standard LLW Emplacement Room Dimensions & Packing Efficiency

The stacking arrangements of the standard LLW packages are described and depicted in Section 8.4.1.

4.5.3.5.3 Optimisation of ILW and Non-Standard LLW Rooms (East Panel)

As stated previously, the East Panel will generally contain ILW packages and non-standard LLW packages. Relative to the Group A LLW packages in the South Panel, this involves considerably less volume of waste but due to stacking restrictions, lifting limitations, package shapes and sizes and the numbers of each package type, this waste will be stored with considerably less efficiency.

Room optimisation for this condition required a modified approach. Due to the non-standard nature of these waste packages, a standard room concept was not adopted for the detailed room sizing process. Instead, the process proceeded directly to a customised room approach. Stacking restrictions on many packages of ILW with many not permitting any stacking at all or use of gantry cranes for handling resulted in the optimisation effort involving selection of a minimum room height and room width on the basis of package dimensions. Further optimisation was achieved by varying the arrangement of package types in individual rooms. In Section 8 it is shown to be beneficial to packing efficiencies to intersperse shielded and unshielded resin liner packages within single and adjacent rows to ensure that the cumulative dose rates given in [R77] are not exceeded, and hence to minimise the shielding requirements for the resin liners.

The minimum room height is a controlling criterion for several packages. Due to the relatively small number of different packages types, it is also beneficial to combine various packages into the same rows.

A fully customised room approach results in a significant number of different rooms with some of the rooms being very short (as low as 50 metre) relative to the 180 to 200 metre desirable length determined in the geometric layout exercise, which would suggest unnecessary access tunnel lengths and therefore perhaps not the best utilisation of the DGR Project Site footprint. Correspondingly, a room categorisation approach was adopted to reach a more standard room length and reduced number of rooms leading to better footprint utilisation and combined room plus tunnel excavation volume minimisation. The results of this exercise are summarised in Table 4-6. The total excavated volume will be 133,672 m^3 and the overall packing efficiency for ILW and non-standard LLW will be 43.3%. All these rooms will be located in the East Panel.

Room Type	Number of rooms	Contents of Rooms - Disposed Waste Packages	Length (m)	Width (m)	Height (m)	Room Volume (m^3)	Waste Volume (m^3)	Packing Efficiency (3D)	Forklift or Gantry
E-A	2	Group B (SPC) and Group E (HX) Group E (T-H-E's) and remainder (30 off) of Group D Type D6	164.6	8.1	7.2	19,199	2,832	14.8%	G
E-B	1	Group C (THLSTG3) and Group D Type D1 (ETH) Group G Type A.3, C.1, C.2 & C.3 (SG Segments)	170.5	8.6	5.7	8,358	3,657	43.8%	F
E-C	6	Group D (Resin Liners)	170.5	7.7	6.0	47,263	19,877	42.1%	F
E-D	3	Group F (ILW Shield) Group H1 (Retube Waste) - 275 off	162.3	8.6	5.7	23,868	11,976	50.2%	F
E-E	1	Group G Type A.1, A.2 & B.1 (SG Segments) Group G Type B.2 (SG Segments) Group G Type B.3 (SG Segments)	185.5	8.4	6.5	10,128	4,729	46.7%	F
E-F	2	Group H2 (Retube Waste) all + Group H1 (183 off)	182.5	7.4	6.3	17,016	11,448	67.3%	F
TOTALS	**15**		**2,560**			**125,832**	**54,519**	**43.3%**	
Access Tunnel		**(7m H x 6.5m W)**	**244**			**11,109**			
Combined Volume (All Emplacement Rooms and Access Tunnels)						**136,941**	**m^3**		

Note: The room types given above refer to the Panel designation (E = East) and the Room size identifier (A to F)

Table 4-6 – ILW Emplacement Room Dimensions & Packing Efficiencies

The stacking arrangements of the ILW and non-standard LLW packages are described and depicted in Sections 8.4.2 to 8.4.8.

4.5.4 Support Infrastructure (Refuge Station, Electrical Sub-Stations, Workshops, Fuel and Lubrication Bays, Offices)

Table 4-7 lists all the ancillary rooms and their dimensions. The arrangement of these rooms around the ring tunnel is shown in Figure 4-17.

The ring tunnel is logically separated into two sections:

- One encompassing an arc of about 150°, which is on the "non-operations" or "clean" side, where waste packages will not be present at any time. Diesel equipment will also not normally work in this section. This section will be isolated by ventilation doors equipped with auxiliary fans to ensure that clean intake air flows passed these rooms and out to the "dirty" side of the ring tunnel (see Section 5 for details of ventilation system design and operation) thus keeping workers in this section in a clean air flow;
- The remainder of the ring is on the operations/construction side and will contain the maintenance workshop, fuel bay and magazines.

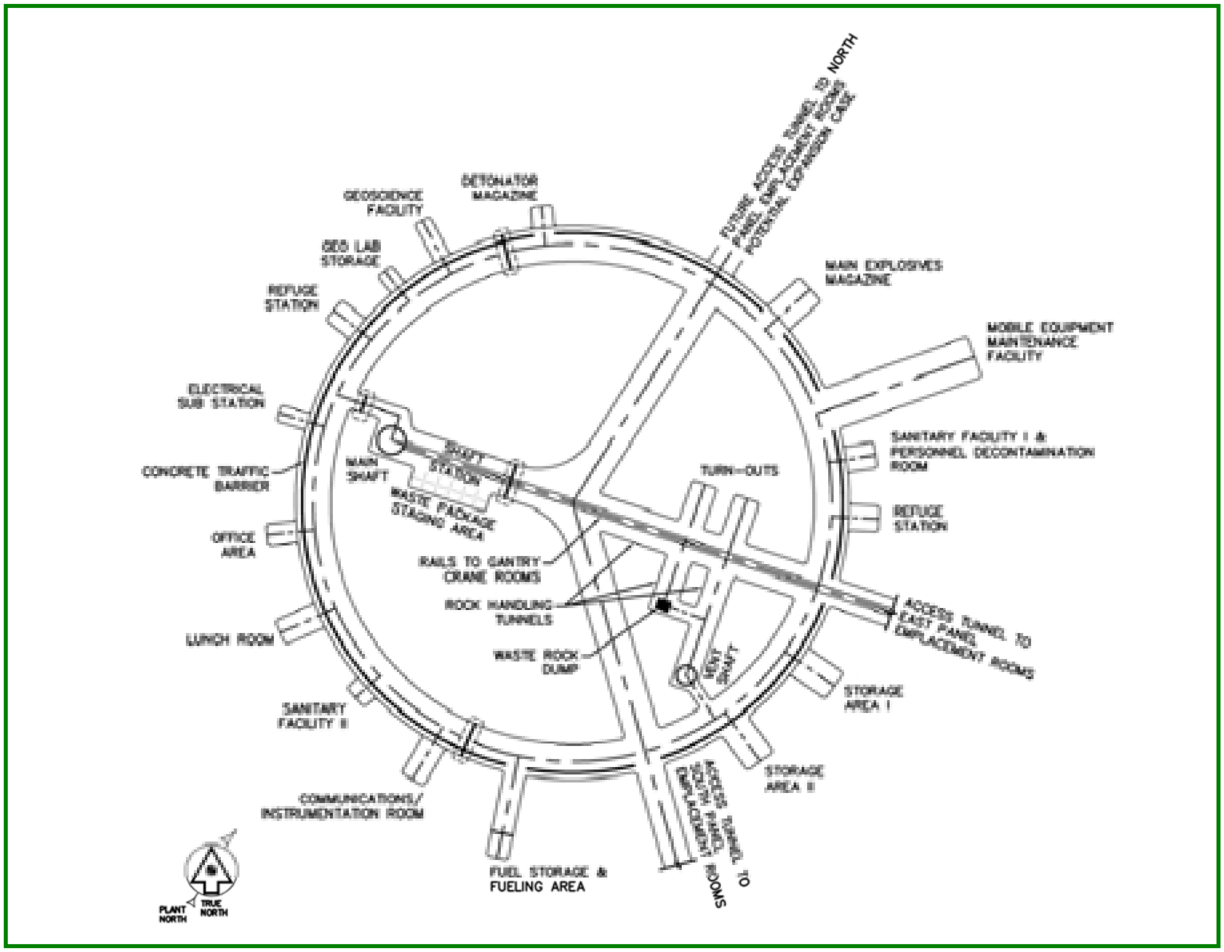


Figure 4-17 – Layout of Ring Tunnel

Ancillary Rooms	Number	Dimensions		
		Length	Width	Height
Office Area	1	7.0	5.0	3.0
Lunch Room	1	10.0	6.0	3.0
Sanitary Facility (West Side of Ring Tunnel)	1	3.5	6.0	3.0
Sanitary & Personal Decontamination Facility (East Side)	1	7.0	6.0	3.0
Refuge Stations	2	7.0	6.0	6.0
Geoscience Laboratory Facility	1	10.0	4.0	3.0
Geoscience Laboratory Store	1	5.0	4.0	3.0
Electrical Sub-Station	1	7.0	4.0	5.0
Communications & Instrumentation Room	1	10.0	6.0	3.0
Mobile Equipment Maintenance Workshop	1	35.0	10.0	7.5
Fuel Storage & Refuelling Bay	1	20.0	5.0	5.0
Explosives Magazine	1	10.0	7.5	6.0
Detonator Magazine	1	5.0	5.0	3.0
Equipment & Material Stores	2	10.0	7.5	6.0 / 3.0
Waste Package Staging Area (at Main Shaft)	1	22.6	5.0	7.0

Table 4-7 – Summary of Non-Waste Storage Rooms and Sizes

The detonator and explosives magazines, which will be used during the construction of the base 200,000 m^3 waste capacity DGR, will be located close to the access tunnel leading to the North Panel that would be required for any potential future expansion of the repository.

They would be re-commissioned for use if and when a future construction campaign for expansion of the repository is required.

The details of the ring tunnel and location of all the support infrastructure are also shown on Drawing 323874DGR-200-004, which is included in Appendix E.

4.5.5 Hazardous Material Storage

A number of materials that are explosive or flammable in nature are required to construct and operate the DGR facility. This will include diesel fuel and lubricants to operate the mobile equipment and explosives for miscellaneous rock excavation.

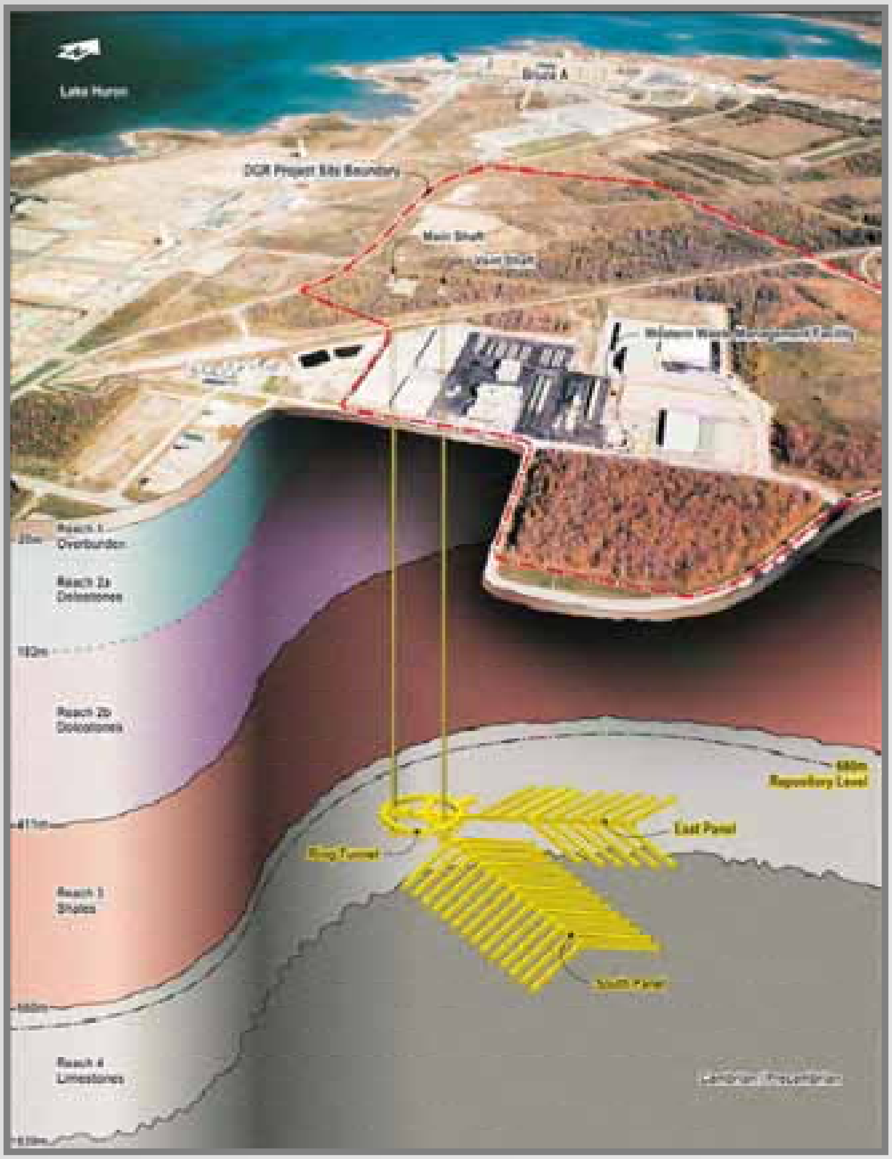
Demand will be greatest during construction when consumption of diesel fuel is estimated to be between 500 to 1,000 litres per operating 8 hour shift. This would require an underground storage capacity of 5,000 litres with replenishment every few days from a tanker that is refuelled on surface and transported underground via the Main Shaft cage. During facility operation replenishment would only need to occur on a weekly basis. The storage area will have a spillage berm and fire suppression.

An underground explosive storage of 1,500 kg should be sufficient for the construction phase where the primary excavation will be mechanical (roadheader). Explosives will be delivered directly to the surface Headframe area by the explosive supplier and moved underground immediately. During facility operations it is not expected that explosives would be required on a regular basis and no explosives should be stored underground. Special projects requiring miscellaneous rock excavation would have specific procedures in place with day-of-use delivery of explosives. There are also several commercially available, non-explosive products for splitting rock that could be considered for small projects.

During shaft construction explosives will be required on a daily basis. It is recommended that "as required' delivery be part of the procurement contract with the explosive supplier. A slight premium will be paid for this service but it will eliminate the need for a surface magazine and the associated costs and risk issues.

CONCEPTUAL DESIGN REPORT

5. Ventilation



5. Ventilation

The reliable delivery of a conditioned supply of fresh air to the underground workplaces is critical for the health and safety of workers. This air supply also will be used to maintain optimal conditions in both empty and filled emplacement rooms with conditioning of the intake air on surface to control temperature and humidity. The total volume of air supplied to the DGR will vary based on the nature of work being performed and number of empty and filled rooms, and will be periodically adjusted throughout the life cycle of the facility.

5.1 Ventilation System and Operation

The primary DGR ventilation circuit will be driven by electrically-powered axial vane fans located on surface, near the final exhaust point as indicated in Figure 5-1. This "exhausting" or "pull" system will operate by applying a pressure differential between the main and exhaust shafts. This difference in pressure will induce an airflow circuit, bringing a continuous supply of fresh air to the underground working level. The location of the fans on surface will require the Ventilation Shaft Headframe to be air-locked to avoid short-circuiting of air. This can be achieved through the use of double doors at the equipment entrance and an engineered airlock system at the waste rock chute.

The finished internal diameters of the Main and Ventilation Shafts are 6.5 and 4.5 metres respectively. The Main Shaft diameter is set by cage size requirements to handle mining equipment and the Ventilation Shaft diameter is set by the anticipated exhaust air volumetric flow, conforming to established ventilation design principles including air velocities and friction losses.

The ventilation system intake will collect ambient air into the HVAC installations located near the Main Shaft Headframe on surface. This air will be conditioned to achieve a nominal temperature of 12°C. Note that cooling ambient air to this temperature in the summer months will also exceed the saturation point of the air, allowing moisture and corresponding humidity to be removed. Low-pressure force fans will be used to deliver a controlled air volume through the HVAC system to the inlet of the adit into the Main Shaft some 5 to 10 metres below the shaft collar, supplying an air volume equal to the demand of the exhaust fans and maintaining a balanced pressure condition in the Main Shaft Headframe.

Delivery of a controlled volume of ventilating air to each access tunnel, emplacement room, maintenance facility and other workplace is achieved using a series of auxiliary fans and ducting circuits. To avoid the use of any airlock doors in the facility, these auxiliary fan circuits exhaust at the ventilation shaft, where the surface exhaust fans draw the air to surface. These auxiliary fans operating points are designed for the total friction in their circuits (i.e. air flow through the access tunnels and down the emplacement rooms plus the return flow in the ducting all the way to the Ventilation Shaft) at a defined air flow volume. The main surface exhaust fans will handle the total flow volume for the pressure losses down the Main Shaft, in the ring tunnel and up the Ventilation Shaft. Since the 'used' air quantity from the auxiliary fan circuits is delivered into the exhaust stream at the entrance to the Ventilation Shaft, it will preferentially be pulled up the Ventilation Shaft by the surface fans, which, at their operating duty point, only then have a small remaining cacacity of 11 m^3/s, which is the maximum amount that can be pulled from the ring tunnel and ancillary room area.

Because these surface and underground auxiliary ventilation systems operate independently, a temporary interruption of one system would not create an unstable condition in the other.

The Ventilation Shaft has been located to the south-east of the Main Shaft with the main air intake being about 150 metres horizontally from the exhaust. This separation combined with the prevailing wind directions (from south to south-west and occasionally from the north – see Section 2.2) are adequate to prevent any short-circuiting of exhaust air back into the Main Shaft fresh air intake.

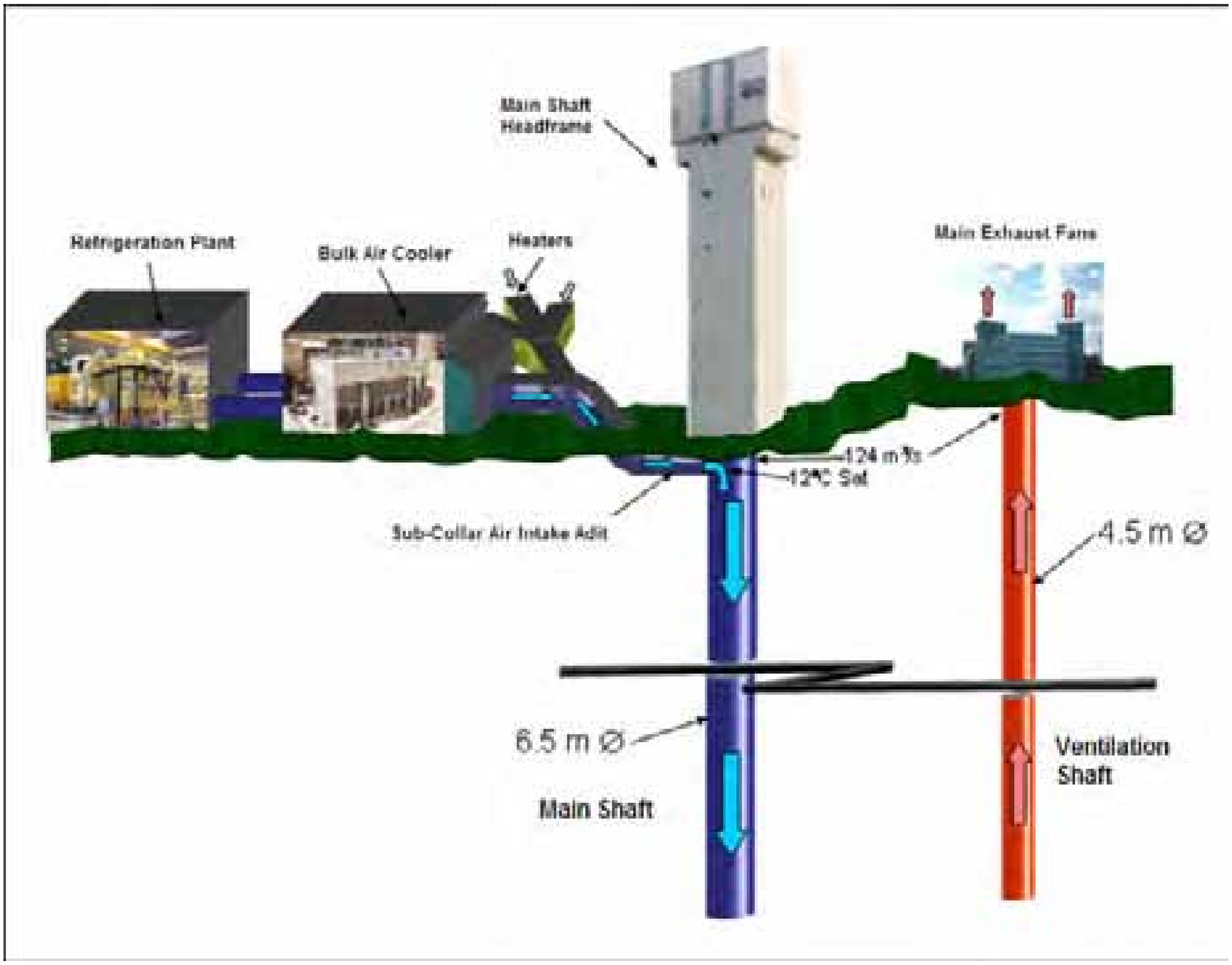


Figure 5-1 – Schematic of the Conceptual Ventilation System

5.2 Ventilation System Capacity

The capacity of the DGR ventilation system will be determined by the types of activities ongoing in the facility. The breakdown of ventilation requirements is given in the following sections, and has been calculated on the basis of air required for mobile waste package emplacement equipment, fixed equipment, occupied areas and emplacement rooms (empty, active being filled, and filled & closed).

In mine ventilation design, air quantities are calculated in terms of mass flow. Air volumes will, therefore, vary depending on the depth of measurement due to the different densities of air with depth. All air quantities in the following sub-sections are stated in terms of volume at the air density at the underground repository level, which equate to greater volumetric flow on surface.

5.3 Construction Activities

The following is a list of equipment that will be used for emplacement room construction:

Equipment	Number of Units	Power (kW) per Unit	Total Air Required (m^3/s)
Personnel Carrier	4	50	12.0
Mobile Work Stage	1	55	3.3
Mobile Bolting Unit	1	55	3.3
Haul Trucks	4	190	45.6
Scoop tram (cleanup)	1	110	6.6
Maintenance Shop			11.0
		Total:	**81.8**

Table 5-1 – Ventilation Requirement for Diesel Construction Equipment

All equipment, apart from the roadheaders, will be diesel-powered. The roadheaders, being electrically-powered, require less air compared to an equivalent diesel-engined machine. By legislation, diesel engines require specific air volumes to clear exhaust fumes, which volumes are normally in excess of those required to remove the heat load alone; whereas roadheaders only require enough air to remove heat loads and clear the dust created during rock cutting. However, an appreciable airflow, amounting to 30 m^3/s, is still needed to ventilate each of the roadheaders. The airflow of 60 m^3/s for the roadheaders is not additive to the DGR design total as it will be drawn from the air already used for other equipment; hence it is not listed directly in Table 5-1. This air volume will achieve an airflow velocity of 0.5 m/s in the emplacement room under construction. For this type of activity, this velocity is required to effectively clear dust, remove the electrical motor and hydraulic power pack heat loads and provide good ventilation for the operators. With over half of the ventilation supply captured in these two workplaces, these tunnels will form major exhaust routes for the DGR and improve the overall fresh air distribution. Ventilation through the maintenance shop is included at a capacity sufficient for one truck or a combination of smaller equipment.

5.4 Emplacement Operations

It is expected that emplacement operations will utilise diesel-powered equipment. Smaller waste packages (<10 tonne) will be handled with a "small forklift" with an engine capacity of 70 kW. A "large forklift", with a higher engine capacity of 155 kW, would be used to handle heavier packages. Based on a regulated volumetric airflow requirement of 0.06 m^3/kW (as stipulated in the Ontario Occupational Health and Safety Act (R.R.O. 1990, Reg. 854 Mines and Mining Plants, Section 183 [R62]), the minimum ventilation rates are 4.2 m^3/s and 9.3 m^3/s respectively for the two sizes of forklift. (See Table 5-2 for summary.) The ventilation hardware installed for construction has more than sufficient capacity to handle these airflows.

HATCH

Equipment	Number of Units	Power (kW) per Unit	Total Air Required (m^3/s)
Small Forklift	4	70	16.8
Large Forklift	2	155	18.6
Personnel Carrier	3	25	4.5
Mobile Work Stage	1	55	3.3
Mobile Bolting Unit	1	55	3.6
Maintenance Shop	1		9.3
		Total:	**56.1**

Table 5-2 – Ventilation Requirement for Emplacement Activities

During the first six years of emplacement operations (clearance of the backlog of waste packages stored in the WWMF), the DGR will operate at full performance with all equipment operating during emplacement years. A discrete event simulation exercise showed that large ILW packages, which take more than 50% of a shift to transfer, would have to be combined with transfer of 'standard' LLW packages during the same shift to use the shift time efficiently and ensure that the backlog clearance can be completed within the planned schedule without the need for working additional shifts. Therefore, it can be expected that all the mobile equipment listed in Table 5-2 would be operating concurrently at certain times and the ventilation system has been designed for such occurrences.

In the later phase of 'slow' emplacement, the number of pieces of equipment will reduce. The ventilation system will be capable of operating at lower air quantities as required, using VFD drives and/or reducing the number of operating fans.

5.5 Peak DGR Ventilation Capacity

The DGR ventilation requirements have been broken down into scenarios that represent different stages in the life cycle of the facility. These scenarios are detailed in Table 5-3.

Scenario		Construction phase	Emplacement phase	Filled Rooms	Empty Rooms	Total
1	Start of excavation of emplacement rooms	82	0	0	0	**82**
2	Excavating last emplacement room, all others empty	82	0	0	20	**102**
3	Starting emplacement operations with clearance of backlog, all rooms empty	0	56	0	20	**76**
4	Continuing emplacement operations once backlog clearance complete, 75% rooms full	0	42	13	5	**60**
5	Finishing emplacement operations, all rooms full	0	42	18	0	**60**

Note: All values are air volumes rounded to the nearest m^3/s.

Table 5-3 – Ventilation Air Volume Requirement Scenarios

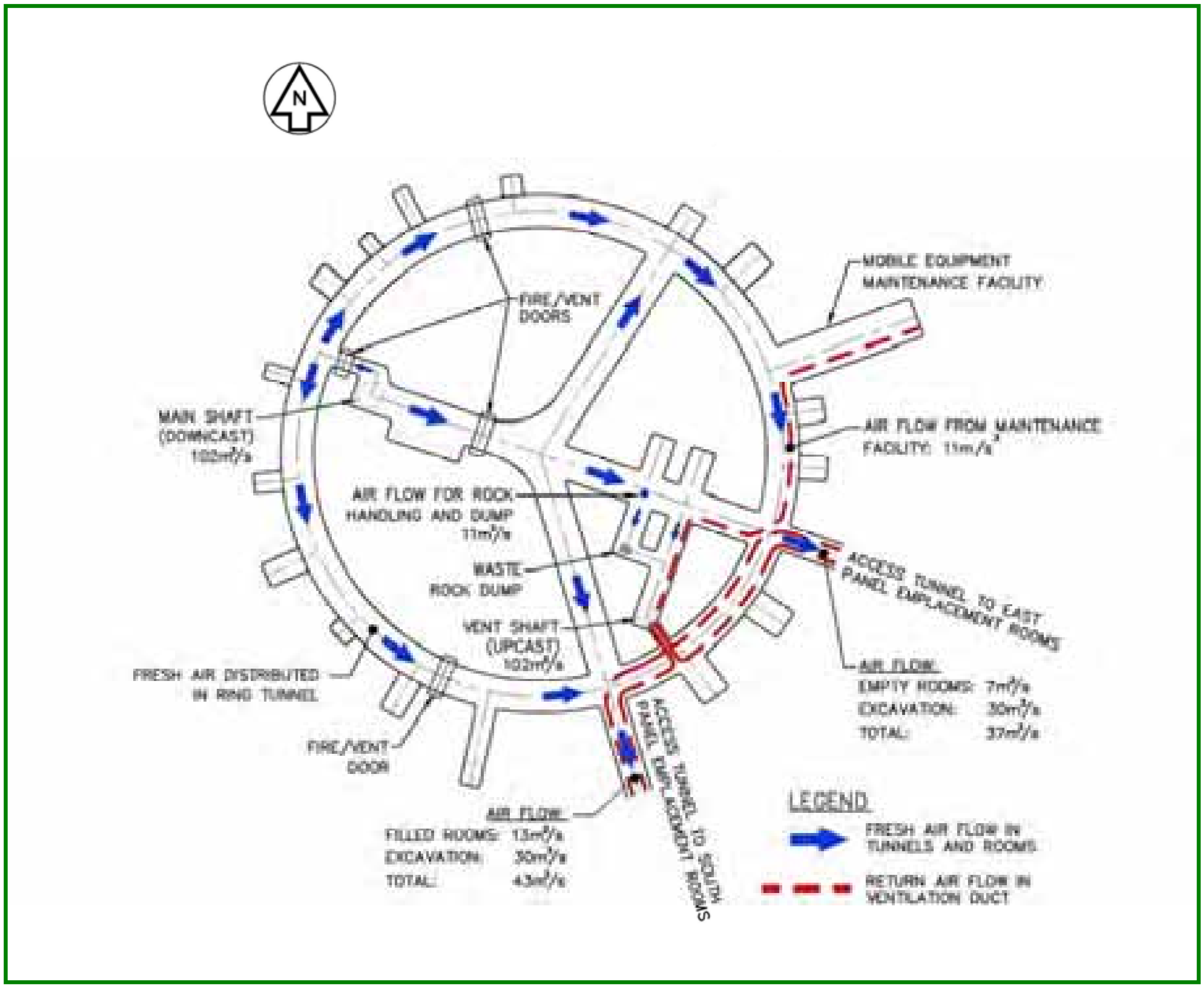


Figure 5-2 – Airflow Distribution for DGR Construction (Scenario 2)

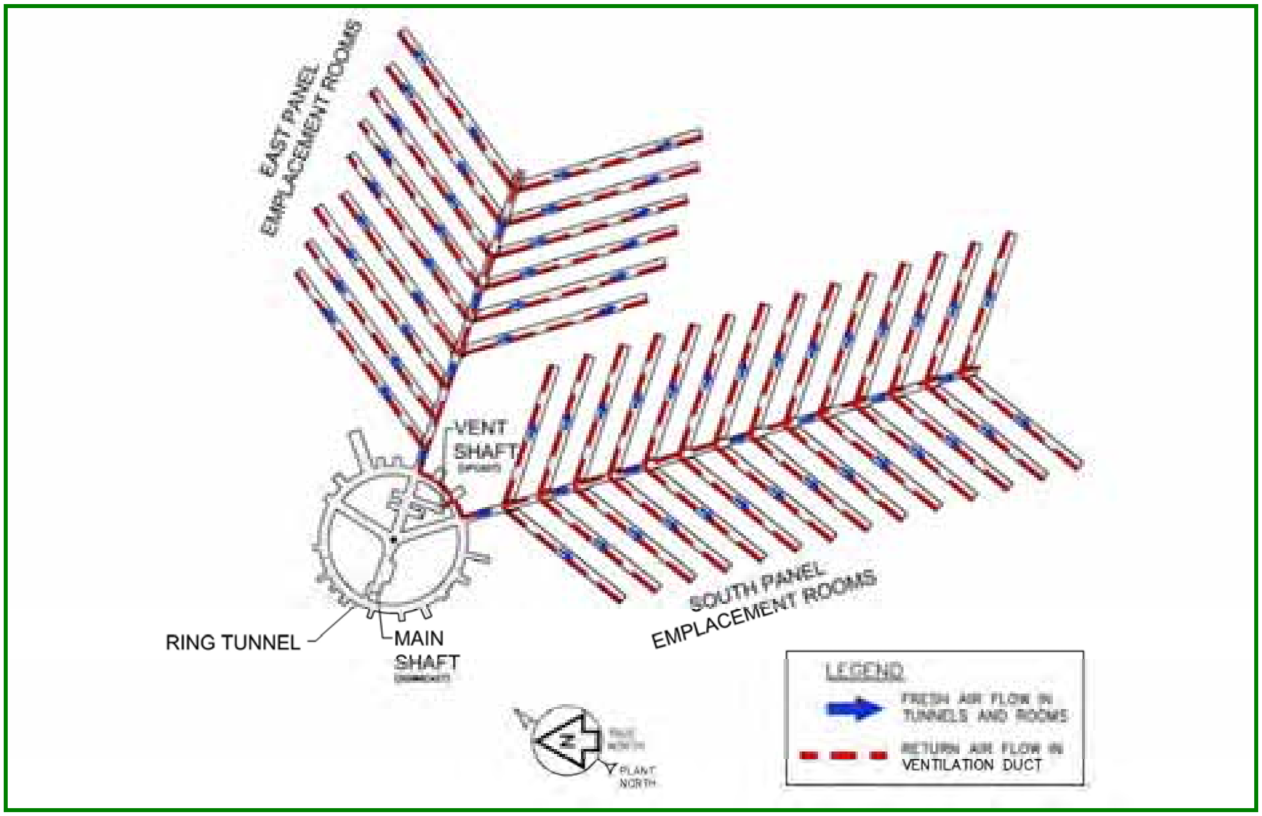


Figure 5-3 – Plan View of Repository Level Ventilation Schematic for Construction (Scenario 2)

5.6 Intake Fans, Heaters and Conditioning Plant

This proposed ventilation design will minimise changes to the temperature of the strata at the repository horizon. In the Main Shaft, air will be conditioned to a nominal 12°C at the collar, which is close to the expected strata temperature near surface. The air will undergo adiabatic compression as it moves down the Main Shaft due to the pressure effects of increasing depth. At the Bruce location, it is an opportune coincidence that the air temperature increase with depth matches the temperature increases associated with the strata at depth. Thus, the auto-compression is expected to increase air temperature by approximately 6.5°C to a delivery temperature on the emplacement level of 18.5°C. This temperature is close to the anticipated strata temperature at this depth, minimising the potential for change in rock temperature, as specified in the Design Requirements (see Section 3 above).

The function of the HVAC system is to provide air at a target value of 12°C to the collar of the Main Shaft. Based on the time of day and season, this could require heating or cooling of the ambient air collected by the booster fans. The ventilation system will be designed to temperature limits of –29°C and +28°C. However, Environment Canada data in the period of 1995 to 2006 indicate that greater extremes of maximum ambient temperatures have occasionally occurred. Were these maxima (+34°C) to occur, the output air temperature from the bulk air cooler would increase to 14.9°C. The underground temperatures would increase to about 21.4°C, which is around 3°C higher than normal, but is still satisfactory for this design and will not lead to unacceptable increases in the rock temperature at the repository horizon.

At the design point, the ventilation model predicted a relative humidity of the air at the DGR horizon of 65%. Over the full annual cycles of ambient conditions, the relative humidity would vary between 60% and 70%. This range provides a good balance to avoiding both excessive humidity that will lead to accelerated corrosion and too dry air that can be detrimental to the health of workers.

5.6.1 Air Cooling

During the summer months an intake air temperature of 28°C was used for the HVAC capacity calculation. A simulation using Environ software was done for the underground repository. The cooling required to maintain the intake temperature of 12°C at the surface is 4,000 kW(R). This would imply a refrigeration plant unit of around 5,330 kW(R), taking into account an estimated 25% energy loss over the system, which is typical for the type of cooling systems used in mining applications.

For this cooling duty, single stage centrifugal compressor-driven refrigeration machines using a hydrofluorocarbon (HFC-134a) as the refrigerant will be used, as it can be safely located close to the bulk air cooler and will not impact on other structures or features in the area.

For the base case DGR with a capacity of 200,000 m^3 of "as-disposed" waste, two 3,515 kW(R) machines will be installed, which will provide adequate stand-by capacity to cater for breakdowns and maintenance. This size machine is a standard within the industrial refrigeration industry and would, therefore, not require any custom designs. If the repository were to be expanded, the total refrigeration capacity requirement would increase to about 6,300 kW(R). Although the existing two machines would meet this duty, there would be a much greater shortfall in capacity were one machine fail. An additional machine would thus be recommended as stand-by capacity, since both the original machines would need to be run at high efficiency levels during the peak summer months.

The surface Bulk Air Cooling (BAC) system would typically be that of a direct contact type system (air and water), which generally have good associated efficiencies. The bulk air cooler will consist of two cells, each handling half of the cooling load and being matched to the refrigeration machine output. These two cells would also be sufficient for a potentially expanded repository. If one cell were to fail, the other could be run above its nominal design capacity while the faulty cell is repaired.

5.6.2 Heating Requirements

During the winter months of the operation, air heating will be required to attain the same fresh air intake temperature of 12°C. Natural gas heaters, being the preferred choice for most Canadian underground mining operations and, therefore, well developed for this duty, will be used. A monthly account of minimum temperatures and associated heating requirements to attain the target 12°C at the intake to the Main Shaft is given in Table 5-4.

Month	Temperature (°C)	Density (kg/m^3)	ΔT (°C)	Heat capacity (kW)
January	-29	1.4189	41	5,386
February	-23	1.354	35	4,387
March	-25.5	1.3501	37.5	4,687
April	-11	1.2965	23	2,761
May		1.1506	-	-
June		1.1419	-	-
July		1.1442	-	-
August		1.1438	-	-
September		1.354	-	-
October	-4	1.3501	16	2,000
November	-17.5	1.3477	29.5	3,681
December	-25	1.3674	37	4,684

Table 5-4 – Design Temperatures and Peak Heating Capacities for Each Month

As indicated, the maximum capacity required will approach 5.5 MW at maximum, although around 4 MW is anticipated to be used as an overall mean (at -22°C average ambient). Although it is sensible to allow for a variance in the design air temperature exiting the heaters, this should never be lower than 6°C for worker health reasons. In mines in Ontario, this minimum limit is applied to designs. Workers can be equipped with warm clothing, but exposure to conditions close to freezing near surface and then warmer conditions underground do lead to increased risks of illness. Additionally, any work which has to be done in the shaft (e.g. maintenance) at cold temperatures is not advised as workers ability to perform the tasks effectively and safely do become compromised at very low temperatures. To avoid overcapitalisation of the heating plant, reductions in temperature of the air intake to the DGR below the target temperature will be allowed on only the coldest of winter days. Workers would be equipped with suitable warm clothing to compensate for a possible reduction in temperature. However, they would still be able to work safely.

Should the repository be expanded in the future to hold an additional 200,000 m^3 of "as-disposed" waste, the peak heating requirement would increase to about 6.5 MW.

5.7 Exhaust Fans

The main DGR ventilation fans will need to exhaust an air quantity of 105 m^3/s (measured at ambient surface temperature and pressure). Two fans will be installed on surface on the Ventilation Shaft. Each fan will be able to handle 52.5 m^3/s at a modelled system pressure of 360 Pascals (Pa). A "top-up" pressure of 250 Pa is required for this arrangement to allow for plenum, intake, and exit losses. This relatively light fan duty will be achieved by use of vane axial-type fans. A third back-up fan, similar in construction and operation, will also be installed in case of emergency or maintenance requirements. These fans will be designed to be able to run on power from a diesel generator to cover any risk of power failure. The fans will be the counter-rotating type, which operate at high efficiencies. The motor power requirements per fan would be about 55 kW. The total fan power requirements would be 110 kW (2 x 55 kW), excluding the stand-by unit.

Two axial intake force fans, plus a stand-by unit, will be installed to push air through the heater plant to the collar of the Main Shaft. These fans would be required to produce 52.5 m^3/s each. The fan pressure requirement will be about 220 Pa, which implies a low pressure, high quantity type of fan. The motor power requirements will be 35 kW per fan. The total fan power requirements will be 70 kW excluding the standby unit.

Two force fans would also be required in the summer months to pass air through the BAC plant. Power consumption would be about 30 kW in total. The fan motors will each be rated at 22.5 kW to account for losses.

If the repository is expanded in the future, the total air volume will increase to 124 m^3/s (measured at ambient surface temperature and pressure). An additional fan will be required in the main exhaust fan building and at the intakes through the heating plant and bulk air coolers.

5.8 Underground Ventilation System and Controls

5.8.1 Emplacement Room Construction

The emplacement rooms will be excavated using two 600 kW electrically powered roadheader-type mechanical excavators. It is expected that the broken material will be carried from the excavator by truck. The ventilation requirement for this process will need to:

- Clear dust generated by the cutting / material handling process.
- Remove heat generated from the diesel engine and the roadheader machine.
- Dilute diesel engine exhaust to acceptable levels.

To define the required ventilation flow for the excavation heading, a minimum flow velocity of 0.5 m/s can be considered effective for this type of workplace. This velocity will ensure a "positive flush" of dust and gasses and will provide adequate dilution of diesel exhaust. Based on a tunnel size of 8.1 by 7.5 metres, this relates to a quantity of 30 m^3/s.

The room under construction would use an "exhausting" system, with a fan mounted near the face forcing exhaust air out of the room to collection ducts in the access tunnels. This fan will be periodically advanced to follow the excavator, with sections of permanent duct installed at this time. This arrangement is shown in Figure 5-4.

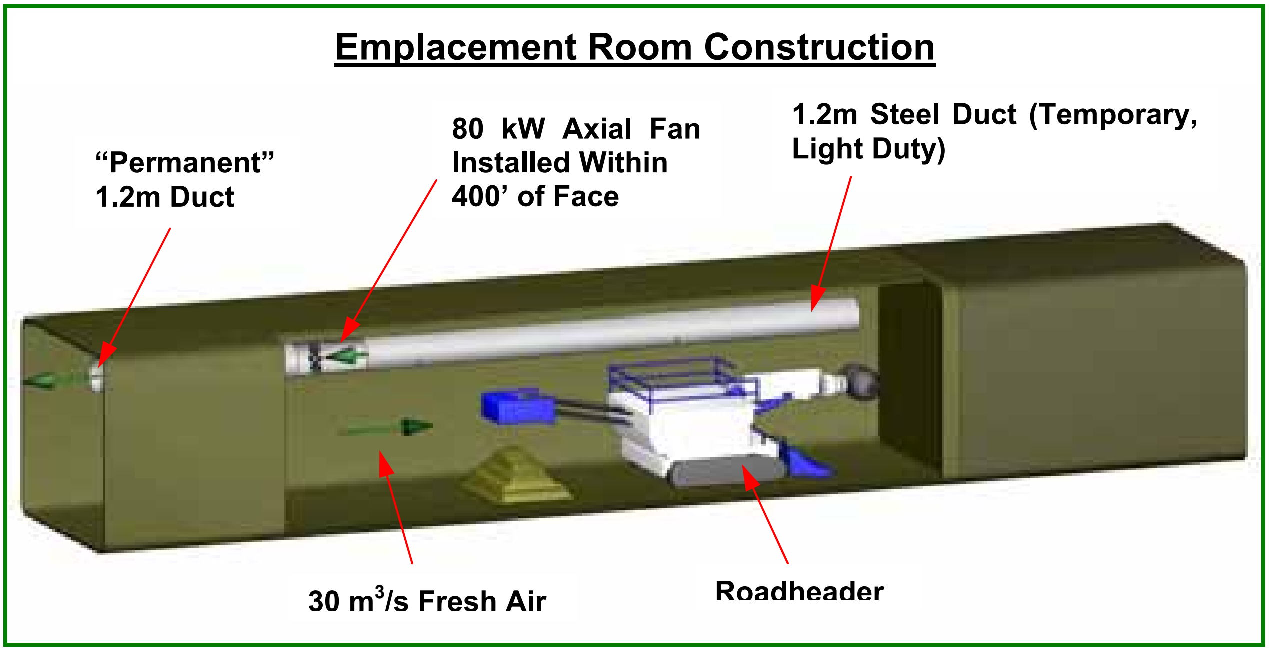


Figure 5-4 – Showing Ventilation Arrangement for Emplacement Room Construction

5.8.2 Empty Emplacement Rooms

Ventilating air will be supplied to empty emplacement rooms on a continuous basis to ensure that the atmosphere remains safe for human occupancy at all times. Empty emplacement rooms may remain open for many years before the waste filling and closing process take place. It is anticipated that a small amount of potentially explosive methane may be emitted from the strata. Small amounts of moisture over the months would also generate humidity, accelerating corrosion of metal ground support and ducting items.

The "permanent" duct installed during construction activities may be used to remove this air. This arrangement is demonstrated in Figure 5-5.

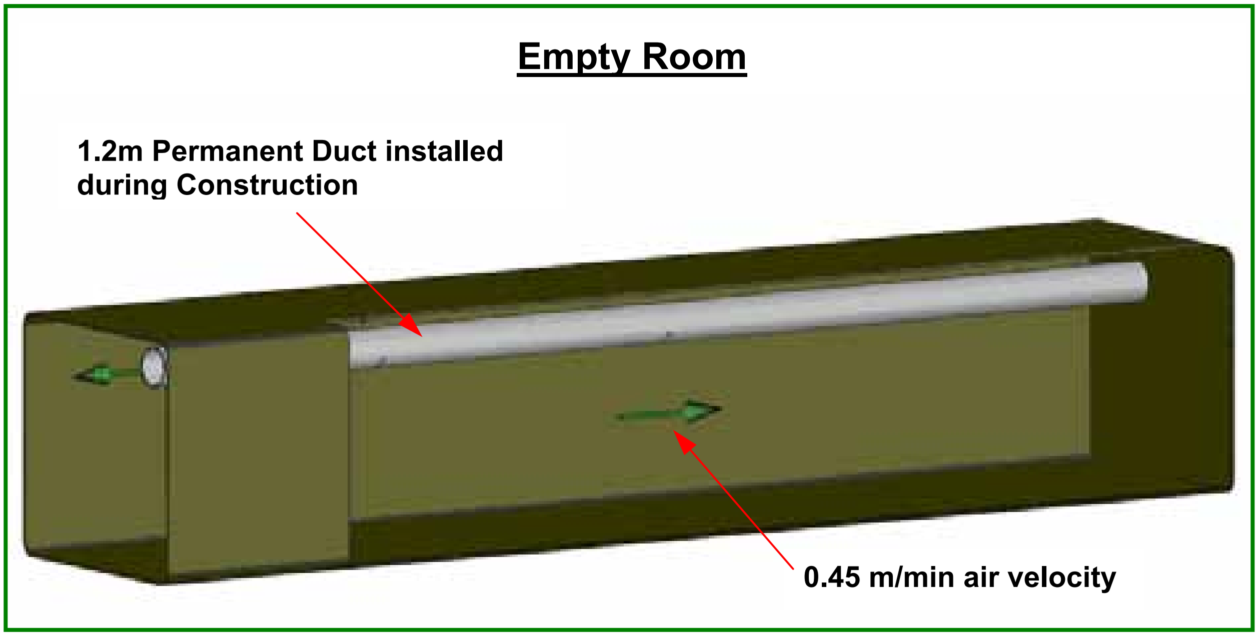


Figure 5-5 – Showing Ventilation Scheme for Empty Emplacement Rooms

5.8.3 Active Emplacement Rooms

Upon commencement of emplacement operations, the auxiliary exhaust ducting system will be used to collect all air that has passed over waste packages and duct that "dirty" air to the base of the upcast Ventilation Shaft. All occupied underground space will thus be in a stream of fresh air or air that has only passed through non-contaminated rooms and tunnels. The system used to collect exhaust will be used for both active and closed emplacement rooms. Coming from areas of potential contamination, this air will be transported in ducts to the Ventilation Shaft.

Typical arrangements for these scenarios are demonstrated in Figure 5-6 and Figure 5-7. To achieve the optimal distribution of fresh air throughout the DGR, the exhaust system in active emplacement rooms will be used as primary exhaust points. So the majority of air flowing into the repository will be removed from the ends of the ducts in those rooms. Therefore, since the total air flow in the repository needs to be greater than that required for the emplacement rooms on their own, and the portion of exhaust air to be drawn through the room ducts for return to the upcast Ventilation Shaft is designed to be greater than the portion required for the emplacement rooms, the air flow within a room will be maintained above the minimum design volume, which provides a factor of safety for room ventilation.

These room auxiliary fans will be installed at the entrance to the room to ensure that all maintenance can be carried out upstream of the emplaced waste packages.

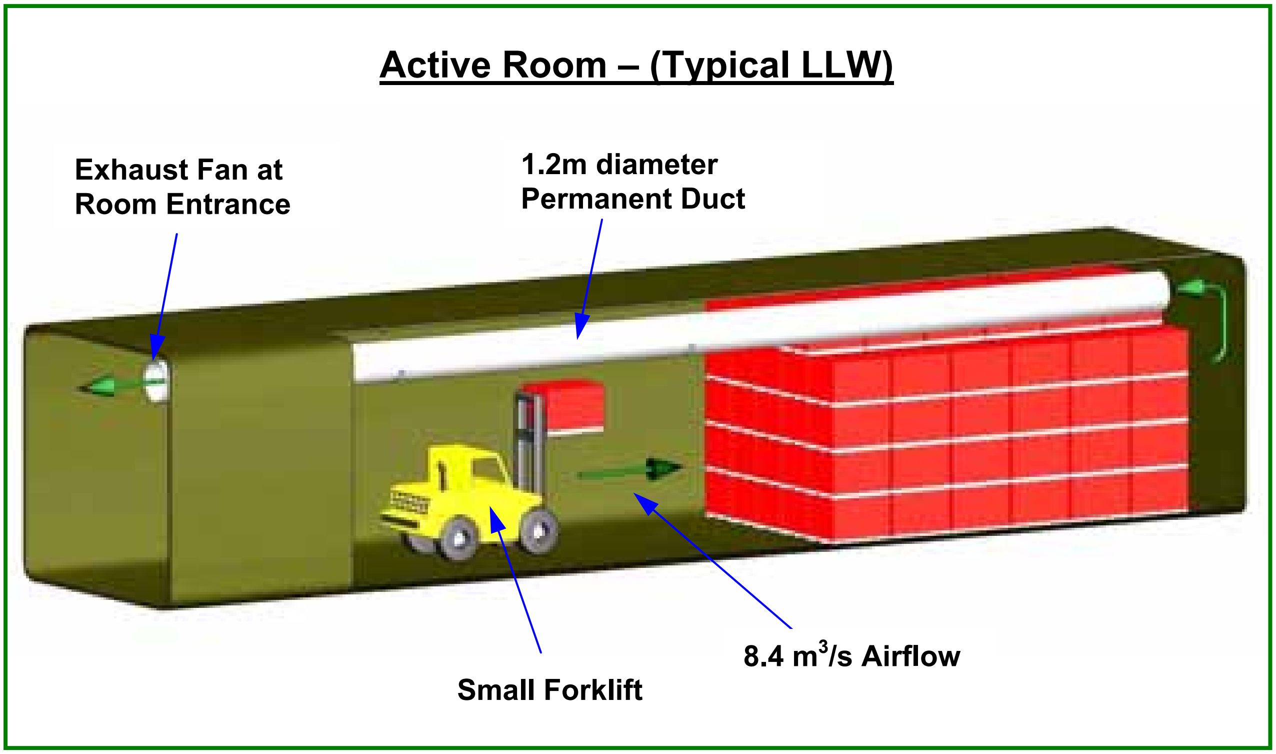


Figure 5-6 – Ventilation Arrangement for Active Emplacement Room with Small Forklift

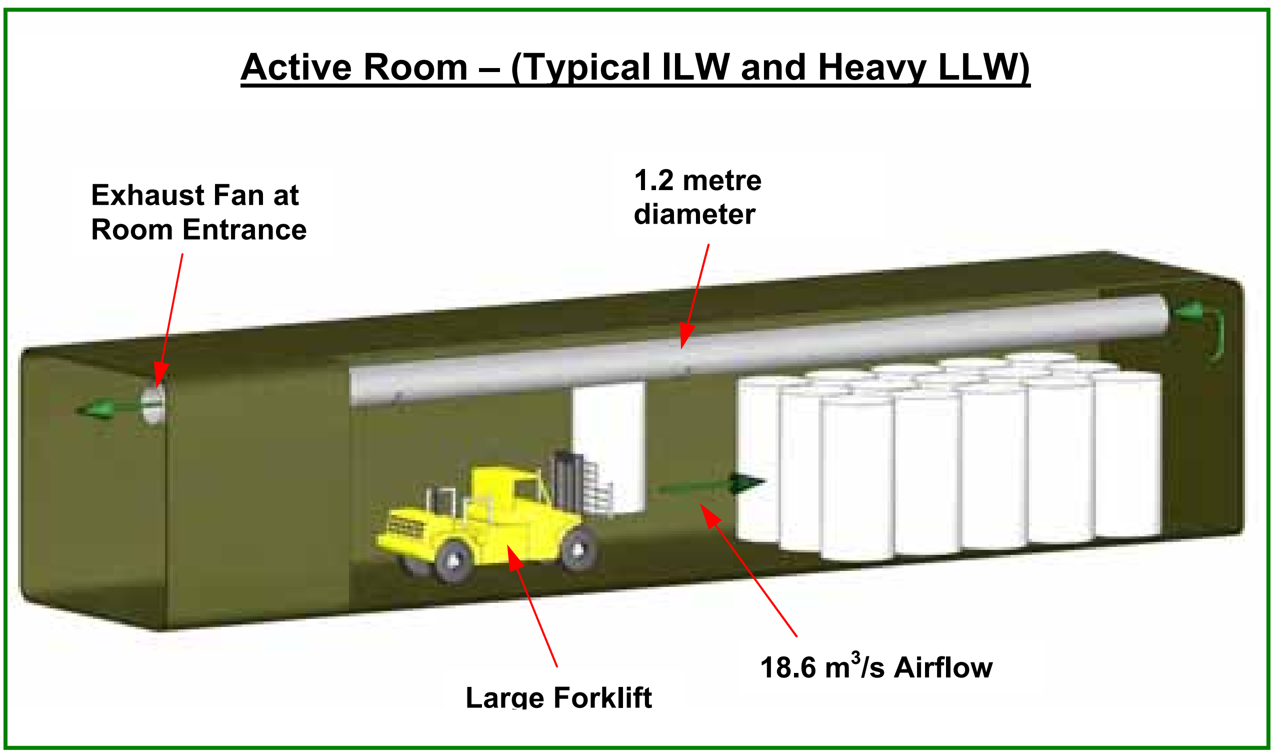


Figure 5-7 – Ventilation Arrangement for Active Emplacement Room with Large Forklift

5.8.4 Filled Emplacement Rooms

Once an emplacement room is filled to capacity with waste, it will be closed to prevent inadvertent access or contact with the waste packages. The closing process will involve construction of a rigid bulkhead, with access portals for ventilating air and monitoring equipment.

There is a potential scenario where explosive gases accumulate in a room after closure. This could be due to hydrogen generation from corrosion of steel containers, methane generation from decomposing organic wastes, and/or natural methane seeping into the room from the surrounding rock. These gas sources would be slow, but could build up to significant levels during the operational period if the room is well-sealed and if there is sufficient water to support corrosion processes.

There are three options to manage this risk: prevent the build-up of gases to explosive levels; prevent any ignition of these gases; and mitigate the impact in the unlikely event that an explosion should occur. Options considered during this conceptual design were:

- Keep room continuously aerated so gases are not generated (the corrosion reactions only generate gas under anaerobic conditions) or are removed without build-up.
- Monitor closed rooms and periodically flush any room where gas build-up is detected.
- Close and seal rooms with strong walls capable of preventing mixing with air from the access tunnels and withstanding a gas explosion.

Once a room has been filled with its allocation of waste packages and closed, the exhaust air will be monitored for explosive gasses. Should monitoring show that gases are not being generated in quantities that could lead to an explosion risk, then the airflow may be adjusted or stopped to suit the observed conditions and requirements for that room. This method will ensure that there is no build-up of gases and the room air is kept in a safe state at all times, humidity levels can be controlled within each room (no water build-up), and there is continuous monitoring of humidity, contaminants and gas generation, including methane and carbon monoxide in the ducts exhausting the air from the rooms to provide quick detection of any problems (i.e. explosive gas build-up, fire). Gas detection instruments are ideally installed in the exhaust ducts to ensure that they are always in an airflow that has passed through the emplacement room and over the waste packages. Additionally, by locating the instrumentation in the ducts outside the rooms, they are easily accessible for calibration, testing and maintenance. If continuous ventilation of rooms, in which gas generation has been identified, is not performed, then such instrumentation would have to be installed at various points inside the room, which would cause maintenance staff to be exposed to the wastes even if accessibility for maintenance is not precluded because of the location of monitoring equipment inside the room.

Although a small air exchange rate on the order of once per month may be sufficient, continuous venting at higher exchange rates of around once every three hours are recommended. This rate ensures that the room is well flushed, can use the existing ducting installed in each room during construction, and is a small addition to the overall DGR ventilation system load. It is also sufficient to remove any decay heat from within a room. The auxiliary fan, which will pull the air through the closed room, will be mounted on the outside of the closure wall. Monitoring instrumentation will be installed in flanged wells in the ducting outside the room, which will allow for easy and safe replacement. Maintenance personnel will, therefore, not need to enter the closed rooms to do such work.

No advantage is gained by either method of purging rooms of gases in terms of release of contaminants to the outside environment, since the cumulative amount of contaminants will be the same over the long term.

5.8.5 Ventilation Ducting

It is anticipated that permanent ducting will be installed in the emplacement rooms following on behind the progress of the mechanical excavator. This permanent duct will be used through the filling and closed room ventilation duties and will be engineered to function for the remainder of the active life of the DGR. The duct will have strength requirements to withstand small impacts and deflections associated with localised ground loosening over the decades. Corrosion considerations will also be factored into the detailed engineering design. Ducting used during excavation of the rooms could be a simple flexible or light steel tube system, but the permanent ducting would be solid steel, corrosion-protected piping.

5.9 Ventilation for Potential Expansion Case

As the ventilation system and sizing of the main access-ways (shafts) need to be able to handle any potential expansion of the DGR at some stage in the future, the ventilation design allows for such a potential increase. The design has, therefore, been considered for this potential expansion to a total "as-disposed" waste volume of approximately 400,000 m^3. However, the ventilation system would be operated at the lower air volumes required for the base case repository capacity of approximately 200,000 m^3.

Additionally, the DGR construction activities will require greater air volumes through the repository than during waste emplacement operations and, therefore, dictate the maximum capacity that must be installed.

Scenario		Construction phase	Emplacement phase	Filled Rooms	Empty Rooms	Total
6	DGR Expansion, excavation last room of new capacity	82	0	18	20	**120**
7	DGR Expansion, all rooms full	0	56	36	0	**92**

Note: All values are air volumes rounded to the nearest m^3/s.

Table 5-5 – Ventilation Air Volume Requirement for Potential Expansion Scenarios

It is thus determined that the peak ventilation requirement will occur in Scenario 6, if future expansion of the DGR is required. This requirement is only 20% higher than Scenario 2 (see Table 5-3), and the lower air speeds and resultant lower pressure losses will provide enable only two of the three operational fans to be installed and reduce power consumption. It is also possible that requirements for filled room ventilation will be able to be decreased over the years as a result of lower rates of gas generation than expected. This would provide additional safety margin in the design capacity.

For the worst case quantity of 120 m^3/s (155 kg/s or 124 m^3/s at the surface density) required by the underground repository in Scenario 6, the key velocities of air in the shafts are:

- Main Shaft downcast velocity of 3.73 m/s.
- Ventilation Shaft upcast velocity of 7.70 m/s.

These velocities have been determined on the basis that air will flow across the entire cross-section of the shafts with allowance made for loss of area due to shaft steelwork and other furnishings.

In both the Base Case and Potential Expansion Case, the air velocity in the Ventilation Shaft is safely below the lower limit of the critical range for the suspension of water droplets. Within this critical range of 8 to 15 m^3/s, condensation droplets may be suspended and collect in the air stream when the upcast velocity matches the free-fall velocity of the predominant water droplet size. This occurrence is typically affected by season and humidity levels, and adjustments to the exhaust air velocity may be required to avoid damage to the exhaust fans.

The airflow distribution for this scenario is given in Figure 5-8 with the overall layout of the repository ventilation network shown in Figure 5-9.

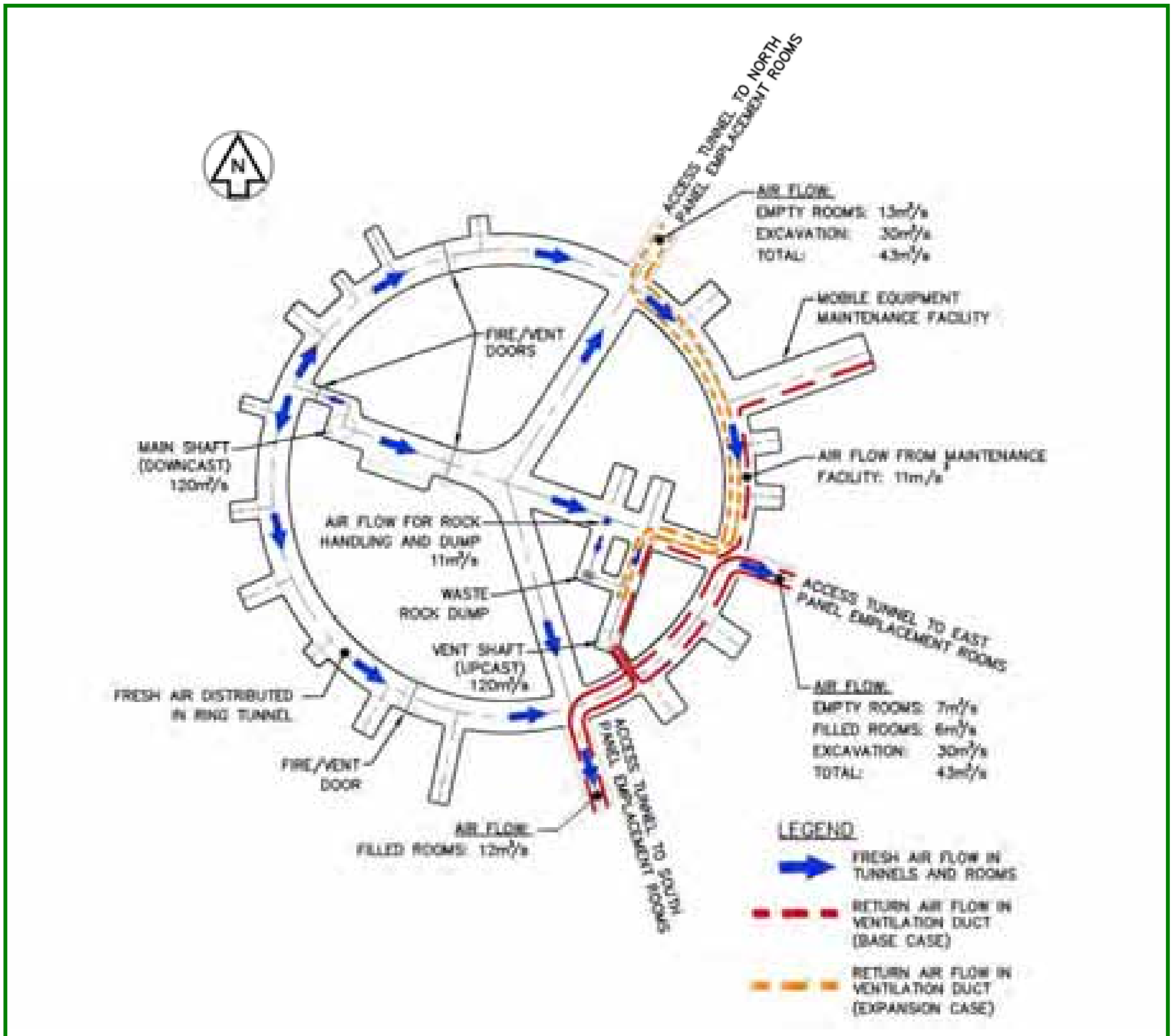


Figure 5-8 – Airflow Distribution for Potentially Expanded DGR – Peak Demand (Scenario 6)

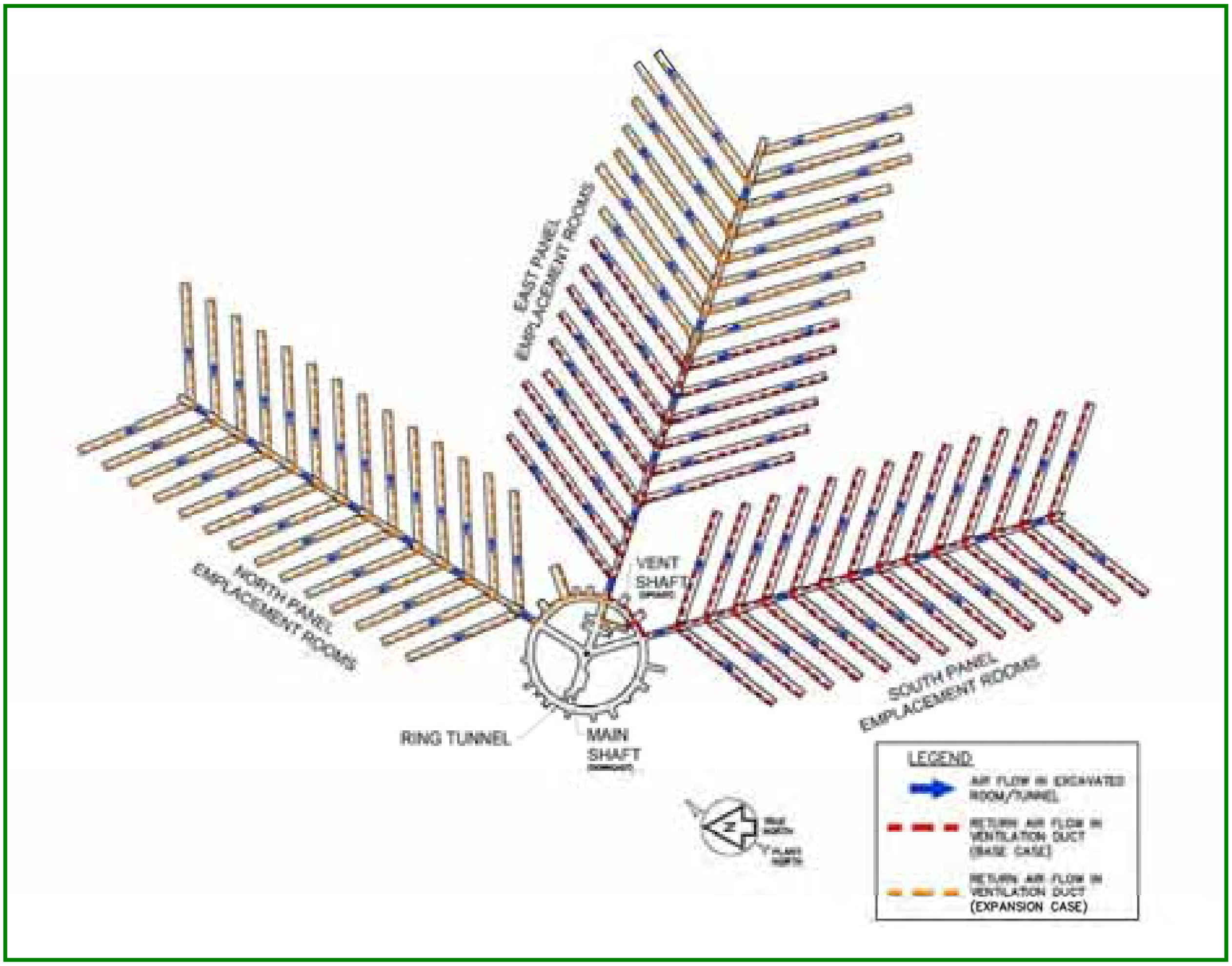
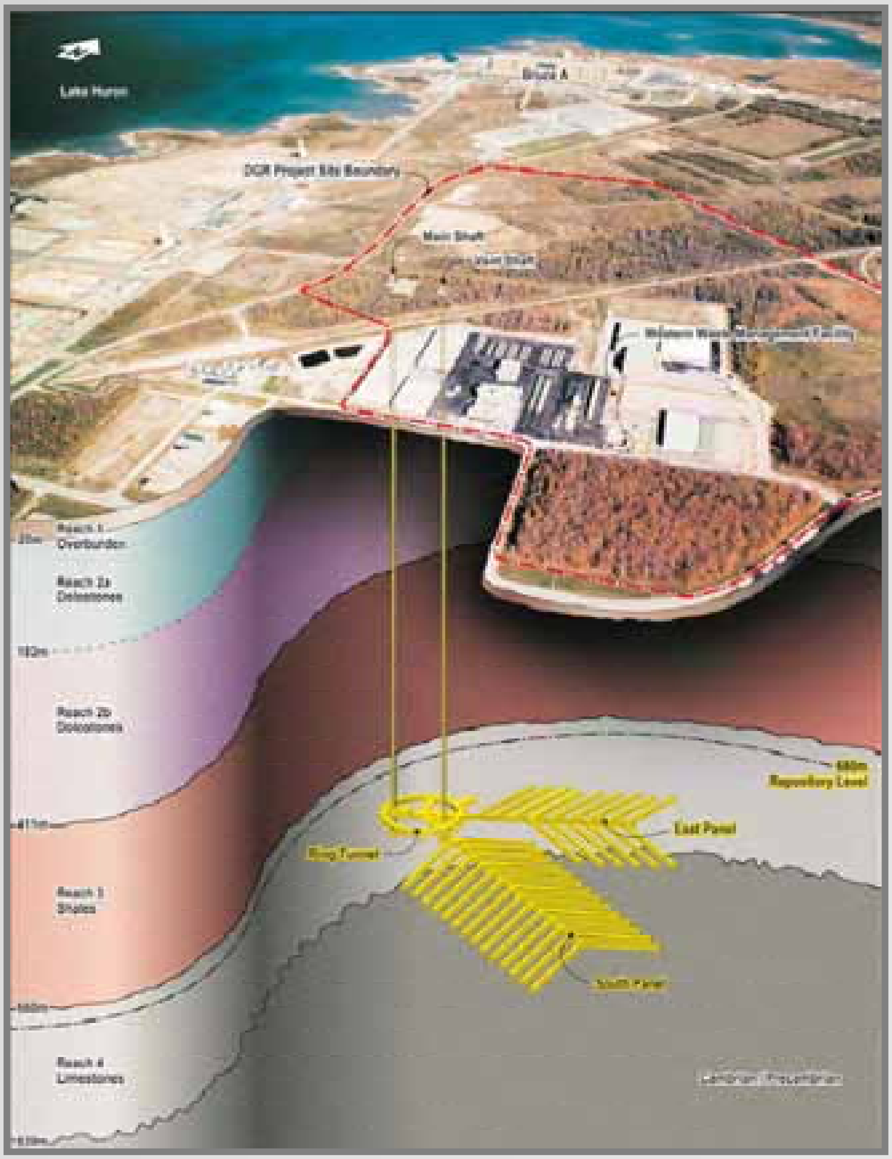


Figure 5-9 – Plan View of Potentially Expanded Repository Level Ventilation Schematic for Peak Demand (Scenario 6)

CONCEPTUAL DESIGN REPORT

6. Shaft Design and Construction



6. Main and Ventilation Shafts – Geotechnical-Based Design and Construction

The construction of two shafts is required as part of OPG's proposed Deep Geologic Repository (DGR) located at their Western Waste Management Facility. The shafts provide access to the repository and a means of ventilating the repository during its 100 year operational phase. Both shafts will extend from ground surface to the repository horizon located at 680 m depth plus an additional 30 m (main shaft) or 40 m (vent shaft) to shaft bottom for hoist overrun and sump arrangements for a total excavated shaft length of 710 to 720 m. The main shaft will have a finished internal diameter of 6.5 m and the ventilation shaft will have a finished internal diameter of 4.5 m. Excavated diameters will vary depending upon ground reach, initial support types and excavation methods (as described below).

The geotechnical based design of initial support, final support and selection of construction methods has been based on the assumption that it is necessary to construct the shafts to provide:

- 100-year design life (with minimal maintenance requirements),
- Sufficient size for safe waste haulage operations,
- Sufficient size to accommodate efficient construction activities for the access way and the repository,
- Limit ingress of groundwater, control of provided ventilation, utility and fire-life-safety requirements and
- Ensure the ability to reliably seal the repository access upon the completion of waste handling operations (assumed to be 100 years).

The proposed construction methodology for the shafts is presented herein. This includes: the selected ground improvement, excavation, and rock support techniques. Due to the varied nature of the stratigraphy at the site, the shaft construction methodology is presented according to the four stratigraphic reaches described in Section 2.5.

Each of the shafts will require a final concrete lining as an essential component of shaft support during the operations period to:

- installation and short duration.
- Assure reliability of the support with minimal support requirements over the planned 100 year design life.
- Provide swelling control and prevent degradation (slaking) of the rock in Reaches 3 and 4. A final lining with properly detailed stress relief provisions can control swelling in these rocks that exhibit time-dependent behaviour and minimise exposure of the rock to fresh water and humidity and control the slake potential of shaly rocks.
- Provide a stiff retaining structure that will limit relaxation of the rock mass and support the shaft hoisting appurtenances.

6.1 Sinking Methodology - Reach 1: Overburden

The excavated diameters for the Main and Ventilation Shafts in the 20 metres deep, Reach 1 Overburden material will be 9.4 and 7.2 metres respectively.

6.1.1 Reach 1: Excavation and Ground Improvement Methods

Prior to excavation through the overburden, groundwater control via permeation grouting or freezing will be required due to the presence of sand layers. Being below the water table, these soil units will exhibit flowing behaviour if not treated. A grout curtain consisting of 2 concentric rows of grout holes circumferentially spaced 1m around the perimeter of the shaft excavation will be used. Cementitious grout using micro-fine cement or chemical grout using sodium silicate suspension will be injected through a sleeve port grout pipe (SPGP) system that facilitates multiple grouting stages through the same grout holes. This grouting will also limit groundwater inflow into the shaft through the initial support system. If groundwater control for inflows into the shaft via grouting is not felt feasible (based upon investigations at selected shaft locations), a ground freezing set-up can be used to augment the grouting program. Alternatively, a slurry wall system may be used.

Shaft excavation through the lower portion of the 20 metres of overburden will likely be accomplished using a small backhoe and muck skips hoisted to the surface by a crane or possibly using a clamshell depending upon the contractor's selected means and methods.

6.1.2 Reach 1: Initial Support

Initial support of the shaft in overburden will consist of circular steel liner plate supported by circular W200x52 ring beams as shown in Drawings 323874DGR-200-019 and 200-020 contained in Appendix E. Figure 6-1 depicts a similar arrangement.

A reinforced collar beam at the soil/rock interface is often installed to stiffen the initial support, permit transition from a steel lined shaft into a shotcrete lined rock excavation and to provide a groundwater dam to collect and channel groundwater inflows at the contact. This feature results in a larger excavated diameter in the overburden reach relative to the rock reaches.

Figure 6-1 – Large Diameter Shaft in soil with liner plate and ring beams

6.2 Sinking Methodology - Reach 2: Dolostones

The excavated diameters (A-line – i.e. no allowance for over-break) for the Main and Ventilation Shafts in the 291 metre deep, Reach 2 Dolostones will be 8.0 and 5.80 metres respectively.

6.2.1 Reach 2: Excavation and Ground Improvement Methods

Excavation through the dolostone will be accomplished using drill and blast excavation techniques. Controlled perimeter blasting will limit over break of the shaft walls. Drill and blast has been proven to be a suitable excavation technique in similar rock conditions during mine shaft sinking operations near Goderich Ontario.

Reach 2 is roughly 390 m thick. This thickness will be excavated in 3.0 m benches/cuts resulting in a total of approximately 130 individual blast rounds. However, a change in sinking methodology from drill and blast to that recommended for Reach 3 and 4 should be considered for the final 30 m of Reach 2 in order to minimise damage to the surrounding bedrock in Reach 3 and portions of Reach 2 where the bentonite annulus ring and primary sealing materials will be placed. This decision will depend upon the intact rock properties (strength) of the dolostones at this depth.

On the basis of underground excavation experience in the Reach 2 dolostones, a systematic, engineered grouting program will need to be implemented to control water inflows and permit excavation in the dry. Formation grouting will be accomplished using a drilled hole pattern to create a low permeability grouted zone consisting of a curtain or canopy around the ground to be excavated and a full face plug ahead of the advancing face. A typical shaft grout pattern and canopy arrangement is shown in Figure 6-2 and Drawing 323874DGR-200-021 in Appendix E. The arrangement consists of 25 primary and 25 secondary grout holes extending 25 m in front of the shaft face. Secondary grouting will be directed on the basis of inflow criteria applied the observed inflow from a second probe hole advanced after primary grouting is completed. The grouting sequence will be repeated after every 18m advance of the shaft depending upon the rate of groundwater inflow through probe holes (see Figure 6-3), resulting in a total grout hole length of 10.8 to 21.6 km over the 390 m reach.

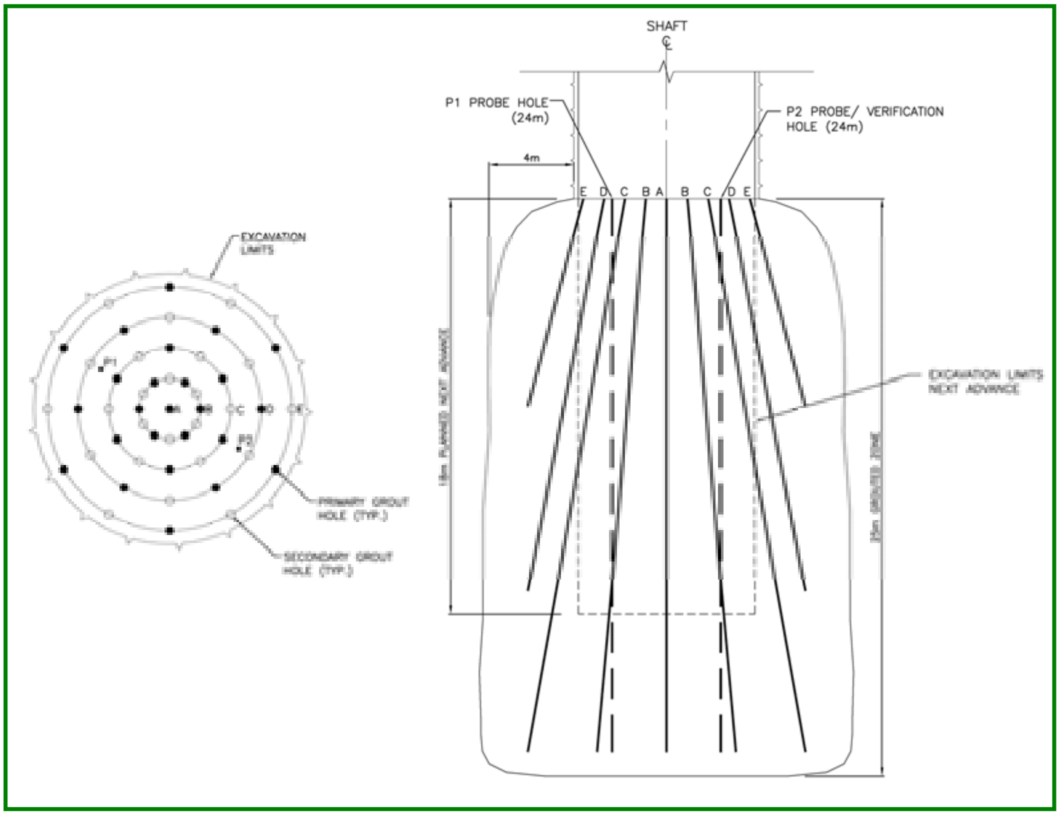


Figure 6-2 – Reach 2 Grouting Arrangement

Based upon the results from the DGR-1 and DGR-2 investigations indicate that the lower ~ 230 m of Reach 2 (denoted Reach 2b) is significantly less permeable than the upper portion of Reach 2. Correspondingly, this section may not require grouting as substantial as that outlined above. The beneficial effects of the reduced permeability are partially offset by the increased pressure heads that will exist at these depths. As a result, it is currently assumed that the grouting methodology identified above will be necessary for the entire ~ 390 m length (vertical distance) of this Reach. The magnitude of groundwater inflows from probe holes drilled ahead of the excavation face will be used to direct primary and secondary grouting efforts. Correspondingly, if inflows in Reach 2b are less than Reach 2a, grouting requirements will reduce commensurately and shaft advance rates will increase proportionately. Similar to Reach 1, if controlling groundwater inflows into the shaft can not be adequately controlled with grouting, a ground freezing set-up may need to be used to augment the grouting program.

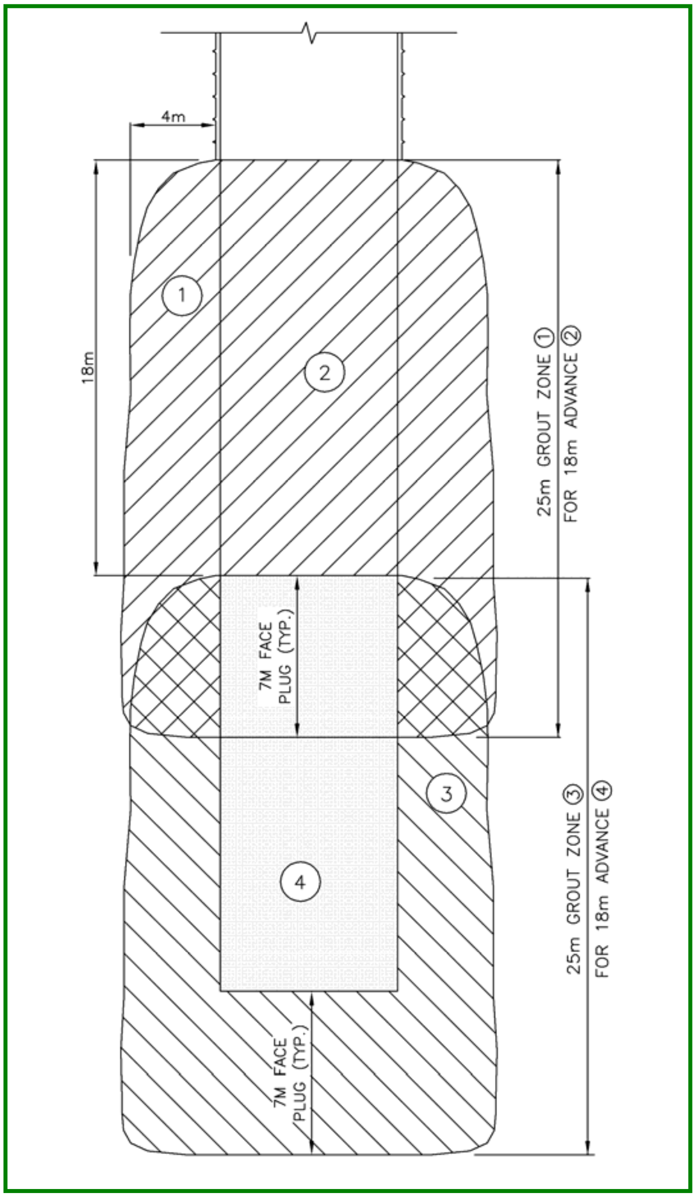


Figure 6-3 – Reach 2 Grouting and Sinking Sequence

6.2.2 Reach 2: Initial Support

Initial support for Reach 2 will be provided by 3m long, 25M resin-dowels @ 1.5m spacing (vertically and circumferentially) with 150x150x10mm base plates covered with a 75mm fibre-reinforced shotcrete layer (See Drawings 323874DGR-200-019 and -020 in Appendix E). Panning is placed between the rock and the shotcrete and weepholes through the shotcrete will be necessary to prevent groundwater pressure build-up behind the shotcrete.

During shaft sinking, a ground water inflow collection system consisting of pumps and vertical discharge lines will be necessary. Such a system should be capable of handling flush inflows of up to 250 l/s (4,000 US gpm). After completion of excavation and lining, this system will not be required. At the surface, water treatment facilities will be required due to the presence of suspended solids and possibly dissolved hydrogen sulphide and methane gases in the effluent groundwater.

6.2.3 Reach 2: Final Support

Following completion of shaft sinking to the Reach 2/Reach 3 contact, a cast-in-place concrete liner will be slip-formed from the bottom of the shaft to the ground surface to provide final support and limit inflows along the length of the shaft (See Drawings 323874DGR-200-019 and -020 in Appendix E). Slip-lining from the bottom is felt necessary in lieu of advancing the shaft lining concurrent with sinking in order to achieve the quality of concrete necessary to provide a water-tight system capable of achieving a 100 year design life.

While the likelihood of a significant quantity of groundwater movement along the concrete liner and rock face of the shafts is considered low, as an additional level of contingency, horizontal bentonite ring barriers similar to that planned for the Reach 2b/3 contact (see Figure 6-7) will be designed for installation behind the concrete liner at the Reach 2a/2b contact zone. This will minimise the likelihood of any cross-formational groundwater flow during the operational period of the facility.

The liner will be 600 mm thick for the access shaft and 500 mm thick for the smaller vent shaft. For structural reasons, the concrete will be reinforced with steel rebar (estimated at approximately 1% by volume radially and 0.4% by volume vertically). During slip-forming, panning will be necessary to prevent groundwater inflow into the concrete and to prevent pressure build-up until the concrete has reached sufficient strength. Following completion of the concrete placement and strength gain, contact grouting will be performed through the lining to seal these panning measures and the interface between the rock and final lining to minimise the potential for shunt flow caused by differential groundwater gradients.

6.3 Sinking Methodology - Reach 3 Shales and Reach 4 Limestones

The excavated diameters (A-line – i.e. no allowance for over-break) for the Main and Ventilation Shafts in the Reach 3 Shales and Reach 4 Limestones will be 8.15 and 5.95 metres respectively. Accounting for the 30 m sump depth, the combined depth of shaft through these two reaches will be approximately 300 metres – 250 metres in Reach 3 and 50 m in Reach 4.

6.3.1 Reach 3/4: Excavation and Ground Improvement Methods

Mechanical excavation is required through Reach 3 and 4 to minimise the creation of an excavation damaged zone (EDZ). Blasting will not be used in the Reach 3 shales. Instead, a vertically-oriented roadheader is proposed (see www.herrenknecht.de [R63] and Figure 6-4). This type of machine offers greater flexibility in shaft diameter and easier access to the tunnel face during construction relative to a full face shaft boring machine. The same unit can be modified to excavate both the main and ventilation shafts. The fragment size of the waste rock permits mucking from the shaft excavation bottom via an airlift or small clamshell to a deck on the stage (above the roadheader level). Muck would then be lifted by bucket to the surface in the traditional manners (muck skips or slurry line). Some limited drill and blasting would be used to enlarge the opening at the base of the shaft for the shaft station. Final excavation in this area would be by roadheader.

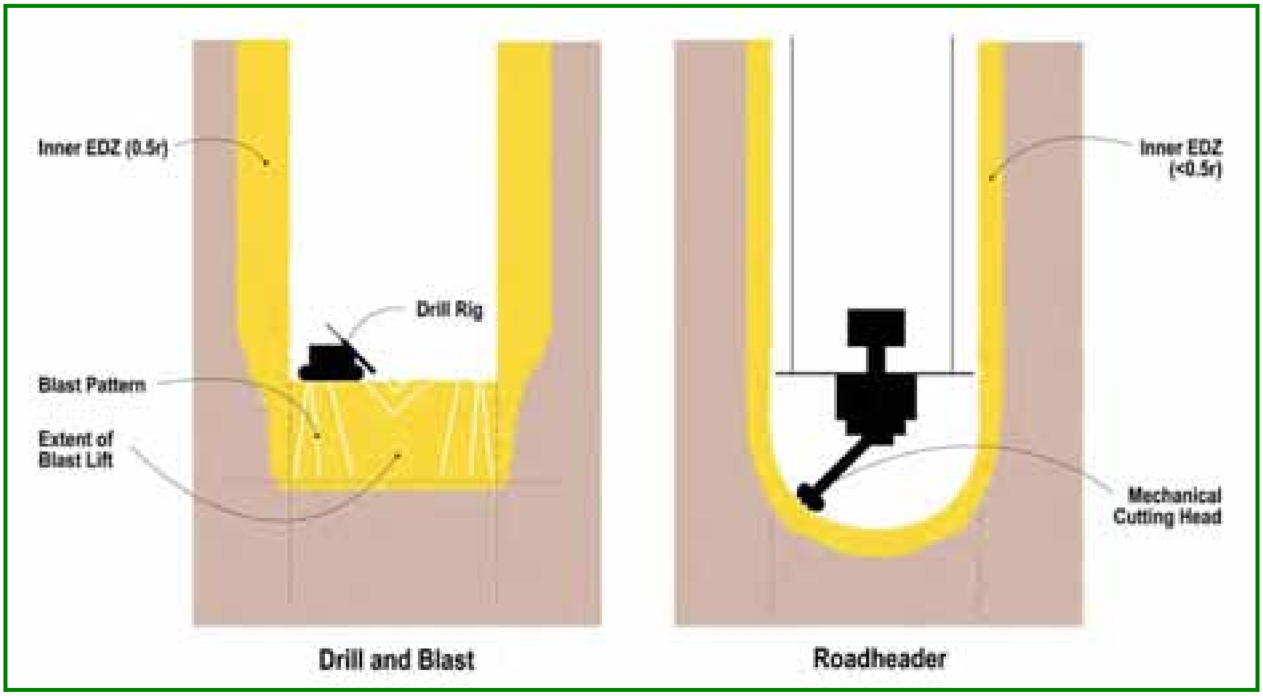


Figure 6-4 – Example EDZ Formation for Drill and Blast vs. Mechanical Excavation in Crystalline Rocks (Extent of EDZ based on [R86]). Images not to scale.

Herrenknecht ([R63]) has developed a shaft roadheader or VSM (Vertical Shaft Sinking Machine), illustrated in Figure 6-5 and Figure 6-6. These machines have been developed for shafts construction in both soft and hard ground conditions. All of the machines consist of 3 major components (Figure 6-5):

1. Excavation Unit – A rotary grinder fitted with special tools, mounted on a telescoping roadheader boom that loosens the rock material by making swinging movements at the shaft bottom. The unit is braced against solid rock or against a segmental concrete liner with gripper arms similar to a TBM.
2. Shaft Lining Unit - A working stage located above the excavation unit which allows the installation of support such as bolts, mesh, shotcrete, or a segmental concrete liner.
3. Lifting/Lowering Unit - A lifting lowering unit raises and lowers the cutting head in the shaft. This unit is located at the ground surface above the shaft opening and is connected to the cutting head by cables.

Figure 6-5 – Arrangement of Shaft Sinking using a Vertical Shaft Sinking Machine

The excavated material is removed hydraulically through pipelines up to the surface or through a pilot hole to a drift below for secondary shafts.

Figure 6-6 – Example of Vertical Shaft Sinking Machines (Herrenknecht, 2007)

Significant groundwater inflows are not anticipated due the low hydraulic conductivities in Reach 3 and 4 and the concreting and secondary grouting performed in Reach 1 and 2. However, the shales must be protected from fresh groundwater from above as this can cause degradation and swelling. An annulus ring filled with bentonite will be placed at the Reach 2/3 contact (see Figure 6-7) to prevent downward seepage of fresh ground water into Reach 3 along the compressible foam gap (See Drawing 323874DGR-200-022 in Appendix E).

This ring will be approximately 600 mm thick outside the concrete and extend approximately 4 m along the shaft wall. Excavation of the bentonite ring would be carried out using the vertical roadheader or other mechanical means. A similar bentonite ring may need to be installed at the Reach 2a/2b interface depending upon hydrogeologic conditions at that location as well.

Prior to shaft sinking into the Reach 3 shales, secondary formation grouting near the dolostone/shale contact will be needed to control groundwater flow along this contact zone (See Drawing 323874DGR-200-022 in Appendix E). This grouting is felt necessary to seal alternative pathways around the bentonite ring through fractures in the dolostones and the upper section of the Queenston formation caused by blasting. Secondary grouting will consist of an inner and outer microfine cement-based suspension grout zones, while the central zone will be completed with a suitable solution grout agent (e.g., polyurethane, arcylamides or acrylates). The grouted zone would extend approximately 10m vertically and 6m horizontally and key into a concrete collar around the shaft wall.

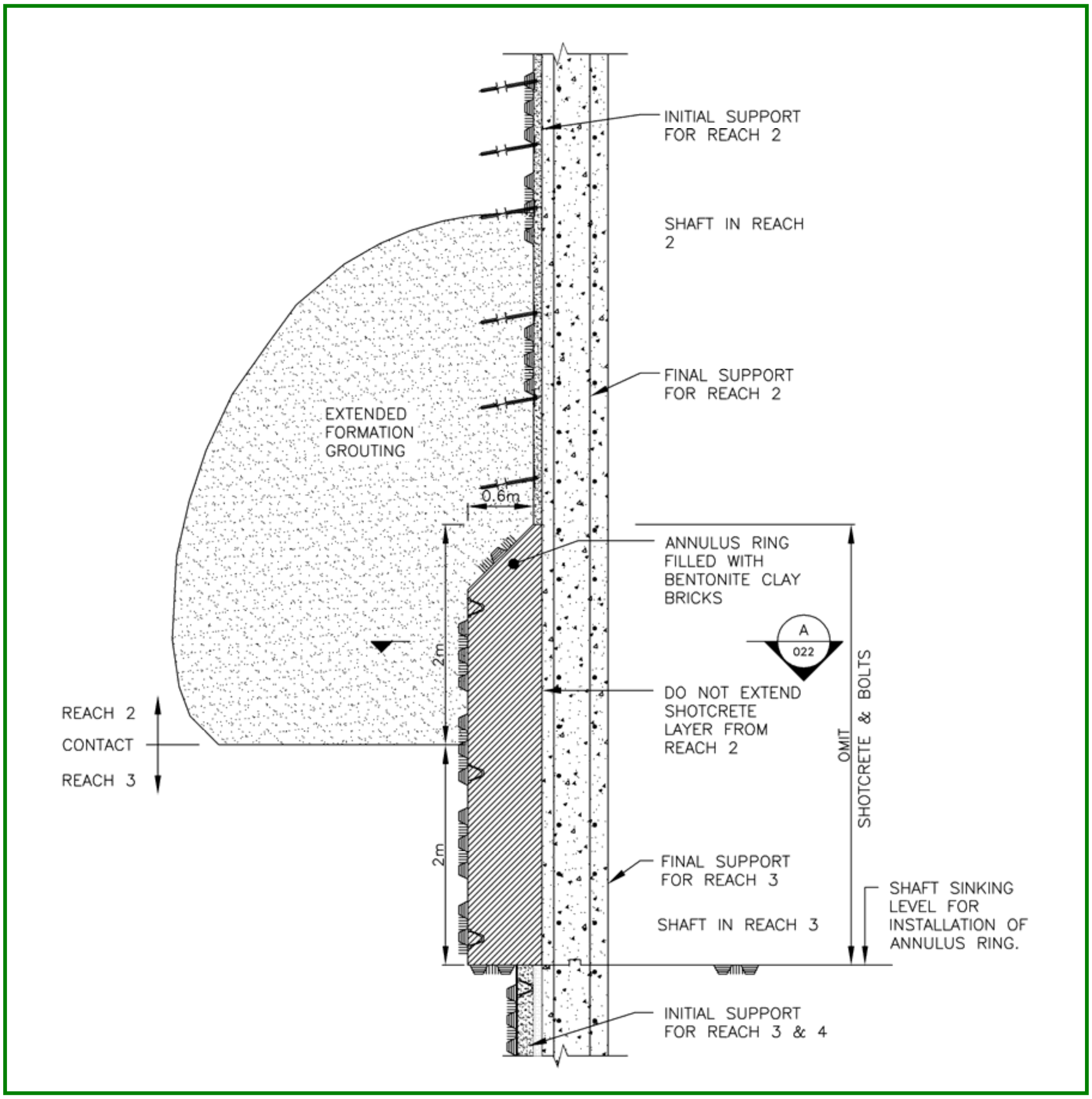


Figure 6-7 – Final Lining and Bentonite Ring Details at Reach 2 / 3 Interface

6.3.2 Reach 3/4: Initial Support

Considering the need to minimise the extent of the EDZ in Reaches 3 and 4 to ensure the integrity of the recommended sealing system, the use of rock dowels will be minimised as their installation can potentially enlarge the EDZ and complicate its removal upon DGR closure and shaft sealing. To permit removal during future sealing and to permit time dependent deformations (swelling) to occur without undue distress to the initial support, TH145x40 expandable/yielding steel ribs developed by Bergbau (see Figure 6-8) vertically spaced at 1.5m will be used in lieu of rock doweling throughout Reach 3 and 4 (See Drawings 323874DGR-200-019 and -020 in Appendix E). A 150mm fibre-reinforced shotcrete layer which completely infills the space between successive steel ribs will provide additional support. Weep holes through the shotcrete and panning between the rock and the shotcrete will be used to prevent groundwater pressure build-up behind the shotcrete.

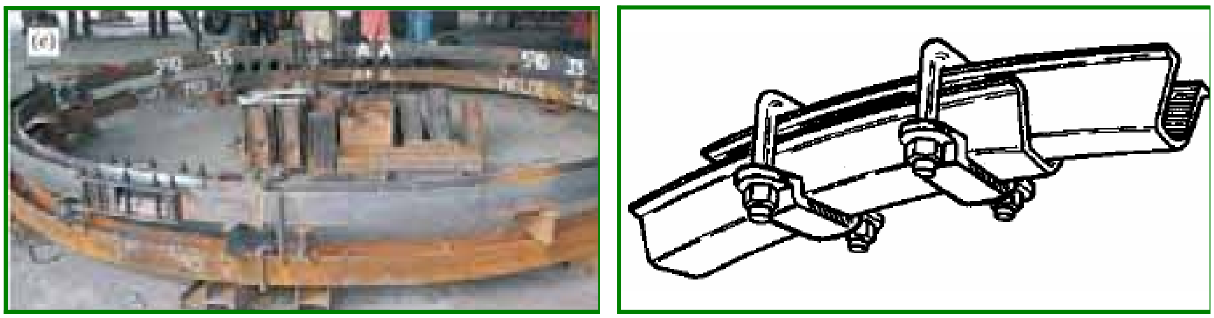


Figure 6-8 – Examples of steel ribs with sliding joints; wide flange (left) and top hat (right)

6.3.3 Reach 3/4: Final Lining

Final support will be provided in a similar fashion to the concrete liner discussed in Reaches 1 and 2 (See Figure 6-7 and Drawing 323874DGR-200-022 in Appendix E). In addition, a 75mm compressible layer consisting of expanded polystyrene foam (see www.plastifab.com) will be installed on the initial support layer and prior to final support concrete throughout Reach 3 (see Figure 6-9). The purpose of this compressible layer is to accommodate convergence of the shale units that exhibit time dependent deformational (swelling) behaviour in the presence of fresh water and stress relief caused by excavation. Alternatively, if predicted swelling pressures are low enough, the shaft lining may be designed to accommodate swelling pressures rather than accommodate swelling deformations.

Rock dowels are not to be used in Reach 3 to facilitate the future removal of final and initial support and the EDZ during post-closure sealing requirements.

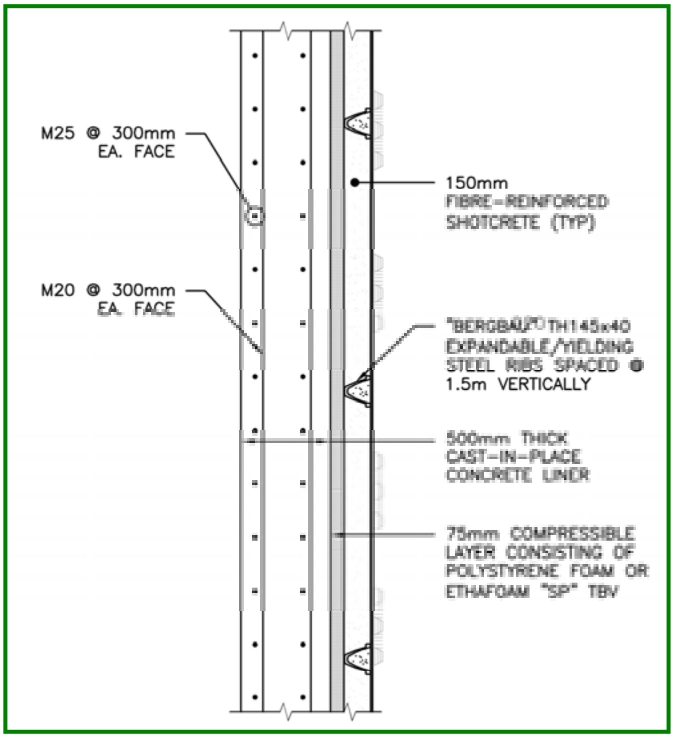
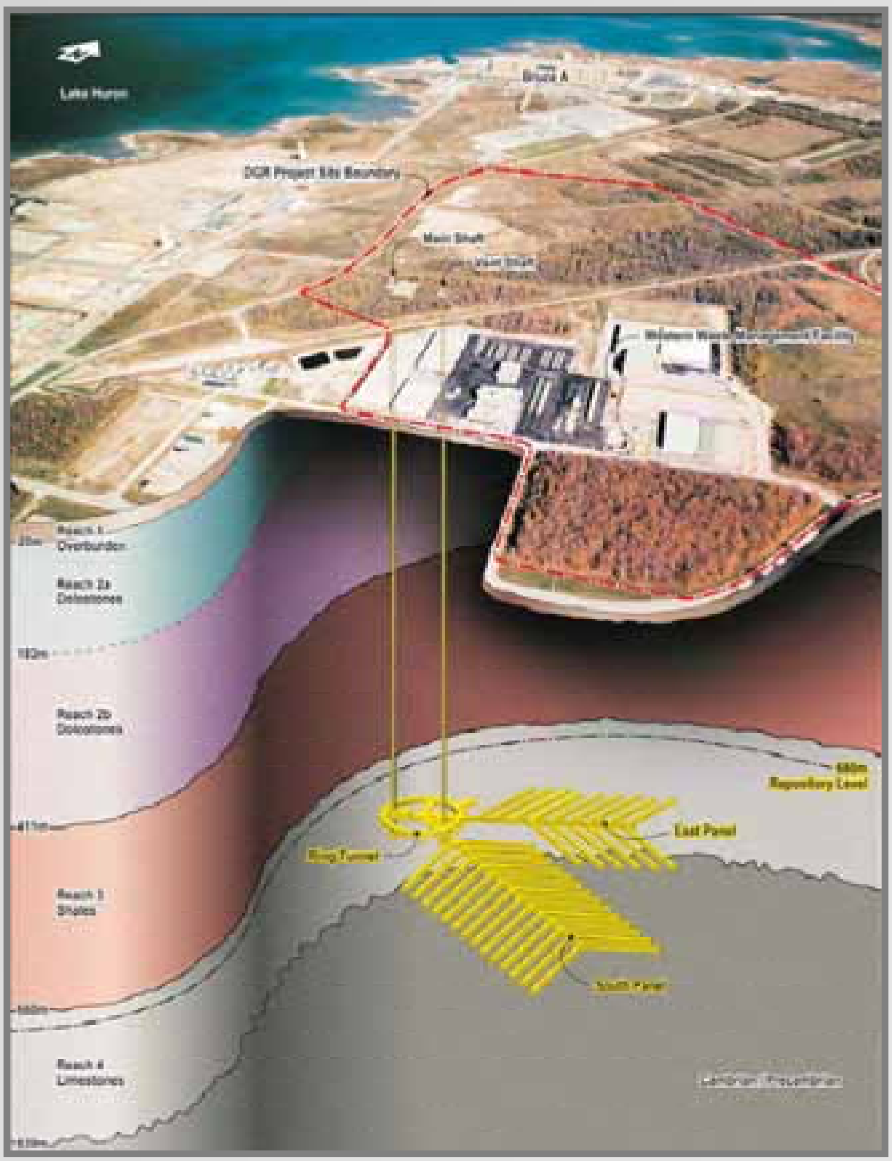


Figure 6-9 – Initial Support and Final Lining Details at Reach 3 / 4

Conceptual Design Report

7. Emplacement Room and Access Tunnel Design and Construction



7. Emplacement Room and Access Tunnels – Geotechnical-Based Design and Construction

The geotechnical-based design of emplacement rooms and access tunnels involved:

1. Establishment of an optimal emplacement room configuration,
2. Recommendation of a preferred emplacement room shape,
3. Assessment of room orientation with respect to in-situ stress field.
4. Establishment of repository depth in consideration of geomechanical strength parameters and in-situ stress levels.
5. Establishment of rock support requirements for the emplacement rooms and access tunnels.
6. Selection of emplacement room and access tunnel excavation method.

This effort involved consideration of:

- The full range of possible geomechanical properties of the Cobourg (Lindsay) formation in which the emplacement rooms and access tunnels for the repository would be constructed.
- The full range of in-situ stress conditions at the repository depth and location.
- An appropriate and consistent level of safety for the design of DGR emplacement rooms and tunnels.
- Functional requirements for waste storage envelopes and room sizing.
- Requirements to achieve a 100 year operating design life for the repository.

7.1 Approach to Optimal Emplacement Room Configuration

In the context of planned geometric layouts for the repository, the following optimisation approach (statement) was adopted to select and optimal room configuration:

Minimise cost of emplacement room construction subject to the following constraints:

- Waste Storage Requirements.
- Access & support facilities.
- Rock mass conditions.
- Full range.
- Expected values.
- Room size requirements.
- Room shape.
- Orientation of in-situ stresses.
- Property lines.
- Achieving the required level of safety.

Key Assumptions:

- Rock support in the roof of the emplacement rooms and tunnels would be required for worker safety and to prevent damage to waste packages prior to DGR closure. Since such roof support requirements will be required regardless of span width, optimal emplacement room span or width is then controlled by functional requirements (waste package stacking) and not geotechnical requirements. This rock support is not considered to provide structural reinforcement to the pillars.

- On the basis of experience and mining practice, it is less expensive and more reliable to utilise a larger unreinforced pillar than to utilise a smaller reinforced pillar. In other words to rely on the strength of the rock rather than to reinforce it. The cost of structurally reinforcing the pillars to reduce their required width (relative to unreinforced pillars) will be significantly more than the cost of increasing pillar width.

For a given emplacement room size (established on the basis of practical and functional requirements), the minimum construction cost is achieved by minimising the size of the pillars between the rooms and hence minimising the length of access tunnels. Correspondingly, the determination of minimum cost for emplacement rooms (excavation and support installation) reduces to determination of the smallest acceptable width for an unreinforced pillar between rooms for the expected rock mass conditions.

Once this width was established for expected rock conditions, the design approach was extended to determine the optimal pillar width over the full range of rock mass conditions. This approach provides a flexible design basis that provides a basis to alter the pillar width in response to different than expected rock mass conditions as they are encountered. Determination of the minimum pillar width, and thus, the optimal room spacing, involved the following tasks:

- Carrying out numerical modeling (short-term stability - 100-year DGR operating life) – of rock mass behaviour (roof and pillar) in response to room excavation for a range of various pillar widths over the full range of rock conditions.
- Selecting of an appropriate level of safety for design.
- Applying the appropriate level of safety to select the minimum required pillar width to generate design curves covering the range of rock mass conditions.

7.1.1 Pillar Spacing – Modelling

This section describes the numerical modeling methodology used to model the rock response to excavation of emplacement rooms at repository depth. Numerical modelling was performed using FLAC version 5.0. The programs are based on explicit finite difference method, specifically developed for modelling geotechnical problems. These programs can simulate the behaviour of media consisting of soil, rock or other materials that may undergo plastic flow when their yield limits are reached. Materials are represented by zones (elements) that are configured in a grid, with each element behaving according to a prescribed linear or nonlinear stress/strain law in response to the applied forces or boundary restraints, with ground water/pore pressure effects included in the model. Explicit discontinuities, as well as distinct structural elements, can be modeled within the grid.

The basis for the modelling work is described in this section and the detailed modelling report entitled *OPG's Deep Geologic Repository for Low & Intermediate Level Waste prepared by Supporting Technical Report - Geomechanical Modelling*, (Hatch Report No. 323874DGR GMR109 Rev0 dated 30 May 2008, OPG Report Number OPG 00216-REP-03902-00005-R00) that forms a supporting report to this CDR [R67].

7.1.1.1 Geotechnical Design Basis – Parameters

Modelling and design parameters were initially selected to bound the range of conditions that may be encountered at the Bruce Site and to provide a reasonable range of expected conditions. Table 7-1, Table 7-2 and Table 7-3 summarise selected design parameters describing the bedding planes, stress conditions, and rock mass properties, respectively.

The initial range of parameters was selected to satisfy three categories, highlighted with tan shading in the tables:

- Least Favourable
- Expected
- Most Favourable

The first and third categories were selected to be the lowest conceivable and highest conceivable rock mass conditions that could be encountered at the site. The values are roughly the lowest and highest values contained in the geomechanics database developed by Lam et al 2007 [R15]. The Rock Mass Rating System (RMR) ([R64]) was used to classify each of the rock mass conditions. The resultant RMR values for each condition were used to estimate equivalent Geologic Strength Index values.

Note that the data used to establish these bounds was obtained from different locations and different depths throughout Ontario. The full range of data, from least to most favourable, should not be interpreted as the statistical range present at the Bruce Site but rather each is a distinct condition that may occur.

Parameter		Least Favourable	Selected Range	Most Favourable
Bedding Joint Parameters	Friction Angle	20	30	40
	Cohesion (MPa)	0	0.3	0.6
	Tensile Strength (MPa)	0	0.3	0.6
	Normal Stiffness K_n (GPa/m)	175	250	325
	Shear Stiffness K_s (GPa/m)	7	10	15
Horizontal Joint spacing (m)		0.3	1	2

Table 7-1 – Bedding Plane Parameters

Parameter	Lower Bound	Expected	Upper Bound
In-situ horizontal pressure coefficient, K_0	1.0	1.5	2.5
In-situ vertical stress, σ_v (MPa) (at repository depth 660-680m below grade)	17.2	17.2	17.2
Unit Weight of Rock (MN/m^3)	0.026	0.026	0.026

Table 7-2 – Rock Stress Conditions

Modelling and design calculations using the least and most favourable cases showed that intermediate parameters were necessary. The least favourable condition produced complete pillar failure, while the most favourable condition produced zero pillar failure. The refined range of parameters, more closely centered on the expected conditions, are shaded light green in Table 7-3. A second phase of modelling and design calculations were performed for these parameters.

In addition to the deterministic values described above, statistical distributions of some parameters were necessary to conduct the factor of safety and reliability studies and the pillar width selection described in Section 1.1.2. The geomechanical parameters requiring statistical distributions were the unconfined compressive strength (UCS) and the Geological Strength Index (GSI).

For each of the UCS values used in the study, a normal distribution established using coefficient of variation (COV) equal to 20 percent was used and for GSI values, a COV of 10 percent was employed (see Table 7-4). The geomechanical properties described in this section were reviewed with the Ontario Power Generation Deep Geologic Repository Geomechanics Review Group (GRG).

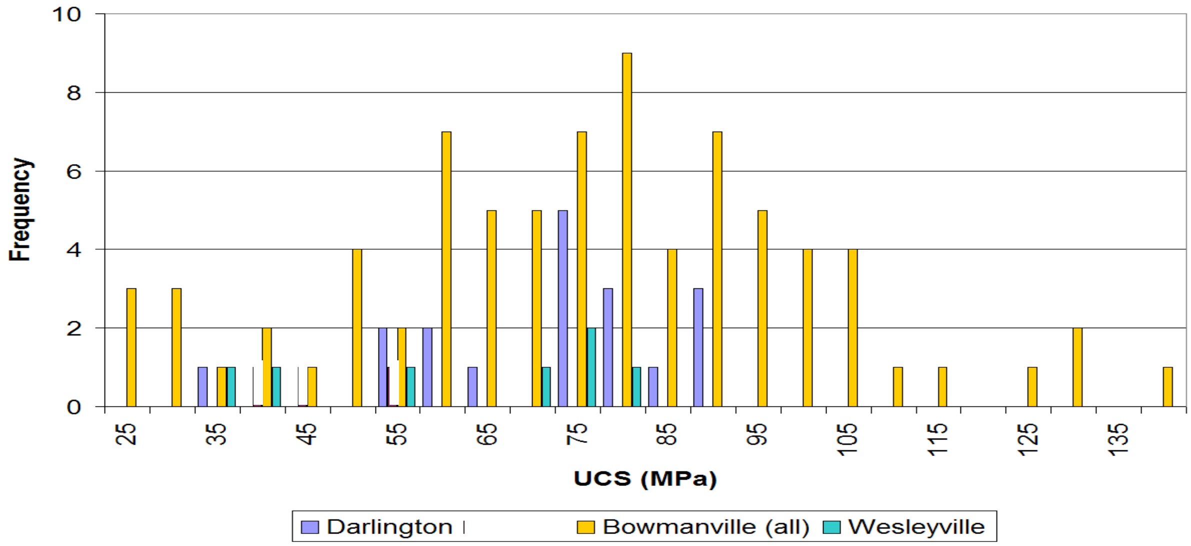


Figure 7-1 – Histogram of UCS Data from Darlington, Bowmanville and Wesleyville

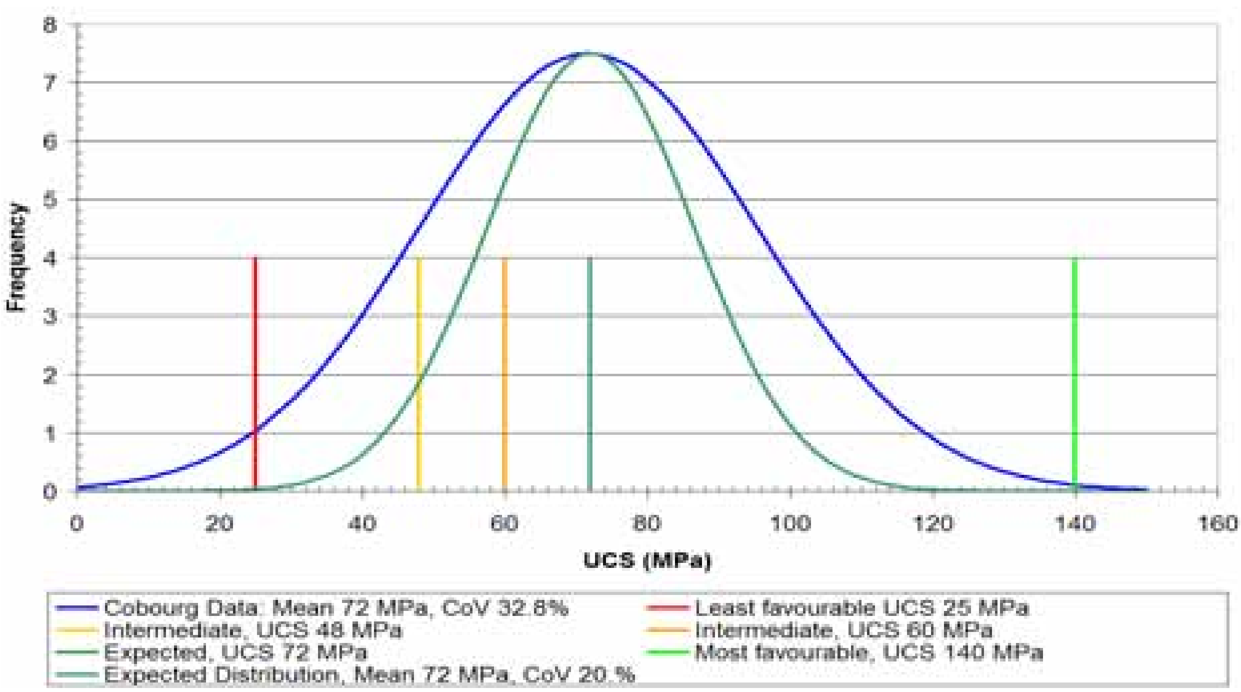


Figure 7-2 – UCS Data Distribution, Parametric Study Values and Expected Distribution

Parameter	Least Favourable	Low End of Selected Range			Middle of Selected Range "Expected" with GSI 69			High End of Selected Range			Most Favourable
UCS intact rock (MPa)	25	48			60			72			140
Rock Quality (Geologic Strength Index, GSI)	66	55	69	80	55	69	80	55	69	80	80
Modulus of elasticity of intact rock (GPa)	16	37	37	37	47	47	47	56	56	56	66
Modulus of elasticity of rock mass (GPa)	10	15	27	33	19	33	41	23	40	49	58
Poisson's ratio	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Hoek-Brown Parameter m_i	9	9	9	9	9	9	9	9	9	9	9
Hoek-Brown Parameter m_b	2.67	1.80	2.97	4.41	1.80	2.97	4.41	1.80	2.97	4.41	4.41
Hoek-Brown Parameter s	0.023	0.007	0.032	0.108	0.007	0.032	0.108	0.007	0.032	0.108	0.108
Hoek-Brown Parameter a	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tested for modelling issues						Yes					
K_o range considered	1.0, 1.5, 2.5	1.5	1.5	1.5	1.5	1.0, 1.5, 2.5	1.5	1.5	1.5	1.5	1.0, 1.5, 2.5

Table 7-3 – Rock Mass Parameters Used in Modelling and Design
(tan – initial range of Least, Expected and Most Favourable; light green – refined range of parameters)

7.1.1.2 Pillar Stability (100 year design life) – Numerical Modelling

For the Pre-closure Case, a range of pillar widths has been considered. The modelling has been carried out for a set of conditions to address the expected range of potential rock properties at the site, which are presented in Table 7-1, Table 7-2 and Table 7-3.

Each case for a particular pillar width and set of geotechnical properties has been analysed. The factors of safety from the numerical analyses, as well as an estimate of the extent of rock damage caused by creating an opening in the highly stressed rock mass were obtained. A sensitivity analysis was, thus, performed to determine the key parameters that have the most significant effect on the pillar requirements.

Two-dimensional modelling of the rib pillars was performed using FLAC version 5.0 using a modified Hoek-Brown failure criterion ([R72]) recognising the brittle behaviour recommended by Martin et al [R66] for low confinement stresses and transitioning to the Hoek-Brown failure line at higher confining stresses (Figure 7-3). The required Hoek-Brown parameters m_b, s, and a (reference is made to [R72] for more details) were obtained from the assumed UCS and GSI values using Rock Lab 1.0 ver.1.031. No post-peak strain softening was incorporated into the modelling.

Various aspects of the modelling tasks were investigated. These included:

- The effect of mesh size on result accuracy and on computing time. A grid element size of 0.25 metres was chosen as the best balance between accuracy and computational time.
- The effect of explicit versus implicit modelling horizontal bedding planes. The results of the analysis demonstrated that by degrading the geotechnical properties used in the model (GSI reduction of 2 to allow for the bedding planes) produced similar results to explicitly modeled bedding planes with considerably less computational effort.
- The effect on numerical analysis results by modeling progressive (incremental) expansion of the facility room-by-room compared with the results obtained by modeling excavation of all rooms concurrently. A single pillar model representing an infinite number of pillars was found to be conservative and was used for simplicity (Figure 7-4).

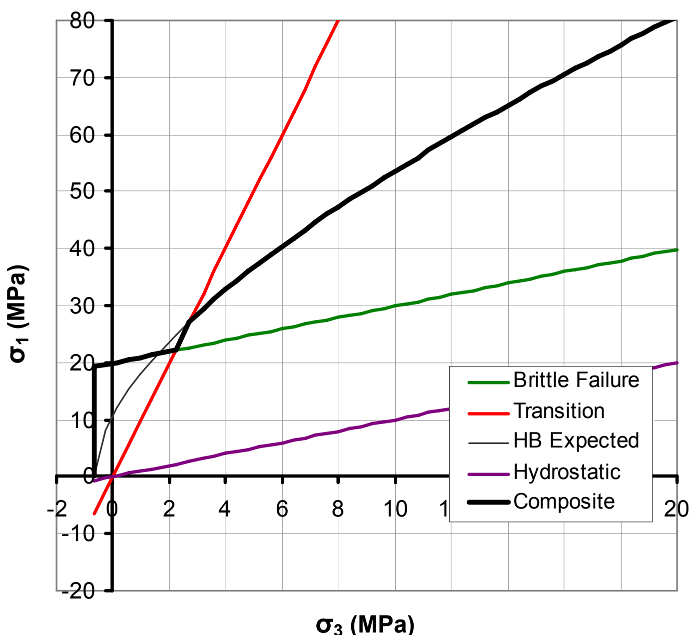


Figure 7-3 – Composite Failure Criteria

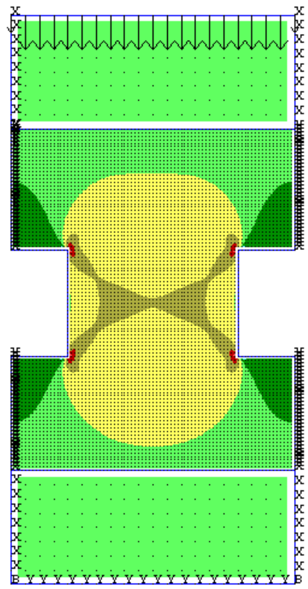
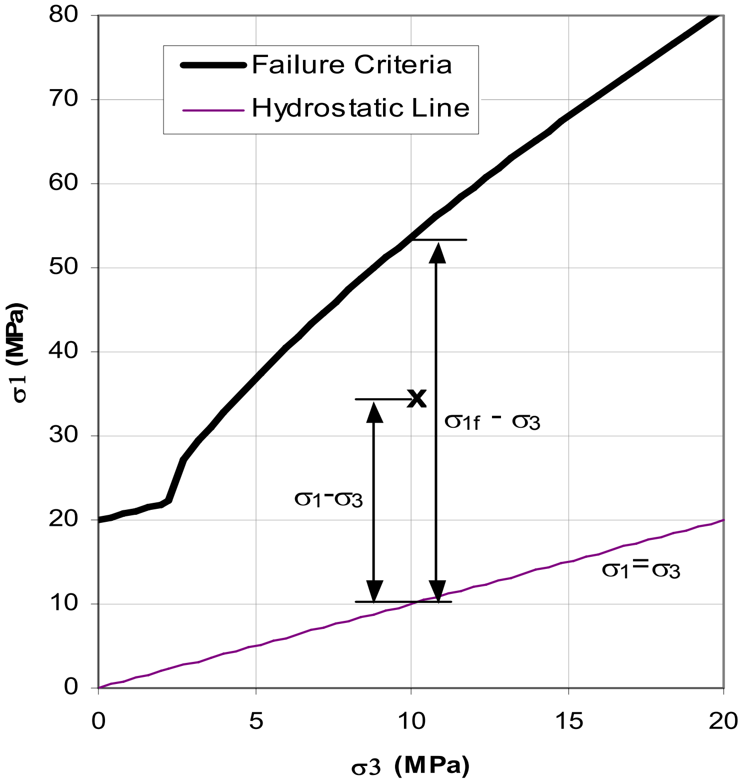


Figure 7-4 – Example of Single Rib Pillar Model Showing Vertical Stresses

Typically, the level of safety (often denoted as a factor of safety) of pillars in mining applications is assessed by comparing pillar capacity determined using empirical relations relative to the average vertical stresses in a pillar calculated on the basis of overburden pressures and pillar tributary widths. While this has served the mining industry well, empirical assessments of pillar capacity are often based on unknown definitions of failure, in-situ stress conditions and rock mass characteristics. Further, average stress levels do not provide an indication of the localized damage that may occur at free surfaces and areas of stress concentration.

To consider these behavioural characteristics, numerical modeling is used as it is capable of calculating the state of stress throughout the entire rock mass (i.e. stress distribution across the pillar) and compares that stress state to constitutive failure criteria at each calculation location. Consequently, the level of stress relative to rock capacity will vary across the pillar.

For each of the geomechanical conditions and for various pillar widths, the stress state across a horizontal section through the pillar (typically at the pillar mid-height) was assessed and used to quantitatively express the level of pillar stability. From each element along the investigated section of the pillar, the stresses were extracted and the individual zone Factor of Safety was assessed as the ratio of the differences between the principal stresses at failure σ_{1f} for the measured σ_3 and the actual differences between the measured principal stresses, as shown in Figure 7-5.



$$FS = \frac{\sigma_{1f} - \sigma_3}{\sigma_1 - \sigma_3}$$

Figure 7-5 – Definition of Numerical Factor of Safety

The results of the 2D single pillar analyses are shown in the full Geotechnical Modelling Report (refer to [R67]). Figure 7-6 shows the results of the analyses for the "least favourable", "expected" and "most favourable" parameters shown on Figure 7-3, presented graphically. As expected, the Numerical Analysis Factor of Safety of a pillar increases with rock strength and the pillar width. Conversely, for the same NAFS the pillar width can be decreased if the rock strength increases.

The effect of higher K_0 values is quite apparent for wider pillars. It is apparent that, as the pillar gets wider, a portion of the high pre-excavation initial horizontal stress remains locked in the pillar and provides lateral confinement for the pillar core. For very large pillars and for K_0 >> 1.0 this locked in stress may lead to a reversal of the principal stresses in the pillar when the horizontal stress becomes larger than the vertical stress, as shown in Figure 7-7, which presents the distribution of factors of safety across a wide pillar showing σ_3 to be orientated horizontally near the edge of the pillar and vertically near the centre of the pillar. For narrower pillars, however, this effect is small.

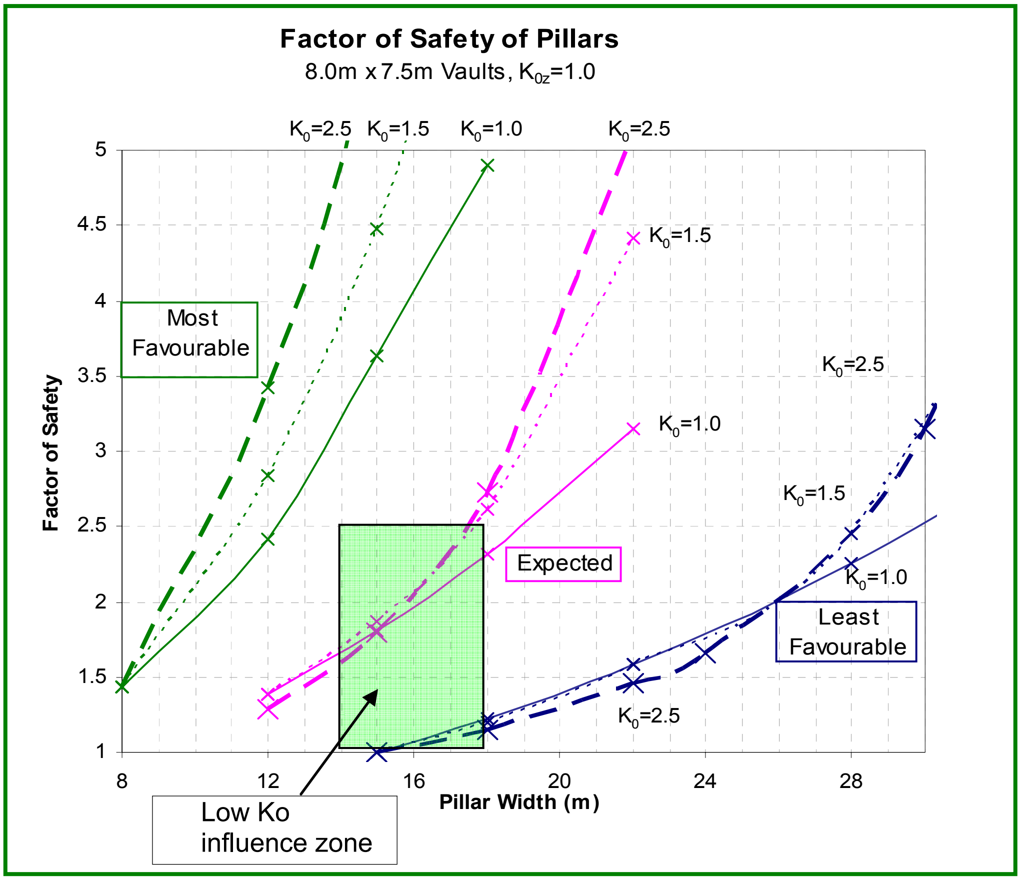


Figure 7-6 – Numerical Analysis Factor of Safety of Pillars for a Wide Range of Rock Properties (7.5m x 8.1m Room Size, K0z = 1.0)

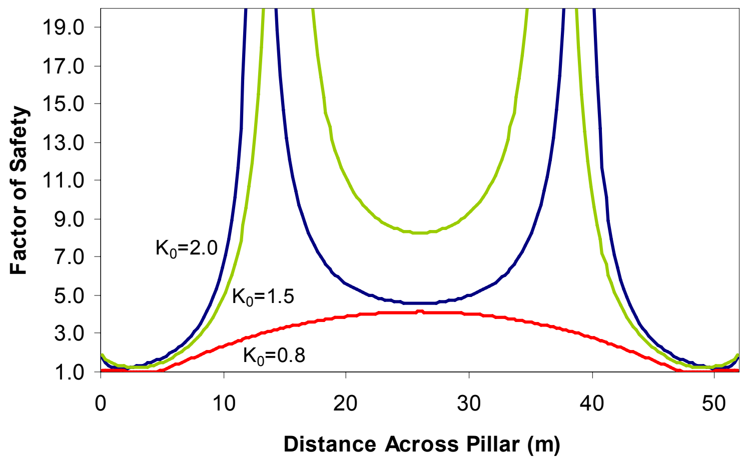


Figure 7-7 – Wide Pillar Local NAFS across a Wide Pillar With Varying K_0

Within the range of pillar widths that can be expected for this facility, the range shown as the shaded area on Figure 7-6, the effect of K_0 on the results is relatively small as indicated by the adjacency of the curves for the various K_0 values within this zone.

For this reason, when the selected narrower range of rock properties was considered as probable on the site, and the large number of analysis cases for the parameters shown on Table 7-3, only K_0 equal to 1.5 was used in the analyses. The results of these analyses are shown below in Figure 7-8.

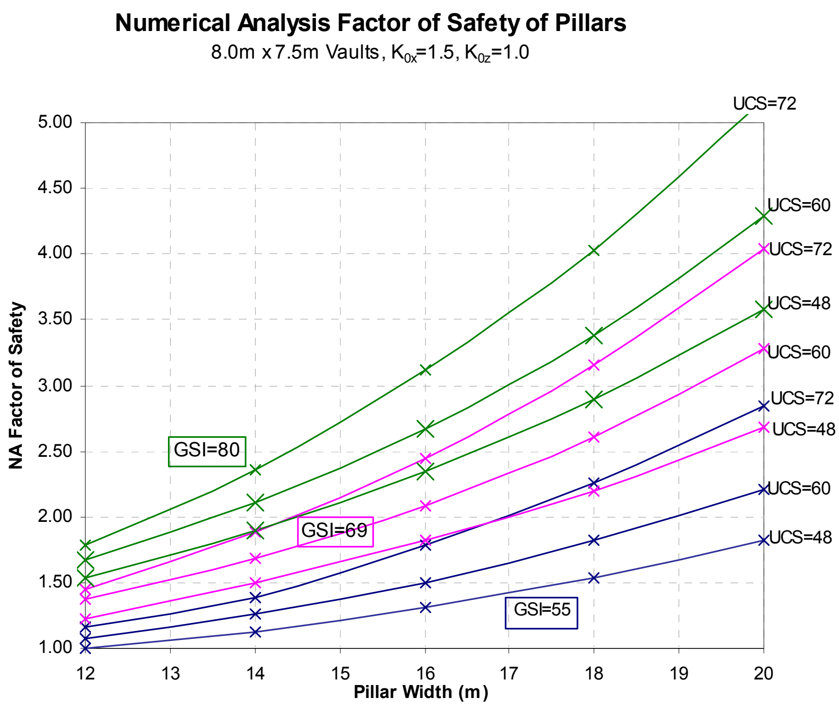


Figure 7-8 – NAFS Results for the Selected Range of Rock Properties

Examples of the typical results for the extent of pillar damage are shown in Figure 7-9. The purple colour identifies the zone of the pillar that is yielding; the green zone identifies the portion that yielded in the past. The pillar damaged zone is a sum of both of these zones. The main conclusion drawn from this analysis was that the depth of the damaged (plastic) zone is inversely proportional to the UCS of the rock and that depth of the damaged zone varies little with changes in the pillar widths.

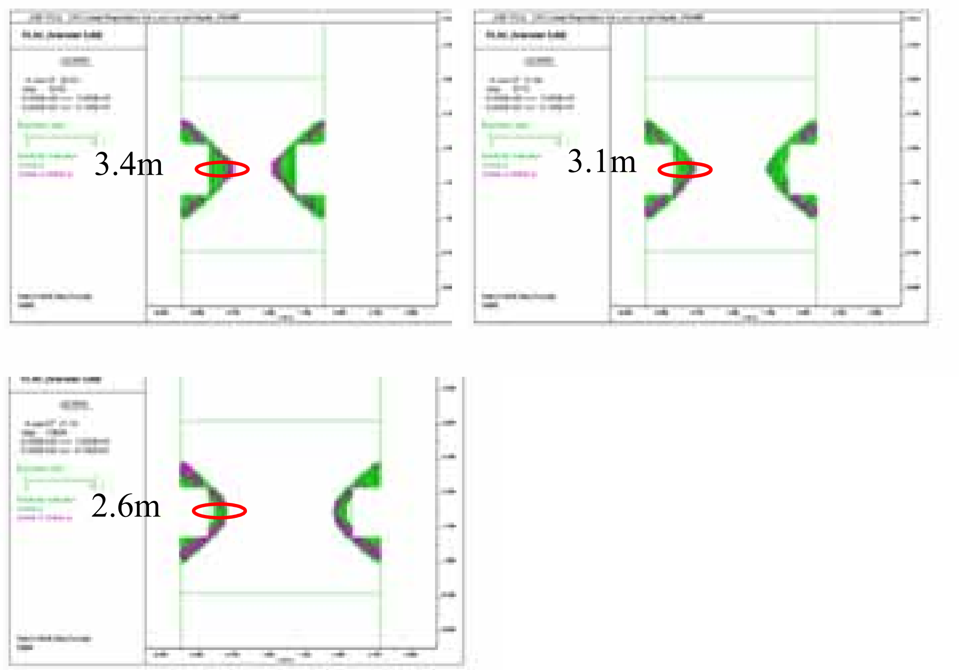


Figure 7-9 – Example of Output Indicating the Depth of Pillar Damage

7.1.2 Selection of Pillar Width

This section describes the development of reliability methods used to estimate the pillar widths necessary for a range of possible Deep Geologic Repository (DGR) rock mass parameters. All estimates are done for emplacement room height of 7.5 m, and emplacement room span of 8.1 m. Two approaches were used, both relying on reliability methods: an empirical design-based method, where the pillar strength is estimated from simple equations containing the pillar and room dimensions, the rock strength and empirical parameters; and a numerical modeling-based method, where the modeling estimates the magnitude of plasticity zones.

Using numerical modeling and a reliability-based approach, pillar width design charts were developed that provide minimum required emplacement room pillar widths with consistent levels of safety over the full range of credible geomechanical conditions for the Cobourg Formation in which the DGR will be located.

7.1.2.1 Level of Safety – Approach

Traditionally, pillar strength in underground facilities has been established on the basis of empirical pillar strength prediction methods and deterministic factors of safety. However, these methods have been developed under mine conditions where functional requirements are significantly different from the DGR. Further, their use has been for operating periods significantly shorter than the 100 year design life of the DGR and do not reflect variability of rock mass quality parameters.

Most modern design methods for structures and geotechnical components utilise reliability concepts. Figure 7-10, taken from ([R69]), illustrates the differences between these approaches. The traditional factor of safety approach considers the load (or demand) and the strength (or capacity) to be single, deterministic values (refer to a). The factor of safety is the ratio of capacity to demand as shown in Figure 7-10 (a).

The capacity and demand of any real-life structure are not single deterministic values, may be difficult to assess and may be correlated. Figure 7-10 (b) and Figure 7-10 (c) illustrate a more general reliability-based approach, where capacity and demand are statistically distributed and the probability of failure can be established on the basis of the probability of both capacity and demand. Once the probability of failure can be established, the impacts of that event relative to the cost to prevent it and available mitigations in the event of it occurring can be evaluated.

The reliability-based methods produce consistent measures of the likelihood of pillar distress levels and are preferred over traditional deterministic factor of safety approaches. Factor of safety methods are found to be inconsistent, in the sense that two pillar designs, with the same factor of safety may have quite different probability of unsatisfactory performance.

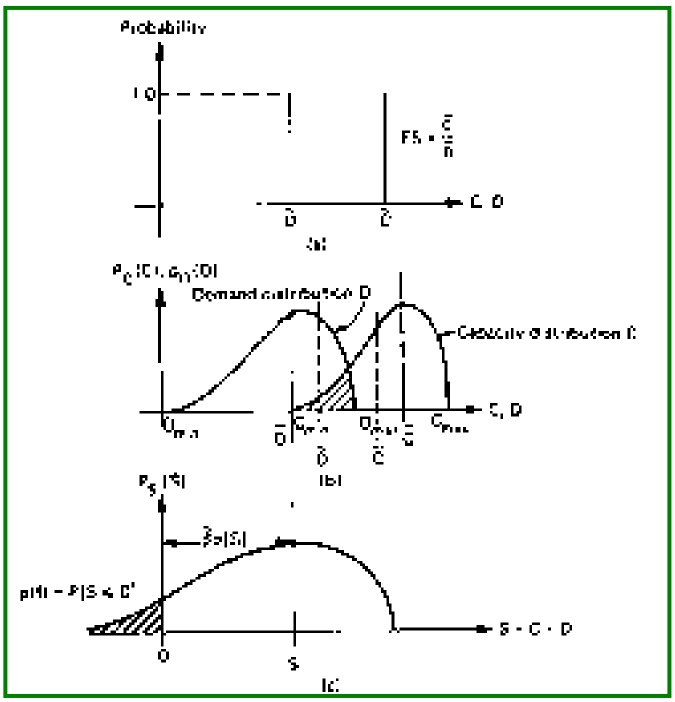


Figure 7-10 – Comparison of Factor of Safety and Reliability

7.1.2.2 Reliability and Expected Cost Approach

Numerical modeling and updated empirical design methods were used to predict pillar damage levels and the probability of damage or unsatisfactory performance for varying pillar widths under the full range of anticipated DGR rock mass and stress conditions. The statistical distributions associated with two key rock mass strength parameters: unconfined compressive strength (UCS) of the intact rock and Geological Strength Index (GSI) for the rock mass provides the probability of a rock mass strength conditions.

Consideration of the modelled rock mass conditions/values relative to the statistical distribution associated with the "expected" (mean) rock mass values was used to establish the probability of occurrence of the pillar damage levels and unsatisfactory performance.

The probability of these damage events was related to the number of repository pillars and the cost of remedial action necessary for each damage level to establish an expected cost for each pillar width. Total costs for each pillar width were determined by combining the expected cost associated with damage levels and the incremental construction costs associated with increasing the pillar width (longer access tunnels, ventilation requirements and repository footprint) relative to the [R3] 12-m wide pillar base case.

The numerical modeling-based method uses modeling results for deterministic rock mass parameters, and generates reliability-based values for the expected cost of remedial measures. For each method, the result is the pillar width required for consistent values of expected incremental cost or probability of unsatisfactory performance. The reliability-based methods produce consistent measures of the likelihood of pillar distress. In comparison, factor of safety methods are inconsistent, in the sense that two pillar designs, with the same factor of safety may have quite different probability of unsatisfactory performance.

7.1.2.2.1 Pillar Behaviour Categories

In underground limestone mining, pillar damage has been categorised into the six conditions illustrated in Figure 7-12. Condition 1 is low stress with no evidence of pillar distress, while Condition 6 is complete loss of capacity (failure), leaving only minor residual strength. In between are four categories with increasing pillar damage. Based on the illustration, these condition categories are for relatively slender pillars. However, the qualitative definitions are applicable to the more squat pillars necessary for the Deep Geologic Repository. Figure 7-13 shows the assumed relationship between the pillar behaviour conditions and the pillar plastic zone categories.

- Pillar condition 1, which is an intact pillar with no indication of stress induced fracturing, is unlikely to occur, and is not used in the DGR scheme.
- Pillar condition 2 has spalling on pillar corners and minor spalling of pillar walls is equivalent to DGR Category A.
- Pillar condition 3, which has more corner spalling and more numerous and continuous wall fracturing, is equivalent to DGR Category B.
- Pillar condition 4, which has open vertical fractures and the start of diagonal fracturing, is equivalent to DGR Category C.
- Pillar condition 5, which has well developed diagonal fractures showing hour-glassing, is equivalent to DGR Category D.
- Pillar condition 6, which has extreme hour-glassing and minimal residual load carrying capacity, is equivalent to DGR Category E.

Pillar behaviour categories were related to the analysis results produced by numerical modeling results (see Figure 7-9) as follows:

- Pillar plastic zone of 0 percent to 10 percent of pillar width—Category A.
- Pillar plastic zone of 10 percent to 28 percent of pillar width—Category B.
- Pillar plastic zone of 28 percent to 50 percent of pillar width—Category C.
- Pillar plastic zone of 50 percent to 78 percent of pillar width—Category D.
- Pillar plastic zone of 78 percent to 100 percent of pillar width—Category E.

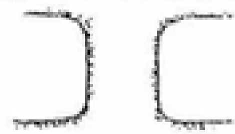
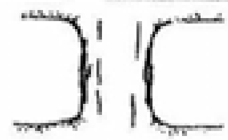
Pillar rating	Pillar Condition	Appearance	DGR Category
1	No indication of stress induced fracturing. Intact pillar.		Not Used
2	Spalling on pillar corners, minor spalling of pillar walls. Fractures oriented sub-prallel to walls and are short relative to pillar height.		A
3	Increased corner spalling. Fractures on pillar walls more numerous and continuous. Fractures oriented sub-parallel to pillar walls and lengths are less than half pillar height.		B
4	Continuous sub-parallel open fractures along pillar walls. Early development of diagonal fractures (start of hourglassing). Fracture lengths are greater than half the pillar height.		C
5	Continuous sub-parallel open fractures along pillar walls. Well developed diagonal fractures (classic hourglassing). Fracture lengths are greater than half the pillar height.		D
6	Failed pillar may have minimal residual load carrying capacity and be providing local support to the stope back. Extreme hourglassing shape or major blocks fallen out.		E

Figure 7-11 – Pillar Condition Rating System for Sedimentary Rock ([R103])

7.1.2.2.2 Review of Numerical Modelling Results

Selection of the preferred pillar width is based on 72 numerical modeling analyses of a single rib pillar in an infinite array of rib pillars. The rock mass parameters used in the analyses produced a range of pillar and roof behaviours. The case of the lowest UCS (48 MPa), lowest GSI (55) and smallest pillar width (12 m) produced complete failure of the pillar, with all pillar zones experiencing plasticity. At the other end of the spectrum, the highest UCS (72 MPa), highest GSI (80) and largest pillar width (20 m) produced small plasticity zones at the upper and lower corner of the pillars.

The metric used to characterize the extent of the plasticity zones was:

$$F(\%) = 100 * \frac{w_{f,left} + w_{f,right}}{w}$$

Equation 7-1

where the numerator is the sum of the width of the plasticity zones at pillar mid-height, and the denominator is the pillar width. Note that the left and right plasticity zones are equal in size, since the model is symmetric about the centerline of the pillar.

Figure 7-12 illustrates the pillar plastic zone size as a function of UCS, GSI and pillar width. The numerical values range from 100 percent for UCS of 48 MPa, GSI of 55 and pillar width of 12 m; to 18 percent for UCS of 72 MPa, GSI of 80 and pillar width of 20 m. Note that the symbols plotted in the figure are plotted with small, random offsets to the left and right in order to improve visibility.

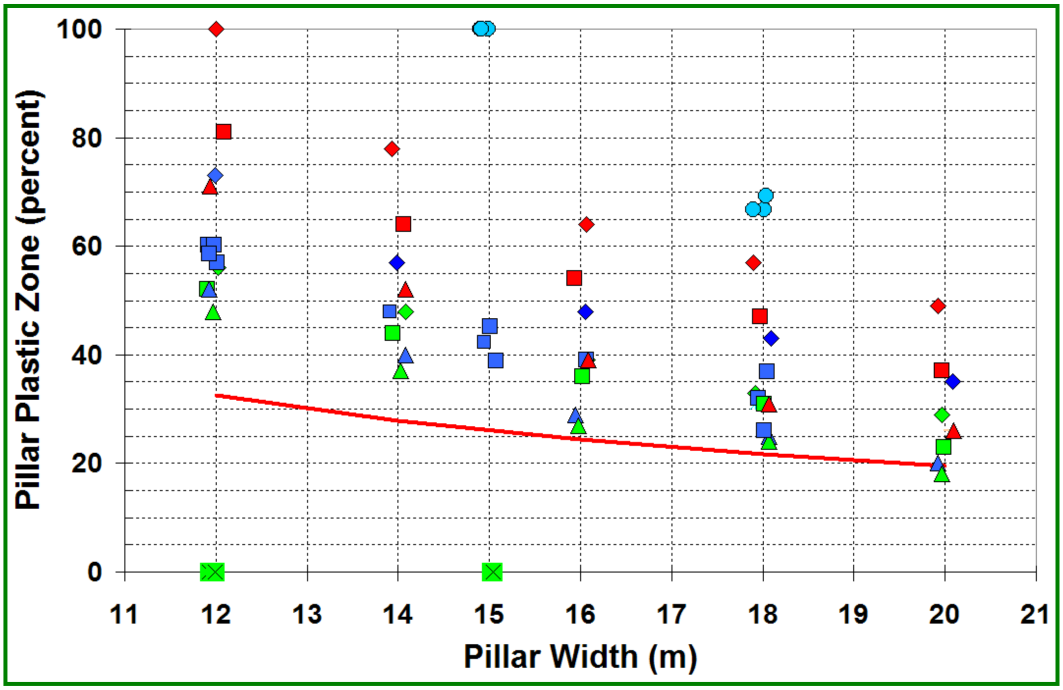


Figure 7-12 – Pillar Plastic Zone as a Function of UCS, GSI and Pillar Width (red=GSI 55, lt. Blue=66, blue=GSI 69, green=GSI 80, circle=25 MPA, diamond=UCAS 48 MPa, square=UCS 60MPA, triangle=UCS 72 MPa, cross=UCS=140 MPa)

7.1.2.2.3 Probability of Damage Category Occurrence for Cases Modeled

The probability of occurrence for each of the 72 modeling cases was determined from assumed normally distributed statistical variations for UCS and GSI. All calculations in this section were conducted for the UCS and GSI values listed in Table 7-4.

Case	Mean UCS	UCS CoV	GSI
1	84 MPa	20 %	Mean 69 CoV 10 %
2	72 MPa	20 %	
3	60 MPa	20 %	
4	48 MPa	20 %	

Table 7-4 – UCS Distributions and Parameters

Probabilities were calculated for each of the 72 rock strength conditions cases modelled. A particular pillar width produces a number of data pairs of the probability of occurrence versus extent of plastic zone. Figure 7-13 shows the data for a 16-m pillar, mean UCS of 72 MPa, and mean GSI of 69, plus the best-fit exponential trend line. Also drawn of the figure are plastic zone category limits and the probability of occurrence within each category.

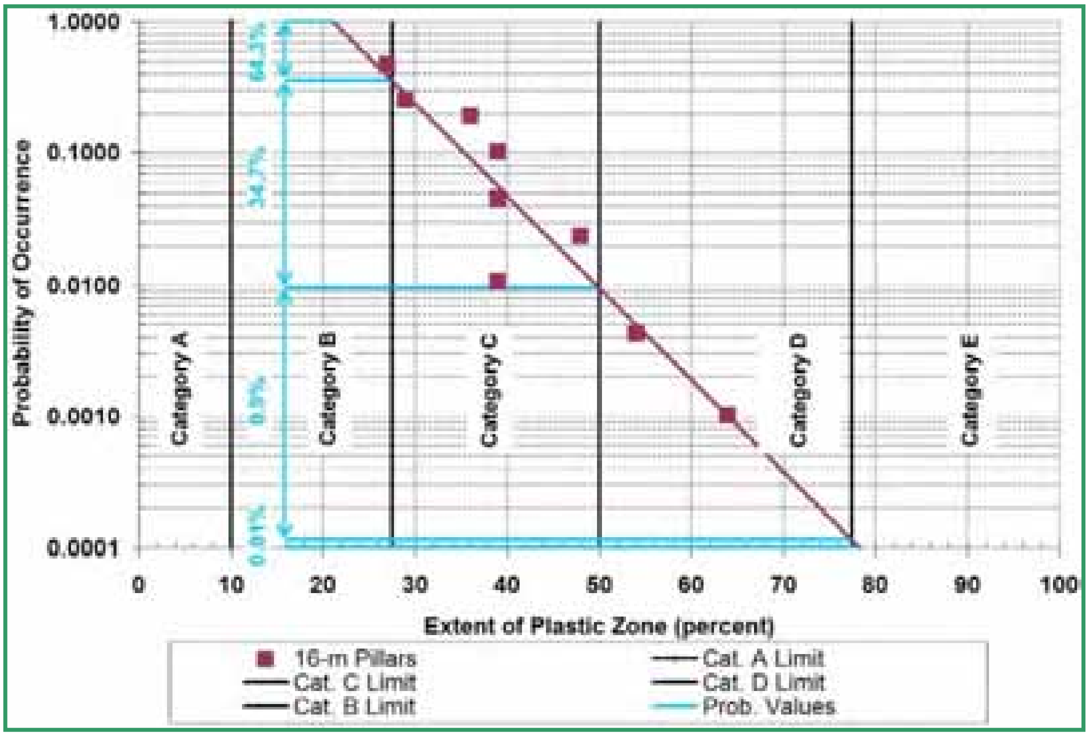


Figure 7-13 – Probability of Damage Event Occurrence for UCS 72 MPa and Pillar Width 16 m (annotations illustrate category limits and associated probabilities)

7.1.2.2.4 Expected Cost

Variations in pillar width affect project costs in two direct ways. Pillar width increases increase the length of the access tunnels that connect the emplacement rooms and increase the repository footprint. Conversely, decreasing pillar size increases the plastic zone size and increases the remedial measures necessary to maintain safe working conditions. In this assessment, all costs are for the Base Case plus Potential Expansion Case repository development, and the preferred geometric layout illustrated in Figure 7-14.

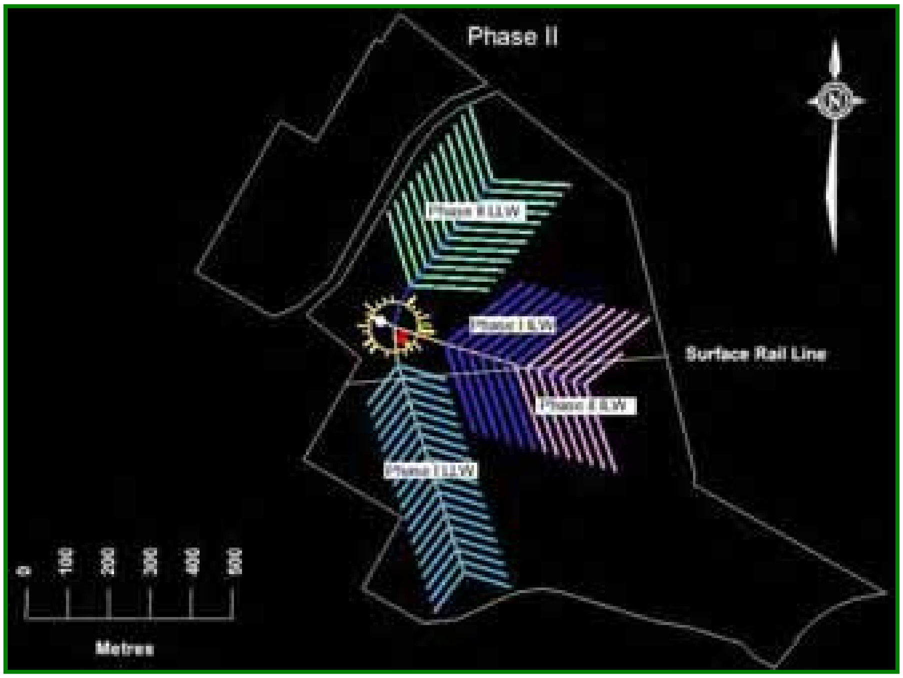


Figure 7-14 – Repository Layout used for the Expected Cost Approach

7.1.2.2.5 Marginal Cost of Access Tunnel Length Increases

As noted, widened pillars between emplacement rooms increase the length of access tunnels and the repository footprint. The unit costs used for estimating these increases include: $500 per m^3 for excavation, ground support and floor; $100 per m^3 for the cost of additional ventilation, power and infrastructure along the access tunnels; and $25,000 per acre for additional repository footprint. Due to the chevron arrangement, with emplacement rooms inclined at 37.5 degrees to the access tunnel, each 2-m increase in pillar width requires 2.52 m longer access tunnel. The access tunnels are 39 m^2 per m in cross section. The Phase 1 plus Phase 2 layout has 41 pillars, so the increase length is about 105 m. Hence, the increase cost for 2-m wider pillars is $2,050,000 for longer access tunnels, $200,000 for additional repository size and $410,000 for additional ventilation, etc. The total cost increase for each 2-m increase in pillar width is $2,660,000.

7.1.2.2.6 Remedial Pillar Costs

The cost of remedial measures increases as the pillar width decreases, and is in addition to the base cost of excavation and ground support. Table 7-5 lists the pillar behaviour category, the cost of remedial action and a description of the remedial action. Costs are based on the following unit prices: excavation $400 per m^3, backfill $300 per m^3, thru rock bolts $1,000 each, rock dowels $200 each and shotcrete $400 per m^3. Costs are also based on an average pillar length of 190 m—actual pillar lengths vary from about 120 m to about 220 m.

Pillar Behaviour Category	Extent of Plasticity	Cost of Remedial Action	Description of Remedial Action
E	78-100%	$16,159,500	Abandon room & backfill
D	50-78%	$1,006,680	Full pattern through bolts & shotcrete both rooms
C	28-50%	$101,333	Additional spot dowels & spot wall shotcrete
B	10-28%	$10,000	Monitor pillar behaviour
A	0-10%	$0	Do nothing

Table 7-5 – Description and Cost of Remedial Action for Each Pillar Behaviour Category

The expected incremental cost chart was constructed by calculating the expected cost for each modeled case (event) relative to the number of expected occurrences as summarised in Table 7-6.

Description	Category E	Category D	Category C	Category B	Category A
Probability, Category Lower Limit	0.011%	0.950%	35.65%	100.0%	100.00%
Probability within Category	0.011%	0.939%	34.70%	64.34%	0.00%
Fractional Number of Events	0.01	0.77	28.46	52.76	0.00
Expected Cost per Event	$16,159k	$1,007k	$101k	$10k	$0
Expected Cost	$150k	$775k	$2,884k	$528k	$0

Table 7-6 – Remedial Pillar Costs for UCS 72 MPa

The remedial pillar costs are plotted in Figure 7-15. Costs range from about $1.25 million for UCS mean of 72 and 22 m pillars, to about $141 million for UCS mean of 48 and 12 m pillars. Starting at pillar widths of 20 m, the expected costs increase by factors of about two to four for each 2-m decrease in pillar width.

7.1.2.2.7 Total Cost

As noted, remedial pillar costs decrease with increased pillar width, while marginal access tunnel costs increase with increased pillar width. Hence, the preferred pillar width may be selected at the minimum cost. Table 7-7 lists, and Figure 7-16 plots the remedial pillar costs, marginal access tunnel costs, and the sum, labelled a Total Cost. Minimum costs occur at 16 m for mean UCS 84 MPa, 16 m for mean UCS 72 MPa, 18 m for mean UCS 60 MPa and 20 m (or above) for mean UCS 48 MPa. These are the preferred pillar widths, based on the modeling results and expected cost basis.

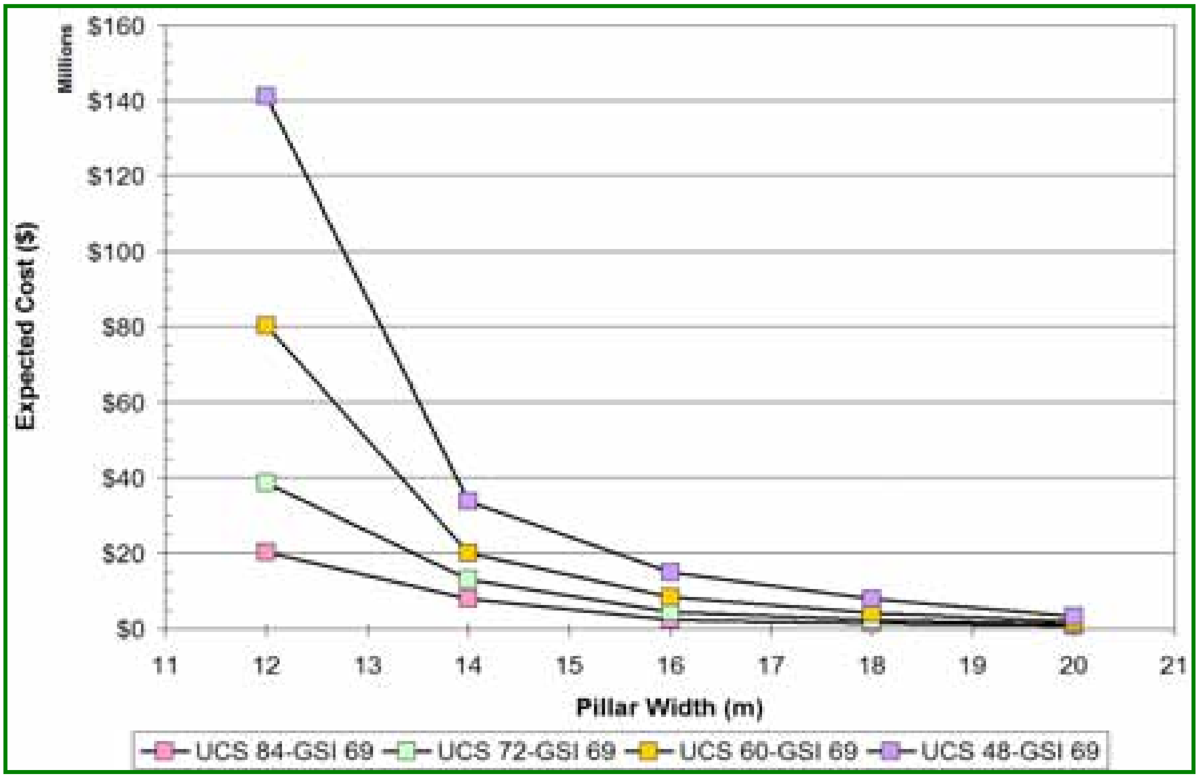


Figure 7-15 – Expected Cost of Remedial Actions as a Function of Pillar Width

UCS (MPa)	GSI	Pillar Width (m)	Remedial Pillar Cost	Marginal Cost of Longer Access Tunnels	Total Cost
84	69	12	$20,230,000	$0	$20,230,000
	69	14	$8,010,000	$2,660,000	$10,670,000
	69	16	$2,310,000	$5,320,000	$7,630,000
	69	18	$1,410,000	$7,980,000	$9,390,000
	69	20	$770,000	$10,640,000	$11,410,000
72	69	12	$38,620,000	$0	$38,620,000
	69	14	$12,910,000	$2,660,000	$15,570,000
	69	16	$4,340,000	$5,320,000	$9,660,000
	69	18	$2,300,000	$7,980,000	$10,280,000
	69	20	$1,250,000	$10,640,000	$11,890,000
60	69	12	$80,140,000	$0	$80,140,000
	69	14	$19,970,000	$2,660,000	$22,630,000
	69	16	$8,440,000	$5,320,000	$13,760,000
	69	18	$4,300,000	$7,980,000	$12,280,000
	69	20	$1,910,000	$10,640,000	$12,550,000
48	69	12	$141,080,000	$0	$141,080,000
	69	14	$33,680,000	$2,660,000	$36,340,000
	69	16	$14,880,000	$5,320,000	$20,200,000
	69	18	$7,950,000	$7,980,000	$15,930,000
	69	20	$3,310,000	$10,640,000	$13,950,000

Table 7-7 – Remedial Pillar Cost, Marginal Access Cost and Total Cost

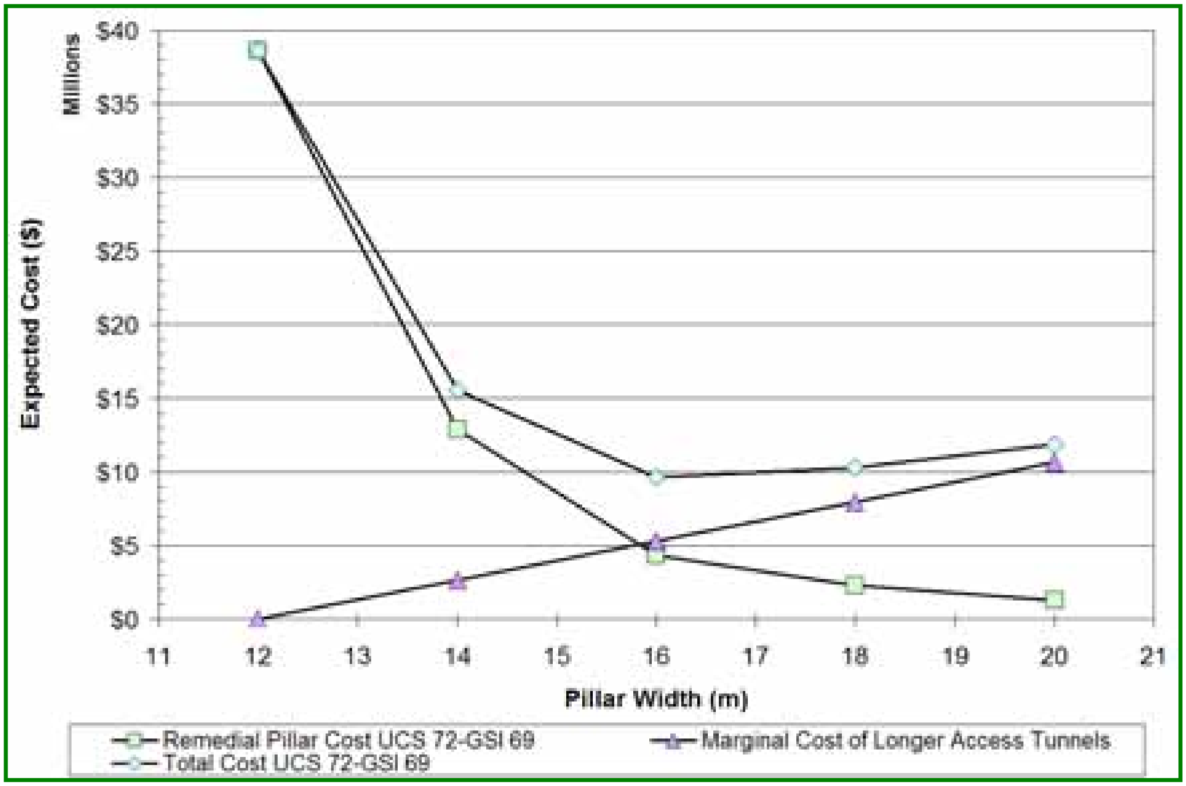


Figure 7-16 – Remedial Pillar Cost, Marginal Access Tunnel and Total Cost – UCS- 72 MPa

7.1.3 Preferred Pillar Width

On the basis of the foregoing sections, it can be seen that, for the expected rock-mass conditions, 16 metre wide pillars are preferred between 8.1 metre wide emplacement rooms. This represents a pillar width which is nominally twice the room span. Correspondingly, a pillar width equal to twice the room width was utilised throughout the development of emplacement room layouts whenever functional room requirements and room size optimisation required a change to room spans. On this basis, a pillar width of 17.2 metres is recommended for the 8.6 metre wide South Panel rooms.

The approach described above was employed using empirical pillar strength prediction methods to extend the modeling-based preferred pillar width to a broader range of rock mass conditions than those considered in the numerical modeling. The resulting acceptable pillar widths versus rock mass conditions are listed in Table 7-8 and plotted in Figure 7-17.

Mean UCS (MPa)	Mean GSI	Pillar Width (m)
25	55	65.0
48	55	32.2
60	55	25.7
72	55	21.4
84	55	18.3
140	55	11.6
25	69	47.3
48	69	23.7
60	69	19.0
72	69	16.0
84	69	13.8
140	69	9.0
25	80	35.3
48	80	18.2
60	80	15.0
72	80	12.7
84	80	11.0
140	80	7.2

Table 7-8 – Pillar Widths for Various UCS and GSI Values

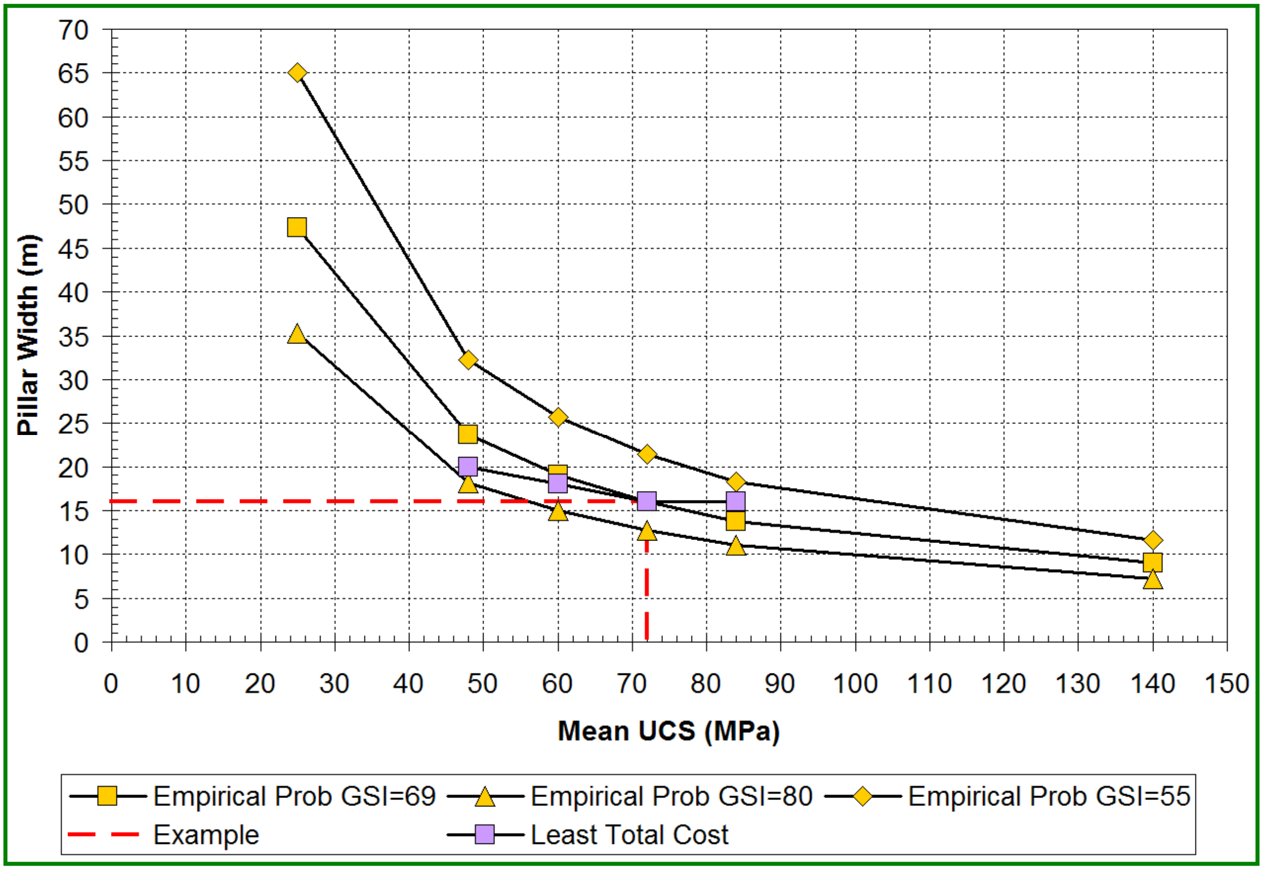


Figure 7-17 – Preferred Pillar Width of 16m for 8.1m Wide Rooms Various Mean UCS and Mean GSI

7.1.4 Impacts of DGR-2 Investigations on Preferred Pillar Width

As stated previously, the recent preliminary geomechanical testing results from DGR-2 for the Cobourg indicate that the design basis of UCS strengths from the literature search desk study is prudently conservative.

The current results bode well for conditions at repository depth relative to those used herein. Once confirmed by future investigations and monitoring during construction, refinement of the pillar width design criteria of twice the room width and the depth location of the repository may be possible.

7.2 Preferred Room Shape

The preferred emplacement room shape depends upon functional requirements for waste storage, constructability considerations and geomechanics. Weighting these often-competing considerations is necessary to achieve the optimum room shape. Rectangular rooms provide the greatest usable volume for waste storage, since most waste packages and corresponding stacking arrangements are also rectangular.

Constructability and geomechanics considerations are closely related. The principal geomechanics factors that control room shape are:

1. The in-situ stress regime.

2. The character of the horizontal bedding of the host rock.
3. The character of rock jointing, which is typically sub vertical.

Sedimentary rocks span the continuum from massive, where bedding planes, if present do not significantly affect the rock mass behaviour to strongly bedded, where the bedding planes are persistent and significantly weaker than the adjacent rock layers. General experience is that excavations in massive rocks may be in any shape appropriate for the stress regime, jointing and the excavation function. Excavations in strongly bedded rocks are nearly always rectangular with the roof following a persistent bedding plane. If persistent bedding planes are present in the roof, ground control elements act to build thicker beams (like a linear arch) to span the room.

Excavation experience in the Cobourg (Lindsay) formation is limited. The OPG projects at the Darlington Intake Tunnel and the Wesleyville Access Tunnel provide some guidance. The Darlington Intake Tunnel is illustrated in Figure 7-18. The photograph shows that the tunnel has an arched roof, the formatting bedding evident in the tunnel sidewall, but the rock appears to be relatively massive.

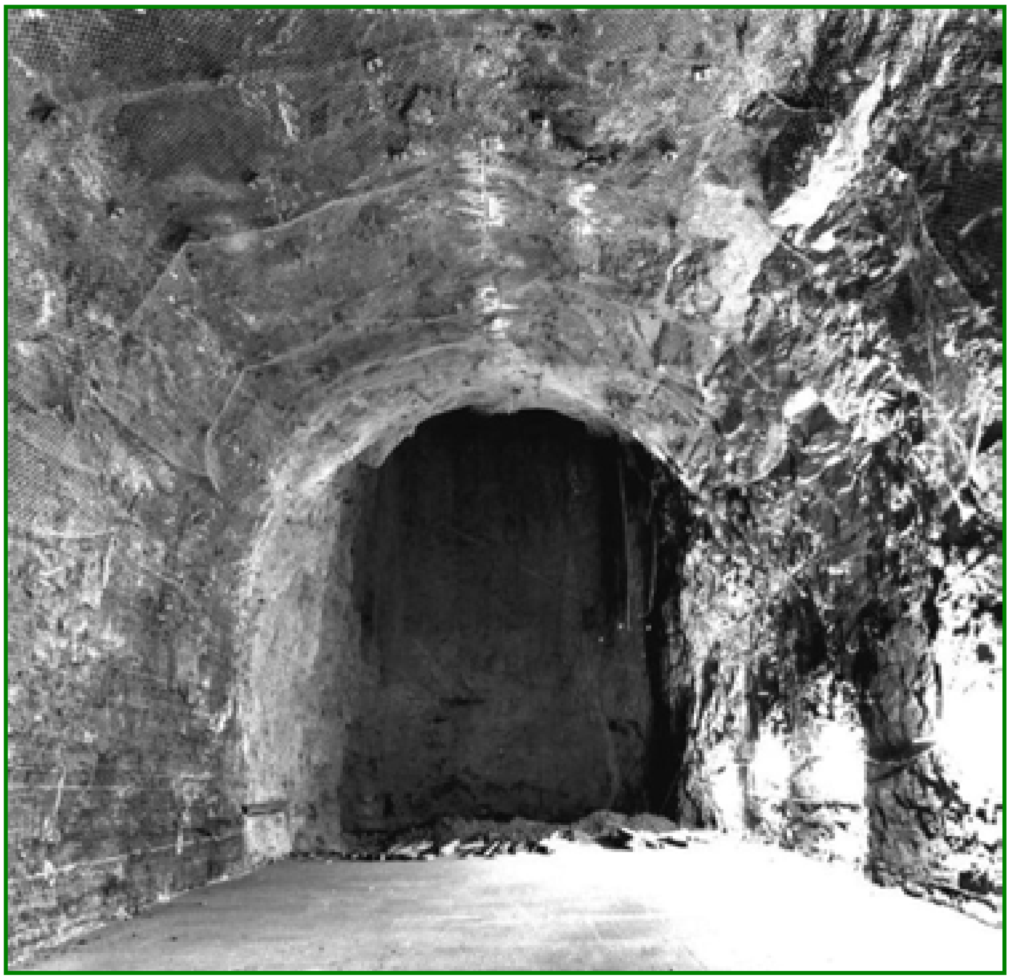


Figure 7-18 – Darlington Intake Tunnel

In comparison, the Wesleyville Access Tunnel is shown in Figure 7-19. The photograph shows a tunnel with a flat roof with a series of rock beams exposed. Formation bedding is evident in sidewall and roof, and overall, the rock appears to be bedded and blocky.

Significant ground control problems may arise if the wrong roof shape is selected. In strongly bedded rock, an arched roof creates ground control problems because the roof arch cuts off the linear arches. This condition is illustrated in Figure 7-20, where a large rock wedge is formed by the excavation roof, a bedding plane above and a vertical joint to the left. Such wedges are thin near the room centerline and may be difficult to support. In massive rock, an arched roof is preferred in order to create a reinforced roof arch. A flat roof leaves in place more rock, requiring longer rock dowels to form the arch.

Emplacement room walls should be vertical, because of the sub-vertical joints commonly present in bedded sedimentary rock. Figure 7-21 illustrates a ground control problem in the upper part of a curved pillar, where a sub-vertical joint has created a rock block requiring rock doweling.

Because rectangular rooms are more efficient for waste storage and the anticipated bedding planes for the Cobourg Formation at the repository level are likely to be sub-horizontal, the preferred room shape is rectangular.

The room shape preference should be revisited in subsequent design phases when additional geomechanics data is available. The final decision may be made during construction after the initial shaft and access tunnels are completed.

Figure 7-19 – Wesleyville Access Tunnel

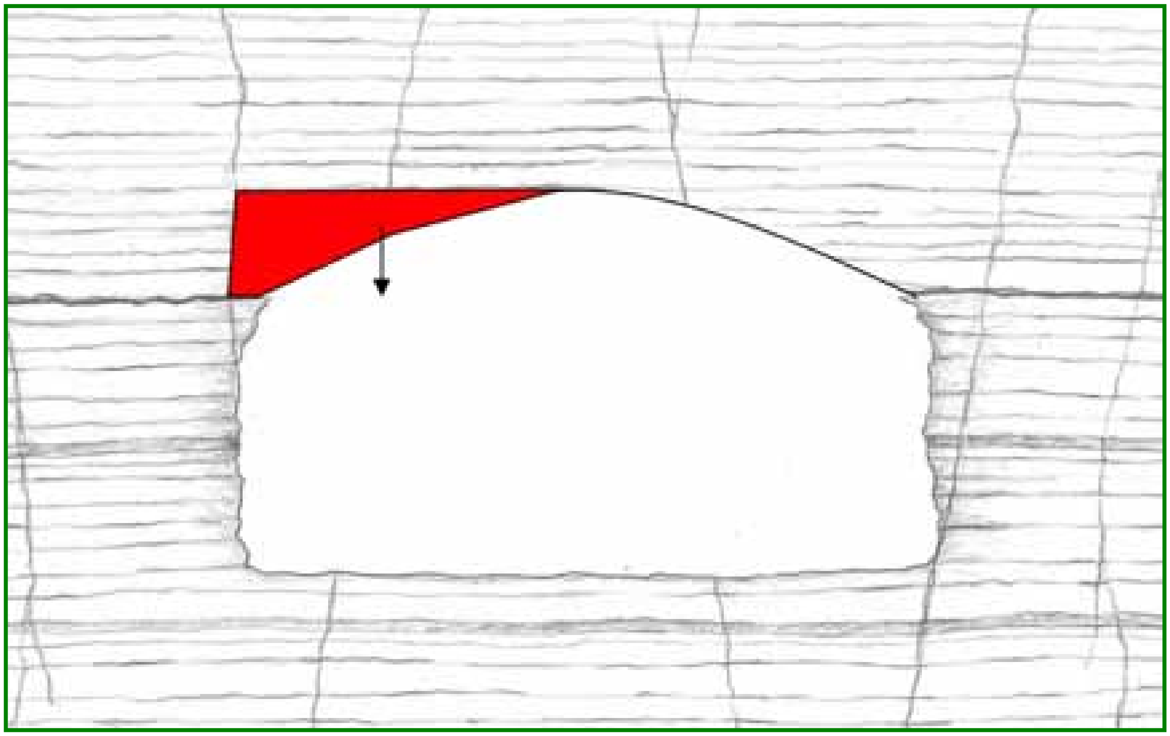


Figure 7-20 – Arched Roof Behaviour in Strongly Bedded Rock

Figure 7-21 – Pillar Ground Control Problems Resulting from Curved Pillars

7.3 Room Orientation

Numerical modelling has established that the magnitude of K_0, within the tested range of 1.0 to 2.5, does not have a significant impact on the factor of safety for the range of pillar widths considered for the DGR. The shaded area in Figure 7-6 shows that within this zone, there is a low influence on the factor of safety due to varying K_0 values when least favourable and expected geotechnical parameters are considered.

Research of the available data from previous testing in the Cobourg stratum ([R15]) established that σ_H ranges from 1.5 to 2.5, σ_h ranges from 1.0 to 1.5, with the ratio of σ_H to σ_h of approximately 1.5. This data illustrates that changing the relevant horizontal stress from σ_H to σ_h would maintain K_0 within the zone of low influence.

Normally, the orientation of the rooms relative to the principle stresses would influence the stability of the roof. As noted above, the influence in this case will be small. Further, considering the roof will be supported for operational safety, the orientation will not be a governing factor in roof design.

Therefore, in general, the orientation of the rooms relative to the principle stresses does not have a significant influence on the overall stability of the rooms. Therefore, there are no constraints on the orientation of the emplacement rooms in the repository layout.

7.4 Determination of Required Repository Depth

It is planned that the DGR be located in the limestone formations beneath the Reach 3 shale formations (Queenston, Georgian Bay and Collingwood). Based upon the results of the DGR-2 borehole investigation, the base of these units is considered to be at 659.5 mbgs. Beneath these formations lie the Cobourg and Sherman Fall formations. Also from the results of DGR-2 borehole, the Cobourg formation is now considered to be nominally 27 m thick and, based on geomechanical testing results on intact rock specimens from DGR2 borehole, is of significantly higher strength than the underlying Sherman Fall formation.

Numerical modeling performed as part of this design effort analysed the response of the host rock formation (Cobourg) to excavation of emplacement rooms in a rib and pillar concept. The modeling results were used in reliability based design approach to establish the minimum pillar width that would provide a safe design over the anticipated 100 year service life of the repository. That modeling was primarily based on desk study results and interpretations of rock mass conditions likely to occur at repository depth at the Bruce Site.

Due to the depth of the repository, differences in vertical and horizontal rock stresses in the vicinity of the repository horizon (one- to two- room heights above and below) are relatively small and hence the height stress redistribution above both the roof and invert of the emplacement rooms are expected to be quite similar but do result in over-stressing of the rock in both areas.

Due to gravity effects, the effects of over-stressing will be more pronounced in the roof than the invert. Rock support will be required in the roof and a reinforced concrete slab is planned for the invert. Gravity effects will reduce the risk of invert buckling which will vary depending upon stress levels, bedding plane thickness and rock strength to be encountered in each room.

On this basis, it is felt that within the finite depth of the host rock (Cobourg formation), a zone of similar strength and thickness should be provided for both the roof and invert, with a smaller zone for the invert. In other words, from a geomechanical perspective and to achieve a 100 year design life expectation, locating the repository approximately mid-height within the Cobourg formation but with a bias towards providing a greater cover over the crown of the rooms to account for gravity effects and to provide a zone of over-head rock support consisting of rock dowels.

To identify the most appropriate horizon where the modelled conditions would exist, a review of the recent testing results and core sampling from DGR-2 was performed. Examination of relevant UCS results from the recent DGR-2 borehole investigation at the Bruce site in the limestone formations (see Table 7-9) at repository depth show a zone of higher strength rock (Cobourg formation) overlying a lower strength rock (Sherman Fall formation).

Specimen		Uniaxial Compressive Strength	Peak Strain	E	Poisson's Ratio	Crack Damage Stress	Crack Initiation Stress	Rock Unit
Test	Depth							
(No)	(m)	(MPa)	(%)	(GPa)	(v)	(σ_s=MPa)	(σ_d=MPa)	
29	654.97	144.83	0.49	36.18	0.21	109.60	45.09	Collingwood
30	655.32	58.32	0.42	22.64	0.05	48.60	27.37	
31	660.68	128.99	0.32	47.46	0.20	125.26	75.00	Cobourg
32	661.61	165.59	0.42	42.47	0.24	161.78	74.44	
33	666.79	110.60	0.31	39.99	0.20	N/A	53.08	
34	668.46	84.23	0.36	34.22	0.26	44.88	34.99	
35	673.26	78.40	0.37	27.79	0.12	55.63	28.23	
36	674.11	111.86	0.39	38.49	0.13	N/A	46.18	
37	676.45	121.06	0.32	43.34	0.15	116.51	49.53	
38	679.83	108.74	0.41	33.45	0.25	105.02	55.95	
39	683.02	94.49	0.38	30.37	0.24	84.63	43.49	
40	688.22	31.98	0.61	4.79	0.03	30.63	13.80	Sherman Fall
41	694.11	39.54	0.40	16.70	0.13	13.79	2.25	
42	695.15	67.32	0.28	36.76	0.47	49.04	16.92	
43	702.69	58.21	0.40	20.63	N/A	N/A	N/A	

Note: "Ultimate Uniaxial Strength" is equivalent to UCS

Table 7-9 – Relevant DGR-2 Geomechanical Testing Results ([R10])

It is evident that UCS tests performed on intact core specimens exhibit strong (R4) to very strong (R5) strength behaviour (following ISRM Rock Strength Classification Guidelines [R104]). This information bodes well for conditions at repository depth relative to those assumed to establish the pillar width. The statement is qualified on the basis that the UCS strength values and their variation with depth have been obtained from a single borehole investigation. The variation in rock mass properties within bedding units and the variation of those bedding units over the lateral extents of the planned DGR is not yet established. As these promising results are confirmed in future investigations, refinement of the design and the locating of the repository should be possible to take advantage of the best rock mass conditions as they are encountered.

On the basis of the UCS test results, it is evident that intact rock of comparable quality (or better) to that used for the emplacement room modeling exists in the depths characterized as 'Cobourg' limestone (659.5 to 686.5 mbgs). It is also evident that similar quality rock exists to a depth of approximately 688 mbgs.

7.4.1 Range of Feasible Depths

From a geomechanical perspective, it is felt to be more important to locate the repository in rock that is compatible with the conditions used in the reliability based pillar design modeling. On the basis of the results from the DGR-2 borehole ([R9] and [R10]), it is evident that such conditions exist between 659.5 and 688.0 mbgs.

Overhead cover dimension above the emplacement rooms within the Cobourg needs to be higher than the underlying dimension due to the presence of 3.5m long rock support dowels in the crown of the rooms and pronounced gravity effects in the crown. On this basis, it is recommended that the emplacement room invert be located at a depth between 677 and 685 mbgs.

The depths described herein apply to the DGR-2 investigation only. Due to the length of the footprint of the repository and expected bedding plane dip of approximately 1 percent (nominally SW), a variation of up to 5 to 10 m could be expected over the footprint of the repository. Further, local variations may occur in bedding layers across the site. The design and permitting of the facility must be flexible to allow adjustments as rock conditions are encountered.

7.4.2 Preferred Depth

Correspondingly, this study has determined that a preferred location of the repository emplacement rooms will be between 673 (roof) to 680 (invert) mbgs. This will locate the DGR within a layer of competent limestone material with sufficient competent material above the roof (between the DGR and the overlying shale cap layers), yet still providing a zone of competent material beneath the invert.

For the purposes of providing a repository depth specification and consistency across all design documents, OPG has indicated that a nominal depth of 680 mbgs is preferred. It is understood that this assessment will be re-visited as additional investigations and data are received during future investigations and during construction.

7.5 Emplacement Room and Access Tunnel Rock Support Requirements

The conceptual rock support design for the 680-metre deep repository facilities includes the shaft stations, the ring tunnel, rock handling tunnels, access tunnels, Low Level Waste (LLW) emplacement rooms, and Intermediate Level Waste (ILW) emplacement rooms. The designs are based on:

- Storage facility operational requirements
- Expected rock mass conditions
- Past underground construction project experience in the Cobourg (Lindsay) Formation
- Long-term operational performance experience of underground excavations in the Cobourg Formation and similar underground facilities and structures.

The repository facilities consist of conventional underground space as follows:

- Shaft Stations: High chambers, located at the shaft bases, equipped with monorail hoists for reception and handling of waste packages to be emplaced.
- Ring Tunnel: Tunnel with a curved, closed circular alignment connecting to the access tunnels.

- Rock Handling Tunnels: Tunnels that cross passage within the rock mass encompassed by the ring tunnel, intended for handling and processing excavated rock and rock debris underground.
- Access Tunnels: Tunnels with a straight alignment leading from the Ring Tunnel to the emplacement rooms.
- Emplacement Rooms: Rib pillar design with long closed-end rooms separated by a 16 metre wide long continuous rock pillar designed for waste package emplacement and storage.

The excavation geometry and rock support for the deep repository facilities will be controlled primarily by the rock mass structural geologic conditions and operational requirements. The sidewalls will be near vertical to vertical in cross-section. The roof (or back) and floor (or invert) will be excavated near horizontal to horizontal or flat in cross-section and profile due to the predominant structural geologic condition of the rock mass.

The deep repository facilities will be outfitted with a ventilation system and concrete floors. The floors will be finished with concrete as described later in this section.

7.5.1 Rock Support Design Requirements

The rock support for the repository facilities has been designed to meet the following requirements:

- 100 year design life
- Repository operational use
- Protect the structural stability of the tunnels, chambers, and rooms for occupied and unoccupied conditions
- Rock support system to function as both the initial and final or permanent rock support
- Address the rock mass structural geologic conditions
- Protect the repository rock mass from degradation due to environmental exposure
- Protect construction and repository operations personnel from rock falls
- Protect waste packages during transport and emplacement by ensuring good access-way rideability
- Protect waste packages emplaced in the storage rooms from damage due to rock falls
- Corrosion protection for the rock support to address high salinity and the required 100-year design life
- Protect the ventilation and utility systems from damage due to rock falls
- Minimise maintenance and repair of the rock support and rock mass surrounding the repository facilities
- Minimise and control the generation of dust from exposed rock and vehicular traffic.

7.5.2 Previous Experience

The underground space for the proposed storage facilities will be excavated in rock of the Cobourg (Lindsay) Formation. The Cobourg Formation rock mass consists of shaly limestone. This limestone rock mass, associated engineering properties, and structural geologic conditions are described in Section 2 of this report.

Past underground excavation experience in the Cobourg Formation rock mass has been derived from:

- Darlington NGS Intake Tunnel, near Bowmanville, Ontario: The Darlington Tunnel (8 m horseshoe section excavation), as shown in Figure 7-18 and Figure 7-22, was excavated 800 metres using conventional drilling and blasting techniques at a depth of 35 metres below Lake Ontario. Temporary or initial rock support consisted of rock bolts and wire mesh.
- Wesleyville TGS Access Tunnel, near Port Hope, Ontario: The Wesleyville Tunnel (6 m wide by 5 m high rectangular excavation), as shown in Figure 7-19, was excavated using conventional drilling and blasting techniques to a depth of 60 metres near Lake Ontario. Temporary or initial rock support consisted of rock bolts and wire mesh with 3-metre long bolts, longitudinally spaced at 1.8 metres, and 1.7 metres transverse spacing.

Both tunnels were reported to be dry with no significant construction problems or groundwater inflows, with the exception of 20 l/min inflow at the soil-rock interface and an isolated shale seam in the Wesleyville Tunnel.

Figure 7-22 – Darlington Tunnel Top Heading Excavation

Based on a review of these conditions and available geologic literature, the expected rock conditions correspond to the following engineering parameters used in the development of the rock support systems:

- Rock Mass Rating, RMR = 74
- Geologic Strength Index, GSI = 69
- Estimated Tunnelling Quality Index, Q = 6
- RMR-Correlated Tunnelling Quality Index, Q = 28

The shaly limestone of the Cobourg Formation, although subject to moderately high in-situ stress, is not expected to be prone to rock bursting, swelling, or squeezing due to its non-brittle character and low clay mineral composition. The Q index of 6 reflects the high in-situ stress condition, compared to the index correlated from the calculated RMR.

7.5.3 Corrosion Protection for Rock Support

Due to the high salinity of the groundwater encountered within the Cobourg Formation rock mass and the required 100-year design life of the deep repository facilities, passive corrosion protection of the rock support elements is needed. Corrosion protection for the rock support is needed to:

- Ensure the 100-year design life longevity and performance of the rock support systems
- Protect the structural stability of the rock mass and the repository facility openings
- Protect the rock mass quality by ensuring rock support longevity to control rock degradation

Corrosion protection consisting of a double or triple corrosion protection level is required to meet these objectives, and specifically will be:

- Full hot-dip zinc galvanising of all rock support steel elements (i.e. bars, tendons, wire mesh, nuts, plates)
- Full-length plastic sheath encasement of embedded rock bolt steel bars or strand tendons with corrugated high density polyethylene (HDPE)
- Full encapsulation of embedded rock dowel steel bars or strand tendons with Ordinary Portland Cement grout.

7.5.4 Deep Repository Facilities

The design details of the deep repository facilities are summarised in the following paragraphs (all dimensions stated are finished clearances).

7.5.4.1 Shaft Stations

- High chamber design.
- 12.6 m wide by 15.0 m high rectangular section.
- Outfitted with bridge cranes.

7.5.4.2 Ring Tunnel

- Curved alignment tunnel design.
- 8.1 m wide by 7.5 m high rectangular section.

7.5.4.3 Rock Handling Tunnels

- Straight alignment tunnels arranged crossing the ring tunnel.
- 8.1 m wide by 7.5 m high rectangular section.

7.5.4.4 Access Tunnels

- Straight alignment tunnel design.
- 6.5 m wide by 7.0 m high rectangular tunnel section.
- Dual ventilation ducts to be installed.

7.5.4.5 LLW Emplacement Rooms

- Closed-end rib pillar design.
- 8.6 m wide by 7.0 m high rectangular section long rooms.
- Rooms separated by 17.2 m wide long, continuous, rectangular rock pillars.
- Single or double ventilation ducts to be installed.

7.5.4.6 ILW Emplacement Rooms

- Closed-end rib pillar design.

- Various sizes of rectangular section long rooms, ranging from 7.4 to 8.6 m in width and 5.7 to 7.2 m in height.
- Rooms separated by continuous, rectangular rock pillars equal to twice the span of the adjacent emplacement rooms.
- Single or double ventilation ducts to be installed.
- Gantry cranes will be required in three rooms.

7.5.5 Repository Level Floors

The floors will be over-excavated as needed to provide sufficient depth to place a 200-mm thick reinforced (welded wire fabric or rebar) concrete floor slab and to maintain the required finished clearance heights. A concrete floor slab is needed for the emplacement rooms, tunnels and shaft stations to provide:

- Safe and efficient waste package transfer, transport, and emplacement – by rail or rubber-tired vehicle
- Safety of pedestrian operational personnel against tripping and falling hazards
- Safety for the waste packages and operational personnel during package transport in the deep repository facilities
- Uniformly level and engineered drainage profile floor over the 100 year design life of the facility
- Minimisation of long-term access-way grading and rail maintenance
- Rolling stock steel rail encasement
- Rock dust control and to minimise dust generated by pedestrian and vehicular traffic particularly in areas with a high frequency of vehicle turning movements
- Efficient drainage pitching for wash water and groundwater collection
- Improved ventilation efficiency
- Efficient collection and handling of dust and rock fragments
- Control of floor rock spalling
- Floor rock support to protect against floor slab buckling and overstress fracturing

A bare or exposed rock floor will result in an uneven or non-horizontal profile, potholing, and depressions caused by rock overstress fracturing and the undulating nature and any slight horizontal bedding dip of the rock mass.

The likelihood of floor heave will depend upon the level of in-situ horizontal stresses relative to bedding plane thickness and rock strength at each room location. Consequently, the timing of installation of concrete floors relative to planned waste package emplacement will need to be assessed on a room by room basis using geotechnical assessments and instrumentation monitoring performed during and after room excavation. Alternatives available to limit floor heave will include floor rock dowels, additional reinforcement in the concrete or delayed installation of the concrete floors.

7.5.6 Rock Support Design and Rock Mass Quality Control

Rock support for the emplacement rooms and tunnels has been designed to prevent fallout of loosened and failed material from the roof and upper walls for the safety of workers and to avoid damage to waste packages in the pre-closure phase. The rock support has not been designed to act as structural reinforcement of the rock pillars between the emplacement rooms.

The rock support design for the proposed deep repository facilities is based on the expected rock conditions, as previously described in this section and as described in the following paragraphs. The rock support design was performed using:

- Rock Mass Rating (RMR) system according to Bieniawski ([R64])
- Norwegian Geotechnical Institute Q-System according to Barton et al ([R70]) and Grimstad and Barton ([[R71])
- Geologic Strength Index according to Hoek and Brown ([R72])
- FLAC numerical modelling analytical results
- Past experience in the Darlington Tunnel and Wesleyville Tunnel
- Rock bolt length empirical criteria according to Cording et al ([R61]) and Hoek ([R62]).

The expected RMR value was correlated with the Q-System to determine the rock support requirements. According to the Q-System, as described by Barton et al. ([R58]) and Grimstad and Barton ([R59]), the proposed storage facility corresponds to Excavation Category C. This Excavation Category corresponds to an Excavation Support Ratio (ESR) of 1.3. However, due to the currently understood use, required longevity, personnel access, maintenance, operation, and unverified expected rock conditions of the deep repository facilities, an ESR of 1.0 is more appropriate and has been used in the design. This lower ESR is slightly conservative; however, it best reflects the proposed periodic access by specially trained operations personnel, active inspection and rock support maintenance, and the proposed 100 year design life and long-term operation. An ESR of 0.8 would be excessively conservative and is not consistent with the currently understood proposed use of the deep repository facilities.

The recommended rock support design for the emplacement rooms and access tunnels consist of untensioned rock dowels and shotcrete (sprayed concrete) or wire mesh (see Figure 7-23), detailed as follows:

- Rock dowel steel bar: 25 mm diameter uniform solid, Grade 420
- Rock dowel length: 3.6 metres (embedded in rock)
- Rock dowel spacing: 1.5 m center-to-center spaced longitudinally and transversely
- Rock dowel orientation:
  - Roof: orientated vertical in all directions;
  - Roof abutments/corners: orientated vertical in longitudinal profile and inclined 30°-45° from vertical;
  - Sidewalls: orientated perpendicular to the wall in the horizontal plane and 15° above horizontal in the vertical plane.
- Rock dowel coverage: Across the full opening width of the roof of all deep repository facilities and nominally half the room height from the roof down along the sidewalls for all facilities except the shaft stations. Rock doweling for the shaft stations should extend 10 metres down the sidewalls below the roof.
- Rock dowel bearing plate and nuts: 150 mm square or round, 10 mm thick, Grade 235 with shotcrete studs or clips
- Rock dowel bar corrosion protection: Full-length, hot-dip zinc galvanised; full-length, corrugated HDPE sheath encasement; and full-length, cement grout encapsulation
- Rock support corrosion protection: Full, hot-dip zinc galvanising of all steel bearing plates, steel nuts, and steel wire mesh
- Shotcrete (Sprayed Concrete): 35 MPa 28-day compressive strength, steel fibre-reinforced; 50 mm minimum installed thickness

- Shotcrete coverage: Across the full opening width of the roof of all deep repository facilities and two metres below the roof down the sidewalls for all facilities except the shaft stations and emplacement rooms. Shotcrete for the shaft stations and emplacement rooms should extend from the roof down the full height of sidewalls to the floor.
- Steel wire mesh: 100 x 100 – MW25.7 x MW25.7 welded wire fabric or 11 gauge chain link mesh; installed and fastened to the rock surface by the rock dowels.

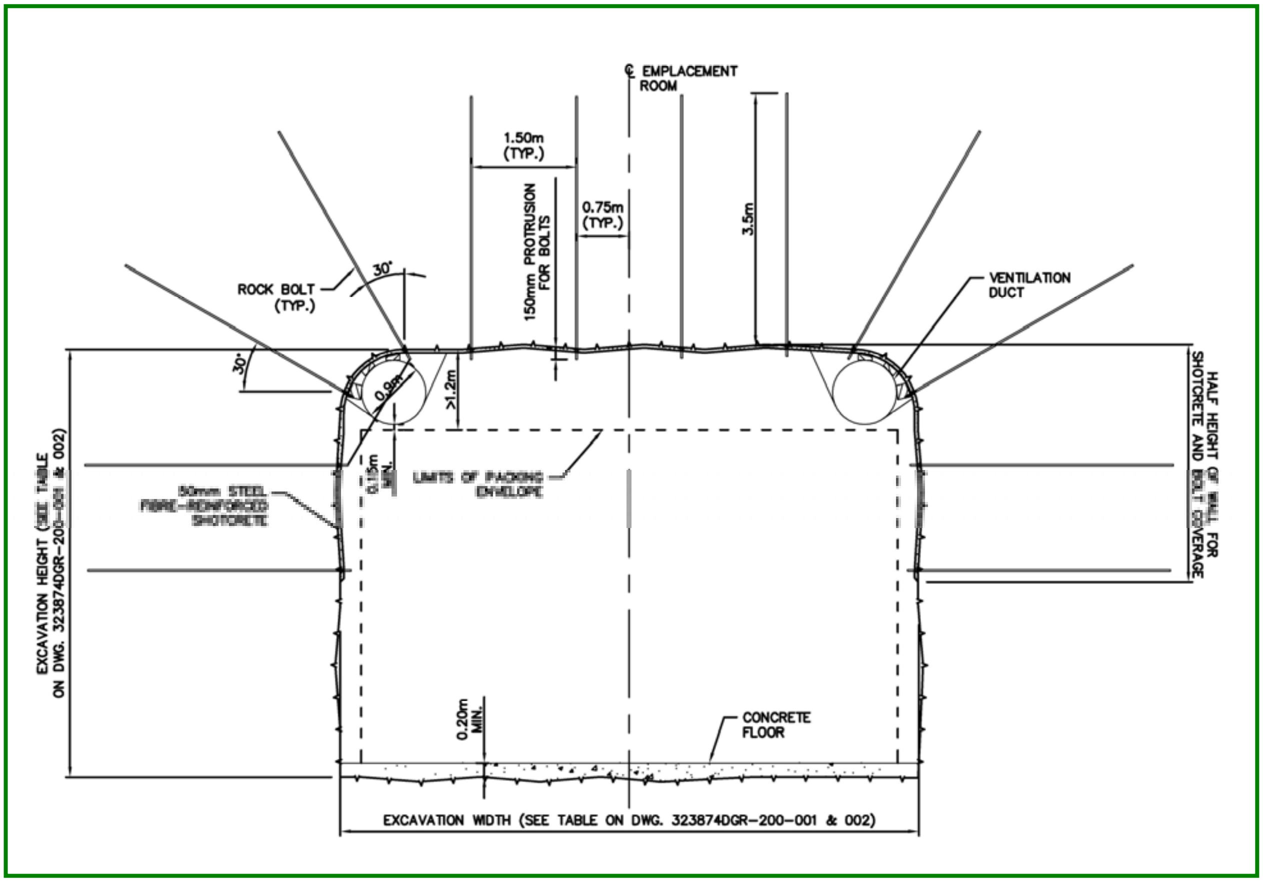


Figure 7-23 – Cross Section Showing Typical Rock Support for Emplacement Rooms and Access Tunnels

The rock dowel length has been specified to extend beyond the plastic zone limits (2.7 metres above the roof) determined by the FLAC analyses. An example of the recommended type of rock dowel is the CT-Bolt as manufactured by Orsta Stal AS of Norway and shown inFigure 7-24 and installation details are shown in Figure 7-25.

Figure 7-24 – Typical Corrosion-Protected Rock Bolt

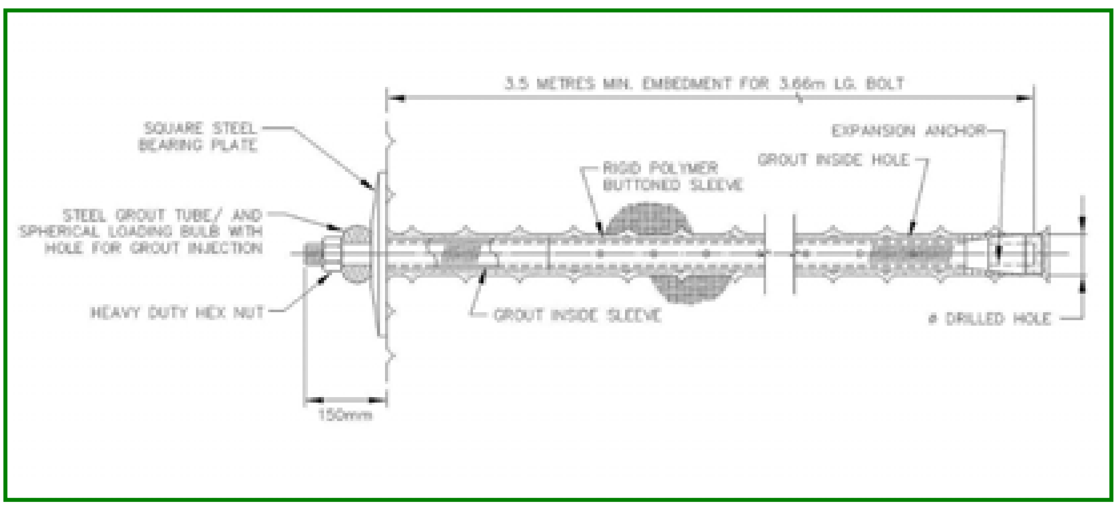


Figure 7-25 – Installation Details for Corrosion-Protected Rock Bolt

Rock dowels should be installed and grouted concurrently with rock excavation. Installation should occur within eight hours of roof exposure and to within a maximum horizontal distance of six feet from the advancing face at all times. Shotcrete should be applied within 24 hours after the rock has been exposed.

Shotcrete is recommended for use with the rock dowels to provide supplemental corrosion protection for the dowels, to protect against rock mass degradation due to environmental exposure, and to preserve the rock mass quality for the 100-year design life of the repository. Shotcrete also provides more effective support for spalling or loosening rock between the rock dowels due to overstress fracturing, relative to steel wire mesh. The increased effectiveness results in less long-term maintenance of the rock support. Steel wire mesh can only be used in areas of highly massive and competent rock as verified at the time of construction. The extended shotcrete coverage and rock doweling in the emplacement rooms and shaft stations is needed to protect the waste packages and shaft station access areas over the 100-year design life of the repository facilities.

Additional rock doweling through the rock pillars and chamfering of rock pillars at the emplacement room openings from the access tunnels may be required to protect the rock pillars if the opening widths are reduced in the next phase of design.

7.6 Construction Methods for Emplacement Rooms and Access Tunnels

The underground level tunnels will primarily be excavated using roadheaders although drilling and blasting techniques may be used for certain sections of excavations, such as room openings, zones of very high strength rock, small rooms, initial enlargement of shaft stations, and the initial access tunnel. After completion of shaft sinking, the access tunnels will be developed simultaneously using two roadheaders, but employing a single roadheader in a room.

A trial emplacement room will be excavated to prove the methods and allow for training of the development crews. Once this 'learning curve' is complete, the remainder of the rooms in both the South and East Panel will be developed.

7.6.1 Excavation Method - Rationale

Selection of excavation method is typically left to a contractor's discretion in most underground excavation projects. Drill and blast techniques are traditionally used in underground metal mines that are typically in plutonic (igneous) rocks of very high strength. For mining and tunnelling in softer sedimentary rocks (coal, gypsum, salt and potash), mechanical excavation using roadheaders is typically employed (in addition to blasting).

Given the unique nature and end use needs of the DGR, it is felt that the excavation method for various elements of the repository should be contractually specified. This applies to the Main and Ventilation Shafts and waste emplacement rooms. To optimise the rib pillar spacing for the DGR emplacement rooms, tight control of the pillar width will be necessary to provide the required level of safety and minimise rock damage, and reduce the rock support requirements.

By its nature, blasting results in overbreak and the development of an extended fracture zone in the rock around the excavation perimeter. While the use of controlled blasting using pre-split and other methods can reduce the amount of overbreak, mechanical excavation methods, such as a roadheader, are superior to blasting in this regard.

The primary considerations in selection of a rock excavation method are the strength conditions of the rock mass to be excavated and required excavation rates.

7.6.1.1 DGR Rock Mass Strength and Quality

Roadheaders operate within a smaller range of rock mass conditions than drill and blast methods. Figure 7-28 provides a qualitative comparison of the applicability of various rock excavation methods relative to rock mass quality conditions (fracturing and unconfined compressive strength or UCS). It is evident that the rock mass range associated with roadheader is less than that drill and blast methods. However, a roadheader is considered a feasible excavation method for the anticipated range of rock conditions within the DGR facility.

The emplacement rooms will be excavated in limestone of the Cobourg formation that has an expected mean UCS of 72 MPa and possible strength range from 25 to 140 MPa. In addition, results from the DGR 2 boring [R10] (see Table 7-9) suggest that rock strengths may be of the order of 100 to 120 MPa. Cerchar Abrasivity Index (CAI) values [R11] ranged from 0.73 to 2.21 with a mean of 1.34 and a standard deviation of 0.3.

This range of UCS and CAI values combined with the anticipated tensile strength range of 3 to 10 MPa for the Cobourg formation puts this rock well within the economical cutting range for a roadheader (see Figure 7-27).

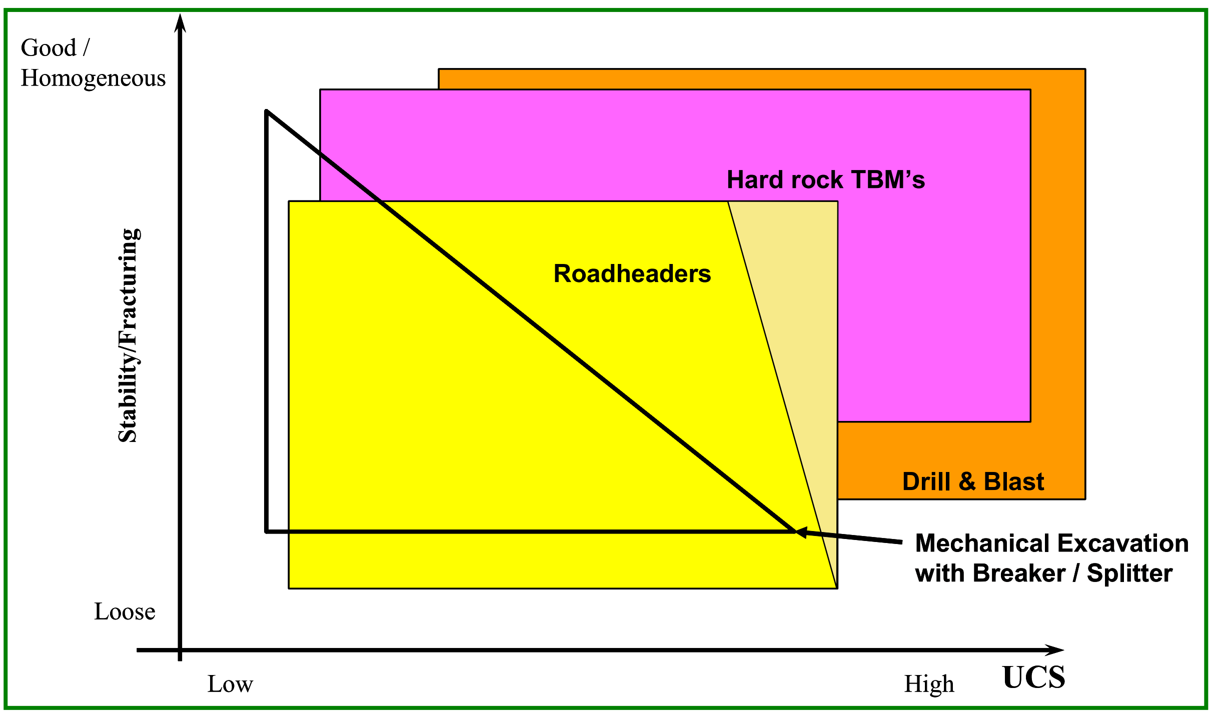


Figure 7-26 – Qualitative Comparison of Rock Excavation Methods versus Rock Mass Conditions [R75]

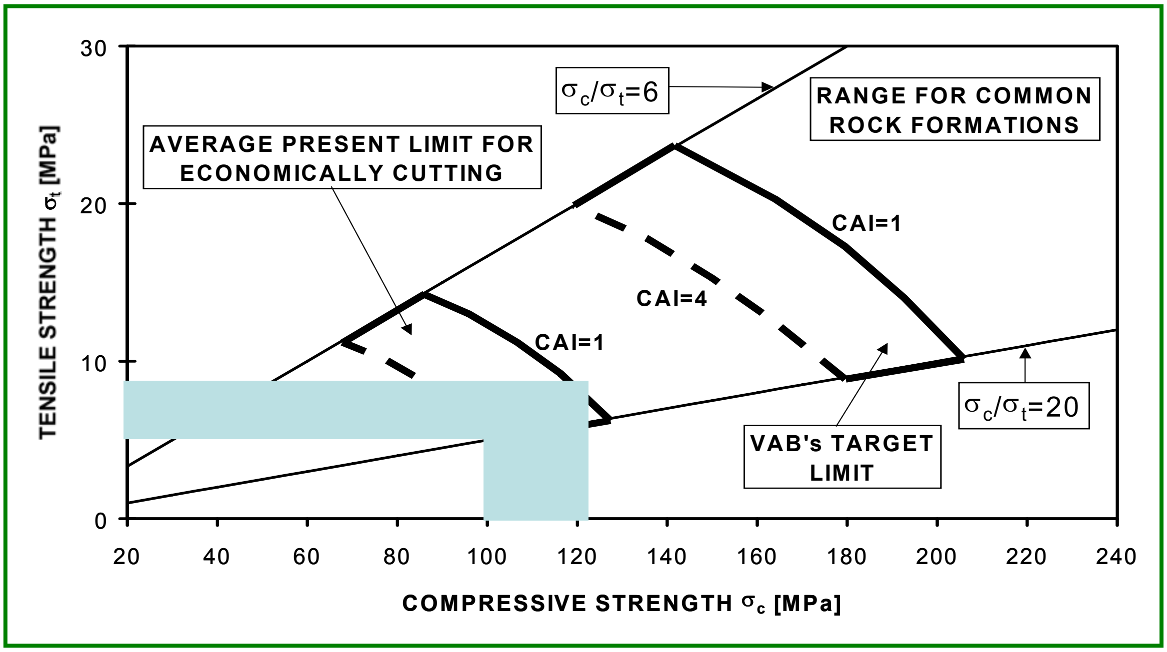


Figure 7-27 – Rock Strength Envelope Suitable for Roadheader Excavation – Typical DGR conditions shown in blue shaded band [R75]

Figure 7-28 provides a photographic comparison of two tunnels excavated in the same rock conditions on the Montreal Metro – Laval Extension. The limestone rock excavated in Montreal is of similar quality to the Cobourg formation and the improvement in excavation quality between the roadheader and drill and blast is evident.

On this basis, it is concluded that a roadheader can operate efficiently within the anticipated rock mass conditions of the OPG DGR while limiting the development of an excavation damaged in rock forming the perimeter of emplacement room seals.

Figure 7-28 – Overbreak comparison of two separate contracts in the same rock conditions [R75]

7.6.1.2 Efficiency

Given the rock mass strength conditions at the DGR, a large roadheader such as a Voest Alpine ATM 105 (Figure 7-29) would be required. Figure 7-30 provides net cutting rates versus UCS for various levels of fragmented rock. For the anticipated typical range of unconfined compressive strength (60 to 100 MPa), an excavation rate of 35 to 55 m^3/hr can be achieved, resulting in advance rates of 6.3 to 9.9 m/day if a single roadheader is operating; and 9.5 to 14.9 m/day if two roadheaders are operating concurrently. For scheduling design, two roadheaders achieving a daily advance of 9.5 metres was selected, which yields a daily in-situ volume cutting rate of 533 m^3.

These rates are calculated on the basis of an average emplacement room cross-sectional area; conservative machine utilisations of 50% for a single operating roadheader and 37.5% for two roadheaders operating concurrently; and with work being conducted on the basis of two 10 hour shifts per day. The overall efficiency for two machines operating concurrently is de-rated to take account of delays that would be expected with mucking of the broken rock due to trucks cycling between the two headings and potential delays at the Ventilation Shaft muck bin due to a truck having to wait until the previous truck has cleared the bin area before dumping its load.

Considering the operating envelope of the Voest Alpine 105, the same unit has enough flexibility to excavate all of the underground emplacement rooms and access tunnels in one pass. For the LLW rooms, however, a 1.5m thick layer of muck will be required to achieve 7.5 m room height (see Figure 7-31).

Use of a roadheader provides several advantages over conventional drill and blast methods. In general, the excavation cycle using a roadheader is simpler relative to drill and blast techniques as illustrated in Figure 7-32. Drill and blast requires several steps involving multiple machines whereas the roadheader excavation only involves the roadheader itself and the selected muck handling vehicle. Installation of some rock support elements (shotcrete) may also be required behind the roadheader.

- Cutting height max. 6.6 m
- Cutting width 9.1 m
- Motor power 555 kW
- Total weight 135 t
- Total length 18.2 m

Figure 7-29 – Example of Roadheader: Voest Alpine ATM 105

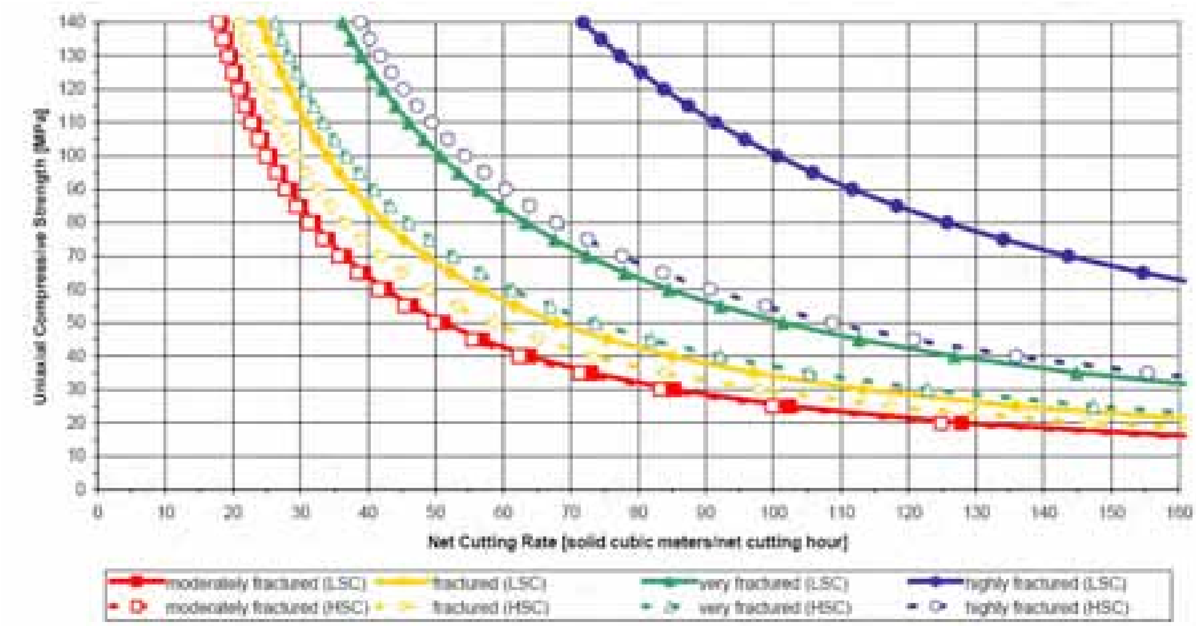


Figure 7-30 – Roadheader Cutting Rates [R75]

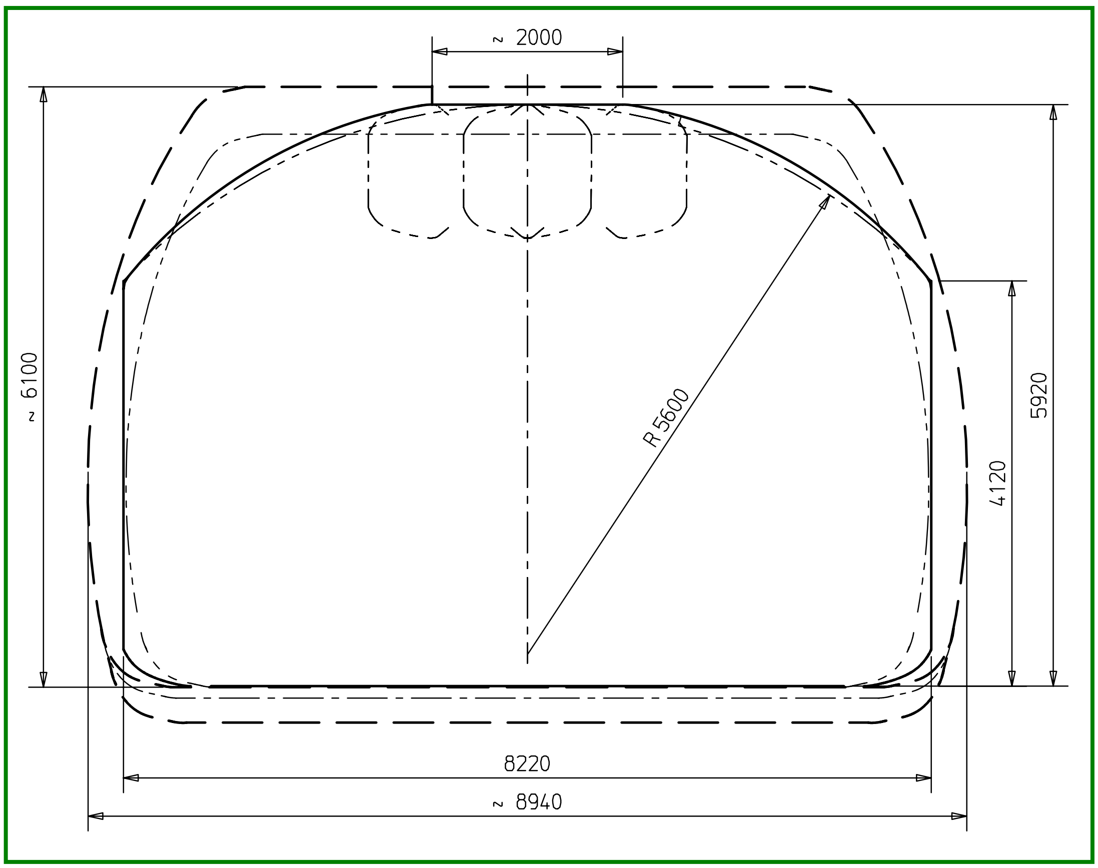


Figure 7-31 – Voest Alpine ATM 105 Cutting Profile [R75]

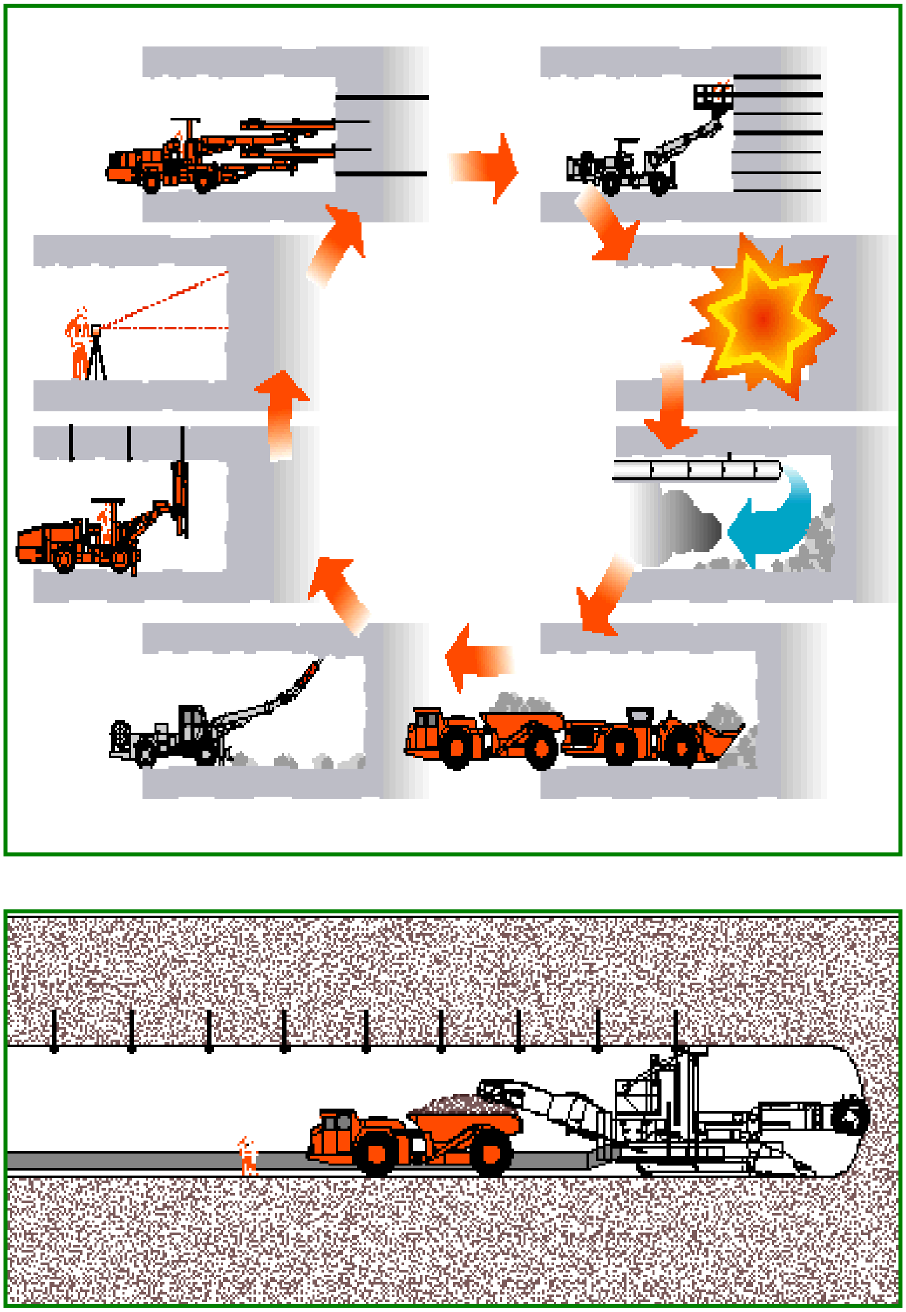


Figure 7-32 – Comparison of Drill and Blast Excavation (top) and Roadheader (bottom) Cycle [R75]

Additional advantages of using a roadheader to excavate the DGR include the following:

- Ventilation requirements – Roadheaders are electrically powered using a main power cable feed. Consequently, ventilation requirements during construction are less demanding when a roadheader is used because there is less diesel exhaust as result of the decreased amount of operating machinery and no blast smoke generated. Water sprayers are used to assist in cutting and to reduce fugitive dust.
- Worker safety – Roadheader excavation is safer than drill and blast techniques as it eliminates the risks associated with the handling and storage of explosives, risks from fly rock and scaling, and the risk of gas exposure to workers.

- Modular design – Roadheaders are designed in a modular fashion so that all main components can be individually transported down mine and tunnel shafts and then re-assembled within the underground facility.

Based on the foregoing discussions, it is concluded that a roadheader should be the preferred method of excavation and be contractually specified for emplacement room construction. Although the use of a roadheader is considered to be the preferred method of excavation, drill and blast methods will still be necessary for aspects of repository development including:

- Room openings.
- Zones of high strength rock.
- Small rooms.
- Initial enlargement of shaft stations.
- Initial access tunnel.
- Periods of roadheader downtime.
- Shaft excavation in Reach 2 dolostones and limestones.

7.6.2 Mucking Cycle

The development of the DGR will not be schedule or through-put driven and contractors may elect to utilise various methods such as rail mounted muck cars, scoop-trams (also referred to as LHDs) or conveyors. Considerations in type selection would be shaft sizing, availability of power, ventilation requirements, cycle distances and times, and economies of scale. Generally, the type of muck transport within an underground development would not be specified by the owner but be selected by the contractor to suit its particular means and methods. For the purposes of conceptual design, a feasible methodology utilising mine trucks is described below.

Removal of the waste rock cutting generated by the roadheader will be handled using the following procedure:

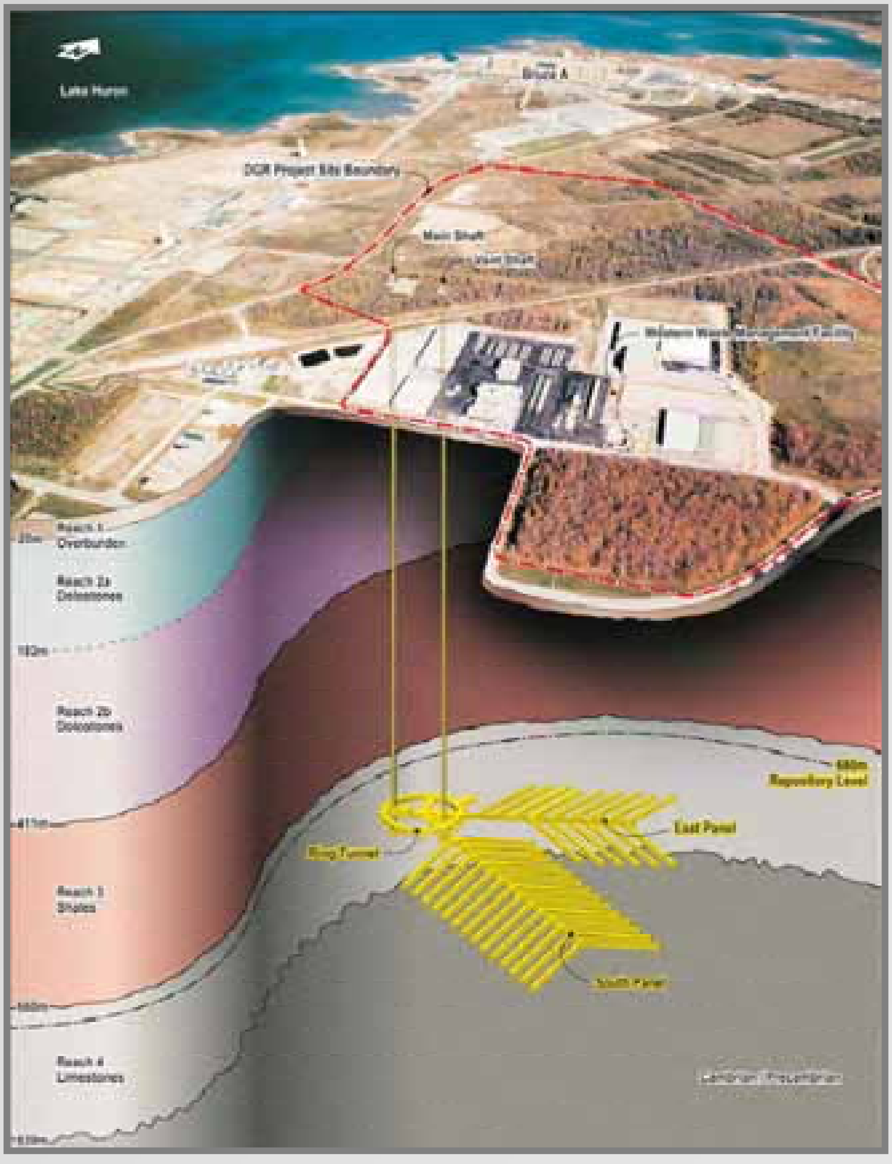
- Collect with muck using loading table located on the front of the roadheader machine.
- Convey from roadheader to waiting rock trucks.
- Rock trucks transport to vent shaft via emplacement room access tunnel.
- Trucks tip to skip hoist.
- Hoist to surface & tip to conveyor.
- Convey from skip hoist to surface muck pile using a stationary main conveyor to a radial conveyor.

The mine truck approach is preferred method of transporting the waste rock from the emplacement rooms to the shaft hoist for several the following reasons:

- Low CAPEX and Operating Expenditure.
- More efficient than scoop-trams.
- Tunnel dimensions do not need to be altered – no overhead allowance for conveyor or width allowance for LHD.
- In transit surge storage controlled by using roadheader loading table and conveyor.
- Flexibility of access/work sequencing.
- High reliability/utilisation.
- Decreased fire risk relative to conveyors.
- Use of a conveyor around the ring tunnel would be very difficult.

CONCEPTUAL DESIGN REPORT

8. Waste Package Handling and Emplacement



8. Waste Package Handling & Emplacement

8.1 Waste Package Inventory

The waste package inventory is reproduced in the OPG Report "Reference Low and Intermediate Level Waste Inventory for the Deep Geologic Repository" (00216-REP-03902-00003-R00-Inventory), dated February 2007 ([R76]).

This information has been used to categorise the waste into a set of logical groups for use within the conceptual designs and selection of material handling equipment, waste package transfer methods, emplacement room sizing and layouts. The final shielding designs for certain ILW packages and revised processing dimensions for the large objects, such as the steam generators, have been included to create a revised summary of the inventory. The LLW and ILW groups are stated in Table 8-1 and Table 8-2 with full details of the final as-disposed dimensions, volumes and masses are given in Table 8-3.

Waste Category	Group	Container Type	Container Code
Operational Wastes	A [1]	Ash Bin (Old) - bottom ash	AIBO2
	A [1]	Ash Bin (New) - bottom ash	AIBN
	A [1]	Drum Rack - baghouse ash	DRACK
	A [1]	Ash Bin (new) - baghouse ash	AIBN
	A	Compactor Box	B25
	A	Bale Rack	BRACK
	A [2]	Drum Rack - non-processible drums	DRACK
	A	Drum Bin	DBIN
	A	Non-Pro Bin (47" high)	NPB47
	A	Non-Pro Bin	NPB4
	A [1]	Low Level Resin Box (90")	RB90
	A	Low Level Resin Pallet Tank	RTK
	A [1]	ALW Sludge Box	NPBSB
	B	Shield Plug Container	SPC
	E	Heat Exchanger	HX
	D1	Encapsulated Tile Hole	ETH
Reactor Refurbishment Wastes	G-A	Steam Generators - Bruce A	SGSGMT
	G-B	Steam Generators - Bruce B	SGSGMT
	G-C	Steam Generators - Pickering B	SGSGMT

Note 1: These packages are planned to be placed into BINOPK overpacks at the time of retrieval from LLSB's;
Note 2: 10% of the non-processible drums in drum racks are assumed to require overpacking in BINOPK's.

Table 8-1 – LLW Package Types by Groups

Waste Category	Group	Container Type	Container Code
Operational Wastes	D2	Resin Liner	RL
	D3	Resin Liner in Overpack (RLOPK)	RLOPK
	D4	Resin Liner - 0.25m concrete shield	RLSHLD1
	D5	Resin Liner - 0.35m concrete shield	RLSHLD2
	D6	Resin Liner - 0.35m conc shield + steel insert	RLSHLD3
	E	IC-2 Liner	THLIC2
	E	IC-18 T-H-E Liner - filters, IX columns, etc.	THLIC18
	E	IC-18 T-H-E Liner - core components	THLIC18
	F	ILW Shield	ILWSHLD
	C	Tile Hole Liner	THLSTG3
Reactor Refurbishment Wastes	H1	Retube Waste (Pressure Tubes)	RWC(PT)
	H2	Retube Waste (End Fittings)	RWC(EF)
	H1	Retube Waste (Calandria Tubes)	RWC(PT)
	H1	Retube Waste (Calandria Tube Inserts)	RWC(PT)

Table 8-2 – ILW Package Types by Groups

The "groups", into which the waste packages have been organised, were selected to organise the packages by size, type and method of handling, which simplified understanding and referencing during the design studies undertaken for each specific work section. The groups are more fully defined in terms of types, transfer methods, hoisting limitations, emplacement stacking requirements and dose rates in Appendix D – Waste Package Category Information Sheets.

It is noted that for disposal, all the Ash Bins (Old), Ash Bins (New), Drum Racks - baghouse ash, Ash Bins (new) - baghouse ash, Low Level Resin Boxes (90"), ALW Sludge Boxes and 296 (i.e. 10%) of the Drum Racks - non-processible drums are assumed to be overpacked in the standard container overpack (BINOPK) (see table 22 of [R76]). Hence within Table 8-3, the dimensions relate to the overpack. There will be 3141 overpacked waste packages in total.

Contact dose rates for the Shield Plug Containers were taken at the time that these containers were placed into WWMF trench storage. These containers will be retrieved last from storage, to allow contact dose rates to reduce below 2 mSv/hr and to allow transfer into DGR without additional shielding.

The Steam Generators will be segmented in a variety of different sizes, which are detailed in Section 8.2.1.5, to maximise the sizes and masses within the limitations of the Main Shaft cage and thereby reduce the total number of cuts required during 're-processing'.

Detailed analysis of the Resin Liner shields enabled those wastes to be split into five different sizes of package, which are described in Section 8.2.2.1.

The IC-2 and IC-18 T-H-E liners masses in Table 8-3 are given inclusive of the re-usable shield as that is the governing factor for transportation, although they will be disposed in a concreted pipe array in the emplacement rooms.

Waste Category	*Group*	*Container Type*	*Number*		*Dimensions (m)*			*Volume*	*Masses [each] (kg)*		
			Items	*Containers*	*L*	*W (or dia)*	*H*	*(m^3)*	Load/ Contents	Overpack/ shield	Total
LLW											
Operational Wastes	A	Ash Bin (Old) - bottom ash *		269	2.54	1.78	1.88	2,286	2,950	1,591	4,541
	A	Ash Bin (New) - bottom ash *		816	2.54	1.78	1.88	6,936	1,604	1,591	3,195
	A	Drum Rack - baghouse ash *		47	2.54	1.78	1.88	399	1,490	1,591	3,081
	A	Ash Bin (new) - baghouse ash *		134	2.54	1.78	1.88	1,139	1,604	1,591	3,195
	A	Compactor Box		5,298	1.84	1.12	1.3	14,194	2,722		2,722
	A	Bale Rack		1,491	2.29	1.22	1.2	4,999	1,256	150	1,406
	A	Drum Rack - non-processible drums *		296	2.54	1.78	1.88	2,516	1,490	1,591	3,081
	A	Drum Rack - non-processible drums		2,663	2.29	1.22	1.2	8,928	1,340	150	1,490
	A	Drum Bin		3,317	1.96	1.32	1.03	8,839	1,450		1,450
	A	Non-Pro Bin (47" high NPB47)		20,327	1.96	1.32	1.19	62,582	1,460		1,460
	A	Non-Pro Bin (NPB4)		0	2.29	1.22	1.47	0	1,066		1,066
	A	Low Level Resin Box (90") *		45	2.54	1.78	1.88	382	3,655	1,591	5,246
	A	Low Level Resin Pallet Tank		1,993	1.24	1.24	1.68	5,148	2,000		2,000
	A	ALW Sludge Box *		1,534	2.54	1.78	1.88	13,039	1,820	1,591	3,411
	B	Shield Plug Container		9	3	1.8	1.8	87	13,000	13,000	26,000
	E	Heat Exchanger	66	82	4.57	2		1,177	30,000		30,000
	D1	Encapsulated Tile Hole		66	4.6	1.5		537	25,000		25,000
Reactor Refurbishment Wastes	G-A	Steam Generators - Bruce A	32	128	3.03	2.4		1,868			35,044
	G-B	Steam Generators - Bruce B	32	192	2.68	2.89		3,457			34,966
	G-C	Steam Generators - Pickering B	48	192	3.68	2.04		2,349			27,435
		Total quantity & volume for SGMT		512				7,673			
ILW											
Operational Wastes	D2	Resin Liner	359	359	1.8	1.63		1,348	3,750	795	4,545
	D3	Resin Liner in Overpack (RLOPK)	400	400	1.9	1.66		1,645	3,750	2,245	5,995
	D4	Resin Liner - 0.25m concrete shield	1,436	718	4.25	2.2		11,600	7,500	19,329	26,829
	D5	Resin Liner - 0.35m concrete shield	364	182	4.45	2.4		3,664	7,500	28,556	36,056
	D6	Resin Liner - 0.35m conc shield + steel insert	153	153	2.62	2.53		2,015	3,750	23,828	27,578
	E	IC-2 Liner		20	7.6	0.61		44	5,196	27,146	32,342
	E	IC-18 T-H-E Liner - filters, IX columns, etc.		422	10.7	0.55		1,073	4,392	27,146	31,538
	E	IC-18 T-H-E Liner - core components		22	10.7	0.55		56	4,392	27,146	31,538
	F	ILW Shield		7,383	1.7	1		9,858	275	2,015	2,290
	C	Tile Hole Liner		201	3	0.61		176	1,550	450	2,000
Reactor Refurbishment Wastes	H1	Retube Waste (Pressure Tubes)		245	1.85	1.85	2.25	1,887	22,500	3,803	26,303
	H2	Retube Waste (End Fittings)		918	1.7	3.35	1.92	10,038	25,542	4,462	30,004
	H1	Retube Waste (Calandria Tubes)		168	1.85	1.85	2.25	1,294	22,500	3,803	26,303
	H1	Retube Waste (Calandria Tube Inserts)		45	1.85	1.85	2.25	347	22,500	3,803	26,303
TOTALS		**LLW**						140,861			
		ILW						45,045			

Notes: LLW Group A items marked * will be overpacked for disposal
Steam Generator Segment masses are for the maximum segment size.

Table 8-3 – Waste Package Inventory Details (revised from [R76] data)

8.2 Surface Handling (WWMF to shaft collar)

All packages retrieved from WWMF storage will be transferred to the DGR in a disposal-ready state on flat-bed transporters to the WPRB adjacent to the Main Shaft of the DGR. At the Main Shaft, they will be off-loaded by forklift or mobile crane and placed into the staging area prior to being moved into the shaft cage. The WPRB will be arranged with an incoming side next to the truck off-loading transfer bay. Separate sections will be demarcated for standard LLW packages, heavy and large LLW/ILW packages, and high dose rate packages.

A detailed roster for transferral will be drawn up prior to commencement of emplacement operations, which will take into account the storage locations and accessibility or the packages at the WWMF and the requirements for emplacement underground, so that groups of packages are delivered to the WPRB in the correct order for transfer. While the emplacement room configurations have been designed to provide a certain amount of flexibility in stacking, it will still be important to define a detailed plan that recognises waste package retrieval and transfer constraints at the WWMF as well as limitations on stacking underground.

A controller based at the DGR Main Shaft will co-ordinate the process and ensure that all packages received are in accordance with planning manifests and undergo an incoming inspection process to confirm that the packages are in a state that meets the Design Requirements (see Section 3 above) and Waste Acceptance Criteria ([R77]). Packages that do not meet the Waste Acceptance Criteria, it will be returned to the point of origin, where the shipper will rectify package conditions that caused it to be rejected.

Any incoming packages, which are not already tagged with a bar-code label at the dispatch location (generally, the WWMF) will have this label attached at the WPRB. The tracking data for all incoming packages within OPG's Integrated Waste Tracking System (IWTS) will be reviewed for completeness and updated as necessary. For packages which are bar-coded at the WPRB, all tracking data will be entered into IWTS at the WPRB. The data will allow the packages to be tracked throughout the transfer process and interface with the DGR monitoring system to provide immediate confirmation of adherence to the schedule on the monitoring system at the DGR Control Room.

Once the large quantity of packages in storage at the WWMF has been cleared and transferred into their final disposal location in the DGR, receipt of waste packages will generally be direct from the WVRB at the WWMF. The major exception will be resin liners which will shipped direct from the nuclear stations to the WPRB. Shipments from the nuclear power stations will be planned with the DGR Controller to ensure that underground emplacement allocations are made available to suit the delivery schedule from the stations.

The DGR Waste Acceptance Criteria (WAC) ([R77]) requires that each package meets two specific dose rate limits:

- 2 mSv/hr contact dose rate limit
- 0.1 mSv/hr at 1 metre dose rate limit

All waste package shields will be generally designed to ensure that these limits are achieved. However, there may be some packages, on which the 1 metre dose rate limit is exceeded. Potentially 20% of the resin liners (540 liners), 5% of the T-H-E liners (22 liners containing core components) and the nine shield plug containers may not meet this limit. The dose rates reported in the OPG Waste Package Inventory ([R76]) were taken at the time that the packages were placed into storage at the WWMF. By the time these wastes are due to be retrieved from the in-ground storage for transfer to the DGR, it is likely that the doses will have decayed further. If any package then still has an unacceptably high dose rate, the package will be left in surface storage until they can be safely retrieved, shielded and transferred. If necessary, spot shielding may be used and/or temporary shielding attached to the transport equipment to protect workers from any dose rate in excess of the WAC limits.

8.2.1 Low Level Wastes

8.2.1.1 Standard Packages

As noted in Section 8.1, 3141 of the standard bin wastes will be overpacked in the BINOPK before transfer to the DGR.

Shielded overpack containers will be used if the dose rates of the packages exceed the acceptable limit of 2 mSv/hr in a non-shielded overpack container.

These packages will all be transported in large quantities from the WWMF and will be off-loaded and stacked in a staging area on the incoming side of the WPRB by a light duty forklift. A second forklift will transfer the packages to the shaft cage from the opposite side of the staging area.

8.2.1.2 Shield Plug Containers

The Shield Plug Containers are large and heavy items, which can only be handled by crane. They will be transferred on a flat-bed truck to the DGR and off-loaded into the staging area by a mobile crane. The overhead crane in the WPRB will be used to place these waste packages on a rail car for transfer into the DGR.

Contact dose rates listed for the Shield Plug Containers range from 2 to 250 mSv/hr, but were taken at the time that these containers were placed into WWMF trench storage. These containers will be retrieved last from storage, to allow contact dose rates to reduce below 2 mSv/hr and to allow transfer into DGR without additional shielding

8.2.1.3 Heat Exchangers

Prior to transfer, the heat exchangers will need to have any protuberances (e.g. nozzles, supports) cut off and any openings so created welded closed with a seal plate. This will be done to improve the stackability of these items in the underground emplacement room. All off-cuts can be disposed in low level disposal bins providing dose rates are within the WAC. In preparation for transfer at the WWMF, lifting lugs will be affixed to the exterior of the heat exchangers to allow them to be lifted by crane.

The heat exchangers will be moved in one piece on a truck from the WWMF to the DGR. Once at the WPRB, they will be lifted using the 40 tonne overhead crane and placed on a rail car, which will be used for the remainder of the transfer process.

It should be noted that due to insufficient data in the OPG Waste Inventory Report ([R76]) for developing a conceptual design for the heat exchanger handling system, on discussion with OPG, it was assumed that all heat exchangers will be the same dimensions and the most common size from the Pickering Power Plant (2.0 metre diameter x 4.57 metre long) was taken as representative. Should any heat exchangers exceed the shaft cage dimensional limitations, they would be grouted to stabilise the contents and cut into sections. This sectioning process is described in more detail for the steam generators in Section 8.2.1.5 below.

8.2.1.4 Encapsulated Tile Holes

Encapsulated Tile Holes are 4.6 metre tall x 1.5 metre diameter low level wastes, having a mass of 25 tonnes. For the purposes of this study, it assumed that the ETH package is comprised of an outer cylindrical steel pipe (9.5 mm thick walls) that encapsulates the waste-filled tile hole that was once in the ground. The contents of the tile hole are stabilised with grout and the annular space between the steel pipe and the tile hole is also filled with grout. Concrete is used to seal the base of the steel pipe.

The ETH package has features that allow lifting by crane or handling by forklift. The forklift pockets are an integral part of the outer steel shell. It is assumed that at the time of retrieval from in-ground storage the ETH package will be lifted by crane onto a flat-bed trailer for transfer to the WPRB. The ETH package will then be off-loaded by either the overhead crane or a heavy duty forklift and moved to the staging area. The ETH package will be in a vertical orientation throughout the entire transfer process.

8.2.1.5 Steam Generators

The steam generators are very large and heavy items. They will be segmented in their storage building or in a nearby building, which is specifically built for the processing of these steam generators and other large objects prior to transfer to the DGR.

Each steam generator will be filled with light-mass grout to stabilise the internal parts, then cut into sections using a diamond wire saw. Each segment will be sealed with a plate welded to each cut end. These plates will serve a dual purpose of increasing the shielding of the grouted segment, and providing a flat surface to aid stacking in the emplacement rooms. Forklift pockets will be welded onto one seal plate on each segment to facilitate safe lifting and transfer of these segments.

The segment sizes have been determined based on either dimensional or mass limits to suit the shaft cage and cage ratings and thereby minimise the number of cuts required.

At the WPRB, a heavy duty forklift or the overhead crane will be used to off-load the segments. The bulk of the segments (all except for the steam drum segments from the Bruce 'B' plant) will be transferred into the shaft cage directly by the heavy duty forklift. The Bruce 'B' steam drum segments will be placed in a cradle mounted on a rail car using the overhead crane.

Segments from the different steam generators will be handled as follows:

8.2.1.5.1 Pickering Steam Generators

Each steam generator will be cut into four segments. All the segments, including the wide steam drum can be placed with their diameters flat on the floor of the cage, which makes for simpler and quicker handling of these items.

The head end and main sections will be divided into three segments all having a diameter of 1.8 metres. The steam drum will form a single segment of diameter 2.5 metres. The proposed sectioning is shown in Figure 8-1 with dimensions given in Table 8-6. There are 48 Pickering steam generators yielding 192 segments.

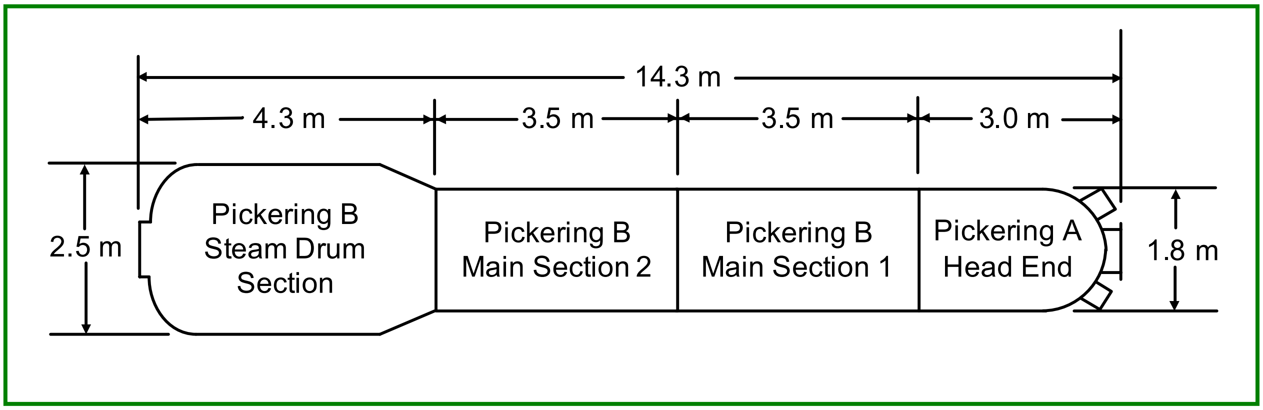


Figure 8-1 – Steam Generator Segments for Pickering

8.2.1.5.2 Bruce 'A' Steam Generators

These steam generators will be cut into five pieces. All the segments will be transported in the cage with the cut faces flat on the cage floor.

The head end has a slightly larger diameter (estimated at approximately 2.6m) than the main and tail sections. The head end of the steam generator will become one of the segments. The tail end and main sections will be divided into three segments all having a diameter of 2.4 metres. The proposed sectioning is shown in Figure 8-2 with dimensions given in Table 8-6. There are 32 Bruce À' steam generators yielding a total of 128 segments.

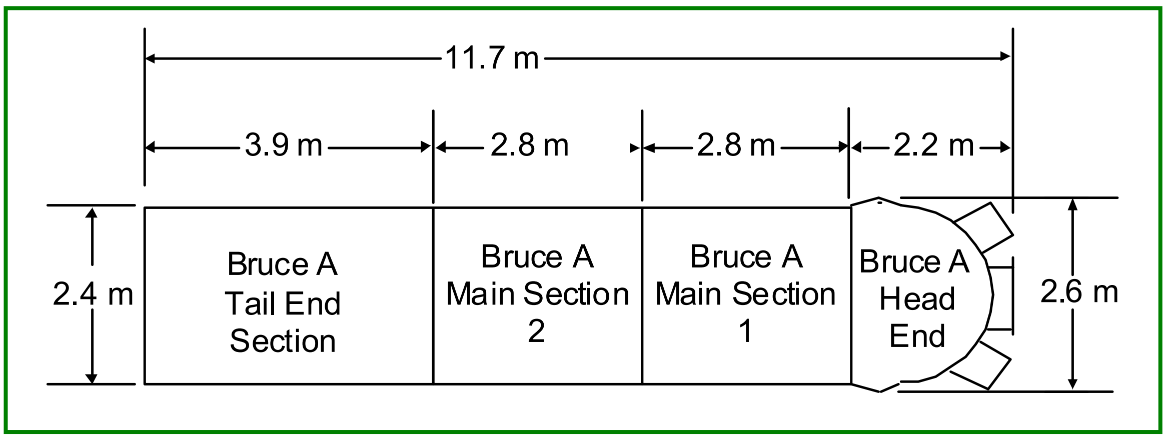


Figure 8-2 – Steam Generator Segments for Bruce 'A'

8.2.1.5.3 Bruce 'B' Steam Generators

Bruce 'B' has the largest steam generators, and will require cutting into six segments. The head and main sections have a diameter of 2.5 metres, and will be cut into one and three segments respectively. These segments will be able to be transported in the shaft cage flat on their cut faces. The steam drum will be cut into 2 segments with a large diameter of 3.6 metres, making those segments the only ones that will not fit in the hoist cage with the cut edge horizontal. There are 32 Bruce B steam generators yielding 192 segments, of which 64 will be large diameter steam drum segments.

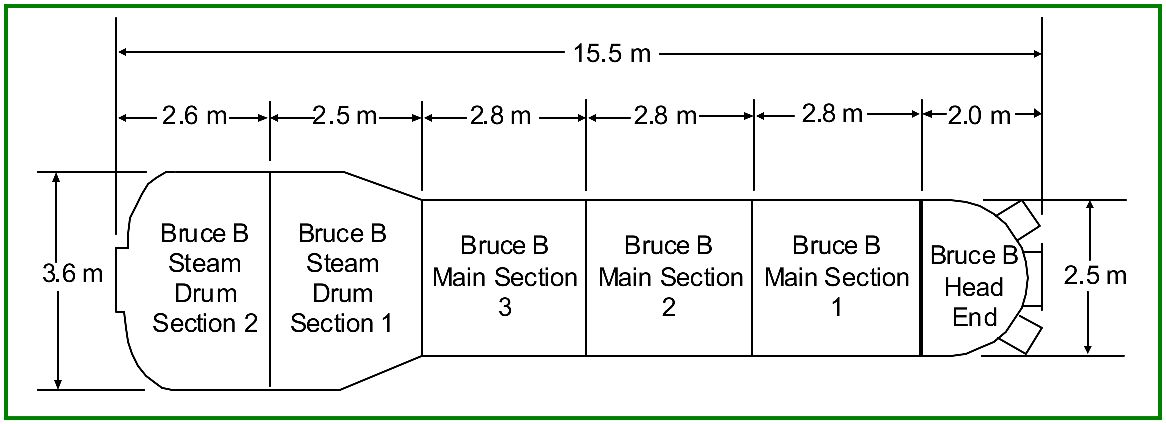


Figure 8-3 – Steam Generator Segments for Bruce 'B'

8.2.2 Intermediate Level Wastes

8.2.2.1 Resin Liners

The dose rates emitted by the resin liners vary and to optimise underground packing efficiencies while ensuring the waste package emissions do not exceed the WAC limits, five different configurations of package will be employed.

The first category (approximately 28.1%) of resin liners meets the dose rate limits in the DGR Waste Acceptance Criteria ([R77]), such that they can be emplaced without a shield. Stacking a high number of unshielded resin liners together could potentially cause a localised dose rate within an emplacement room to exceed allowable levels. To prevent such an event, large groups of unshielded liners will not be allowed to be stored next to each other. Instead, groups of unshielded liners will be separated by placing shielded liners in between them.

As given in the OPG Waste Inventory Report ([R76]), 400 resin liners, which are in carbon steel liners, have been placed in stainless steel overpacks.

The standard cylindrical concrete shield for resin liners will employ a 250 mm thick wall. This standard shield, in which two resin liners per shield will be stacked, will effectively handle 53% of the resin liners yielding a dose limit on the exterior of the shield of less than 2 mSv/hr.

The balance of the resin liners (19.1%) will require placement in cylindrical concrete shields with wall thickness greater than 250 mm to meet the dose limit. 364 of these (amounting to 13.4% of the total resin liner inventory) will be stacked two high in a 350 mm thick concrete shield. It should be noted that the total mass of this package will be 36 tonnes, which exceeds the waste package limit of 35 tonnes. However, the shaft cage payload limit is 40 tonnes and, therefore, an exception to this design criterion (see Section 3 above) will be allowed to obviate the need for a large number of additional single liner packages.

The highest dose rate liners (153 off or 5.7% of the inventory) will be placed in a shorter 350 mm thick concrete shield with a 40 mm thick steel insert. To limit the total mass to ensure that the hoist payload is not exceeded, only one liner will be contained in each of these shields.

Table 8-4 provides a summary of the various resin liner shield quantities.

Resin Liner Shield Required	Quantity of Resin Liners	
	Percentage	Number
No shielding required	28.1%	759
250 mm Concrete (2 liners per shield)	52.8%	1,436
350 mm Concrete (2 liners per shield)	13.4%	364
350 mm Concrete with Steel Insert (1 liner per shield)	5.7%	153

Table 8-4 – Resin Liner Shielding Requirements

Resin liners are currently stored in Quadricells and In-Ground Containers (IC's). The Quadricells are assumed to be disposal-ready. Lifting eyes will be installed in the shell container lid and the shell container will be lifted by the crane and placed on a sacrificial pallet on a low bed trailer adjacent to the Quadricell.

IC-12's are used to store four resin liners and IC-18's are used to store six resin liners. For the resin liners that require shielding, an overhead/mobile crane will recover them from the IC's and place them into the shields, with either a single or two liners placed in a vertical stack inside each shield. The shield, which will have embedded forklift pockets cast into the concrete, will be on a flat-bed trailer.

The shield will then be transported to the DGR, where it will be off-loaded by the heavy duty forklift, placed in the staging area and inspected to ensure the package meets the requirements for transfer underground.

For the liners that do not require shielding and weigh around 5 to 6 tonnes, a mobile crane will be used to lift them out of the in-ground containers and onto a sacrificial forklift pallet, where they will be secured by locking mechanisms built-into the pallet. A light duty forklift will then be used to load them onto the flat-bed trailer used to transfer them to the DGR. Similarly at the WPRB, a light duty forklift will be used for off-loading, placement in the staging area and transfer to the shaft cage.

Resin liners that are produced after the start of DGR Operations will be delivered directly to the WPRB, where they will be off-loaded using the overhead crane. Depending on their dose levels, they will either be transferred into the final disposal shield inside the building or if the dose rates are within the WAC limits, placed in the staging area for direct transfer to the shaft cage as is. An area in the WPRB will be designated to receive the resin liners and any other high dose rate packages. This area will be separated from the rest of the building by a concrete wall to provide protection for the workers from radioactive emissions, as described in Section 4.2.1.3.

8.2.2.2 IC-2 and IC-18 Tile Hole Equivalent Liners

Long tile holes are currently stored in in-ground IC-2's and IC-18's. The IC-2s contain one T-H-E liner and the IC-18s contain seven. The inventory is as defined in Table 8-5.

IC #	Diameter (m)	Length (m)	Quantity	No. of Liners per IC
2	0.6	7.6	20	1
18	0.55	10.7	444	7

Table 8-5 – T-H-E Liners Inventory

Since both liners are of a similar magnitude in terms of length, the preferred methodology for handling, transporting and disposing T-H-E liners is applicable to both liners.

The T-H-E liners will be retrieved from the appropriate IC, after grouting internally to stabilise the contents, utilising a shielded transfer bell as shown in Figure 8-4. The shielded transfer bell is designed to be positioned vertically, using an overhead crane, above the open IC. The T-H-E liner grappling tool, mounted through the top end cap of the transfer bell, will be lowered to engage the T-H-E liner to be retrieved. The T H-E liner will then be retracted into the transfer bell and the articulated bottom end cap closed. The transfer bell with the T-H-E liner inside will be rotated to the horizontal position and positioned and secured in the cradle of a custom-made "T-H-E Handler" rail car, which will already be mounted on a flat-bed truck, that will be used for transport to the WPRB.

Upon arrival at the shaft building, the transfer bell and "T-H-E Handler" will be lifted off the truck by an overhead crane and placed on the rails leading to the shaft cage.

The use of Disposable Shields (similar to the Resin Liners) was considered for the T-H-E Liners. On closer analysis, a disposable concrete pipe shield following this concept has a number of shortcomings which include:

- Insufficient shielding for a reasonable wall thickness to limit the loaded mass to within the shaft cage load limit of 40 tonnes;
- Poor structural integrity;
- No easily effective method for attaching lifting/handling equipment.

On this basis, the concept of a disposable shield for the T H E liners was not considered further and a re-useable shield concept was developed.

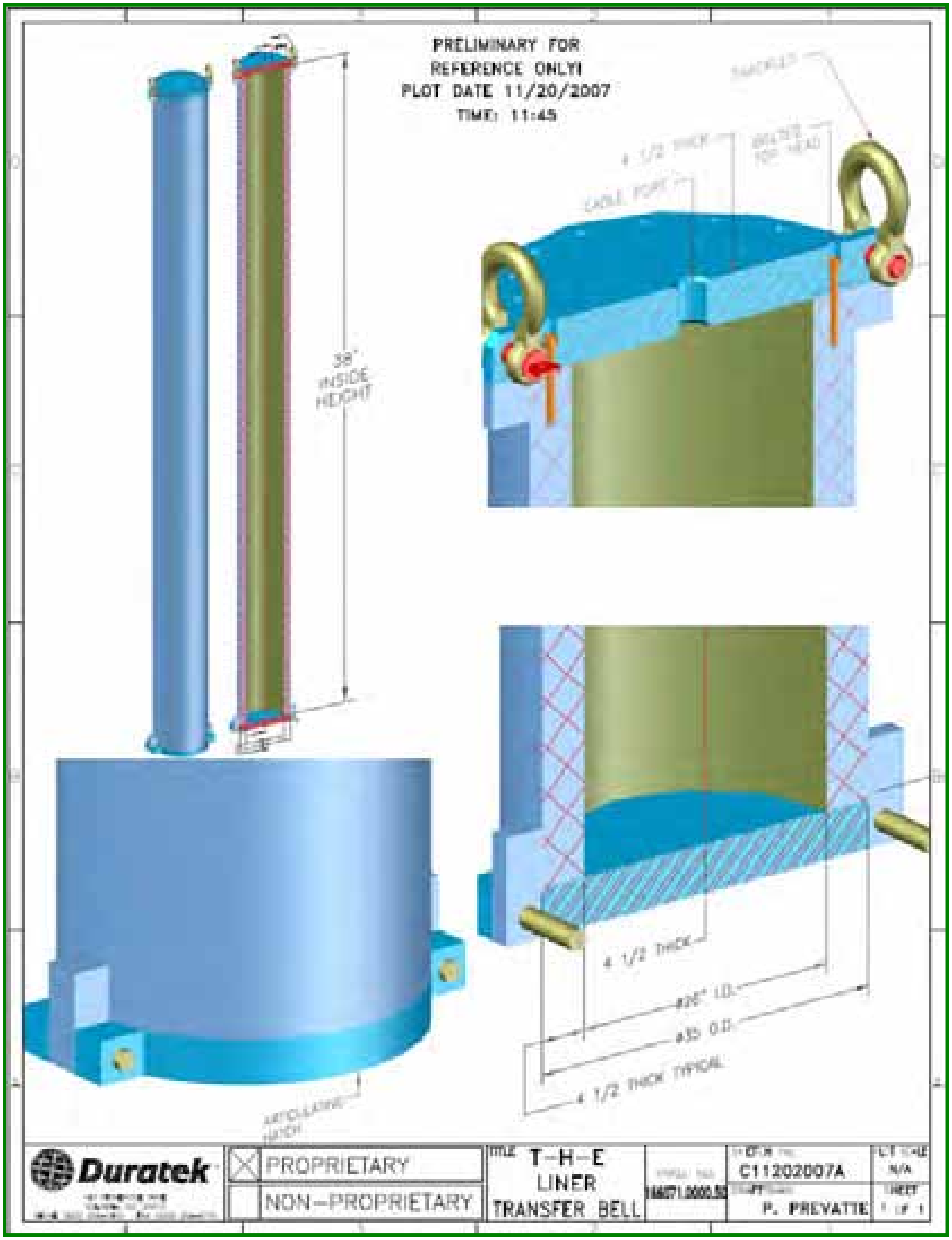


Figure 8-4 – Re-usable Steel Transfer Bell for T-H-E Liners

The mass of the transfer bell, loaded with the grouted T-H-E liner will be 32.3 tonnes for the IC-2 and 31.5 tonnes for the IC-18 Liners.

8.2.2.3 ILW Shields

After 2018, all tile-hole wastes, which are currently stored in IC-18s, will be disposed of in small, light concrete cylinders (1.0 m diameter x 1.7 m high with a full mass of 2,290 kg). These packages will be delivered to the WPRB by truck, where they will be off-loaded by a light duty forklift and placed in the staging area.

8.2.2.4 Tile Hole Liners

The tile hole liners are a steel tube, which have dimensions of 3.0 m long x 0.61 m in diameter. At the time of retrieval, grout will be added to these liners to stabilize the contents and to provide a shielding effect. The mass of the grouted line will be about 2 tonnes.

The tile hole liner is equipped with lifting brackets, which will be used to lift the container from the tile hole with a mobile crane. Because of the liners' small size, they will be placed horizontally on a rack at the WWMF, which will hold multiple liners for transfer. The racks will be loaded by light duty forklift onto flat-bed trailers for transfer to the WPRB, where they will be off-loaded by forklift and placed in the staging area for inspection.

8.2.2.5 Retube Waste Containers

Two types of containers will be used for the re-tube wastes: one, designated RWC(PT), for volume reduced components (pressure tube, calandria tubes, and calandria tube inserts); and one, designated RWC(EF) for uncut end-fittings. Conceptually, the boxes will be a steel-concrete-steel construction. The resultant waste packages will be heavy at a mass of between 26 and 30 tonnes.

On receipt at the WPRB, they will be off-loaded into the staging area from the transport truck by a heavy duty forklift.

8.3 Shaft Handling

8.3.1 Regular Packages

In terms of transport within the shaft, "regular" packages are considered to be all those that are of regular shape and can be simply placed in the cage directly on the decks using either light or heavy duty forklifts. The following packages fall into this category, and are sub-divided into two lists to differentiate between waste packages that are overpacked in the standard BINOPK, and waste packages that will be transferred underground as is:

8.3.1.1 Overpacked Waste Packages (in BINOPKs)

- Ash Bin (Old) - bottom ash AIBO2
- Ash Bin (New) - bottom ash AIBN
- Drum Rack - baghouse ash DRACK
- Ash Bin (new) - baghouse ash AIBN
- Low Level Resin Box (90") RB90
- ALW Sludge Box NPBSB

8.3.1.2 Waste Packages to be handled as is

- Compactor Box B25
- Bale Rack BRACK
- Drum Rack - non-processible drums DRACK

• Drum Bin	DBIN
• Non-Pro Bin (47" high)	NPB47
• Non-Pro Bin	NPB4
• Low Level Resin Pallet Tank	RTK
• Encapsulated Tile Hole	ETH
• Tile Hole Liner	THLSTG3
• Resin Liners	RL, RLOPK, RLSHLD
• ILW Shield	ILWSHLD
• Retube Waste (Pressure Tubes)	RWC(PT)
• Retube Waste (End Fittings)	RWC(EF)
• Retube Waste (Calandria Tubes)	RWC(PT)
• Retube Waste (Calandria Tube Inserts)	RWC(PT)

Due to the size and mass of the packages, various numbers can be transported in the shaft cage at any one time. Details of the number of packages that can be loaded into the shaft cage are given in Appendix D.

The ILW Shields will be placed onto the cage decks by the light duty forklifts. Twelve packages can be transported in the shaft cage per trip, three on each deck of the cage.

The Tile Hole Liners in their supporting cradles will be placed in the cage using a light duty forklift. 10-12 liners can be transported per trip of the cage. Since the cradles are stackable, up to four liners can be loaded onto each cage deck.

The Retube waste containers are heavy concrete encased wastes with masses up to 30 tonnes. Only a single item can be transported per cage trip. The waste package will be placed on the bottom deck of the cage using the heavy duty forklift.

The remaining packages (Shield Plug Containers, Heat Exchangers, Steam Generators, Resin Liners, IC-2 Liner and IC-18 T-H-E Liners) are special cases and are discussed in the following sections.

8.3.2 Shield Plug Containers

The Shield Plug Containers (SPC) are reasonably large and heavy at 26 tonnes. They are not stackable and must be handled using a crane.

To facilitate shaft transport, they will be loaded on rail cars in the WPRB using the overhead crane. A forklift will be attached to the rail car and be used to push the car into the cage. Only one SPC can be hoisted per cage trip.

8.3.3 Heat Exchangers

The Heat Exchangers (HX) will be loaded horizontally onto a custom-designed rail car in the WPRB using the overhead crane for transport in the cage. (This rail car will form part of the custom "T-H-E Handler" described below in Section 8.3.5.) A heavy duty forklift will be connected to the rail car to push it under control onto the cage deck. Depending on the mass of the heat exchangers, either one of two may be transported in each cage trip.

8.3.4 Encapsulated Tile Holes

The Encapsulated Tile Holes (ETH) will be loaded onto the bottom deck of the cage using a heavy duty forklift. Because of their mass, only one can be transported in the cage per trip. The height of the ETH is 4.6 metres. Since the cage decks have a vertical open space of only 3.25 metres, the hinged second deck will be raised and locked in a vertical position to create a high enough opening for the waste package.

8.3.5 Steam Generators

The internal dimensions of the conveyance are the defining restraints for the size of large/heavy segmented sections of the steam generators that can be handled. Table 8-6 illustrates the relationship of the conveyance dimensions to the size of the segmented sections, and the position that the pieces must be in to ingress and egress from the conveyance.

The masses and dimensions account for the attachment of steel plates to seal the cut ends and forklift pockets. The dimensions shown in Figure 8-1, Figure 8-2 and Figure 8-3 are the basic cut lengths and do not include the sealing plates and forklift pockets.

Item	Length (m)	Height (m)	Width (m)	Mass (tonnes)	Positioning in Conveyance (see Notes)
Conveyance Limits	5.20	13.50	2.65	35.0	Note 1
Pickering Head	Ø 1.80	3.17	Ø 1.80	25.5	Horizontal
Pickering Main	Ø 1.80	3.74	Ø 1.80	26.3	Horizontal
Pickering Steam Drum	Ø 2.50	4.46	Ø 2.50	27.4	Horizontal
Bruce A Head	Ø 2.60	2.37	Ø 2.60	33.7	Horizontal
Bruce A Main	Ø 2.40	3.01	Ø 2.40	26.4	Horizontal
Bruce A Tail	Ø 2.40	4.12	Ø 2.40	35.0	Horizontal
Bruce B Head	Ø 2.50	2.27	Ø 2.50	35.0	Horizontal
Bruce B Main	Ø 2.50	2.99	Ø 2.50	30.5	Horizontal
Bruce B Steam Drum	Ø 3.60	Ø 3.60	2.66	33.9	Vertical

Table 8-6 – Steam Generators Dimensions/Mass Summary

Notes to Table 8-6:

1. The conveyance (cage) limits represent the dimensional envelope available for waste packages, including transfer cars, supports, cradles and rigging. The actual internal cage dimensions are 200 mm larger on the two plan axes and 500 mm larger on the height. These allowances allow for manoeuvring loads into and out of the conveyance safely.
2. A vertical position means the sealed surface of the segmented piece is vertical.
3. A horizontal position means the sealed surface is horizontal.
4. "Ø" indicates diameter.
5. Masses include grout, end plates (2,311 kg each) and forklift pockets (500 kg/set) and dimensions include sizes of end plates (65 mm each) and forklift pockets (100 mm), where relevant.

8.3.5.1 Handling Attachments

Notes 2 and 3 of Table 8-6 differentiate between the two orientations of the segmented pieces in the conveyance. The orientation also affects the types of attachments as described below.

8.3.5.1.1 Horizontal Segment Handling Attachment and Emplacement

The 'horizontal' segment can be moved by a heavy duty forklift and set inside the shaft conveyance on the cage deck with the cut line horizontal.

The base of the 'horizontal' segments will be outfitted with forklift pockets, which will be designed to not only withstand the loads imposed during lifting and handling, but also the loads due to stacking of segments in the emplacement rooms. These pockets will be welded to the bottom seal plate in the fabrication workshop. The assembly will be stress-relieved and machined if necessary to remove any distortion caused during welding before it is welded to the segment. Although the steam generator tubes are not expected to exhibit any appreciable dose rates on any external surfaces, this method will also limit potential exposure time should dose rates of the segments exceed safe levels.

This category represents all but 64 segments of the steam generators in the waste inventory.

8.3.5.1.2 Vertical Segment Handling Attachments and Emplacement

The 'vertical' segment handling attachments are defined in Figure 8-5, which depicts a three dimensional view of a 'vertical' segment positioned in the shaft conveyance. With the previous cage dimensions, only the main and head end sections of the Pickering steam generators could have been accommodated in the cage flat on their cut ends. With the larger cage, only the steam drum portions of the Bruce 'B' steam generators will need to be transported vertically in the cage.

These 'vertical' segments will require the addition of vertical lifting lugs. Although the Bruce 'B' steam drum segments will only have a theoretical mass of about 30 tonnes, the lifting lugs will be designed for the 35 tonne cage load limit to provide an added factor of safety against possible increases in mass due to unknown factors in the construction and processing of the generators. The lugs and forklift pockets should be installed prior to segmentation for ALARA reasons.

After being inspected and accepted, the segment will then be placed onto the deck of the shaft cage by a heavy duty forklift.

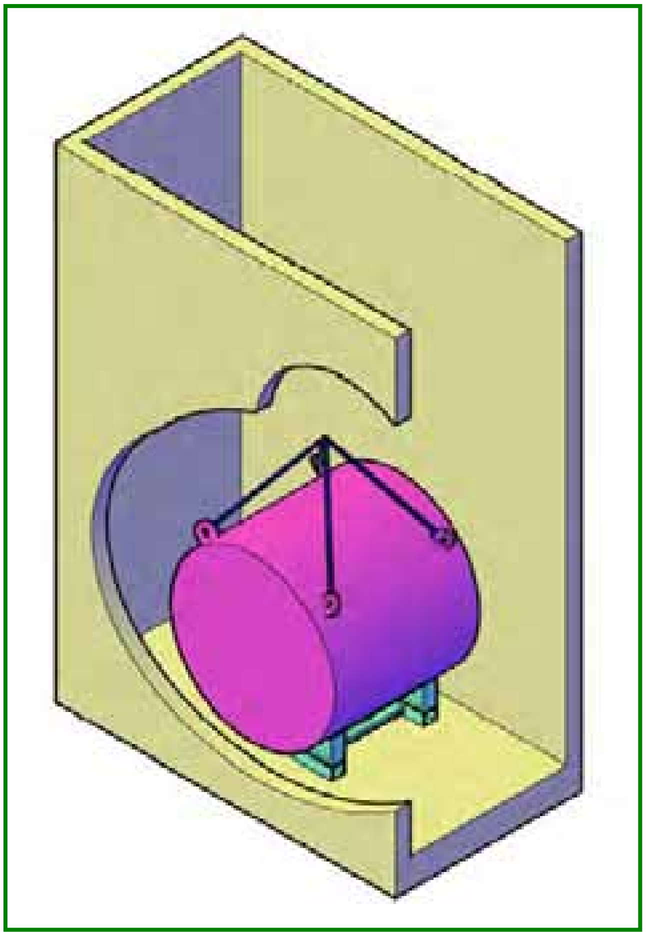


Figure 8-5 – Shaft Cage Handling of Vertical Steam Generator Segment

8.3.6 Resin Liners

The unshielded ad overpacked resin liners (types D2 & D3) are relatively low in mass (< 6 tonnes). Up to six of these packages can be transported in the cage per trip. They would be moved into the cage by the light duty forklift.

Only one concrete shielded resin liner waste package can be transported per cage trip due to the heavy mass of the loaded shield. They will be loaded into the cage by the heavy duty forklift. For the double liner shields (types D4 & D5), the hinged second cage deck would be raised vertically to accommodate the height of the package, similarly to the ETH's. The single liner shield would fit in the first deck of the cage without the need for raising the second deck.

8.3.7 IC-2 and IC-18 Tile Hole Equivalent Liners

These waste packages will be transferred on a custom designed "T-H-E Handler", whose primary purpose is to rotate the 11.8 m long T-H-E packages from an horizontal to vertical position for shaft transfer to the repository depth and then back to horizontal for transfer to an emplacement room. It will consist of two rail cars. One of the rail cars will be 5 metres long and designed to fit into the shaft cage. This rail car will be equipped with a cradle to support the T-H-E in its re-usable shield, connected to hydraulic cylinders, which can rotate the assembly from the horizontal to the vertical. The second rail car will be 7 metres long and will be connected to the first car to provide full length support to the shield bell during horizontal transfer.

At the WPRB, the hydraulic cylinders on the "T-H-E Handler" will rotate the shield bell to the vertical position. The longer rail car will then be removed to enable the "T-H-E Handler" and transfer bell to be moved into the shaft cage. As the full height of the cage will be used to fit the vertical-orientated transfer bell on its rail car support, the intermediate cage decks will be hinged to allow a section of each to be raised to create the 14 metre clear height. Once in position in the cage, the T-H-E shield will be clamped to each intermediate deck to ensure stability during the cage descent. To the repository horizon.

The steps in lowering the T-H-E shield to the horizontal are shown schematically in Figure 8-12. The process used on surface in the WPRB is a reverse of this procedure.

8.4 Underground Transfer and Emplacement in Rooms

At the underground shaft station, all packages will be off-loaded from the cage and, with the exception of items which are transported singly in the cage, will be placed in the staging area next to the shaft station (see Drawing 323874DGR-200-003 in Appendix E). This will enable the cage to be off-loaded relatively quickly and allow it to return to surface for another load while the off-loaded packages are being moved to their emplacement rooms.

For the standard "Group A" waste packages, Table 4-5 in Section 4.5.3.5.2 defines the room size and the emplacement room South Panel is detailed in Drawing 323874DGR-200-005 in Appendix E. For the ILW and non-standard LLW waste packages, Table 4-6 in Section 4.5.3.5.3 defines the room sizes and contents, with details being shown on Drawing 323874DGR-200-006.

8.4.1 Standard Packages

Standard packages refer to all the LLW items that will be emplaced in the South Panel of the underground repository.

At the shaft station, these packages will be removed from the decks of the cage using a light or heavy duty forklift as is appropriate to their mass, and placed in the staging area.

Figure 8-6 – 10 Tonne Capacity Forklift Off-loading a Cage

Once the cage is fully unloaded, the forklifts will transfer the packages to the emplacement rooms.

As the emplacement rooms within the "South Panel" have the same cross-sectional dimensions, there is versatility to mix up different types of the standard LLW packages within any one room.

However, to maximise the use of available space within the rooms, each row of packages should ideally only contain one type of package. This will be achieved during the planning of the transfer process. To provide some leeway in the transfer planning, it is envisaged that up to three rooms may be open at any one time to allow an incomplete row in one room to be filled when that package type is next transferred from the WWMF.

The different sizes of packages in the "Group A" list of LLW bins and racks is:

- 2.54 m long x 1.78 m wide x 1.88 m high (3,141 packages – all in BINOPK)
- 1.84 m long x 1.12 m wide x 1.30 m high (5,298 packages – Compactor Boxes)
- 2.29 m long x 1.22 m wide x 1.20 m high (4,154 packages – Bale and Drum Racks)
- 1.96 m long x 1.32 m wide x 1.03 m high (3,317 packages – Drum Bins)
- 1.96 m long x 1.32 m wide x 1.19 m high (20,327 packages – Non-pro Bins)
- 1.24 m long x 1.24 m wide x 1.68 m high (1,993 packages – LL Resin Pallet Tanks)

Stacking arrangements for these various size packages within the emplacement rooms is shown in Figure 8-7. Because the compactor boxes, drum bins and non-pro bins are all very similar in size, these are all shown on the same cross-sectional view of a row of packages in the drawing.

8.4.1.1 LLW Container Overpacks

The containers that are to be overpacked are the Ash Bins, ALW Sludge Boxes, Low Level Resin Boxes and about 10% of the drum racks. The overpacks can be stacked 3 packages high in the LLW emplacement rooms.

There may also be several shielded overpacks used to contain the LLW packages that have higher than acceptable dose rates. Since the shielded overpacks will be thicker, they would only be stacked 2 high.

8.4.1.2 Drum Racks and Bale Racks

OPG are currently assuming that 10% of the drum racks will need to be overpacked for emplacement, but the remaining 90% can be stored in the LLW emplacement rooms in stacks 5 racks high. Since bale racks and drum racks are essentially the same, the two package types can be stacked together provided the heavier drum racks are on the bottom. The structure of the racks is such that other packages cannot be stored on top of them. These two packages can also be stacked with old-style non-pro bins (NPB4).

8.4.1.3 Compactor Boxes

Compactor boxes can be stacked 5 high in the LLW emplacement rooms. With some exceptions, compactor boxes are designed to be stackable with each other.

8.4.1.4 Drum Bins

Drum bins can be stacked 5 high in the LLW emplacement rooms. The bin tops have lids and can be stacked with new style non-pro bins (NPB47).

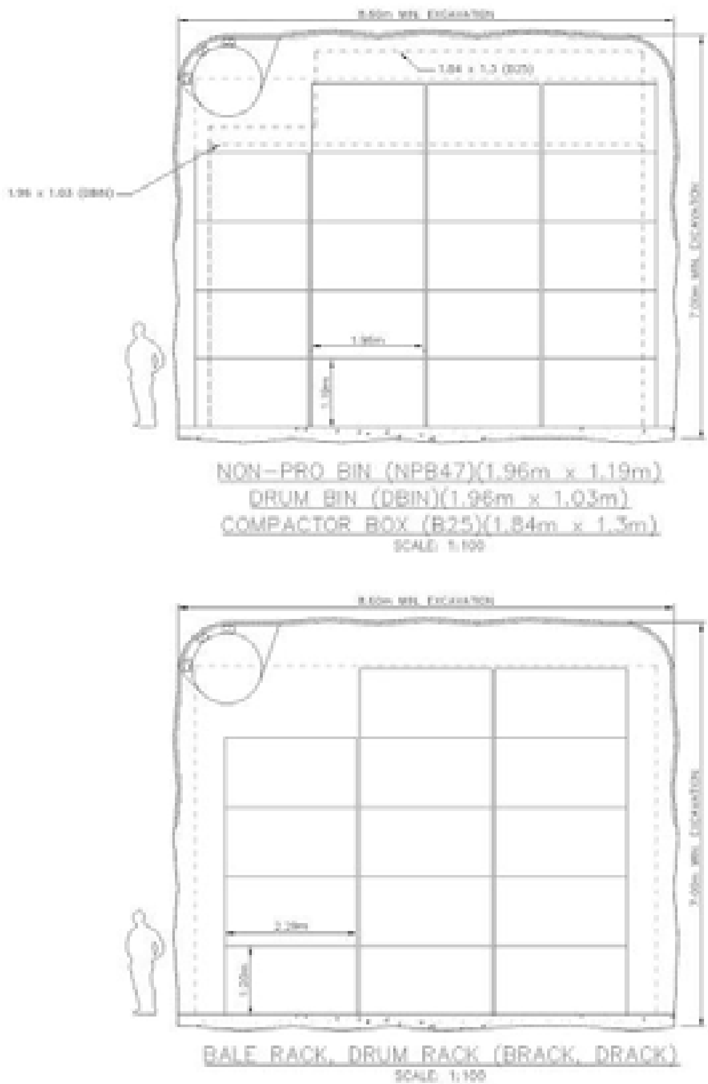


Figure 8-7 – Stacking Arrangements for Standard LLW Packages

8.4.1.5 Non-Pro-Bins (47" high NPB47)

For the purposes this design study and for sizing of the emplacement rooms, it was assumed that the NPB4 bins had the same dimensions and features as the NPB47 bins (see Table 8-3).

Non-Pro (non-processible) bins can be stacked 5 bins high in the LLW emplacement rooms. The new style non-pro bins can be stacked with drum bins as the corner posts provide the structural strength and both package types have the same basic design and plan dimensions using corner posts. Non-Pro Bins will be covered with lids, which are not structural members, so other waste packages cannot be stacked on top of these lids.

8.4.1.6 Low Level Resin Pallet Tanks

Low level resin pallet tanks can be stacked 3 high in the LLW emplacement rooms. They have an open top, but a cage-like structure surrounding it so they should not be stacked with other package types.

8.4.2 Heat Exchangers and Shield Plug Containers

The heat exchangers and shield plug containers will be transported on rail cars in the cage.

On arrival at the shaft station, the package on its rail car will be hooked up to the heavy duty forklift and pulled out of the cage and straight to the emplacement room in the "East Panel".

At the emplacement room, they will be lifted off the rail car by the gantry crane and stacked on the floor of the room. Heat exchangers will be stacked in pyramid-shaped pile 2 high (a row of 3 on the emplacement room floor and a row of 2 sitting on top).

It is not possible to stack Shield Plug Containers due to their mass (26,000 kg) and shape of the container. The top of the container is not flat, so smaller boxes cannot be stacked on top of them. Since there are only nine of these packages, these stacking limitations will, therefore, have minimal effect on the overall packing efficiency of the DGR.

Drawing 323874DGR-200-015 and Figure 8-8 show the typical arrangement of these two packages in the emplacement room. Although this figure shows a single room, to optimise use of underground space, these items will be emplaced in a portion of one of the T-H-E rooms (see Section 8.4.6).

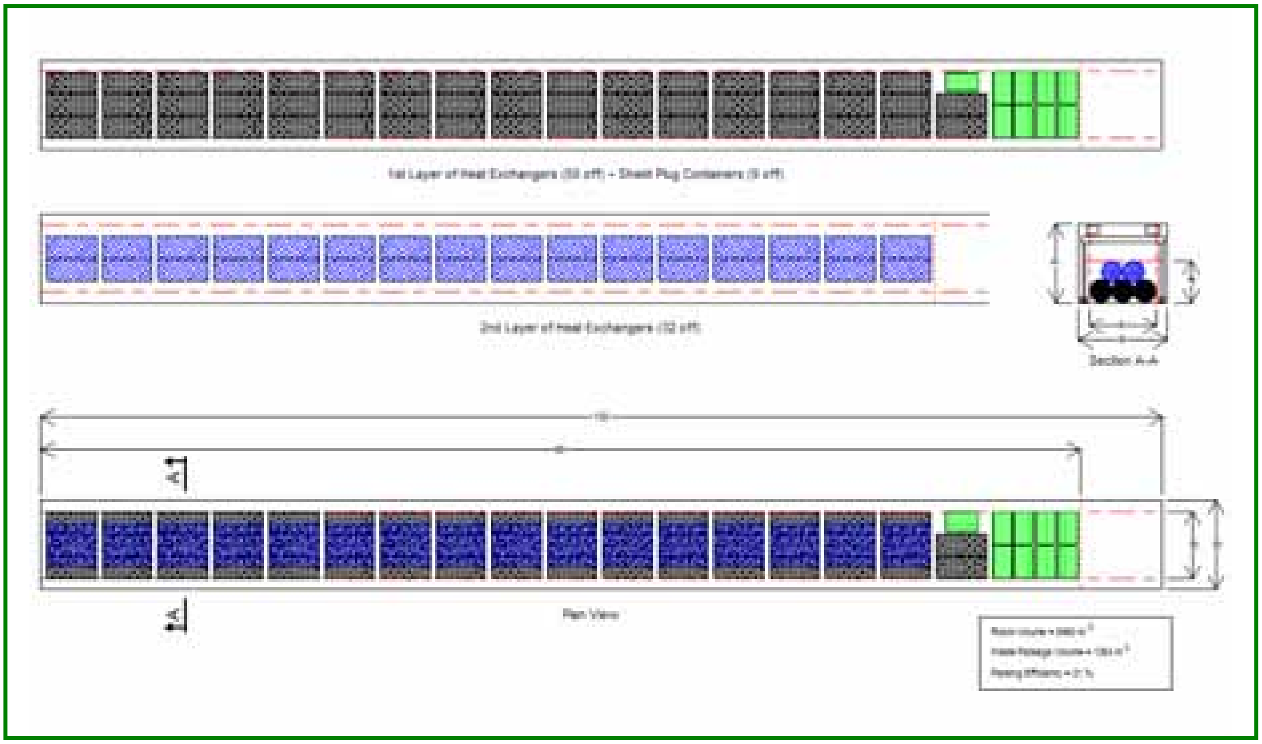


Figure 8-8 – Arrangement of Heat Exchanger and Shield Plug Container Emplacement

8.4.3 Steam Generators

At the shaft station, the largest steam drum segments from the Bruce 'B' plant, that have been transported on a support saddle in the shaft cage, will be re-oriented to the horizontal position by a monorail hoist so that a sealed face is in the horizontal position facing downward. The transport saddle will be returned to the surface in the conveyance for reuse. Due to its very large diameter (3.6 metres), the segment will be placed on a rail car and pulled by the heavy duty forklift to the emplacement room where it will be off-loaded and stacked by the forklift.

The other steam generator segments, which are transported in the cage on their flat cut ends, will be transferred to the emplacement rooms directly from the cage by the heavy duty forklift.

Stacking within the rooms will be one or two high depending on the height of the particular segments. The longer Bruce 'A' tail end segments and Pickering head end segments will not have any other segment stacked on top of them. All other segments will be stacked two high. Apart from some of the Bruce 'B' and Pickering segments, the rows of segments will be set at an angle of 53° to the room axis to optimise use of space and improve packing efficiencies, as indicated in Table 8-7. A typical arrangement of stacking within a room is shown in Figure 8-9.

Source	Diameter (m)	No. of Segments @ Diameter	Row Axis (deg.)	No. per Row	Row Centre Lines (m)	No. of Rows
Bruce A	2.4	96	53	3	2.7	11
Bruce A	2.6	32	53	3	2.7	6
Bruce B	2.5	128	53	3	2.9	22
Bruce B	3.6	64	90	2	3.59	11

Pickering	1.8	144	90	3	1.9	32
Pickering	2.5	48	53	3	2.7	16

Table 8-7 – Emplacement Room metrics for Steam Generator Segments

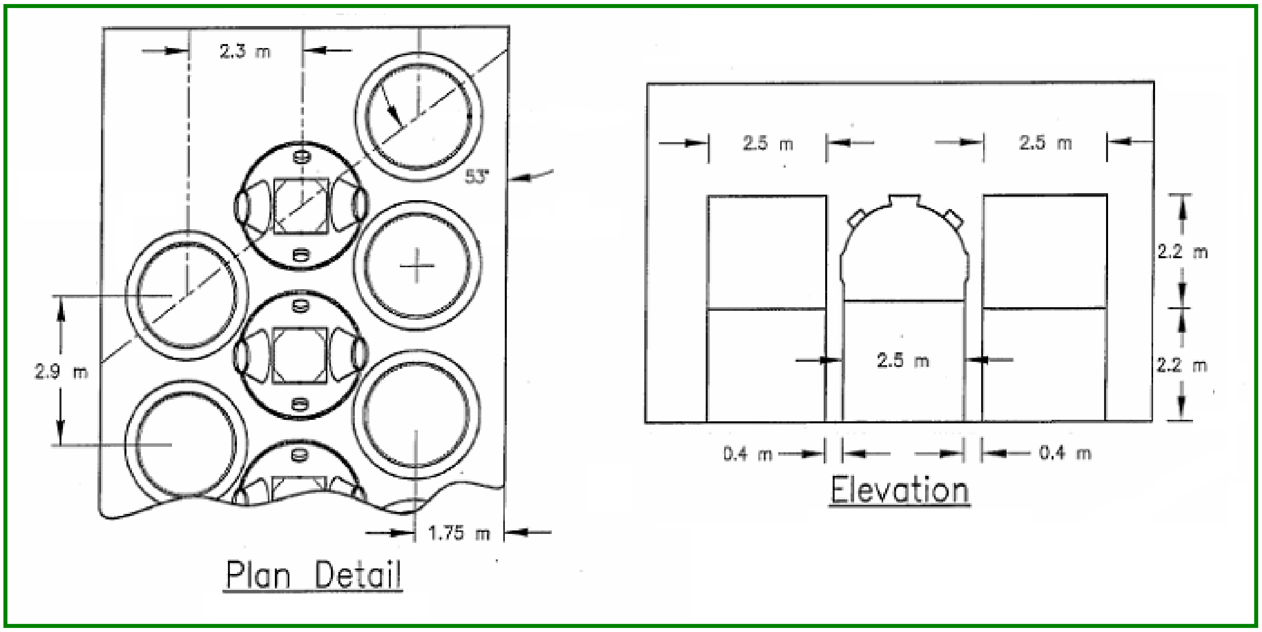


Figure 8-9 – Typical Layout of Steam Generator Segments in Emplacement Room

Two rooms will be required for the steam generator segments. One will be dedicated and the other will also store the encapsulated tile holes and tile hole liners (see Section 8.4.4).

8.4.4 Encapsulated Tile Holes and Tile Hole Liners

Encapsulated Tile Holes (ETH) are large (4.6 metres high), heavy, cylindrical packages. As they will be emplaced on their ends, nothing will be stacked on them. Stacking in emplacement rooms will be achieved in a similar manner to the resin liner shields that contain two liners each (see Section 8.4.5).

The Tile Hole Liners are smaller cylinders than the Resin Liners or the Encapsulated Tile Holes, and therefore there is more flexibility in the method of emplacement. However, because of their slender aspect ratio (ratio of 5:1), they will be placed on a rack that holds either 2 levels of 2 liners per level or 1 level of 2 liners for transfer in the cage. These racks will be off-loaded at the shaft station and transferred directly by the forklift to the emplacement room.

In the emplacement rooms the racks will be stacked 3 high (2 double level racks and 1 single level rack) for a total stack height of 5 Tile Hole Liners.

These two packages will be stored in the same room.

Drawing 323874DGR-200-013 and Figure 8-10 show the typical arrangement of these two packages in the emplacement room. Although this figure shows a single room, to optimise use of underground space, these items will also be disposed in a room with some of the steam generator segments (see 8.4.3).

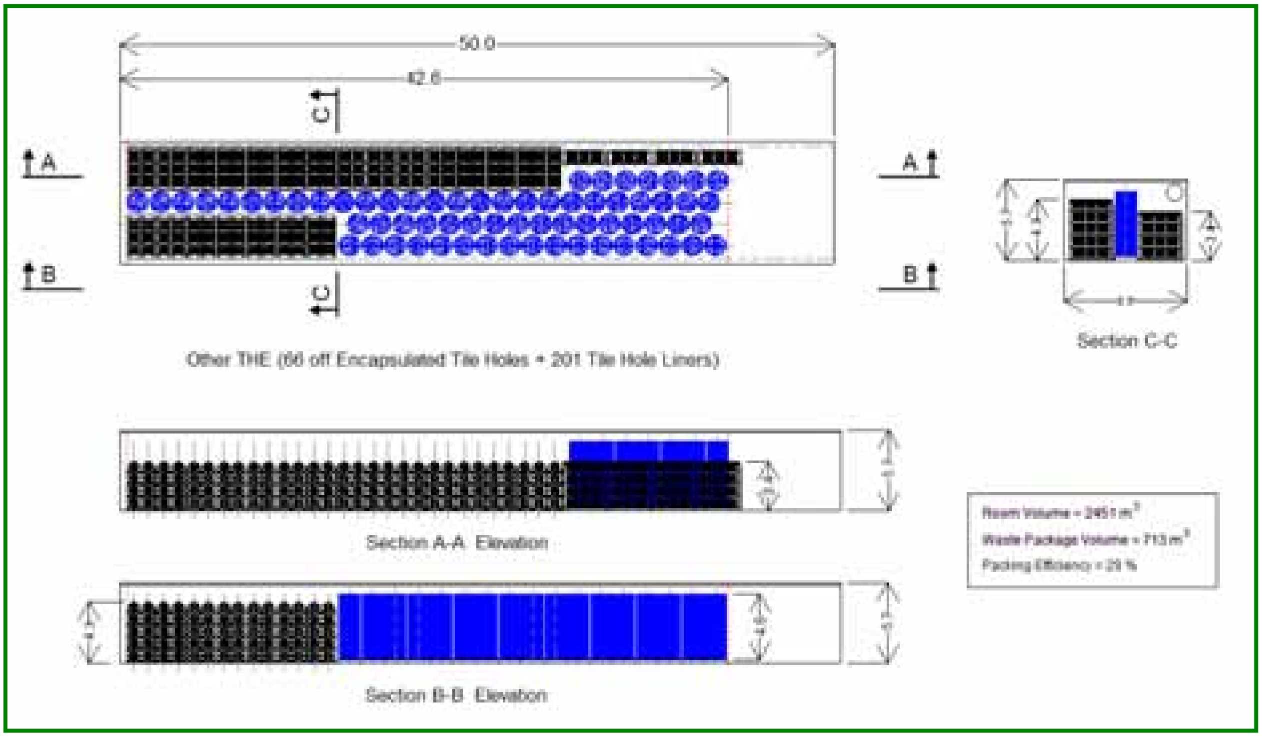


Figure 8-10 – Arrangement of THLSTG3 and ETH Emplacement

8.4.5 Resin Liners

The 250 mm and 350 mm concrete encased resin liners shields will only be transported one per cage trip. They will be off-loaded at the shaft station by the heavy duty forklift and transferred directly to their emplacement room.

The cage will have a capacity for 6 or 5 of the unshielded carbon-steel-overpacked resin liners and unshielded stainless-steel-overpacked resin liners, respectively, which will be individually loaded onto different decks of the cage, but not stacked. On arrival at the station, these packages will be off-loaded into the staging area by a light duty forklift, before being taken to the emplacement room.

While on an individual basis the unshielded resin liners can be handled and emplaced in the DGR without employing shielding, the accumulation of a number of these resin liners in a relatively small area within the confines of the repository room can, potentially, result in a dose field that exceeds repository limits. This will be easily mitigated by staging placement to permit placing several rows of unshielded resin liners followed by placement of one or more rows, of shielded resin liners (higher dose rate liners inside the standard cylindrical concrete shield) to provide area shielding for the unshielded resin liners.

The 52.8% of liners that fit in the 250 mm thick concrete shell and 13.4% that fit in the 350 mm thick concrete shell will be stacked 2 high inside each shield. The highest dose liners (5.4%) require much heavier shields which would be too heavy to meet the Design Requirements (see Section 3 above) or the maximum hoisting load, so they will have to be stored in shorter shields. These shorter shields will have unshielded resin liners stacked on top of them. The resin liners that do not require any amount of shielding will be stacked two high in the emplacement rooms.

Each resin liner concrete shield is 2.2, 2.4 or 2.53 metres in diameter and either 4.25, 4.45 or 2.74 metres high. The shields containing two resin liners will be placed in the ILW emplacement room one level high, except for the unshielded and single-liner shields, which will be placed two high.

Three resin liner concrete shields will be placed across the width of the ILW emplacement room, although the resin liners with no shields are small enough to be placed 4 across the room. They will be stored in a somewhat staggered fashion to maximise use of floor area in the emplacement room.

Drawing 323874DGR-200-014 and Figure 8-11 provides diagrams of the plan and sectional views of the resin liner concrete shields in the ILW emplacement room, which yields a packing efficiency of about 42%.

The shields containing two resin liners will be placed in the ILW emplacement room one level high, while the 350 mm thick single-liner shield with steel insert, unshielded resin and overpacked resin liners will be stacked tow high. Only three resin liner shields can be placed across the width of the ILW emplacement room, although unshielded resin liners can be placed four across. Utilising a somewhat staggered approach to placement, a total of 312 resin liner shields can be placed in an ILW emplacement room. This placement arrangement is based upon a clearance of 50 mm between adjacent resin liner shields on both the X and Y axis. Minimum clearance from the back wall of the ILW emplacement room to the back row of resin liner shields is 500 mm. Minimum clearance from the ILW emplacement room side wall to resin liner shields is 300 mm.

All but 30 of the resin liners will be disposed in six rooms. The remainder will be placed at the front end of one of the T-H-E rooms.

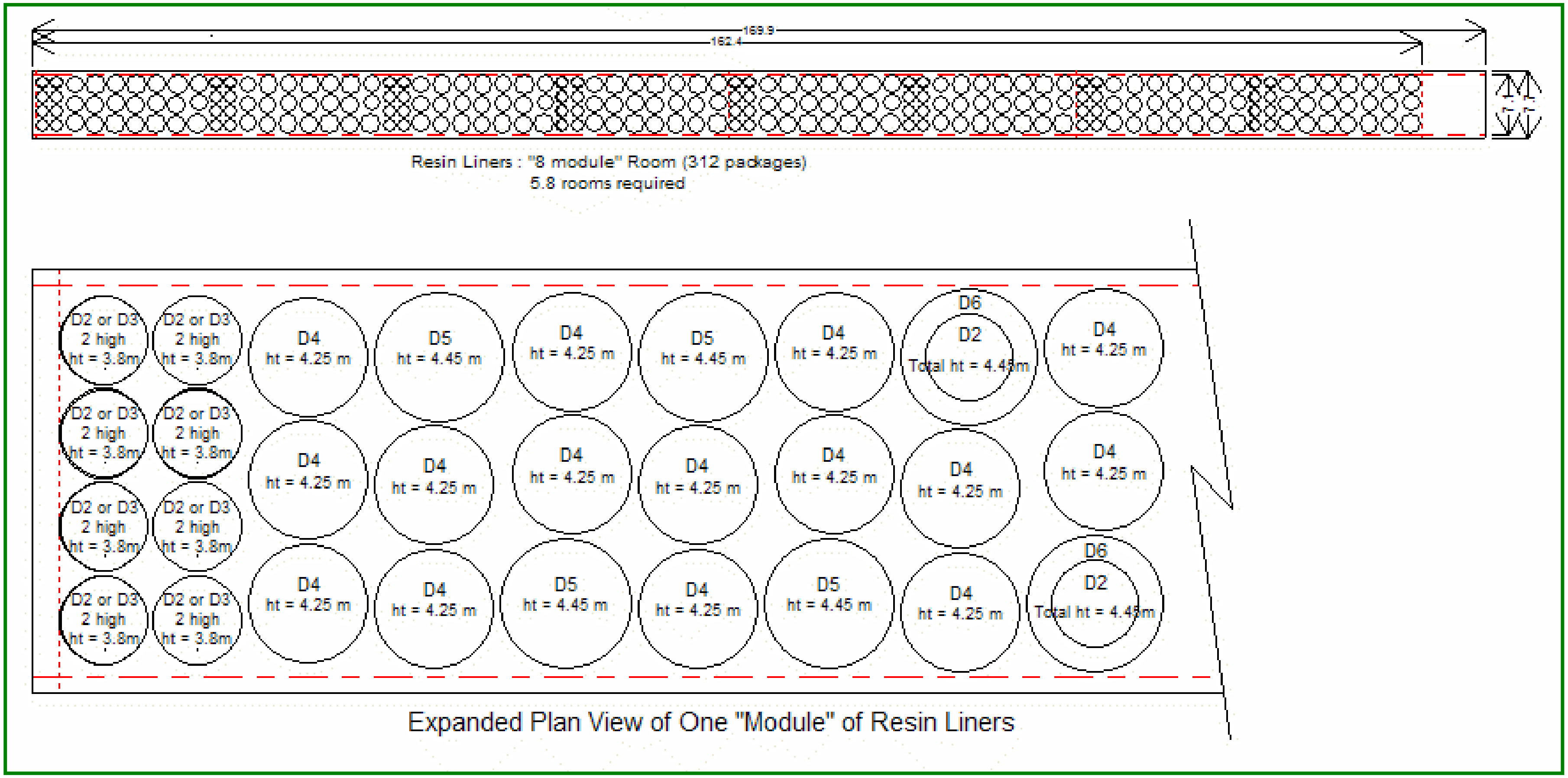


Figure 8-11 – Resin Liner Emplacement Room Arrangement

8.4.6 IC-2 and IC-18 Tile Hole Equivalent Liners

Upon arrival at the repository horizon, the transfer bell on its "T-H-E Handler" rail car will be pulled out of the cage by a heavy duty forklift and rotated to the horizontal for transport to the designated emplacement room. The forklift will be used as a "mule" to pull the T-H-E loaded handler to the emplacement room.

The size of the packages will require two custom-designed rail cars that work in tandem to achieve this rotation in a safe and controlled manner. The rotation will be done using a specially designed cradle that would hold the waste package securely. The cradle will be mounted to a pivot system with an hydraulically powered lifting and lowering mechanism. The shorter rail car will hold the cradle, the other car will contain the hydraulic system.

During the rotation phase or for horizontal transfer of the T-H-E packages, the two cars will be hooked up together to provide a stable base. At the repository level station, the hydraulic system car will be connected to the cradle car and the T-H-E package will be lowered onto both cars for transport to an emplacement room. The T-H-E Handler would be pulled into the emplacement room by the heavy-duty forklift, where the gantry crane will off-load and place the T-H-E package in its re-usable shield into an emplacing machine, which will push the T-H-E out of the shield and into a concrete pipe array followed by a concrete plug to fully seal up the radioactive waste package. There is adequate width (6.0 metres) in the room to allow the gantry crane to lift the T-H-E transfer bell off the T-H-E Handler rail car and move it laterally from the room centre-line and past the 2.14 m wide forklift.

Guides will be incorporated in the shaft station layout to ensure that the T-H-E package can only rotate along one plane with absolutely no chance of tipping-over.

Figure 8-12 provides a schematic showing the stages in rotation of the T-H-E liner from the vertical to the horizontal at the shaft station.

The designated emplacement rooms will be equipped with horizontal arrays of T-H-E disposal tubes using pre-cast reinforced concrete pipes surrounded by mass concrete to create the necessary permanent shielding. Each horizontal array will permit disposal of 30 T-H-E liners in 0.69 metre diameter x 11.8 metre long holes created by the reinforced concrete pipes. In one room there will be 11 arrays, which will contain 330 T-H-E liners and in the second room only 5 arrays will be required to dispose of the remainder of the liners. The unused length in that room will be used for the heat exchangers and shield plug containers. The T-H-E array arrangement is shown in Drawing 323874DGR-200-015 in Appendix E.

Each array will be constructed by first building a steelwork lattice on which the pipes can be positioned, after which the front of the array will be shuttered and mass concrete poured into the void outside the pipes to provide stability and additional shielding to limit the "shine" dose from the accumulated assembly. The concrete caps, which will close the holes once the T-H-E liners have been pushed out of the transfer bell and into the pipe array, will be 300 mm thick to ensure that contact dose rate on the outside of the concrete array does not exceed 2 mSv/hr and that the 1 metre dose rate does not exceed 0.1 mSv/hr. This arrangement will provide adequate protection for the construction workers, who will build the next adjoining array.

A hydraulic powered positioning/placement frame similar to the "Horizontal Emplacement and Retrieval Equipment" used at the Waste Isolation Pilot Plant in New Mexico (HERE), will be positioned at the face of the horizontal array. The device will be mounted on a separate platform, which can be raised to align the ram with the hole in the array, into which the T-H-E is to be loaded.

The shielded transfer bell will be placed in a horizontal position in the positioning/placement frame by the room gantry crane and the frame will be aligned in front of the horizontal tube designated to receive the T-H-E liner. Shielding collars will be located at the transition from the positioning frame to the face of the emplacement array and at the rear of the shielded transfer bell. A hydraulic placement cylinder (or ram) will be aligned at the rear of the shielded transfer bell and the end cap of the shielded transfer bell removed to permit insertion of push rods between the hydraulic cylinder and the T-H-E liner. The hydraulic ram will push the T-H-E liner into the tube. Additional push rods will be utilised to push the T-H-E liner completely into the disposal tube and the disposal tube will finally be closed with a concrete cap.

The ram will be about four metres long and would be extended twice during the emplacement process. In this way the overall length of the rooms will not have more than 20 metres length, which cannot be used for T-H-E liners. The unused space in the first room, which will have 11 arrays, will be filled with the remainder of the Type D6 resin liners, which will be left over from the dedicated resin liner rooms. In the second room, only five arrays are required and, as stated above, this room will also be filled with the heat exchangers and shield plug containers.

The shielded transfer bell will be returned to surface to repeat the cycle with another T-H-E liner. Schematics of the arrangement and emplacement machine are shown in Figure 8-13 and Figure 8-14.

Each horizontal array will be constructed, loaded with T-H-E liners and closed prior to constructing a subsequent horizontal array.

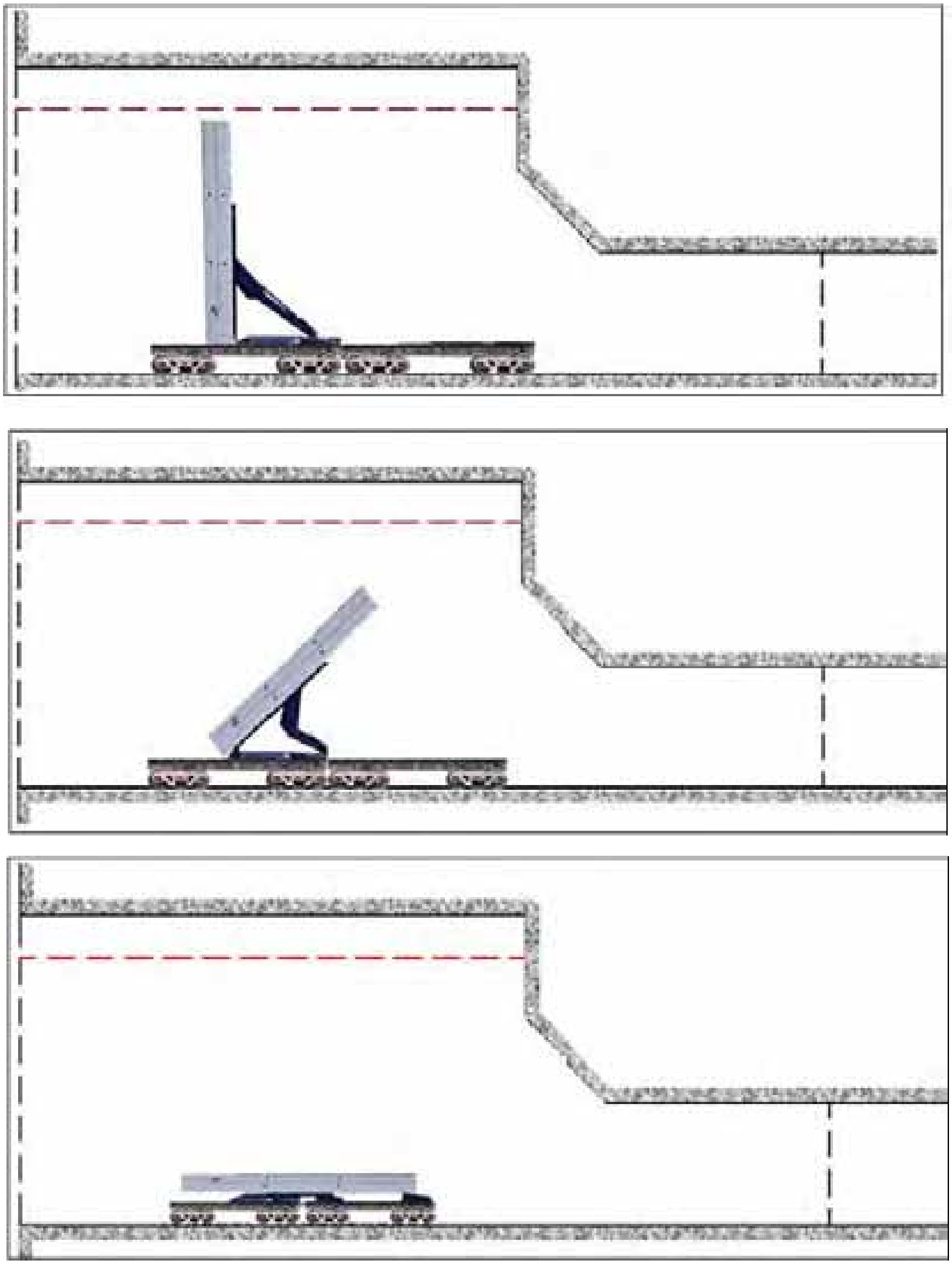


Figure 8-12 – Schematic of rotating loaded T-H-E Transfer Bell to Horizontal for Level Transfer

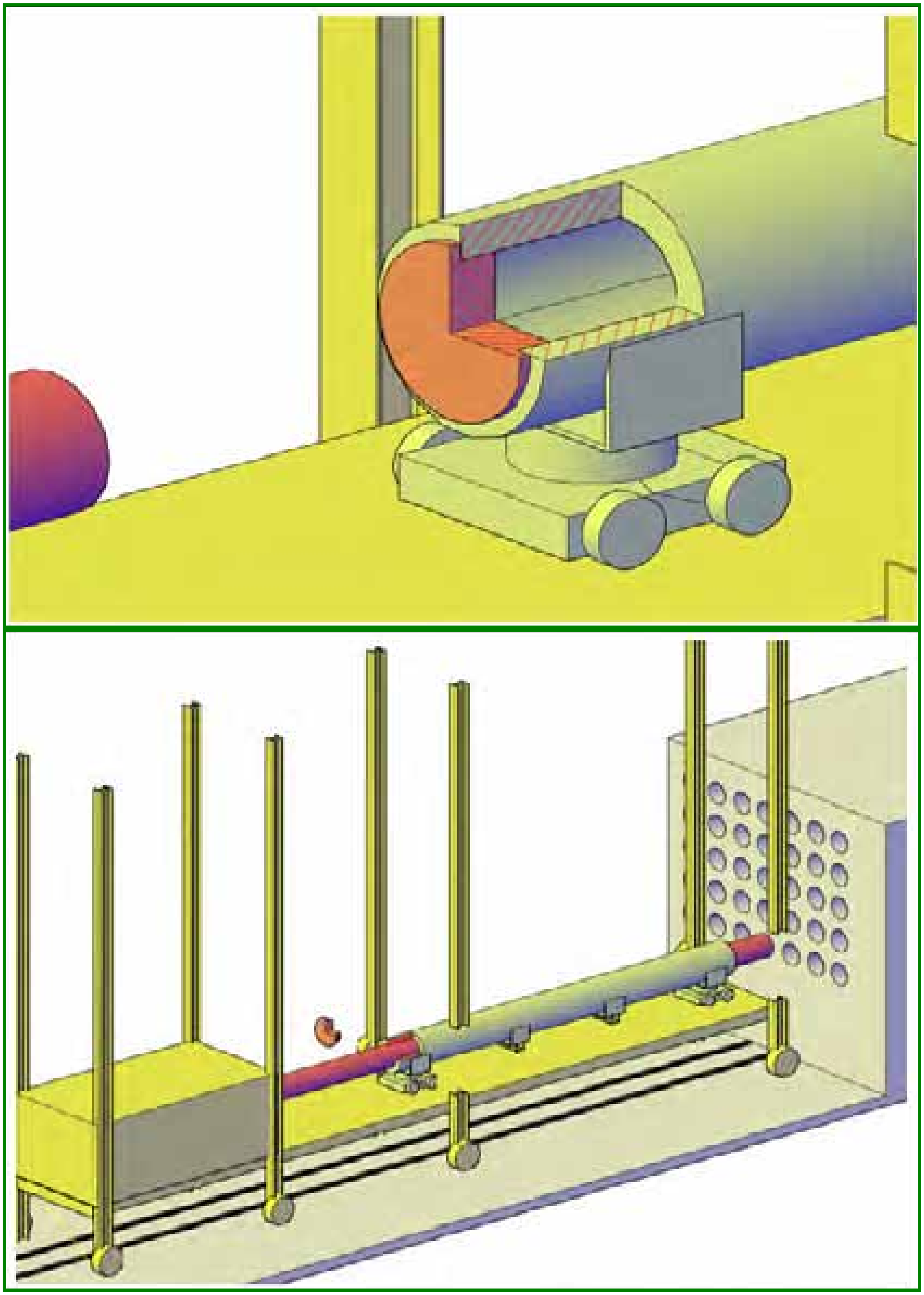


Figure 8-13 – Concrete Pipe Array and T-H-E Liner Emplacement Schematic

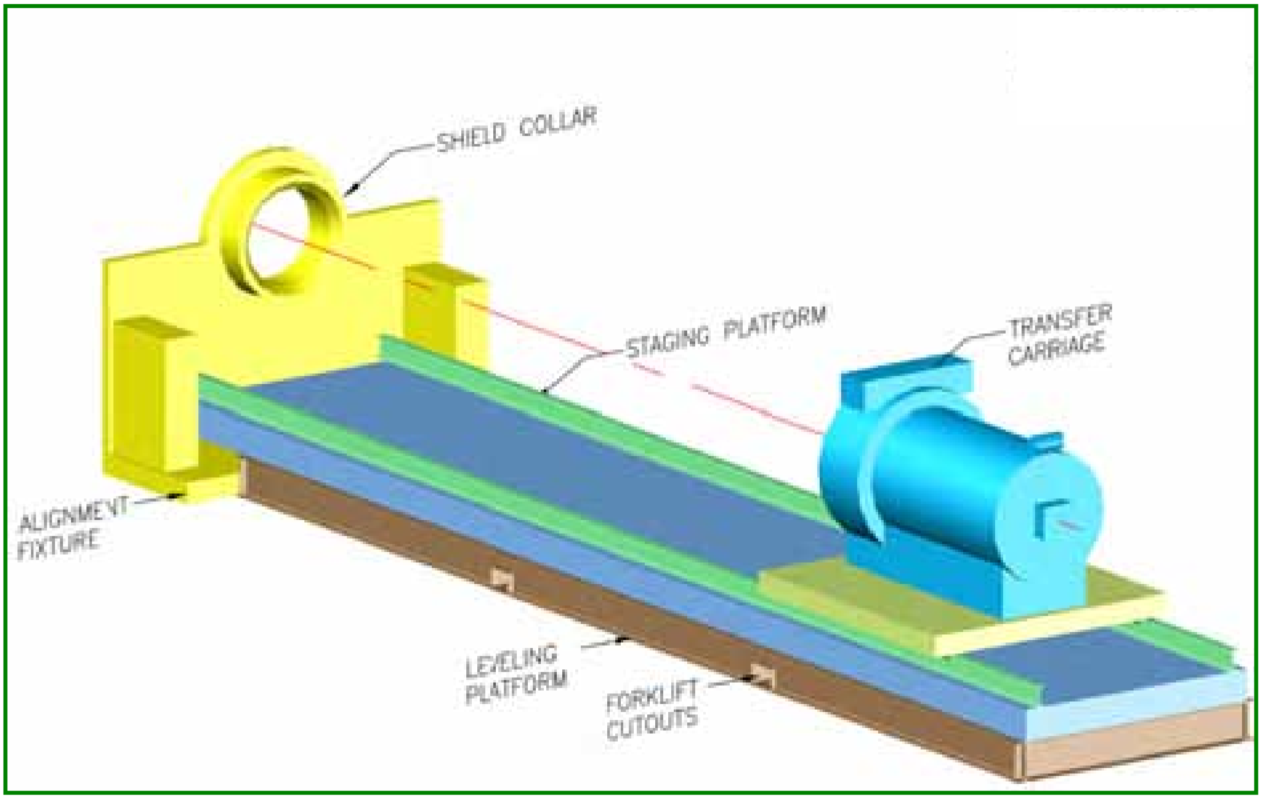


Figure 8-14 – Horizontal Emplacement and Retrieval Machine

8.4.7 ILW Shields

In future, wastes that are currently being stored in the T-H-E liners may be stored in the proposed new ILW shields. They will be small, light-weight and stackable. It is estimated that there will be 7,383 of these new containers to be emplaced. On arrival at the underground station, a light duty forklift will remove these packages from the shaft cage and stack them in the staging area as 12 of these packages will be accommodated in each cage trip.

After fully off-loading the cage, the forklift will transfer each shield in turn to the emplacement room, in which they will be disposed.

ILW shields will be stacked up to 3-high in a manner that will maximise utilisation of the available space in the emplacement room. The ILW shields are stackable and are relatively small (1 m diameter and 1.7 m high) and will therefore be efficiently packed.

8.4.8 Retube Wastes

The Retube waste containers will be off-loaded from the shaft cage by the heavy duty forklift and transferred by forklift to their emplacement rooms.

Retube Waste Containers are heavy but have been designed to be stacked on top of each other. There are two types of container: the end fitting container and the pressure tube container. The end fitting container will be stacked 3 high and the pressure tube container will be stacked 2 high. They have flat, solid tops so other packages could be stacked on top of them, but only the pressure tube container would be within the room height limits with any of the shorter (less than 1.5 m) LLW packages placed on top.

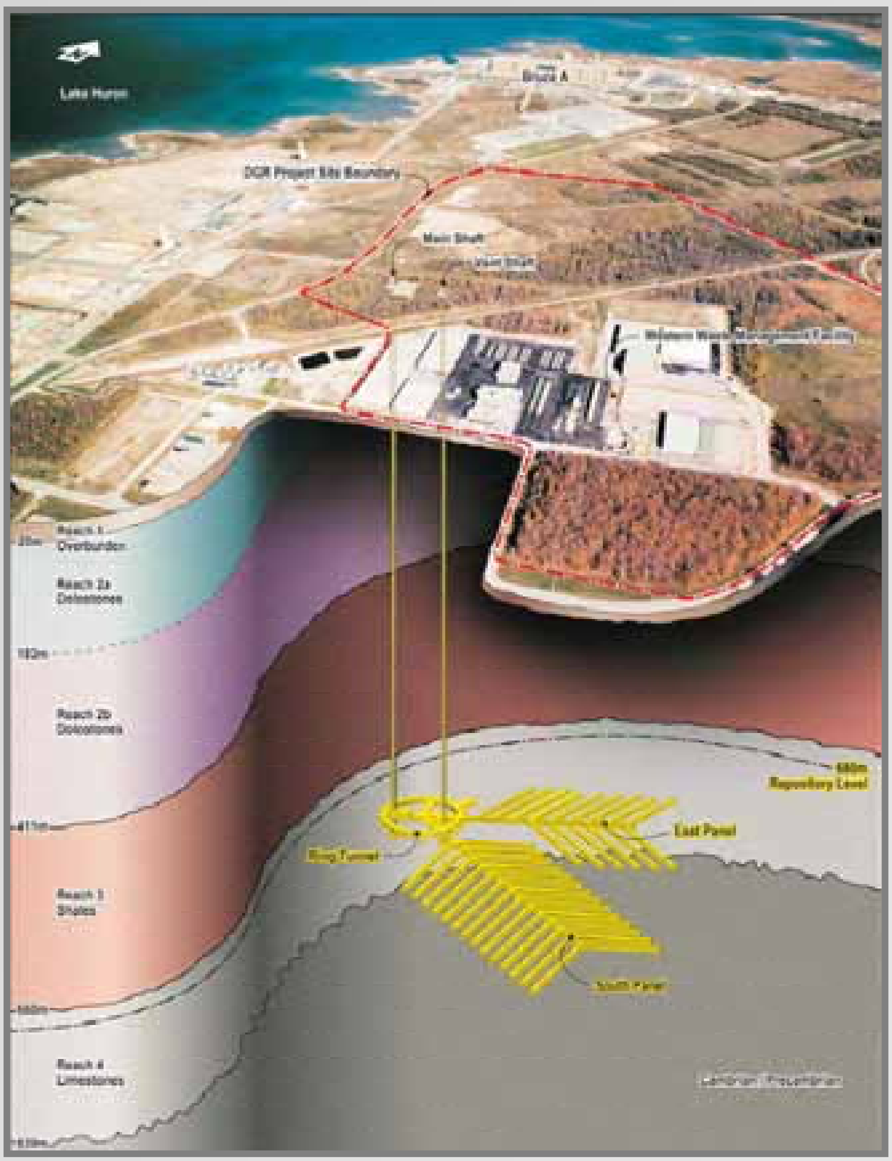
HATCH

Two rooms, 182 m long will be required for all the pressure-tube packages and 183 of the end-fittings waste containers will also be stored in one of these rooms. The remaining end-fitting retube waste containers will be disposed of in one of the ILW shield emplacement rooms.

Some versatility is available in these packing arrangements as the rooms would have adequate headroom to allow lighter ILW packages to be placed on top of the stack of end-fitting retube waste containers.

Conceptual Design Report

9. Support Services



9. Support Services

9.1 Dewatering

Waste water will be generated from several sources:

- Infiltration from the ground rock
- Fire system maintenance
- Wash water for cleaning equipment
- Hose down water for dust suppression (during construction)
- Diesel equipment combustion products
- Condensation from humid air in tunnels and upcast Ventilation Shaft

9.1.1 Repository Development and Construction

During shaft sinking, level excavation and construction of the repository, all dirty water used for was-down of equipment, suppression of dust and cleaning of the excavated rock faces will be directed into a sump at the bottom of the Ventilation Shaft, from where it will be pumped to surface for discharge into the surface water control run-off system (see Section 4.2.5.8). All tunnels will be graded back towards the shafts to facilitate quick removal of water from the construction headings. As a back-up, there will also be a sump at the bottom of the Main Shaft, to which the water flow can be diverted if there are any shut-downs on the Ventilation Shaft system.

9.1.2 Operations

During operations, the two sumps at the bottom of the sumps will be used to collect water that is not potentially contaminated (e.g. seepage from the shafts; leaks in water pipes; condensation in the Ventilation Shaft).

Additionally a third sump will be constructed at the maintenance facility at the ring tunnel to collect any water that may potentially be contaminated (e.g. water emanating from the emplacement room panels and access tunnels; wash-down water used to clean mobile emplacement equipment in the maintenance facility). This water will be kept separate from the water collecting in the shaft bottom sumps.

The water will be pumped into totes using a low-lift sump pump and transferred in the Main Shaft cage to surface for controlled disposal. Should the water be found to be radiologically contaminated, it will be sent to the Bruce plant for treatment. In this way, follow-on contamination of the main shaft sumps, pumps and pump columns will be avoided.

Ditches will be provided in the tunnels to collect the water and lead it back under gravity flow to the appropriate sump to assist in maintaining a clean environment on the floors of the excavations.

9.1.3 Sump and Pump Design

Although water inflow volumes are expected to be small at average rates of about 3.5 l/s, with occasional maxima up to 15 l/s during equipment washdown, each shaft bottom sump will be sized to contain one hour's water production at the maximum expected rate of 15 l/s. This sump capacity will also be able to accommodate a rupture or a controlled draining of the potable water line or pump column in the shaft.

The sumps will be split into two sections, separated by a mesh screen. Water will flow into the first section and then through the screen into the second section. The screen will trap any grits and thereby protect the pumps from sudden mechanical failure. This first section will have a graded floor to facilitate occasional cleaning out of the grits, which will be removed and dumped into the waste rock bin at the Ventilation Shaft loading pocket.

The 'clean' water flowing into the second section of the sump will be pumped in the shaft column to surface where it will be discharged into the retention pond shown on Drawing 323874DGR-111-001 (see Appendix E) and as described in Section 4.2.5.8). In this way, any suspended solids or contaminants will be retained within the DGR boundaries to allow for measurement of contaminant levels and treatment before release outside the DGR.

Each sump will be equipped with two positive discharge plunger pumps, such as Gardner-Denver FXD model pumps, which are ideally suited to handling relatively low volumes of dirty water. One pump will normally operate with the second acting as a stand-by in the event of failure of the first pump or to supplement pumping capacity to clear any excessive short-term in-flow of water. Each pump will be rated to pump at a rate of 8 l/s. The full pumping capacity of each system with both pumps operating would be 16 l/s, which will provide adequate surplus capcity to cater for a pipe rupture or similar event.

Each sump will be equipped with a level instrument, which will transmit the level of water in the sump to the surface control room. The pumps will be arranged to automatically run when levels exceed 50% of capacity, but may also be manually started from the control room or locally.

9.2 Potable Water

Potable water will be supplied in a 50 mm diameter pipe column from surface, primarily for underground workers use and also as a feed to the wash rooms and refuge chambers.

The potable water supply will be drawn from a conection to the existing feed to the WWMF.

9.3 Sewerage System

All human effluent will be collected at the Main Shaft in a tank and be pumped across to the existing sewerage system at the WWMF.

9.4 Compressed Air

Compressed air will be required in the DGR for:

- Shaft sinking
- Repository construction
- Surface and underground maintenance
- Underground refuge stations

The air will be supplied from surface by an air compressor located in the Main Shaft maintenance building. Two compressors will be installed, one acting as a stand-by.

Both shafts will be equipped with compressed air pipes during sinking. Once sinking is complete, only the pipeline in the Main Shaft would be required to supply the underground needs during repository construction and operations. However, the Ventilation Shaft pipeline will be left in place to act as a back-up to supply air underground, which is especially important for refuge stations.

9.5 Electrical and Lighting

Class 4 electrical power will be supplied to the facility by a high voltage (44 kV) transmission line from the Hydro One substation at Douglas Point. The voltage will be reduced to 13.8 kV at the main substation located adjacent to the Main Shaft complex for distribution to major loads and via further step down transformers to the motor control centres (MCC) on surface and underground.

The highest power users will be supplied directly at 13.8 kV. These include the Main Shaft hoist, Ventilation Shaft hoist, and HVAC refrigeration machines. Motor control centres will run at a voltage of 600 V AC and also transform down to 110 V AC for smaller sized loads. Among other electrical power users, the MCC's will feed:

- Intake fans at the Main Shaft;
- Main exhaust fans at the Ventilation Shaft,
- Overhead electric crane in the WPRB;
- Surface workshop and offices.
- Lighting, receptacles and other typical facilities service loads at 110 V AC.

Power will be fed down the two shafts at 13.8 kV to the electrical sub-station at the repository level, where it will be transformed down to 600 V and 110 V for distribution to the underground users. Shaft power cables will be Hi-Tensile Verlok® ([R78]), which meet the ICEA mining standards' safety factors and are approved for shaft use by CSA and MSHA. Each cable consists of three individual stranded copper conductors, which are shielded and insulated with XLPE. The full cable is armoured with interlocked galvanised steel and encapsulated with a flame-retardant (FT4) PVC outer sheath suitable for hazardous locations to provide protection from mechanical damage, prevent electrical discharge and minimise the fire risks.

An emergency diesel generator will be installed to assure safety in the event of a failure of offsite power. The generator will have a capacity of about 2,500 kVA to serve the site loads that are essential for personnel safety and to maintain overall conditions in a satisfactory state. The diesel will be located at the surface substation and will feed equipment through the cables and switchgear used for normal operations. The diesel generator will not support continued waste placement operations. The only loads that will be served by the diesel generator are:

- 2nd Egress and Emergency Ventilation Shaft Hoist, which will be able to then run under power to remove personnel from underground to surface.
- Main Shaft Koepe hoist brakes and controls to allow for controlled lowering of the cage under by gravity, but by control of the brakes and not via the motor. It should be noted that because the Koepe is a 'balanced hoist', such gravity winding is likely only possible in the event that the cage is either lowly loaded (with only personnel) or fully loaded with a heavy waste package load.
- Exhaust fans.
- Emergency lighting and communications in the repository and on surface.

Diesel-powered backup generators are commonly used at underground mining operations in Ontario. This generator would power-up critical components within 30 seconds of an unscheduled power outage. Capacity for the diesel fuel storage system is driven by the risk of any sustained severe weather occurrence, but may be minimised at 8,000 litres with a secondary fuel supply available at the WWMF. Specialised controls and switchgear are used to initiate the generator start-up and shed non-critical loads during an outage, as well as allowing an uninterrupted switchover when the supply grid is re-energised.

Only one diesel generator will be provided. Mines do not normally have more than one emergency generator, as this provides the redundancy necessary to guard against electrical power supply failures. Having two generators would be providing triple redundancy; risk assessments for mines have not found this to be necessary. For deep level, hot mines, emergency power is probably more critical than for a facility like the DGR since failure of cooling and ventilation systems would pose a threat to the lives of workers underground because of the high virgin rock temperatures at depth.

Major maintenance on electrical systems and an emergency diesel generator will normally be carried out during off-shifts (e.g. weekends). Minor maintenance can be performed during working hours if easy and quick reconnection and start-up can be achieved. Additionally, the generator will be tested off-line regularly, and at least once per year the mains power would be deliberately disconnected and the generator used to prove running of the relevant hoists and fans using the generator power supply system.

The total connected load for the facility is estimated to be approximately 16 MVA.

Surface		**Underground**	
Main Shaft Hoist	4,300 kVA	Station Gantry Crane	80 kVA
Main Shaft Hoist Brakes *	80 kVA	Emplacement Room Gantry Crane	80 kVA
Ventilation Shaft Hoist *	1,500 kVA	Maintenance Shop Hoist	10 kVA
Overhead Crane	100 kVA	Sump Pumps at Shaft Bottoms *	200 kVA
Exhaust Fans *	270 kVA	Auxiliary Fans	600 kVA
Intake Fans	95 kVA	Lighting * (50% emergency)	60 kVA
Refrigeration Machines	8,000 kVA	Miscellaneous loads	20 kVA
Bulk Air Cooler Pumps	90 kVA		
Lighting * (50% emergency)	100 kVA		
Miscellaneous loads	40 kVA		
Total Load	**14,575 kVA**		**1,050 kVA**

* Emergency diesel generator loads

Table 9-1 – Electrical Power Loads

9.6 Natural Gas

Heating of the intake air in winter for DGR ventilation will preferably be achieved using natural gas. Two 3.75 MW direct-fired burners, which are a standard sized unit and readily available, provide a degree of redundancy in supplying the predicted 5.5 MW peak gas demand. The typical gas supply volumes in mid-winter are near 0.3 m^3/s with a peak of 0.53 m^3/s.

Final pipeline sizing will be based on exact distances from utility take-off locations and are expected to be in the range of 75-90 mm, on the basis that the utility provider would run their connection up to the intersection of the "Interconnecting Road" and the DGR access road. From this point, natural gas would be delivered onto the DGR project site via a buried pipeline that extends from this intersection to the Heater Building (see Dwg 323874DGR-200-001).

Should it not be viable for a utility to run natural gas to the site, electrical heaters would be an alternative, although less cost-effective, method for winter heating of the facility.

9.7 Communication

Communications through the repository will be available. A telephone system will enable communication between the offices, shaft collars, hoist control cabins, and underground infrastructure such as the repository level shaft stations, underground offices, refuge chambers, maintenance workshop and geotechnical laboratory. Additionally a leaky feeder system will be installed in all the main access tunnels, which will both enable tracking of vehicles and allow for communication with hand-held or vehicle mounted devices.

The telephone system will be digital and all signals will be transmitted via fibre optic systems.

9.8 Control and Monitoring

Control and monitoring systems will perform several functions:

- Monitoring and alarming any detection of fire, noxious or explosive gases
- Monitoring radioactivity and other contaminants in underground water (in the shaft sumps) and air (in underground ventilation ducts and at the exhaust fan intakes)
- The status of equipment and installations
- The location of vehicles underground
- The status of the shaft hoists and positions of conveyances
- Tracking waste package locations
- Provide input to the planning system for control of waste package movement and transfer schedule.
- Monitoring changes in underground rock/excavation conditions (e.g. rock movement, stress)

As well as providing real time data for daily management and safety control, the monitoring system will capture and save data over time to establish repository facility and environmental baseline conditions, and assess the performance of various structures, systems and components relative to design specifications and baseline conditions.

Using the leaky feeder and fibre optic system, all data will be transmitted from the source instrument or electronic device either directly, or via a hub in the underground instrumentation room, to the surface control room.

A leaky feeder is a communications system used in underground mining and other tunnel environments. The system will consist of cables run along the tunnels and in shafts, which emit and receive radio waves. The leaky feeder cable or backbone is analogous to a surface antenna system. The cable network will be installed to effectively radiate the signal throughout the DGR facility. The cable utilised is designed to "leak" signal, which allows radio transmissions to both leak from the cable and also enter the cable.

The leaky feeder system will provide the basis for not just basic two-way voice and data applications, but allow full telemetry control of remote equipment, such as the pumps and fans.

Fibre optics are a technology that use glass fibres to transmit data. A fibre optic cable consists of a bundle of glass threads, each of which is capable of transmitting messages modulated onto light waves. Fibre optics has several advantages over traditional metal communications lines:

- Fibre optic cables have a much greater bandwidth than metal cables. This means that they can carry more data.
- Fibre optic cables are less susceptible than metal cables to interference.
- Data is transmitted digitally rather than as analog signals.

Leaky feeders will be used in the access tunnels for voice communication and data transmission back to a hub at the communications room on the ring tunnel. Information will be transmitted to the surface control room in a fibre-optic cable to maintain integrity of the data. Signals will also be able to be sent underground to start and stop equipment.

The information will be stored on hard drives in the surface control room and backed up regularly to remote servers.

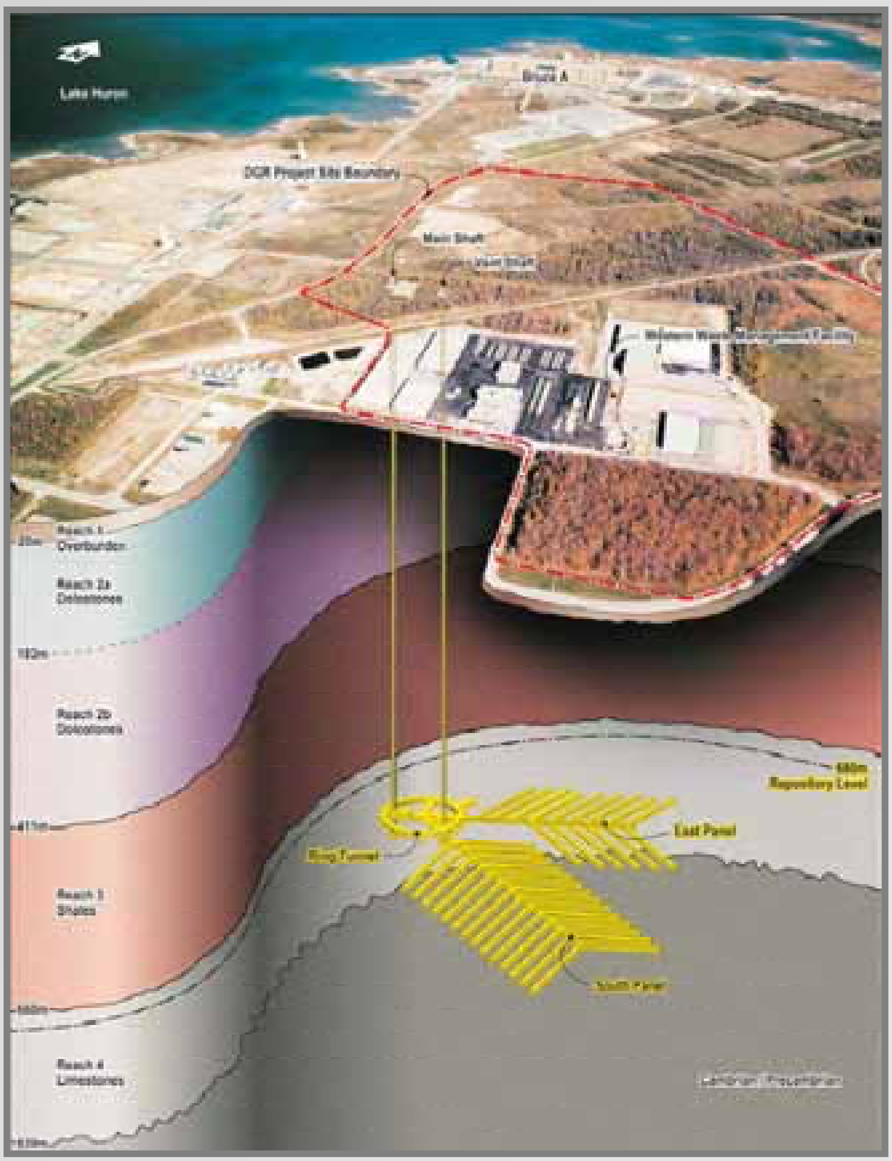
Underground rock and shaft concrete structures will be monitored using rock mass and pillar convergence instrumentation (MPBX), embedded and surface-mounted concrete load cells in the shaft linings, and rock dowel load cells. All this real-time data will be transmitted to the surface control room for collection and analysis as stated above.

As noted in Section 8.2, each waste package is tagged with a bar-coded strip to facilitate tracking. Hand-held readers will be used by the operations personnel to scan the waste package on surface, when received underground at the shaft staging area and when emplaced in a room. The hand-held devices will provide the operator with the ability to input key data, such as the location and the status of the package. In this way, a permanent real-time record will be recorded of the location of each package within the specific emplacement room for any future analysis and in the event that the package has to be retrieved at some stage. All tracking data will be interfaced to the OPG Integrated Waste Tracking System ("IWTS"). The hand-held readers can store their data locally and it can be downloaded at the end of each shift. Alternatively, the data can be immediately transferred to the control system on surface using the leaky feeder and shaft fibre optic link.

The WVRB Control Room at the WWMF will also be equipped with a DGR monitoring station, to which all information concerning the status of the DGR is transmitted. At off-shift times, when there are no personnel underground, audio-visual alarms associated with ventilation, fire detection and sump levels will be triggered at the WVRB control room where the duty operator will be able to interrogate the system to determine the cause of any alarm or review any settings and take action to call out the relevant persons or emergency services.

Conceptual Design Report

10. Fire and Life Safety



10. Fire and Life Safety

The proposed Deep Geologic Repository (DGR) is unique in that it combines aspects of mining within a nuclear facility. The facility will consist of surface infrastructure and an underground facility. Fire and life safety requirements are of paramount importance and will determine much of the principles and implementation of designs. There are two specifically different activities that will be associated with underground works for this facility: mining and construction of an underground facility, and emplacement of the waste within the repository.

OPG has confirmed that all nuclear waste management facilities fall under federal jurisdiction and therefore federal acts, regulations and codes will apply to the DGR facility. The DGR facility will be licensed through the CNSC, and the Nuclear Safety and Control Act and its regulations. Under the Nuclear Safety and Control Act, the repository facility would be classified as a Class 1B nuclear facility and Class 1 Nuclear Facilities Regulations apply ([R79]).

In accordance with Canadian Federal Regulation 98-180 ([R80]), the responsibility for workplace health and safety at all OPG nuclear facilities, including OPG nuclear waste management facilities, has been delegated to the Province of Ontario. Therefore, workplace health and safety during the construction and operation of OPG's proposed Deep Geologic Repository will fall under Ontario Occupational Health and Safety Act (OHSA) and its associated regulations ([R82] and [R83]).

Although the facility, with regard to the definition of a mine in the OHSA and the OMR, does not fall under the definition of a mine, there are many aspects of the facility (hoists and shafts) that are not covered adequately in any regulations other than the Mining Regulations, and many clauses of the NBC are not relevant or possible to apply to a deep underground facility. The MOL would be responsible for the monitoring and enforcement of the underground DGR facility from a health and safety perspective.

10.1 Fire Detection and Alarm

Fire detection will be achieved using smoke and carbon monoxide detectors in key points in the facility. The points will include:

- All underground infrastructure rooms situated around the ring tunnel;
- The exhaust ventilation air ducts exiting each emplacement room (whether under construction, empty and awaiting start of emplacement operations, during emplacement operations, or closed);
- In the intake adit at the exit from the HVAC system at the Main Shaft;
- At the discharge of the main exhaust ducts at entry to the upcast Ventilation Shaft.

These points will provide levels of redundancy so that any failure of one or other instrument will not enable a fire to remain undetected. All in-duct monitors will be located external to any emplacement room and will be accessible via flanged ports for ease of maintenance.

All instrumentation signals will be displayed, locally and also be transmitted via a dedicated fibre optic link to the shaft stations, underground instrumentation room, shaft surface collars and surface control room. If alarm levels are reached, audible and visual alarms will be automatically activated. At any control station, it will be possible to identify which sensor has detected an alarm condition and whereabouts it is in the repository.

However, in underground mining environments, audible alarms may not be fully effective on their own due to the nature of the environment. The "stench gas" system used in Ontario mines is well proven. A stench gas is a foul-smelling, but safe gas that is injected into the downcast air stream and quickly and effectively reaches workers in all parts of the facility. Therefore once a fire condition has been detected, the stench gas will be released into the intake adit at the Main Shaft.

All mobile equipment, apart from roadheaders, will be diesel-powered underground. In terms of the Ontario Occupational Health and Safety Act (R.R.O. 1990, Reg. 854 Mines and Mining Plants, Section 28 [R82]), these vehicles must be fitted with fire detection and suppression systems.

10.2 Refuge Stations

The first line of protection for underground workers are refuge stations. There will be two permanent fixed refuge stations on either side of the ring tunnel, one being in the "non-operations" section and the other on the "operations" side close to East Panel access tunnel. (see Figure 10-1). There will always be at least two routes for any worker in the ring tunnel area to reach a refuge chamber.

Within the panels and rooms there is only one exit route to reach the shafts. Therefore, to provide the same level of protection, a mobile refuge will be positioned close to the far end of each panel access tunnel, which will again provide any workers with routes to a refuge chamber. As the access tunnels are advanced during development, these mobile refuge chambers will also be advanced beyond the opening of the furthest developed emplacement room. The refuge chambers will never be located close to any significant combustible mass, so that any fire will not reach the proximity of the refuge chamber and cause any risk to the protection of workers inside the chamber. It is good underground practice to ensure that the location of all refuge chambers takes this need into account, and sections around these installations will be demarcated to prevent such a situation.

In total there will be two fixed and two mobile refuge chambers.

As required by Ontario Occupational Health and Safety Act (R.R.O. 1990, Reg. 854 Mines and Mining Plants, Section 26 [R83]), all the refuge chambers will

"(a) be constructed with materials having at least a one hour fire-resistance rating;
(b) be of sufficient size to accommodate the workers to be assembled therein;
(c) be capable of being sealed to prevent the entry of gases;
(d) have a means of voice communication with the surface; and
(e) be equipped with a means for the supply of,
  (i) compressed air, and
  (ii) potable water. R.R.O. 1990, Reg. 854, s. 26."

In addition to these regulatory requirements, the refuge stations will also be equipped with radiation protection equipment for monitoring and decontamination of staff in the event that an accidental radiation release from any waste packages should occur.

The number of underground workers is not expected to exceed 15 during construction and 10 during operations. However, to cater for occasions when visitors are present, the refuge chambers shall be capable of holding up to 25 persons.

The DGR has been designed to avoid the need for self rescuers since there will always be two routes to reach a refuge station. However, it is possible that certain work may require to be performed where multiple escape routes are not available. In this case, workers, whose access to a refuge station may be inhibited due to distance or route, would be provided with a self-rescuer device. These devices are commonly employed in the mining industry and provide short-term protection from unsafe atmosphere while en route to a refuge station. They would be provided to workers where relevant before going underground and in addition would be available in select locations such as shaft conveyances and in mobile equipment cabs. During detailed planning of all underground construction and operations, any such events would be identified using HAZOP (Hazard and Operability studies) and workers equipped with such necessary safety equipment.

10.3 Fire Protection

10.3.1 Fire Suppression

Fire suppression will be achieved by four systems:

- Hand-held fire extinguishers, which are foam based and mounted on clearly demarcated boards in or close to all rooms on the ring tunnel with more than one in the maintenance workshop, fuel/lubricant bay, and electrical sub-station. At any workplace that is not a fixed location, workers must have a fire extinguisher available and close at hand (e.g. mounted in the cab of their vehicle or if the location is reached on foot, the extinguisher will need to be carried there by the worker).
- Inert gas generator for extinguishing any fire that develops in a *closed* emplacement room. The generator would mounted on a mobile trailer, which can be towed by any other vehicle. The generator would normally be stationed on surface and would only be moved underground by the mine rescue team (see Section 10.4) called out to extinguish the fire. Once at the site, the output from the generator would be hooked up to the intake vent on the room bulkhead and the inert gas blown into the room. All gas would be retained in the return air system, which is ducted to the Ventilation Shaft and workers and rescue teams would therefore not be exposed to the gas.
- A portable foam generator for extinguishing any fire that develops in an *open* emplacement room. The generator will be mounted on a mobile trailer similarly to the inert gas generator, and will also be stationed on surface. It would be controlled by the mine rescue team and taken underground with the team to extinguish a fire in an open emplacement room.
- Automatic, foam-based fire suppression systems mounted on all diesel equipment. These systems are mandated for diesel-powered equipment operating underground and will be triggered on detection of any fire on the vehicle.

The use of inert gas to extinguish an underground fire is preferred as it will avoid any collateral damage to waste packages. Foam will create a difficult clean-up once a fire is extinguished, but would be required for an open emplacement room as it would not be possible to ensure that inert gas could be safely contained and completely directed into the ducted exhaust system.

It should be noted that water sprinkler systems and fire hose systems are not recommended as their use could create a large volume of contaminated water that would have to be collected and treated before it could be released form the DGR facility. In addition. the use of water for fire suppression would introduce high levels of humidity, which could negatively affect the long-term integrity of other waste packages, structures and ground supports, which are not exposed to or close to the fire.

10.3.2 Ventilation Controls

Ventilation fans on each of the ducts carrying the exhaust air from emplacement rooms can be shut down remotely. On a fire alarm condition, the repository controller can initiate shut down of relevant fans to reduce feed of oxygen to a potential fire.

For safety reasons, any alteration or disruption to the ventilation system would be minimised until all underground workers are accounted for in the refuge stations. Once all workers are safe, either in a refuge chamber or evacuated to surface, the operation of the ventilation system would then be altered to minimise propagation of the fire and release of resulting gasses and particulate matter.

If the incident has occurred within an emplacement room or in one of the panel access tunnels, the fans in that room or panel would be remotely stopped to minimise the amount of contaminants being drawn into the exhaust system. The auxiliary underground fans would be controlled to provide a safe access route for mine rescue personnel to fight or isolate a fire or seal off and clean up a radioactive contaminant spillage.

There will also be fire doors located to isolate the downcast Main Shaft and the ancillary room side of the ring tunnel, as indicated on Figure 10-1. These will be equipped with hydraulic power packs and cylinders to allow for remote or local operation.

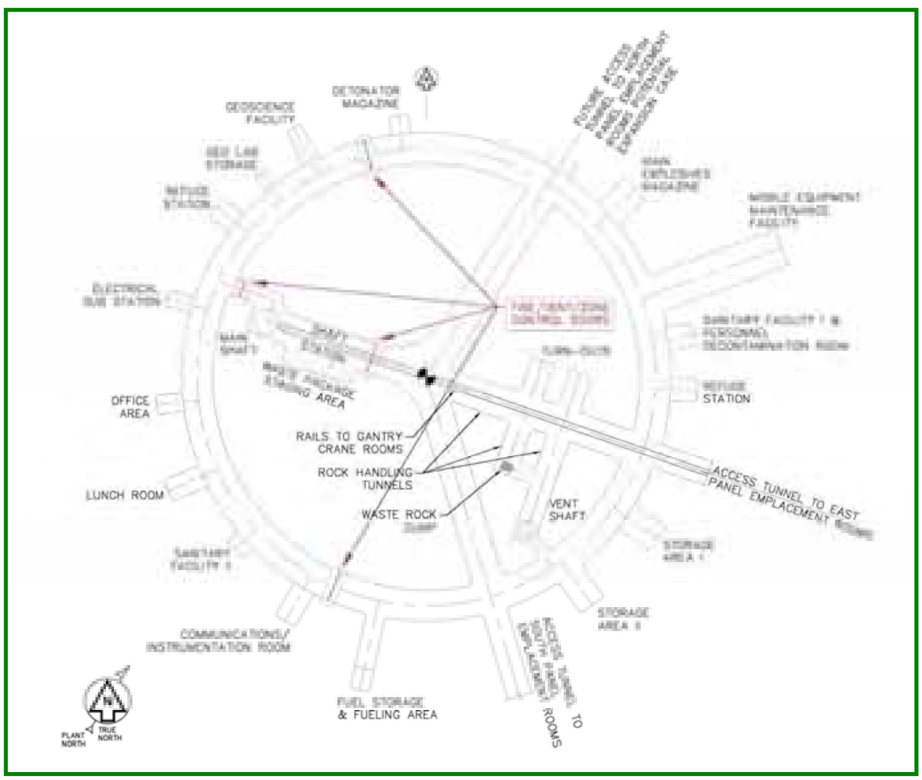


Figure 10-1 – Plan View of Underground Ring Tunnel and Ancillary Rooms Layout

The fire doors will also act as zone control doors and will normally be closed. The bulkheads for the three sets of doors separating the "non-operations" and "active emplacement" sides of the ring tunnel and Main Shaft area will be equipped with fans to blow a controlled quantity of fresh air from the Main Shaft through the "non-operations" side of the ring tunnel.

The bulkhead of the main vent door in the central tunnel to the east of the waste package staging area will be equipped with a self-closing louvre to allow the majority of the total air to flow through into the "active operations" area. The louvre will automatically close in the event of any failure of the surface ventilation fans to prevent any reversal of flow into the Main Shaft area. Similarly, each auxiliary fan in the other bulkheads will be equipped with self-closing dampers to seal off the bulkheads if the auxiliary fan should stop.

In the event of fire, any bulkhead fire door, which is open at the time, will be closed remotely or locally once the DGR controller or on-site supervisor has determined that there are no obstructions (i.e. vehicles or workers passing through the door) and that it is safe to close.

10.4 Emergency Response

Three types of event could occur that will require a planned emergency response:

- Fire
- Rock fall
- Radiological contamination release

10.4.1 Fire

Immediately on initiation of a fire alarm, all workers would report to a refuge chamber. Any workers in the vicinity of a visible fire and who are in a position to assess the risk and use the nearest available fire extinguisher, while remaining upstream of the fire, would do so. If the fire cannot be extinguished promptly, the worker should also report to a refuge chamber.

The repository controller would call out the nearest Mine Rescue unit, with whom the DGR is affiliated. No workers would leave the refuge chambers until a member of the rescue team has determined that it is safe to do so, either by extinguishing a fire or by identifying a safe route to whichever shaft is in the fresh air supply and uncontaminated by any combustion products.

The DGR will need to have its own Mine Rescue Team, which will likely co-ordinate its activities with the Emergency Response Team for the Bruce Nuclear site. The DGR Rescue Team will have its own related equipment so that it can immediately respond to a fire or emergency. Mine rescue policy requires a second team to be readily available before the first team is sent underground, so reliance on one of the salt mine teams in the region will be necessary. This network is the basis upon which mine rescue works with any team from any mine in Ontario being available if required. Mine rescue teams are made up from volunteers from both the hourly and staff work force and get special training from the Mine Rescue Branch of the Ministry of Labour 6 times per year.

In the event of a fire it is likely that repository workers would spend at least two hours in the refuge station before the rescue team is assembled, travels underground and assesses the hazard. Workers will not be removed from the refuge station until fresh air passage back to surface can be guaranteed. Refuge stations must have a supply of fresh air and water and can potentially be used for several days.

10.4.2 Rock Fall

In the unlikely event of workers trapped by a rock fall or other extraordinary event, management of the facility will coordinate the response and utilise the mine rescue teams to assess the situation and recommend a recovery strategy depending on the circumstances.

10.4.3 Radiological Contamination Release

For a container failure in an emplacement room, the ventilation system is active and will pick up the radiation from a spill (see Section 5.8.3). It is designed to pull any contamination in the airstream away from the workers doing emplacement work and is ducted to the main return ventilation duct all the way to the upcast Ventilation Shaft. In a contamination event like a dropped box, the workers will evacuate the area to a refuge station, after which the axial fan(s) in the relevant emplacement area would be stopped. Management would implement a pre-developed plan for rescue of the personnel (similar to that described in Section 10.4.1) and clean-up. Clean-up will, in most cases, involve the use of protective suits and breathing air, which will be available on surface for the rescue team.

A container failure in an access tunnel, would result in contamination spread throughout the panel since the air flow is from the main shaft and moves in the direction of the open emplacement areas. All workers downstream of the incident will evacuate to a refuge chamber at the end of the panel access tunnel. The ventilation will continue to operate and pull contaminated air into the ducted exhaust stream. Once all workers are safely within the refuge chamber, the fans in the access panel will be stopped, while the personnel rescue and clean-up are performed.

Non active emplacement areas have minimal air flow, therefore, any contamination released will tend to move in the direction of the active emplacement areas. The main duct system will have dampers at strategic locations of sufficient size that the exhaust flow comes from the incident area and is minimised from the emplacement areas. The employee response should be the same as outlined above.

10.5 Zoning

Radioactive waste storage containers that arrive at the DGR are controlled by way of the DGR Waste Acceptance Criteria ([R77]). These procedures ensure that the waste containers satisfy the applicable requirements for receipt and emplacement in the DGR.

The transfer of waste from its current storage locations to the DGR will be handled in a controlled and safe manner at all times. Existing site procedures will be modified to add the additional steps necessary to move the waste from its current location to DGR Receiving Building and DGR specific procedures will be developed for transfer of waste to the DGR operating level, transfer to the emplacement rooms and emplacement. Waste containers will be inspected on arrival at the WPRB to ensure that the surface of the containers are free of surface contamination and that the radiation field is within the applicable limits. Containers that do not meet the requirements will be returned to the point of origin for rectification.

10.5.1 Radiological Control

Ontario Power Generation's system for managing health and safety includes a set of documents intended to guide management action and control facility operations.

- The Level 1 Policy on Health and Safety heads this set of documents.
- The five Level 2 Policies on Leadership, Assessment, Exposure Management, Hazard Management and Information Management provide further corporate direction.

- The Ontario Power Generation Radiation Protection Policies and Principles document is a concise set of objectives, principles, responsibility statements and policies that govern radiation protection at Ontario Power Generation. It is the controlling document for all other radiation protection-related documents in the corporation and is intended for use by Ontario Power Generation staff responsible for preparing or issuing policies, practices and information related to radiation protection. It also applies to those who are responsible for making decisions that may impact on radiation protection and for which more detailed instructions do not exist.
- Two documents direct much of the application of the Policies and Principles. These are the Radiation Protection Requirements for general use and the Radiation Protection Regulations Part 2 for radiography. Both documents are referred to by the acronym RPRs.

The RPRs comply with the Federal Nuclear Safety and Control Act and Canadian Nuclear Safety Commission (CNSC) Regulations. Ontario Power Generation's RPRs apply the intent of the principles and recommendations established by the International Commission on Radiological Protection (ICRP). They also take into account the knowledge gained through Ontario Power Generation's long experience in designing, constructing and operating a nuclear-electric generation program. At all stages of the life cycle, management produces documents subsidiary to the Radiation Protection Policies and Principles and the RPRs, which specify local application and practice. The Radiation Protection Policies and Principles and the RPRs, and their subsidiaries, stand in addition to and are not substitutes for, documents of similar purpose governing conventional health and safety. These guidance principles will be directly applied to the operation for the transfer, handling, and emplacement of the low- and intermediate-level waste in the DGR.

A key practice in maintaining control of radiation exposure and contamination is through the use of "Zone" areas that define procedures and practices that are mandatory in order to move from one area to another. The zones are defined as follows:

- Zone 1 – Controlled access areas with no potential for contamination or significant radiation dose due to man-made sources (e.g., outside, offices). Radiation monitoring is used only as a precaution.
- Zone 2 – Radiologically controlled areas that do not contain sources of contamination. These may include some personnel support areas in the DGR (e.g., control room, break room, washrooms, etc) with minimal radiation fields. Radiation exposure is actively monitored and doses are controlled.
- Zone 3 – Areas with possible sources of contamination.

The Conceptual Design of zoning for the DGR is based on the following guidance:

- Zoning a facility is often a complex process; it has to take into account the transfers and movement of personnel and materials and work activities associated with the DGR. Although zoning of the surface and underground sections of the DGR will be finalised at a later stage of the design with involvement of the appropriate Health Physics personnel, it is important to consider zoning within this report to determine its impact on the overall facility design.
- All spaces within the DGR facility perimeter would be classified in accordance with criteria for potential contamination, ranging from Zone 2 to Zone 3, laid down in OPG's Radiation Protection Requirements for Nuclear Facilities.
- Appropriate personnel and materials/equipment monitoring devices would be required at each inter-zonal boundary.
- Movement from the existing storage areas at the WWMF to the Headframe buildings would take place through a Zone 2 area of the WWMF.

- During the construction of any additional emplacement rooms if the repository were to be expanded, the shaft and access tunnels would be dedicated to construction activities only, and the filled emplacement rooms would constitute a "repository island" within the construction island. Rezoning (e.g., from Zone 2 or 3 to Zone 1) to facilitate construction would include monitoring, as needed, to confirm status of the areas to be rezoned.

10.5.2 Zoning – Surface

A conceptual design for zoning of the WPRB and downcast Main Shaft and positions of monitoring points are shown in Figure 10-2. In general:

- The WPRB, would be classified as Zone 2.
- The Main Shaft would be classified as Zone 2
- A whole body monitor will be used to exit from the WPRB (at the Main Shaft), and from the Ventilation Shaft Headframe, to the external sections of the DGR Site and the WWMF.
- A whole body monitor would be placed at the loading bay and office/control room exits from the WPRB.

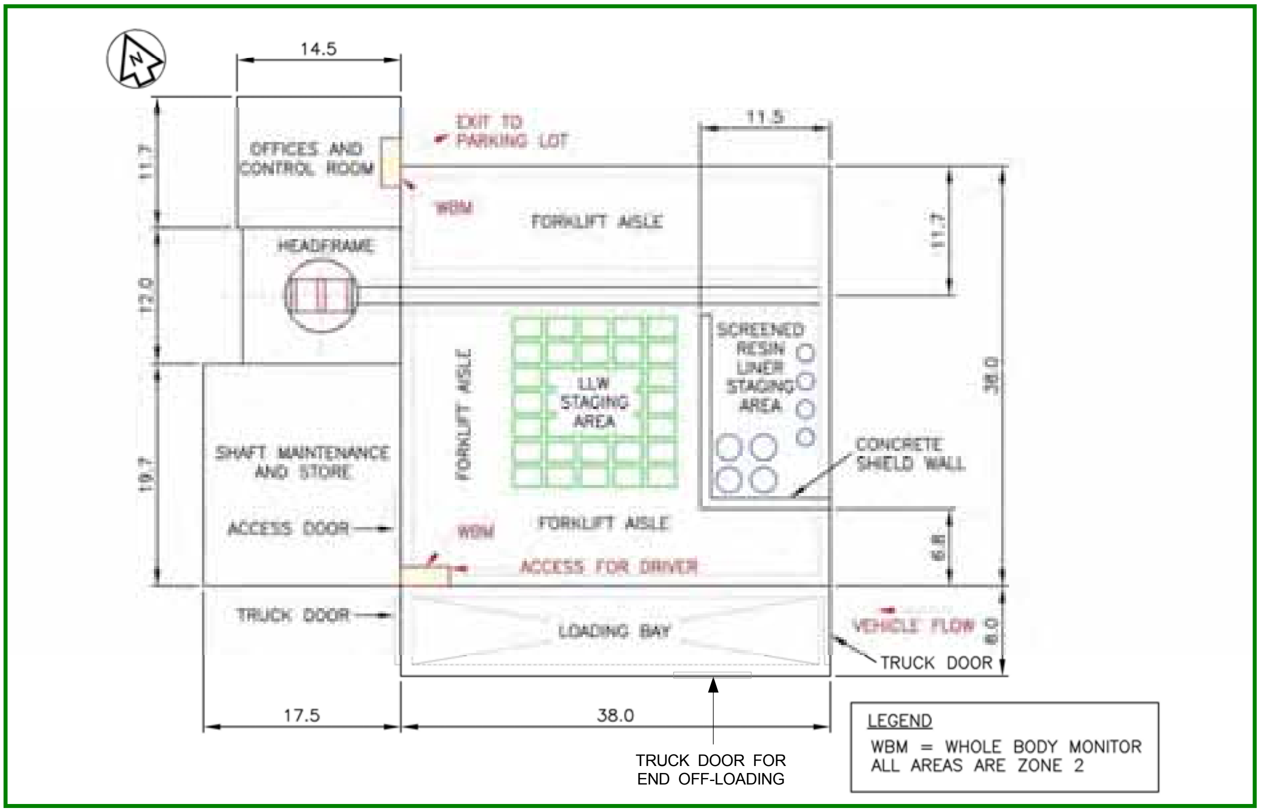


Figure 10-2 – Plan View of Main Shaft Receiving Building showing Radiological Zones

The whole body monitors at the personnel egress points from the building will assist in ensuring that any movement out of the Zone 2 WPRB will be controlled. Although the external areas at the DGR are within the WWMF Zone 2 area, monitoring at the exit from the WPRB will prevent any contamination that might be picked up inside the building during waste package transfer activities being conveyed into the external environment.

10.5.3 Zoning - Underground Ring Tunnel and Emplacement Rooms

Even though the emplacement rooms themselves will likely be classified as Zone 3, it would be impractical to install monitoring equipment at the exits from any emplacement room that is open and packed with wastes and thereby allow the access tunnels to be classified as Zone 2.

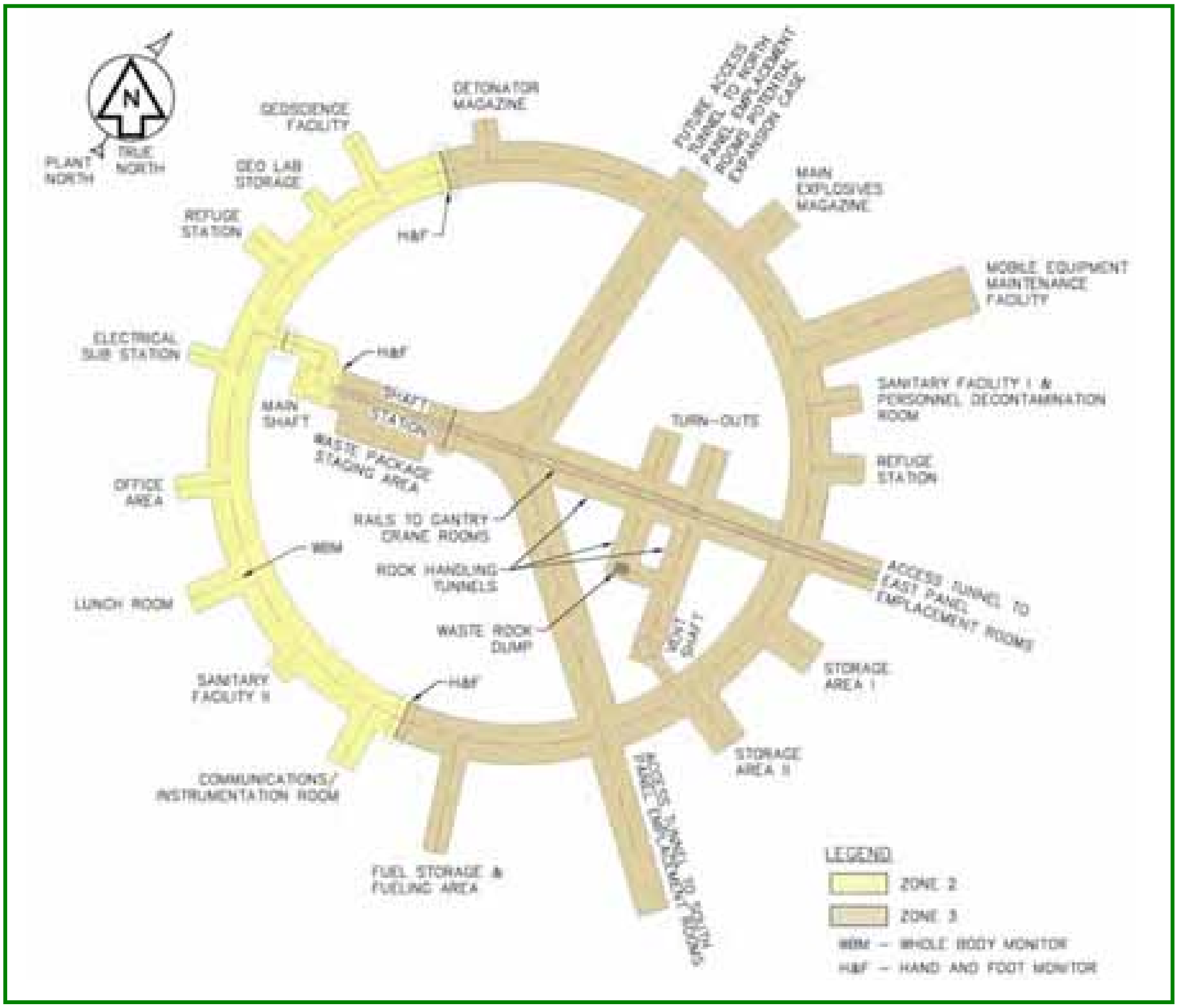


Figure 10-3 – Plan View of Underground Ring Tunnel showing Radiological Zones

A conceptual design for zoning of the Underground Facilities on this basis is shown in Figure 10-3. In general:

- The Active Operations portion of the underground repository (all panel access tunnels and emplacement rooms) would be classified as Zone 3 areas.
- Forklifts in the Zone 3 area would access waste packages in the Zone 2 Main Shaft hoist cage and move them to the Zone 3 waste package staging area or directly to an emplacement room in the underground facility.
- The Zone 2 Main Shaft hoist cage deck will be monitored for contamination at a frequency to be determined by the Responsible Health Physicist.
- Alternatively or in the event of contamination being detected at an unacceptable frequency, during the abovementioned spot checks, the forklift would have the wheels and tips monitored before each access of the Main Shaft hoist cage to pick-up waste packages.

- The upcast ventilation shaft will be Zone 3 and a WBM monitor will be provided for egress at surface (see Section 10.5.2).
- Staff will use a Hand & Foot monitor to access the Zone 2 Main Shaft hoist cage at the DGR Level.
- The non-operations side of the ring tunnel would be Zone 2.
- Hand and Foot monitors would be required to access the Zone 2 non-operations side of the ring tunnel.
- A whole body monitor would be used by staff to access the Zone 2 lunch room.

10.5.4 Control of Radionuclides in Air during Operations

The ventilation system is designed to ensure that the airborne contamination of radionuclides from the waste and any naturally occurring gaseous radionuclides (e.g., radon) are maintained sufficiently low within the access tunnels and the emplacement rooms, both those being filled with waste packages and those that are closed, to ensure a safe working environment.

Additionally, all air that has passed over waste packages in the emplacement rooms will be captured in steel ducts that run all the way back to the upcast ventilation shaft, in which they will discharge the used air. In this way, all areas of most frequent occupancy (i.e. access tunnels, non-operations rooms, empty emplacement rooms and the front sections of emplacements rooms being filling with waste packages) will always be in a clean air stream.

The fire doors in the underground facility will normally be closed, with the exception of the fire door adjacent to the Waste Package Staging Area. Air will be drawn from the downcast air in the Main Shaft into the Zone 2 non-operations area, from where it will exhaust at the fire doors into the ring tunnel, to ensure ventilation flow from Zone 2 to Zone 3. Air will also be drawn into the Zone 3 area on the east side of the Main Shaft cage (next to the waste package staging area).

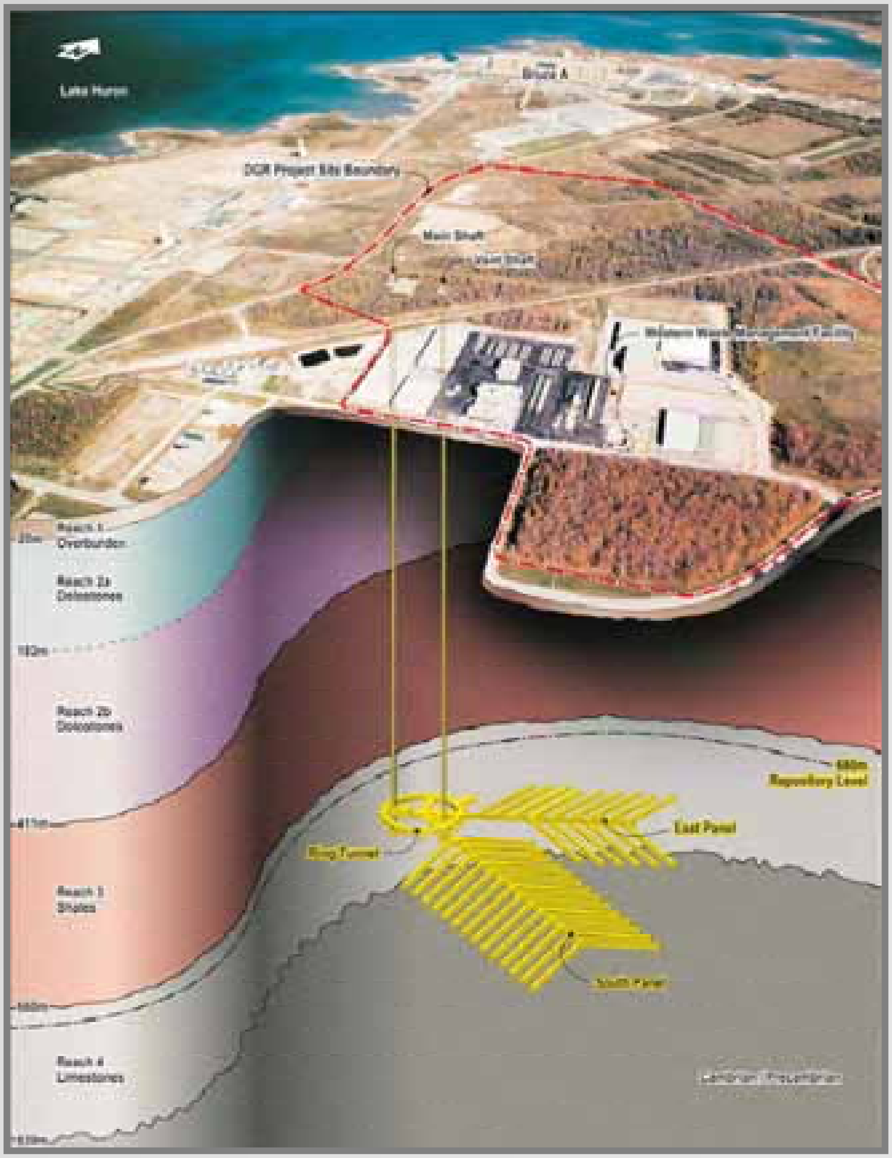
10.5.5 Decontamination

Routine decontamination of underground equipment is not anticipated since one of the key DGR Waste Acceptance Criteria is that there shall be "no loose contamination" on waste packages and that the packages are considered to be 'contact-handleable'. In the event that decontamination underground is required the following facilities will be provided:

- The maintenance facility will contain equipment that can be used to decontaminate forklifts or other mobile equipment that is discovered to be contaminated underground.
- The sanitary facility next to the maintenance facility will include a personnel decontamination chamber.

Conceptual Design Report

11. Security



11. Security

The DGR facility would be located within the Bruce site and would be encompassed by the larger security system for the site. The Bruce site security system would be in place as long as there are operating or shutdown reactors on the site.

The Bruce site is entirely surrounded by a perimeter fence that restricts access to the site via land or water. The only access to the Bruce site is via controlled checkpoints. Only authorised personnel and vehicles are allowed on the site. Security clearances are obtained for all employees and contractors.

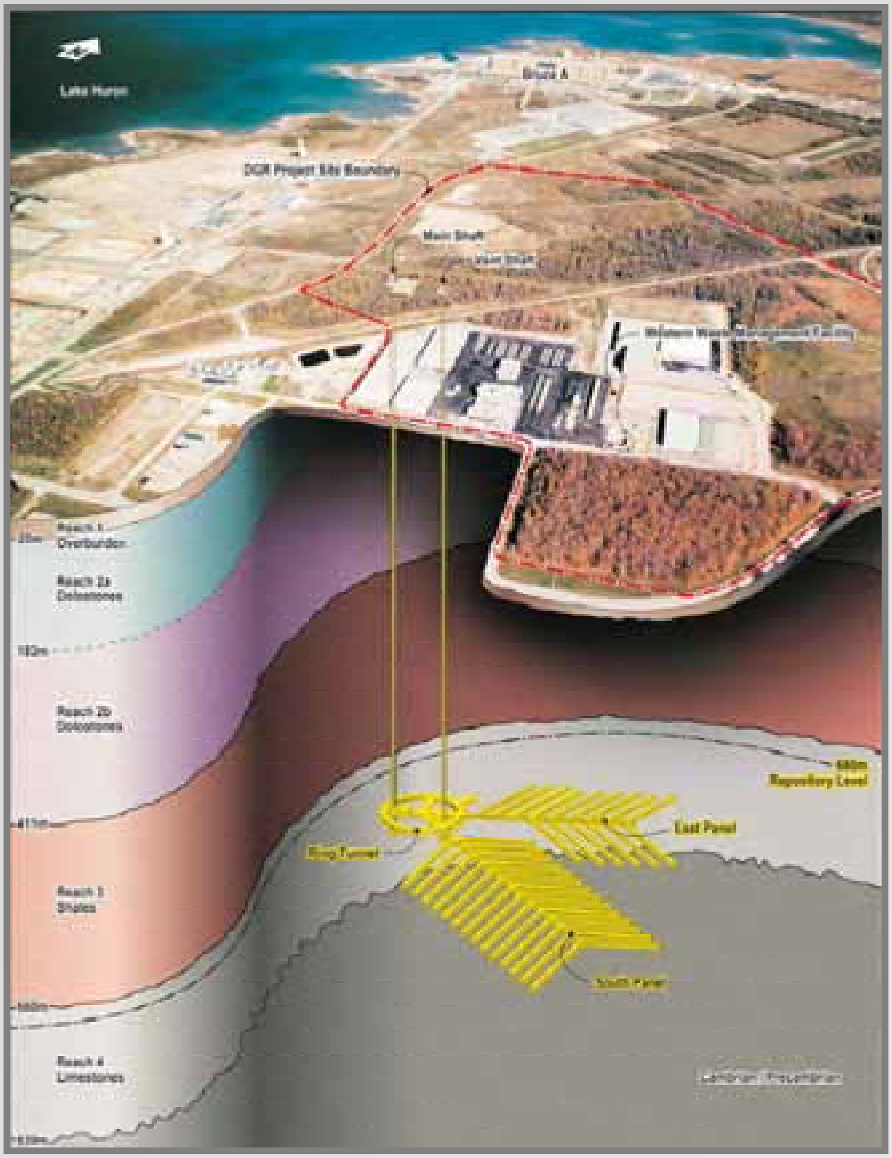
The surface structures of the DGR, including the Main and Ventilation Shaft complex and the road and bridge connection to the WWMF, will be encompassed by a security fence. It is currently envisaged that the security area will be linked to the WWMF, thereby making the DGR an extension to the WWMF security area. Incoming and outgoing vehicles and traffic will pass through existing security check points at the WWMF main access gate immediately adjacent to WVRB and then cross the new bridge over the abandoned railway to reach the DGR operating island. During permanent operations, the waste rock piles would be outside this security fence.

During construction, a separate entrance to the DGR site will lead directly off the "Interconnecting road" and there will be no contact with the WWMF. A separate security station will, therefore, be required for the construction phase.

Details of the security systems, showing compliance with CNSC regulations, will be described in a separate security-protected document.

Conceptual Design Report

12. Repository Construction and Development Phases



12. Repository Construction and Development Phases

Fundamentally, the repository construction and development will be fully completed prior to commencement of operations. However, a phased approach to construction is recommended. This approach is not expected to delay the start of radioactive waste transfer operations, but will provide a significant increase in certainty relating to mitigation of construction design, methods and cost risks.

12.1 Initial Geotechnical Investigations

OPG are currently carrying out a geotechnical characterization program, which is intended to confirm that the geological formations below the Bruce site are suitable to host the repository. All necessary geotechnical investigations will need to be (and are planned to be) completed before construction. Currently completed investigations provide useful information for conceptual and initial preliminary engineering. Additional investigations are planned that will be more geared towards the engineering aspect of the repository and will provide the data necessary for the detailed engineering design of shaft and tunnel construction and support.

To control costs in underground work, it is common to develop a flexible design approach and form of contract when conditions can vary significantly. Such an approach involves the development of a series of progressively more robust designs each determined for specified ground condition and behaviour range. Contract bid documents are structured to use unit rate prices against quantities established on the anticipated distribution of each condition range. This allows the implementation of the design to respond to observed conditions.

Alternatively, in lump sum bidding, bid prices will reflect the level of information provided in the documents. A conservative range of geomechanical conditions will result in higher bid prices and an optimistic range of conditions may result in lower bid prices, but with a higher risk of claims and changes.

Regardless of whether a lump sum or unit price basis is used for bidding, the reliability of the bid prices to reflect the future cost of the work is directly related to the quality and accuracy of the geomechanical and geotechnical basis described in the bid documents. Therefore, it is recommended that prior to finalising designs for construction and issuing any contracts, that two orthogonally oriented, inclined boreholes be advanced to repository depth (to investigate sub-vertical joints and there spacing) and that additional boreholes be drilled on the centre-line of the shafts to provide a full understanding of the actual rock mass characteristics that the sinking contractor will encounter. The data collected will improve the geomechanical basis for design and construction prior to bidding the main DGR shaft sinking and construction contract.

It is further recommended that the construction of the DGR facility be sequenced to advance portions as exploratory works to confirm the characterisation of the rock mass units and permit continued monitoring and design adjustment in response to construction observations. Geotechnical monitoring and observations during these advance portions of the construction should be carried out and results used to select the most appropriate rock support and construction methods in response to conditions. Geotechnical monitoring and observations during construction should be carried out and results used to select the most appropriate rock support and construction methods in response to conditions as observed.

12.2 Surface Facilities

All surface facilities will be constructed during the initial construction phase. For shaft sinking, the two Headframes would be constructed, complete with the permanent Ventilation Shaft hoist house, exhaust fan building and waste bin with airlock for waste rock dumping. Temporary hoist houses for the Main Shaft sinking hoist and both sets of sinking winches (Main and Ventilation Shafts) would be constructed. Additionally, as the shaft sinking would be planned to occur 24/7, 350 days per year, a temporary heating and fan house and equipment would be installed to provide controlled air temperatures to the shaft sinking crew.

The layout of these surface facilities is shown in Figure 12-1 and for quick comparative reference, Figure 12-2 shows the surface layout during the operational phase. Drawings 323874DGR-200-023 and 323874DGR-200-001 respectively show these two arrangements in the full site context (see Appendix E).

Environmental protection measures will need to be considered during both the construction and operation of the DGR facility. These measures will include a number of environmental management plans such as, but not limited to, a site development plan, environmental training plans, water use plan, hazardous material management plan, waste management plan, erosion and sedimentation control plan, emergency preparedness and response plan for spills, site rehabilitation and biological plan, fire protection plan, dust abatement plan and other plans (e.g. environmental monitoring). Environmental monitoring would include surface and groundwater, noise, dust (particulate) and radioactivity.

Specific environmental protection measures will be based on sound engineering principles. Measures will be established to prevent the uncontrolled release of soil materials, chemicals or wastes into the environment at/or near the source. Dust abatement measures associated with the construction of roadways will be implemented during the construction period. Training will be a key component of the plan to increase environmental awareness and to develop contingencies for emergency response. A monitoring plan will assess the impact of these environmental protection measures during construction and operations.

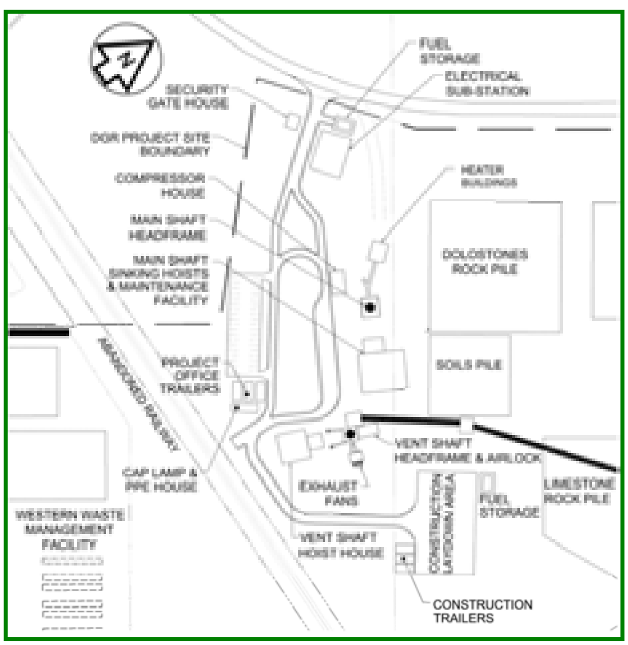


Figure 12-1 – Surface Layout (Construction Phase)

Figure 12-2 – Surface Layout (Operations Phase)

12.3 Completion of Infrastructure

12.3.1 Surface

After completion of shaft sinking and construction, the temporary structures will be removed and the WPRB, Intake HVAC system (heater building, refrigeration plant and bulk air cooler) will be constructed. In addition the Main Shaft Headframe will be furnished for the permanent operations including installation of the large Koepe hoist. The permanent roadways and the bridge over the environmentally sensitive abandoned railway will be constructed.

12.3.2 Underground

During the change-over from the shaft sinking phase to the operations arrangement and commissioning of the Main Shaft, the Ventilation Shaft will be used to develop and equip the ring tunnel and ancillary rooms.

Core drilling along the centre line of the two panel access tunnels or half-sized headings will also be advanced to establish engineering rock mass strength and behaviour conditions across the DGR footprint. This information would be used to select the most appropriate pillar spacing commensurate with the flexible design approach described above and described in Sections 7.1.2, 7.1.3 and 7.4.2.

12.4 Full Underground Repository Development Phase

Once the ring tunnel infrastructure and access tunnel core drilling and analysis have been completed, the contract for the full development of the repository access tunnels and all emplacement rooms will be placed.

Core drilling along the centre line of each emplacement room will be undertaken systematically as the main access tunnels are advanced to confirm the rock support requirements to be followed by the mining contractor.

12.5 Schedule

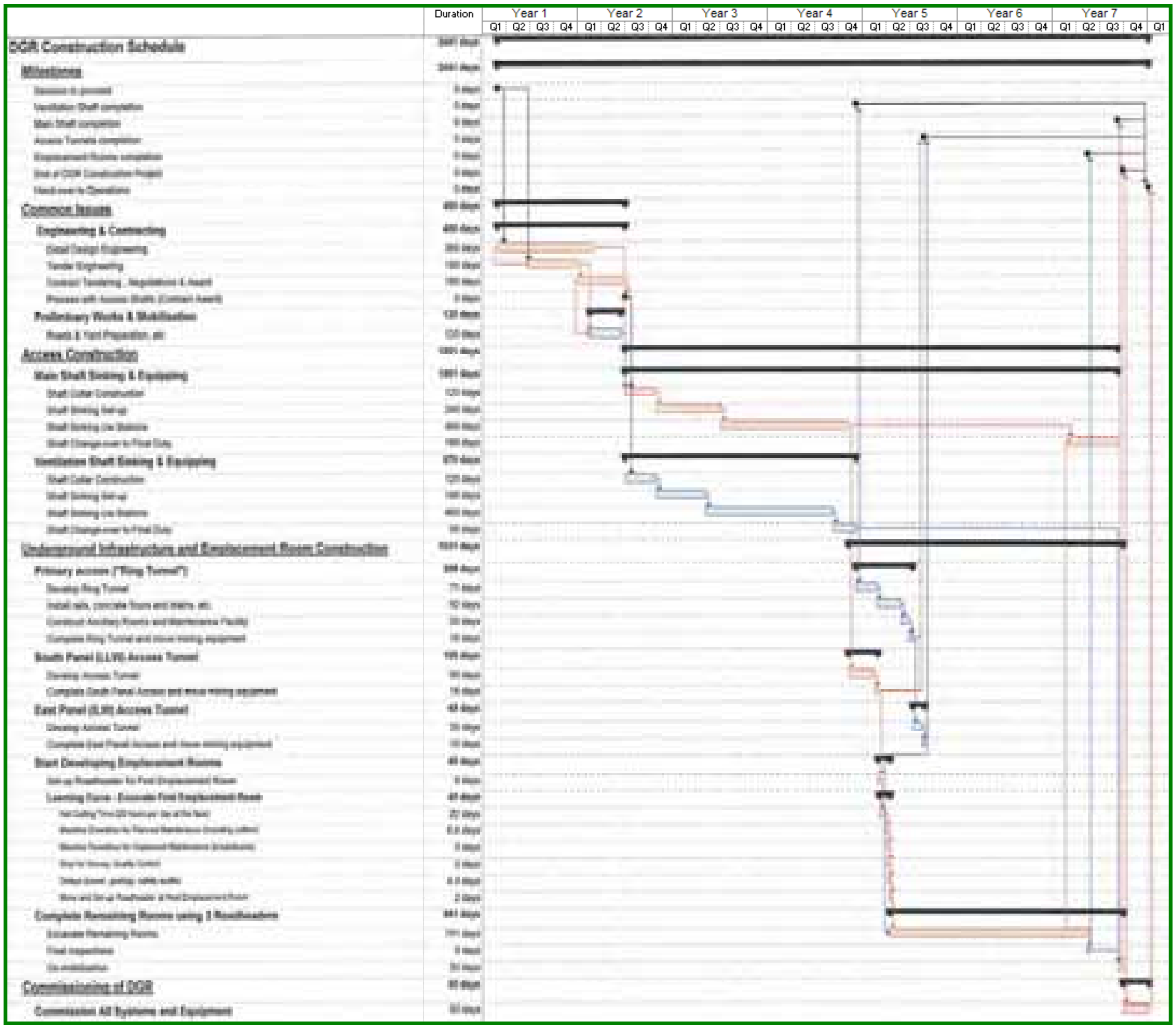


Figure 12-3 – Conceptual Schedule for Repository Development

12.6 Labour Requirements

During the construction phase, it is anticipated that the labour complements shown in Table 12-1 will be required.

Initial surface construction would be performed on a basis of single shifts for 350 days per year. Allowance would need to be made for reduced productivity during winter to account for extreme conditions halting external activities. However, detailed planning in future phases of engineering could enable the heavy construction work to be scheduled for summer months with internal works (e.g. Headframe furnishings, hoist installation) being performed in winter.

Shaft sinking and underground development would be performed on a three shift (24/7) basis over 350 days per year.

Phase	Organisation	Category of Labour	Number
All	Owner	Manager	1
		Safety Officer	1
		Quality Controls	1
		Environmental Officer	1
		Finance	2
		Buyer	1
		Administrative	2
		Security	4
	Engineering Contractor	Project Manager	1
		Safety Manager	1
		Construction Manager	1
		Construction Supervisors	2
		Engineering Manager	1
		Discipline Engineers	5
		Rock Mechanics / Geology	2
		Commissioning Manager	1
		Quality Manager	1
		Purchaser	1
		Expediter	1
		Contract Administrators	2
		General Administrative	2
Surface Construction	Construction Contractor	Site Manager	1
		Discipline Managers	5
		Safety Officers	2
		Tradesmen	30
Shaft Sinking (per shaft)	Construction Contractor	Manager	1
		Sinking Superintendent	1
		Shift Supervisor	3
		Sinking Crew	24
		Maintenance Engineer	1
		Maintenance Team	8
		Safety Officer	1
		Hoist Driver	4

Table 12-1 – Estimated Labour Complement during Construction

In addition to the positions identified in Table 12-1, there will also be a geological characterisation team under direct control of the Owner. The rock mechanics engineer and geologist listed in Table 12-1 will only be involved in construction design and inspection activities.

12.7 Mining Equipment Requirements

The underground mining construction work on the shaft stations, ring tunnel, ancillary rooms, panel access tunnels and emplacement rooms will be preformed using a fleet of mobile mining equipment. All excavations have been designed such that only one size of each type of machine would need to be included in the fleet of equipment, although multiple units may be required to suit the planned construction methods and schedule.

Typically, the suite of equipment would include:

- Drilling jumbo for drill explosives holes in sections that would require drill and blast methods to excavate;
- Roadheader for excavation of all main tunnels, emplacement rooms and the larger ancillary rooms;
- Load haul dumper (LHD) to muck the mined rock;
- Diesel truck to haul the rock excavated from the access tunnels and emplacement rooms to the rock dump at the Ventilation Shaft;
- Rock bolter for rock support and fixing of services (piping, cables) support brackets;
- Scissor lifts for accessing the high excavations for attachment of supports, piping, cables, lighting and any other fixtures.

12.8 Potential for Future Expansion

At some stage in the future, it may become necessary to expand the repository to dispose of additional volumes of waste due to uncertainties in the predicted quantities of future wastes.

The conceptual design has taken this potential into account and ensured that layouts will allow for an expansion of the repository to dispose of an additional reference volume of 200,000 m^3 of "as-disposed" waste.

On surface, there will be no requirement for any changes to infrastructure, with the exception of creating an additional break in the security perimeter to allow for the transport of waste rock away from the Ventilation Shaft Headframe to the waste rock piles. The waste rock piles would be extended in area and height to accommodate the extra rock excavated for the additional underground emplacement rooms and tunnels. The expanded waste rock disposal area is shown on Figure 12-4.

Underground, the emplacement room capacity would effectively have to be doubled from the base design for the DGR. An additional panel of rooms ("North Panel") would be constructed for the additional LLW packages, and the existing "East Panel" would be extended to double the number of rooms on that panel for the additional ILW and large and irregularly-shaped LLW, as shown on Figure 12-5.

To effect the construction of the additional panels and rooms, waste emplacement operations would cease and the existing filled emplacement rooms closed off. The repository would be turned over to the construction contractor, who would then proceed to develop and equip all the new tunnels and rooms required using the Main Shaft for primary access of equipment, materials and labour. The Ventilation Shaft would be used for hoisting the excavated waste rock in the hoist's skip and as a second or emergency egress. Therefore, although the facility would still be classified as a "nuclear site", personnel would not normally be in contact with any exhaust air from the repository. On completion of construction, the construction equipment would be removed and the facility would be re-commissioned for waste disposal activities.

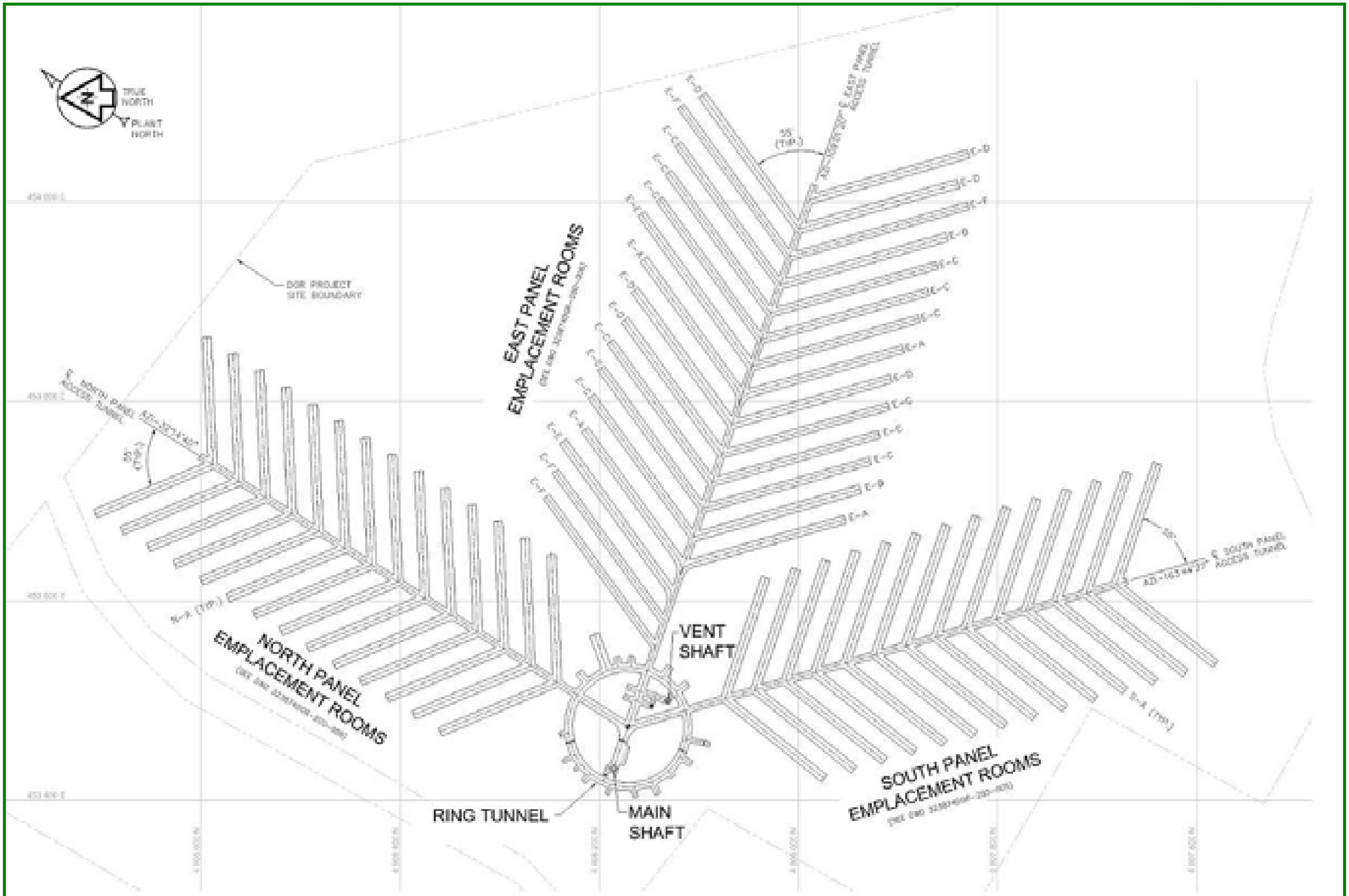


Figure 12-4 – Underground Repository Layout for Potential Expansion Case

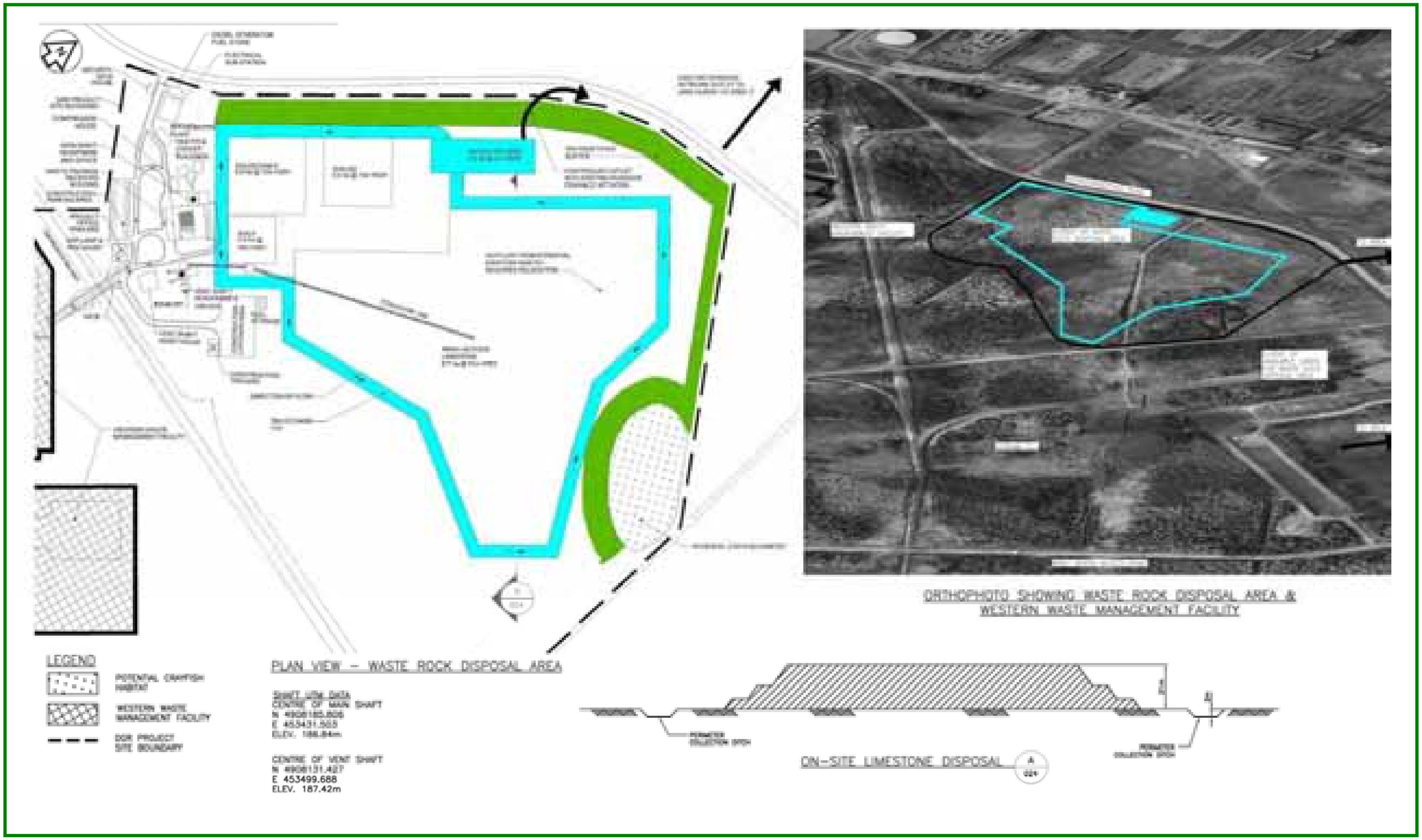
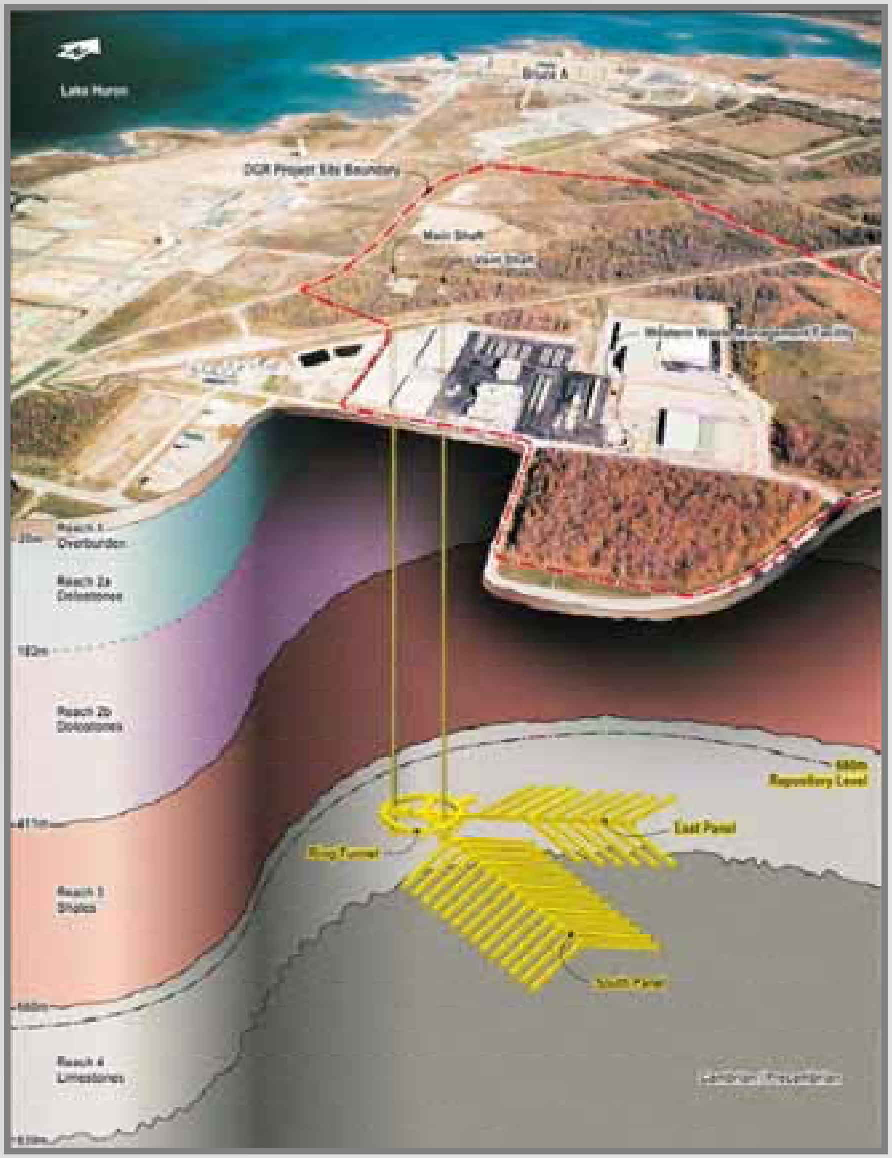


Figure 12-5 – Surface Layout and Rock Pile for Potential Expansion Case

CONCEPTUAL DESIGN REPORT

13. Operations



13. Operations

13.1 Schedule and Sequence of Waste Emplacement

When the DGR construction has been completed, the backlog of waste packages will be cleared from the WWMF over a period of about 6 years. Although the repository is designed to be able to operate continuously (24/7), during this time, continual emplacement operations will occur on a single 8 hour shift, five days per week basis. No specific sequence of transfer for waste packages is required, but there are certain conditions that should be in place when detailed schedules are drawn up in later phases of engineering:

1. Within a three day period, enough of any one type of standard LLW bins or racks should be transferred to fill an integer number of rows in an emplacement room;
2. When large and heavy objects (e.g. steam generator segments, T-H-E liners) are transferred, it is likely that more than half a shift will be used, but there will still be time left over in the shift, during which some quicker-to-move standard LLW waste packages should be transferred.

These guidelines will assist in expediting the clearance of the backlog, preventing delays and lost time, which would otherwise extend this initial period of transfer operations by periods measured in years, and ensuring that at least 24 LLW packages or 4 resin liners can be transferred in one 8 hour shift.

13.2 Labour Requirements

Two phases of operations are identified:

1. Initial Operation to clear the backlog of stored wastes from the WWMF and additional new wastes that will arrive from the nuclear power stations in the interim;
2. Steady-state Operation, in which only new wastes will be received at a considerably slower rate than during the first phase

Phase	Category of Labour	Number
Initial Operations Phase (approximately first 6 years of operations)	Superintendent	1
	Controller and Planner	1
	Safety Officer	1
	Quality Controller	1
	Finance	Shared
	Buyer	Shared
	Administrative	1
	Security	Shared
	Maintenance Engineer	1
	Instrument Technician	1
	Mechanic	2
	Electrician	2
	Hoist Driver	1
	Cage Tender at Collar	1
	Surface Receivers	2
	Underground Material Handlers/ Forklift Operators	6

Phase	Category of Labour	Number
Steady-state Operation Phase	Superintendent / Controller and Planner	1
	Safety Officer	1
	Quality Controller	1
	Finance	Shared
	Buyer	Shared
	Administrative	1
	Security	Shared
	Maintenance Engineer	1
	Instrument Technician	1
	Mechanic	2
	Electrician	2
	Hoist Driver	1
	Cage Tender at Collar	1
	Surface Receivers	1
	Underground Material Handlers	3

Table 13-1 – Estimated Labour Complement during Operations

Apart from the functions noted as 'shared', all staff complements listed in Table 13-1 are incremental to WWMF personnel. The 'shared' positions are assumed to be personnel currently working at the Western Waste Management Facility. Once the initial phase of operations is complete, such personnel may not need to be stationed at the Western Waste Management Facility any more and, therefore unless their services can be shared with other OPG operations, they could need to become full time on the DGR work.

The complements do not include any labour required to retrieve waste packages from storage at the Western Waste Management Facility or transfer the waste packages overland to the WPRB at the Main Shaft.

13.3 Maintenance

A planned maintenance system will be produced prior to commencement of operations to provide full control of maintenance activities and enable the facility to attain an overall availability of 80% during working hours excluding scheduled stoppages for the maintenance activities. Original equipment manufacturers (OEM) will also be engaged to ensure the plan meets their recommendations and requirements and identifies major equipment maintenance or condition inspections that need to be scheduled and would, in all likelihood be contracted to the OEM to perform.

13.3.1 Surface Maintenance

Maintenance and daily, weekly and monthly statutory inspections of surface plant installations (hoists, compressors, refrigeration plants (in summer months), heating plant (in winter), the main electrical sub-station and diesel generator will be carried out by the mechanics, electricians and instrument technician. Such inspections will be overseen by the maintenance engineer, who will also be responsible for testing equipment as required in the Mines and Mining Plant Regulations (R.R.O. 1990, Reg.854).

13.3.2 Underground Maintenance

One of the mechanics and electricians listed in Table 13-1 will perform regular maintenance on the fleet of underground equipment and other underground installations (e.g. pumps and sub-station) in addition to assisting the surface tradesmen on the maintenance of the surface equipment and electrical sub-station.

In addition to the core labour requirements given in Table 13-1, once the repository construction has been completed, maintenance will be required in access tunnels, empty emplacement rooms, shaft liners and other underground facilities during operations.

This will initially consist of scheduled observations and geotechnical instrumentation function to monitor the performance and condition of the rock support elements, the rock pillars, floors, walls and roof of the rooms and tunnels. Instrumentation consisting of rock bolt load cells, multi-point borehole extensometers and room convergence arrays will be specified and installed during construction. These will be read diligently during construction, with frequency reducing post construction in response to the magnitude of changes. As a minimum, results should be performed quarterly throughout the initial life of the repository (10-20 years). At that time an assessment regarding the frequency of future readings can be made.

In terms of maintenance for rock support including concrete floors, it is expected that initial requirements will be minimal for the initial operating life of the repository. However, some limited installation of rock bolts and shotcrete may be required periodically (quarterly). Over time (10 to 25 years) and depending upon traffic levels and corrosion rates in the repository, the concrete running surface in the access tunnels and other support elements may require more extensive repair. At this time, engineering inspections and rehabilitation contracts may be necessary. Such contracts would be similar to scheduled shut-downs of industrial plants and require three to six months to complete, and would be likely occur every 10 to 20 years over the life of the repository.

There are legal requirements for weekly and monthly shaft inspections (Sections 249.1 (a) & (b) of R.R.O. 1990, Reg.854, Mines and Mining Plant), which is primarily visual in scope. In addition, a detailed structural condition survey should be performed annually to supplement these weekly shaft observations. Initial maintenance would likely be minimal, but rehabilitation work similar to that described for the access tunnels, may prove necessary but at a reduced frequency (approximately twice in the 100 year life of the repository).

13.4 Equipment Requirements

The majority of the waste packages will be moved with diesel powered, rubber tired forklifts, both on surface and underground. Forklifts are currently used regularly in the Western Waste Management Facility for movement and placement of waste packages and this approach allows for the use of commercially available equipment that will require little or no customisation for the application.

Diesel equipment is extensively used in underground mining and civil projects and has an exceptional safety record. Ventilation for the facility has been designed to meet the required legislation for diesel use underground. Diesel equipment allows for greater flexibility and range and does not require extensive electrical services or battery charging stations that other options would require.

Large and heavy packages up to 40 tonnes will be moved with forklifts as well. Equipment selection will specify either reversible or side mounted seating to ensure that the operator will have good visibility at all times. This will allow the forklifts to operate with the load either leading or trailing the direction of travel. Such equipment is used (or planned for use) in an underground repository environment at the Waste Isolation Pilot Plant (WIPP) at Carlsbad, New Mexico, and at the Konrad repository in Germany. Examples are shown in Figure 13-1 and Figure 13-2. While both of these forklifts were custom-built, conventional large capacity forklifts are available and it is not anticipated that anything other than some minor customisation would be needed for equipment to be used in the DGR.

Although specific forklift units have not been selected at this stage of the study the small forklifts will be able to fit in the cage and it is expected that the large units would do the same with the removal of the forklift mast.

Shielding could be incorporated into the forklift design if required for any very high dose rate waste packages, although it is proposed that such measures would be best achieved by attachment of temporary shielding mounted on the forklift mast to provide a screen between the operator and the waste package. Additionally, procedures will need to be used when handling any such package to ensure that workers would not be in a proximity that could expose them to dose rates in excess of the criteria limits set in OPG's Waste Acceptance Criteria ([R77]). The nominal distance between the operator and the waste package would be 2 to 3 metres for all forklift transfer operations.

Figure 13-1 – 41 ton Forklift at WIPP
(courtesy: WIPP)

Figure 13-2 – Forklift for Konrad
(courtesy: DBE)

In all cases operating procedures will require the use of proper pallets and attachments. Travelling speeds for larger packages will be controlled to walking speeds (2.5 km/h). The small forklifts have a capacity of up to 10 tonnes, and will travel at speeds of up to 6 km/hr when transferring a waste package. Roadways will be concrete and well maintained, which will allow for secure travel to all extents of the DGR facility. The maximum distance, over which any of the forklifts will travel carrying a waste package, is approximately 620 metres.

Rail cars will be used for the T-H-E Liners (THLIC18 and THLIC2) and other awkwardly sized packages, such as the heat exchangers (HX) and shield plug containers (SPC), that are not amenable to forklift use. These packages will be loaded on rail cars by a gantry or overhead beam crane on surface, properly secured, transported down the shaft and pulled by the large forklift to an emplacement room where they will be off loaded by a gantry crane. The T-H-E Liner packages which are too long to be transported horizontally down the shaft will have a specially designed rail car that will secure and hydraulically erect the package so that it can be transported vertically down the shaft and then laid down again for transport within the facility, as described and shown in Section 8.4.6 and Figure 8-13 above.

There will be a higher level of activity in the early years of operations, therefore, the quantities of mobile equipment may be reduce after the backlog of stored waste packages is cleared about six years after commissioning of the DGR.

The estimated equipment requirements for handling waste packages are given in Table 13-2. The fleet numbers are broken down into the two phases of operation of the repository; i.e. the "Initial Phase" when the backlog of waste packages stored in the WWMF at commencement of emplacement operations, plus the recharge rate of new packages arriving from the power stations during this period, is cleared and emplaced underground; and the "Steady-State Phase", which will follow on to transfer all future packages after clearing of the backlog.

Location	Equipment	Initial Phase Fleet	Steady-State Phase Fleet
Surface	Small Forklift (10 tonne)	2	1
	Large Forklift (3 tonne)	1	1
	Flat-bed Truck	2	0
	Heavy-duty Low-bed Truck	1	1
	Overhead Beam Crane (40 tonne) in DGR Receiving Building (WPRB)	1	1
Underground	Small Forklift (10 tonne)	4	2
	Large Forklift (40 tonne)	2	1
	Personnel Carrier	3	1
	Mobile Work Stage	1	1
	Mobile Bolting Unit	1	1
	Main Shaft Station Monorail Hoist	1	1
	35 tonne Gantry Cranes in Emplacement Rooms type E-A and E-B	2	1
	T-H-E Handler	2	0
	Rail Cars	2	1

Table 13-2 – Mobile Equipment Requirements

13.5 Room Closure

Once an emplacement room has been filled to its design capacity, closure panels will be constructed. These will be reinforced concrete walls designed to provide a secure, relatively air-tight seal to the room. The concrete would need to be doweled into the surrounding rock and contacts sealed through grouting and caulking. A pressure- and fire-resistant door system will be installed to provide both access and security to the closed room. Openings for ventilation will be required. An upper opening will be necessary for ventilation duct which will include a fan to draw air from the room into the overhead ducts in the access tunnel. A lower opening will be necessary to allow air inflow into the room. This opening will need to incorporate a controllable damper that can isolate the room as necessary. The room closure panel will need to be detailed to permit access to the fan and damper for future maintenance and inspection.

13.6 Waste Package Retrieval

In the unlikely event that any waste package needs to be retrieved from a room following emplacement, a specific procedure for retrieving the package will be developed. Two scenarios could apply:

- Retrieval from a room, which is not "closed" and in which waste packages are still being emplaced.
- Retrieval from a room, which has been filled with its allocated quantity of waste packages and is now "closed".

In general, the principle for all waste packages will be similar, and follow the following lines of action:

- First, the position of the waste package to be retrieved will be identified using the IWTS system, and the number and type of packages, that will have to be moved to access the identified waste package, will be determined.
- Alternative locations, which may be temporary or permanent, for these packages that need to be moved will be decided. They could be relocated to another room, which is partially filled or empty. This new location could be suitable as a permanent disposal site for those packages that will have to be moved to reach the package marked for retrieval. Alternatively, it may be necessary to temporarily store some or all of these packages in an access tunnel and then replace them in the room form which they came after the retrieval package has been removed. In this event, it will be necessary to determine whether any special precautions need to be taken because of dose rates of the moved packages. Areas may need to be demarcated in the repository for these packages and personnel access restricted to ensure no worker can be exposed to unacceptable levels of radiation.
- Once the planning has been completed, the retrieval procedure will be actioned in one of two methods:
    - For an open room, packages would be removed using the reverse of the procedures, by which they were emplaced. In most instances this would involve using the same equipment (forklifts, railcars etc) that had been used to emplace the packages.
    - For a closed room, the ventilation fan system for that room would be started and run for adequate time to purge the room of any noxious or other gases and to re-ventilate the room with breathable air before the closure wall is opened. The gas monitoring instrumentation in the exhaust duct would be used to determine when the atmosphere is safe to proceed. Once the wall has been opened, the packages that require removal to reach the waste package marked for retrieval will recovered as for an open room.

Although most waste packages can be removed from a room without excessive difficulty, it is expected that the procedure would be relatively slow to complete to ensure safety at all times.

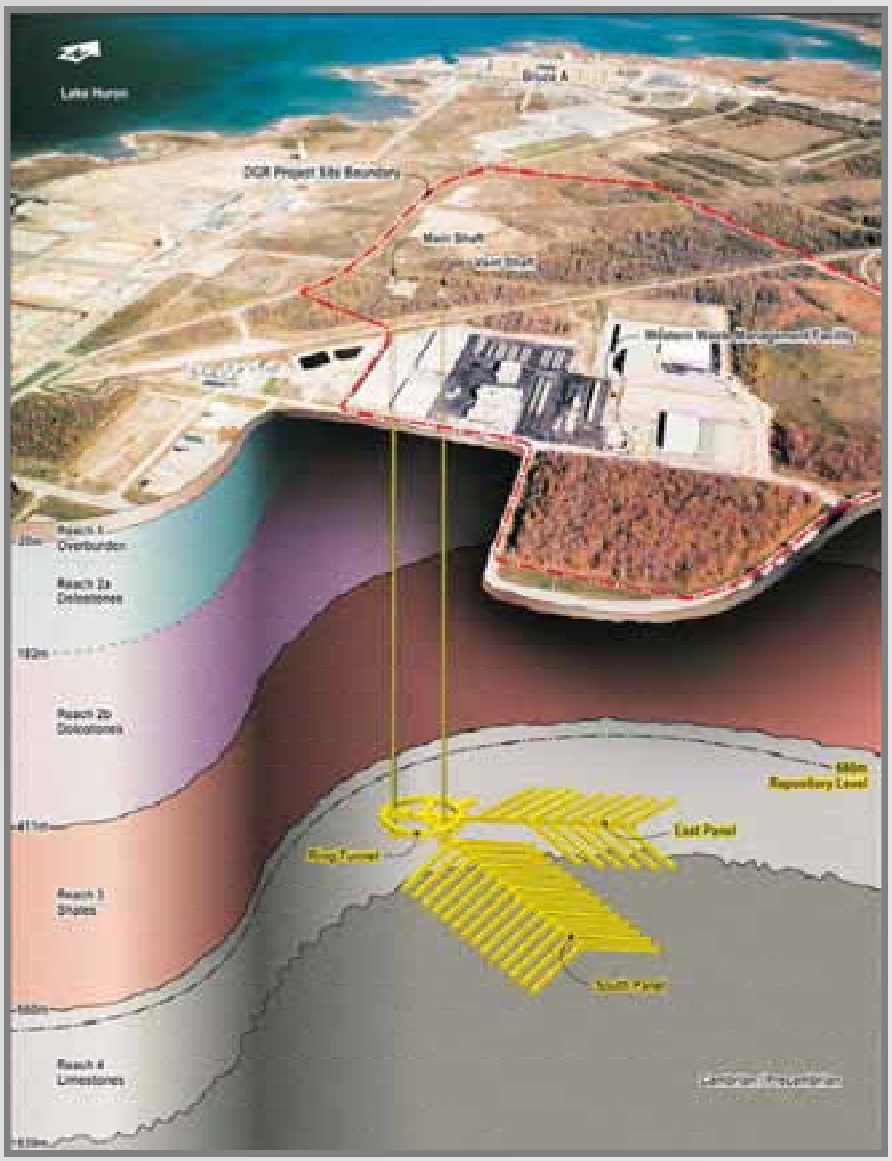
There is one exception to easy retrieval, which is the retrieval of a T-H-E liner embedded in the concrete pipe array. The Horizontal Emplacement and Retrieval Equipment (HERE), which was used to push the liners into the pipe array (see Section 8.4.6 above), would be used in reverse as its name suggests. Before starting on removal of any T-H-E liners, the room would have to be re-equipped with a gantry crane. This retrieval process for the T-H-E's will of necessity be time consuming to perform.

For each T-H-E liner that has to be removed to reach the liner identified for retrieval, the sequence of events would follow these steps:

- The HERE machine would be positioned in the emplacement room and the transfer bell loaded into position on its frame;
- The concrete cap would then be pulled out of the end of the pipe using a grappling attachment fitted to the end of the ram of the machine. (The cap will have cast in attachment pockets to enable easy connection to the grappling attachment)
- The attachment would then be connected to the T-H-E liner similarly to when the T-H-E was originally removed from the in-ground storage cells at the WWMF and the T-H-E pulled into the bell, detaching ram sections as necessary during the operation.
- Once the T-H-E is fully enclosed in the transfer bell, its articulating end closures will be bolted up and the gantry crane will lift the bell with it's T-H-E waste load onto the T-H-E Handler.
- The waste package can then be removed to another room for temporary storage in a fixed concrete shield or removed from the DGR totally to surface.

Conceptual Design Report

14. Decommissioning and Final Sealing of Repository



14. Decommissioning and Final Sealing of Repository

After waste emplacement operations have ended and regulatory approval has been received to decommission the DGR facility, work will begin to dismantle the facility and seal the repository. The scope of decommissioning work for the repository would include preparation and approval of decommissioning plans, decommissioning of underground facilities, sealing of shafts, and demolition of all surface facilities. Following decommissioning of underground facilities, the two shafts will be sealed over their entire length with clay-based, concrete and asphalt materials. For the purposes of this conceptual design study, it is expected that concrete will be the only sealing material considered for limited placement in the Ring Tunnel or any of the underground access tunnels in order to construct a concrete monolith structure at the base of each shaft.

The decommissioning work will be considered complete when the planned end state of the DGR facility, as described in the application for decommissioning licence, has been reached and the regulatory agency has agreed that the decommissioning work has been completed. The decommissioning work is expected to take approximately 6 years to complete.

14.1 Decommissioning of Repository

Decommissioning of the repository will entail the decommissioning of underground, shaft, and surface facilities.

14.1.1 Decommissioning of Underground Facilities (including shaft furnishings)

Equipment and materials required in the repository are described in Sections 4, 5, 8, 9, 10 and 13.

Decommissioning of the underground facilities will occur in several stages.

All equipment employed within the emplacement room panels will be secured for long-term emplacement in the repository; this may involve the removal and separate storage of batteries, residue fuels and other materials from any machinery employed within the emplacement rooms.

Any equipment, which has been used within the ring tunnel, access tunnels or the panels, will remain within the repository as a result of potential contamination, having operated in the Zone 3 areas. The upcast Ventilation Shaft, which is also a Zone 3 area, will be stripped of all steelwork and furnishings (as described in Section 14.1.2 below), which will be transferred back into the repository down the Main Shaft and emplaced in the access tunnels for perpetuity.

Following this, all infrastructure connections (power, ventilation, water) to the panels will be disconnected and the access tunnels will be sealed preventing further entry.

This process will then be repeated for the ring tunnel connecting the access shafts and panels, followed by stripping of the Main Shaft steelwork and furnishings (as described in Section 14.1.2 below). Particular caution will be employed in areas where potentially hazardous materials, such as any waste fluids from vehicle maintenance, may exist to ensure long-term stability of this site. Bulkheads will then be created at the extreme of the proposed concrete monolith (see Section 14.2.3 below). These bulkheads will seal the ring tunnel from any further entry.

It is anticipated that all equipment and structures required underground will remain in the repository after decommissioning as a result of potential contamination from waste stored in the facility. Any fuels and explosives remaining in the repository at the time of decommissioning will be removed to the surface to reduce flammable materials within the area. Electrical connections to the repository will be severed prior to the commencement of sealing, while ventilation equipment will be removed in stages in order to maintain air supply during installation of the shaft seals.

14.1.2 Decommissioning of Shafts

Decommissioning of the shafts will consist of the sequential removal of shaft infrastructure and installation of the proposed shaft seal (see Section 14.2.3 below).

The Ventilation Shaft will be decommissioned and its seal installed before the same operation is carried out on the Main Shaft.

At the Ventilation Shaft, a set of temporary stage winches will be installed, from which a working platform will be suspended on wire ropes to enable the sealing process to be conducted. The existing 2nd egress hoist will be used as the primary means of travel between surface and the shaft bottom for workers, equipment and materials. Shaft infrastructure, such as ventilation, will be removed on a phased basis in a manner to ensure that provide required services to the shaft during shaft sealing. Shaft sealing will be conducted as described in Section 14.2.4 below.

On completion of sealing of the Ventilation Shaft, the same process will be performed at the Main Shaft. In this case, the first stage of shaft decommissioning will consist of removal of the operational Koepe hoist, and replacement by a stage hoist to suspend the working platform and a single drum hoist for worker, material and equipment access during the stripping of the shaft lining and EDZ.

14.1.3 Decommissioning of Surface Facilities

Surface facilities required for operation of the DGR are described in Section 4.2. The majority of surface facility decommissioning will occur following completion of the shaft seals (see Section 14.2), as these resources will be required to maintain service to the shafts during the installation of the seals. It would, however, be expected that the hoist system employed during DGR operation will need to be replaced prior to commencement of seal construction as the Koepe hoist will not be suitable for installation of the seal.

Wherever appropriate, mechanisms and materials decommissioned from surface facilities will be recycled or reused elsewhere to minimise requirements for disposal. Those materials that are not recyclable will be disposed of in an MOE-approved facility. All buildings will be decommissioned and removed from the site.

The expected order of decommissioning surface facilities is as follows:

- Removal of Koepe Hoist system used during operations, installation of hoist system for decommissioning
- shaft maintenance and waste package receiving building
- refrigeration plant and bulk air cooler
- heater building
- exhaust fans
- vent shaft headframe and air lock
- main shaft headframe and office

Following removal of all surface facilities, the site will be graded and re-vegetated using species native to Bruce County, and local genetic stock where practical. The location of the shafts will be appropriately secured to ensure the possibility of accidental entry is minimised. Sustainable systems will be employed on this site to ensure that long-term management of stormwater is provided without impact on the surrounding environment.

14.2 Shaft Sealing

Following the closure of the repository, it is planned that the shafts will be sealed over the full depth from the repository to the top of the Reach 3 – Shales (primary seal) through Reach 2b (secondary seal), Reach 2a (tertiary seal) and Reach 1 (concrete cap).

The specific System Requirements relating to this aspect of the conceptual design are identified in Section 3 above. Design of the shaft sealing system will satisfy the relevant sections within the Ontario Mining Act and Ontario Regulation 240/00 (Mine Development and Closure) under Part VII of this Act ([R84]), as well as Section 11 (Well plugging) of the Provincial Operating Standards, Oil, Gas, Salt Resources of Ontario ([R85]).

As these sealing systems are unproven in terms of the large time over which they must be effective, the approach to this conceptual design was to research and consider other proposed systems designed or proposed for other repositories around the world and test work that had been carried out. Specifically the following case studies were investigated:

- Waste Isolation Pilot Plant (WIPP) in the USA, where a full design has been produced and approved;
- Morsleben Repository in Germany;
- AECL's conceptual design for a spent fuel repository in Canada;
- ANDRA's conceptual design for a spent fuel repository sealing system in France.

The main conclusions from the review of these designs were:

- Multiple materials serving repetitive functions should be incorporated into the design to maximise redundancy.
- Bentonite-based materials are universally recognised as a suitable primary sealing material, and should be utilised in the DGR sealing system.
- Engineered and compacted native material should be used as a tertiary seal (fill) in the upper reaches of the DGR shafts, where the restriction of radionuclide flow is not a concern.
- Concrete bulkheads should be part of the primary and secondary sealing system and should be keyed into the shaft walls to increase the structural integrity of the sealing system.

14.2.1 Design Approach

The design approach for the shaft seal design focussed on the use of simple, proven materials and methodologies for emplacement. Seal materials, construction methods, and arrangement are outlined below.

A key consideration in the design approach for the shaft sealing system is the potential formation of excavation damage zones (EDZ) during shaft sinking and operations. When man-made openings are created in rock formations, disturbance and damage to the surrounding host rock is expected to occur as a result of damage due to the excavation method itself, or mechanical changes resulting from stress redistribution. It is well understood that the creation of these zones occurs; however defining the extent and characteristics of these zones remains a contentious issue ([R86]). For the purposes of this report, the EDZ is defined as the region of rock around repository openings that has been physically or chemically affected as a result of the excavation process, with significant changes in flow and transport properties (e.g., one or more orders of magnitude increase in flow permeability). The EDZ can be divided into Inner and Outer regions:

- Inner EDZ - zone closest to the shaft wall where hydraulic conductivity is anticipated to increase by 2-4 orders of magnitude (as instructed by OPG).
- Outer EDZ - zone closest to the host rock where hydraulic conductivity is anticipated to increase by 1-2 orders of magnitude (as instructed by OPG).

As a result, the EDZ will show significant increases of permeability to flow. This has a significant impact on shaft sealing, as the potential flow of groundwater into the DGR and the potential migration of contaminants out of the DGR through the EDZ must be assessed and controlled. In order to establish an effective seal for the DGR, the extent of the Inner and Outer EDZ were defined, as instructed by OPG, based on expert judgement and supported by results presented in NEA ([R87]). For purposes of developing a robust DGR shaft seal system, it was conservatively assumed that both the Inner and Outer EDZ are assumed to have a width of $0.5*r$ (radius of circular excavated shaft) for each zone (for a combined total of $1*r$). Information presented below considers these conservative EDZ values.

The extent of EDZ remaining at the end of the operational period of the DGR may be less than would be initially expected as a result of salt or mineral precipitation from the host rock into the openings of the EDZ. Such precipitation may reduce the flow of groundwater through the EDZ to a limited extent. As such, the extent of EDZ formation has been estimated without considering any potential benefits of salt or mineral precipitation in the design of the seal.

14.2.2 Seal Materials

Concrete, bentonite clay, and asphalt are considered as primary and secondary seal materials (Reaches 4, 3 and 2b). Native earthen materials excavated during shaft sinking can be used to "fill" the shaft following in Reach 2a, however these materials are considered to be tertiary seal materials and are not discussed below.

14.2.2.1 Concrete

Nearly all the scientific and engineering literature regarding the sealing of deep waste repositories propose the use of mass concrete for some components of the sealing system (e.g. [R88]; [R89]; [R90]; [R91]). Concrete is utilised in structural components designed to key into the shaft wall to provide support and confinement for other sealing media while providing a redundant low permeability barrier.

The following engineering properties of concrete are considered advantageous for deep repository shaft sealing systems:

- Rapid development of structural properties.
- High strength.
- Low permeability in short-term (10^{-11} m/s and 10^{-14} m/s)

- Broad range of performance objectives can be achieved by changing the mix – type and proportion of ingredients, and the means by which it is emplaced.
- Typical ingredients are abundant and inexpensive.
- Extensive experience with concrete design, construction, and testing.
- Technology established for underground uses in the petroleum and mining industries.

Some potential drawbacks of concrete that must be addressed in the design and construction of a repository sealing system include:

- Geochemical compatibility with the host rock and groundwater. Mix design can be altered, such as by the incorporation of brine, to ensure compatibility with host rock.
- Interface problems at the contact between concrete and host rock (i.e., shrinkage of concrete results in separation at rock concrete contact). Contact grouting will be installed at all concrete bulkheads in order to minimise flow around the contact zone.
- Excessive heat generated from exothermic hydration reaction in large emplacements can result in thermal cracking of the concrete. The high temperatures may also negatively affect other sealing materials and influence the behaviour of the host rock surrounding the shaft opening. In order to control for this possibility, proper mass concrete construction procedures must be followed.
- Longevity of concrete. Concrete materials will remain stable in the long-term, however this will not be in perpetuity. As the cement leaches from the concrete, it will degrade into a mixture of granular materials (i.e., gravel and sand). This could have potential impacts on:
    - Structural stability of the seal: Granular materials remaining following concrete degradation can be designed to ensure a high degree of grain to grain contact and interlock is maintained (i.e., a large aggregate content) for provision of structural support for surrounding seal materials in perpetuity.
    - Performance of seal: As the concrete degrades, it will no longer serve as a primary seal material preventing the flow of groundwater. Therefore any potential seal design using concrete should ensure use of additional materials, such as bentonite clay, to minimise long-term hydraulic conductivity. If bentonite clay is used, the concrete can serve as a primary seal material preventing the flow of groundwater in the short-term while the bentonite clay cures.

14.2.2.2 Bentonite Clay

Compacted clays or clay/sand mixtures are the most commonly proposed sealing materials for nuclear waste repositories (e.g. [R88]; [R90]; [R92]; [R93]). The use of compacted clays has been extensively investigated and tested against a variety of seal performance requirements. Montmorillinite-rich smectite (bentonite) clays have received the most attention as they have higher swelling potential and sorptive capacity compared to other clays.

The addition of sand aggregate to the bentonite mixture increases the strength of the mixture. Furthermore, as the cost of bentonite is high relative to sand or aggregate, these materials act as fillers to decrease the required quantity of bentonite. The addition of aggregate to the clay also reduces the capacity for shrinkage and increases thermal conductivity. The ratio of bentonite to sand must be optimised such that the bentonite content is minimised while maintaining the desired properties of bentonite.

Research by AECL ([R94]) indicates that sand:bentonite ratios up to 50:50 do not significantly alter the hydraulic conductivity or swelling pressure as compared to pure bentonite under conditions of identical compactive effort. However, with an increased effort, highly-compacted pure to low-sand content bentonite forms can be obtained which provide higher swelling potential and much lower hydraulic conductivity ([R94]). Therefore, a bentonite:sand ratio on the order of 70:30 would be more appropriate in order to provide the structural stability associated with the sand content, while maintaining a low level of hydraulic conductivity.

The following engineering properties of compacted bentonite or bentonite/sand mixtures make it an advantageous material for use in a shaft sealing system:

- Low permeability (10^{-10} to 10^{-14} m/s).
- High sorptive capacity for radionuclides.
- High swelling potential allows bentonite to heal itself when fractured and penetrate small voids and fractures of the EDZ. The swelling potential also maintains tightness between the seal material and shaft wall. As bentonite sorbs water the interstitial layer in the clay material will expand to create swelling pressure, thereby developing fluid-like properties within the bentonite. This may then squeeze into the openings in the EDZ along the shaft wall, providing a partial seal in the EDZ immediately adjacent to the shaft wall.
- Demonstrated longevity in many natural environments.
- Demonstrated success sealing waste containment structures such as landfills.

Potential issues related to the use of bentonite as a sealing material are listed as follows:

- Material quality and emplacement techniques must be carefully supervised and tested for quality assurance.
- Swelling pressures develop as the bentonite becomes saturated, according to tests in Sweden (as cited by [R95]) the saturation of the compacted bentonite occurs at different rates around the circumference of the shaft. Thus, the time required for a tight seal to develop between the compacted bentonite material and the shaft wall must be considered. The use of concrete seal materials, described in Section 14.2.2.1 above, will enable a seal of the shaft to be maintained during this period when the bentonite materials are developing their tight seal.
- Cation exchange between the bentonite and saline groundwater may result in the loss of swelling pressure and a corresponding increase in hydraulic conductivity through the bentonite materials ([R94]). The compaction of bentonite clays to an effective clay dry density (ECDD) greater than 1.6 t/m^3 will limit the impact of salinity on swelling pressure ([R96], [R97]). As with seal designs for the WIPP ([R93]) and AECL tunnel sealing experiment ([R97]), target ECDD for the bentonite-based materials will be on the order of 1.8-2.0 t/m^3.

14.2.2.3 Asphalt

Asphalt, (bitumen with fillers), is cited in the engineering literature as suitable sealing material for repository access shafts because its many desirable engineering properties (e.g. [R95], [R96], [R98]). The following properties of asphalt produce a suitable sealing system material:

- Readily adhesive.
- Low permeability (10^{-11} to 10^{-14}).
- History of successful use in mine shafts.
- Ability to heal if deformed (visco-elastic).

- A range of viscosity can be achieved - viscosity can be made sufficiently low such that it penetrates and seals the EDZ.
- Resistant to most acids, salts, and alkalis.
- Longevity.

The use of asphalt would also provide another independent barrier to groundwater flow.

There are some potential issues with asphalt as a sealing system that must be considered:

- The longevity of asphalt can be reduced due microbial degradation. However, asphalt situated in a deep shaft is unlikely to be exposed to the oxidizing conditions and ultraviolet light that promote degradation ([R96]).
- If asphalt is to be placed as a liquid, a significant amount of heat will be introduced to the surrounding host rock. The influence of this heat on host rock behaviour must be considered.

14.2.3 Seal Arrangement

The arrangement of the recommended sealing system, including an explanation of the selected components, their relative location and role in the sealing system, is discussed in ascending order from the repository horizon to the ground surface. Figure 14-1 and Drawing 323874DGR-200-025 in Appendix E provide a layout of the full seal design.

Concrete monoliths are planned for placement at the base of the seal system on each shaft. Concrete will provide a stable foundation for the overlying seal materials and a high degree of support to the repository station openings. Moreover, the concrete monolith will ensure the necessary structural strength to withstand an internal gas pressure of 14 MPa. The monolith will be extended from the vertical shaft into the transitional area of the horizontal excavations to seal the repository and temporarily restrict the possibility of gas pressure damaging the overlying seal system components. Over time gas will leak into the shaft bottom via the EDZ; however, preliminary conservative modelling of the forces at work on the seal elements has shown that the downward forces of the overlying seal materials will outweigh the uplift force provided by gas pressure.

Concrete for the monoliths will be placed in mass (i.e. without structural reinforcement). Construction of bulkheads at the maximum limit of the monoliths in the ring tunnel and other openings will be required prior to placement of concrete. The concrete monolith for the Main and Ventilation Shafts will be created by filling the shaft station (i.e. to heights of 15 m and 7.5 m respectively) and into any access tunnels, ring tunnels, or peripheral rooms (i.e. to a height of 7.5 m) to a length of approximately 20 m beyond the circumference of the excavated shaft diameter. A typical section for the concrete monolith is provided in Drawing 323874DGR-200-026 in Appendix E. There will be no removal of the Inner and Outer EDZ at the repository station elevation. Mass concrete will also be poured 30-40 m down into the base of the shaft (i.e. through the extra shaft depth excavated for the sump) and approximately 5 m above the monolith into the shaft. The installation of this monolith could potentially generate large amounts of heat during the curing process. To control such heat build up, proper mass concrete construction procedures will be followed. Contact/seal grouting will be applied around the monolith in order to minimise the potential impacts of shrinkage at the interface with the Cobourg formation limestone.

The concrete monolith is then overlain by two columns of compacted bentonite/sand separated by an intermediary concrete bulkhead. The compacted bentonite/sand materials act as a low permeability barrier to fluid flow to retard the movement of radionuclides out of the repository and minimise the potential for groundwater flow down into the repository. With the aid of an applied brine to commence swelling, the compacted bentonite/sand materials will generate swelling pressures which will aid in the development of a tight seal at the shaft wall contact and, in combination with swelling potential of the Georgian Bay and Collingwood formations, promote some healing of the EDZ. Hydraulic conductivity of the EDZ may also be reduced as a result of salt and mineral precipitation from the host rock into these features.

As previously discussed in Section 14.2.2.2, mixing of sand with the bentonite will increase the strength of the column, providing additional support for the seal materials above, while also reducing the capacity for shrinkage and increasing the thermal conductivity. A bentonite:sand ratio of approximately 70:30 is recommended to ensure stability of the column while maintaining the desired low permeability barrier provided by the bentonite. Grouting is not recommended around the bentonite/sand columns as shrinkage of the shales is not expected to occur and drilling in this reach is to be minimised in order to restrict provision of additional potential pathways; however, some local grouting may be required at contact zones or major discontinuities.

Throughout this section, and all seal sections up to the Reach 2b/3 contact, shaft support structures and concrete liners will be removed to ensure a complete seal of the shaft column to the surrounding low-permeability host rock. Also, an additional 0.5*r of host rock will be excavated beyond the initial shaft diameter to remove Inner EDZ formed during shaft sinking and the operational period of the DGR. The removal of existing Inner EDZ rock and shaft support structures will occur in small vertical lifts in a sequential manner, through mechanical means. Each section of removal will be closely followed by backfilling of the lift with densely compacted material. This process will minimise the stress changes in the rock and hence supplemental growth of the EDZ.

The intermediary concrete bulkhead is located in the Blue Mountain Formation to ensure compaction of the bentonite column overlapping the Reach 3/4 contact, while restricting the depth of the bentonite/sand column above to less than 70m, as a conservative structural approach. The bulkhead prevents differential deformation of the bentonite column which could potentially generate preferred flow pathways, allowing release of radionuclides and inflow of groundwater into the repository. In order to ensure structural stability, the concrete bulkhead will be constructed of a height equivalent to the diameter of the excavated shaft (following Inner EDZ removal). Further, in order to minimise the potential for groundwater flow through the Outer EDZ and along a preferential flow path between seal materials and the low permeability host rocks, the bulkhead will be keyed into the surrounding rock an additional 0.25*r beyond the edge of the prepared shaft to intercept a portion of the Outer EDZ. A second concrete bulkhead (see Drawing 323874DGR-200-027 in Appendix E) is located at the top of the second bentonite/sand column to provide the confinement required to develop swelling pressure and provide a separation between the bentonite/sand material and overlying asphalt column. All concrete bulkheads will be constructed to the same specifications (though key depths will vary depending on the value of r), and the concrete used to construct all bulkheads will be similar to that selected for the shaft station monolith. Concrete bulkheads will also be pressure grouted to increase the tortuosity of the concrete/rock interface in order to minimise groundwater inflow.

An asphalt column is then placed above the concrete bulkhead. The asphalt column extends over a length of the Georgian Bay formation to just above the Queenston/Georgian Bay contact. Asphalt was selected for this location because it has the ability to flow into the contact between the Queenston and Georgian Bay formation and seal it against potential inflows and it will be compatible with the expected hydrocarbon bearing layers of the Georgian Bay formation. Furthermore, the use of another low permeability sealing material provides an additional level of redundancy to the sealing system against upward or downward fluid flow. Asphalt is also stronger than bentonite/sand materials and will provide additional structural support for the seal materials. The thickness of the asphalt column illustrated in Figure 14-1 is approximately 60 m. The asphalt column is capped by a third concrete bulkhead to separate it from an overlying bentonite/sand column and provide structural support of the overlying seal materials.

The bentonite/sand column overlying the asphalt forms another low permeability barrier increasing the redundancy of the system. It will be constructed using the same methods and materials described for the lower bentonite/sand columns. Once brine is applied to commence swelling, it is expected that the swelling potential of the bentonite/sand in combination with the swelling potential of the Queenston shale will develop a very tight contact seal and potentially heal the EDZ in this section.

Two concrete asphalt waterstops (see Drawing 323874DGR-200-027 in Appendix E) are located above this bentonite/sand column to isolate and protect the Manitoulin formation. The waterstops, separated by an additional bentonite sand/column are comprised of a 0.6 m thick layer of asphalt mastic sandwiched by two concrete bulkheads which act as independent seals of the shaft and EDZ. The concrete bulkheads will be constructed as those described above, however the asphalt mastic will be keyed to a depth of 1**r* from the excavated shaft diameter in order to provide seal of both the Inner and Outer EDZ. Keying for the asphalt materials will result in the creation of new EDZ along the perimeter, however this is expected to heal shortly after construction of the waterstop ([R96]). The asphalt waterstop is located between the upper and lower concrete plugs. The concrete and asphalt comprising the waterstops will be similar to that used in the concrete bulkheads and asphalt column respectively. The use of two waterstops will isolate and protect the Manitoulin formation, which may prove to be a separate aquifer between the Cabot Head formation and the Queenston formation based on its relatively high hydraulic conductivity. This will prevent upward and downward migration of poor quality groundwater, where water quality concentrations exceed those defined by the Ontario Ministry of the Environment ([R99]), into this upper freshwater aquifer. These waterstops will also serve as additional protection against the downward migration of groundwater from Reach 2 into the repository.

Following the placement of the uppermost waterstop, a single bentonite/sand column will be placed through the Reach 2b/Reach 3 contact to the upper portion of the compacted bentonite rich mix annulus ring in the Fossil Hill unit, installed during shaft sinking, where another concrete bulkhead will be placed. This bentonite/sand column and concrete bulkhead will be placed and designed as with those used elsewhere in the seals. Apart from the bentonite annulus ring, all other support elements will be removed through this section. During exposure of the annulus ring, it will be tested to determine if any remedial works are required to ensure an effective seal at this contact. The placement of this concrete bulkhead represents the end of the primary seal system, designed to restrict groundwater flow into and radionuclide flow out of the repository.

Flow model calculations performed on this conceptual level design resulted in an overall effective bulk hydraulic conductivity of 6.48×10^{-11} m/s, which confirms that the proposed primary sealing system design through these Reaches meets the Design Requirement (see Section 3 above) of an overall bulk hydraulic conductivity of 10^{-10} m/s.

From this bulkhead, two compacted bentonite/sand columns, evenly interspersed with concrete bulkheads will be inserted to the top of the B Unit as part of the secondary seal. Through this reach, initial shaft support structures will be removed, however no removal of host rock will be required as the main purpose of primary seal materials in these areas is to minimise groundwater flow through the shaft. Some groundwater flow through the EDZ will be controlled through contact/seal grouting previously applied through this section during drill and blast excavation for shaft sinking. Intermediary concrete bulkheads in this section will be keyed to a depth of 0.25**r* of the excavated shaft diameter to ensure stability within the column.

Above this section, a compacted bentonite/sand column will be inserted through the C through F Units, separated by two concrete bulkheads. Unit F represents a lower permeability zone within the dolostones (an aquitard) between a fresh water aquifer above and a more saline aquifer below. To prevent movement of the poor quality, saline groundwater from the lower aquifer upwards through the shaft cross-section into the upper fresh water aquifer, concrete bulkheads and the bentonite/sand column will be constructed as per the primary seal. This will entail removal of host rock comprising the Inner EDZ (0.5**r*) from this entire section, and keying of concrete bulkheads to a depth of 0.25**r* of the prepared shaft. Though higher flow pathways may exist above the Salina F Unit, movement of primary seal materials beyond the F unit is not recommended for the following reasons:

- If the bentonite/sand column is to be extended in this area, the shaft lining would need to be stripped through portions of Reach 2a, which could cause some release of saline water volumes behind the seal during construction of the seal and thus compromise the upper section of the bentonite/sand column; and
- The rock surrounding the shaft "cylinder" would have a lower hydraulic conductivity in Reach 2a than what would be attained the shaft column, so any saline water would migrate upwards faster than in the shaft seal.

The installation of this bentonite/sand column and concrete bulkheads in this location will separate these two aquifers, preventing the interaction of saline groundwater from the lower aquifer with the freshwater upper aquifer. This is consistent with the applicable requirements within Section 11 (Well plugging) of the Provincial Operating Standards, Oil, Gas, Salt Resources of Ontario ([R85]).

The shaft is then filled to the top of Reach 2a with crushed rock obtained during shaft excavation. The fill material, a tertiary seal component, will be engineered and compacted to an equal or lower permeability than the surrounding host rock in order to ensure the stability of both the primary and secondary seals. Removal of the concrete liner throughout this section is not essential. Therefore, it will be left in place to avoid the time and labour required for its removal; however the state of the liner and the possibility of removal should be examined prior to seal construction to determine the potential costs and benefits of removal prior to a final decision being made.

The fill will be topped by a surficial concrete cap through Reach 1, representing the final element of the seal system. This cap, which will comply with the [R84] requirements, will serve to:

- prevent surface water inflow into the shaft cross-section by creating a solid, impermeable seal of the shaft entrance;
- further reduce the potential for subsidence, as concrete is stronger than compacted fill;
- provide a permanent monument marking the shaft locations; and
- reduce the potential for accidental human entry by providing a restrictive barrier at the surface.

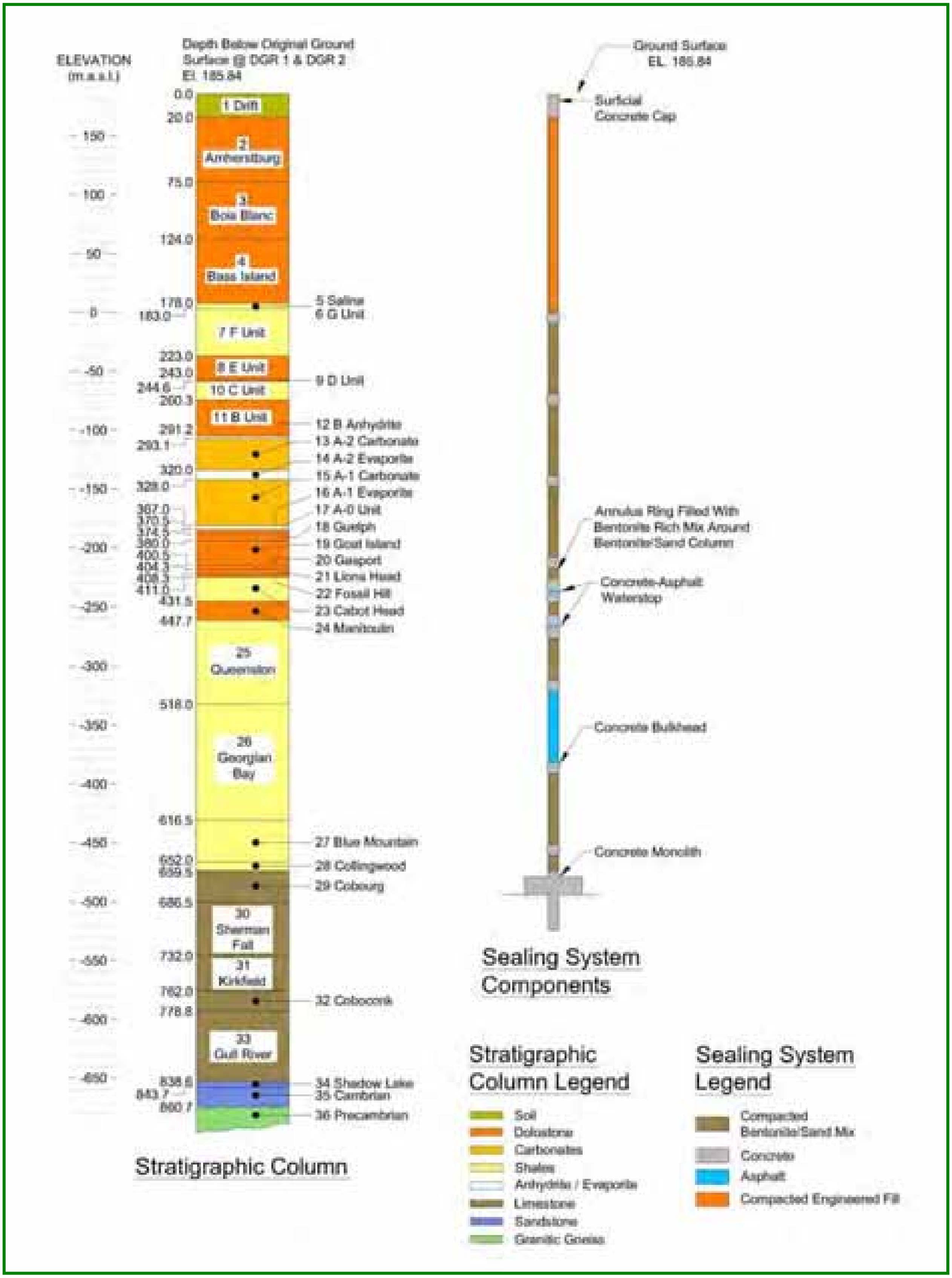


Figure 14-1 – Recommended sealing system for DGR shafts

14.2.4 Seal Construction

The technology for placing the above seal materials in the access shafts is well established. Emplacement techniques generally fall into three categories: (i) slickline and header, (ii) in-situ compaction, and (iii) placement of pre-compacted material. In general, the placement of seal materials will take place in a retreating mode from the repository horizon to the top of the Reach 3 shales, as illustrated in Figure 14-2. Starting with the intact tunnel liner (far left), the seal placement continues as follows:

- Remove section of concrete liner, ribs, shotcrete and EDZ.
- Place selected seal materials in either compacted lifts (sand/bentonite) or singular casting to eliminate formation of construction joints (concrete and asphalt)
- Remove next section of liner and repeat the process.

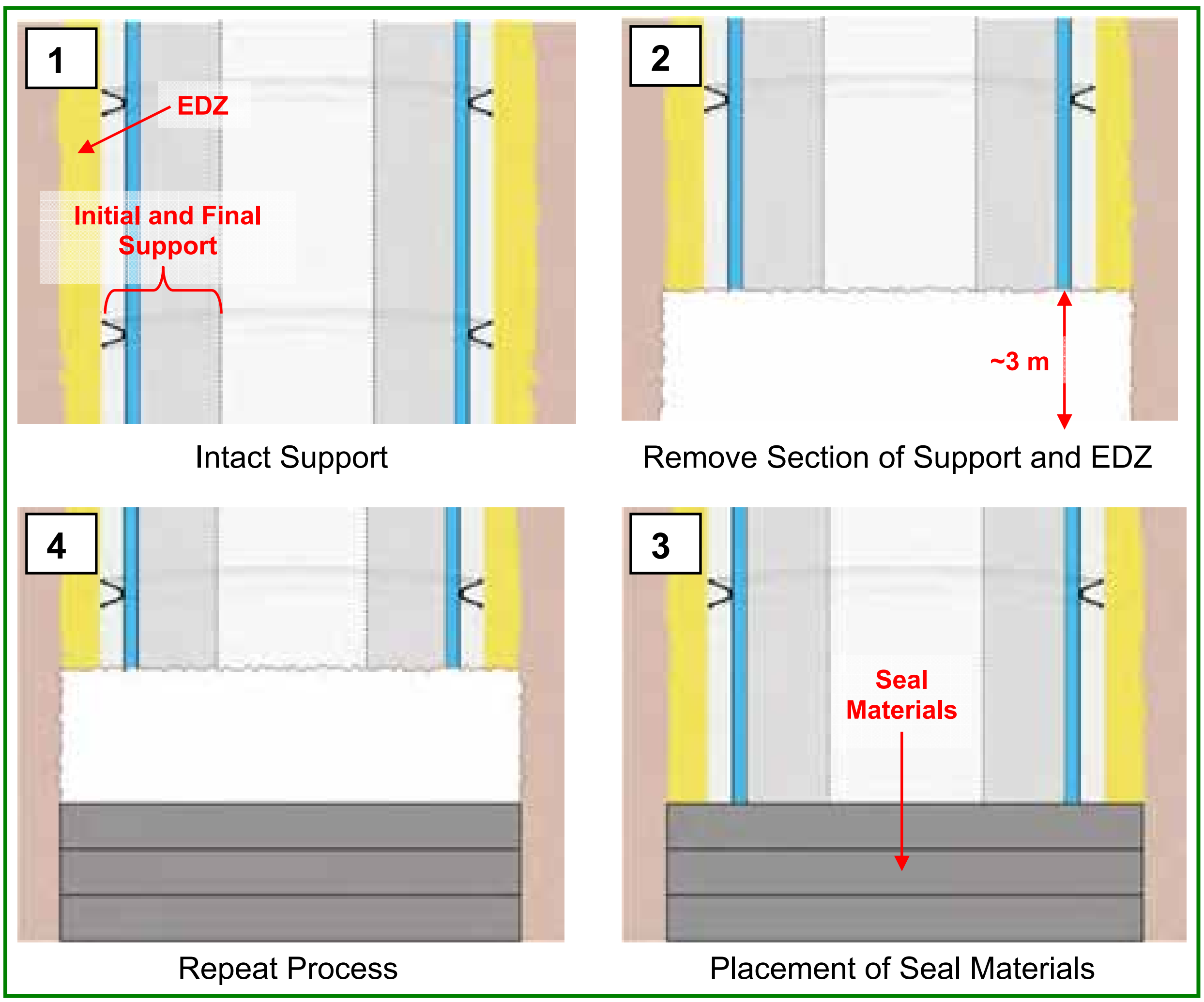


Figure 14-2 – Seal construction sequence

14.2.4.1 Slickline and Header

A slickline is essentially a steel pipe secured to the shaft wall to transport fluid seal materials such as concrete and molten asphalt from the surface to the required depth. At the base of the slickline, a slightly larger steel pipe called a header diverts the downward flow of material 45 degrees, dissipating the impact energy of the falling material. A flexible hose is then connected to the header enabling exact placement of the material.

The DGR requires the placement of seal materials up to depths of 720 metres. Experience with concrete placement to depths of this magnitude is common in mining applications. Placement of molten asphalt via a slickline system requires heating of the line to maintain the asphalt's molten state. A proposed system for emplacing the asphalt components of the WIPP sealing system was developed by Sandia National Laboratories ([R100]).

14.2.4.2 In-situ Compaction

The reference assumption is that bentonite-based materials will be placed loose and compacted in-situ within the DGR shafts as described below. A potential alternative to in-situ compaction is the preparation and placement of pre-compacted blocks of bentonite-based materials, which is described in Section 14.2.4.3.

Bentonite based materials, and native earthen materials can be graded and hydrated to optimum moistures on the surface and then transported into the shaft and compacted in-situ. Compaction can be performed using vibratory plate compactors, sheepsfoot rollers or by dropping a large weight onto the materials. Vibratory plate and sheepsfoot compactors (as shown in Figure 14-3) require the placed lift of seal materials to be roughly 150 mm to 300 mm to compact the full depth of material. Weight dropping can compact much thicker lifts depending on the size of the weight and the height, from which it is dropped. The proposed seal system design for the WIPP, for example, comprises a 4.69 tonne weight dropped 18 m, which results in a compaction depth of 4.6 m.

Figure 14-3 – Examples of in-situ compaction equipment

14.2.4.3 Placement of Pre-Compacted Material

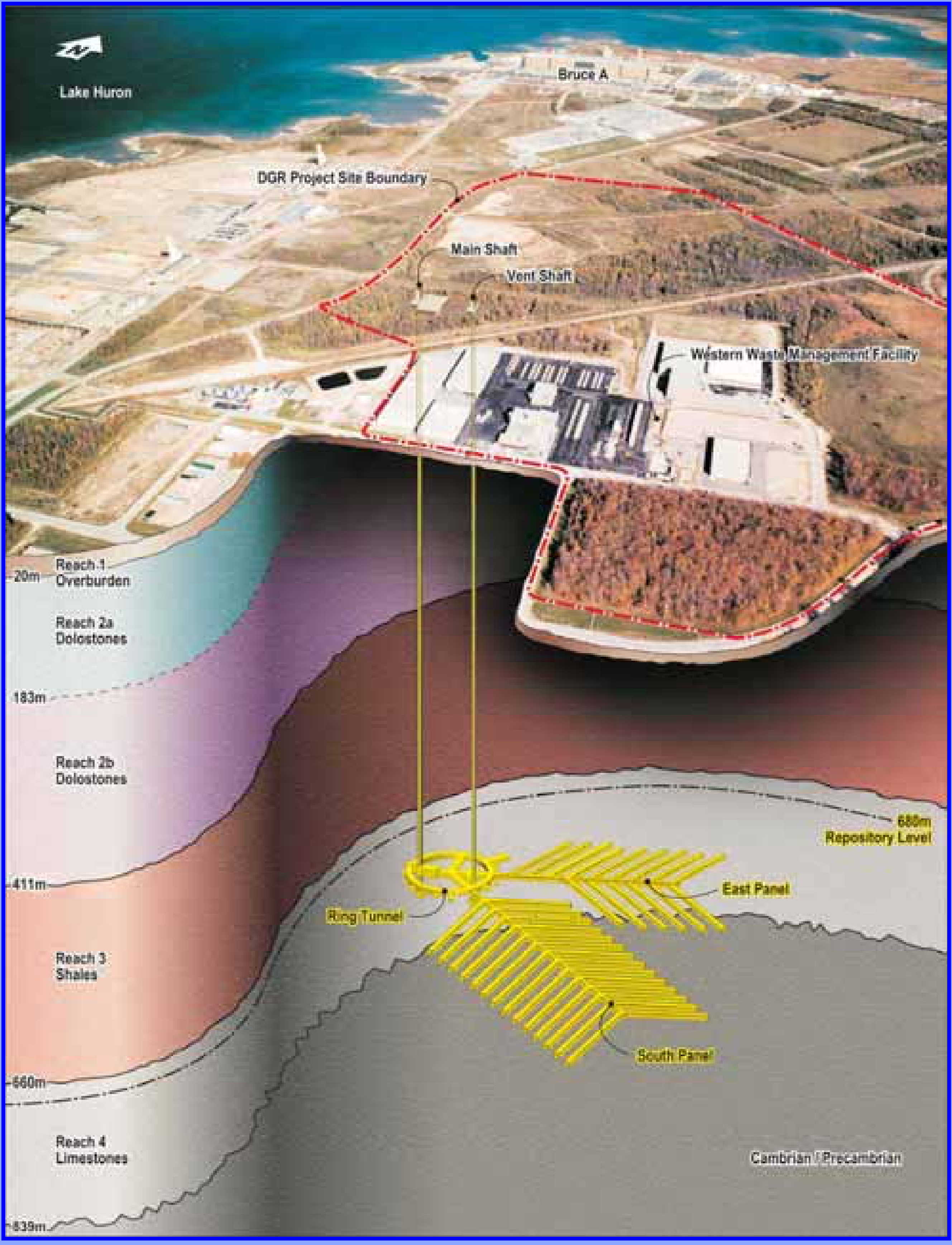
The placement of salt and bentonite as pre-compacted blocks has been presented as a viable option in several research programs including the WIPP, ANDRA, and AECL. The seal material is compacted into blocks to the desired density and lowered into the shaft using the same hoisting system used to transport labourers. The blocks are fitted together as tightly as possible and individually trimmed to fit against the shaft wall as tightly as possible. The tunnel sealing experiment conducted by AECL ([R101]) demonstrated that the placement of 70:30 bentonite/sand blocks with a density of 1.9 t/m^3 @ 15% moisture in 1998 (Figure 14-4) resulted in measured bulk densities ranging from 1.85-2.00 t/m^3 @ 13% - 17% moisture during decommissioning in 2004. The measured densities less than 1.9 t/m^3 are the result of material expansion into voids left between the block and shaft wall during initial placement. The densities of greater than 1.9 t/m^3 are a result of compression from various loadings applied to the seal as part of the experiment.

The advantage of using pre-compacted block is guaranteed emplaced material densities. However, great time and effort is required to make, transport, and place the blocks relative to in-situ compaction methods and hydration of the blocks is required before the contacts between the individual blocks begin to seal.

Figure 14-4 – Example of pre-compacted bentonite blocks [R102]

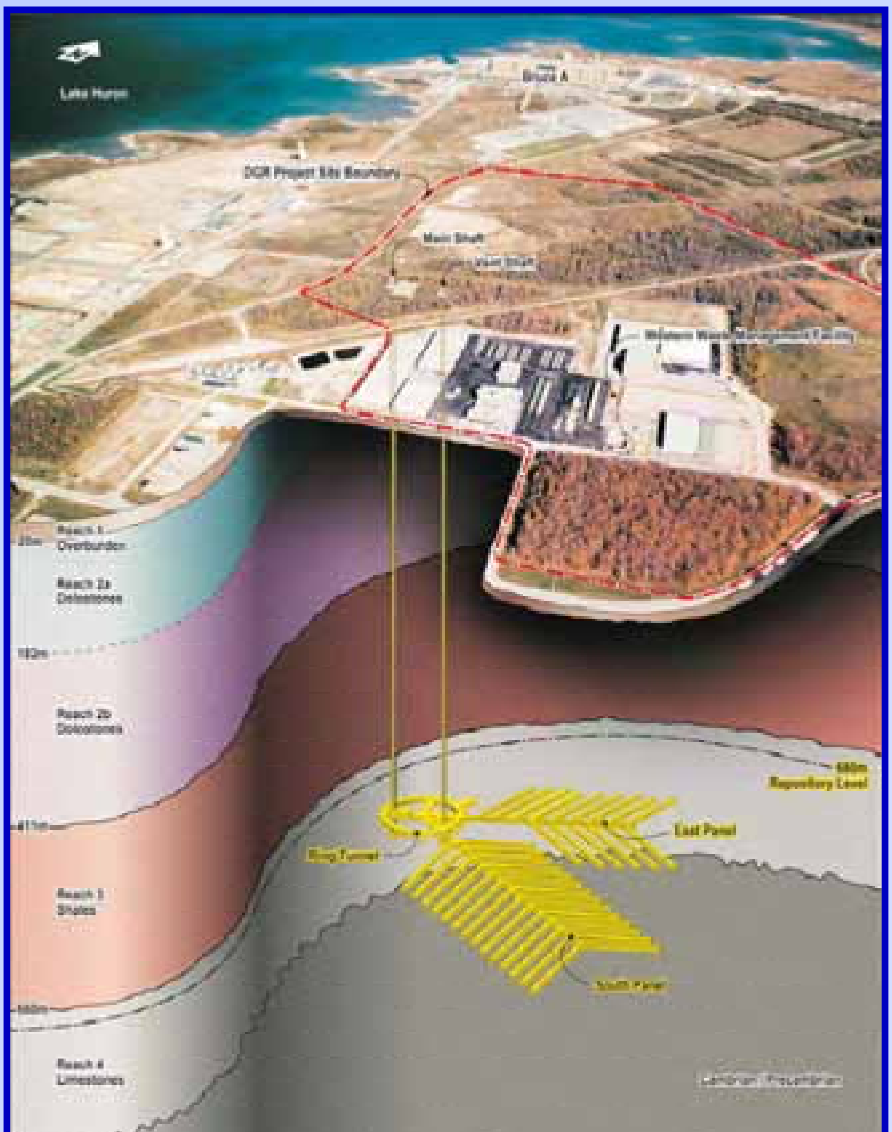
CONCEPTUAL DESIGN REPORT

APPENDICES



Conceptual Design Report

Appendix A – List of References



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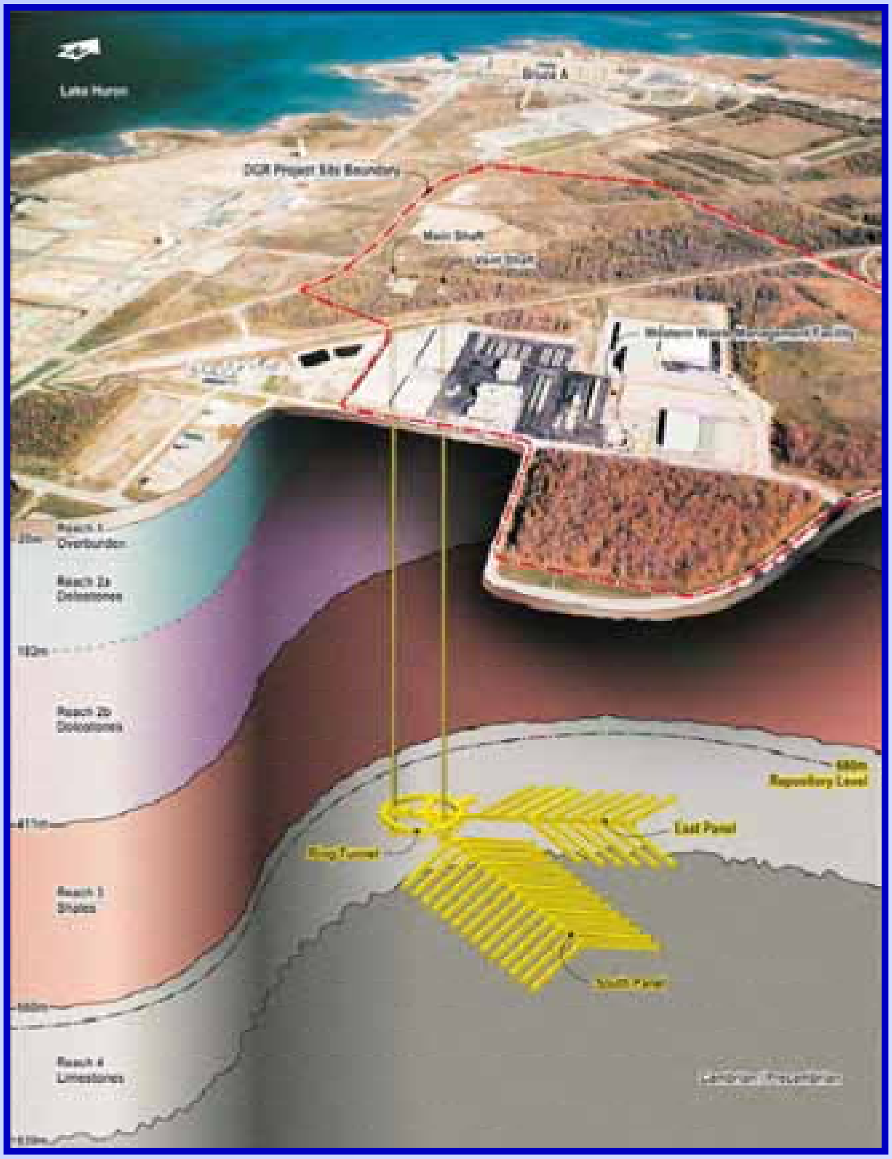
Appendix B – Definitions & Abbreviations



Appendix B – *Definitions & Abbreviations*

Ontario Power Generation's DGR Project Glossary [R4] provides the primary source for definitions and abbreviations. The following listing includes the more commonly used acronyms within this Conceptual Design Report, some of which may be specific to certain of the specialised topics presented herein, or may be otherwise misinterpreted.

ACGIH	American Conference of Governmental Industrial Hygienists
AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonably Achievable
amsl	Above Mean Sea Level
ANDRA	French National Agency For Radioactive Waste Management
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAC	Bulk Air Cooling
BC	Below Shaft Collar
bgs	Below Ground Surface
BINOPK	LLW Containers Overpack
BTEX	Benzene, Toluene, Ethylene, and Xylene
CAPEX	Capital Expenditure
CNSC	Canadian Nuclear Safety Commission
CoV	Coefficient of Variation
CSA	Canadian Standards Association
DGR	Deep Geologic Repository
ECDD	Effective Clay Dry Density
EDZ	Excavation Damage Zone
ESR	Excavation Support Ratio
ETH	Encapsulated Tile Hole
GPa	Gigapascal
GRG	Geomechanics Review Group
GSCP	Geoscientific Characterization Plan
GSI	Geological Strength Index
H&F	Hand and Foot (Monitor)
HAZOP	Hazard and Operability Study
HDPE	High Density Polyethylene
HEPA	High-Efficiency Particulate Air

HERE	Horizontal Emplacement and Retrieval Equipment
HVAC	Heating Ventilation and Air Conditioning
HX	Heat Exchanger
IAEA	International Atomic Energy Agency
ICEA	Insulated Cable Engineers Association
ICRP	International Commission on Radiological Protection
ICs	In-ground Containers
ILW	Intermediate Level Waste
ISRM	International Society for Rock Mechanics
IWTS	Integrated Waste Tracking System
kV	Kilovolt
kVA	Kilovolt-Ampere
L&ILW	Low and Intermediate Level Waste
LHD	Load Haul Dumper
LLSB	Low Level Storage Building
LLW	Low Level Waste
MASL	Metres Above Sea Level
MCC	Motor Control Centre
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
MOL	Ontario Ministry of Labour
MPa	Megapascal
MSHA	Mine Safety and Health Administration (US government)
MVA	Megavolt-Ampere
NAFS	Numerical Analysis Factor of safety
NBC	National Building Code of Canada
NEA	Nuclear Energy Agency
NHIC	Natural Heritage Information Centre
NPB47	Non-Pro Bin 47” high
NWMD	Nuclear Waste Management Division
OEM	Original Equipment Manufacturer
OHSA	Occupational Health and Safety Act
OMR	Ontario Mining Regulations
OPG	Ontario Power Generation
Pa	Pascal

PHC	Petroleum Hydrocarbons
PVC	Polyvinyl Chloride
REC	Core Recovery
RMR	Rock Mass Rating System
RPR	Radiation Protection Regulation
RQD	Rock Quality Designation
SPC	Shield Plug Container
SPT	Standard Penetration Test
t *or* tonne	metric ton (=1,000 kilograms)
t/m^3	(metric) tonnes per cubic metre
TBM	Tunnel Boring Machine
TCLP	Toxicity Characteristic Leaching Procedure
TDD	Time-dependant Deformation
TDS	Total Dissolved Solid
T-H-E	Tile Hole Equivalent
THLIC18	IC-18 Tile-Hole-Equivalent Liner
THLIC2	IC 2 Tile-Hole-Equivalent Liner
TSS	Total Suspended Solid
UCS	Unconfined Compressive Strength
USA	United States of America
V	Volt
V AC	Volt - Alternating Current
VSM	Vertical Shaft Sinking Machine
WAC	Waste Acceptance Criteria
WBM	Whole Body Monitor
WIPP	Waste Isolation Pilot Plant
WPRB	Waste Package Receiving Building (at the DGR Main Shaft)
WRDA	Waste Rock Disposal Area
WRDA	Water Resources Development Act
WVRB	Waste Volume Reduction Building
WWMF	Western Waste Management Facility
XLPE	Cross Linked Polyethylene

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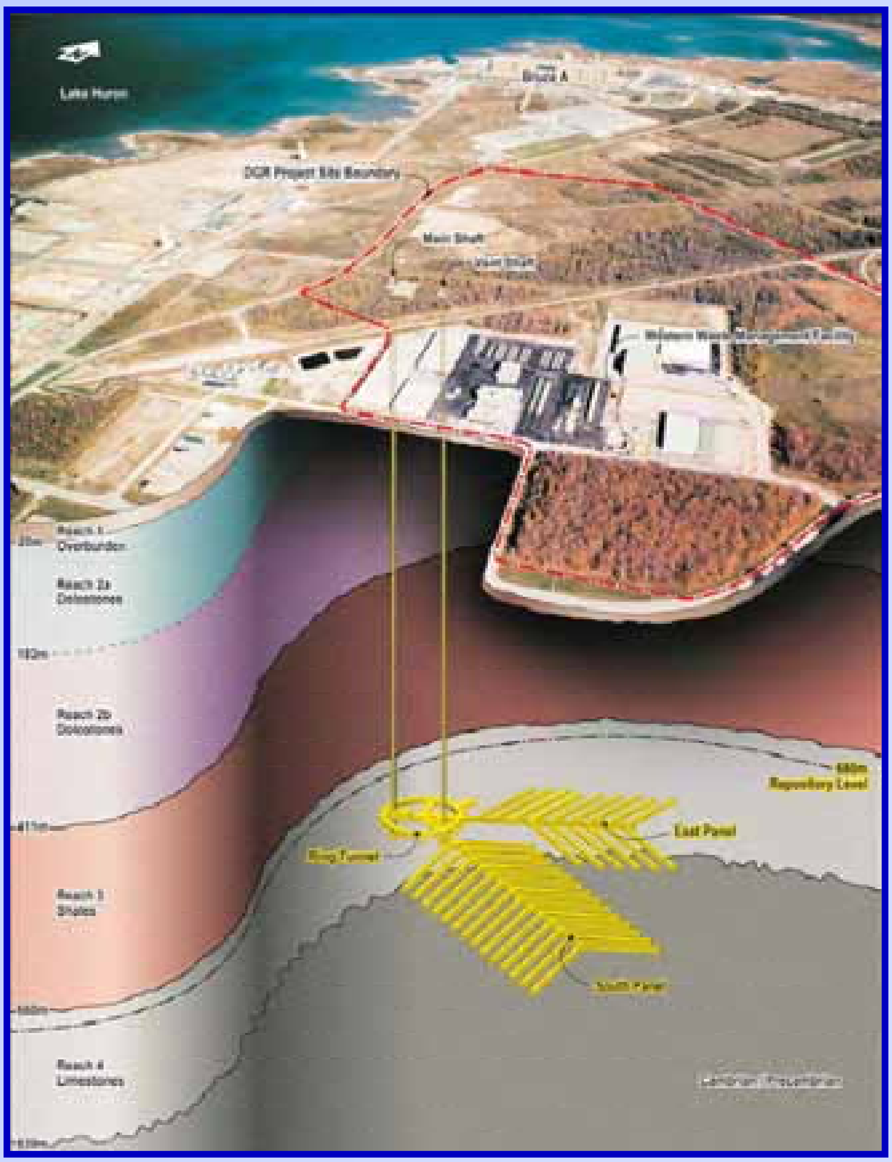
Appendix C – Compliance with Design Requirements



Appendix C – *Compliance with Design Requirements*

The table in this appendix provides an index to demonstrate where the Design Requirements (see Section 3) have been met in this Conceptual Design Report. Items under Sections 3.1 and 3.18 of the Requirements are generic in nature and have been taken into consideration throughout the conceptual design study. These items are, therefore, not included in the table, which provides a cross-reference to the more specific requirements.

Section	*Sub-Section*	*Reference Section in Main Report*	*Comments*
3.2 Performance Requirements			
	3.2.1	4.5.3	and all sub-sections
	3.2.2	4.2.1.3, 13.1	
	3.2.3	4.2.1.3, 13.1	
	3.2.4	4.2.5.2	Waste rock chemical composition
		4.2.5.8	Stormwater control
		9.1	Underground water discharge control
		10.3.2	Exhaust ventilation control in fire event
		10.4.3	Exhaust ventilation control in radiological spill event
		12.2	Environmental plans during construction and operations
	3.2.5	5.6	
3.3 Interfacing Requirements			
	3.3.1		
	a)	4.2.1.3, 4.2.4, 8.2 & all sub-sections	
	b)	8.2, 8.2.1.3, 8.2.1.5	
	c)	4.2.1.3, 8.2, 8.2.2.1	
	3.3.2	8.2.1, 8.2.2	systems are not described in the various sub-sections
	3.3.3	4.2.1.5	Offices
		4.2.4	Figure 4-8 and Drawings 200-001, 200-023 & 200-024 show the roadway connections to WWMF and Bruce Interconnecting Road

Section	Sub-Section	Reference Section in Main Report	Comments
3.3 Interfacing Requirements continued			
	3.3.3 continued	9.2	Potable water connection from WWMF
		9.4	Electrical power connection from Hydro One Sub-station at Douglas Point
		9.5	Communications (Phone and Data) externally to DGR & WWMF
		9.7	Interface with IWTS at WWMF
		11	Security
	3.3.4	9.2	Potable water
		9.4	Electrical power
		9.7	Communications and monitoring system; alarms
		11	Security
	3.3.5	8.2, 9.7, 13.5	
3.4 Design Limits			
	3.4.1	4.2.1.1	Main Shaft Headframe
		4.2.1.2	Main Shaft Koepe hoist
		4.2.2.1	Vent Shaft Headframe
		4.2.2.3	Vent Shaft hoist
		4.5.3.3.8	Ventilation ducting underground
		6	specifically 6.1.5 - Shaft lining construction design
		7	specifically 7.1.1.2, 7.4, 7.5.1, 7.5.4.6, 7.5.5 - underground excavation design inc rock support
	3.4.2	4.2.1.2	
		8.1	Table 8-3
		8.2.2.2	
		8.2.2.5	
		8.3.5	Table 8-6 & 8.3.5.1.2 - lifting lugs for steam generators
	3.4.3	4.2.2.1	Vent Shaft Headframe rock tipping arrangement
		4.5.2	Ease of potential expansion with shaft island panel layout
		4.5.3.5	Emplacement room and panel configurations
		4.5.4	location of explosive & detonator magazines
		5.6.1	cooling of intake air

Section	Sub-Section	Reference Section in Main Report	Comments
3.4 Design Limits continued			
	3.4.3 continued	5.6.2	heating of intake air
		5.9	Ventilation
		10.5.1	Zoning during expansion
		12.8	surface & underground layouts
	3.4.4	7.1.2	
	3.4.5	4.2.5.3, 4.2.5.4, 4.2.5.6, 4.2.5.7	Drawings 200-023 & 200-024
3.5 Seismic and Anthropogenic Vibration Requirements			
	3.5.1	2.6	
	3.5.2	7.6.1	
	3.5.3		
3.6 Design Constraints			
	3.6.1	2, 4.5.3.5	Drawings 200-001, 200-002 & 200-003
	3.6.2	7.4	and sub-sections, specifically 7.4.2
	3.6.3		Generic statement. Limited holes through the geosphere (i.e. only 2 vertical shafts) and depth is below shale
	3.6.4	7.2	Emplacement room shape
		12.1	General flexible approach with suite of designs for potential differing rock conditions and shaft boreholes
		12.4	Core drilling of underground excavations prior to complete development
	3.6.5	7.3	Modelling shows that orientation is not significant
	3.6.6		Drawing 200-001
	3.6.7	2.2	Climatic conditions
		5.1	Vent Shaft exhaust downwind of Main Shaft intake and 150 m separation
	3.6.8		See Site Base Plan
3.7 Room Closure and Package Retrievability			
	3.7.1	5.8.4	
	3.7.2	5.8.4, 13.4	

Section	Sub-Section		Reference Section in Main Report	Comments
3.7 Room Closure and Package Retrievability continued				
	3.7.3		5.8.4	
	3.7.4		13.5	
3.8 Shaft Seal Systems				
	3.8.1		14.2.3	paragraph 11 of section
	3.8.2		14.2.2.2, 14.2.3	Bentonite sorptive capacity for radionuclides; seal arrangement
	3.8.3		14.2.1, 14.2.2, 14.2.3	
	3.8.4		14.2.3	
	3.8.5		14.2.2, 14.2.3	
	3.8.6		14.1.3, 14.2.3	Concrete surficial cap
	3.8.7		14.2.4	
	3.8.8		6.1.5	Bentonite ring barrier behind shaft lining
	3.8.9		14.2.3	Monolith design
3.9 Environmental Requirements				
	3.9.1			Generic requirement principles used throughout conceptual design, *for example*:
		a)	4.2.1.2, 4.5.2, 4.5.4, 5.6	Safe modern hoist; quick access in clean air to underground infrastructure with offices, laboratory, lunch room etc being close to Main Shaft and remote from waste emplacement rooms; air conditioned ventilation system
		b)	7	Good quality excavations and rock support designed for long-term operation
		c)	5.8.4	Ventilation of closed rooms to limit risks of corrosion
		d)	4.2.5.8, 9.1	Water control (surface and underground)
	3.9.2		5.6	
	3.9.3		6	Grouting of shafts and reinforced concrete lining
			9.1	Sumps to capture water
	3.9.4		7	Generic requirement principles used in geotech design
3.10 Operability Requirements				
	3.10.1		13.1	
	3.10.2		4.2.1.7, 9.7	Surface and Underground control rooms with off-shift back-up to WVRB

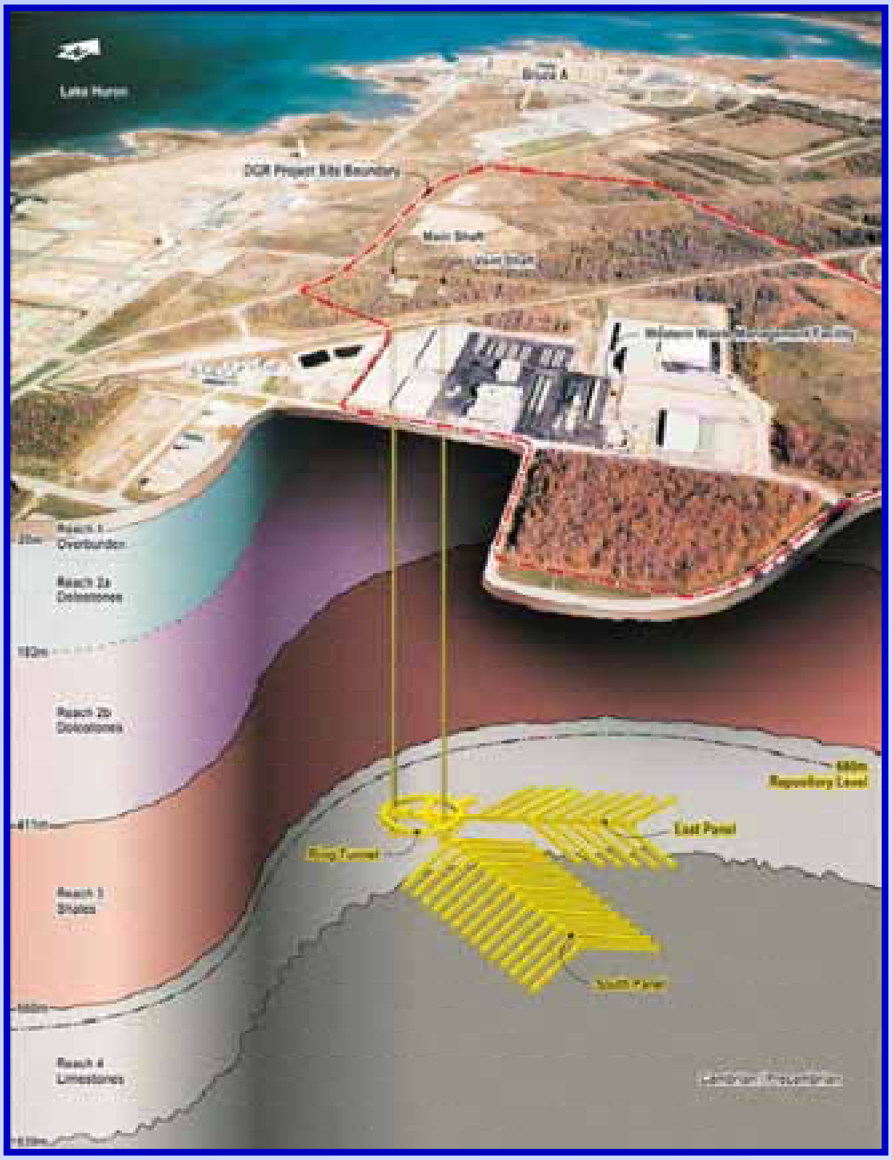
Section	Sub-Section	Reference Section in Main Report	Comments
3.10 Operability Requirements continued			
	3.10.3	4.5.2	
	3.10.4	10.5.7	Rezoning for expansion
		12.8	Expansion construction
	3.10.5		*refer to 3.13.1 below, which is also applicable to this requirement*
	3.10.6	8.2 - 8.4	Shielding and transfer methods
		13.3	Mobile equipment
	3.10.7	4.5.3	Room sizing and stacking principles
		8.4	Underground transfer into emplacement rooms and stacking details
	3.10.8	5.8	specifically 5.8.1 and 5.8.3
	3.10.9	9.1	
	3.10.10	9.1	Maintenance facility sump - separate from shaft bottom sumps
3.11 Reliability Requirements			
	3.11.1	13.2	
	3.11.2	9.4	Load tables and diesel generator for utility power outages
	3.11.3	4.2.3.1	Emergency diesel generator location
		4.4	Vent Shaft hoist designed to run off diesel generator power
		5.7	Exhaust fans designed to run off diesel generator power
		9.4	Diesel generator information and loads to be supplied in case of main supply power failure
	3.11.4	4.2	Elevations of shafts above stormwater run-off and Lake Huron flood levels
3.12 Maintainability Requirements			
	3.12.1	13.2	Generic to DGR conceptual design
	3.12.2	7.5.5	Underground rock support system description
		13.2.2	Rehabilitation contracts (3-6 month) may be required during life of DGR
	3.12.3	4.5.3.3.10	Only ventilation ducts remain permanently in rooms
		5.8.3	Auxiliary fan position
		5.8.4	Fan and instrumentation maintenance
	3.12.4	5.8.4	Fan and instrumentation maintenance
	3.12.5	4.5.2, 4.5.4, 13.2.2	

Section	Sub-Section		Reference Section in Main Report	Comments
3.13 Periodic Inspection and Monitoring Requirements				
	3.13.1			
		a)	9.7	
		b)	13.2.1	Surface maintenance
			13.2.2	Underground maintenance
		c)	9.7	
		d)	9.7	
		e)	9.7	
	3.13.2		8.2	
	3.13.3		4.5.3.3	Implied through stacking arrangement design
	3.13.4		5.8.4, 9.7	
3.14 Occupational Safety Requirements				
	3.14.1			Generic consideration given throughout conceptual level design
	3.14.2		4.2.1.3, 8, 13.3	Shielding of waste, but with some additional localised protection
	3.14.3		8.2	All packages designed to be contact-handleable or finally disposed in underground encapsulation (e.g. T-H-E Liners)
	3.14.4		N/A	Calculations did not form part of the study scope as there is inadequate detail within a conceptual level study to produce any meaningful results. However, from expert-judgement based on similar procedures adopted to those used at WWMF, Hatch considers that overall annual dose rate will be below limits. But, this will have to be confirmed in future design phases, which may lead to shielding being added to equipment, workers being rotated out to spread the workload, or the waste transfer program being arranged to ensure greater time separation between transfer of higher dose rate packages. Any of these options could successfully be applied to reduce workers' annual exposure time of proximity to waste packages and thereby ensure that the annual limits are met.
	3.14.5		5	Ventilation design principle
3.15 Fire Safety				
	3.15.1			Generic, as impact of fire is considered in all aspects of design
	3.15.2		10.3.1	

Section	Sub-Section	Reference Section in Main Report	Comments
3.16 Security Requirements			
	3.16.1	11	
	3.16.2	11	
	3.16.3	11	
	3.16.4	4.5.5	
3.17 Constructability Requirements			
	3.17.1	6.1.1, 6.2.1, 6.3.1	Shaft sinking - Overburden; Dolostones; Shales & Limestone
		7.6	Underground tunnelling
	3.17.2	12.7	List of suite of various mobile mining equipment
	3.17.3	9.7, 12.6	
	3.17.4	6.3	Shaft sinking through Shales
	3.17.5	6.3	Shaft sinking through Shales

CONCEPTUAL DESIGN REPORT

Appendix D – Waste Package Category Information Sheets



Appendix D – *Waste Package Category Information Sheets*

The primary source of data for this appendix is the OPG Inventory Report [R76]. The data presented hereunder has, however, been modified to account for revisions in quantities, dimensions and masses of waste packages as developed during this Conceptual Design Study.

It should be noted that the dose rate data given in the tables of each Group sub-section are those taken at the time the packages were placed into storage at the WWMF. Decay will reduce those rates by the time the packages are retrieved at the WWMF and transferred into the DGR for disposal.

D1 Group A

Waste Category: LLW

Container Specifications:

Container Type	*Stack*	*Dimensions*			*Weight*	*Number*
		L	W (or dia)	H	kg	
BINOPK Overpack		2.54	1.78	1.88	1,591	3,141
Overpacked in BINOPK:						
Ash Bin (Old) - bottom ash **#**	3	2.54	1.78	1.88	4,541	269
Ash Bin (New) - bottom ash **#**	3	2.54	1.78	1.88	3,195	816
Drum Rack - baghouse ash **#**	3	2.54	1.78	1.88	3,081	47
Ash Bin (new) - baghouse ash **#**	3	2.54	1.78	1.88	3,195	134
Drum Rack - non-processible drums **#**	3	2.54	1.78	1.88	3,081	296
Low Level Resin Box (90") **#**	3	2.54	1.78	1.88	5,246	45
ALW Sludge Box **#**	3	2.54	1.78	1.88	3,411	1,534
No Overpacking Requirement:						
Compactor Box	5	1.84	1.12	1.3	2,722	5,298
Bale Rack *	5	2.29	1.22	1.2	1,406	1,491
Drum Rack - non-processible drums	5	2.29	1.22	1.2	1,490	2,663
Drum Bin	5	1.96	1.32	1.03	1,450	3,317
Non-Pro Bin (47" high NPB47) **	5	1.96	1.32	1.19	1,460	15,349
Non-Pro Bin (NPB4) **	-	2.29	1.22	1.47	1,460	4,978
Low Level Resin Pallet Tank	3	1.24	1.24	1.68	2,000	1,993
Total						**38,230**

Note: Explanation of note marks #, * and ** are given in “Overpack” sub-section below.

Packages:

- Small package size (maximum 2.54 m x 1.78 m x 1.88 m high).
- Light weight (<5.4 tonnes).

Stacking:

- Stored in stackable metal bins.
- Stacking height limited by the DGR emplacement room height and numbers in table above.
- Similar packaging allows for easy storage.

Handling:

- Specifically designed to be handled using a forklift.
- Time efficient for loading and unloading (easy staging).

Overpack:

- Waste containers will be overpacked as required. All containers marked **#** are assumed to require overpacking (included in dimensions and masses).
- The bale racks (marked *) may be required to be overpacked in an LLW overpack container as their contents are contained by a thin plastic sheet. The inventory of BINOPK's (totalling 3,141) does not currently include any allowance for overpacking any bale racks. On their own the bale racks can be stacked 5 high in the DGR and any in overpack containers would be stacked 3-high. The overpacked drum racks will be stacked 3-high, the non-processible drums that are emplaced in the drum racks will be stacked 5-high in the DGR.
- All Non-Pro Bins (marked **) are assumed to be the type NPB47, on instruction from OPG.

Cage Capacity:

- 6-12 (per trip).

Retrieval Period:

- Stored inside buildings to ensure retrieval and staging for movement to the repository can be pursued regardless of the weather or season.

Gantry:

- Not required.

Hoist Speed:

- Full speed.

Arrangement Pattern and Stacking Method:

- Packages will be placed in standard LLW rooms. Any particular row of packages can contain only one type of container to maximise efficiencies due to different stacking limitations for different types and structural constraints on stacking methods. However, within any one room, different containers can be emplaced as long as each row only contains one type of container. A gap of 50 mm is allowed between each adjacent stack.
- Room and stacking optimisation are discussed in Section 4.5.3 in the main Section of the report.

Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group A packages:

Description / Name	Surface Radiation Field (mSv/hr)				
	<0.1	0.1 to 1	1 to 2	2 to 10**	> 10**
Ash Bin (Old) - bottom ash	29.8%	68.5%	1.3%	0.4%	0.0%
Ash Bin (New) - bottom ash	29.8%	68.5%	1.3%	0.4%	0.0%
Drum Rack - baghouse ash	29.8%	68.5%	1.3%	0.4%	0.0%
Ash Bin (new) - baghouse ash	29.8%	68.5%	1.3%	0.4%	0.0%
Compactor Box	93.5%	5.9%	0.5%	0.1%	0.0%
Bale Rack	62.8%	28.8%	4.9%	3.1%	0.4%
Drum Rack - non-processible drums (overpacked)	89.4%	6.2%	1.0%	2.9%	0.5%
Drum Rack - non-processible drums	89.4%	6.2%	1.0%	2.9%	0.5%
Drum Bin	89.4%	6.2%	1.0%	2.9%	0.5%
Non-Pro Bin (47" high NPB47)	87.1%	9.9%	1.1%	1.8%	0.1%
Non-Pro Bin (NPB4)	87.1%	9.9%	1.1%	1.8%	0.1%
Low Level Resin Box (90")	65.3%	7.7%	1.8%	12.6%	12.6%
Low Level Resin Pallet Tank	65.3%	7.7%	1.8%	12.6%	12.6%
ALW Sludge Box	75.0%	25.0%	0.0%	0.0%	0.0%
** Storage containers with surface dose rates greater then 2 mSv/hr will be overpacked in disposable shielding containers for disposal.					

D2 Group B

Waste Category: LLW

Container Specifications:

Container Type	*Dimensions*			*Weight*	*Number*
	L	W (or dia)	H	kg	
Shield Plug Container	3	1.8	1.8	26,000	9
Total					9

Packages:

- Large package size.
- Heavy (>25 tonnes).

Stacking:

- Not stackable.

Handling:

- Currently designed to be handled using crane
- They will be lifted onto a truck at the WWMF and onto a rail car in the Main Shaft Headframe using an overhead crane. Can then be treated like heat exchangers underground and put in same room using gantry crane – see Group E.

Overpack:

- Shielded already.

Cage Capacity:

- 1 (per trip).

Gantry:

- Not required.

Hoist Speed:

- Full speed.

Arrangement Pattern and Stacking Method:

- Shield Plug containers are to be placed in a single layer in the front end of the Heat Exchanger Room.

Container Dose Rates:

Description / Name	Surface Radiation Field (mSv/hr)				
	<0.1	0.1 to 1	1 to 2	2 to 10**	> 10**
Shield Plug Container	0%	6.6%	6.7%	26.7%	60%

D3 Group C

Waste Category: ILW

Container Specifications:

Container Type	*Dimensions*			*Weight*	*Number*
	L	W (or dia)	H	kg	
Tile Hole Liner	3	0.61		2,000	201
Total					**201**

Packages:

- Long cylinder.
- Light - 2 tonnes.

Stacking:

- In support cradles 4 or 5 high – in same room as Encapsulated Tile Holes (Group D - “ETH”)

Handling:

- To be handled using a forklift
- Transfer in cradle combination on truck from WWMF to Main Shaft Headframe; then placed on rail car at collar using forklift; push rail car into cage, pull out on underground Station and remove to staging area with forklift
- Two lifting brackets at 180°
- Handling and placement of these liners will utilise the standard forklift.

Overpack:

- Not relevant – this is already protected by grout filling.

Cage Capacity:

- 10 to 12 should be able to be transported per trip (4 per deck in 2 x 2 configuration on combination cradle)

Gantry:

- Not required.

Hoist Speed:

- Move at full speed

Arrangement Pattern and Stacking Method:

- Tile hole liners that have a diameter of 0.61m will be stored horizontally in cradles, which are stackable. They will be stored in the same room as the Encapsulated Tile Holes (ETH).

Container Dose Rates:

Description / Name	**Surface Radiation Field (mSv/hr)**				
	<0.1	0.1 to 1	1 to 2	2 to 10**	> 10**
Tile Hole Liner	3.6%	4.4%	4.1%	57.2%	30.7%

D4 Group D

Waste Category: LLW (ETH) and ILW (RL)

Container Specifications:

Container Type		***Dimensions***			***Weight***	***Number***
		L	W (or dia)	H	Kg	
D1	Encapsulated Tile Hole (ETH)	4.6	1.5		25,000	66
D2	Resin Liners (Unshielded) (RL)	1.8	1.63		4,545	359
D3	Resin Liners (Unshielded in Overpack)	1.9	1.66		5,995	400
D4	Resin Liners (0.25 m concrete shield)	4.25	2.2		26,829	718
D5	Resin Liners (0.35 m concrete shield)	4.45	2.4		36,056	182
D6	Resin Liners (0.35 m concrete shield with steel tube insert)	2.65	2.53		25,190	153
Total						**1,878**

Packages:

- Large package size.
- Heavy (> 20 tonnes), except Unshielded Resin Liners (4.5 to 6 tonnes).

Stacking:

- Unshielded Resin Liners – 2 high
- Shielded Resin Liners and ETH's – 1 high

Handling:

- Handled using the heavy load forklift, either on sacrificial pallets or via cast-in forklift pockets (for shielded RL) or welded on forklift pockets (ETH)
- Individually retrievable.

Overpack:

- ETH's: Concrete shielded (included in dimensions).
- Resin Liners:
  - 759 require no shielding – will be transferred unshielded (see p.105 of OPG Inventory Report [R76]) or overpacked in RLOPK (see p.107 of OPG Inventory Report [R76]) or in new stainless steel liners;
  - 1,436 will be placed two high in 0.25 m thick cylindrical concrete shields;
  - 364 will be placed two high in 0.35 m thick concrete shields;
  - 153 will be placed in a 40 mm thick steel tube and then encased in the 0.35 m thick concrete shield.

Cage Capacity:

- Unshielded Resin Liners: Type D2 – 6 per trip; Type D3 – 5 per trip
- All other packages - 1 (per trip).

Retrieval Period:

- Retrieval will be done on days with low wind and a lower probability of precipitation.
    - Based on movement of the resin liners occurring outdoor and involves moving heavy objects with a crane.

Gantry:

- Not Required.

Hoist Speed:

- Full speed.

Arrangement Pattern and Stacking Method

- Resin Liners
    - 6 dedicated rooms, except for 30 Type D6 liners, which will be placed at access end of T-H-E rooms (refer to Group E).
    - Type D2 and D3 will be stacked two high;
    - Types D4 and D5 will be one high only;
    - Type D6 will be one high with 1 x Type D2 on top.
    - Vent duct will run down top corner of room yielding a room height of 6 metres.
- Rooms for Resin Liners (Each module contains 10 x Type D2 or D3, 15 x Type D4, 4 x Type D5 and 2 x D6.) Rooms will be at least:
    - 8-module room: 6 rooms @ 168 m long
- ETH will be in same room as Tile Hole Liners (see Group C)
- Note: Actual room height will be determined by the maximum of package heights plus clearances or mining equipment limitations.

Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group D packages:

<table>
<tr><th rowspan="2">Description / Name</th><th colspan="5">Surface Radiation Field (mSv/hr)</th></tr>
<tr><th><0.1</th><th>0.1 to 1</th><th>1 to 2</th><th>2 to 10**</th><th>> 10**</th></tr>
<tr><td>Encapsulated Tile Hole</td><td>82.6%</td><td>17.4%</td><td>0.0%</td><td>0.0%</td><td>0.0%</td></tr>
<tr><td>Resin Liners in Resin Liner Shields</td><td colspan="2">100%</td><td>0.0%</td><td colspan="2">0.0%</td></tr>
</table>

D5 Group E

Waste Category: ILW (IC-2 & IC-18) and LLW (HX)

Container Specifications:

Container Type	*Dimensions*			*Weight*	*Number*
	L	W (or dia)	H	kg	
IC-2 Liner	7.6	0.61		32,342	20
IC-18 T-H-E Liner – filters, IX columns, etc.	11.2	0.55		31,538	422
IC-18 T-H-E Liner – core components	11.2	0.55		31,538	22
Heat Exchanger	4.57	2.0		Up to 30,000	82
Total					546

Packages:

- IC-2 & 18 - Long packages.
- Heavy.

Stacking:

- See "Arrangement Pattern and Stacking method" below.

Handling:

- Crane used to transfer to T-H-E shield on surface during retrieval.
- Loading and unloading is labour intensive.
- Staging not easy (need rails).
- Time consuming (needs to be removed from in-ground storage) – also underground where slow, careful and supervised handling will be a must.

Overpack:

- T-H-E's will be grout-filled and transported in re-usable shield (Note: Dimensions in table do not include re-usable shield);
- HX's require no additional shielding.

Cage Capacity:

- T-H-E's: 1 (per trip) partially removing decks and locking T-H-E Handler railcar and transfer bell (re-usable shield) to deck steel.
- HX's: 1 per trip flat on rail car (will fit horizontally in cage)

Retrieval Period:

- T-H-E's are stored in-ground; therefore, assume retrieval period is limited to non-snow bound months (5 months mid April to mid October).

Gantry:

- Gantry crane required in emplacement rooms to: place T-H-E's in a hydraulic powered positioning/ placement frame; lower the HX's in a pyramid stack in the emplacement room.

Hoist Speed:

- T-H-E's - half speed.
- HX's – full speed

Arrangement Pattern and Stacking Method

- T-H-E's: Pushed out of re-usable shield bell into concreted pipe array (5 h x 6 w).
- HX's: Pyramid shaped stack: three on bottom row, two on 2nd row (at front of T-H-E Room with Shield Plug Containers (see Group B)).

Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group E packages:

Description / Name	Surface Radiation Field (mSv/hr)				
	<0.1	0.1 to 1	1 to 2	2 to 10**	> 10**
IC-2 T-H-E Liner	3.6%	4.4%	4.1%	57.2%	30.7%
IC-18 T-H-E Liner - filters, IX columns, etc.	3.6%	4.4%	4.1%	57.2%	30.7%
IC-18 T-H-E Liner - core components	3.6%	4.4%	4.1%	57.2%	30.7%
Heat Exchanger	56.1%	36.6%	7.3%	0.0%	0.0%

D6 Group F

Waste Category: ILW

Container Specifications:

Container Type	*Dimensions*			*Weight*	*Number*
	L	W (or dia)	H	kg	
ILW Shield	1.7	1		2,290	7,383
Total					**7,383**

Packages:

- Small package size.
- Light weight (~ 2.5 tonnes).

Stacking:

- Can stack up to 3 high.

Handling:

- Handled using a standard forklift.

Overpack:

- Not required – concrete-encased package is self-shielding.

Cage Capacity:

- 12 (per trip) – 3 per deck.

Retrieval Period:

- No restriction – can be moved throughout the year

Gantry:

- Gantry Not Required.

Hoist Speed:

- Move at full speed.

Arrangement Pattern and Stacking Method

- ILW shields will be placed 7 containers across the room x 3 high (except for line below vent duct, where only 2 high) with a minimum spacing of 0.05m between each adjacent container, leaving 0.35m between end containers and the walls for a room of width 8.0m.
- A total emplacement length of 388 metres is required.
- 3 rooms, each 162 m long – will be combined with 275 of the pressure tube retube waste containers (see Group H) to fully utilise the third room.
- Maximum package height above concrete floor = 4.45 m. With 0.3 m clearance to roof, nominal room height = 5 metres. (Note: Actual room height will be determined by the maximum of package heights plus clearances or mining equipment limitations.)

Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group F packages:

Description / Name	Surface Radiation Field (mSv/hr)				
	<0.1	0.1 to 1	1 to 2	2 to 10*	> 10*
ILW Shield	N/A	N/A	N/A	N/A	N/A

D7 Group G

Waste Category: LLW

Container Specifications:

Container Type	*Dimensions*			*Weight*	*Number*
	L	W (or dia)	H	kg	
Steam Generators – Bruce A	2.4 - 4.1	2.4 - 2.6		35,044	128
Steam Generators – Bruce B	2.3 - 3.0	2.5 - 3.6		35,000	192
Steam Generators – Pickering B	3.2 - 4.5	1.8 - 2.5		27,435	192
Total Quantity / Max Dimensions & Mass	**4.5**	**3.6**		**35,044**	**512**
See Section 8.2.1.5 of the main body of this Report for more details on steam generator segments					

Packages:

- Moderate sized package.
- Extremely heavy (~ 35 tonnes).

Stacking:

- 2-high.

Handling:

- Can be moved using a crane or a forklift.
- Larger components will undergo a size reduction to lower the difficulty of handling and to meet the size and weight capacity of the hoist cage.

Overpack:

- Overpacking not required; shielding achieved by stabilisation grout and section seal plates.

Cage Capacity:

- 1 (per trip).

Gantry:

- Not Required.

Hoist Speed:

- Move at full speed.

Arrangement Pattern and Stacking Method

- All segments will be placed on a flat end, created by seal plates with forklift pocket structure welded to seal plate. Some segments can be stacked two or three high, larger ones (will be single
- Four sizes of rooms provide optimum efficiency:
  - 1 off 75m (l) x 8.2m (w) x 5.9m (h) for Bruce A Main Sections, Bruce A & B Head Ends;
  - 1 off 55m (l) x 8.4m (w) x 6.5m (h) for Bruce B Main Sections;
  - 1 off 64m (l) x 7.9m (w) x 6.7m (h) for Bruce B Steam Drums;

    - 1 off 126m (l) x 8.6m (w) x 5.7m (h) for Pickering (all segments) and Bruce A Tail Ends.
- Optimisation determined that the overall minimum amount of excavation (rooms and access tunnel portions) is achieved by combining all segments from Pickering steam generators with the tail ends of Bruce A steam generators in a room with the Tile Hole Liners (THLSTG3) and the Encapsulated Tile Holes (ETH). The remaining segments would be stacked in a single room dedicated to those segments.
- Note: Actual room height will be determined by the maximum of package heights plus clearances or mining equipment limitations.

Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group G packages:

Description / Name	**Surface Radiation Field (mSv/hr)**				
	<0.1	0.1 to 1	1 to 2	2 to 10**	> 10**
Steam Generators - Bruce A	N/A*	N/A*	N/A*	N/A*	N/A*
Steam Generators - Bruce B	N/A*	N/A*	N/A*	N/A*	N/A*
Steam Generators - Pickering B	N/A*	N/A*	N/A*	N/A*	N/A*
*The dose rate from the steam generator segments is not currently available, it is expected to be less than 2 mSv/hr.					
** Storage containers with surface dose rates greater then 2 mSv/hr will be overpacked in disposable shielding containers for disposal.					

D8 Group H

Waste Category: ILW

Container Specifications:

Container Type		Dimensions			Weight	Number
		L	W (or dia)	H	kg	
H1	Retube Waste (Pressure Tubes)	1.85	1.85	2.25	26,303	245
H2	Retube Waste (End Fittings)	1.7	3.35	1.92	30,004	918
H1	Retube Waste (Calandria Tubes)	1.85	1.85	2.25	26,303	168
H1	Retube Waste (Calandria Tube Inserts)	1.85	1.85	2.25	26,303	45
Total						**1,376**

Packages:

- Small package size.
- Heavy

Stacking:

- Type H1 Retube Waste (Pressure tubes, calandria tubes, calandria tube inserts) stacked 2 high.
- Type H2 Retube Waste (End fittings) stacked 3 high.

Handling:

- Specifically designed to be handled using heavy duty forklift.

Overpack:

- Already shielded = overpack

Cage Capacity:

- 1 (per trip).

Gantry:

- Not required.

Hoist Speed:

- Move at full speed.

Arrangement Pattern and Stacking Method

- 275 Type H1 packages will be placed 4 across with a minimum spacing of 0.1m between each adjacent container, leaving 0.5 m spacing between the end containers and the wall of an 8.6 m wide room. Each row will hold 7 packages with space for the vent duct. One room of length 80 m long x 4.3 m minimum height will be required or they may be combined in a longer room with Type F (ILW Shields).

- Type H2 packages will be placed 2 across x 3 high on one line and 2 high on the second line. One Type H1 package will be placed on top of the second layer of Type H2 packages on the second line to allow space for the vent duct. There will be a spacing of 0.1m between adjacent containers, leaving 0.3 m between the end containers and the wall of 7.4 m wide rooms.
- 275 of the H1 pressure tube containers will be emplaced with ILW shields;
- 2 rooms x 182 m long rooms are required for the remainder of the H1 pressure tubes and all the H2 end fittings. Minimum room height will be 6.3 m.
- The retube waste containers have a relatively high thermal power (~ 100 watts/container).

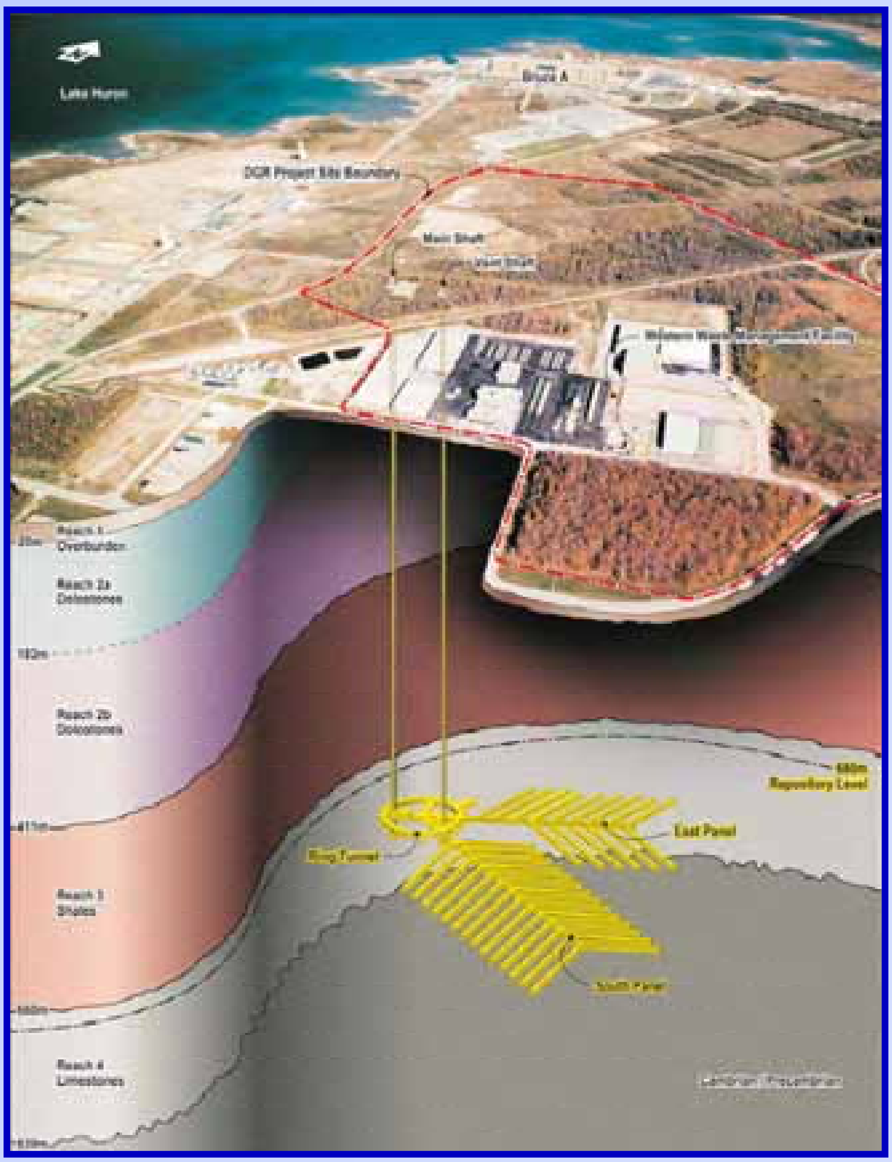
Container Dose Rates:

Based upon current data, the following is a summary of the surface radiation fields from the various Group H packages:

Description / Name	Surface Radiation Field (mSv/hr)				
	<0.1	0.1 to 1	1 to 2	2 to 10	>10
Retube Waste (Pressure Tubes)	100%				
Retube Waste (End Fittings)	100%				
Retube Waste (Calandria Tubes)	100%				
Retube Waste (Calandria Tube Inserts)	100%				

CONCEPTUAL DESIGN REPORT

Appendix E – Drawings



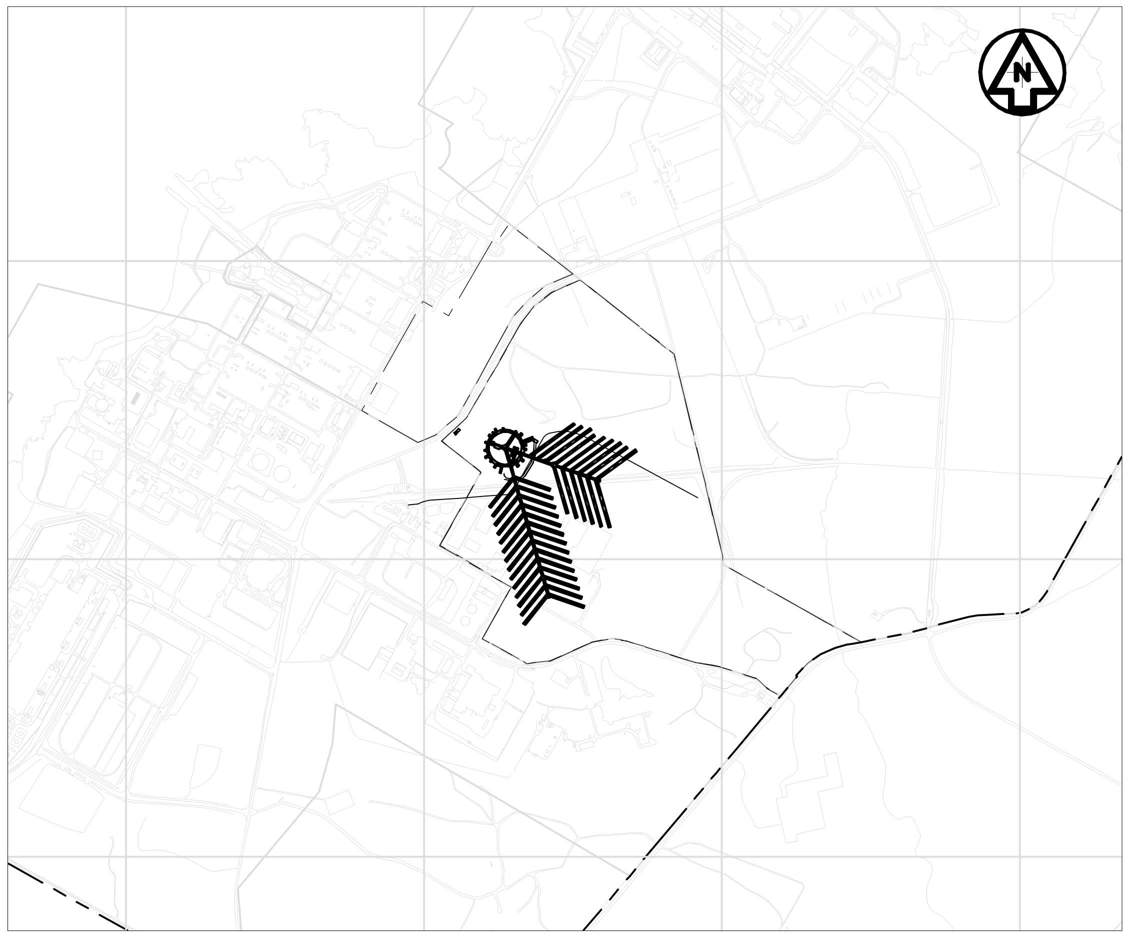
ONTARIO POWER GENERATION

DEEP GEOLOGIC REPOSITORY PROJECT

MAY 2008

ONTARIO POWER GENERATION

HATCH™



LOCATION MAP

CONCEPTUAL DESIGN REPORT DRAWINGS

PRELIMINARY
NOT FOR CONSTRUCTION

THIS DRAWING IS FOR ESTIMATING USE ONLY

All ratings and sizes of equipment, concrete, steel, and materials, shown on this drawing are approximations only and must not be considered as final design requirements.

DO NOT USE FOR CONSTRUCTION

DWG. NO. 323874DGR-200-COVER	REV. 0

DWG. NO.

INDEX OF DRAWINGS

DRAWING NO.	DESCRIPTION
GENERAL	
323874DGR-200-COVER	OPG DEEP GEOLOGIC REPOSITORY
323874DGR-200-INDEX	INDEX OF DRAWINGS, GENERAL NOTES & SYMBOLS
LAYOUT	
323874DGR-200-001	SURFACE SITE LAYOUT
323874DGR-200-002	SHAFT ISLAND PANEL UNDERGROUND LAYOUT PLAN VIEW – BASE CASE
323874DGR-200-003	SHAFT ISLAND PANEL UNDERGROUND LAYOUT PLAN VIEW – POTENTIAL EXPANSION CASE
RING TUNNEL AND PANELS	
323874DGR-200-004	RING TUNNEL PLAN VIEW
323874DGR-200-005	NORTH & SOUTH PANEL EMPLACEMENT ROOMS PLAN VIEW
323874DGR-200-006	EAST PANEL EMPLACEMENT ROOM PLAN VIEW
UNDERGROUND LAYOUT	
323874DGR-200-007	TYPICAL EMPLACEMENT ROOM PLAN & LONGITUDINAL PROFILE
323874DGR-200-008	RING TUNNEL & ACCESS TUNNEL CROSS SECTIONS
323874DGR-200-009	EMPLACEMENT ROOM CROSS-SECTIONS & DETAILS 1 OF 2
323874DGR-200-010	EMPLACEMENT ROOM CROSS-SECTIONS & DETAILS 2 OF 2
ACCESS TUNNEL/EMPLACEMENT ROOMS	
323874DGR-200-011	EMPLACEMENT ROOM SIZING ALLOWANCES AND CLEARANCE
323874DGR-200-012	WASTE PACKAGE STACKING ARRANGEMENTS 1 OF 4
323874DGR-200-013	WASTE PACKAGE STACKING ARRANGEMENTS 2 OF 4
323874DGR-200-014	WASTE PACKAGE STACKING ARRANGEMENTS 3 OF 4
323874DGR-200-015	WASTE PACKAGE STACKING ARRANGEMENTS 4 OF 4
323874DGR-200-016	VENTILATION LAYOUT – BASE CASE
323874DGR-200-017	VENTILATION LAYOUT – POTENTIAL EXPANSION CASE
SHAFT DRAWINGS	
323874DGR-200-018	MAIN AND VENT SHAFT PERMANENT CROSS-SECTIONS
323874DGR-200-019	MAIN SHAFT SINKING PLANS, SECTIONS AND DETAILS
323874DGR-200-020	VENT SHAFT SINKING PLANS, SECTIONS AND DETAILS
323874DGR-200-021	GROUTING ARRANGEMENT AND SHAFT SINKING FOR REACH 2
323874DGR-200-022	SUPPORT MATERIAL AND BENTONITE RING INSTALLATION AT INTERFACE REACH 2 AND 3
SURFACE LAYOUT	
323874DGR-200-023	WASTE ROCK MANAGEMENT PLAN REFERENCE BASE CASE
323874DGR-200-024	POTENTIAL REPOSITORY EXPANSION CASE
SHAFT SEALS	
323874DGR-200-025	STRATIGRAPHY & SHAFT SEALING SYSTEM LAYOUT
323874DGR-200-026	SEALING SYSTEM WATERSTOP AND MONOLITH DETAILS
323874DGR-200-027	SEALING SYSTEM GROUTING DETAILS

ABBREVIATIONS & SYMBOLS

- B.G.S. – BELOW GROUND SURFACE
- A.M.S.L. – ABOVE MEAN SEA LEVEL
- N – NORTHING
- E – EASTING
- DGR – DEEP GEOLOGIC REPOSITORY
- WWMF – WESTERN WASTE MANAGEMENT FACILITY
- AZI – AZIMUTH
- G – GANTRY
- F/L – FORK LIFT
- ℄ – CENTERLINE
- W.P. ◈ – WORK POINT
- TYP. – TYPICAL
- EXP. – EXPANSION
- NTS – NOT TO SCALE
- DWG – DRAWING
- (A / 006) – SECTION A ON DWG. 323874-200-006
- (2 / 006) – DETAIL 2 ON (OR FROM) DWG. 323874-200-006

NOTE:

ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE

PRELIMINARY
NOT FOR CONSTRUCTION

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THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE

REVISIONS

REV.	ISSUE FOR	AUTH. BY	DATE
0	ISSUE FOR CDR REV.01	MRD	30-5-08

ISSUE AUTHORIZATION

HATCH™

DESIGNED BY G.J.E.K. DATE	DRAWN BY C.P.W DATE
CHECKED BY M.R.D. DATE	DISCIP. ENGR. G.J.E.K. DATE
PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

INDEX OF DRAWINGS
GENERAL NOTES AND SYMBOLS

SCALE: OR AS NOTED | DWG. NO. 323874DGR-200-INDEX | REV. 0

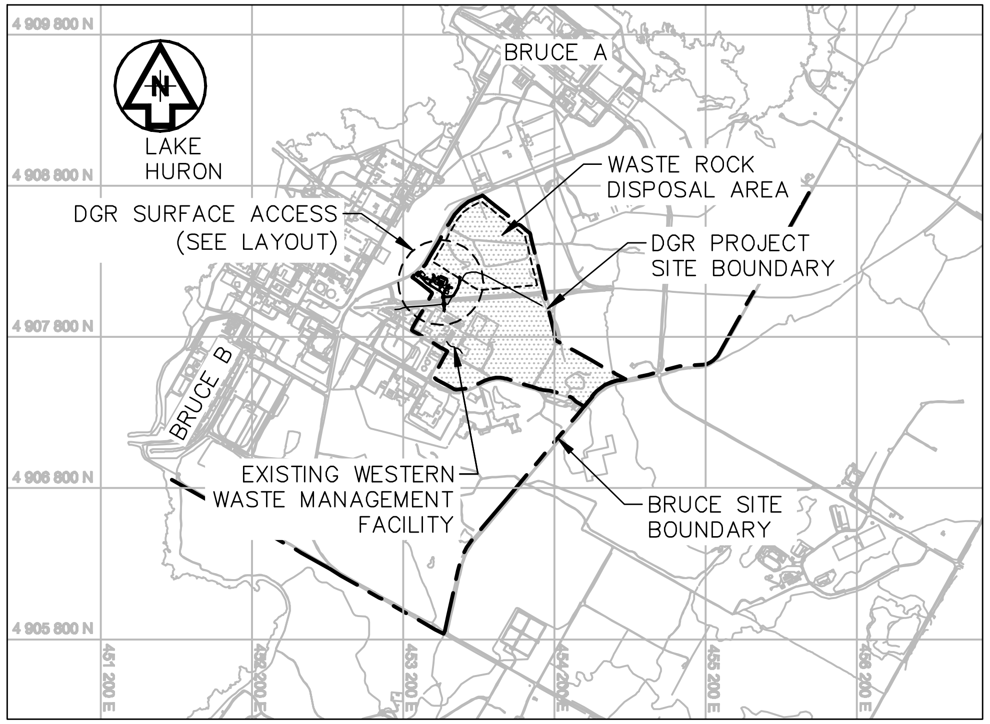
DWG. NO.

NOTE:

1. ALL NORTHINGS AND EASTINGS TO NAD83 UTH ZONE 17N COORDINATE SYSTEM.

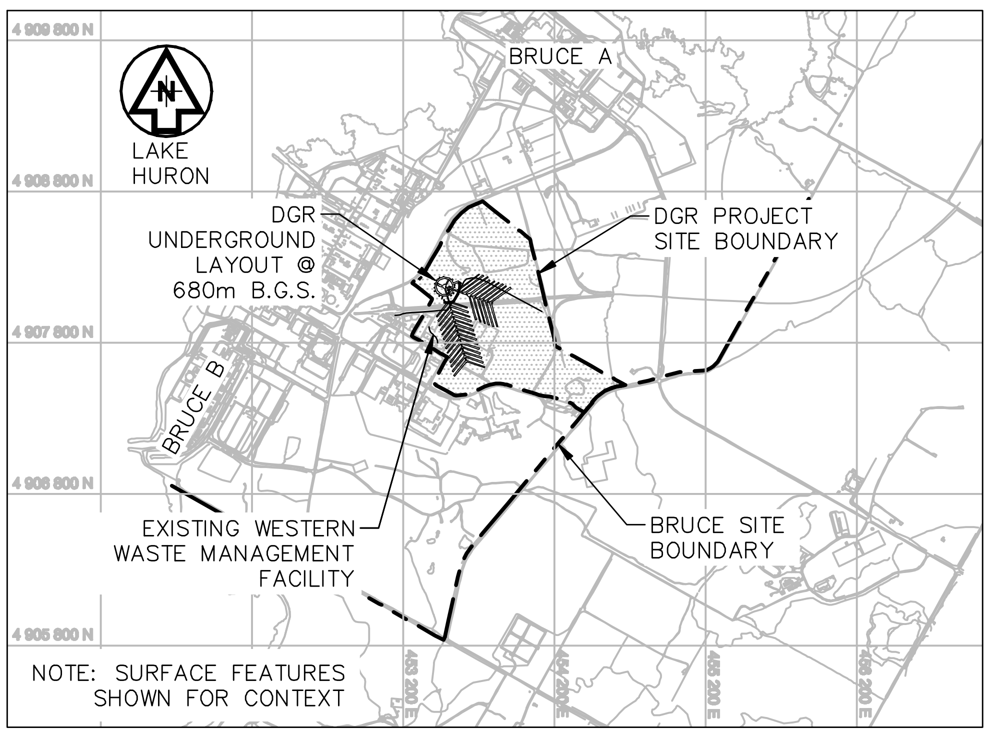
LEGEND:

——— (light line)	EXISTING FEATURE
——— (heavy line)	NEW FEATURE



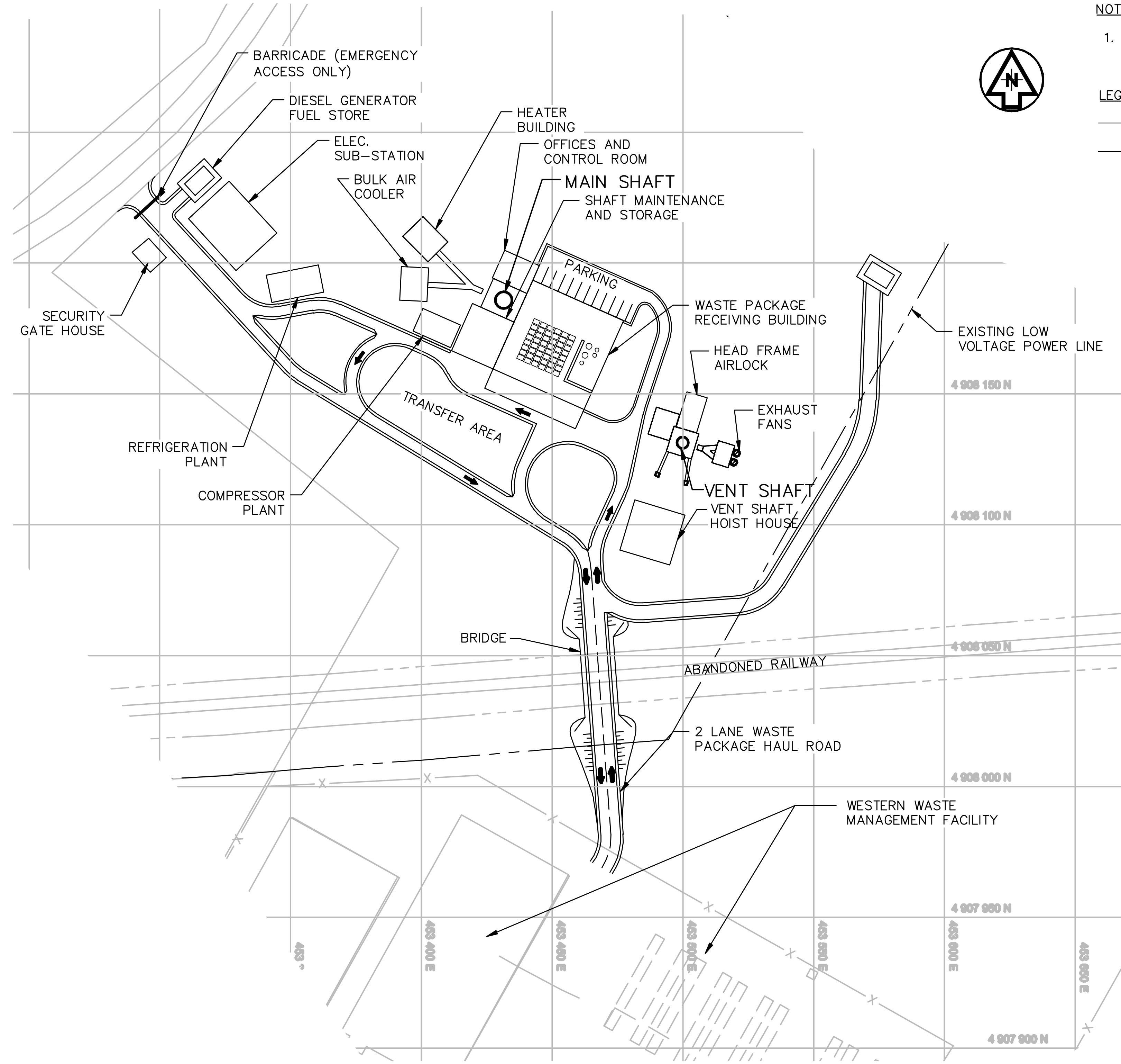
DEEP GEOLOGIC REPOSITORY SURFACE ACCESS AREA

SCALE: 1 : 5000



DEEP GEOLOGIC REPOSITORY UNDERGROUND LAYOUT

SCALE: 1 : 5000



DEEP GEOLOGIC REPOSITORY SURFACE ACCESS AREA LAYOUT

SCALE = 1:2000

PRELIMINARY
NOT FOR CONSTRUCTION

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DO NOT USE FOR CONSTRUCTION

THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

REV.	ISSUE FOR	AUTH. BY	DATE
0	ISSUE FOR CDR REV.01	MRD	30-5-08
ISSUE AUTHORIZATION			

HATCH

DESIGNED BY D.W DATE	DRAWN BY C.P.W DATE
CHECKED BY G.J.E.K. DATE	DISCIP. ENGR. M.R.D. DATE
PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

SURFACE SITE LAYOUT

SCALE	DWG. NO.	REV.
OR AS NOTED	323874DGR–200–001	0

DWG. NO.

TRUE NORTH
PLANT NORTH

EMPLACEMENT ROOM LEGEND

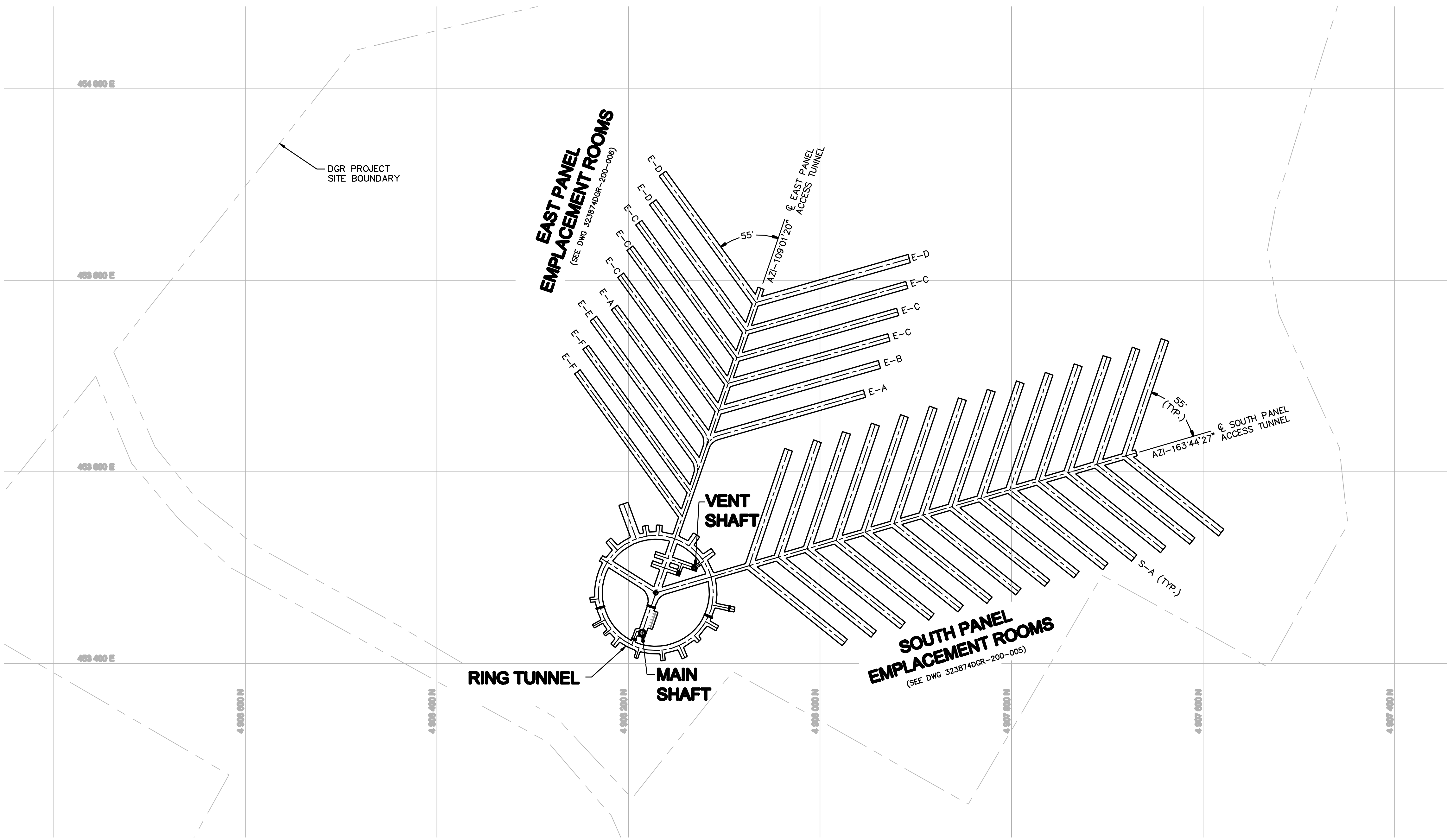
E–A

PANEL IDENTIFIER
E–EAST
S–SOUTH
N–NORTH
R–RING

EMPLACEMENT ROOM SIZE IDENTIFIER (WITHIN PANEL)

BASE CASE					
EMPLACEMENT ROOM TYPE	NO. OF ROOMS	LENGTH (m)	WIDTH (m)	HEIGHT (m)	GANTRY OR FORKLIFT
SOUTH PANEL					
S–A	28	123.90	8.60	7.00	F/L
EAST PANEL					
E–A	2	164.60	8.10	7.20	G
E–B	1	170.50	8.60	5.70	F/L
E–C	6	170.50	7.70	6.00	F/L
E–D	3	162.30	8.60	5.70	F/L
E–E	1	185.50	8.40	6.70	G
E–F	2	182.50	7.40	6.30	F/L

TUNNEL & SHAFT CENTRE COORDINATES			
	NORTHING	EASTING	DIA.
MAIN SHAFT	4908185.81	453431.51	6.5m
VENT SHAFT	4908131.44	453499.70	4.5m
RING TUNNEL	4908171.38	453473.38	120m



PLAN VIEW – BASE CASE
(FLOOR @ 680m BELOW GROUND SURFACE)
SCALE: 1:5000

THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

PRELIMINARY
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CHECKED BY M.R.D.	DISCIP. ENGR. G.J.E.K.
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

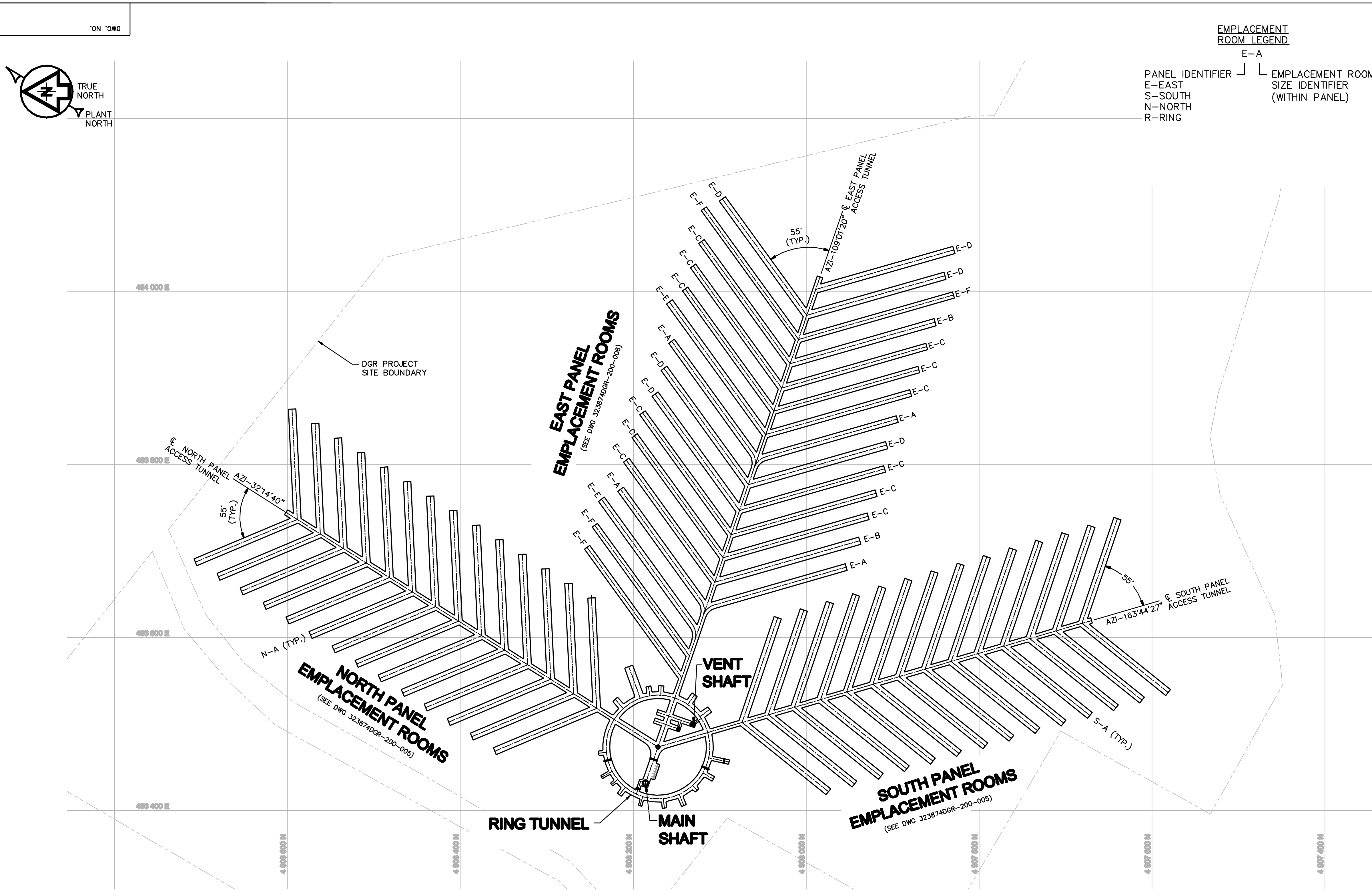
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

SHAFT ISLAND PANEL UNDERGROUND LAYOUT
PLAN VIEW – BASE CASE

SCALE: OR AS NOTED
DWG. NO. 323874DGR–200–002
REV. 0

DWG. NO.



PLAN VIEW – POTENTIAL EXPANSION CASE

(FLOOR @ 680m BELOW GROUND SURFACE)
SCALE: 1:5000

BASE CASE & POTENTIAL EXPANSION CASE					
EMPLACEMENT ROOM TYPE	NO. OF ROOMS	LENGTH (m)	WIDTH (m)	HEIGHT (m)	GANTRY OR FORKLIFT
SOUTH PANEL					
S–A	28	123.90	8.60	7.00	F/L
EAST PANEL					
E–A	4	164.60	8.10	7.20	G
E–B	2	170.50	8.60	5.70	F/L
E–C	12	170.50	7.70	6.00	F/L
E–D	6	162.30	8.60	5.70	F/L
E–E	2	185.50	8.40	6.70	G
E–F	4	182.50	7.40	6.30	F/L
NORTH PANEL					
N–A	28	123.90	8.60	7.00	F/L

TUNNEL & SHAFT CENTRE COORDINATES			
	NORTHING	EASTING	DIA.
MAIN SHAFT	4908185.81	453431.51	6.5m
VENT SHAFT	4908131.44	453499.70	4.5m
RING TUNNEL	4908171.38	453473.38	120m

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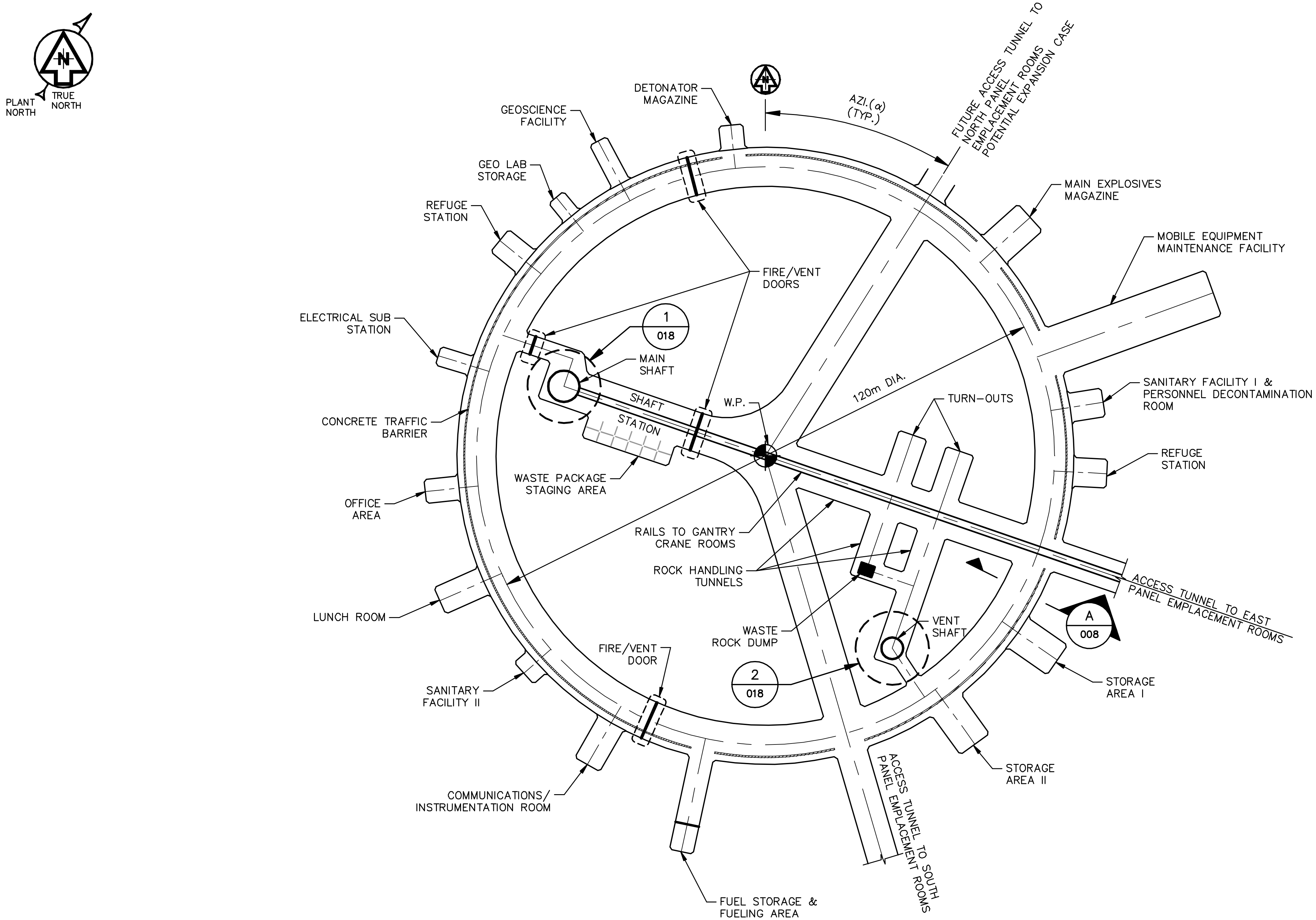
PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

SHAFT ISLAND PANEL UNDERGROUND LAYOUT
PLAN VIEW – POTENTIAL EXPANSION CASE

SCALE OR AS NOTED | DWG. NO. 323874DGR–200–003 | REV. 0



PLAN VIEW RING TUNNEL

SCALE: 1 : 1000

ROOM	DEPTH/ LENGTH	WIDTH	HEIGHT	ROOM ℄ AZI (α)
EXPLOSIVES MAGAZINE	10.0	7.5	6.0	48°
MOBILE EQUIPMENT MAINTENANCE FACILITY	35.0	10.0	7.5	70°
SANITARY I	7.0	6.0	3.0	81°
REFUGE STATION	7.0	6.0	6.0	93°
STORAGE AREA I	10.0	7.5	3.0	125°
STORAGE AREA II	10.0	7.5	6.0	144°
FUEL STORAGE/FUELING	20.0	5.0	5.0	192°
COMM/INSTR. ROOM	10.0	6.0	3.0	210°
SANITARY II	3.5	6.0	3.0	228°
LUNCH ROOM	10.0	6.0	3.0	246°
OFFICE AREA	7.0	5.0	3.0	264°
ELECTRICAL S/S	7.0	4.0	5.0	287°
REFUGE STATION	7.0	6.0	6.0	309°
GEOLAB STORAGE	5.0	4.0	3.0	321°
GEOSCIENCE LAB	10.0	4.0	3.0	332°
DETONATOR MAGAZINE	5.0	5.0	3.0	354°
TURNOUTS	10.0	6.0	7.5	
MAIN SHAFT STATION	22.6	12.6	15.0	
VENT SHAFT STATION		VARIES	7.5	
RING TUNNEL		8.1	7.5	
ROCK HANDLING TUNNELS		8.1	7.5	
ACCESS TUNNEL TO NORTH PANEL		6.5	7.0	32.2°
ACCESS TUNNEL TO EAST PANEL		6.5	7.0	109.0°
ACCESS TUNNEL TO SOUTH PANEL		6.5	7.0	163.7°

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PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

RING TUNNEL
PLAN VIEW

SCALE: OR AS NOTED

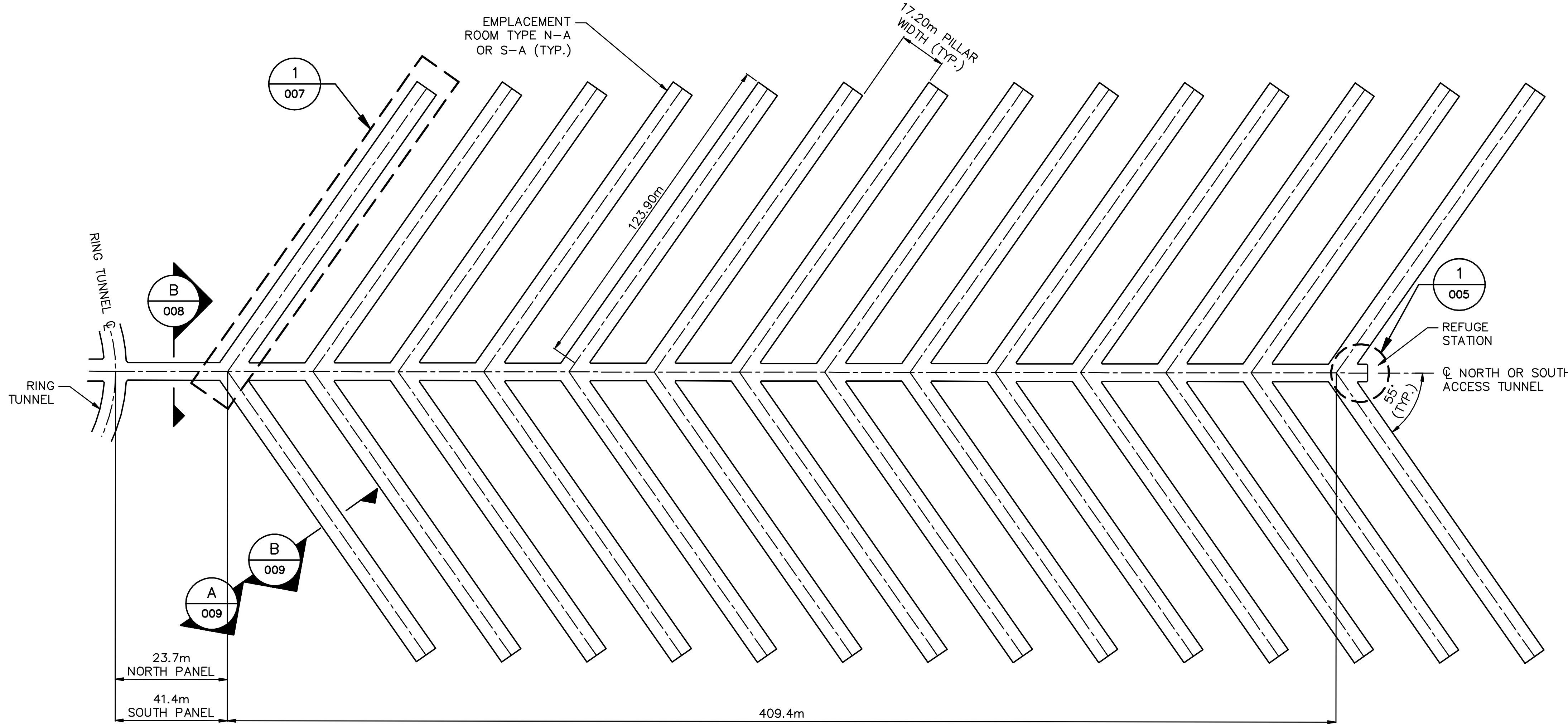
DWG. NO. 323874DGR-200-004

REV. 0

DWG. NO.

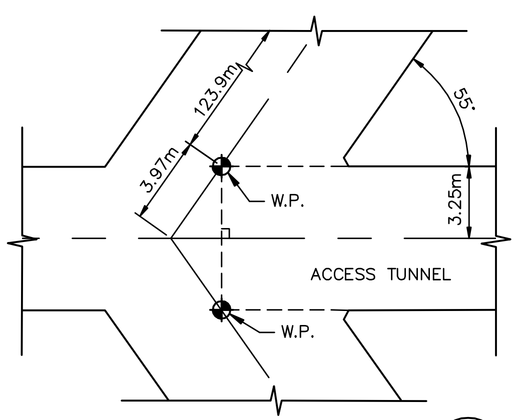
NOTES:

1. FOR EMPLACEMENT ROOM LENGTHS AND DIMENSIONS SEE DWG. 323874DGR-200-001 AND 002.



PLAN VIEW SOUTH & NORTH PANEL EMPLACEMENT ROOMS

SCALE: 1:2000



TYPICAL DIMENSIONING OF EMPLACEMENT ROOMS (1/005)

SCALE: NTS

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CHECKED BY M.R.D.	DISCIP. ENGR. G.J.E.K.
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

NORTH & SOUTH PANEL EMPLACEMENT ROOMS PLAN VIEW

SCALE: AS NOTED

DWG. NO. 323874DGR-200-005

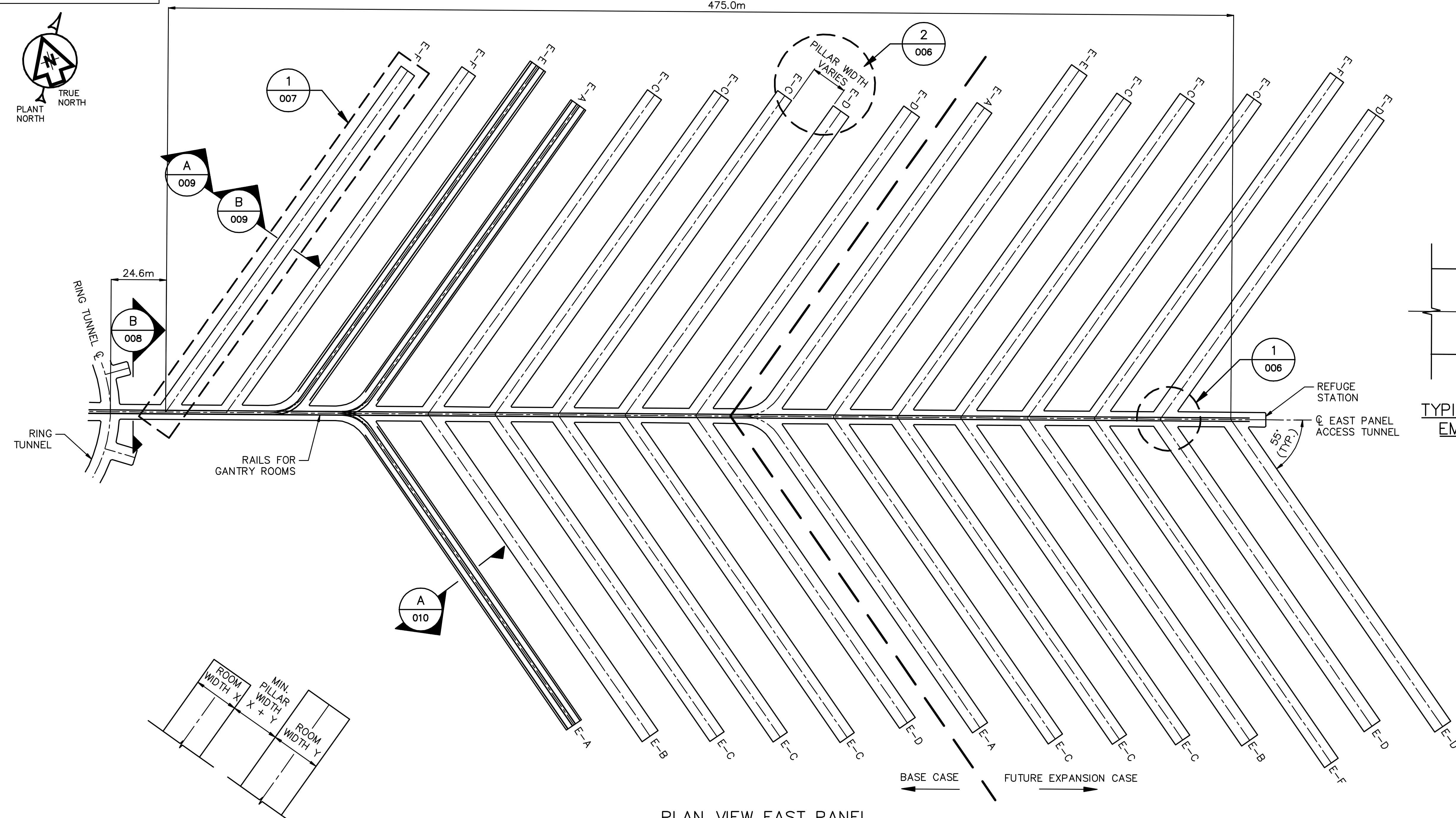
REV. 0

DWG. NO.

DWG. NO.

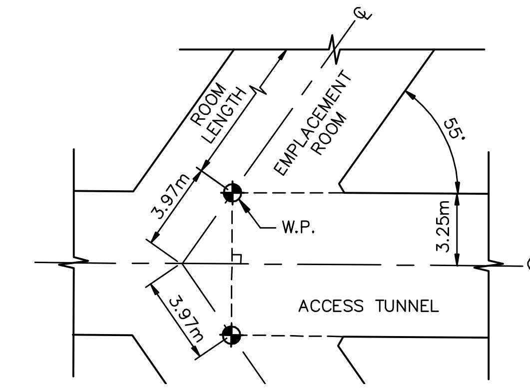
NOTES:

1. FOR EMPLACEMENT ROOM LENGTHS AND DIMENSIONS SEE DWG. 323874DGR-200-002 AND 003.
2. MIN. PILLAR WIDTH BETWEEN ADJACENT ROOMS IS DETERMINED ON BASIS OF THE SUM OF THE ROOM SPANS (EAST PANEL ONLY). AVERAGE WIDTH FOR ESTIMATING = 16.36m.



PLAN VIEW EAST PANEL EMPLACEMENT ROOMS

SCALE: 1:2000



TYPICAL DIMENSIONING OF EMPLACEMENT ROOMS (1 / 006)

SCALE: NTS

TYPICAL DIMENSIONING OF PILLAR WIDTH (2 / 006)

SCALE: NTS

PRELIMINARY
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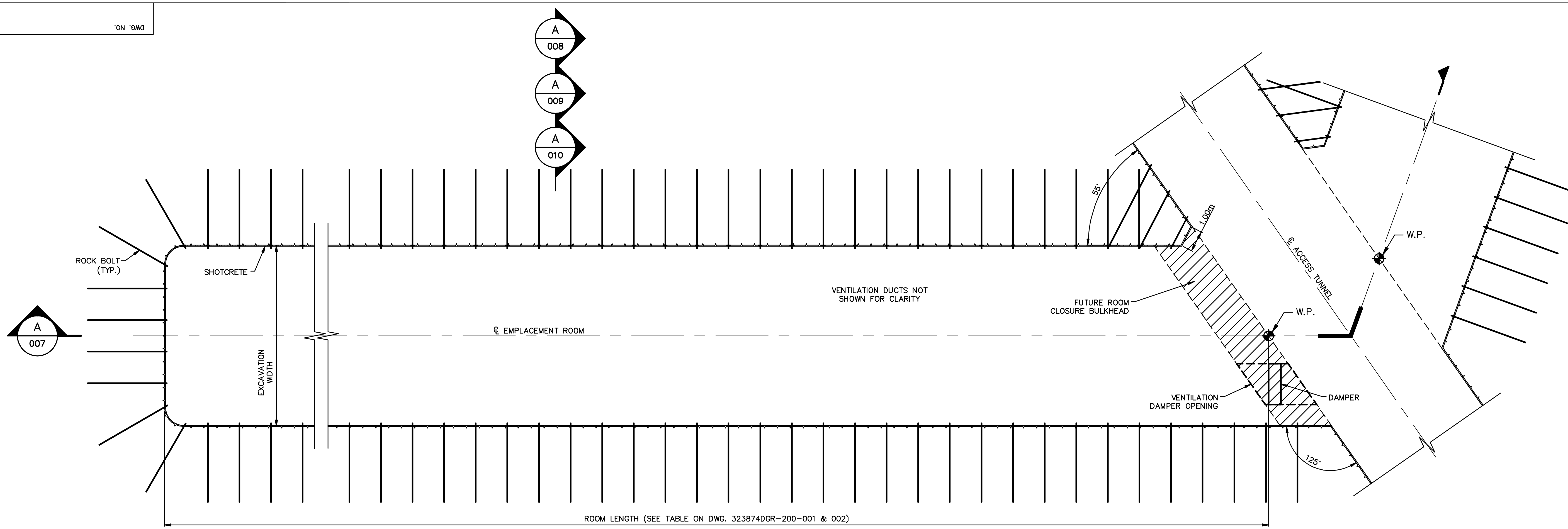
CHECKED BY M.R.D.	DISCIP. ENGR. G.J.E.K.
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

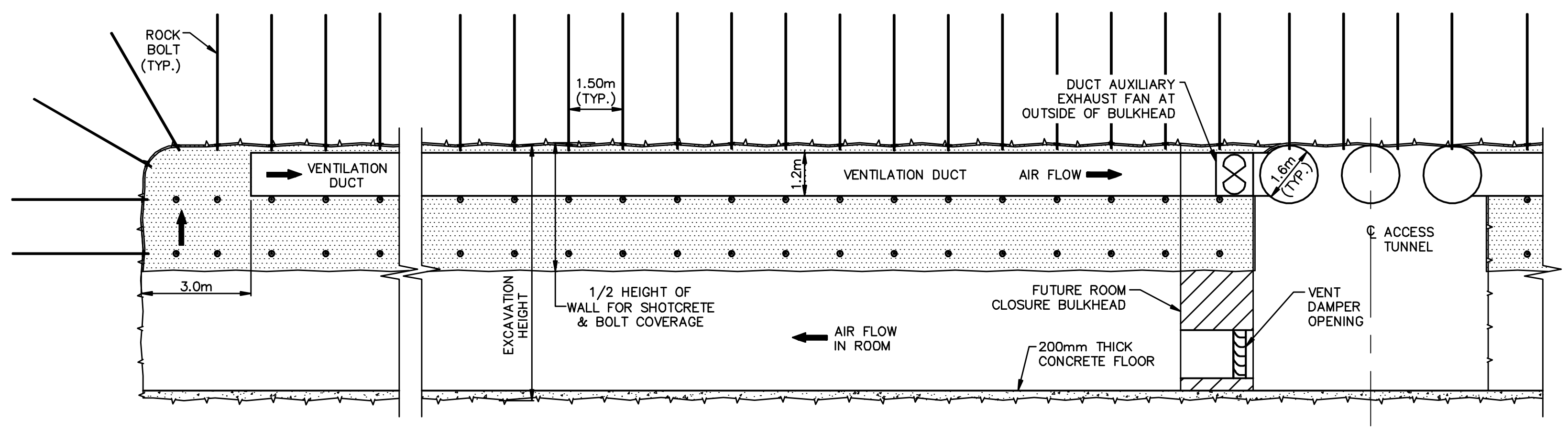
EAST PANEL EMPLACEMENT ROOM PLAN VIEW

SCALE: OR AS NOTED | DWG. NO. 323874DGR-200-006 | REV. 0



PLAN VIEW – EMPLACEMENT ROOM
ILW & LLW ROOMS
SCALE: 1:200

1/005 1/006



SECTION – EMPLACEMENT ROOM
ILW & LLW ROOMS
SCALE: 1:200

A/007

PRELIMINARY
NOT FOR CONSTRUCTION

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PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

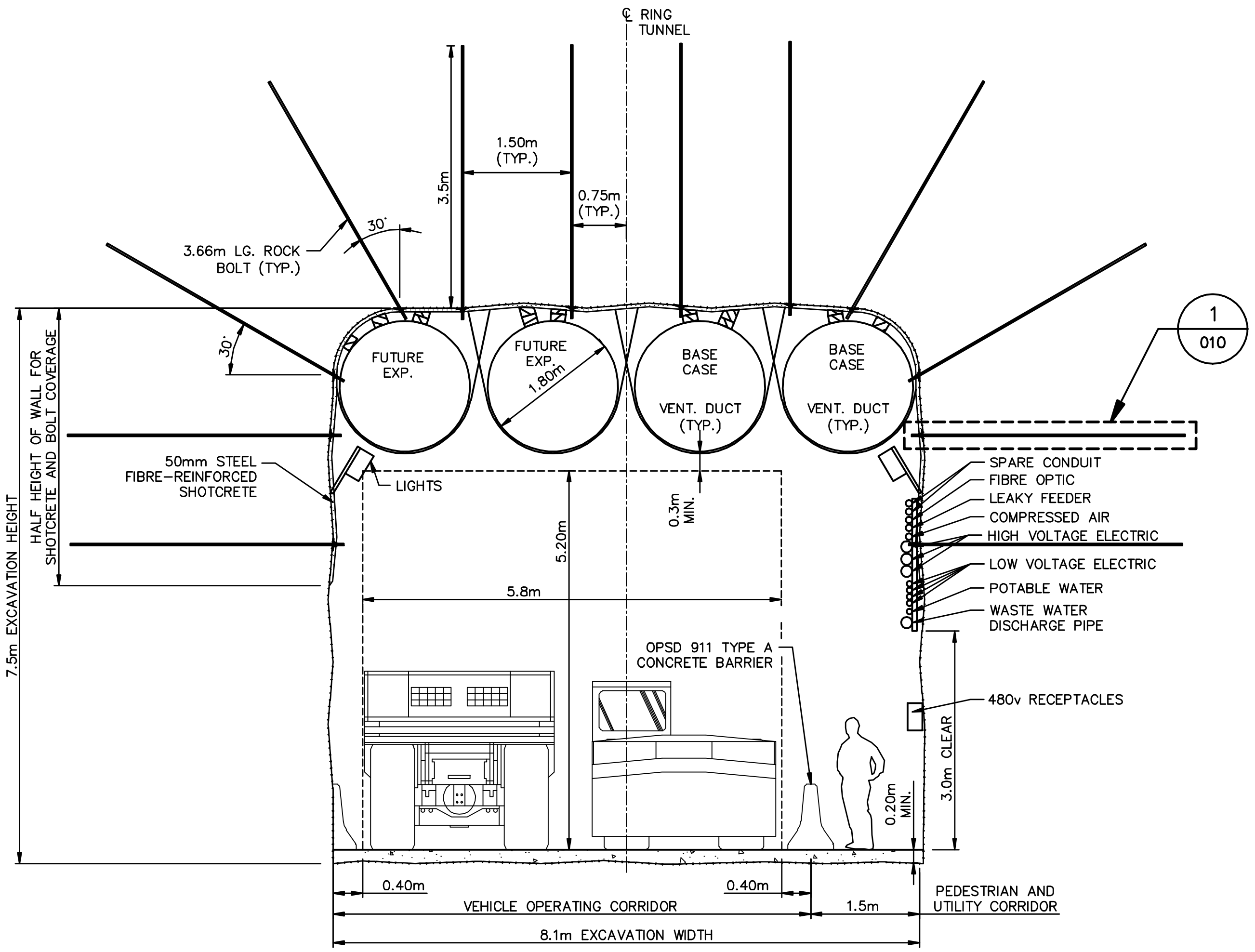
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

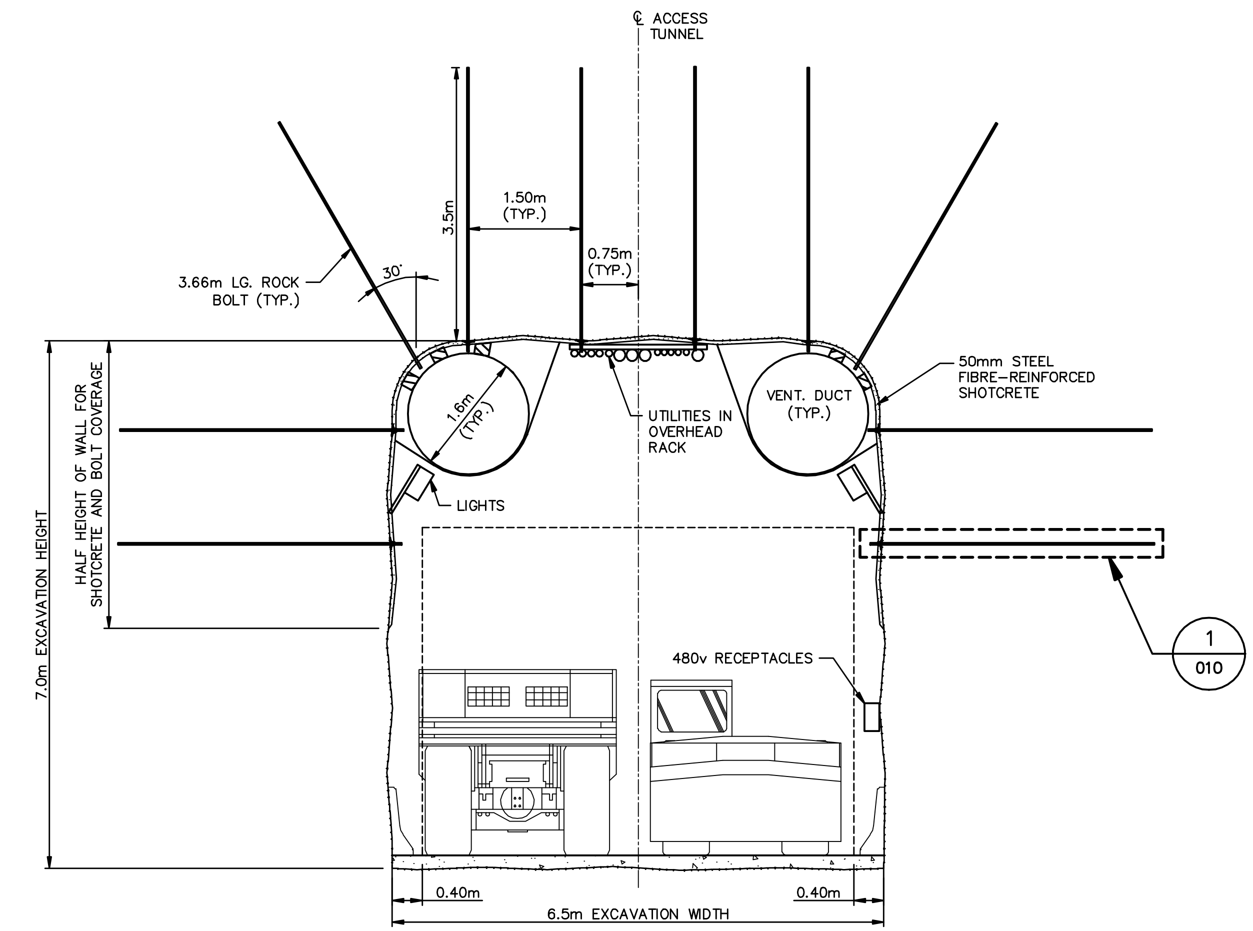
TYPICAL EMPLACEMENT ROOM
PLAN & LONGITUDINAL PROFILE

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-007 | REV. 0

DWG. NO.



RING TUNNEL (A / 004)
SCALE: 1:100



TYPICAL ACCESS TUNNEL (B / 005) (B / 006)
SCALE: 1:100

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PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

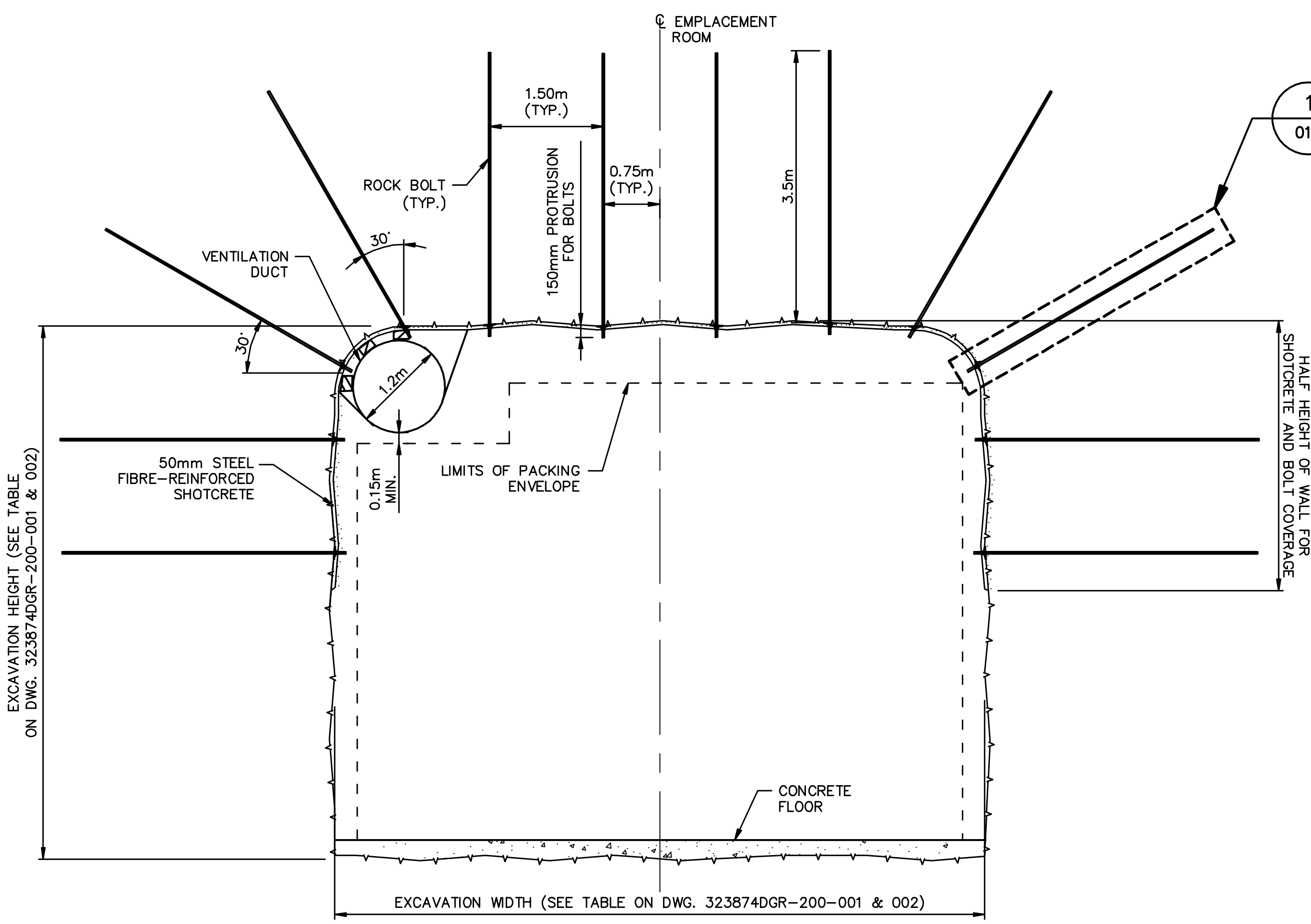
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

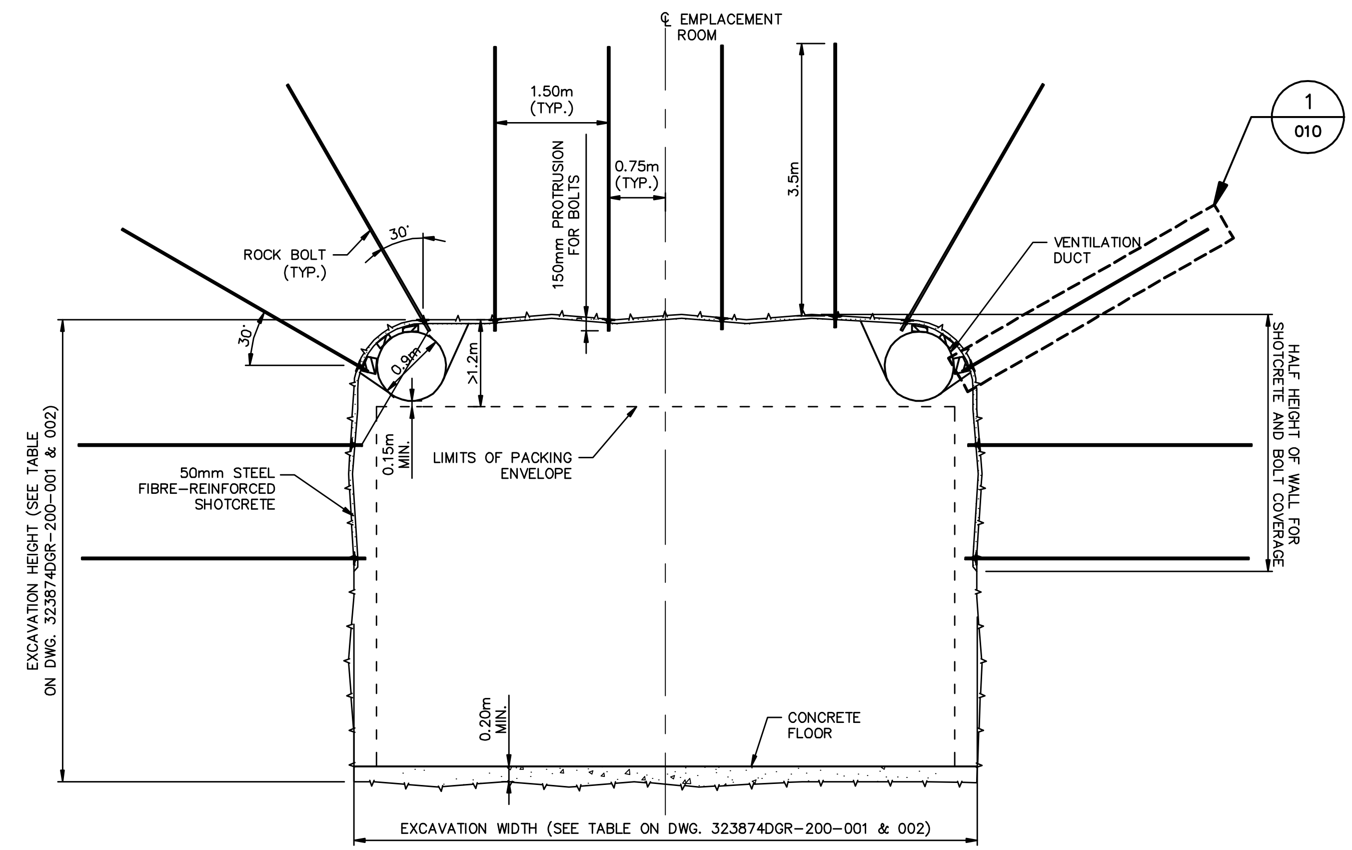
RING TUNNEL & ACCESS TUNNEL CROSS SECTIONS

SCALE: OR AS NOTED | DWG. NO. 323874DGR–200–008 | REV. 0

DWG. NO.



TYPICAL CROSS-SECTION LLW & ILW FORKLIFT EMPLACEMENT ROOMS (WITH 1 VENT. DUCT) (B/007)
SCALE: 1:100



TYPICAL CROSS-SECTION LLW & ILW FORKLIFT EMPLACEMENT ROOMS (WITH 2 VENT. DUCTS) (B/007)
SCALE: 1:100

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ISSUE AUTHORIZATION			

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DESIGNED BY R.C.D.	DRAWN BY C.P.W
DATE	DATE
CHECKED BY G.J.E.K	DISCIP. ENGR. G.J.E.K
DATE	DATE
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
DATE	DATE
PROJ. MGR. M. DAWBORN	
DATE	

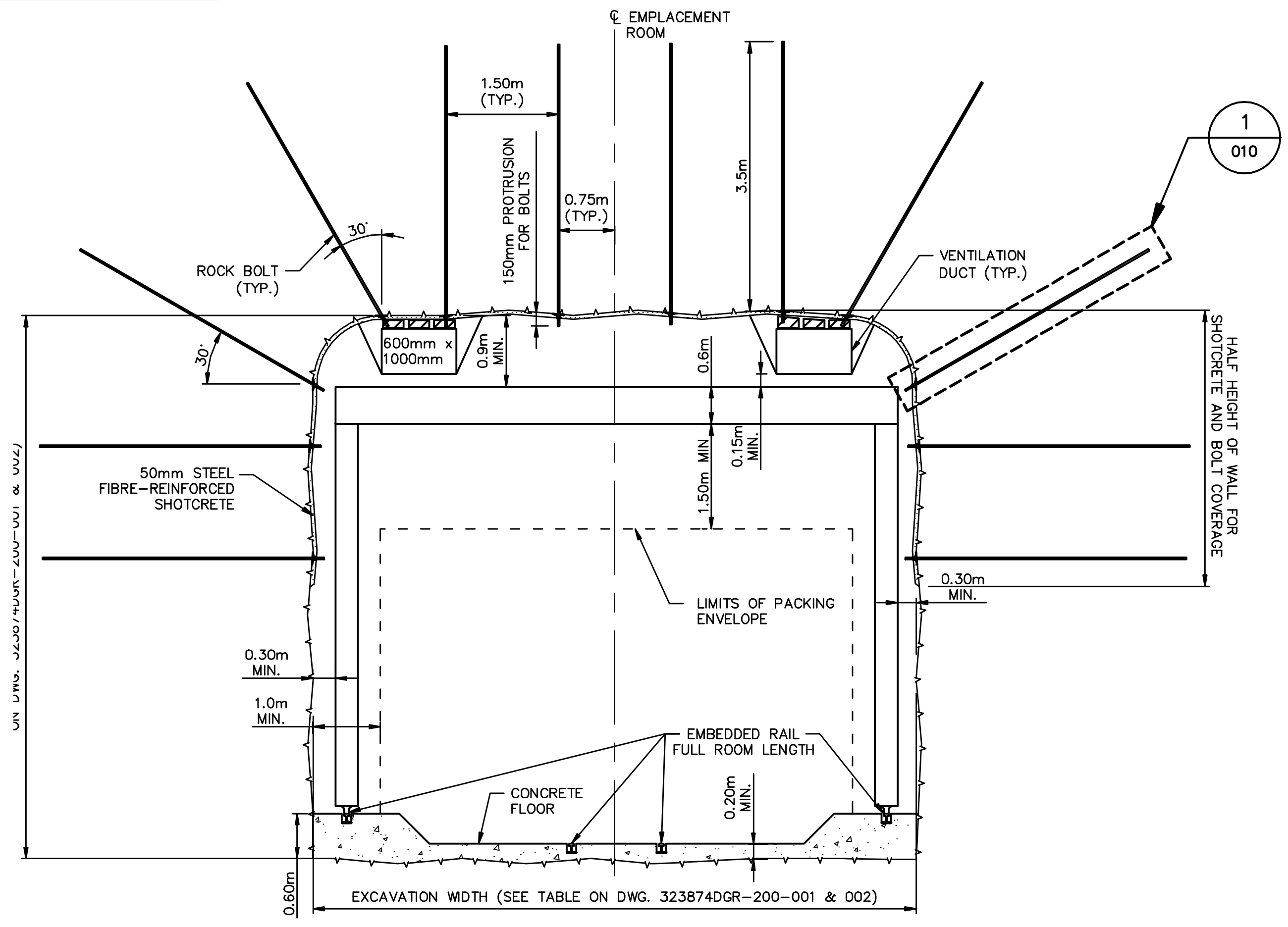
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

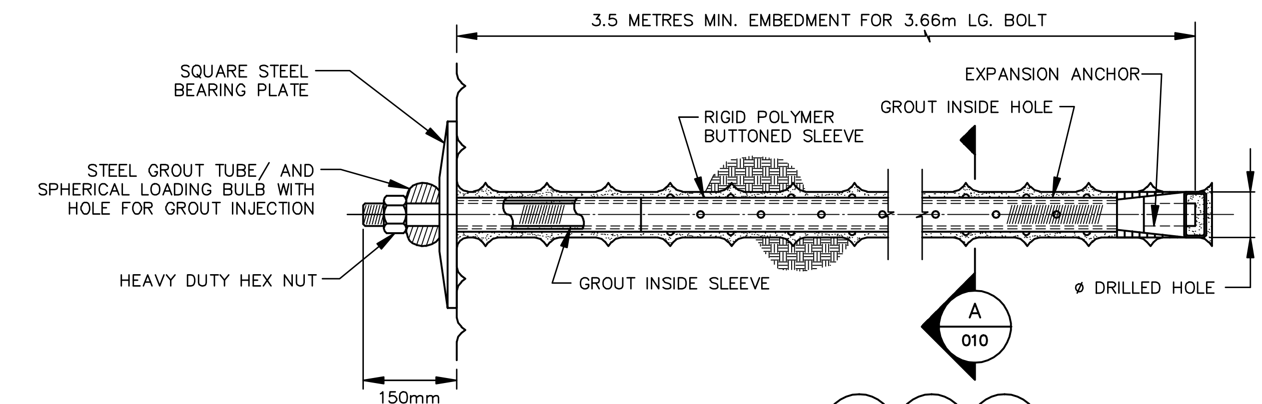
EMPLACEMENT ROOM
CROSS-SECTIONS & DETAILS 1 OF 2

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-009 | REV. 0

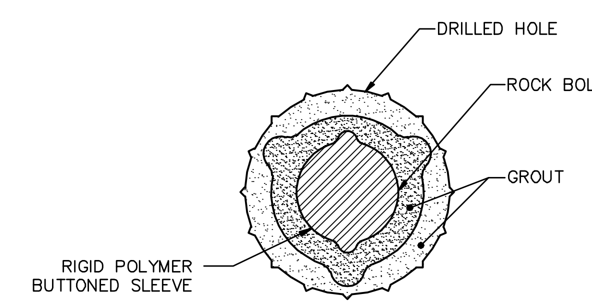
DWG. NO.



LLW & ILW GANTRY EMPLACEMENT ROOMS (B / 007)
SCALE: 1:100



ROCK BOLT DETAIL (1 / 008) (1 / 009) (1 / 010)
SCALE: NTS



ROCK BOLT SECTION (A / 010)
SCALE: NTS

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PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

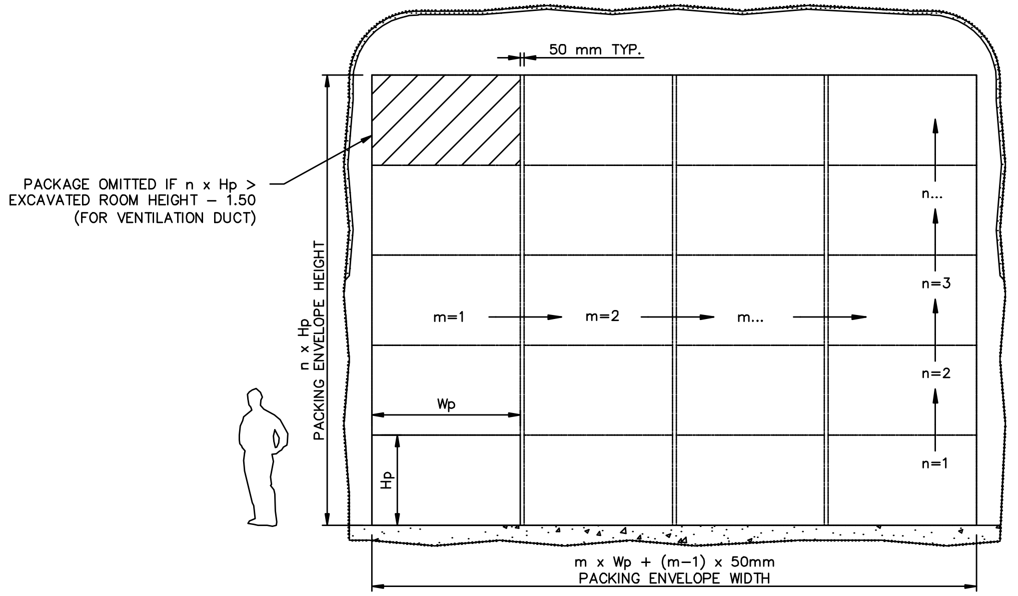
CONCEPTUAL DESIGN REPORT

EMPLACEMENT ROOM
CROSS-SECTIONS & DETAILS 2 OF 2

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-010 | REV. 0

NOTES:

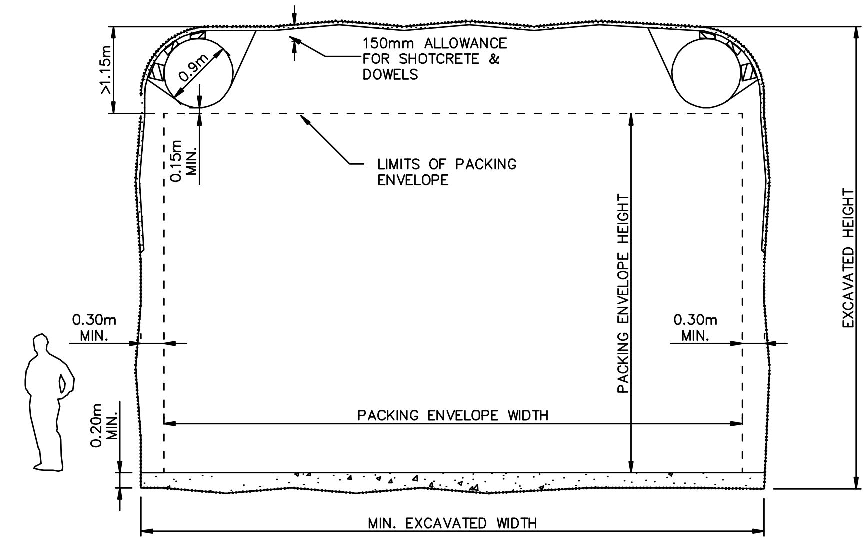
1. Hp = HEIGHT OF PACKAGE.
2. Wp = WIDTH OF PACKAGE.



NOTE:
n ≤ MAX ALLOWABLE STACKING # FOR PACKAGE TYPE

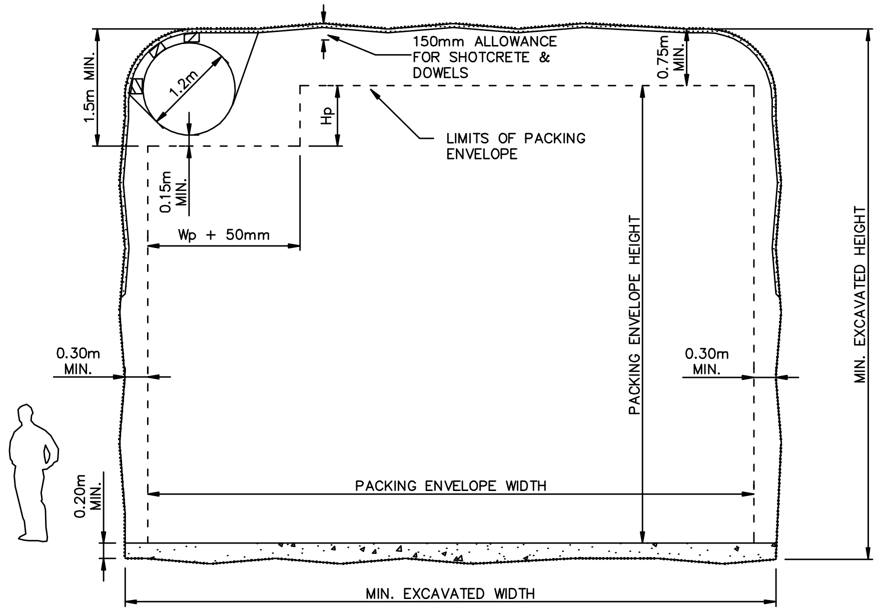
PACKING ENVELOPE WITH STANDARD LLW PACKAGE TYPES

SCALE: 1:100



LLW & ILW ROOMS WITH 2 DUCTS

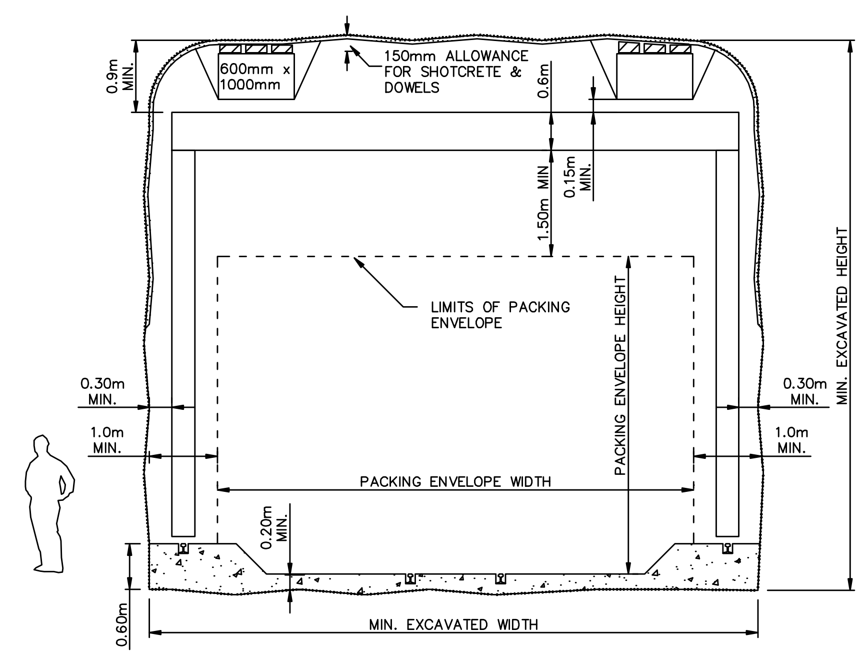
SCALE: 1:100



NOTES:
CORNER PACKAGE TO BE OMMITTED WHEN NECESSARY FOR VENTILATION DUCT

LLW & ILW ROOMS WITH 1 DUCT

SCALE: 1:100



GANTRY ROOMS

SCALE: 1:100

PRELIMINARY
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REFERENCE DRAWINGS	

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DESIGNED BY G.J.E.K	DRAWN BY C.P.W
CHECKED BY M.R.D.	DISCIP. ENGR. G.J.E.K.
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

EMPLACEMENT ROOM SIZING ALLOWANCES AND CLEARANCES

SCALE: OR AS NOTED

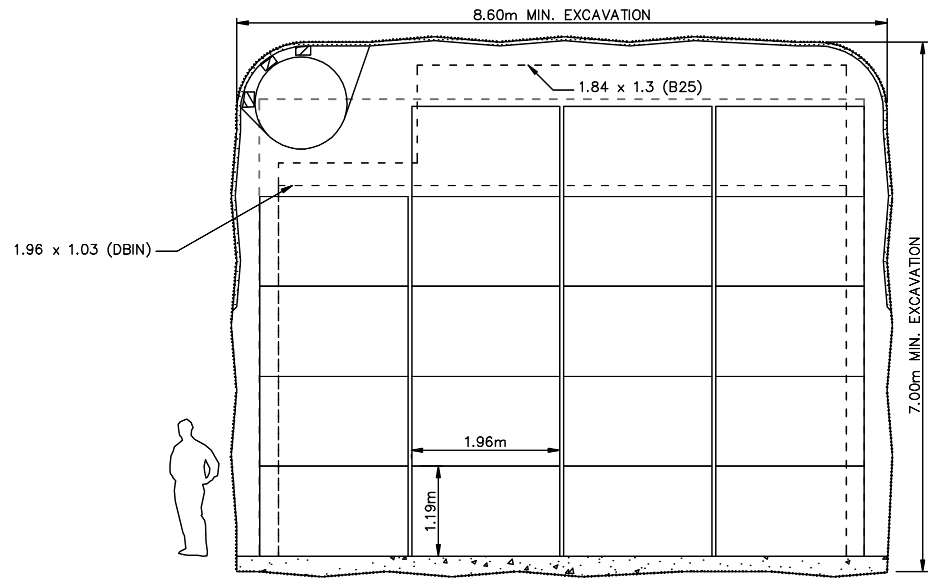
DWG. NO. 323874DGR–200–011

REV. 0

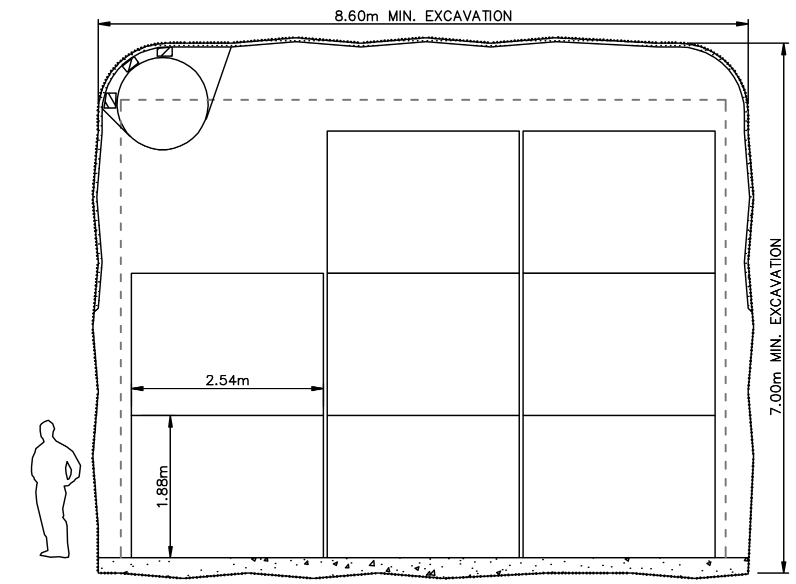
DWG. NO.

NOTES:

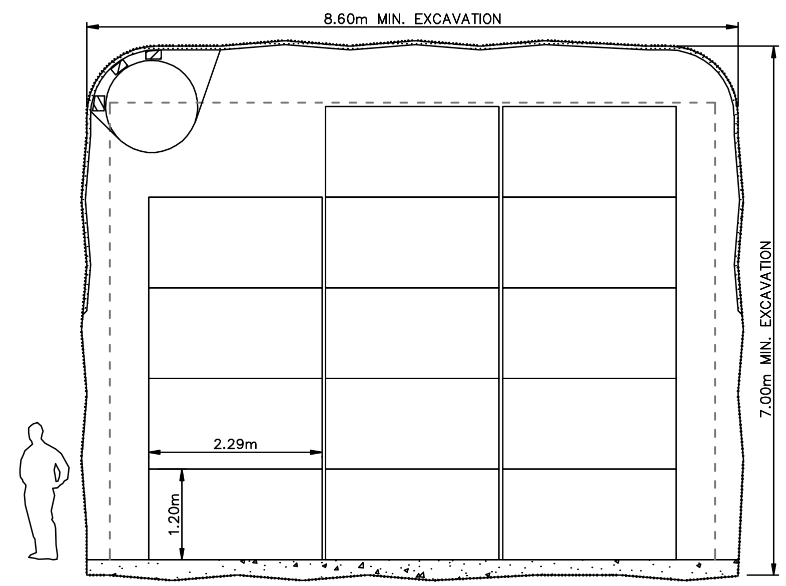
1. STACKING ARRANGEMENTS ARE APPLICABLE TO ALL LOW LEVEL BOXED AND RACK PACKAGES STORED IN ROOMS IN THE SOUTH AND NORTH PANELS (ROOM TYPES S-A & N-A).



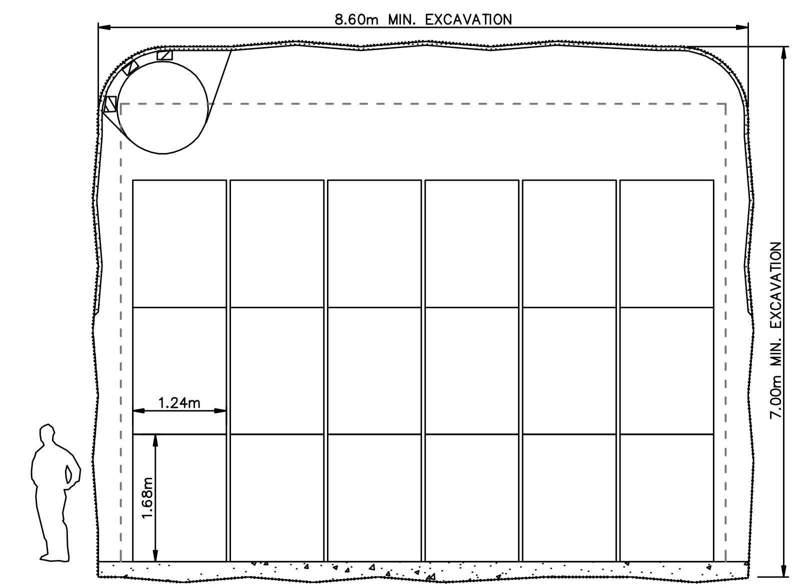
NON-PRO BIN (NPB47)(1.96m x 1.19m)
DRUM BIN (DBIN)(1.96m x 1.03m)
COMPACTOR BOX (B25)(1.84m x 1.3m)
SCALE: 1:100



LLW IN OVERPACKS (BINOPK)
SCALE: 1:100



BALE RACK, DRUM RACK (BRACK, DRACK)
SCALE: 1:100



LOW LEVEL RESIN PALLET TANK (RTK)
SCALE: 1:100

PRELIMINARY
NOT FOR CONSTRUCTION

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DO NOT USE FOR CONSTRUCTION

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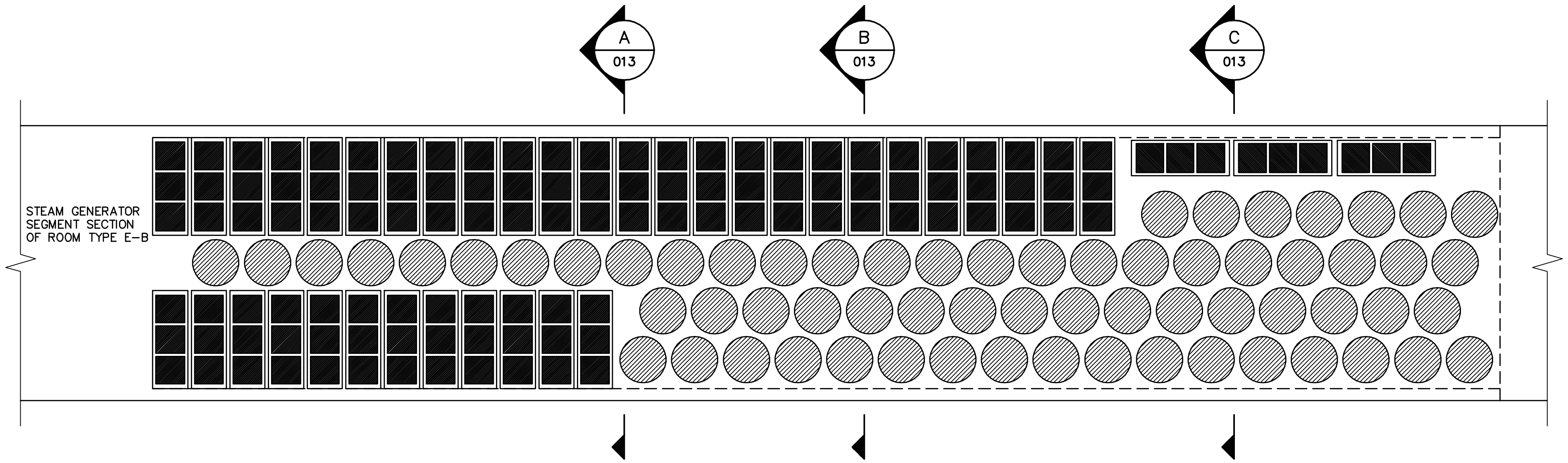
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

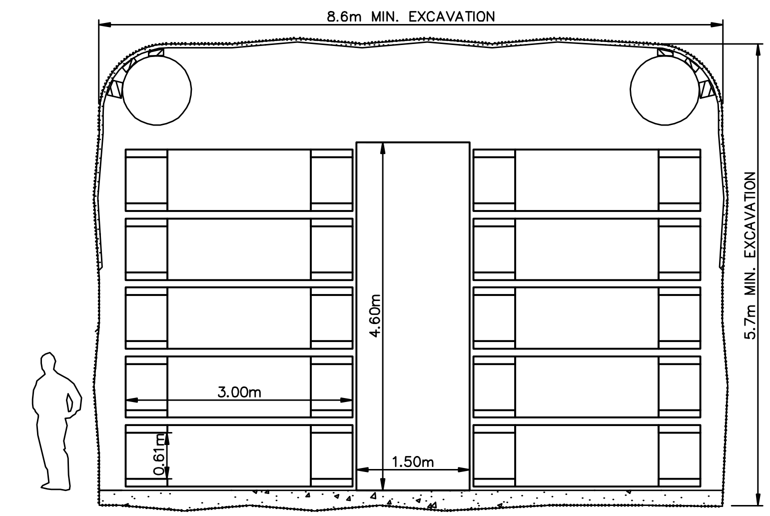
WASTE PACKAGE STACKING ARRANGEMENTS
1 OF 4

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-012 | REV. 0

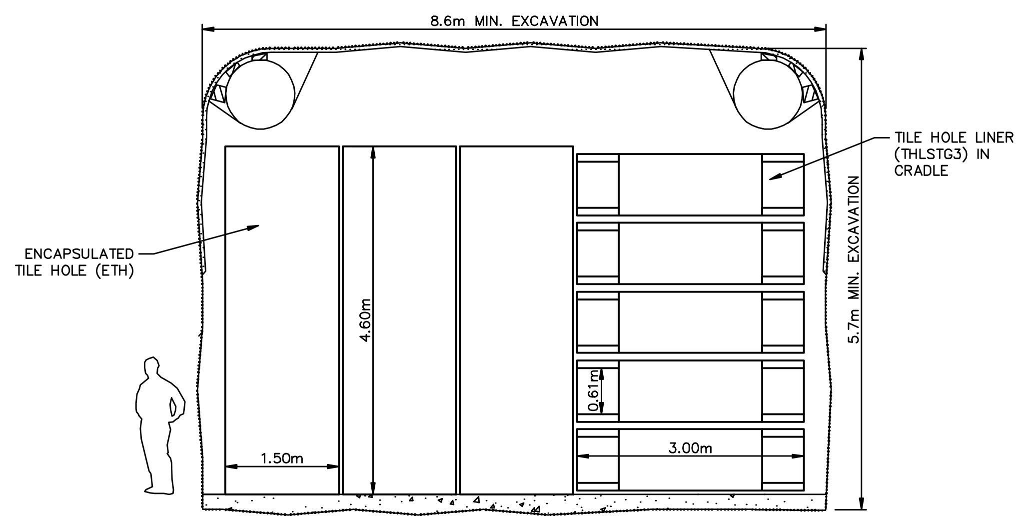
DWG. NO.



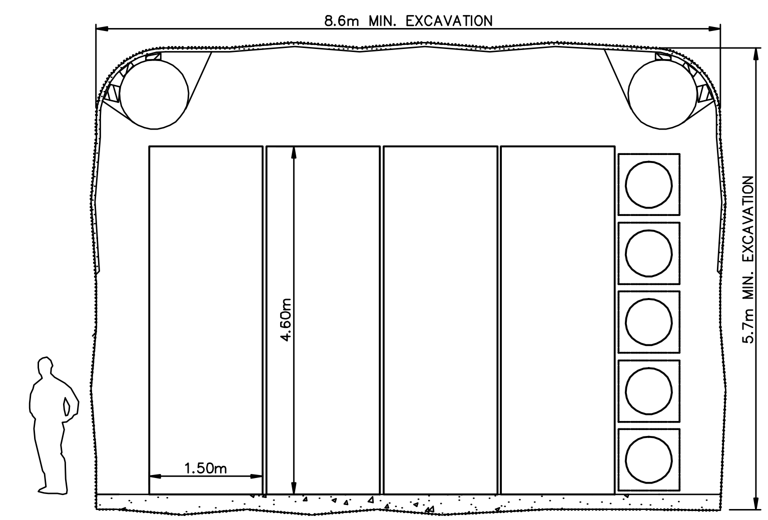
PLAN OF ROOM TYPE E-B
(ENCAPSULATED TILE HOLE/TILE HOLE LINER PORTION)
SCALE: NTS



SECTION A 013
SCALE: 1:100



SECTION B 013
SCALE: 1:100



SECTION C 013
SCALE: 1:100

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PROJ. MGR. M. DAWBORN DATE

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

WASTE PACKAGE STACKING ARRANGEMENTS
2 OF 4

SCALE OR AS NOTED — DWG. NO. 323874DGR-200-013 — REV. 0

DWG. NO.

KEY TO RESIN LINER TYPES:

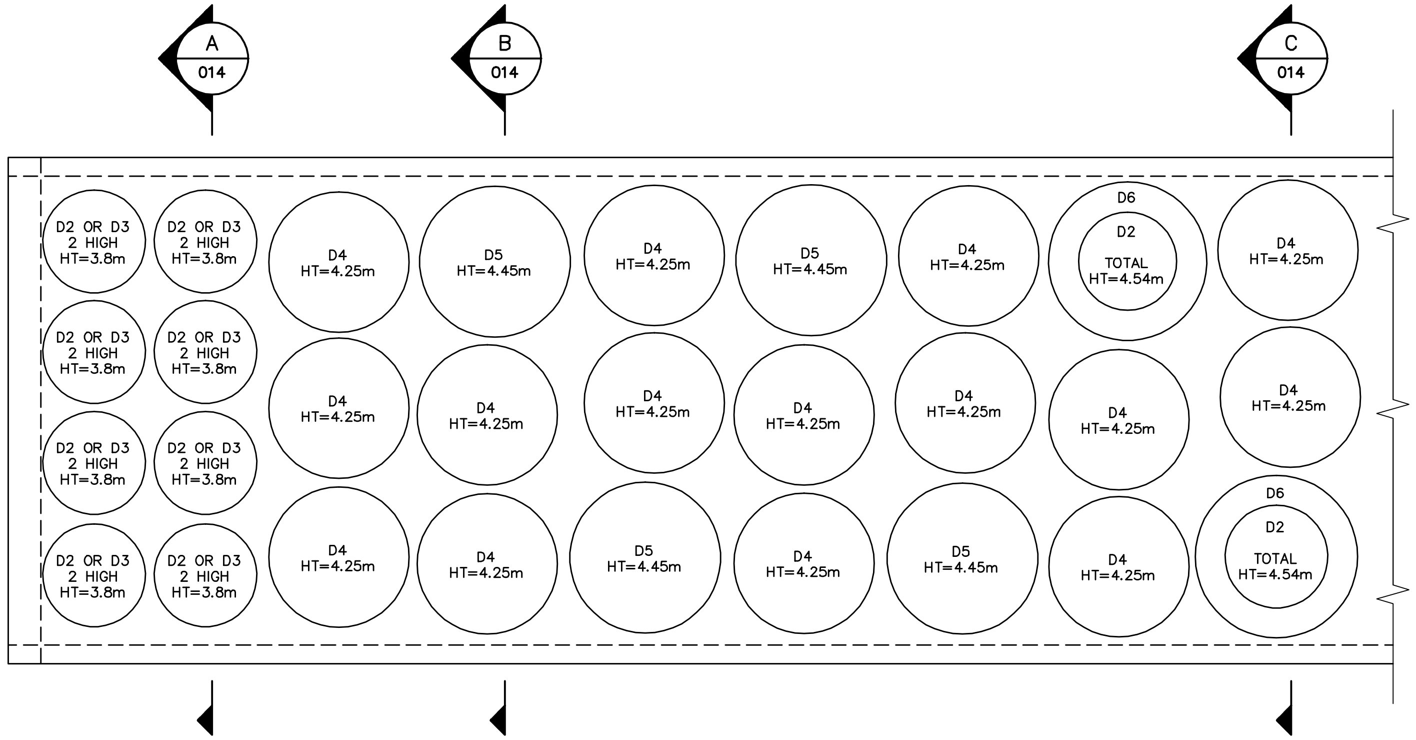
D2 : UNSHIELDED (RL)

D3 : RL IN OVERPACK (RLOPK)

D4 : 2xRL IN 250mm THICK CONCRETE SHIELD (RLSHLD)

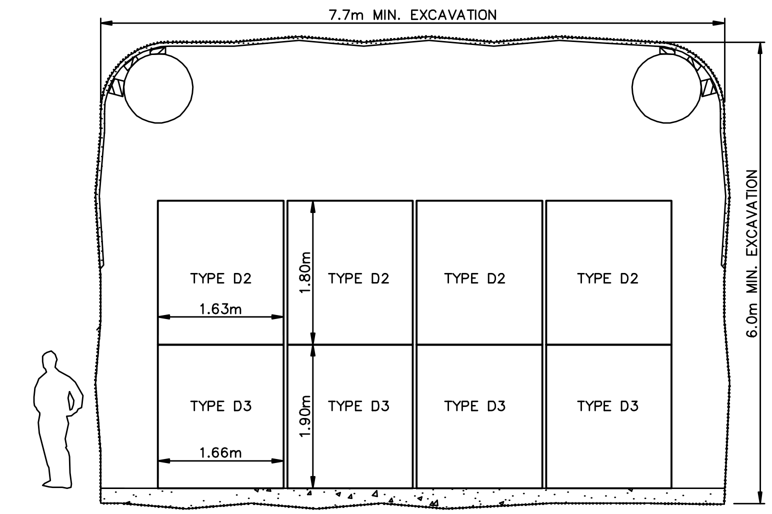
D5 : 2xRL IN 350mm THICK CONCRETE SHIELD (RLSHLD)

D6 : 1xRL IN 40mm THICK STEEL INSERT IN 350mm THICK CONCRETE SHELD.



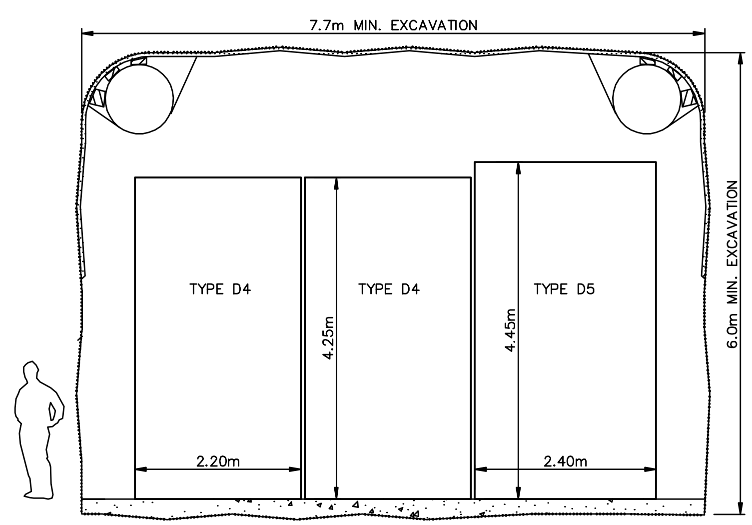
PLAN VIEW OF ONE "MODULE" OF RESIN LINERS IN ROOM TYPE E-C

SCALE: NTS



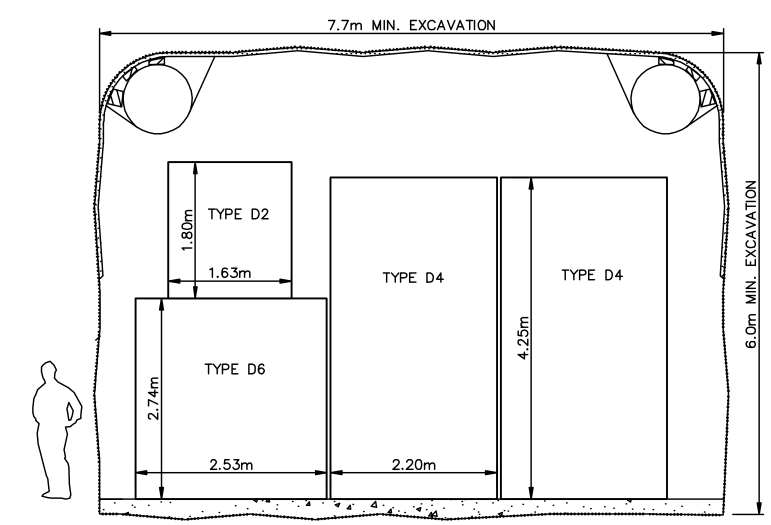
SECTION A 014

SCALE: 1:100



SECTION B 014

SCALE: 1:100



SECTION C 014

SCALE: 1:100

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PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

WASTE PACKAGE STACKING ARRANGEMENTS
3 OF 4

SCALE OR AS NOTED

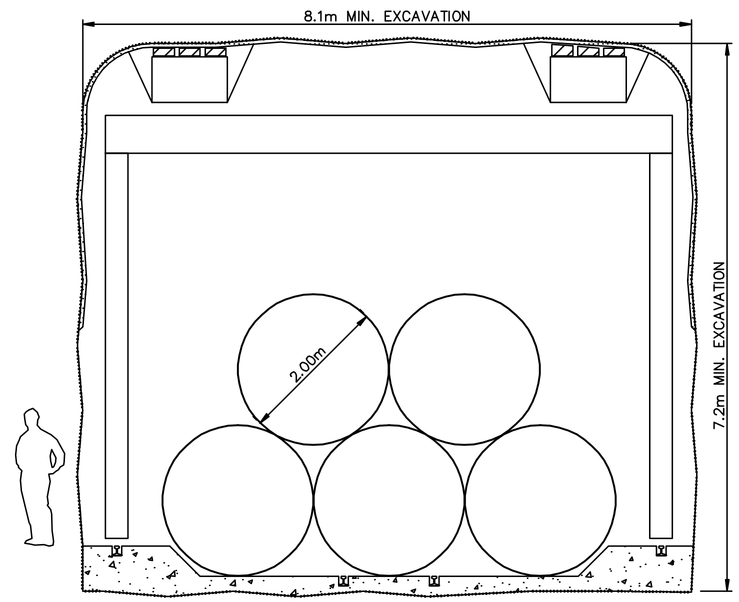
DWG. NO. 323874DGR-200-014

REV. 0

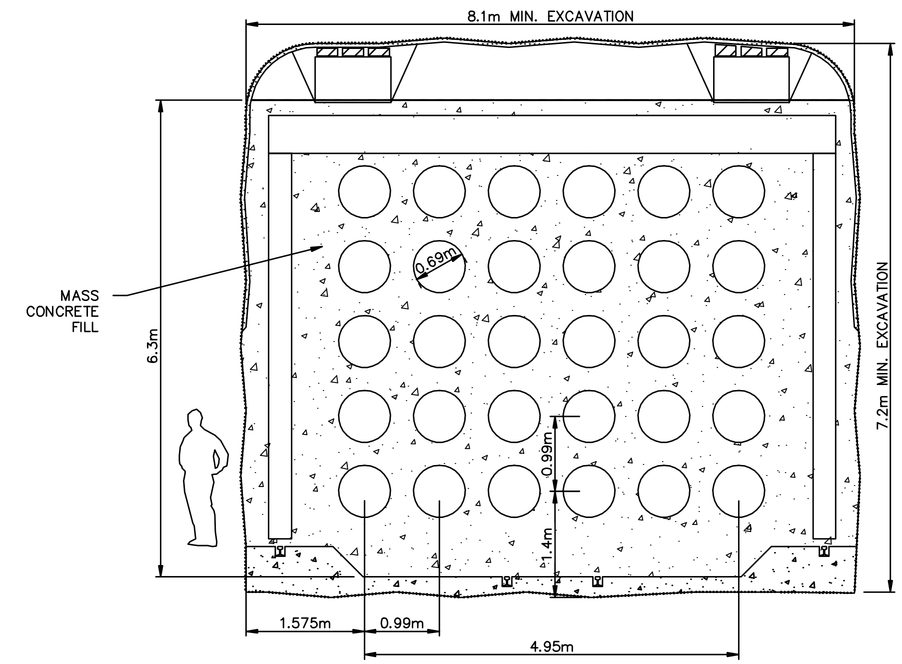
DWG. NO.

NOTES:

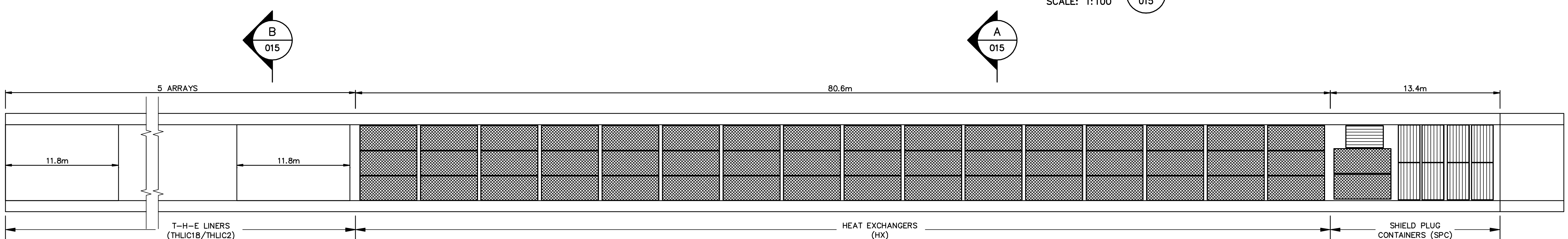
1. THE DRG SHOWS PACKAGES IN ONE OF THE TWO ROOM TYPE E–A'S, THE OTHER TYPE E–A ROOM CONTAINS 314 T–H–E LINERS (+30 RESIN LINERS.)



SECTION A/015
SCALE: 1:100



SECTION B/015
SCALE: 1:100



PLAN VIEW OF ROOM TYPE E–A
SCALE: NTS

THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

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ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

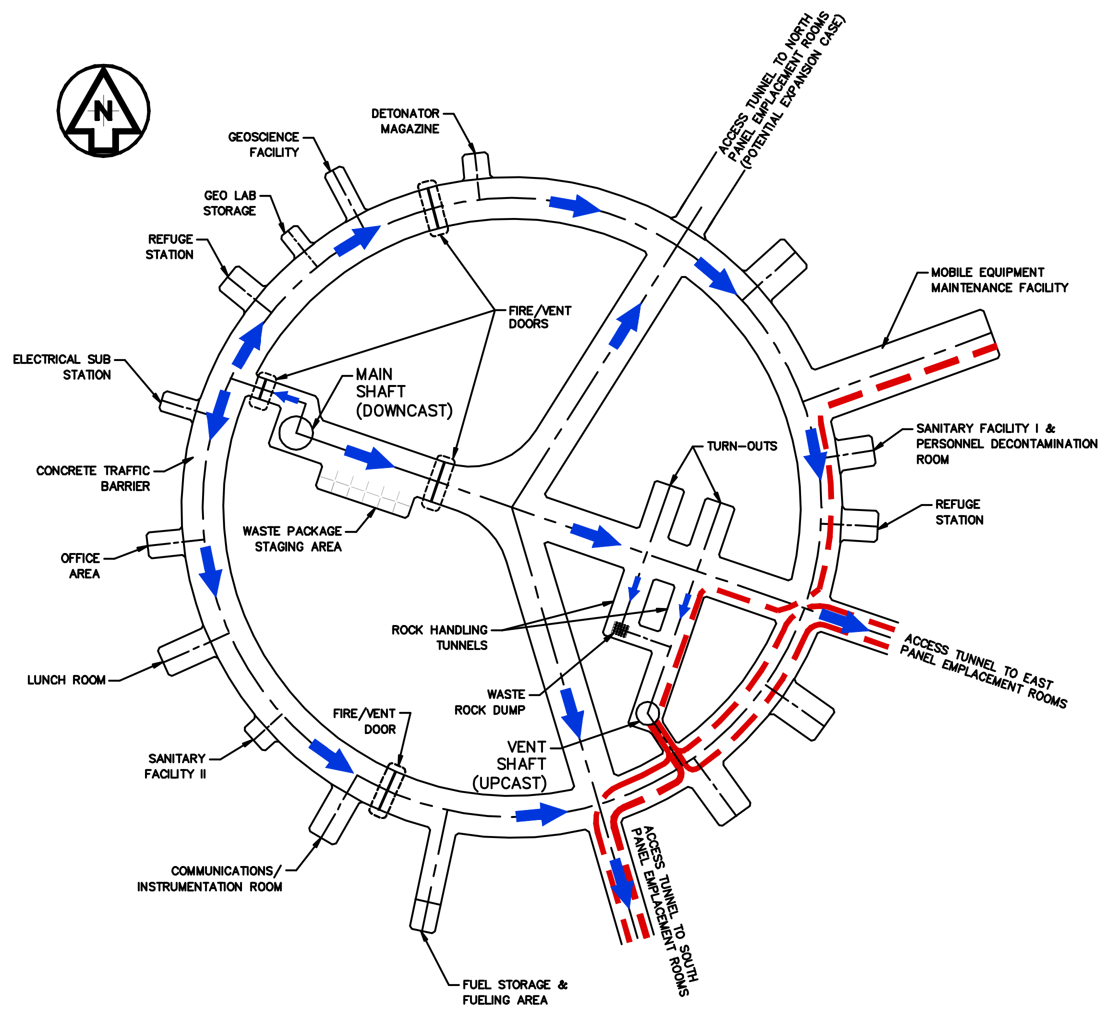
WASTE PACKAGE STACKING ARRANGEMENTS
4 OF 4

SCALE OR AS NOTED | DWG. NO. 323874DGR–200–015 | REV. 0

DWG. NO.

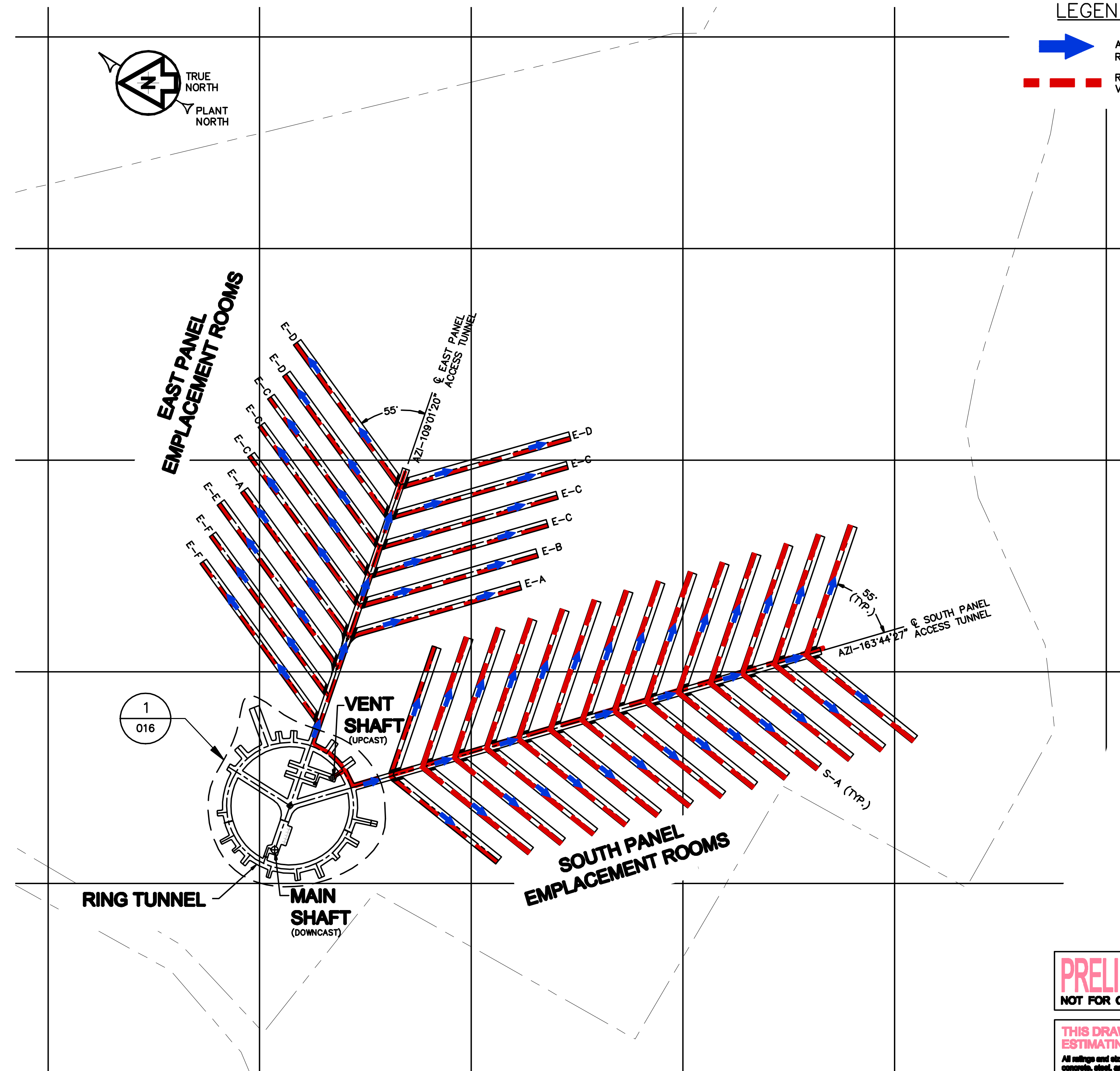
LEGEND

- AIR FLOW IN EXCAVATED ROOM/TUNNEL
- RETURN AIR FLOW IN VENTILATION DUCT



RING TUNNEL VENTILATION SCHEMATIC 1/016

SCALE: NTS



PLAN VIEW – BASE CASE

SCALE: 1 : 5000

THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

PRELIMINARY
NOT FOR CONSTRUCTION

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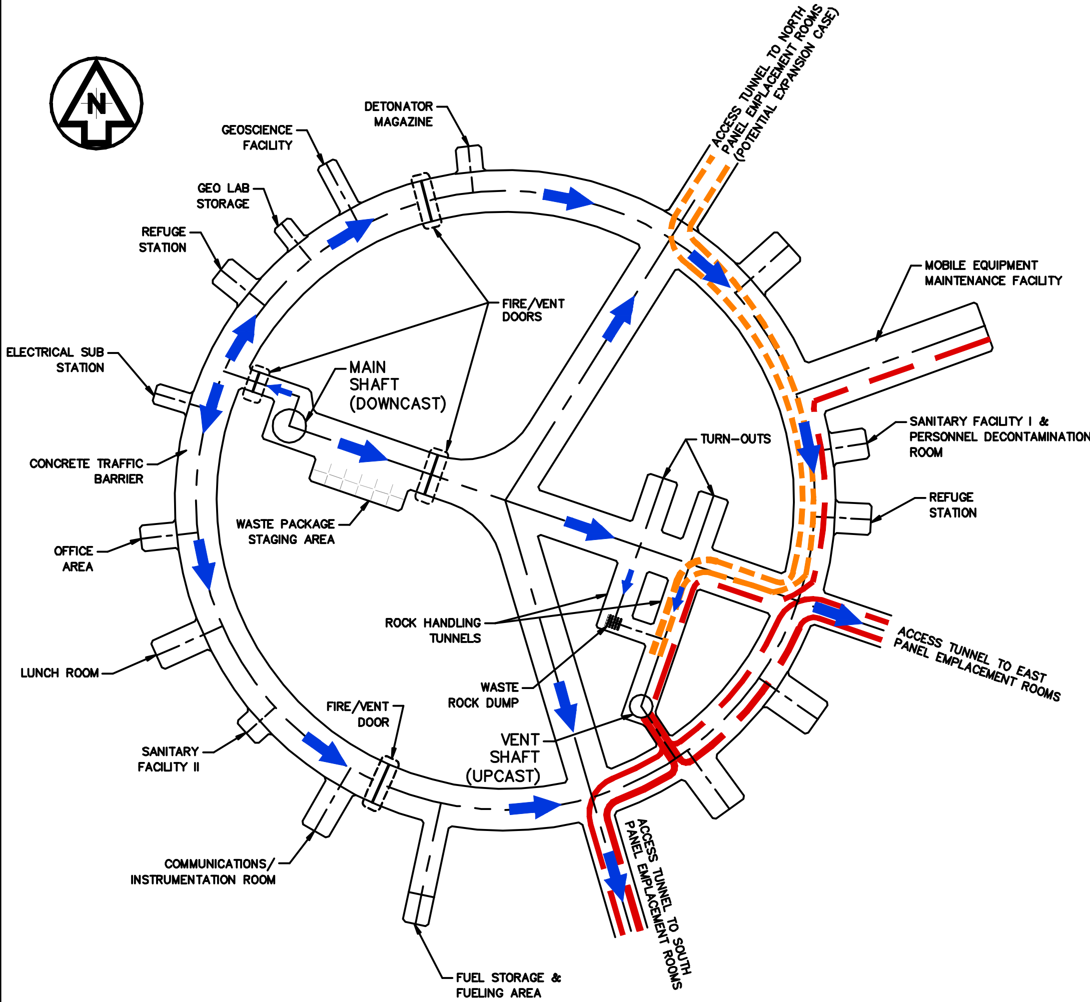
DATE	DATE
PROJ. MGR. M. DAWBORN	
DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

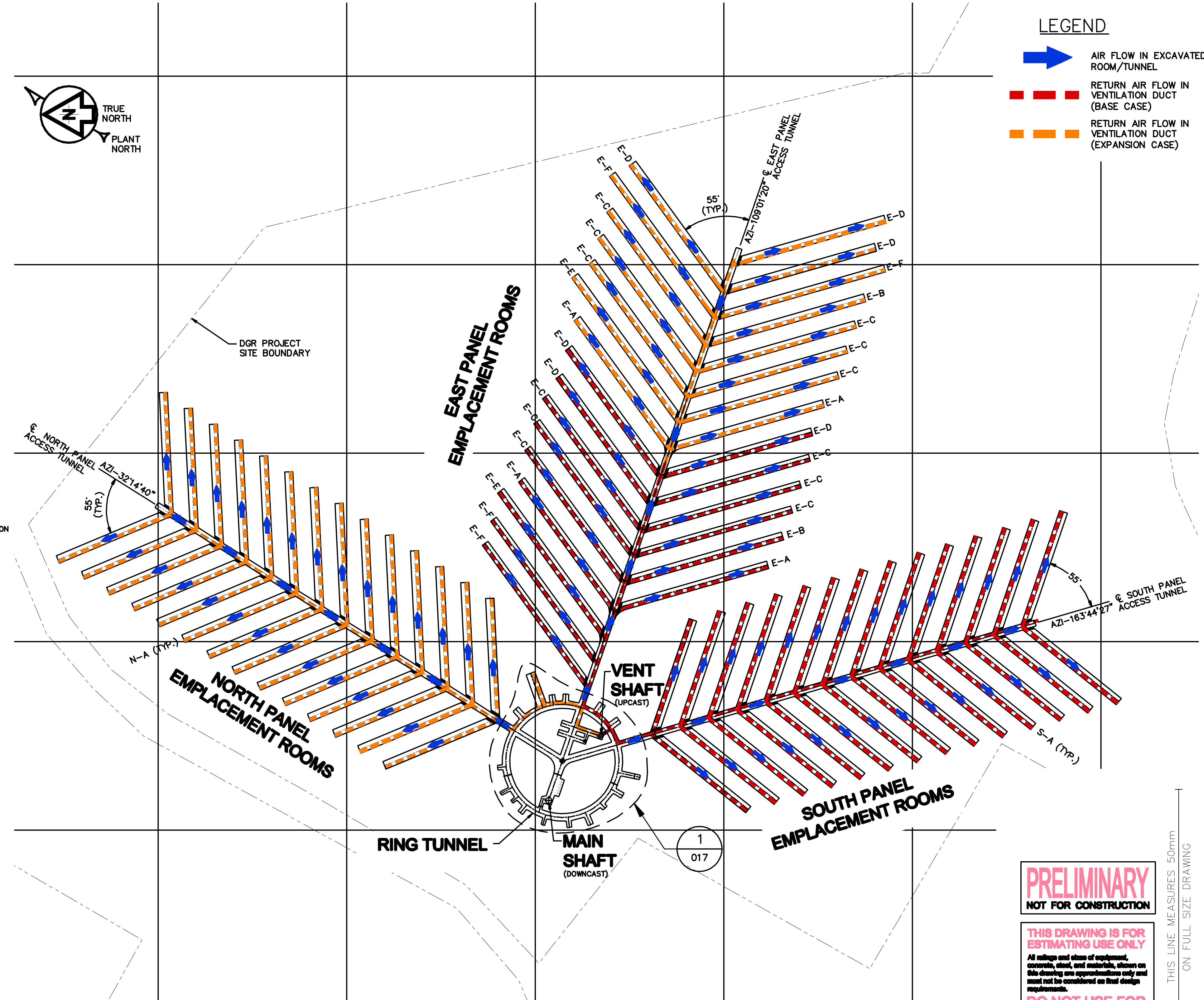
VENTILATION LAYOUT
PLAN VIEW – BASE CASE

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-016 | REV. 0



RING TUNNEL VENTILATION SCHEMATIC (1/017)

SCALE: NTS



PLAN VIEW – POTENTIAL EXPANSION CASE

SCALE: 1 : 5000

PRELIMINARY
NOT FOR CONSTRUCTION

THIS DRAWING IS FOR ESTIMATING USE ONLY

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DO NOT USE FOR CONSTRUCTION

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DWG. NO.

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PROJ. MGR. M. DAWBORN	

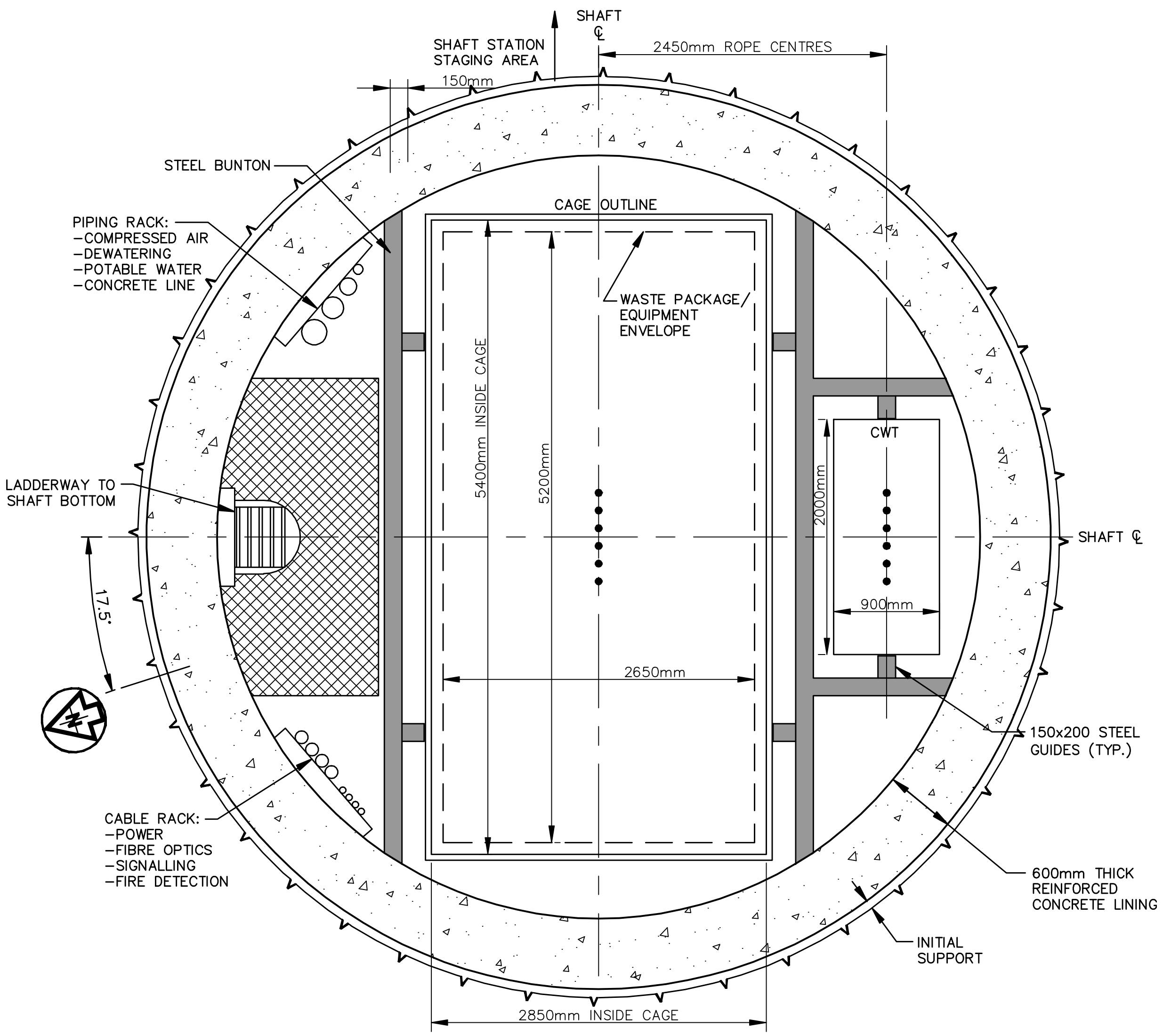
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

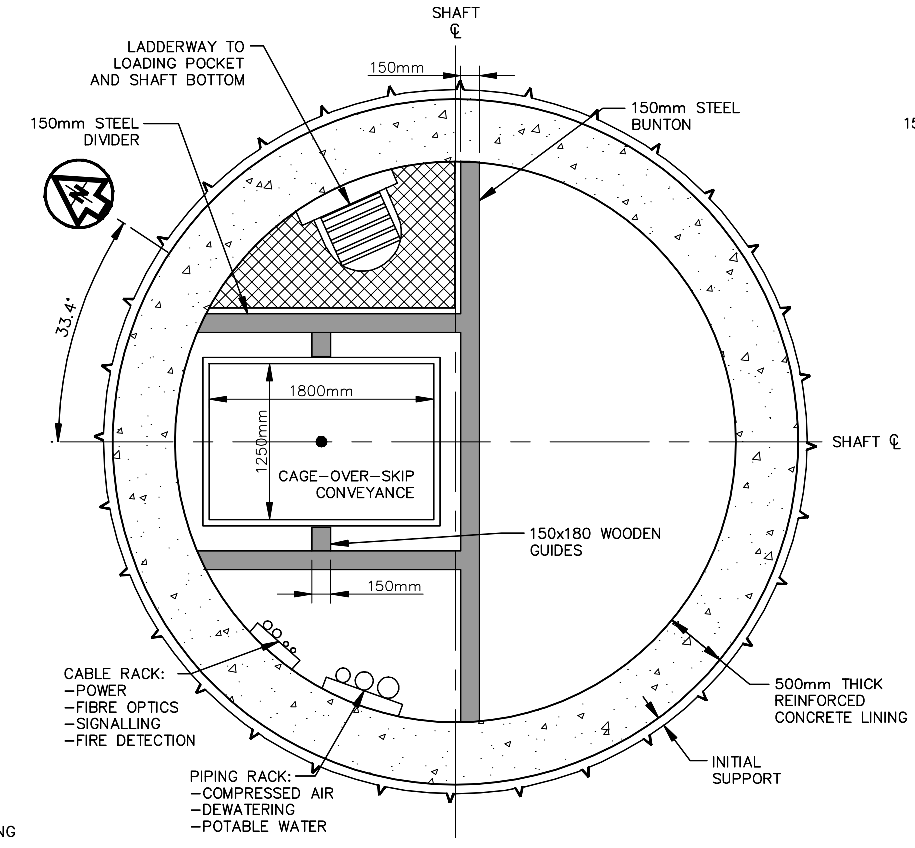
VENTILATION LAYOUT
PLAN VIEW – POTENTIAL EXPANSION CASE

SCALE: OR AS NOTED | DWG. NO. 323874DGR-200-017 | REV. 0

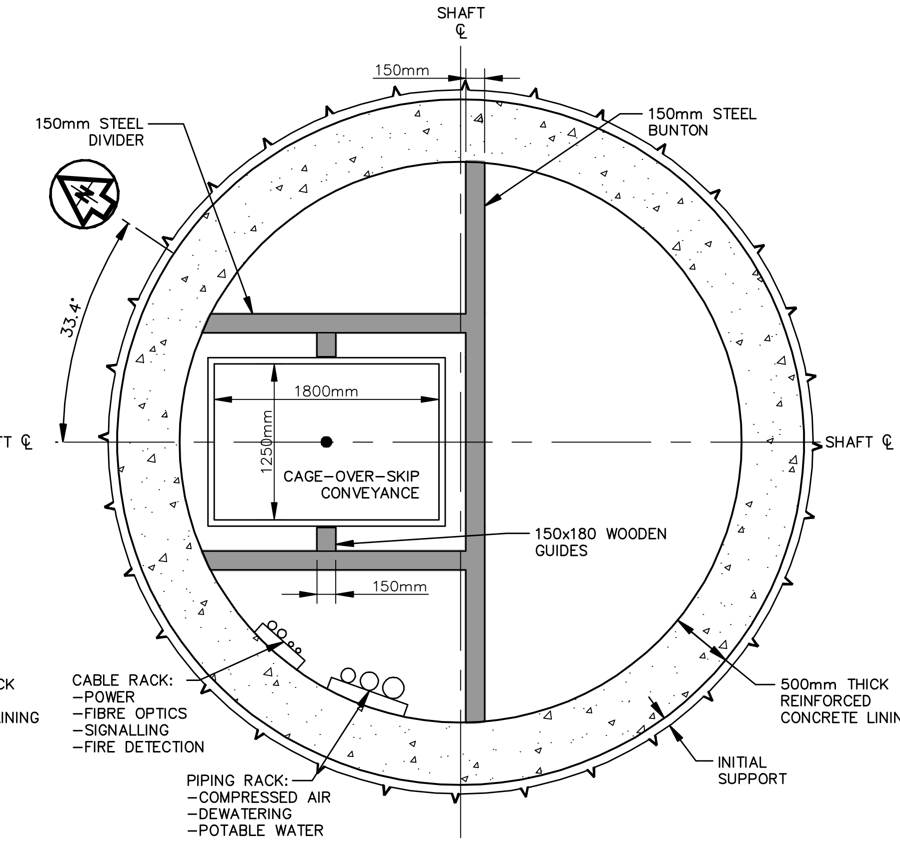
DWG. NO.



6.5m INTERNAL DIA. MAIN SHAFT CROSS–SECTION
SCALE: NTS



4.5m INTERNAL DIA. VENT SHAFT CROSS–SECTION
(680m BGS STATION TO SHAFT SUMP BOTTOM)
SCALE: NTS



4.5m INTERNAL DIA. VENT SHAFT CROSS–SECTION
(SURFACE TO 680m BGS STATION)
SCALE: NTS

THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

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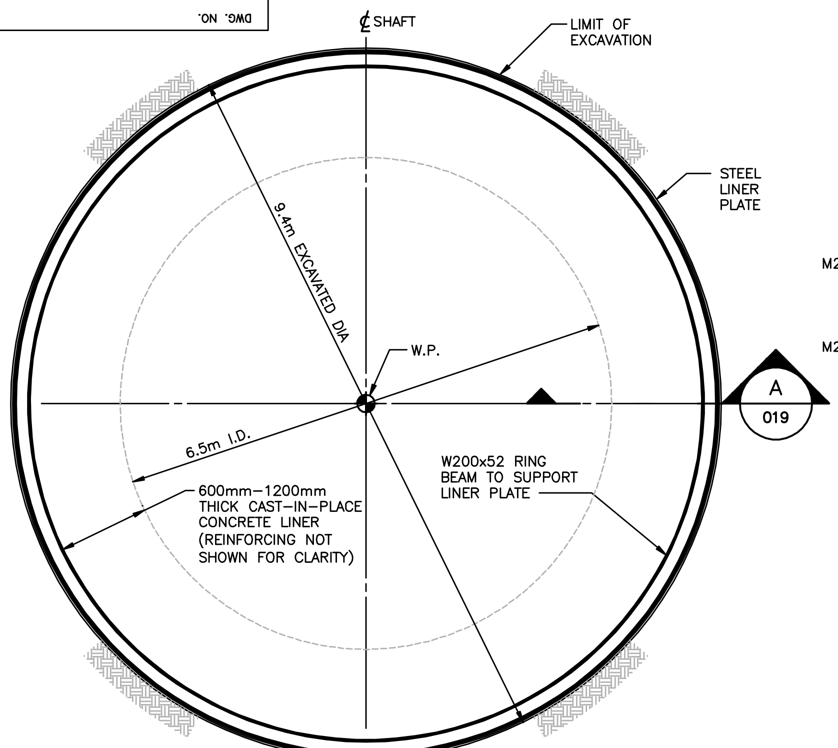
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

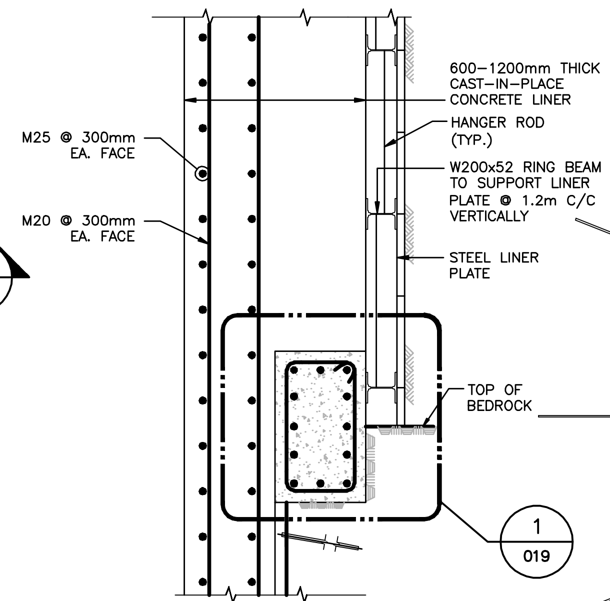
CONCEPTUAL DESIGN REPORT

MAIN AND VENT SHAFT
PERMANENT CROSS–SECTIONS

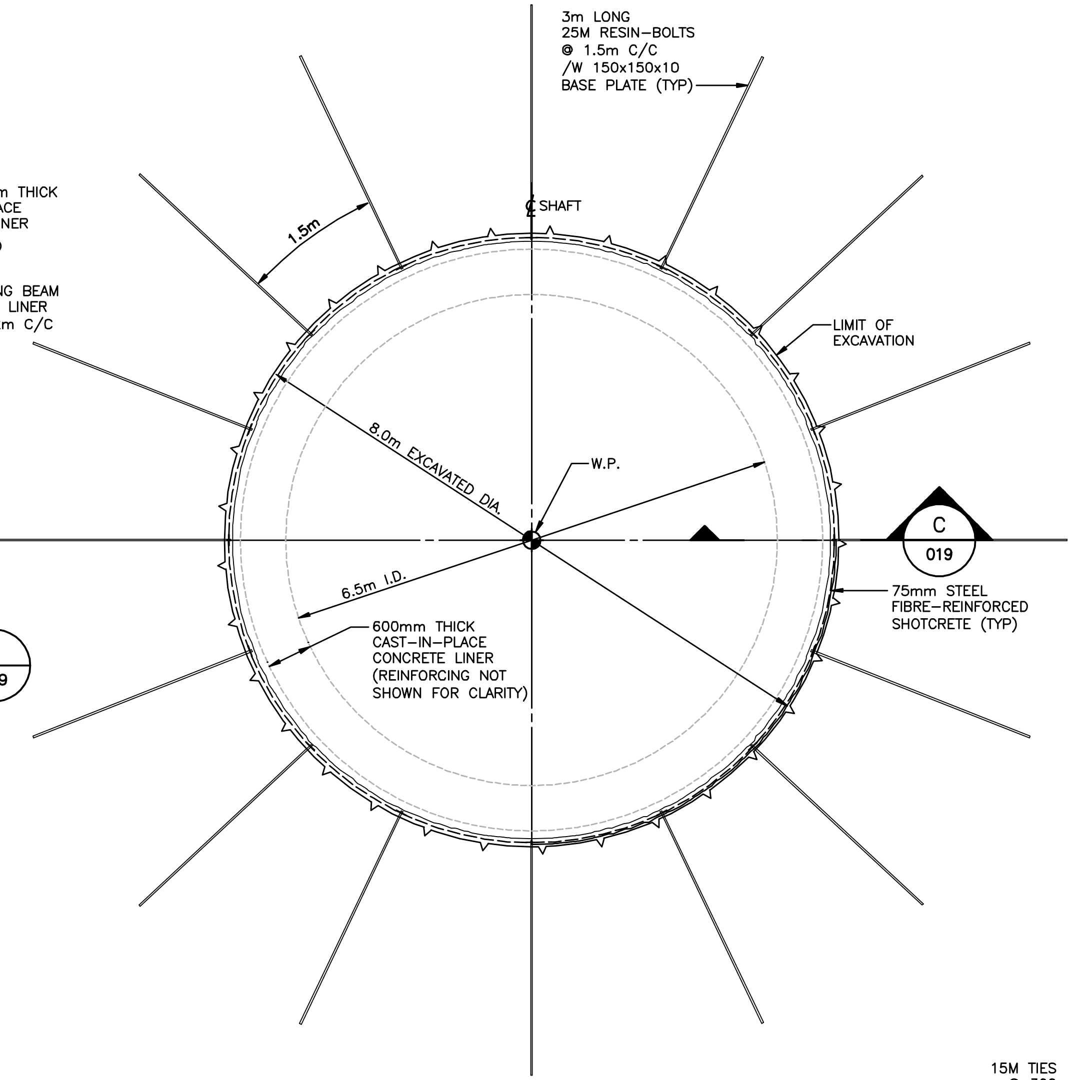
SCALE OR AS NOTED | DWG. NO. 323874DGR–200–018 | REV. 0



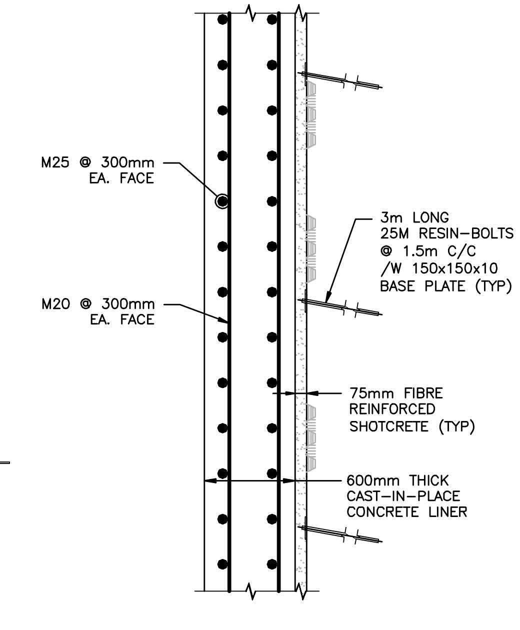
SHAFT SUPPORT – REACH 1 OVERBURDEN
SCALE: 1:100



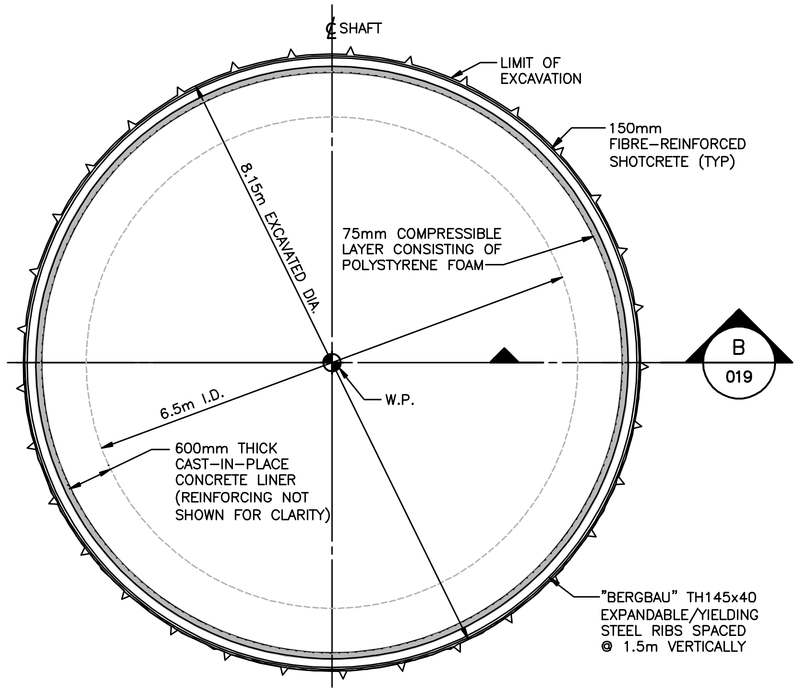
SUPPORT SECTION – REACH 1 (A/019)
SCALE: 1:50



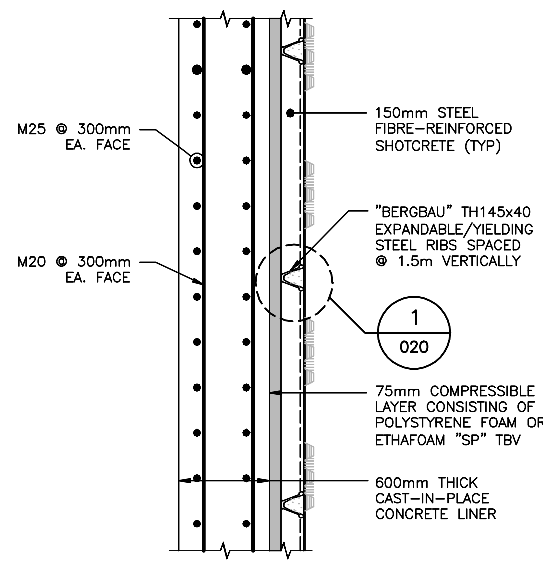
SHAFT SUPPORT – REACH 2 ROCK
SCALE: 1:100



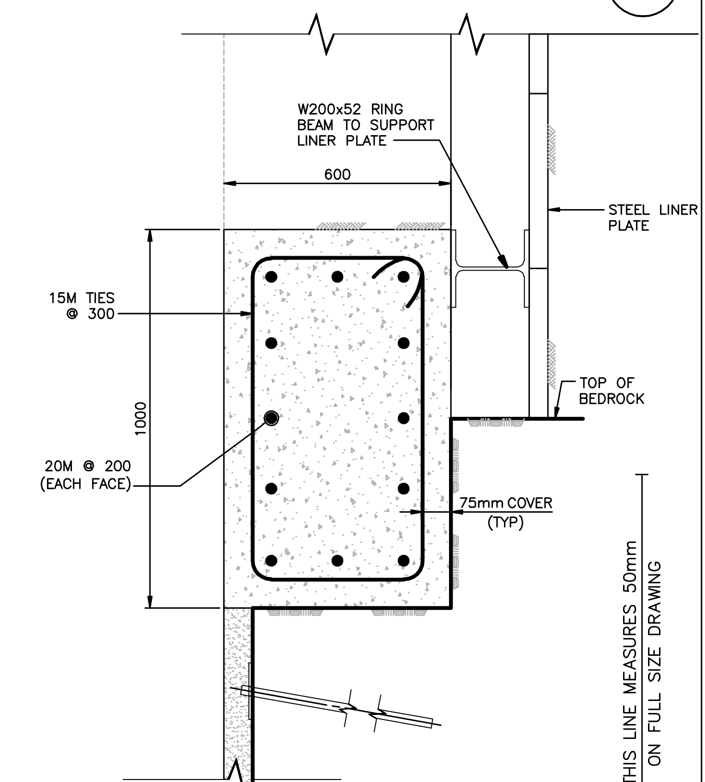
SUPPORT SECTION – REACH 2 (C/019)
SCALE: 1:50



SHAFT – REACH 3 & 4 ROCK
SCALE: 1:100



SUPPORT SECTION – REACH 3 & 4 (B/019)
SCALE: 1:50



CONCRETE COLLAR BEAM (1/019) (1/020)
SCALE: 1:20

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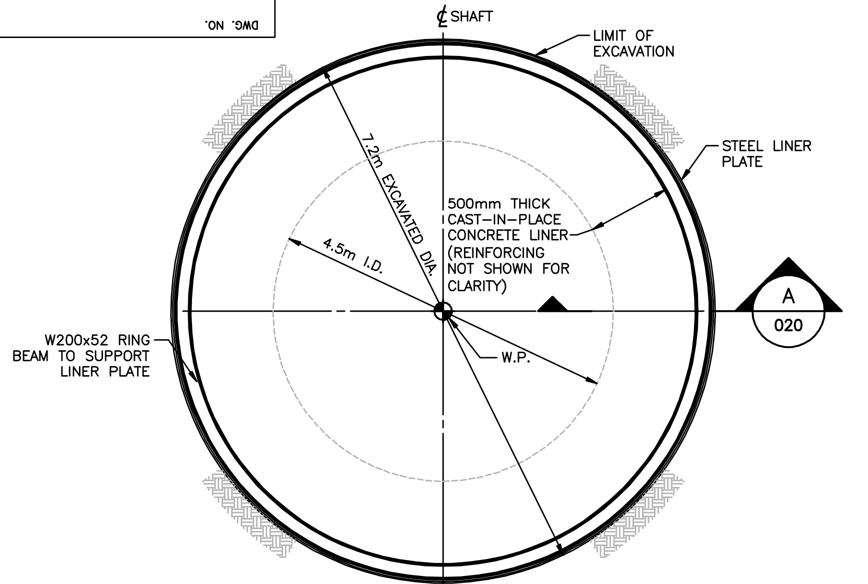
PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

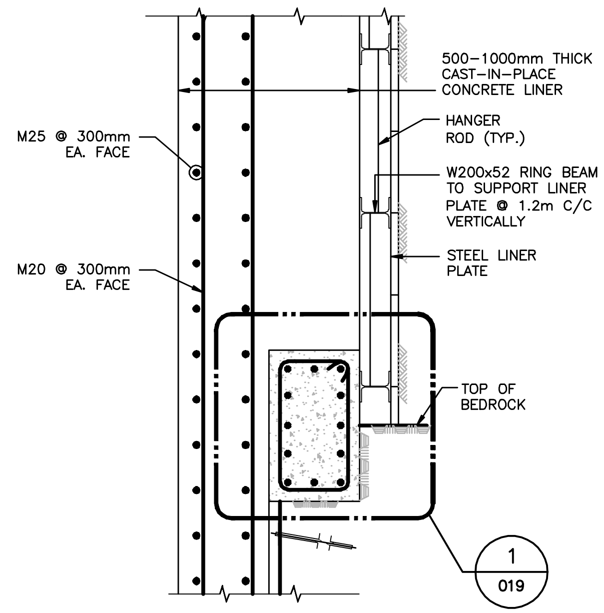
CONCEPTUAL DESIGN REPORT

MAIN SHAFT SINKING
PLANS, SECTIONS AND DETAILS

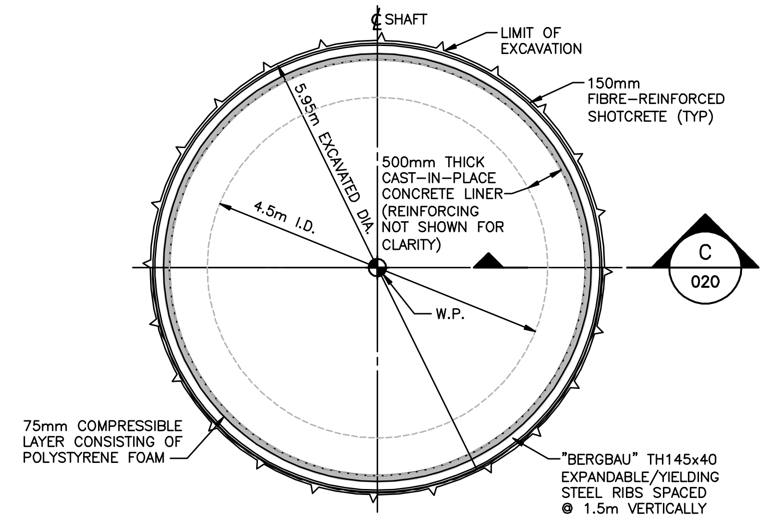
SCALE: OR AS NOTED | DWG. NO. 323874DGR–200–019 | REV. 0



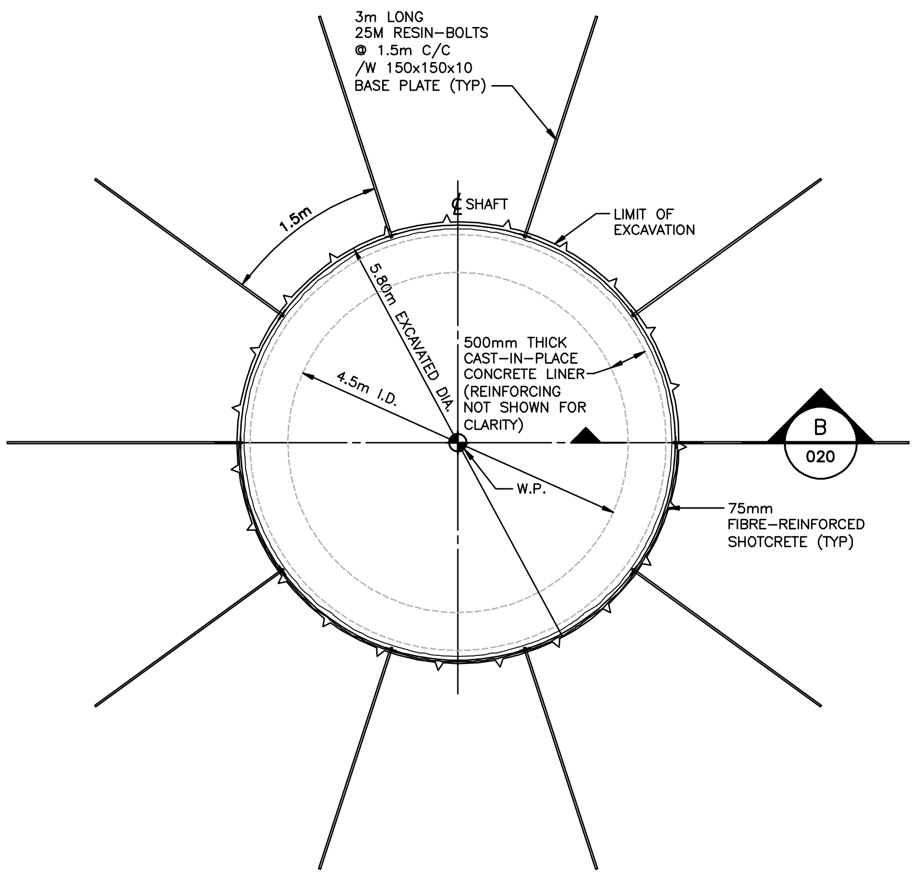
SHAFT SUPPORT – REACH 1 OVERBURDEN
SCALE: 1:100



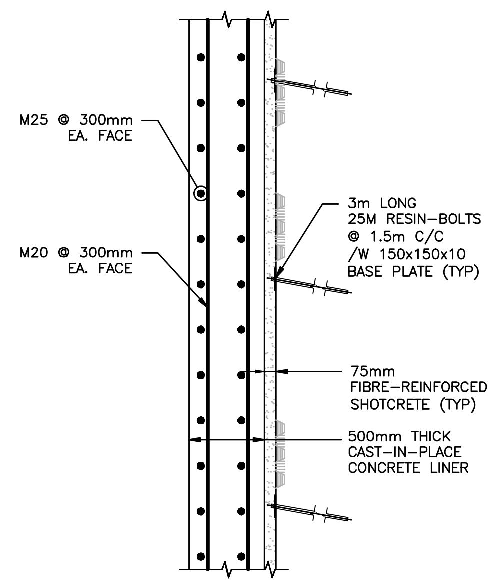
SUPPORT SECTION – REACH 1 (A / 020)
SCALE: 1:50



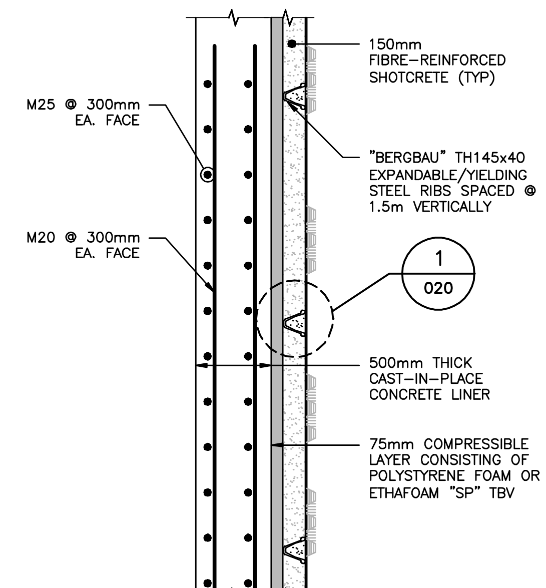
SHAFT SUPPORT – REACH 3 & 4 ROCK
SCALE: 1:100



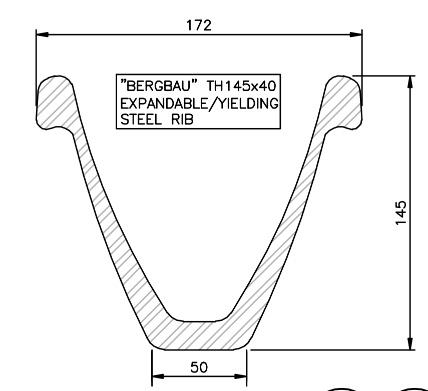
SHAFT SUPPORT – REACH 2 ROCK
SCALE: 1:100



SUPPORT SECTION – REACH 2 (B / 020)
SCALE: 1:50



SUPPORT SECTION – REACH 3 & 4 (C / 020)
SCALE: 1:50



STEEL RIB DETAIL (1 / 019) (1 / 020)
SCALE: NTS

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ISSUE AUTHORIZATION			

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DESIGNED BY G.J.E.K. DATE	DRAWN BY C.P.W DATE
CHECKED BY W.H. DATE	DISCIP. ENGR. G.J.E.K. DATE
PROJ. DES. COORD. N/A DATE	PROJ. ENGR. N/A DATE
PROJ. MGR. M. DAWBORN DATE	

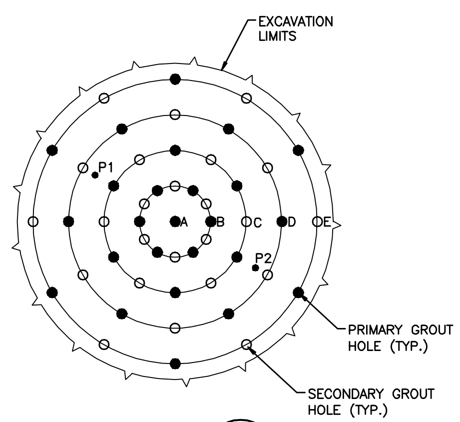
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

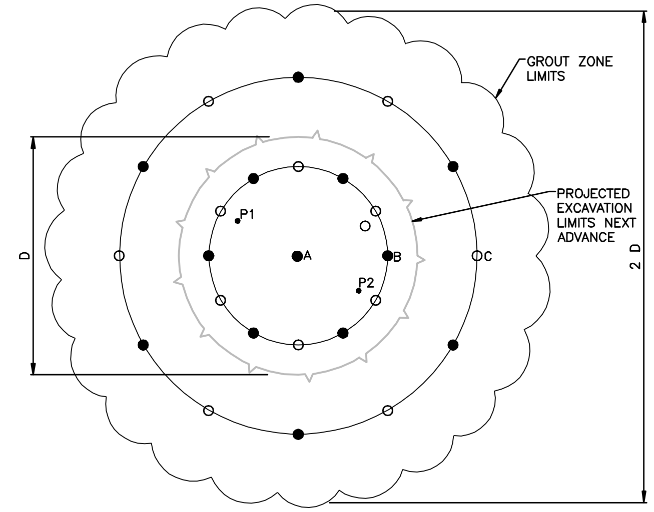
VENT SHAFT SINKING
PLANS, SECTIONS AND DETAILS

SCALE: OR AS NOTED | DWG. NO. 323874DGR–200–020 | REV. 0

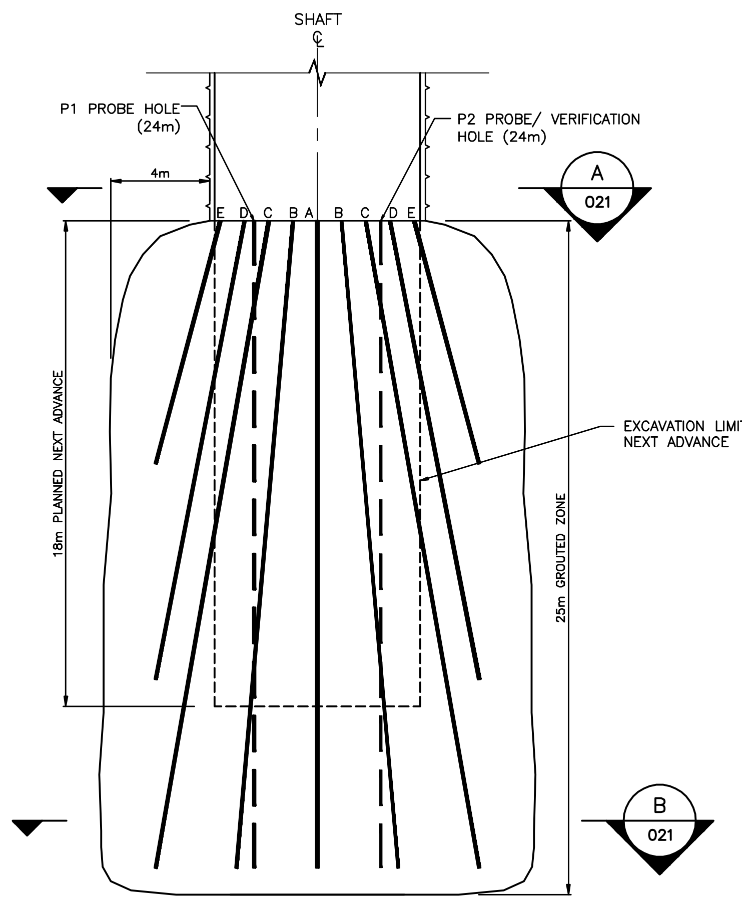
DWG. NO.



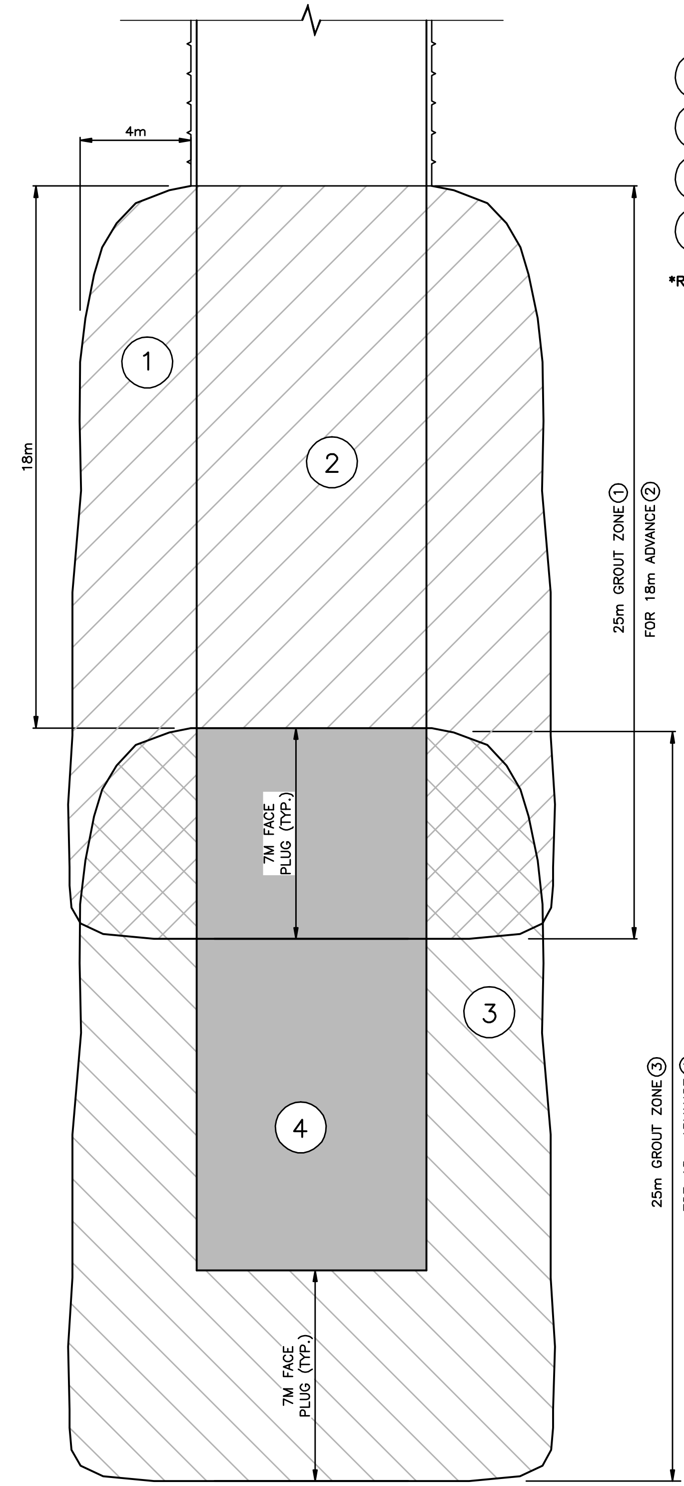
SECTION A/021
SCALE: NTS



SECTION B/021
SCALE: NTS



GROUT AND PROBE PATTERN FOR SHAFT SINKING IN REACH 2
SCALE: NTS



GROUTING SEQUENCE FOR SHAFT SINKING

1. GROUT 25m DEPTH FOR FIRST 18m ADVANCE
2. SINK SHAFT 18m LEAVING A 7m (MIN.) DEEP FULL FACE BULKHEAD AHEAD OF THE ADVANCING FACE.
3. PROBE AND GROUT 25m FOR THE NEXT 18m ADVANCE
4. CONTINUE SINKING SHAFT INTO NEXT 18m GROUT ADVANCE, ONCE AGAIN LEAVING FACE PLUG AHEAD OF THE ADVANCING FACE

*REPEAT STEPS 1 TO 4 FOR THE ENTIRE 370m REACH

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THIS LINE MEASURES 50mm ON FULL SIZE DRAWING

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PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

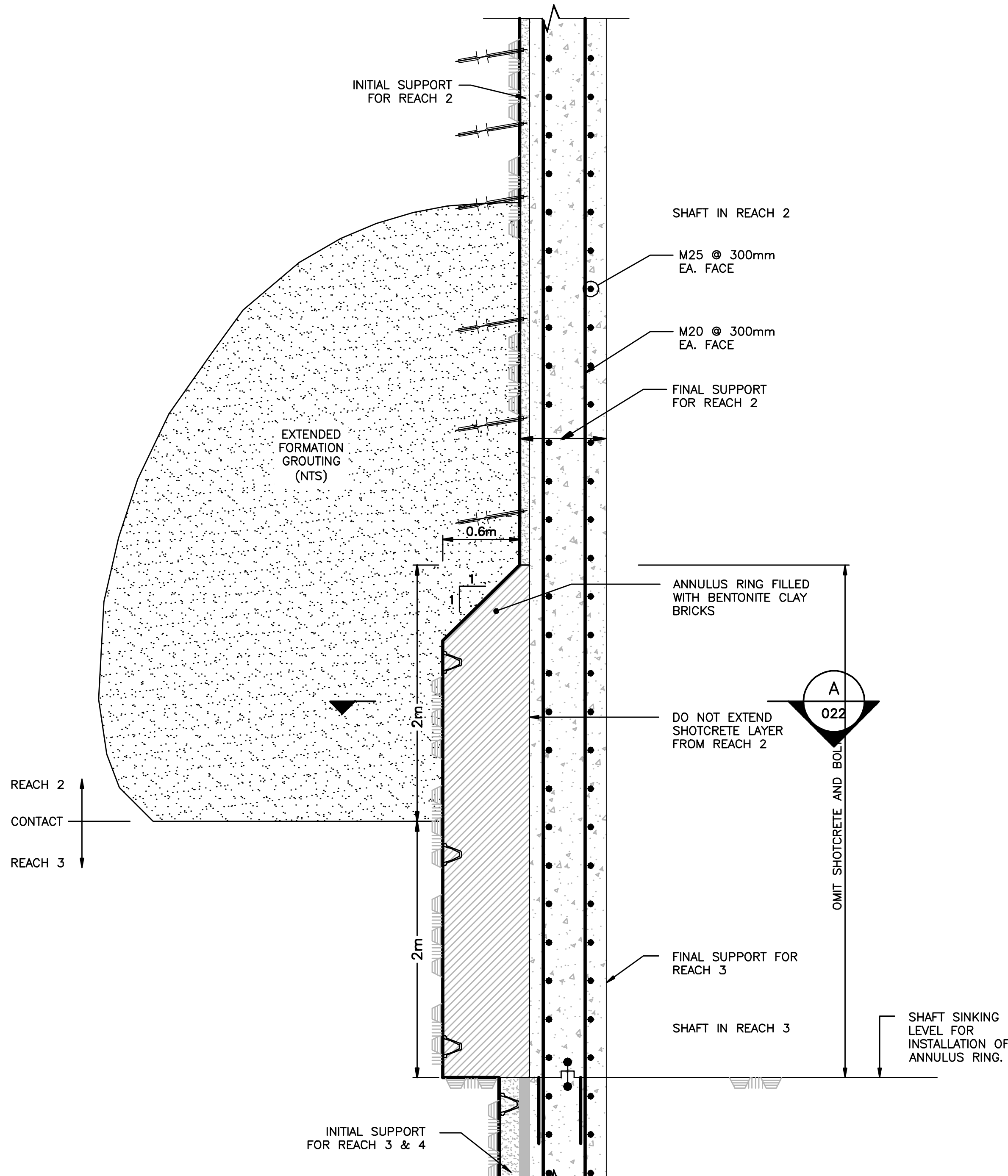
GROUTING ARRANGEMENT AND SHAFT SINKING FOR REACH 2

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-021 | REV. 0

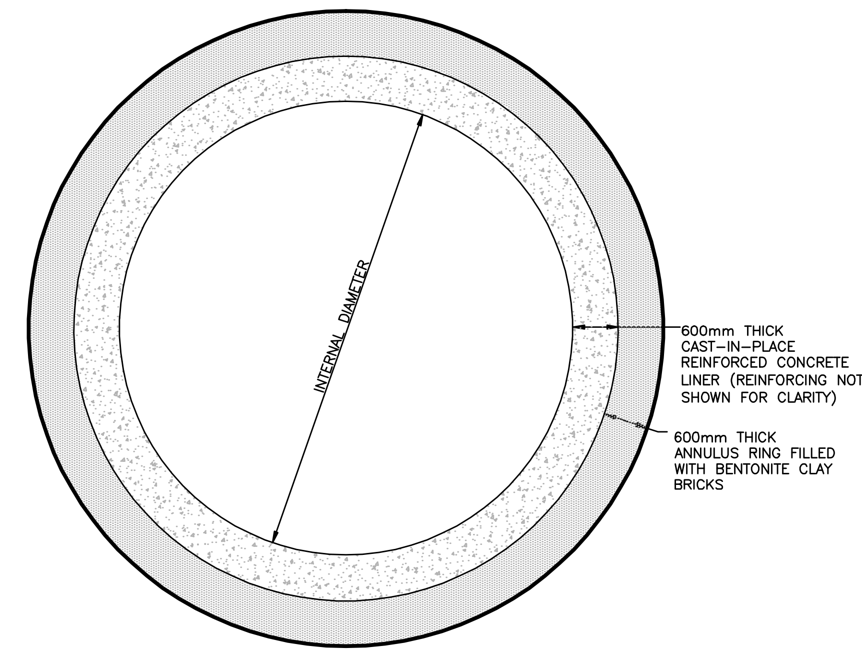
DWG. NO.

NOTE:

1. ANNULUS RING DETAIL IS APPLICABLE TO BOTH MAIN SHAFT AND VENT SHAFT.



SECTION SHOWING SUPPORT & BENTONITE RING INSTALLATION SEQUENCE
SCALE: 1:50



ANNULUS RING SECTION A/022
SCALE: 1:100

SEQUENCE:

1. SINK SHAFT THROUGH REACH 2 AND 2m BEYOND CONTACT INTO REACH 3.
2. EXCAVATE 600mm THK ANNULUS RING.
3. PLACE BENTONITE CLAY BRICKS IN ANNULUS RING GAP.
4. SLIP FORM FINAL LINING FROM CURRENT SHAFT TO BOTTOM COLLAR.
5. FORMATION GROUT THROUGH LINER.
6. CONTINUE EXCAVATION INTO REACH 3.

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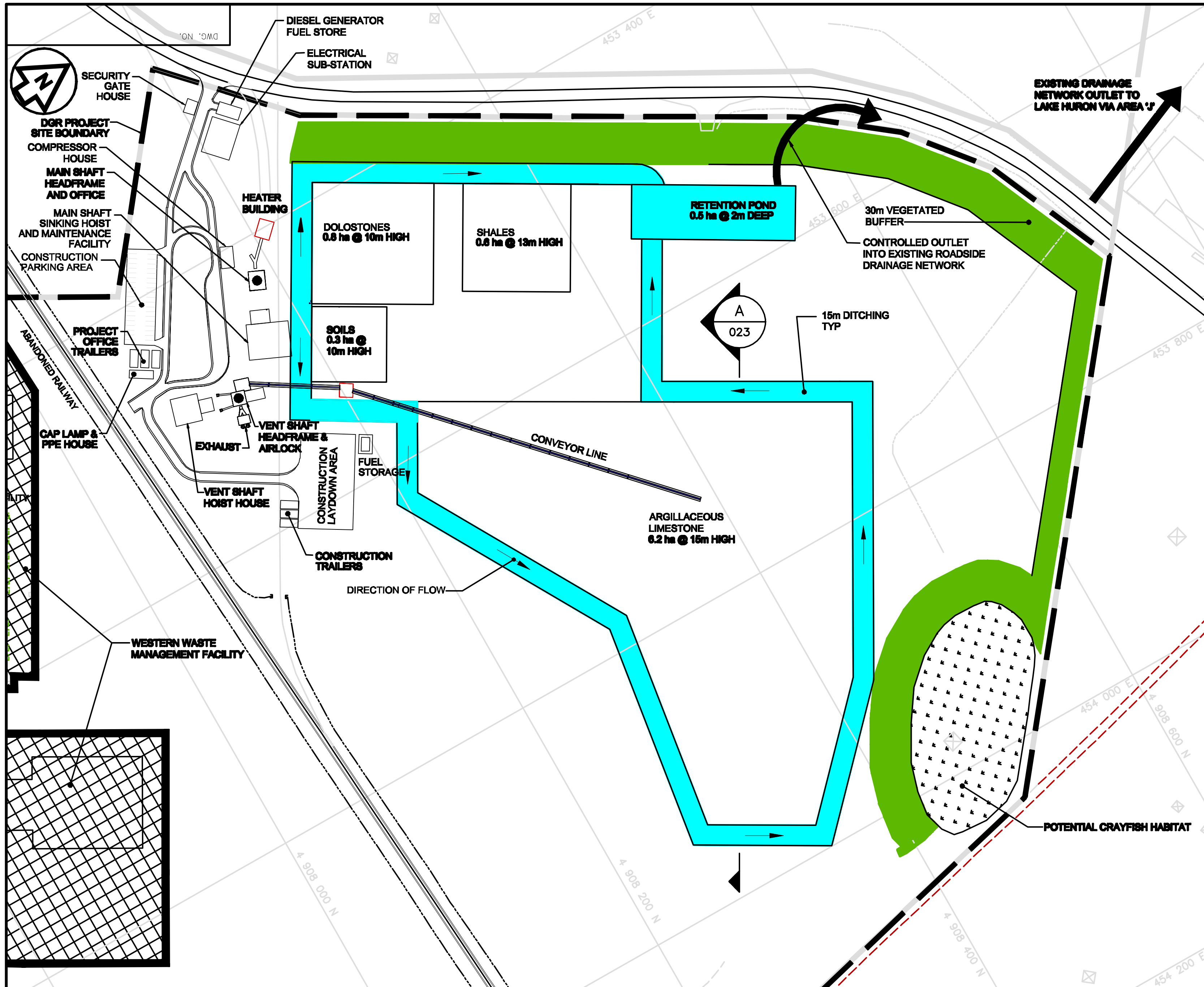
ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

SUPPORT MATERIAL AND BENTONITE RING INSTALLATION AT INTERFACE REACH 2 & 3

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-022 | REV. 0



PLAN VIEW – WASTE ROCK DISPOSAL AREA

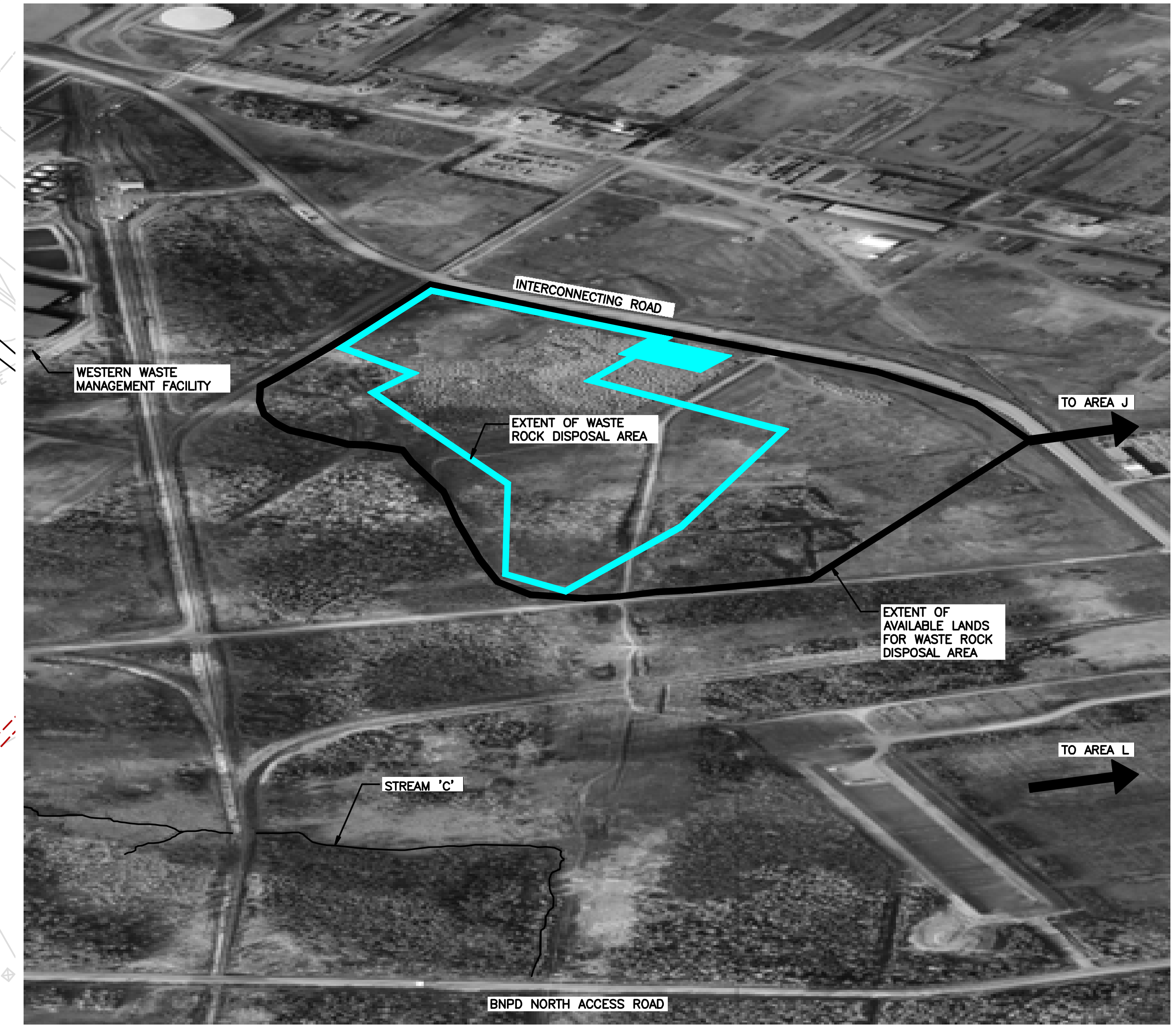
LEGEND

- POTENTIAL CRAYFISH HABITAT
- WESTERN WASTE MANAGEMENT FACILITY
- DGR PROJECT SITE BOUNDARY

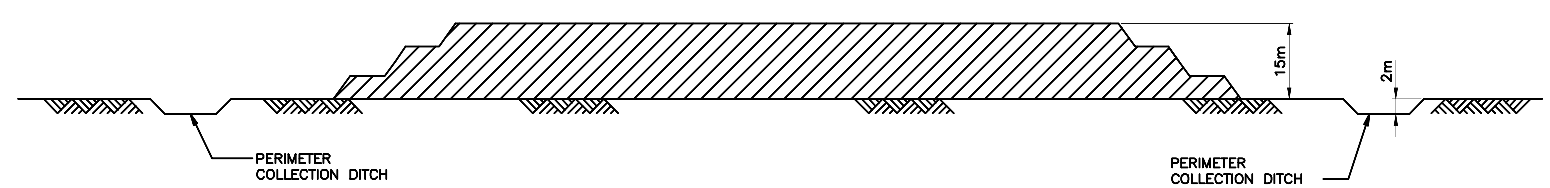
SHAFT UTM DATA

CENTRE OF MAIN SHAFT
N 4908185.806
E 453431.503
ELEV. 186.84m

CENTRE OF VENT SHAFT
N 4908131.427
E 453499.688
ELEV. 187.42m



ORTHOPHOTO SHOWING WASTE ROCK DISPOSAL AREA & WESTERN WASTE MANAGEMENT FACILITY



SECTION A–A – ON-SITE LIMESTONE DISPOSAL (A / 023)

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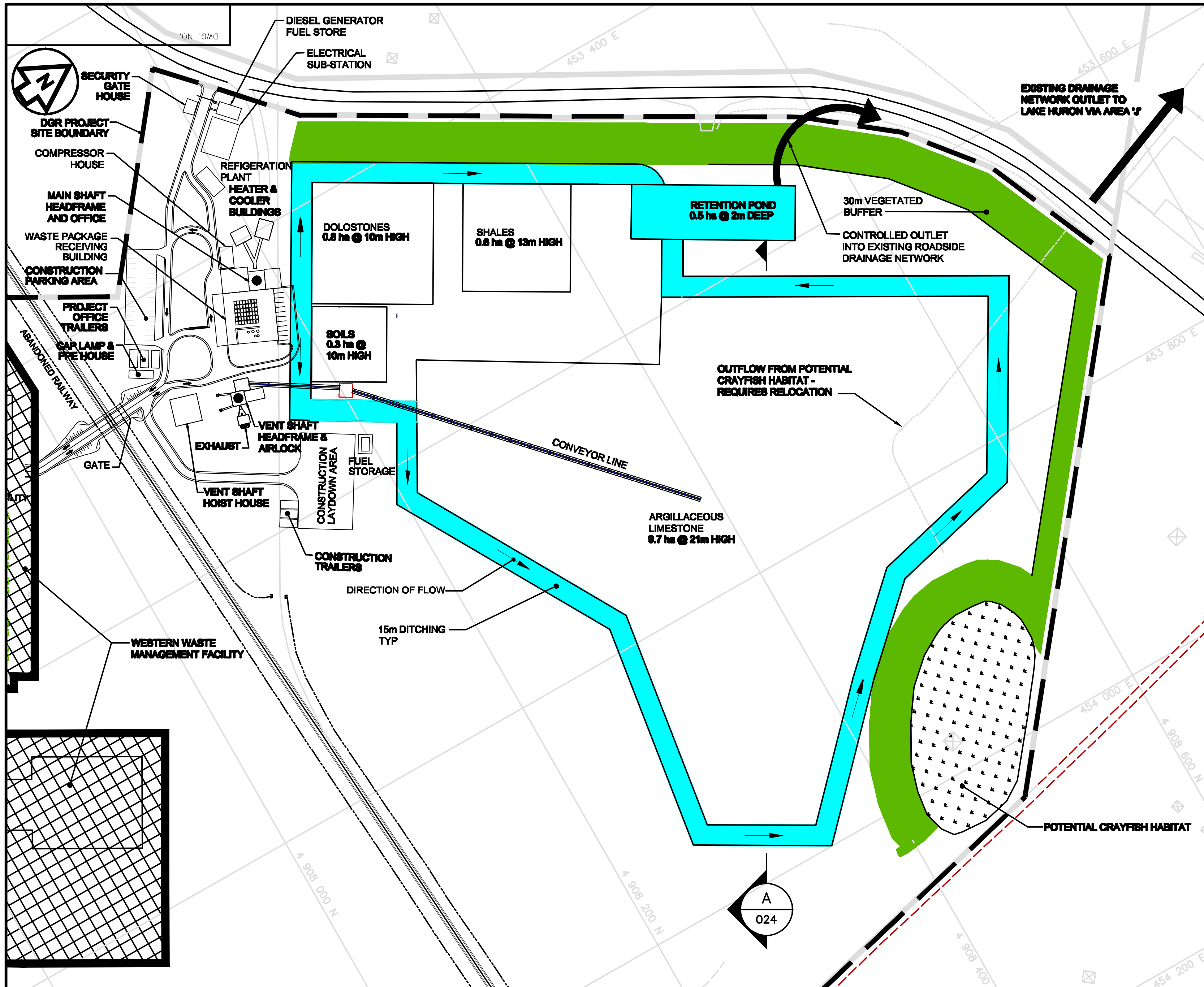
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
PROJ. MGR. M. DAWBORN	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

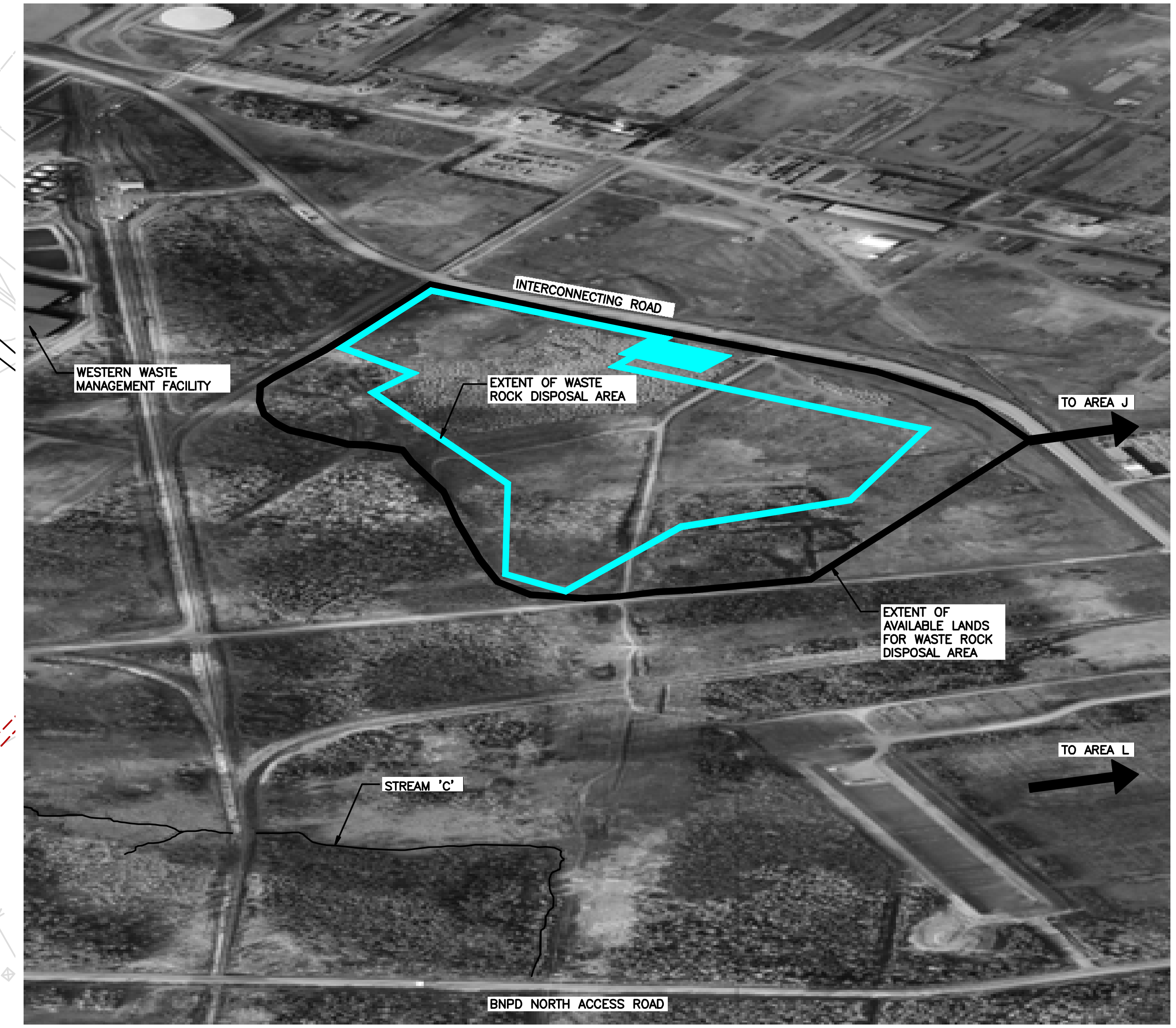
CONCEPTUAL DESIGN REPORT

WASTE ROCK MANAGEMENT PLAN
REFERENCE BASE CASE

SCALE: OR AS NOTED
DWG. NO. 323874DGR-200-023
REV. 0



PLAN VIEW – WASTE ROCK DISPOSAL AREA



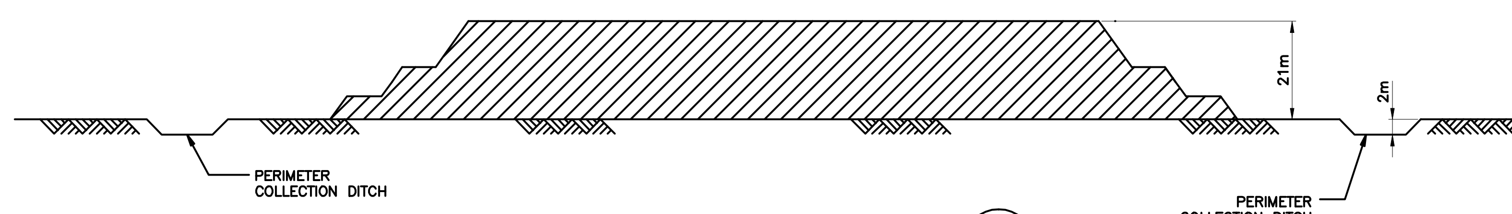
ORTHOPHOTO SHOWING WASTE ROCK DISPOSAL AREA & WESTERN WASTE MANAGEMENT FACILITY

LEGEND

(dotted pattern)	POTENTIAL CRAYFISH HABITAT
(cross-hatch pattern)	WESTERN WASTE MANAGEMENT FACILITY
(dashed line)	DGR PROJECT SITE BOUNDARY

SHAFT UTM DATA
CENTRE OF MAIN SHAFT
N 4908185.806
E 453431.503
ELEV. 186.84m

CENTRE OF VENT SHAFT
N 4908131.427
E 453499.688
ELEV. 187.42m



ON–SITE LIMESTONE DISPOSAL

A
024

PRELIMINARY
NOT FOR CONSTRUCTION

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PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

POTENTIAL REPOSITORY EXPANSION CASE

SCALE OR AS NOTED | DWG. NO. 323874DGR–200–024 | REV. 0

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PRELIMINARY
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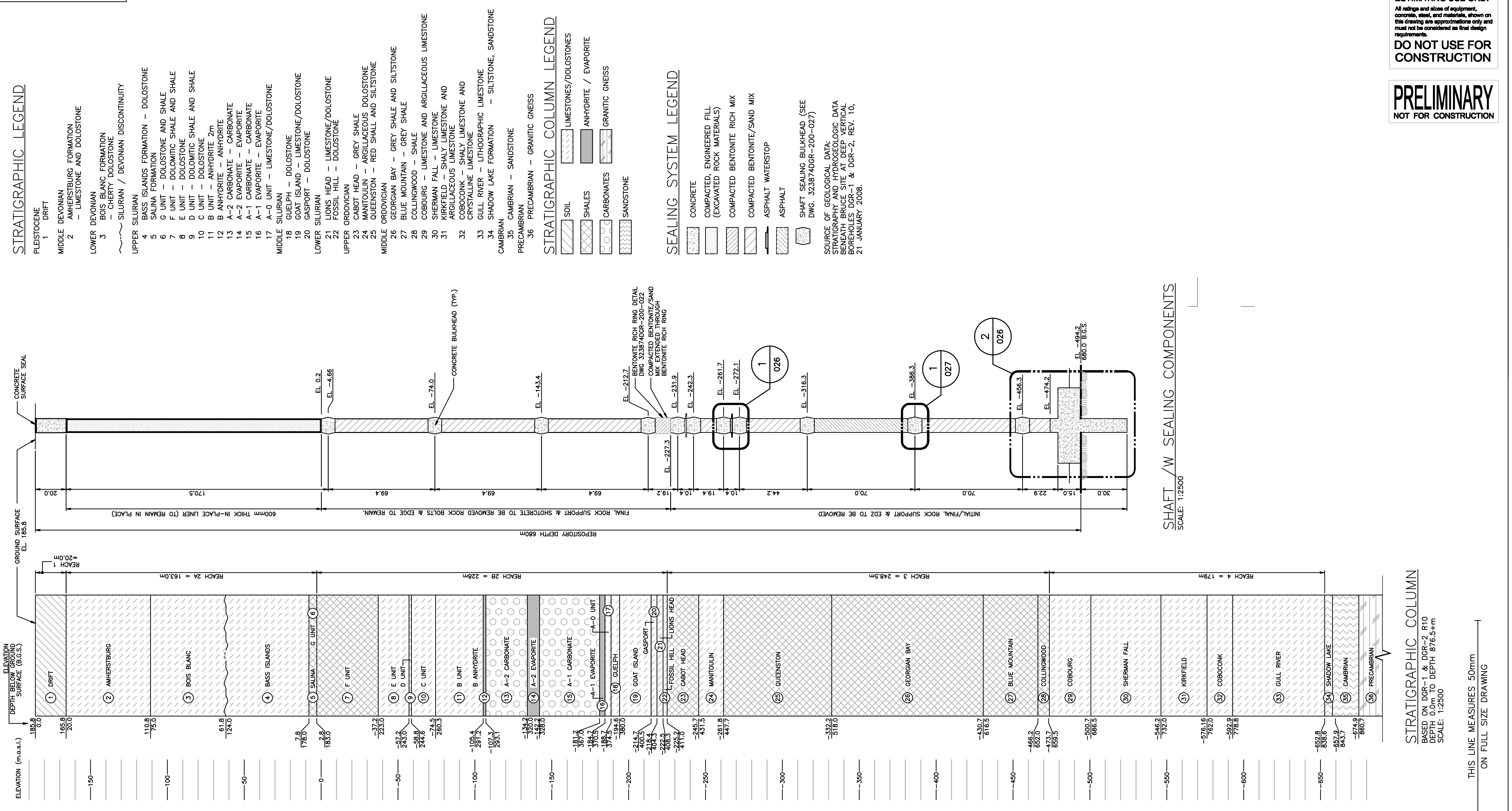

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DATE	DATE
PROJ. DES. COORD. N/A	PROJ. ENGR. N/A
DATE	DATE
PROJ. MGR. M. DAWBORN	
DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

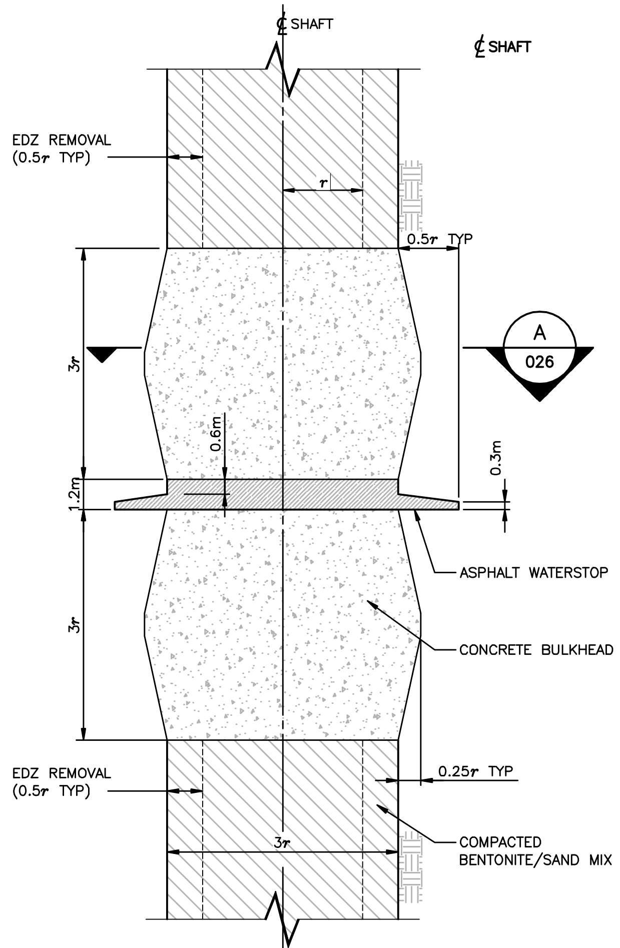
STRATIGRAPHY & SHAFT SEALING SYSTEM LAYOUT

SCALE OR AS NOTED

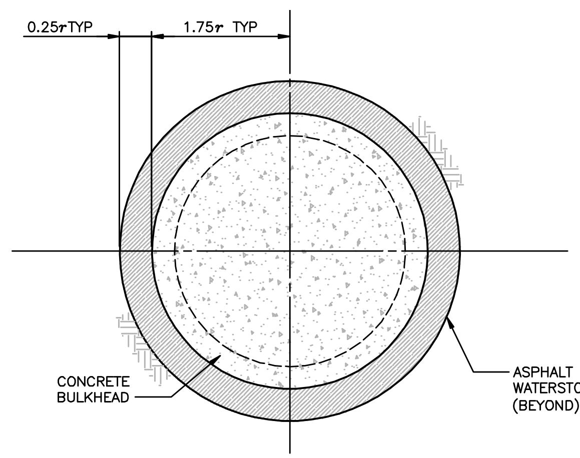
DWG. NO. 323874DGR-200-025

REV. 0

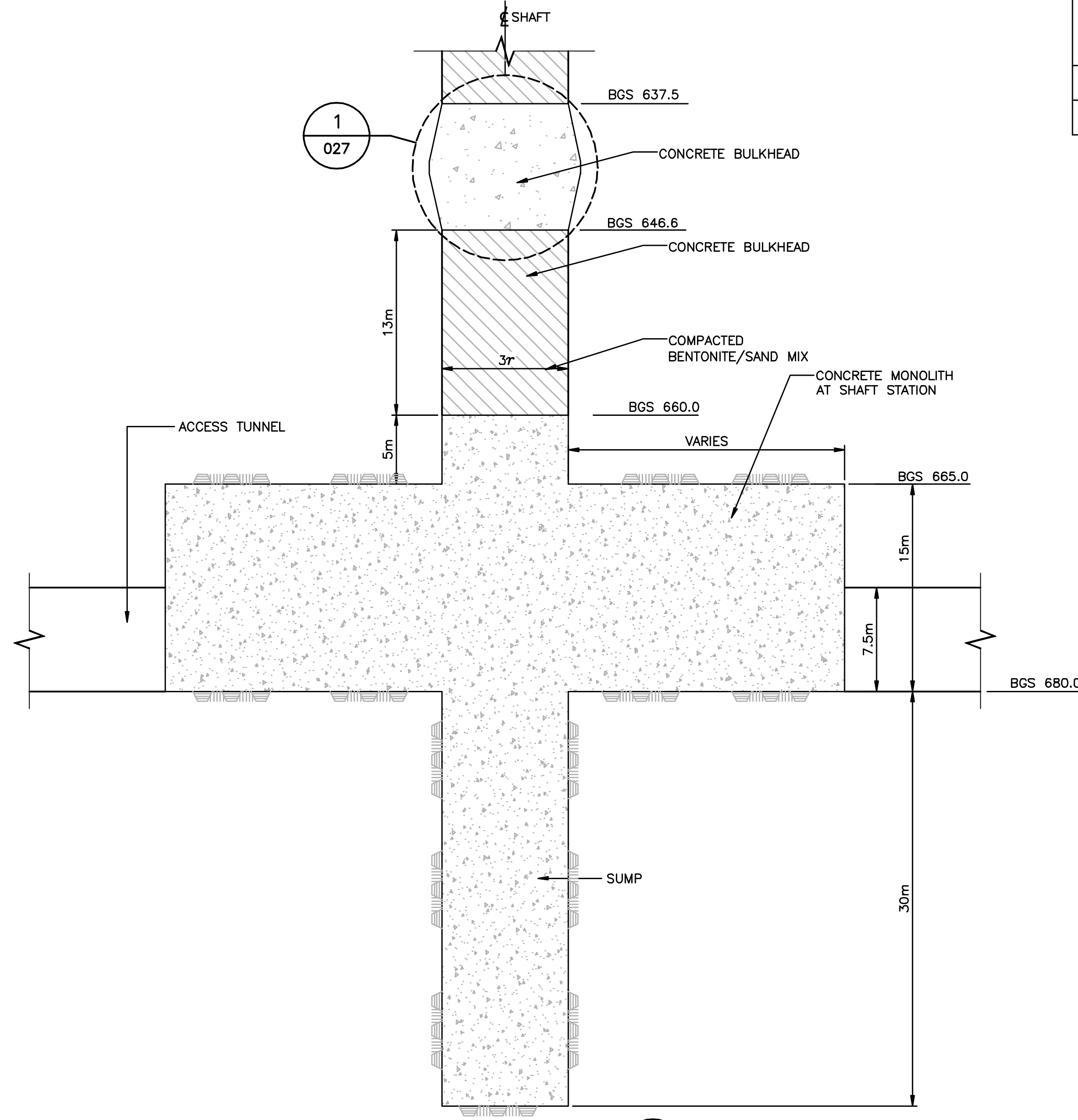
TYPICAL VALUES FOR MAIN AND ACCESS SHAFT (m) – REACHES 3 & 4				
SHAFT	EXCAVATED DIAMETER (2r)	DIAMETER FOLLOWING EDZ REMOVAL (3r)	KEY DEPTH OF CONCRETE BULKHEAD (0.25r)	DEPTH OF ASPHALT WATERSTOP (0.5r)
MAIN	8.15	12.24	1.02	2.04
VENT	5.95	8.94	0.75	1.49



DETAIL 1/025
UPPER CONCRETE BULKHEAD /W ASPHALT WATERSTOP
SCALE: 1:300



SECTION A/026
SCALE: 1:300



DETAIL 2/025
SHAFT STATION MONOLITH
SCALE: 1:500

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PROJ. MGR. M. DAWBORN DATE	

ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

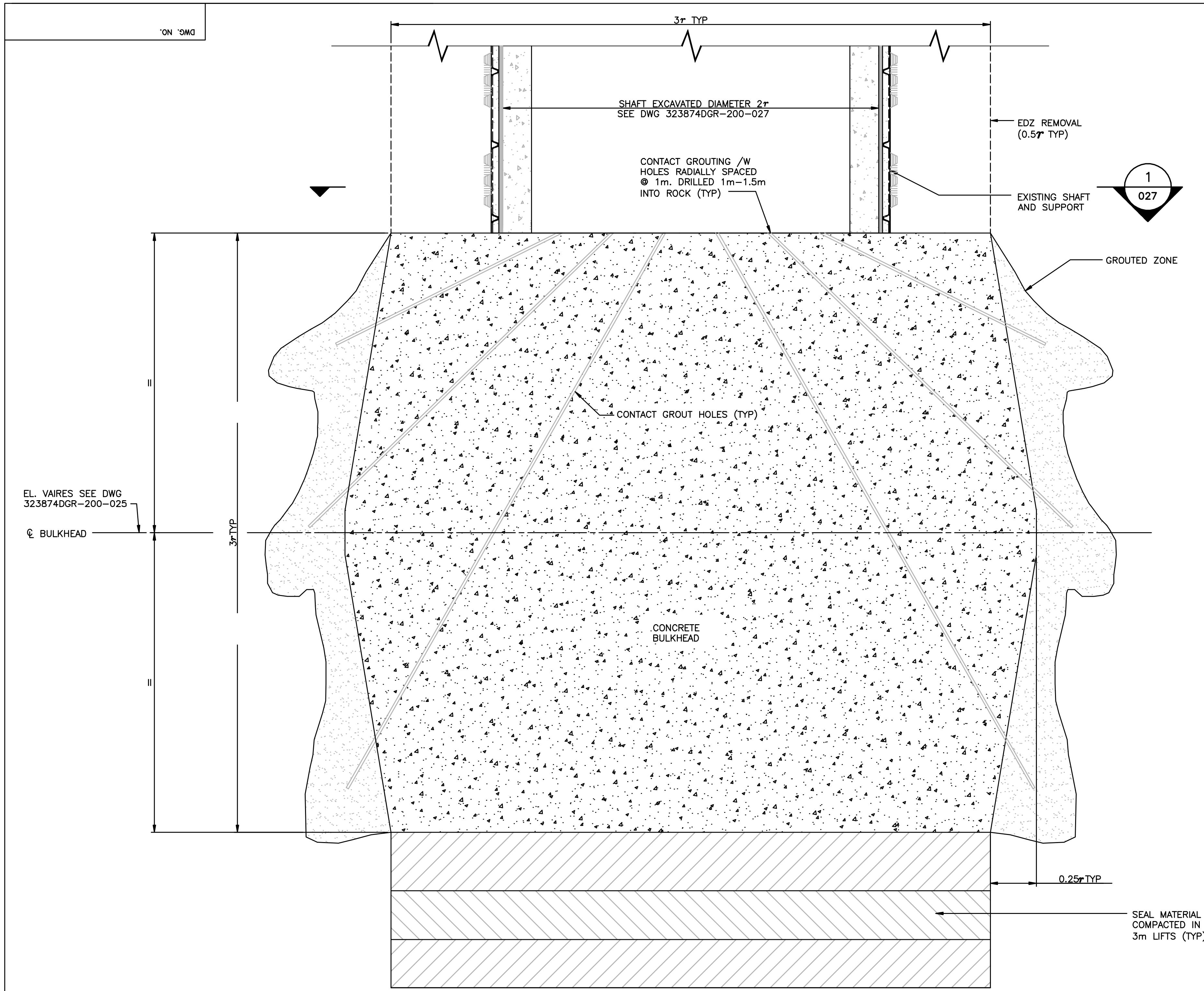
CONCEPTUAL DESIGN REPORT

SEALING SYSTEM
WATERSTOP & MONOLITH DETAILS

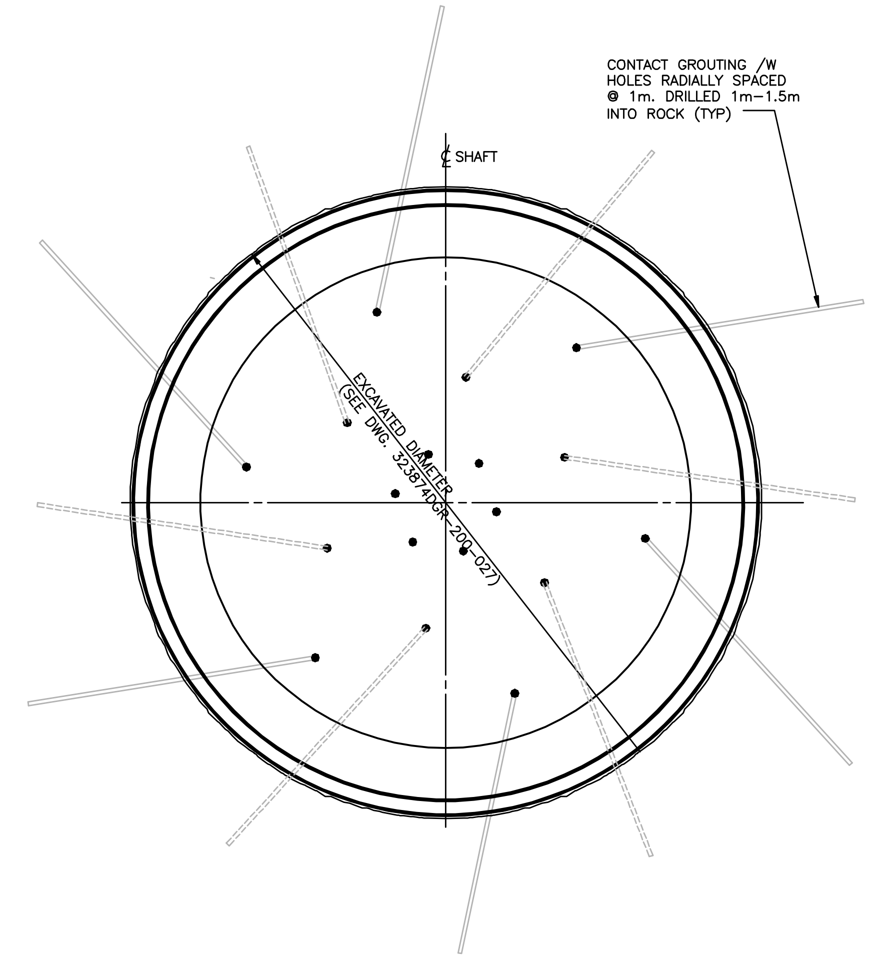
SCALE OR AS NOTED | DWG. NO. 323874DGR-200-026 | REV. 0

DWG. NO.

DWG. NO.



SHAFT SEALING BULKHEAD DETAIL (1/025) (1/026)
TYPICAL FOR MAIN & VENT SHAFT (REACH 3 & 4)
SCALE: 1:100



CONTACT GROUT PATTERN (1/027)
SCALE: N.T.S.

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ONTARIO POWER GENERATION
DEEP GEOLOGIC REPOSITORY PROJECT

CONCEPTUAL DESIGN REPORT

SEALING SYSTEM GROUTING DETAILS

SCALE OR AS NOTED | DWG. NO. 323874DGR-200-027 | REV. 0